Cleaning and Purification of Air in Buildings: Proceedings of a Program Conducted as Part of the 1960 Spring Conferences of the Building Research Institute, Division of Engineering and Industrial Research (1960)

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Milton C. Coon, Jr.
MILTON C. COON, JR.
Executive Director

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Inquiries concerning this publication or the
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Abstracts of Conference Papers

WHAT IS PURE AIR?
Arthur J. Hess, Hess-Greiner & Polland, Inc.

This report points out the need for greater responsibility on the part of the general public for the increasing problem of air pollution throughout the country, mentioning that the issue has today become a political football similar to water pollution at the turn of the century. A two-pronged attack is recommended to help solve the problem: 1) control of smog at the source of pollution; 2) removal of pollution from air entering buildings. Pure air is defined in terms of freedom from particulate matter of various types, and the economic benefits of cleaner air in air supply systems for buildings are discussed. Reduction of the use of outdoor air for cooling or ventilation to a bare minimum is recommended. Types of equipment available today for cleaning and purifying are described.

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ODORS: CLASSIFICATION, DETECTION AND REMOVAL
H. L. Barnebey, Barnebey-Cheney Company

In this paper, odors are classified according to reaction on the human nose, chemical composition, or source, and the advances of science, industry and the standard of living are mentioned as stimulating increased public consciousness of odors. Methods used to eliminate odors in living and working spaces by dilution with outside air, masking by other odors, and adsorption by activated charcoal are discussed. Resulting benefits of the use of activated charcoal adsorption are cited as: more healthful and pleasant atmosphere, saving of heating costs in winter and cooling costs in summer, and elimination of the necessity for ventilation with outside air. A suggested specification for air quality is given.

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ORIGIN AND REMOVAL OF AIR CONTAMINANTS
Louis C. McCabe, Resources Research, Inc.

The natural and man-created sources of air pollution are enumerated, and it is pointed out that air pollution can most effectively be controlled at the source. An index for evaluating the amounts of air contaminants released where controls are not present is given. However, the author points out, with the increase in industrial and other human activities, the amount of pollution that escapes tends to grow in spite of the most effective means of control. The role of activated carbon in the reduction of air contamination is cited briefly.

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Keynote Address

By John E. Haines,* Vice President
Minneapolis-Honeywell Regulator Company

Great progress has been made in recent years in controlling temperature, ventilation, air distribution, humidity, light, color, and sound in homes and commercial and industrial buildings.

But there are other conditions that affect our comfort and efficiency.

I am convinced that clean, pure air is a vital factor in a completely controlled indoor environment. And, I believe that the cleaning and purifying of air represents the next important area of growth in the technical advancement of year-round air conditioning.

The air is not clean and it is not pure. It contains soil, sand, smoke, coal dust, fly ash, particles of rubber, unburned products of combustion, oil mist, gases, fumes, odors, ceramic particles, metal chips, paint, pollen, tobacco smoke, lint, fibers, bacteria, viruses, silicates, and probably a number of other things. And the air is becoming dirtier all the time.

There are two reasons why clean air is important. One is the effect of air pollution on human health. The other is how much it costs us in dollars and cents.

Air and water are basic elements that we need for life. Water pollution has been recognized as a serious health and economic problem for more than 100 years. Control has come about by reducing the amount of waste which could be disposed of in our watersheds, and by the development of equipment to purify all water used for human consumption.

Medical science has made magnificent strides with wonder drugs for the care and relief of persons afflicted with nearly all kinds of virus infections and allergies. However, real control of many ailments is dependent upon the elimination of infectious viruses and other disease producing organisms from the air we breathe, just as we have successfully eliminated them from the water we drink.

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*JOHN E. HAINES, has a B.S. in Chemical Engineering, Purdue University; Past-pres. American Society of Heating, Refrigerating and Air Conditioning Engineers, American Society of Mechanical Engineers, Building Research Institute, Producers' Council; associated with Minneapolis-Honeywell since 1929.

Some steps already have been taken to reduce the amount of pollution that enters the air. But complete elimination of the sources of most of these irritants can be accomplished only if we are willing to shut down our factories and refineries and junk all of our automobiles. Control must come, therefore, by purification of the polluted air.

Our bodies are amazing mechanisms. They can function fairly effectively in spite of the impurities that we put into them. For that reason, I don't expect people will become too excited over the potential health hazards of dirty air. In fact, the businessman is likely to be more interested in the economic aspects of the subject.

One person who is apt to get worked up over the subject, however, is your wife. She may spend more than half of her day removing dust and grime and other foreign materials from the tops of her tables, from her carpets and rugs, from the collar and cuffs of your good white shirt, and even from the faces, necks and ears of your children.

So we find that physicians and allergy sufferers are concerned with the health aspects of dirty air. Businessmen are interested in how many millions of dollars dirt costs them each year. And housewives are eager for ways of easing their task of keeping the house clean.

Yet, most heating and air conditioning installations do not actually clean and purify the air. Undoubtedly, one reason is that the need for clean air has not been sufficiently recognized, nor has it been dramatized to us as much as the problem of water pollution.

A second reason is that it has been fairly easy to sell devices that will filter air. Most of them are inexpensive. Because they get dirty and have to be replaced from time to time, we are convinced that they are doing an adequate job. Remember we are talking today about cleaning and purifying the air--not simply filtering it.

A considerable amount of research is needed in order to develop more economical and efficient methods of cleaning and purifying air, but in addition, the building industry and the general public must learn the need for, and the importance of, clean, pure air.

What Is Pure Air?

By Arthur J. Hess,* President
Hess-Greiner & Polland, Inc.

The deterioration in the quality of the atmosphere that we breathe is becoming of major concern to engineers and health authorities today, and the trend is still downward. The pollutant effluents resulting from combustion, other industrial processes and rubbish disposal is converting our atmosphere into a malodorous, poisonous and irritating mess. Even nature contributes to the condition. Through photosynthesis the hydrocarbons in the effluents are converted into the irritating peroxides that cause stinging on contact with wet human body surfaces. Nature also produces large volumes of gaseous hydrocarbons from vegetation growing on the earth. Considerable pollution is found in the atmosphere over the Central and South American jungles where there is practically no industry.

That a problem exists is now recognized by many scientists. In the United States and Canada today there are over 60 air pollution control bodies working on the problem, but owing to the great increase in mechanization of industry and transportation, the progress being made is concealed by the greater production of pollutants. Air pollution control agencies are also hampered by lack of public recognition that people produce as much pollution as does industry. So far, the general public seems to take the attitude that "someone should do something"--someone else, that is. This attitude has allowed air pollution control to become a political football, a factor that greatly reduces the efficiency of control agencies. The situation is reminiscent of water pollution control at the turn of the century. Those familiar with the history of water pollution control will recall that our cities were beset with violent typhoid epidemics that annually cost thousands of lives, yet since the water supply systems were generally controlled by local politicians, nothing was done until the people rebelled. Today we have safe water supplies and no one thinks twice about the problem, except the engineers and technicians who maintain the purity of the water. Air pollution is sadly in need of a good public relations program to accomplish this necessary public education. In the end it is the public who must spend the money to control this growing problem.

The attack on air pollution or smog is a two-pronged one, performed by two different groups of engineers. One prong is the attack on smog at the source of the pollution where the

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*HESS, ARTHUR J., is also President, Heat and Power Equipment Co.; holds degrees from University of California and University of Southern California; Member of Air Pollution Control Association; presidential member of American Society of Heating, Refrigerating and Air Conditioning Engineers.

pollutants are prevented from forming, neutralized, or reduced before being emitted into the atmosphere. The other prong is the attack at the point of usage of air, by the removal of the pollution from air streams that are to be used for ventilating or air conditioning in buildings, thus providing relatively clean air inside. This paper is concerned with the cleaning of air for ventilating or air conditioning usage. By the accepted definition of air conditioning I include warm air heating.

The answer to the question of what pure air is, on an exact basis, would have to be that there is practically no such thing. Air is a mixture of gases that continuously vary in quantity as related to the whole. Oxygen (of greatest interest to people) constitutes about 16% of air but varies in quantity due to the enormous emission of oxygen from growing vegetation, the result of the plant absorbing carbon dioxide from the air, taking out the carbon for food and returning the oxygen to the air. Since this carbon dioxide is taken from air, it can be concluded that both carbon dioxide and oxygen content in air will vary. Animals complicate this by taking in oxygen from the air, combining it with carbon and emitting the resultant carbon dioxide into the atmosphere. There are other gases that vary the composition of the atmosphere from locale to locale, owing to the locations of the emission of these gases. It is customary to call the air pure if it does not contain foreign matter detrimental to human beings. Water vapor is a natural variant in the atmosphere because of the processes of evaporation and condensation that vary with the heat content of the atmosphere. For our purposes, therefore, I think we can say that pure air is normal atmosphere free of particulate matter and without any detrimental gases.

The particulate matter in the atmosphere is visible with a microscope or, if in sufficient quantity and size, by the naked eye either directly or by reason of the defraction of the sunlight on the particles, which provides us with a rough scale to judge the amount of this type of pollution. The amount of particulate matter in the air is enormous in terms of the number of particles. In so-called clean air in rural areas there are two to three million particles per cu. ft., while in heavy industrial areas the count can run as much as 30 million particles per cu. ft. These particles are made up of dust, smoke, bacteria, pollen, industrial debris, and even water. Though these particles exist in great quantities, most of them are microscopic in size which means that the amount of particles by weight is relatively small. Particulate matter in the atmosphere is usually easier to remove than other pollutants, but it should be noted that there is little removal of the great number of small particles. Some of these particles are so small they never settle out as dust.

The gaseous pollutants are equally as bad, or in many cases much worse than the particles, but are not as apparent because most pollutant gases are invisible. This presents problems to air pollution control enforcement people, because the sources of these gases are hard to find, and it is difficult to prove violations of air pollution laws, yet gases are probably the worst producers of irritation of certain body surfaces. Gases are also subject to chemical change after emission, and many times form an irritant gas out of innocuous gases. The sun supplies the energy for this photosynthesis.

Some of the usual pollutant gases found in smog are: hydrocarbons, both saturated and unsaturated, which are emitted from vegetation, most combustion processes and automobiles; oxides of nitrogen resulting from the oxidation of nitrogen in passing through any combustion process that utilizes the atmosphere as a source of combustion air; peroxides, ozone and many others including the intermediate semi-gaseous aerosols.

Damage to animals by such gases is known, but not quantitatively. Medical and health authorities are not in agreement. As a matter of fact, there is not even agreement on the effects of our self-generated smog, tobacco smoke. However, we do know that heavy infestations of air pollution such as occurred at Donora, the black fog of London, and in the Meuse Valley do affect health and even cause death. It seems logical that health is affected by air pollutants. The evidence is certainly sufficient to justify air pollution control and smog removal.

Bacteria are another pollutant we know too little about, but studies and experiences in hospital operating rooms point out that there is a problem and it is important. Post-operative staphyloccus infections are as well known as the bacteria that cause them. It is still a problem to determine their source. Work done at the University of Toledo indicates that supply air is probably a carrier. Plenty of money is spent cleaning everything else in and about operating rooms, why not the air?

Removing the contaminates from air in air supply systems to buildings has beneficial economic effects in addition to the health considerations. Usually these are sufficient to justify the cost of operation and maintenance of an air filter system. Some of these benefits are:

1) Clean air can reduce cleaning and painting inside buildings by as much as 70% because the dirt is intercepted before entering the structure. This is not only important to building owners, but it is equally important to housewives.

2) The reduction in dust and dirt deposits in duct systems reduces greatly the fire hazard in ducts and also duct cleaning costs. Dirty ducts will spread a fire rapidly throughout a structure. This situation is greatly magnified when grease is present.

3) Air conditioning heat exchangers are kept clean of dust and dirt that could deposit and clog up the system, thereby reducing efficiency and increasing the cost of operation by raising the resistance to air flow.

4) Merchandise such as dry goods or food on store shelves will retain quality and value longer in a clean atmosphere. In the case of dry goods that are often tested by shoppers with their fingers, the presence of dust creates an even worse situation.

5) By reducing the quantity of dust in the air, there will be much less transmission of bacteria from person to person because the dust particles which act as vehicles for the bacteria will be reduced.

Outdoor air for buildings is usually provided to dilute or remove odors created by people, food, industrial processes, infiltration of polluted air, smoking, or other causes. Ventilation is seldom required to replenish the oxygen consumed by human beings, or to remove the carbon dioxide created by human beings, because infiltration and exfiltration take care of this. A small amount of outdoor air is usually desirable in order to create a small internal pressure and to prevent excessive infiltration around windows and doors; and large quantities of outdoor air may be used for cooling during certain weather conditions. Also, outdoor air may be required under some circumstances, for instance, in schools to dilute or remove the moisture created by the students. However, outdoor air should never be required to remove moisture from spaces which are equipped with adequate air conditioning.

As I have already indicated, outdoor air, particularly in urban areas, is usually polluted with both solids and gases and is expensive to heat, cool, and clean. Therefore, the use of outdoor air should be reduced to a practical minimum, and when the supply air is properly cleaned and purified, a more satisfactory atmosphere will be created in any building which is properly air conditioned.

At one time the term, "fresh air," was used to indicate the use of outdoor air, but the air conditioning industry and the American Society of Heating and Ventilating Engineers officially discontinued the use of "fresh air" in favor of "outdoor air" about 25 years ago, because even then nearly all of the outdoor air was polluted with dirt or gases, and it was recognized that the term, "fresh air," should be applied only to air which had been cleaned and purified.

The removal of pollutants from air is a problem that still requires study, but the great amount of research now under way is making good progress. One of the principal problems was to determine what polluted air actually was, and what the pollutants were. This has been determined to a great extent, although there are still many special cases. It is possible to remove, by means of simple impingement or strainer type filters, or by water sprays, the bulk of the weight of particulate matter from the air. These filters are not highly expensive to buy or operate. They will generally take out about 90% of the dirt by weight, but only a small percent of the number of particles in the air, meaning, of course, that most of the smaller particles are not removed. These filters take several forms, depending usually on a price classification. One form, consisting of an impingement unit made up of any one of several media available, is intended to be utilized until it is full of dirt and then thrown away and replaced by another unit. Another form consists of a unit that can be removed, cleaned and replaced. This is a more expensive type and usually requires a mechanic to clean and replace it. Another form is automatic in operation, utilizing a revolving screen or dry medium that automatically renews itself.

Higher quality filtration is obtainable with electronic air cleaners or absolute air filters. Both are much more expensive than the previously mentioned types, but they remove some 90% of the dirt by weight and also the fine particles and bacteria. The electronic type operates by placing a high voltage charge on the dirt particles and removing them on electrically charged plates or filter media. The absolute filter removes by straining the air through a dense medium and its application is usually industrial in character. Electronic air cleaners have been perfected to a point where practical residential units are available.

Gases present a different problem, since using activated charcoal is the only practical method on the market for general ventilation and air conditioning systems. The gases are adsorbed in the cells of the activated charcoal. These filters are generally used in combination after a particulate matter filter and are available in practical form for residential and industrial use. These filters are also used to increase the amount of return air in a system, since they take out odors and space-generated impurities. The more return air circulated, the more economically the system will operate.

Bacteria control in air streams has been noted as a problem in the past few years and new techniques are developing to combat it. However, there is a need for more research on the sources of bacteria and life span of bacteria in air streams. To date glycols, lithium chloride, ultraviolet lights and electronic filters are being used.

Air filtration has been neglected woefully by the air conditioning industry in favor of heating and cooling equipment, or in other words, comfort. We should re-appraise the situation, and place proper emphasis on research in this field so vital to the public health.

Odors: Classification, Detection and Removal

By H. L. Barnebey,* Vice President
Barnebey-Cheney Company

Odor is the property of a substance that affects the sense of smell. An odor is a chemical compound or mixture of compounds in gas or vapor form which, because of molecular structure, affects the nose in such a way as to create the sensation of smell. To have an odor, the substance must have sufficient vapor pressure to give a concentration in air high enough to produce the sensation of odor. Most vapors have odors; some are irritating, toxic, or affect other parts of the body.

A little odor goes a long way since concentrations of some substances as low as one part in 100 billion give the sensation of odor. Concentrations lower than required to cause odor can give the feeling of stuffiness. Odor is an elusive thing. You can't see it, even with the strongest microscope, and its weight is so small that it defies measurement. With the exception of a few compounds such as ammonia, all odor-producing substances have vapors heavier than air. However, when once thoroughly mixed with air, they do not settle out.

Odors can be classified according to reaction on the human nose, chemical structure, or source. They can be pleasant or unpleasant, sweet, sour, fruity or rotten. Certain types of chemical structures are known to have odors, but we can as yet make no complete generalization between structure and odor. We know that a molecule which has the same shape as a camphor molecule will smell like camphor even though it may be quite unrelated to camphor chemically. Odors can be classified according to their origin, such as food, animal, tobacco, or according to the type of building or enclosure that generally contains them, such as kitchen, laboratory or conference room. An odor can be good or bad, depending on where we meet it.

Odors in themselves do not cause organic disease. The disagreeableness brought about by obnoxious odor is temporary; it disappears when the odor is eliminated. An odor may be obnoxious to one person and not to another. Odors serve as an index to personal discomfort but do not indicate reduced oxygen or excess carbon dioxide. The continued

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*BARNEBEY, H. L., B.S. in Chemical Engineering, Ohio State University; Member of American Chemical Society, American Institute of Chemical Engineers, American Oil Chemists' Society, American Society of Heating, Refrigerating and Air Conditioning Engineers; principal in his own company since 1951, previously associated with Blaw-Knox Co. of Pittsburgh.

presence of odor in occupied space reduces comfort and efficiency. Higher concentrations of many odors cause irritation of the eyes and respiratory system.

What shall we do about odors--ignore them, don't have them, remove them, obscure them, or go where there aren't any? We can get used to odors, but why do it? Odors can be controlled effectively and inexpensively. The advances of science, industry and our standard of living have brought increased public consciousness of odors. There is now a demand for and an appreciation of adequate odor control. A number of technical societies, including American Society for Testing Materials, American Society of Heating, Refrigerating and Air Conditioning Engineers, American Public Health Association, and Air Pollution Control Association are giving attention to the problems of odors, their classification and control. The new ASHRAE Guide will have a chapter on odors. A committee of the American Industrial Hygiene Association recently defined industrial hygiene as "that science and art devoted to the recognition, evaluation and control of those environmental factors or stresses arising in or from the work place, which may cause sickness, impaired health and well-being, or significant discomfort and inefficiency among workers or citizens of the community." This includes odors.

Odors can be eliminated in living and working spaces by dilution with outside air, masking by other odors, or absorption by a liquid or solid such as activated charcoal. Dilution is usually expensive because the outside air must be heated in the winter or cooled in the summer. Outside air is frequently not pure and may require treatment to be usable. Masking functions by dulling the sense of smell or covering up one odor with another. In many cases, the mixture is a questionable improvement.

Ancient writings stated that charcoal had the property to purify air and water. It has been known for a hundred years that the capacity of charcoal to adsorb odors can be increased by chemical treatment. In World War I activated charcoal received a sudden boost because it was required in gas masks. Since then, commercial applications have been developed, including industrial gas masks, purification of air in occupied spaces, water treatment, solvent recovery and food product purification.

Activated charcoal adsorption is a widely-used method of air treatment which will efficiently and completely eliminate all odor-producing substances even though they are present in low concentrations. The contaminated air is passed through a thin layer of activated charcoal and emerges free from odor. As charcoal adsorbs odor it increases in weight until its capacity is reached, then it must be replaced or regenerated by heat. Activated coconut shell charcoal will take up about one-fourth its own weight of most odors. One pound (about a quart) adsorbs the quantity of odor that the average person breathes in his lifetime. Unless he wears a mask, however, the quantity of air purified must be many times that which he breathes so that he will have space to move about. By using charcoal adsorption, enclosed spaces are made more healthful and pleasant; heat is saved in the winter, and cooling in the summer, by reducing or eliminating ventilation with outside air.

Charcoal adsorption removes most toxic gases whether they have odor or not. Los Angeles smog has some odor but this is not its most important characteristic. It irritates the eyes and lungs. Activated charcoal removes smog completely. Frequently the odor of a chemical vapor is only one of its harmful characteristics. Many gases and vapors are poisonous and there is a limit to the amount that the human body can tolerate. Tables of maximum allowable concentrations are found in the ASHRAE Guide and other reference manuals.

It requires only a small concentration (1 ppm, for example) of the vapor of many chemical compounds to give the sensation of odor. The amount that is just barely perceptible is called the threshold level. An increase in concentration does not produce a proportional increase in physiological effect. Ordinarily it requires about 10 times the threshold concentration to give a definite sensation of odor, and another 10-fold increase before the odor is considered strong. Another 10-fold increase goes from strong to overpowering. One of the useful sensory scales for evaluating odor intensities is based on this relationship, as follows:

0 - No odor
1 - Threshold (just discernible)
2 - Definite (about 10 thresholds)
3 - Strong (about 100 thresholds)
4 - Overpowering (about 1000 thresholds)

Sometimes a preference scale is used such as:

+1 - Pleasant
0 - Not unpleasant or objectionable
-1 - Objectionable

We have developed no instrument for odor detection or measurement. We must rely upon appraisal by the human nose. There are a number of mechanical devices based on diluting odors to the threshold level which can assist the human nose in determining the concentration of an odor expressed in thresholds.

Odor removal must be quite complete to be effective. If we start with an overpowering concentration, the removal of 99% still leaves a definite odor, or a removal of 99.9% leaves a barely perceptible odor. When the concentration of odorous vapors is too low for perception, the air is said to be odor-free.

Odors in high concentrations, or if the odor-causing material is in the form of smoke, tend to accumulate on clothing, drapes, rugs and other surfaces. Odor leaves these storage places only by volatilizing into the air. This means that the odor control system must continue to function even after the original source may have disappeared. A ventilation or purification system does not increase the rate of evaporation. It serves only to remove the odors as fast as they are released.

It has not yet been proved that the complete absence of odor is the best atmosphere for human living. Some people think that a delicate fragrance is better than no odor at all. This is the same sort of problem as trying to prove whether the normal composition of air as it exists, that is, 1/5 oxygen and 4/5 nitrogen, is the optimum. Tests have shown that other compositions appear to be equally adequate. Until we have better proof, it is safest to assume that no odor at all is the ideal atmosphere for human occupancy.

The atomic submarines are excellent examples of modern odor control in hermetically sealed spaces. The composition of the atmosphere is kept constant by adding oxygen from tanks and removing carbon dioxide chemically. Odors are adsorbed in activated charcoal. If it were not for odor control, the subs would not be able to reuse the air, nor stay down a long time. In space ships, collective protection shelters and other sealed spaces, odor control is equally important. The smaller the space per person the more important it is. Did you ever try smoking a cigarette in an unventilated phone booth?

In a tight space of that size you can't stand the fumes from as much as one cigarette. The odor and irritants have to be removed for human existence to be possible.

The ventilation codes are set up to control odors, although this isn't always recognized. If the code states, for example, that 30 cfm per person must be used to ventilate a conference room, it means that quantity of air is needed to keep odor at a reasonable level. The sensation of stuffiness is often attributed to lack of oxygen. This is definitely not so. Lack of oxygen gives no such sensation. Stuffiness or staleness is due to odors. When these are removed, the air is again fresh. In most buildings, oxygen and CO_2 content are not problems. We have tested this in a large number of buildings, many with 100% air recirculation, and have found no serious diminishment of oxygen or increase of carbon dioxide. Ordinarily, sufficient air comes in by infiltration or with the opening and closing of doors to keep oxygen and CO_2 within the proper range. There is nothing wrong with the practice of bringing in a little outside air for pressurization or cooling on certain days but, in general, it is costly to heat or cool sufficient quantities of this air for ventilation.

Activated charcoal air purification is not contrary to ventilation codes. These regulations are established to insure adequate ventilation. Charcoal adsorption is an excellent method for doing this. Although adsorption is recognized as such by some of the newer codes, it conforms to all of them by a logical interpretation. It is generally considered that charcoal purified air is, as far as the code is concerned, equivalent to outside air. Actually it is better than outside air because it contains none of the industrial and automobile odors.

Tobacco smoke is a mixture of odor in vapor form and in the form of liquid droplets of tobacco tar. These small, sticky particles readily adhere to any surface. As they evaporate, they create more odor in vapor form. To eliminate tobacco smoke, it is best to remove the droplets by an efficient mechanical filter or electrostatic cleaner and adsorb the vapor with activated charcoal.

We often hear references to the carbon monoxide odor in garages. Carbon monoxide has no odor at all. The odor present is due to unburned and partially burned fuel and is made up chemically of hydrocarbons and aldehydes. These can be completely removed by activated charcoal which does not, however, adsorb the carbon monoxide.

The Bureau of Standards has issued Circular No. 491 on the Control of Odors. This is an excellent general summary and I recommend it to everyone interested in the subject. I quote two short paragraphs:

"Beyond question, the most important method of gas analysis ever employed is the sense of smell. One compact, but amazingly intricate, apparatus for the purpose is possessed by every human being. Although smelling has important limitations, chief of which is that it is never quantitative, it has many advantages over other means of analysis. The apparatus is nearly always in position to obtain the sample of greatest immediate interest to the analyst, sampling is automatic, and the analysis is made and the results reported almost instantly. No other method of analysis is capable of distinguishing between and correctly reporting so large a variety of chemical substances by a single operation.

"Except in a few cases, the most practicable method of concentrating the odor is by adsorption, usually by means of activated carbon. A good grade of activated carbon adsorbs most of the organic vapors, which comprise the worst odors, without difficulty. It is necessary only to force the air through a bed of the fresh adsorbent thick enough to insure intimate contact between the solid and all of the air."

Norman Sharpe of the California State Polytechnic College has written an interesting paper entitled "Air Purification as a Means of Reducing Air Conditioning Equipment and Duct Sizes." I quote a few sentences:

"To obtain complete removal of all air pollutants, all of the common air-cleaning devices would be required. Of course this is not practical, so we must remove pollutants in their order of nuisance. It has been pointed out that bacteria are sustained by particulate matter; therefore, air filtration is of prime importance in all air purification. Discomfort, nausea, bronchial irritation and eye irritation are caused by a combination of odors, vapors and particulate matter. Indoor odors are usually of organic origin and may be removed by carbon adsorbers. Often the main outdoor pollutants are dust, sulfur dioxide and sulfur trioxide. Where this is the case, good air purification of both indoor and outdoor air can usually be achieved with a combination of dry filters and carbon adsorbers."

By specific examples, he shows that the operating costs for both heating and cooling are less if recirculation and activated charcoal purification are used.

An excellent approach to air purity in occupied space is to set a specification for air quality. Then, with this in front of you, use whatever system supplies air of these specifications at the lowest cost. Such a specification might read somewhat as follows:

Specifications for Air Quality

Absolute pressure	-	23-35" Hg.
Oxygen content	-	18-21%
Carbon Dioxide	-	.6% maximum
Dust (and other particulate matter)	-	.05 gr./1000 cf max.
Bacteria count	-	5 per cf max.
Odor	-	20 ppm max. 2 thresholds max.
Toxic vapors	-	Below published limits

These figures are not presented as a final suggestion. Each of the values must be selected with care and may vary with different types of occupied space and in various parts of the world. It is the principle that I wish to offer. Ventilation, including odor control and other aspects of air purity, should be approached in two steps. First, decide what we want and record it in figures. Second, use the best, most reliable, and least expensive method of achieving this desired atmosphere.

Origin and Removal of Air Contaminants

By Louis C. McCabe,* President
Resources Research, Inc.

Air pollution may arise from natural sources such as volcanoes, dust storms, pollen, bacteria and forest fires, or it may be generated by the activities of man in the burning of coal, oil and gas, incinerators, chemical activities, mining, and the use of vehicles for transportation. In those categories of air pollutants arising from the activities of our society, we are concerned with substances which arise directly from industrial, commercial, domestic, transport or agricultural activities, and those pollutants which do not come from primary sources but are by-products of the inter-action among primary pollutants under the influence of natural forces in the atmosphere.

Air pollutants, dust, smoke, fumes and liquid droplets obscure the sunlight, interfere with aircraft operations, soil buildings and clothing, may give rise to offensive odors and, in some cases, are lethal to plants, animals and man.

The variety of pollutants[1] due to human activities has been described as follows:

1) Odors from sewage disposal plants, paper mills, food processing plants, chemical plants, incinerators, and truck and bus engines.

2) Chemical substances which may cause paint blackening, corrosion or other undesirable effects, such as sulfur dioxide, chlorine, hydrogen sulfide, hydrogen fluoride, acid mists, solvent vapors and hydrocarbon vapors.

3) Dust of industrial origin, such as cement dust, metallurgical fumes and fertilizer dust.

4) Dust of nonindustrial origin, such as soil particles picked up by wind, salt particles found near sea coast, road dust, and dust derived from construction work.

5) Smoke of industrial and nonindustrial origin from coal burning furnaces, incinerators, power plants, junk yard operations and other activities.

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*McCABE, LOUIS C., B.S., M.S. and Ph.D. from University of Illinois in geology and mining engineering; Member of American Chemical Society; American Institute of Mining, Fellow of AAAS, and Fellow of Geological Society of America; was first director of Los Angeles County Air Pollution Control District.

(1) Numbers in parentheses refer to List of References at end of paper.

A recent index of pollutants may be applied to most localities for evaluating the amounts of air contaminants released where controls are not present[2].

1) Oxides of sulfur, estimated as SO_2, are emitted from:

   a) Fuel oil combustion--about 30 lbs. per 100 lbs. of oil.
   b) Coal burning--about 40 lbs. per ton of coal.
   c) Automobile engines--about 17 lbs. per 1000 gallons of gasoline consumed.
   d) Diesel engines--about 15 lbs. per 1000 gallons of fuel used.

2) Oxides of nitrogen, estimated as NO_2, are produced from:

   a) Fuel oil burning--about 13.5 lbs. per 1000 lbs. of oil.
   b) Natural gas burning--about 6-9 lbs. per 1000 lbs. of gas.
   c) Coal burning--8 lbs. per ton of coal.
   d) Automobile engines--25-75 lbs. per 1000 gallons of gasoline consumed.
   e) Diesel engines--75 lbs. per 1000 gallons of fuel used.
   f) Waste incineration--about 4 lbs. per ton of mixed refuse.

3) Solids such as dusts, smoke, condensed fumes, etc., result from:

   a) Waste incineration--about 25 lbs. per ton burned.
   b) Fuel oil combustion--about 2.5 lbs. per 1000 lbs. of oil used.
   c) Coal burning--around 200 lbs. per ton of coal.
   d) Automobile engines--about 0.3 lbs. per 1000 gallons of gasoline consumed.
   e) Diesel engines--about 100 lbs. per 1000 gallons of fuel used.

4) Aldehydes, estimated as formaldehyde, are emitted by:

   a) Automobile engines--about 18 lbs. per 1000 gallons of gasoline consumed.
   b) Diesel engines--about 30 lbs. per 1000 gallons of fuel used.

5) Carbon monoxide is produced from gasoline engines in normal operation at the rate of about 3500 lbs. per 1000 gallons of gasoline. (This is the only really significant source of CO, with the possible exception of improper household heating.)

6) Organic vapors, often referred to as "hydrocarbons," are emitted as pollutants from:

   a) Automobile engines at an average rate of 200-400 lbs. per 1000 gallons of gasoline used.
   b) Evaporative losses from automobile carburetors and tanks at a highly variable rate with air temperature--at 100°F the loss may be 2.5 to 5.0% of the gasoline throughput.
   c) Evaporative losses from the use of organic paint and lacquer thinners, diluents, solvents, degreasing agents, cleaning compounds, etc., can be assumed to equal the amount used.
   d) Evaporation of gasoline during storage, handling, and marketing is estimated at about 100 lbs. per 1000 gallons.

The pollutants, which do not come ready-formed from primary sources but are inter-action products among the primary pollutants under the influence of natural forces in the atmosphere, are primarily hydrocarbons. In Los Angeles County, approximately 1450 tons of hydrocarbons are lost to the air on an average day and 52% of this is attributed to the automobile. The primary source of pollution of Manhattan is also motor vehicle traffic. In the presence of sunlight, the exhaust gases of the automobile are oxidized and form aerosols which may produce smoke screens under certain conditions. In Los Angeles particularly, concentrations of the oxidation products are high enough to cause eye irritation and damage to vegetable crops.

The New York City Department of Air Pollution collects data with respect to particulate matter in the atmosphere[3] based on dustfall samplings and dust counts, gaseous impurities in the atmosphere such as sulfur dioxide, hydrogen sulfide, nitrogen dioxide, oxidants, ozone, ammonia, aldehydes, carbon monoxide and others.

Sootfall is highest in New York in January and February at the peak of the heating season. The monthly average in the five boroughs in 1956 was as follows:

Sootfall Average, 1956	Tons per sq. mi. per month
Manhattan	103
Brooklyn	67
Queens	58
Bronx	49
Staten Island	38

A study of dustfall in Perth Amboy, N. J., in 1955 showed the average to be 200 tons per sq. mi. per month.

Air pollution can be most effectively controlled at the source but, with the increase in industrial and other human activities, the amount of pollution that escapes tends to grow in spite of the most effective means of control at the source. Therefore, there is an increasing interest on the part of hospitals, food processing plants, instrument manufacturers and other industrial and manufacturing firms to clean the air in the enclosed space in which their immediate activities are carried out. Removal of air contaminants of the particulate type may be done with cloth filters, electrostatic precipitators, various types of wet scrubbers and impingement filters.

It is impossible to prevent some atmospheric contamination by objectionable vapors in gases. A large number of activated carbon installations have been made to purify the air drawn into buildings by ventilation systems[4]. The concentration of odors or otherwise objectionable materials in this air is low, and the load on the carbon used to remove it is so small as to permit the carbon to be used for months before it becomes ineffective. Such equipment prevents air contaminants from adversely affecting occupants of buildings and such diverse manufacturing operations as making bread and making photographic film. It also prevents unsatisfactory operation of equipment, such as automatic telephone exchanges and other equipment sensitive to the action of sulfur dioxide or other corrosive gases. The air drawn into several important libraries is subsequently freed from sulfur dioxide by suitable activated carbon equipment in order to prevent deterioration of valuable books. Reported results of tests state that normal sulfur dioxide content of the air was reduced from 0.12 parts per million by volume down to two parts per billion.

Another use to which activated carbon is being put is for the removal of indoor odors and impurities from air circulating in buildings of all kinds, railway cars, buses, airplanes, ships, etc. In this application of carbon, the overload is extremely small and the carbon can remain effective for a relatively long period of time before reactivation. In the removal of odors and impurities from recirculated air, less intake air is required and the over-all cost of conditioning an area is reduced.

List of References

1) Chambers, Leslie A., Proceedings, Natl. Conference on Air Pollution, U. S. Dept. of H.E.W., p. 35, 1959

2) Op. cit., pp. 35-36

3) Smoke and air pollution, Interstate Sanitary Commission, p. 7, 1958

4) Ray, Arthur B., Air pollution, McGraw-Hill, p. 357, 1952

Air Purification in Hospitals

By V. W. Greene,* R. G. Bond and G. S. Michaelsen
University of Minnesota

In recent years the medical world has become greatly concerned with the phenomenon of nosocomial, or hospital-acquired infections. It is now recognized that this problem is a complex one resulting from a variety of situations, some of which are clearly understood and others which are still undefined. A great deal of effort and money is being expended to resolve some of these problems. One of the major areas now being studied is the relationship of airborne microorganisms and their control to nosocomial infections. This paper will attempt to review several highlights in this field and to mention some of the observations our research team at the University of Minnesota has made about the hospital environment.** In this presentation we can do no more than discuss generalities. Those interested in more detailed research results should consult the writings of Bourdillon (2, 3), Shooter(10), Fredette(4), Blowers(1) and Williams(13) which represent some of the best recent work in this field.

At the outset it might be necessary to orient ourselves to this subject by reviewing the nature of the microorganisms with which we are concerned. In general, we are dealing with creatures that range in size from the bacteria (1 to 5 microns or 1/25,000" to 1/5,000") down to the smaller viruses (10-100 millimicrons) that are too small to be seen with the light microscope and can pass through filters which retain even the smallest bacteria. These microbes comprise a strange and wonderful world of living particles of varied shapes and capabilities, which influence our lives and most of our activities. Many microorganisms are essential to the very existence of the human race, whereas others are capable of inflicting upon us dread disease. These microbes are ubiquitous.

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*GREENE, V. WILLIAM, is Assistant Professor of Public Health and Bacteriologist, University Health Service, University of Minnesota; B.S.A., University of Manitoba; M.S. and Ph.D., University of Minnesota; Member of Society of American Bacteriologists, Henrici Society, American Dairy Science Association, International Association of Milk and Food Sanitarians; formerly assistant professor of bacteriology, Southwestern Louisiana Institute. R. G. BOND is a Professor in the School of Public Health and Bacteriologist, University Health Service. G. S. MICHAELSEN is Associate Professor, School of Public Health, and Industrial Health Engineer, University Health Service.

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1) Numbers in parentheses refer to List of References at end of paper.

They can be found just about anywhere--in waters and soils, on our skin, our clothing, our food, in our intestinal tracts, in the air--indeed, unless some specific treatment has eliminated microbial life in an environment, one or more varieties of bacteria or viruses will usually be found in that environment.

Superimposed upon their ubiquity is their speed of proliferation. To a large extent they multiply by dividing into two. Each cell, in a suitable environment, produces two cells; these two produce four, the four produce eight and so on. It has been calculated that 10 staphylococci multiplying at a reasonable generation time of 30 minutes, in theory will produce a total population of 80 billion cells in only 16 hours. Each new cell would then be capable, when introduced into a suitable environment, of multiplying and starting this cycle over again. Thus, when we consider their dissemination in our environment, their extremely small size, and their potential of producing disease, we can readily understand how formidable is the foe which confronts us.

However, we are going to concentrate only on airborne microorganisms, and more specifically on airborne bacteria. Previous discussions of this subject were concerned mainly with those illnesses whose causative agents were transmitted by the respiratory route like diphtheria, pneumonia, streptococcal infections, and tuberculosis.[8] Today, one must amend this list to include airborne diseases transmitted by pathways other than nasopharyngeal droplet expulsion, such as staphylococcal infections, airborne salmonella enteritis, and pseudomonas infections. In fact, many of the classic respiratory diseases have been declining because of mass immunization measures and other public health advances as well as progress in the fields of antibiotics and chemotherapy. On the other hand, the increased incidence of staphylococcal complications and postoperative infections reported during the last decade in hospitals on this continent and in the United Kingdom indicates that closer attention must be paid to the control of all viable airborne contaminants than in the past.

The subject of aerobiology is at once intriguing and difficult. The problem of sampling air for microbial contamination is, in itself, a challenge. Since the pioneering studies by Wells[12] 25 years ago, many attempts have been made to develop suitable techniques for this purpose, but it must be admitted that the problem is far from being satisfactorily solved. The available literature reveals little about the distribution and nature of airborne viruses. Even the relatively easier job of studying airborne bacteria is complicated by biological and technical difficulties. Bacteria may exist in air either as single cells or in fairly large microscopic clumps. Some may exist as delicate vegetative cells or as hardy spores. Some may be easily destroyed by light or dessication, whereas others survive as a potentially infectious hazard for years.

Bacteria may be present as free cells, or as nuclei in a dried mucous droplet, or may be attached to any of the infinite types of dust and lint particles in the environment. Bacteria are capable of carrying electrostatic charges, and thus are attracted and repelled by charged surfaces and other charged particles. Above all, they are living organisms and exhibit the idiosyncrasies of living organisms such as adaptability and mutation, nutritional and environmental preferences, and lack of cooperation with those who study them.

In recent years, new attempts have been made to study these organisms and to determine the normal ranges of their airborne distribution (Table I). It must be emphasized that these ranges are quite variable and dependent on many factors. However, they do illustrate the relative numbers of bacteria encountered in different environments. These counts may now be compared to those recorded in Table II, which illustrates representative data from the hospital environment.

TABLE I

Airborne Bacterial Counts Reported For Different Locations

Environment	Investigator	Count/Ft^3
Extramural Industrial	Wolf et al	2 - 28
" Rural	"	1 - 5
" Hospital	Greene	1 - 8
Schoolrooms	Williams et al	58 - 79
Cloakrooms	"	153
Clerical Offices	"	28 - 46
Shoe Factories	"	30
Public Offices	"	68
Homes	"	5 - 8
Subway Trains	"	40

TABLE II

Airborne Bacterial Counts Found in Hospital Environments

Environment	Investigator	Count/Ft^3
Burns Dressing Station	Bourdillon & Colebrook	20 - 291
Ordinary Ward	"	20 - 619
Operating Theatre	"	2 - 150
Ward (During Bedmaking)	"	up to 2000
Nurses' Station (10:30 AM)	Greene et al	10 - 50
Nurses' Station (11:30 PM)	"	1 - 3
Nursery	"	1 - 2
Delivery Room	"	2 - 7
Pediatrics Isolation	"	20 - 100

It is noted at this point that the significance of these counts or, more precisely, the relationship of the counts to incidence of nosocomial infection has not yet been established. On the other hand, work by Blowers(1), Bourdillon et al(2) and Shooter(10) indicates a fairly good relationship between reduction in wound sepsis rate and improvements made in the bacterial quality of air. Contaminated air is only one of many factors influencing the occurrence of cross-infection. Heavy airborne contamination is, nonetheless, a serious problem, and its reduction will be one step forward in the program of eliminating a potential hazard from our hospitals and institutions.

It would be well to evaluate the theoretical possibilities concerning the role of air in cross-infection (Fig. 1). One obvious possibility is the situation wherein infected droplets are transmitted directly from one person to another through a short distance, in which case the air is merely an inert medium. This event is well understood, and is the basis for the classic illustration of a person's sneeze or cough, wherein myriads of dangerous-looking droplets are forcibly expelled, saturating the immediate environment with potentially harmful microbes. This concept is largely responsible for precautions such as masking, though here again there is some doubt as to the absolute efficiency of normal hospital masks as microbial filters.

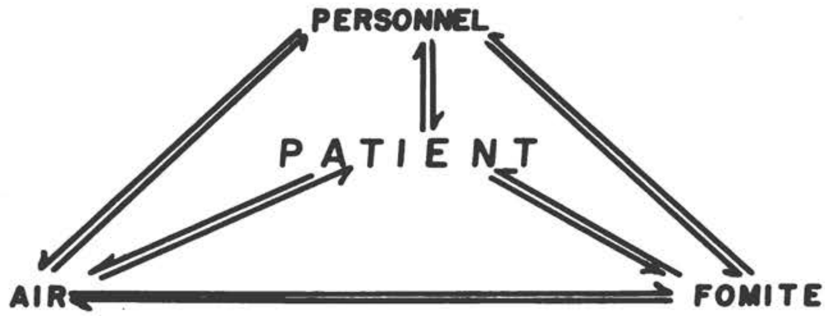


Fig. 1 - Theoretical interaction of personnel, fomites and air in a cross-infection cycle

The situation becomes more complex as further possibilities are considered. Pathogenic bacteria can be introduced into the air at a considerable distance from susceptible patients, and can be transported to these hosts by means of air currents and inert, airborne particulate matter. Thus, an unguarded sneeze or cough, or indeed, any activity which disseminates viable pathogens, may contaminate a patient several hundred feet and several stories removed, and at a time well after the activity terminates. These viable airborne bacteria can lodge on the inanimate fomites, survive, and be reintroduced into the air during dusting or other air disturbances, thus possibly initiating a new cycle of hazards. Similarly, a person walking through a contaminated atmosphere becomes contaminated himself (Fig. 2), and can transport the organisms to a relatively clean area where they may be shed into the clean air (Fig. 3) and contaminate it.

It may not be clear why cross-infections can develop despite the routine precautions employed specifically against respiratory disease. In order to control cross-infection adequately, one must break each link in this chain, or the organisms may use an alternate route. Similarly, precautions designed to isolate patients must isolate against contaminated air as well as contaminated people or fomites. Any space that permits passage of particles in the 1-10 micron range is sufficiently large to permit passage of pathogenic bacteria. A space beneath a closed door 3' wide with a 1/2" clearance from the floor presents, to a bacterial cell like the staphylococcus, an area of access which, to a man, would be the equivalent of a space 1000 miles wide by 14 miles high, certainly not a grave barrier.

The ultimate solution to hospital cross-infection can not be accomplished solely by medical and nursing personnel, but will also require the cooperation of many related disciplines such as hospital administrators, housekeeping and custodial staff, and the serious consideration of engineers, hospital designers and builders. In this fashion, by an understanding of the fundamentals of infection and contamination, all concerned can contribute towards resolving the basic problem.

The basic problem, as it relates to this discussion, is the efficient purification of hospital air and the control of airborne contamination. We have already seen the ranges in bacterial counts which one might encounter in typical environments. Where do these organisms come from? One apparent source is the outside air which is itself contaminated in varying degrees depending on such factors as location, season, climate, soil and dust. Other sources, and probably more significant ones, are the fomites of the hospital environment--the floors, furniture, bedding and all of the inanimate objects which collect airborne dust and particulate matter.

Fig. 2 - Contamination of a nurse's clothing and person after walking through an artificially contaminated room

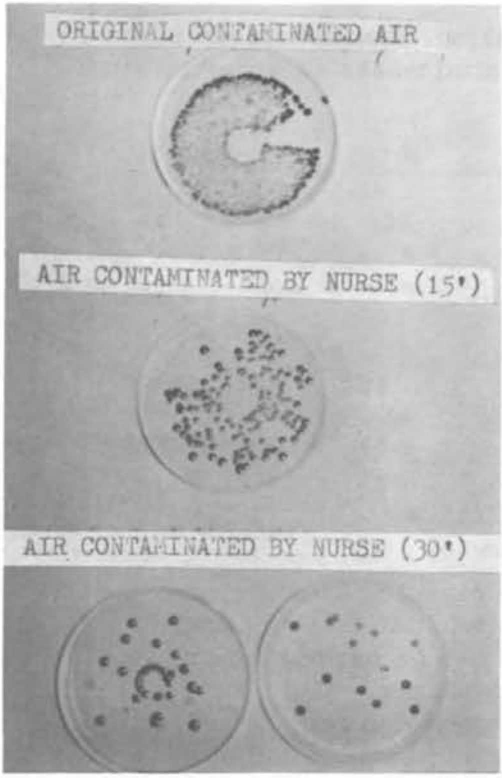


Fig. 3 - Airborne bacteria disseminated by contaminated nurse

Most important, however, from an infection point of view, are infected people. Patients, hospital personnel and visitors can all harbor pathogens in and upon themselves, and can disseminate these organisms into the environment where they can become part of the cross-infection cycle illustrated previously. Probably the overwhelming factor leading to the dissemination of bacteria from people and fomites is the degree of associated activity. A very active person who moves vigorously will contribute more bacteria to the air than a person who moves slowly and deliberately. Four people walking through a hallway contribute more bacteria than one person (Fig. 4). A nurse who makes a bed vigorously may create an impression of industriousness, and will also disseminate bacteria into the air in direct proportion to the vigor expended (Table III). Some relevant data in support of these contentions are shown in Table IV.

It is now evident that a primary means of control of airborne bacteria would be the control of activity. This may be done by design and planning, or perhaps it is more of an administrative problem. What might interest us more would be to control the flow of airborne bacteria through ventilation design. In general, hospital ventilation systems in the past were primarily designed with temperature and humidity control in mind, but it is also important to think of bacteria transportation. Just as we protect delicate hospital areas such as surgical suites, delivery rooms and nurseries from unwanted visitors by means of doors and barriers, so must we protect these areas from unwanted bacteria by planned air flow patterns. Work similar to that being done in the United Kingdom and at the National Institutes of Health[11] on operating room ventilation should be expanded to encompass the whole hospital area with regard to pathways available for airborne transport of pathogens.

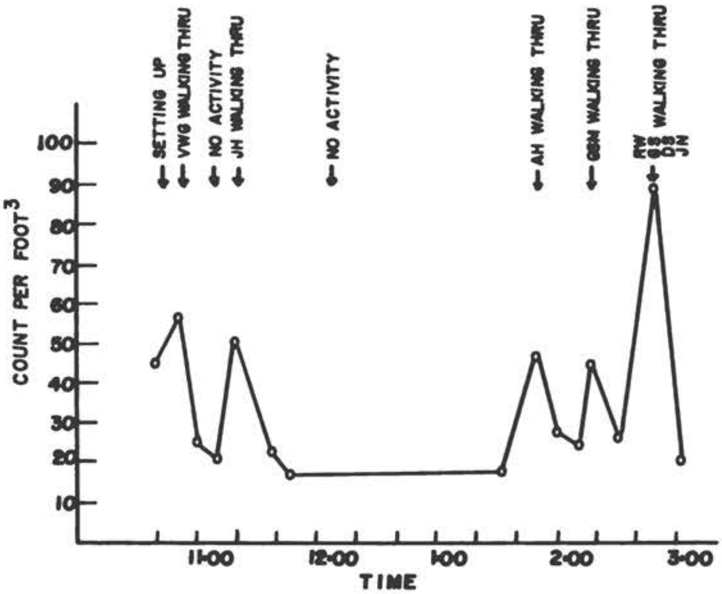


Fig. 4 - The relationship of airborne bacterial count in a ventilated room to the movement of people

TABLE III

The Influence of Bedmaking on the Airborne Bacterial Count of Hospitals

	Count Per Foot^3	
	Inside Patient's Room	Hallway Near Patient's Room
Background	34	30
During Bedmaking	140	64
10 Minutes After	60	40
30 Minutes After	36	27
Background	16	
Normal Bedmaking	100	
Vigorous Bedmaking	172	

TABLE IV

The Relationship of Hallway Traffic in a Hospital Ward to the Airborne Bacterial Count

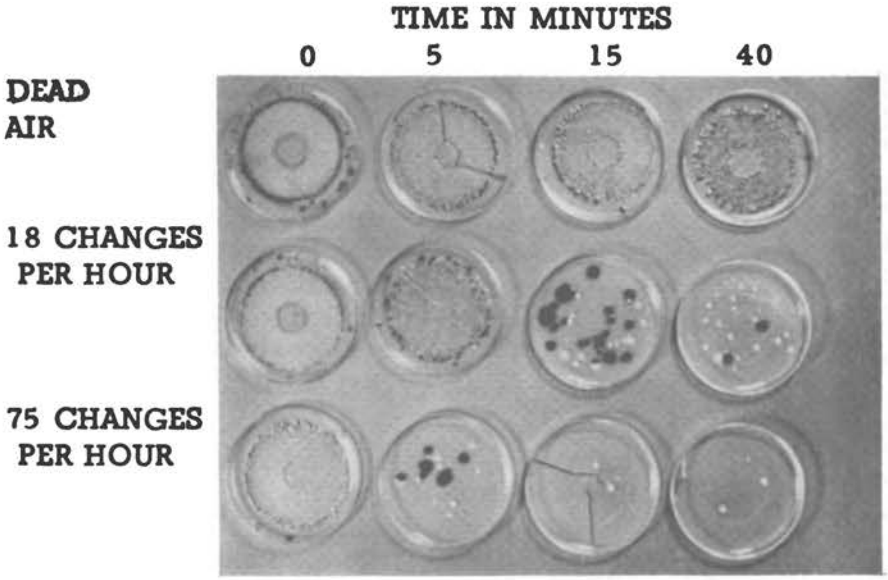
Time	Number Passing Station Per Hour				Count/Ft^3
	Personnel	Visitors	Patients	Total	
11 - 12 AM	242	55	46	343	40 - 46
3 - 4 PM	135	120	11	266	15 - 20
11 - 12 AM	165	15	8	188	9 - 11
9 - 10 AM	113	18	8	139	7 - 8
10 - 11 PM	38	5	2	45	3 - 4
11 - 12 PM	5	0	0	5	0 - 3

Thus, one must consider each hospital area, and design the ventilation specifically for that area. For example, in a nursery or delivery room where uncontaminated air would be most desirable, the air pressure should be greater than that in the nearby hallways, to minimize movement of contamination from the latter source. On the contrary, a similar system installed in an isolation ward might endanger everyone in the surrounding area by pushing pathogens from already infected patients out of their rooms into the hallways. Under special conditions, air lock arrangements might be used to maintain proper pressures and to prevent the movement of contaminated air into areas where it presents a hazard.

The forces which influence air flow in a hospital must also be considered in ventilation design. These institutions are literally honeycombed with chutes, stairwells, elevators, duct shafts, conduits and other pathways not necessarily accessible to human passage, but suitable for transport of microbe-laden air. Changes in outside wind direction will influence air flow characteristics within the building. The piston action of elevators and laundry bags in a chute will displace air vertically throughout the building. It is not sufficient to consider transport of bacteria merely by studying floor plans; the over-all structure must be kept in mind.

Similarly, some thought must be given to critical areas in a hospital other than operating theatres and nurseries. The possibility that foodborne outbreaks may originate from airborne bacteria in kitchens indicates the need for careful planning of ventilation for food preparation areas. Certainly outpatient waiting rooms deserve some attention as possible foci of infection. Laboratories handle pathogens and should perhaps be considered as critical areas of microbial generation. This whole problem is a field for fruitful research and future study.

In addition to controlling the direction of flow of contaminated air, a hospital ventilation system should be designed to eliminate these bacteria, rather than merely push them around. One way in which this can be accomplished is by dilution of contaminated air with pure air. This method is commonly employed to reduce smoke, odors and noxious gases in areas intended for human occupancy. It appears that bacterial contaminants can be removed in a similar fashion. We have performed some experiments using bacterial aerosols. Figure 5 illustrates how the contaminants remained suspended for relatively long periods in a dead air space, whereas they were very quickly removed by ventilation providing 18 air changes per hour, and almost instantly removed during 75 air changes per hour. British workers recommend as a practical figure for operating rooms 18-20 air changes per hour to give rapid clearance of contamination from the theatre.[9] More work should certainly be carried out to develop a sound basis for optimum ventilation rates, before any generally applicable values are accepted.



PERSISTENCE OF AIRBORNE BACTERIA

Fig. 5 - Persistence of bacterial aerosols in rooms with different ventilation rates

A refinement of the dilution method mentioned above is the so-called "piston" effect, which involves introducing supply air over the total ceiling area and forcing it to move uniformly toward the floor, where it is exhausted. The pure supply air is supposed to push the contaminated air out of the critical areas, and is theoretically more effective in reducing the airborne bacteria count than the simple dilution process. This system, however, poses some new design problems such as the optimal configuration of the space in order to enhance the piston effect and minimize mixing of the clean and contaminated air; furthermore, the effect of normal personnel activity and equipment on the vertical piston direction has to be considered. At any rate, this type of ventilating system is applicable only in a very few areas of a hospital, and thus does not by itself resolve the over-all problem of airborne contamination in the whole institution.

Any discussion of hospital ventilation must consider the bacteriological quality of the air supply. The employment of either a simple dilution system or a complex displacing piston arrangement presumes that the fresh air will not contribute appreciably to the airborne contamination. However, the occasional presence of high bacterial counts in extramural air invalidates this presumption. Furthermore, economic considerations may require recirculation of heated or cooled inside air. Consequently, our supply air at different times may contain appreciable numbers of airborne bacteria from the hospital environment, as well as from the outside. The situation would be analogous to the use of dirty water for dishwashing wherein the utensils would never become any cleaner than the water used to wash them.

To resolve this, it is generally agreed that the air be treated in some manner to reduce its bacterial count. No standards have been established in this field and, in fact, any standard for supply air alone would be of doubtful value considering the large numbers of organisms disseminated by normal activity in the hospital environment, which is really the space of importance. Nonetheless, on the basis of experimental trials, it is possible to obtain counts consistently less than 1-2 bacteria per cu. ft. by treating incoming air with commercially available air cleaning systems. Considering the fact that the ultimate level of airborne contamination in a given space will never be lower than that of the supply air to that space, we suggest that 1-2 bacteria per cu. ft. be considered a maximum count for supply air.

Techniques for air purification, insofar as bacteria are concerned, fall into four major categories:

1) Mechanical and Adhesive Filters
2) Chemical Germicides
3) Ultraviolet Radiation
4) Electronic Air Cleaners

Each of these systems has certain marked advantages and, similarly, each has certain drawbacks. It is beyond the scope of this paper to evaluate them in detail, and indeed the bacteriological data available for some are too meager to lend themselves to comprehensive discussion. Therefore, we will attempt only to review these systems briefly and to indicate how they can fit into the airborne microbiology problem. The reader is referred to the more comprehensive report edited by Govan(6) for performance data and evaluations.

To remove bacteria efficiently, filters must have a high operating arrestance. In limited trials, different dry media filters were shown to remove from 56% to 92% of the ambient bacteria and molds, indicating a considerable variation in efficiency ratings. Unfortunately, the high arrestance units which are most effective as bacteria filters become dust laden quickly and must be replaced often. In regions of high humidity and heavy mold infestation, mold growth on the filter and resulting mustiness may become a problem. Media filters have an important role to play in hospital air purification, but by themselves they cannot yet solve all of the problems.

Chemical germicides for air purification have been attracting an increasing amount of attention. Very early workers used corrosive and irritating materials, and thus were limited in raising the chemical concentrations to effective germicidal levels in occupied spaces. The development of less irritating formulations such as the glycols overcomes this objection. However, one of the disadvantages of this technique is the selective action of chemical germicides. Usually they are highly effective against certain species and relatively inert against others. It must be further remembered that chemical disinfection is a function of exposure time as well as concentration, leading to technical problems of disinfecting large volumes of air moving at high velocities. Again, this technique may have an important role to play, but cannot yet be considered the ultimate answer.

A useful and popular system of air sterilization is irradiation with ultraviolet light. This technique has proved itself effective in many installations, and it has some excellent applications. However, there are still some serious drawbacks to considering this system as a universal panacea. First of all, ultraviolet irradiation will not penetrate through solid particles and destroy microorganisms on the underside of dust or lint. By itself, it does not remove from the air the vehicles of bacterial air transport. Its effectiveness is dependent upon proximity to source and time of exposure. Above all, unless the air gaining access to the UV source is efficiently pre-cleaned, the lamps become coated with dust films and require frequent maintenance.

The final system to be considered, the electronic air cleaner, is often recommended for use in critical areas. Tests show that commercial models removed more than 90% of bacteria-laden particles from the air, and that the counts of duct air downstream from the unit were usually lower than two per cu. ft. On the other hand, certain questions still remain unanswered. We do not know what happens to the removed contamination during a power failure. We should investigate reports that it has a low removal efficiency for lint. We would like to study the bacterial release during the washing cycle. In brief, all of the information on all of these systems is by no means complete and will require some renewed research efforts in the future.

The future might also yield a solution to the problem of airborne infection. Perhaps a combination of building design and construction will be forthcoming that will reduce the potential hazards of these bacteria. We hope that air flow design will in the future take cognizance of the septic air streams that can result from haphazard or ill considered planning. Perhaps someone will work up the ideal air purification system, using a combination of the different systems already available, arranging the components so that the supply air into a space will be bacteriologically clean as well as fresh. Perhaps in the future the doctors and nurses, bacteriologists, engineers, architects and builders will join forces to re-emphasize what Florence Nightingale said a hundred years ago, "The hospital should do the sick no harm."

List of References

1) Blowers, R., Mason, G.A., Wallace, K.R. and Walton, M., Control of wound infection in a thoracic surgery unit, The Lancet 269: 786-794, 1955.

2) Bourdillon, R.B. and Colebrook, L., Air hygiene in dressing rooms for burns or major wounds, The Lancet 250: 601-605, 1946.

3) Bourdillon, R.B., Infection of "clean" surgical wounds by the surgeon and from the air, The Lancet 260: 597-603, 1951.

4) Fredette, V., The bacteriological efficiency of air-conditioning systems in operating rooms, Canadian Journal of Surgery, 1: 3; 226-229, 1958.

5) Fredette, V., Air conditioning systems in operating rooms, Hospital Management 88: 2, 93, 112, 127, 1959.

6) Govan, F.A., Selection and maintenance of air filters. Publication #703, Building Research Advisory Board, National Academy of Sciences--National Research Council, 1959.

7) Greene, V.W., Bond, R.G., Michaelsen, G.S. and Vesley, D., Unpublished data, University of Minnesota, 1960.

8) O'Hara, D., Airborne infection, The Commonwealth Fund, 1943.

9) Sandison, J.P., Air conditioning in hospitals and some related aspects of lighting, Journal of Heating and Ventilating Engineers, November, 1958.

10) Shooter, R.A., Taylor, G.W., Ellis, G. and Ross, J.P., Postoperative wound infection, Surgery, Gynecology & Obstetrics 103: 3, 257-262, 1956.

11) Snow, D. L., Personal communication, National Institutes Of Health, 1959.

12) Wells, W. F., Airborne hygiene and air contagion, Harvard University Press, 1955.

13) Williams, R. E. O., Lidwell, O. M. and Hirch, A., The bacterial flora of the air of occupied rooms, Journal Of Hygiene 54: 4, 512-523, 1956.

14) Wolf, H. W., Skaliy, P., Hall, L. B., Harris, M. M., Decker, H., Buchanan, L. M. and Dahlgren, C. M., Sampling microbiological aerosols. Public Health Monograph No. 60, 1959.

New Concepts for Obtaining Better Air Quality

By William L. McGrath,* Chief Engineer, Unitary Equipment Division,
Carrier Corporation

With a basic background of knowledge of the present and future aspects of air contamination and the methods which are being made available for alleviation, I would like in this paper to raise a question. To what concepts in air treatment and building design does this background lead us?

The answer may at first glance be controversial, but I feel it is inescapable. It encompasses two propositions:

1) Design that contemplates the substantial exclusion of outside air from our living and working areas beyond the quantity required for physiological reasons.

2) The total treatment of the air in the spaces in which we live and work.

There are a number of valid and important reasons why we should not take substantial quantities of outside air into our controlled living areas:

1) Because, in our urban areas, the outside air is contaminated with wastes from industry, commerce and transportation, or in other words, smog. It is disturbing to consider the fact that many plants won't even grow in such an atmosphere. For example, it is estimated that for every 1000 gallons of gasoline consumed, approximately 3500 pounds of noxious gases enter the atmosphere, including nitrogen and sulfur oxides, aldehydes, carbon monoxide and unburned hydrocarbons. Further, there is every reason to believe that the problem will get worse before it gets better.

2) Another reason is the ever-present possibility of sudden air contamination by radioactive debris. Even the governor of New York State is diligently promoting the idea that every citizen should build a bomb shelter in his cellar. It appears that even a war on the other side of the globe could, with the assistance of the jet stream, provide a level of contamination in our atmosphere that would not be tolerable.

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*McGRATH, W. L., B.S. in Architectural Engineering, University of Minnesota; Member of American Society of Heating, Refrigerating and Air Conditioning Engineers and American Association for the Advancement of Science; previously associated with Minneapolis-Honeywell Regulator Co.

3) With a constantly changing menu, the outside air seems to provide a never-ending diet of pollen, spores, and other allergens that afflict large segments of our population.

4) The cost of cleaning which follows from the introduction of large quantities of dirty air, either by mechanical ventilation or through open doors and windows, tends to be overlooked in the over-all accounting in the home or business. Yet, one authority has estimated that the price of air pollution amounts to approximately $65 per year for every man, woman and child in the country and a substantial part of that figure represents cleaning and deterioration costs.

5) In buildings employing mechanical ventilation, the cost of heating and cooling the enormous quantities of outside air introduced represents an economic waste of great proportion. For example, an office building of 500,000 sq. ft. floor area employing one air change per 30 minutes for so-called ventilation could use an air conditioning plant about 50% smaller if only the interior air were treated. This is an important cost penalty. In addition, it represents that much more connected electrical demand on the powerhouse, the distribution system and the transformers, and at a very poor load factor. In a climate like New York City the owner of such a building would have to spend $3,000 or $4,000 more for power used in summer air conditioning. The added cost of heating this enormous quantity of air would be on the order of $7,000 to $10,000 per year. All in all, this is a substantial economic waste.

Perhaps ventilation, in the first place, is largely a tradition. Most frequently, people feel that they need ventilation to replenish oxygen. But, in the average 2000 sq. ft. house, the leakage through the walls, window structure, etc., amounts to approximately 20,000 cu. ft. of air per hour. This provides enough oxygen for 2000 people, but to keep the carbon dioxide concentration at an acceptable level, this amount of make-up air would probably still take care of 200 to 300 people.

Actually, the present standards of ventilation were set back in the dark ages, i.e., before air conditioning. The function of ventilation at that time was cooling. Before air conditioning, this was the only means of alleviating what would otherwise be insufferably high temperatures. This concept has affected the design of our buildings long after the means were available to eliminate the problem. Large and small buildings have been, and still are being, wastefully designed in the shape of L's, O's, H's, U's, E's and T's (a veritable alphabet soup) largely for the purpose of providing cross ventilation. Even house design is hamstrung by the same tradition.

At this stage in our technology I can see only one major function for ventilation (meaning the deliberate admission of outside air beyond specific physiological requirements). That is for the diluting of odors, and even this justification could be an anachronism.

To illustrate what I mean by the "total treatment" of air, we can state, with some certainty, specific objectives:

1) Heating when needed and to the degree needed.

2) Cooling when needed and to the degree needed.

3) Humidifying when needed and to the degree needed.

4) Dehumidifying when needed and to the degree needed.

5) Constant removal of dirt and dust (a much smaller problem when we keep the dirty, outside air out).

6) Constant removal of pollen, spores, and other allergens.

7) Constant removal of odors created within the space.

8) Constant removal of airborne bacteria and virus organisms. (In addition to the ever-present danger of radioactive contamination, we have added the disturbing possibility of our atmosphere being polluted as a result of germ warfare.)

9) Constant removal of air contamination due to leakage of outside air into the building, i.e., the irritating constituents of smog, or the atmosphere indigenous to crowded urban places.

This makes a quite specific list. Yet, in the future perhaps, other functions might be added. All of these, however, will rely on the ability of the building to purify the air contained within it. A controversial example is the question of ion polarity. At any rate, there seem to be at least three schools of thought. One school believes that positive ionization of the air makes one feel bad. Another school of thought feels that negative ions in the air make one feel good, and a third thinks that it is all nonsense. Personally, I think it important that we get better evidence.

If you conclude that these concepts of total air treatment are necessary, you might ask, then, how close we are to realizing them. Here you may be surprised to know that even with today's technology they are, to a large measure, obtainable, and in most cases at an actual economic saving over traditional practice. Here's what we can do:

1) The heating and cooling equipment available today is excellent. There is no reason for any structure not being totally air conditioned.

2) The dehumidifying we mentioned comes along fortuitously as a bonus, so to speak, with good summer cooling.

3) Humidification is not too much of a problem, but the means of adding humidity can be improved and certainly building construction must be reexamined if we are to maintain desired levels of relative humidity in colder climates.

4) Equipment for air cleaning is excellent, although some improvement could be contemplated to make it more service-free, particularly in homes and smaller buildings.

5) Pollen, spores and allergens are very easily removed. Even with average filter media (provided the space is air conditioned so that occupants do not resort to open windows) it has been proven that the pollen count is reduced to 1 or 2% of that existing outdoors--well below the threshold of irritation for most people.

6) Effective equipment is available for removing odors. While satisfactory, some additional improvement of equipment in the direction of making it more service-free is indicated.

7) As to outside contamination, the smog and the aerial garbage from civilization, we have helped to solve this problem by controlling internal odor level, thereby making it unnecessary to bring in any quantity of this contaminated air.

8) As to the removal of bacteria and virus organisms, we have very good evidence that the better types of filtration equipment do an excellent job of removing such airborne organisms. It appears that the organisms are suspended in the air attached to dust particles, or are present as droplet nuclei (i. e., surrounded by mucous). While opinion varies as to the importance of each method of transport, in either case the particle size is such as to be readily filterable. Having removed them, it is probably desirable to kill them, but evidence also indicates that this can be accomplished. Certainly it remains for the medical profession to document the benefits to be derived from living in a more sterile atmosphere. Evidence already collected, however, points to a sharp decline in the spread of contagion when the atmosphere can be really controlled.

Let's consider some concrete examples of how this industry has provided the mechanism for total air treatment in the home as well as in the industrial or commercial building.

Simplified versions of the electrostatic filter are now within the means of the normal homeowner. True, it will not give as high a dirt removal efficiency on fine particles as the larger commercial and industrial type of electrostatic filter, but it does a very adequate job on the type of dirt indigenous to the home or smaller commercial establishment. An electrostatic filter coupled with a filter bed containing activated charcoal in sufficient quantity and depth can perform an adequate odor removal function. However, it is true that both the filtration element and the odor-adsorbing element do require manual attention from time to time for cleaning or replacement.

Then we have another new development in which I am personally interested, primarily because I first proposed this approach some years ago and I am quite delighted to see it come into being. This device is called the "Air Purifier," and takes a slightly different approach to the problem of air cleaning and odor removal. Figure 1 shows the device applied as part of a heating and cooling system for a residence. Actually, it is made in different sizes and will be available for commercial and industrial buildings as well. The slanting filter is bathed in a solution of water and a special liquid. The solution continuously washes the filter, absorbs odors and permits the release of water vapor to the air. At lower right is the regenerator which removes odors to the outside via the ventpipe. The humidistat at bottom left controls the winter humidity by governing the water content of the solution.

Figure 2 shows how it works. We have a filtration medium of very large surface area through which the air twists and turns, with the dirt particles being thrown out on the turns. This surface is wetted by the flushing action of a solution of certain glycols. The fluid is constantly purified in the regenerator where it is heated to 170°F and hot air is bubbled through it.

The device does these things:

1) Provides adequate air filtration for most applications, with the added advantage of being self-cleaning. This is so because the fluid is released at periodic intervals (every 20 seconds), flushing the dirt which has been intercepted down into a collecting basin. The dirt settles out in the basin and at infrequent intervals may be thrown away.

2) It is a continuous odor absorber. That is to say, the odor substances removed from the air do not just build up in the fluid until replacement is needed. The function of the regenerator is to drive off the odors continuously at the elevated temperature and discard them outdoors through a vent connected to the regenerator. I believe this is the first time a continuous odor absorber has been developed.

3) The wet, sticky surface provided is quite effective in removing pollen, spores, and sundry other airborne organisms that produce allergic reactions.

4) The fluid has a desiccating action so that molds and other organisms can't grow. In this respect, I should point out that this fluid has a nature similar to that of glycerine.

5) It makes an excellent humidifier. Here again, it largely eliminates the maintenance required in the normal humidifier because of mineral deposits. It does this by providing what amounts to a built-in water softener. The lime is precipitated by the heat in the regenerator, and the lime particles are returned to the collecting sump, where they settle out.

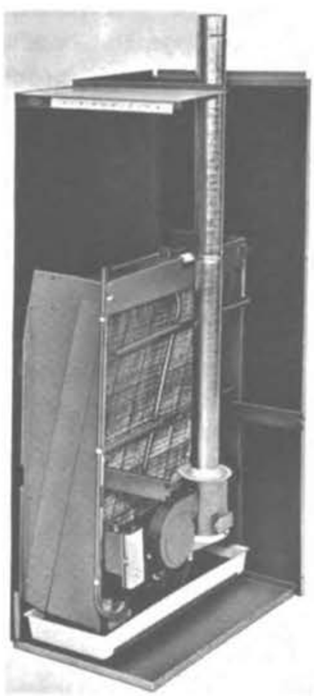

Figure 1

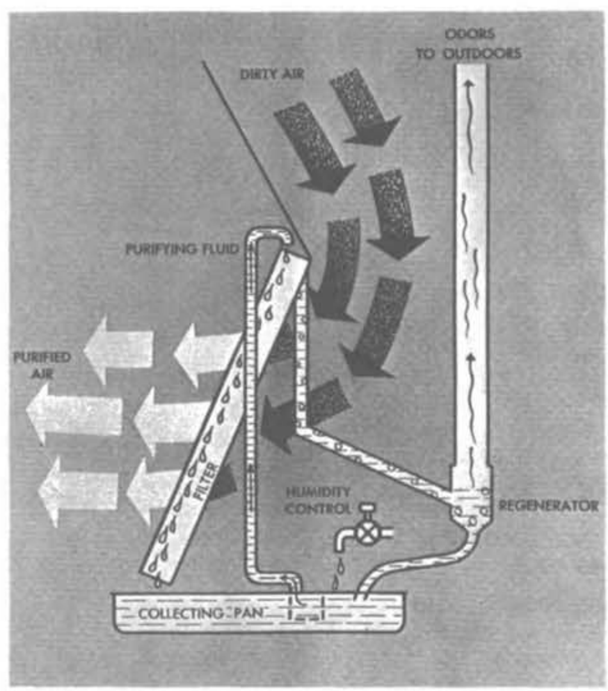

Figure 2

These devices are forerunners of many future improvements in the art of total air treatment. Note that, when coupled with a good heating and cooling system, most of the concepts we set down as objectives are attained.

To summarize future objectives:

1) I recommend that total air treatment as we have discussed it today be accepted as a key principle in the design of our buildings--schools, offices, factories, hotels and homes. To accept a concept of controlled environment implies a conviction that every building should be air conditioned (cooled as well as heated), since this is the only way we can control the quality of the air we breathe.

2) The future importance of establishing a properly controlled environment for living and working is such that considerable emphasis should be placed on research and development to confirm these objectives further and to improve equipment. Those industries having to do with air conditioning and air treatment have an important objective in developing even better equipment. Further research is essential to confirm the benefits of the elimination or removal of the aerial wastes of civilization--smog and related conditions. I believe, too, that much investigation is warranted to define further the benefits of air sterilization and the removal of bacteria, viruses and other organisms from the air in our controlled environment--and we ought to resolve the ion question.

3) Our practices of building design should be reoriented to the concept of total air treatment. It seems certain that this approach could radically change the basis of design for homes as well as commercial and industrial buildings, schools or hospitals. The "alphabetical" building would be a thing of the past.

With total air treatment, windows will have no possible utility other than a scenic diversion. To place this issue in proper perspective would free the designer of traditional cobwebs, permit the design of buildings at much lower cost than at present, and permit design to be more functional and of greater utility. Think what this concept could mean to the urgent problem of providing sufficient school space for our children. Even the home will benefit. A house may be designed to take better advantage of a site by employing windowless walls where indicated, and providing the scenic view in the directions where it is important.

There is no other profession that has the unique heritage of creativity that the architectural profession enjoys. Here is an opportunity.

Future Methods of Air Purification

By Finn J. Larsen,* Vice President, Research
Minneapolis-Honeywell Regulator Company

An increasing concern about man's environment has been evident in recent years. The problems connected with smog in the outdoor environment, plus smoke, odors and dirt indoors, have attracted the attention of scientists and engineers as well as all those who endure excessively polluted air. Before any attempt to predict how we will cope with these problems in the future, let us examine how competent engineers have recently solved some of the most severe air conditioning problems in existence today.

Our company has recently completed a space cabin simulator for the Air Force School of Aviation Medicine. (See Figs. 1, 2, 3) While the cabin remains on the ground, and is subject to the possibility of over-ride control by observers, two men soon will take a 30-day "flight" in this small space capsule. The two men, plus complete provisions for all the physiological requirements of breathing, eating, drinking and personal hygiene, will be contained in elliptical cylinder, 5' x 8' x 12'. Atmosphere control was probably the most difficult task our designers faced. Not only were they required to supply clean air at correct temperature and proper humidity but altitudes up to 28,000' were to be simulated, while percentage of oxygen and carbon dioxide were separately controllable. Carbon monoxide is held to less than 0.07 mm partial pressure.

An insulated room around the cabin is cooled to permit normal heat losses from the simulated space vehicle. The outdoor temperature (from the viewpoint of the space cabin occupants) is actually controlled to keep the interior at approximately the correct point. For precise control the air circulated in the cabin is heated or cooled.

Controlling the temperature of a cabin in space, not including the re-entry problem, may be somewhat simpler. Calculations show that total heat losses can be controlled to produce a comfortable temperature by the proper balance of heat-reflecting and heat-absorbing materials on the outer surface of the cabin. The only real problem is to avoid baking on one side and freezing on the other, the same effect that exists when we try to heat with a fireplace. To avoid this, one of our scientists has suggested we slowly rotate a flying

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*LARSEN, FINN J., B. E., Mankato State Teachers College; M.A. in Physics, Drake University; Ph. D. in Physics, Iowa State College; Member of American Physical Society, Institute of Radio Engineers, Atomic Industrial Forum, NAS-NRC Maritime Research Advisory Committee, Signal Corps Research and Development Advisory Council; associated with Minneapolis-Honeywell since 1948.

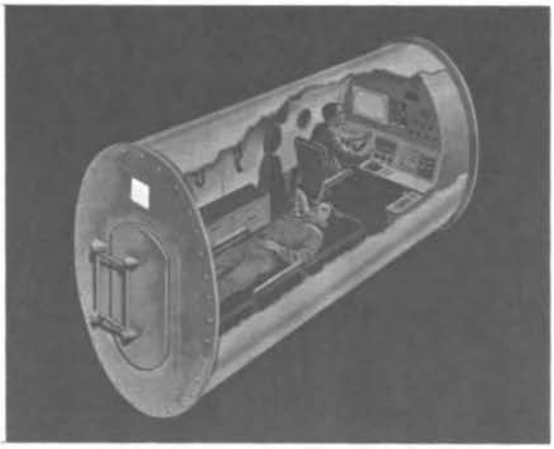

Fig. 1 - Artist's conception of completed space capsule

Fig. 2 - Equipment for capsule ready to be installed

Fig. 3 - Exterior controls for capsule

space vehicle about its flight axis once every two minutes! Our scientists studying human factors tell us this may be a satisfactory solution, since the occupants would not feel the rotation if they are away from the gravitational field of any planet.

In the simulated space vehicle, air is collected on both sides at the aft end of the cabin and carried through an electrostatic air cleaner which lies beneath a false floor. A catalyzer converts carbon monoxide to carbon dioxide. Without it, the occupants could not smoke. Up to one-third of the air flow can be diverted through chemical beds for absorption of carbon dioxide. Downstream from this point, baffles direct all of the air through activated charcoal for odor adsorption. An adequate activated charcoal odor removal system was installed as a result of experience with the week-long, one-man space cabin test. When the hatch was opened at the completion of that test the odor was noticeable in the building four stories away!

Humidity control in an occupied, hermetically-sealed cabin is entirely a problem of removing moisture, since the human occupants will continuously give off water vapor. The water removal is accomplished by the conventional technique of a chilling coil to condense vapor plus reheating of the air to the proper temperature. A hermetically-sealed cabin of the type described is not, contrary to general impression, particularly clean. Lint, dried mucus, skin particles, bacteria and tobacco smoke, which includes particulate matter, are all present. The electrostatic air cleaner was a necessity, since it permitted smoking, and removed particulate matter which might otherwise have clogged the activated charcoal filters.

An easy way of visualizing the problems of waste removal is to imagine that you and one other person are trapped in your home for thirty days, without any outside contact. No trash can be carried out, the garbage disposer does not work, no water is supplied, and the sewage system is not operating. The complete mechanism to dispose of all waste is contained under the floor in the space 18" x 30" x 18". Solid wastes are incinerated; all liquid wastes are distilled, frozen and passed through activated charcoal. The water which results is purer than that we ordinarily consume, and is used for drinking and washing.

One of the most interesting aspects of the space cabin project is that it is possible to deal with the most difficult ecological problems, and that the techniques of handling them are not appreciably different from the methods in current use by the air conditioning industry. I believe we should realize that the commercial and residential air conditioning industry is using the best available techniques, and be proud of the progress that has been made.

While tremendous strides have been made in home and office comfort during the last few decades, the approach to true comfort and complete control of our environment is only well underway. Many of us remember growing up in homes in which daytime warmth was provided by a kitchen stove and a "heater" in the parlor, while at night room temperatures went below the freezing point of water. Today we have genuinely good heating comfort, in fact, good thermostats control temperature so closely that we cannot sense the variations, and modern heating systems steadily deliver that comfort without fuss or trouble. We also enjoy equally comfortable, well controlled cooling during our summer months.

While nearly all air cooling systems remove excess moisture from the air, and many heating systems increase the humidity, there are comparatively few systems in use which control the relative humidity in our homes. In modern commercial buildings, of course, humidity control is recognized as being almost essential to the comfort of occupants.

At the present time the best available comfort in our environment is largely a matter of control of temperature, humidity and air circulation, plus one other factor--clean air.

Have we reached the golden age of comfort? Can we go even further in controlling our environment? Many research scientists believe that we are just beginning to have insight into some very interesting possibilities. For example, a few years ago experiments conducted at a California university indicated that the presence of negative ions in the air made a class of students learn faster than their normal rate, and they also seemed to feel better. A negative ion is simply a molecule with an extra electron, and it seems amazing that their presence can influence our feelings. Positive ions (molecules lacking an electron) were also tried and seemed to depress the learning rate and the attitudes of the students. Other experiments have reported that healing after surgery or recovery from disease occurs more rapidly in an atmosphere which includes negative ions.

Unfortunately, these experiments are not regarded as conclusive. In dealing with human beings, it is very difficult to remove unwanted influences or to control adequately all the factors which influence a young person's attitudes and learning rate. It also seems to be much easier to produce positive ions than negative. Additional experimentation will be conducted, and we will find out whether or not negative ions actually have a beneficial and stimulating effect. If all the effects are good, our homes, classrooms and office buildings of the future will have the optimum amount of negative ion content in the air, and all of us will feel better and work better.

However, even the salubrious effects of good air conditioning should be only the beginning. Most of us have at some time stood on a mountain top, breathed deeply of invigorating, pine-scented air, and felt gloriously alive, refreshed and ready to conquer the world. That tremendously invigorating, stimulating feeling is one most of us seldom experience, but there is no real reason why we could not touch a button on a wall panel and completely reproduce that exhilirating atmosphere. Imagine how rapidly the weekly housecleaning would go in a mountain top atmosphere! Or, can we learn which components of that mountain atmosphere make us feel energetic and well? Perhaps those effects should be introduced in every factory and office. The additional productivity might make our standard of living even higher.

If we can determine and then produce the ingredients of an atmosphere that can invigorate, we should also be able to produce a relaxing, soothing environment. The housewife might like to push another button and enjoy a sunny afternoon at the seashore. The air could be warmer, the humidity ought to be increased, and other as yet unknown aspects of the atmosphere could be produced by the air conditioning system. To complete the illusion, we might have both infrared and ultraviolet lamps turned on at the same time. The infrared lamps would provide radiated heat to give the "feel" of the sun, and the ultraviolet lamps would give the lady of the house the tan that would complete the illusion. On other occasions one might want a warm and cozy atmosphere to go with a fire on the grate, soft music, and relaxation. The possibilities of controlling our indoor environment seem limitless, but cannot be realized until we learn the secrets of nature's recipes. Only then will we be able to reproduce every desired aspect of an outdoor atmosphere in our homes and commercial buildings.

If eventually we are successful in achieving complete control of our indoor atmosphere, we may be able to do even more than simulate various outdoor atmospheres. Why not control moods? Instead of continuing to feel dull and logy and irritable, we might select an invigorating, exhilarating atmosphere and at least modify the depressed attitude. Or, the reverse might be true; a properly selected atmosphere could make a nervous, frantically busy homemaker more relaxed and less worn out at the end of the day. If this becomes possible, our air conditioning systems will indeed be approaching their "golden age." They will be near their ultimate development when they directly control man's moods and happiness.

Much research will be required before we learn how to reproduce nature's wonderful atmospheres, and still more before we can directly modify our attitudes and moods. In the meantime, however, we are making rapid progress. Every day increasingly greater numbers of us are enjoying the comfort of excellent air conditioning systems which materially better our living and working conditions, but we may have to wait a bit for the "mountain top" atmosphere or the "happiness" button!

Open Forum Discussion

Moderator - John E. Haines, Vice President
Minneapolis-Honeywell Regulator Co.

A. W. Hajjar, Penn. State University: Does plant life have any effect on absorbing odor?

Mr. Barnebey: I think plant life does absorb certain gases and vapors, not because they're odors, but because of some other chemical characteristic. It is generally agreed that if you pass air containing odors through a large enough mass of plant life it probably will take out most of the odors. It's not an accepted method of removing odor, but it is possible to a certain extent.

Mr. Green: I suggest that it is not so much a question of removing the odors as masking them, because plants themselves have a great many odors associated with them--the smell of flowers, the smell of chlorophyll itself. It's not a removal as much as a replacement of an odor with the more pleasant odors of plant life.

J. H. Stuart, Merck, Sharp & Dohme: Recently, I heard that new legislation in California would require all seven million cars in the state to be equipped with smog-prohibiting apparatus. What are the working principles of this apparatus? Is it the same as the Houdry Oxy Catalyst apparatus?

Mr. Hess: The news story is a little exaggerated. The intent is that all new cars sold in California will have to be equipped with a device of that nature. The one that seems to be working out at the moment is the catalytic type muffler. An automobile engine is actually very inefficient, and the problem is to complete the combustion all the way to CO_2 and H_2O and then emit it into the atmosphere. That is what this catalytic muffler endeavors to do. The big problem with this type of muffler is the lead in the gasoline. The little cars that run around manufacturing plants use white gasoline and do a good job of taking out the lead and completing the combustion.

Mr. McCabe: I'd like to comment a little further on this subject. The California law recommended for passage proposed that the State Health Department be given authority to set up and test different equipment for control, or completion, or combustion of the exhaust. Then, they can pass judgment on the equipment and enforce its use. They don't specifically require it within a year, but it must be approved.

Mr. McGrath: One of the first steps in the law's requirements, is that the breather tubes from the crankcase be introduced into the carburetor inlet.

Mr. Haines: Yes, that will be required on all new cars but it controls only a minor amount of the exhaust to take care of the so-called "blow-by."

George A. Nelson, Veterans Administration: Do you consider complete recirculation through activated charcoal filters satisfactory for an air conditioned hospital?

Mr. Barnebey: It's satisfactory as far as taking out odor, but it doesn't accomplish everything that needs to be accomplished in the hospital atmosphere. One of the big requirements in the hospital is bacteria removal, and a little activated charcoal will take out some bacteria, but that is not its prime purpose. It should be used for odor removal only; other types of devices are needed to remove particulate matter.

Unsigned question: The use of thoroughly cleaned returned air, with contaminating gases removed, in place of outside air is frequently considered as a cheap compromise with the quality of the system. Is this belief reasonable?

Mr. Hess: As for cost, it isn't cheaper to install that kind of system, but it's cheaper to operate. I see nothing wrong with using it if we can actually remove the contamination from the return air. There is no reason why we shouldn't reuse it, because so-called "fresh" air isn't always pure air.

Mr. Greene: In most cases the air that is returned, having been purified by a dust filter and activated charcoal, is purer than outside air. Let us compare activated charcoal cells that have done two types of service in the same locality--one cell purifying outside air and one cell purifying returned air. We find that the cell purifying outside air loads up much faster with vapors (and this is also true of particulate matter) than the cell that's working on returned air. You get much better air by recirculating and properly purifying it than you would have if you used outside air. It's not second best at all, in most circumstances.

Charles M. Sanders, Minneapolis-Honeywell: Could you comment on the relative importance of gaseous and solid contaminants from a health viewpoint?

Mr. McCabe: That would vary a great deal with the nature of the gas or particulate contaminant. Generally, the particulate contaminant concerns us most, together with gaseous contaminants such as carbon monoxide, sulphur dioxide, etc. We have established maximum allowable concentration levels for gas and they can be measured readily for our protection. With a particulate, we don't know too much about the health effects, although there are indications of some chronic, long-time health effects. Probably our greatest concern is with the particulate matter in the long-range view of air pollution control.

C. J. Fuccella, Procter & Gamble Co.: What is an approximate cost for activated carbon treatment of air, based on either CFM, square foot of floor space, number of occupants or other units?

Mr. Barnebey: One pound of activated charcoal, which might cost from 50¢ to $1.00, will purify the air breathed by 1 occupant in a home if he doesn't smoke. If he does smoke, it probably will take two pounds per year, per person. If you go to another extreme and ask how much does it take per seat in a bar, it probably will take about five pounds per year, per seat, because as soon as someone leaves, someone else sits down and most patrons are smoking all the time they are there. On the basis of cubic feet of space in a building, or in a home where people don't smoke, one pound of activated charcoal may purify 5000 cu. ft. and, in a bar, one pound may purify 100 cu. ft. per year.

Mr. Fuccella: Under what circumstance have you found activated charcoal treatment economically justified on the basis of eliminating heating and cooling of make-up air?

Mr. Barnebey: It would be easier to discuss the types of locations where it is not economical. It's hard to justify in a home unless you are providing an extremely nice atmosphere, because there is so much infiltration relative to the size of the building, that a lot of outside air comes in. Unless you are in an area where the outside air is really bad, it's hard to justify the use of activated charcoal. However, it easily removes odor peaks which occur if you entertain or cook a great deal. Another type of location where you can't justify activated charcoal is in a public building where you would be satisfied with the type of ventilation that uses 10% outside air. If that small amount of outside air does ventilating well enough to suit you, then you can't justify activated charcoal. But, if it requires 20, 30, 40 or 100% outside air in order to remove odors, then you can easily justify its use and likewise make a saving.

Eugene A. Sloane, Air Engineering: Which is the more important influence affecting health in a large metropolitan area--individual pollutants or synergistic effects of many pollutants?

Mr. McCabe: I am not sure that we know the answer to that yet. When you think of air pollution in the metropolitan area, you think of SO_2. One of the reasons for this is that it is easy to measure; therefore we measure it as an indicator of the level of pollution of all contaminants. The hydrocarbons are far more serious to health problems than SO_2 is, because we have men working in 5-10 parts per million SO_2. The maximum allowable concentration now for the workingman, per eight hours, has been lowered to five parts per million. However, rarely will you get a half part per million in an area because when you get to that level, you begin to burn vegetation and, you get such an outcry from farming people that you are going to get some relief. SO_2 has been given too much attention and the hydrocarbons are the more serious pollutants but in that case you're not dealing with a single substance. In the problem of eye irritation in Los Angeles, we don't yet know which of the hydrocarbons cause irritation. When the Bureau of Standards did some work there they found 120 hydrocarbon compounds. That's such a complex group that you just can't sort out easily which compound specifically is causing the difficulty, but we do know that there is carcinogenic material in the hydrocarbons. I would say that's a very definite threat and our number one problem, if we want to be specific, but dust and other particles may also pick up and absorb materials and produce synergism.

Unsigned question: Is it feasible to remove CO_2 by use of vegetation in a building?

Mr. Hess: The answer to that is no. On a theoretical basis it could be done by using many plants in a building, because they live on CO_2.

Mr. Larsen: We've had problems with building shelters for the Government where there may be danger of bringing in outside radioactive air. The CO_2 could then become a real problem, but it was solved by chemical removal of CO_2. CO_2 can build up to a hazardous level. In coal mining we get CO_2 at a level where it causes so-called "white damp" and the men collapse due to an excess of CO_2. An interesting approach to the problem may be the part that plants will play in any space ship operation, where you have a completely enclosed space. Many people are working on algae as a possible method of removing carbon dioxide, using the algae to provide oxygen. But I quite agree with your statement that, generally, it wouldn't be a feasible way of doing it.

Unsigned question: If activated carbon is used in an air conditioning system, is it necessary to treat all of the return air?

Mr. Barnebey? Not necessarily. In most ordinary spaces such as an office building, you can treat about 20 or 30% of the returned air, i.e., you would treat that fraction of the return air that you might otherwise have used in outside air. If you used 20% outside air to accomplish a ventilation job, then you could, if you used activated charcoal, recirculate the air 100% and treat 20% of it.

Mr. Haines: I would assume from that, if you reduce the outside air from 20 to 10% that you could treat 10% on the same basis, rather than the full 20.

Mr. Barnebey: In some types of spaces, where odor removal is difficult, as in some hospital locations where you might use 100% outside air, it would be better to treat 100% of the recirculated air.

Mr. Haines: What happens to the odors in the untreated return air?

Mr. Barnebey: They are treated the next time around. The same thing happens when only 20% of the outside air is brought in.

Eugene A. Sloane, Air Engineering: Will the new California air standards, in your opinion, be enforceable?

Mr. McCabe: It's at the experimental stage and that's the way most of these air pollution regulations are going to be until we learn more about them. Certain levels are set for hydrocarbons, carbon monoxide, oxides of nitrogen, ozones, etc., by a group of experts who have given considerable thought to it. However, the State Health Department would be the first to say that these levels aren't permanently fixed. Public pressures pose a real problem in California. The public doesn't want to wait long enough, and neither do the elected officials, for you to do a great deal of research. So you have to try the best thing you can, and do your research along with it, to see if you were right. The major plank in any political platform in California is smog, and yet the politicians don't do anything about it after they are elected.

A. M. Feibush, American Standard: How readily are odors, already absorbed by charcoal, displaced by new odors?

Mr. Barnebey: If the charcoal is used in accordance with instructions from the manufacturer you won't have this kind of trouble, but if you use charcoal beyond its capacity, odors of higher molecule weight will dispose the odors of lower molecule weight. However, that is using it in a manner contrary to the way it should be used.

Norman Goldberg, Voorhees Walker Smith Smith & Haines: What contaminants are present in cigarette smoke and which of these are not removed by either electrostatic precipitators or activated charcoal?

Mr. Barnebey: There is a list of several hundred contaminants in cigarette smoke and neither electrostatic precipitators nor activated carbon will remove the water vapor, the carbon dioxide or the carbon monoxide, but they will remove just about everything else.

G. C. Riegger, International Harvester: Are you saying we can use less outside air than code requirements, by the charcoal treatment, and thus reduce heating bills?

Mr. Barnebey: Yes.

Mr. Riegger, International Harvester: With modern office ventilation (electrostatic and continuous fibre glass filters) is the complaint of stuffiness due to the higher effective temperature or the odor?

Mr. Barnebey: In most cases the stuffiness would be caused by odor, however a temperature that's uncomfortably high certainly can impart the feeling of stuffiness too. Yet even with a high temperature, if all the odor was gone, I don't think you would have a definite sensation of stuffiness.

Unsigned question: What effect does particulate matter in the air stream have on the life of activated carbon filters?

Mr. Barnebey: It's best to remove the particulate matter first by some good dust filter, but the main effect that particulate matter has is a mechanical blocking of the charcoal filter. It fills in the space between the activated carbon grains, but the dust particles are generally too large to enter into the pores of the charcoal that absorb odors.

Mr. Haines: I've heard the statement made by you and others that one pound of activated charcoal has the equivalent of six million sq. ft. of area for purposes of odor absorption. How could that be possible?

Mr. Barnebey: We're dealing with atomic figures here. The little pores in activated charcoal are so small you can't see them, even with the best optical microscope. The pores that do the absorbing are in the neighborhood of 20 angstrom units in size, or two millimicrons. If six million sq. ft. seem high, consider the length it would be if you took all these little pores and put them end to end. The length would be fantastic because they are so small. It takes an enormous number to make one square foot, let alone six million. Therefore, if you could put them all in one line, the pores from one pound of activated charcoal, would stretch about 50 billion miles.

C. M. Sanders, Minneapolis-Honeywell: Until better control is established for air contamination at the source, wouldn't it be logical to require, by code or law, the local control of contaminants in schools where children must spend a large part of their time?

Mr. McCabe: It would undoubtedly be desirable, but I doubt very seriously whether we ought to use the legislative route to accomplish that. Your first emphasis should be on control of the source, if as I indicated before, the amount of contaminants left is going to be substantial. You may want to pursue that further, but to require local legislation before you require the control of the source would not arouse my enthusiasm.

Unsigned question: Are any air conditioning jobs performing satisfactorily to your knowledge in spaces of high occupancy and with no outside air supply whatever?

Mr. Barnebey: If there is no possibility of outside air coming in, if it's a tightly sealed space, then of course oxygen will be consumed by the occupants and you will have to replace it in some manner and remove the carbon dioxide. This is done now in atomic submarines. However, if it is a normal building, even of the most modern construction, there will be enough air infiltration from the opening and closing of doors so that you don't have to worry about oxygen and carbon dioxide. In that kind of space there are a number of buildings equipped for 100% recirculation and they are working very well. This 100% is just a figure, because they take all the air brought in with the blower and, after purifying, put it right back through the building. We all know there is some oxygen, some air, being added by infiltration. We run oxygen and CO_2 tests in such buildings and there is very little diminishment of oxygen--probably only .1 or .2% below outside air.

C. A. Wojan, Polytechnic Institute of Brooklyn: You mentioned that bacteria were charged particles. Does a particular charge (positive or negative) predominate among the various groups of bacteria?

Mr. Greene: Yes. In the neutral environment of the PH_7 most bacteria have a small negative charge. One crude system of air sampling, incidentally, is to rub an ebonite bar against one's clothes and wave it through the air to attract enough bacteria to give a quantity of measurement when you rub it on a Petrie dish.

Mr. Larsen: I would like to comment further on that question. There is much evidence that if you blow bacteria down a duct under certain circumstances you could have a positive charge and in other circumstances you could have a negative charge. Some years ago, for a military program, we were blowing fine dusts of various kinds. Some of these were talc, some were very finely divided plastics, etc., and, depending upon the material of the duct and the dust material selected, we received either a positive or a negative charge in the wall of the duct and the reverse charge on the particles. This is the same kind of an experiment Dr. Greene mentioned when he rubbed an ebonite rod. In an elementary physics book there is a list of materials in the order in which they will form an electrostatic charge on each other. If you take one from the middle of this table and rub it on one higher, you get one charge; if you rub it on something lower down, you get another. Bacteria, I would imagine, are somewhere in this list. Therefore, depending upon whether you rub them over a material higher or lower on the list, you will get reverse charges.

Mr. Haines: This is a common procedure, moving the particles through a duct to change the charge.

Mr. Greene: I might say that in the test we ran, we found the same thing. There are both positive and negative charges in about equal proportion. About 70% of airborne particulate matter carries the charge of one to the other.

C. J. Fuccella, Procter & Gamble: Would you say that there would be value to a study of the total treatment of air for a community, or even a city, along the principles of the space capsule versus the individual attempts of home owners, industry, office and public building owners, etc.?

Mr. Larsen: I'd definitely say yes to that. As to its realization, I think we're a good many years away from that kind of study, and I won't attempt to predict whether or not we will eventually live in the kind of age that our science fiction writers describe, with a big cover over every city. As Mr. McGrath mentioned, if we contaminate the atmosphere badly enough with radioactive materials, etc., this might be a necessary thing.

R. A. Avery, Cambridge Filter Corp.: Were any of the media you mentioned comparable to those tested by Decker et al (HPAC-Oct. 1951) or by H. F. Allen (J.A.M.A.-May 16, 1959), and if so can you explain their higher results?

Mr. Greene: We've tested the same type of absolute filters. They have a graded series of arrestments and, of course, the higher the arrestment for dust the better it was for bacteria. The lower the arrestment for dust the worse it was for bacteria. Very interestingly, the efficiency curves for both dust and bacteria fell on practically the same line, so if you have a rule of thumb for dust arrestment you can use it for bacteria for that series of filters.

Hal Chamberlain, Minneapolis-Honeywell: Isn't there a need for outside air to partially pressurize homes, thus permitting less leakage of foreign particles, particularly around window sills?

Mr. McGrath: In my opinion it's impossible to pressurize a home or any other building against leakage. The rate is so high that while efforts have been made to do this I have never seen it proven successful.

H. T. Sparrow, Minneapolis-Honeywell: What is known about the chemistry of odors?

Mr. Larsen: I can answer that in two words--very little. Also, I do not believe we are going to make much further progress in the more sophisticated means of odor treatment than we currently have. The use of an activated charcoal filter in absorbing odors is excellent, but the improvement that chemists dream about has a number of ramifications. One of them is the need to thoroughly classify, in a really scientific sense, like we can with the wavelength of light. We know what the wavelengths of light are that correspond to red, orange, yellow and green and we know about ultraviolet and infrared. We have a thorough scientific knowledge and can make measurements on light, but we can't do that with odors. There have been attempts and systems developed to classify odors, but they're based on the empirical reaction of the human nose, and not on on machine recognition, although there have been a few machines made to do a particular kind of a job. We won't really have a classification system until we learn a great deal more about the structure of odors. The only odor of which we know the chemical composition is H_2S, but we don't know the molecular structure of the more sophisticated odors. If we knew this, we could handle them easily and make all odors pleasant. We could put odors outside the range of the human nostril into a different spectrum, just as we can take light rays and move them into longer wavelength areas. We can, for example, convert ultraviolet to visible light rays by fluorescence, and we can convert visible light to infrared rays, etc. We ought to be able to take odors that are noticeable and change them so they can't be detected by the human nose. We are beginning to work on some of these areas and one of the approaches we intend to use is to study very sensitive surfaces that we know a great deal about, such as the surface of semi-conductors. We hope to learn something about odors by watching how they affect semi-conductors. We think we can get at the molecular arrangement and correlate that with some of the effects we see. We are in a very embryonic stage in this field and the first intelligent approach, other than what we are already doing in adsorbing the odors, will have to come from a basic physical and chemical understanding of their nature.

R. H. Avery, Cambridge Filter Corp.: You mentioned the problem of mold on media filters. Under the same condition of high humidity would other types of air cleaners, such as electronic, have operated any better?

Mr. Greene: I don't know. I have never operated an electronic air cleaner in Louisiana. Maybe someone else could answer that.

P. J. Zilles, Westinghouse Corp.: Our experience with electronic air cleaners is that they will operate just as well in atmospheres up to 99% relative humidity.

R. H. Avery, Cambridge Filter Corp.: Should the air cleaner not have been the last item downstream of the air conditioning unit to be certain that there was no by-pass of the filter?

Mr. Greene: You are assuming that there was an air conditioning system. This is not so. All we had was filters. It was a rather crude setup. They were using outside air and trying to filter it and this was the problem. An air conditioning system that controls humidity may have decreased the mold growth.

Mr. Haines: Under these conditions wouldn't the problem of mold be eliminated, since the relative humidity would be 50%.

Mr. Greene: Yes, you can just about eliminate mold when you get down to 50%. Mold growth requires high humidity for the spores to germinate, but once the mold starts growing the humidity can come down as low as 13 - 20% and it will keep on growing. So the initial growth, and growth by itself, are two different things. Once the spores germinate, low humidity doesn't stop them from growing.

E. C. Rieger, International Harvester: Assuming a pressurized building, which necessitates the use of outside air, what is the needed amount of such air for occupants of the space, disregarding city and state codes?

Mr. McGrath: The minimum quantity of air for physiological reasons, I believe is about 100 cu. ft. an hour to hold carbon dioxide at a proper level.

A. Monem Saleh, Pratt Institute: What is the temperature range beyond which bacteria are not capable of existing?

Mr. Greene: I've seen them grow at Fort Churchill in Canada as long as there was liquid water. They would grow at temperatures as low as 5^{o} below freezing as long as the water was liquid, and they also grow in Old Faithful Geyser in Yellowstone National Park, where of course the water is extremely hot. There are some that will grow at very high temperatures, and some at very low temperature. The normal range for disease-producing bacteria is probably between 20^{o}-45^{o} C. They can, however, survive higher temperatures, but there is a difference between survival and growth. Some of the bacteria spores which cause gangrene and tetanus will survive temperatures up to 118^{o}C for 15 minutes--that's steam under pressure. They will survive liquid air and liquid helium. They won't grow, but they will survive.

S. Sirotta, Navy Department: Why is the distillate frozen and probably melted before it is passed through the charcoal?

Mr. Larsen: The freezing and re-melting can accomplish a kind of separation similar to that accomplished by distilling. Remember, when you boil something in distilling, you're simply boiling off the water and all liquids which have a boiling point lower than water. Therefore when you distill, you carry over those liquids which have a higher boiling point. Then, when you freeze, you're doing the opposite kind of thing. What you thaw is the liquid water itself, and you leave behind all of those things which have a freezing point lower than that of water. Those items which have a lower freezing point have a general tendency to be related to those things which are carried over from the distillation. It is really more efficient to do a single distillation followed by a freezing and partial melting, than it is to do a triple distillation. It requires less heat, less space, etc., and you have a better product by using this double change in state in both directions.

E. A. Sloane, Air Engineering: Do filters capable of stopping sub-micron particles also stop bacteria and, if so, do these filters when approaching loaded stage, or at any point up to this stage, become a focal point of bacterial contamination to air leaving these filters?

Mr. Greene: Filters that will stop particles of sub-micron range will stop bacteria. We don't know about the virus. Whether or not the filter serves as the source of contamination depends on the maintenance. In removing and changing the filter, unless care is taken, you can shake off the bacteria and they will enter the duct work. The maintenance of these systems is at least as important as the original design, and certainly they will not work well unless properly maintained.

Unsigned question: With the new type liquid air cleaner and purifier isn't there a problem knowing when to replenish the chemical solution?

Mr. McGrath: There is not very much solution lost. The fluid used has a boiling point about 350°F, and it's a matter of, for instance in a home, putting in a quart once a year or thereabouts.

C. M. Sanders, Minneapolis-Honeywell: Do negative ions seem to have any effect on odors?

Mr. Larsen: To my knowledge this has not been investigated.

A. M. Feibush, American Standard: Would you recommend extending bacteria control methods to areas other than hospitals, such as homes and offices? If so what, if any, effect would this have on natural immunities?

Mr. Greene: I don't think we've yet come to the time for installing them in homes unless we have the complete air treatment in enclosed spaces that Dr. Larsen was talking about. There is enough natural infiltration and exfiltration in homes to give sufficient air change. Similarly, when people live in a home they become exposed to each other's bacteria and develop an immunity. The big problems arise in institutions where people enter with their own forms of bacteria. For example, the opening week of any children's summer camp or any army post or any hospital invariably gives rise to an influenza epidemic in that location, even if there is none in the rest of the country. Because there are approximately 50 to 70 different viruses which cause influenza, the people in Georgia may have 15 or 20 types, the people in Minnesota 15 or 20 different types, and the people in California another 15 or 20 types. Each group is immune to their own bacteria. However, when you bring people from far distances and place them in a very close environment there is an exchange of micro-organisms to which they have not developed immunity. Consequently, we worry more about institutions rather than offices that have a limited number of people with not much interchange of personnel. We are particularly worried about hospitals, because the people who come in there are sick in the first place. We have more old people in hospitals today than we've ever had before, and more new babies. Children and old people do not have the resistance to disease that comes with good health, and that is why we worry about institutions and hospitals.

M. H. Johnson, University of Florida: In air cleaning studies, are any efforts being made to introduce bacteria that are not harmful to humans, but which will attack specific harmful bacteria?

Mr. Greene: No. We have been trying, but they won't let us into the operating rooms. It has been estimated that of the several hundreds or maybe thousands of species of bacteria only about 20 or 30 are actually disease-producing. About 20 or 30 are beneficial and the others don't do either much harm or good. However every microorganism has the potential to cause infection. If the bacteria that ferment buttermilk get into your eye, they can cause infection. There is a danger, in this respect, of fooling around with living organisms, even though they are not classified as disease-producing.

Unsigned question: How does the continuous regeneration odor removal compare with charcoal in efficiency for commercial or residential use?

Mr. McGrath: There isn't any single answer. It depends on how deep the charcoal bed is and how deep the scrubber is in the liquid remover. They both remove odors and the question of total percentage of odor removal hinges on two factors: one, the contact factor, i. e., the percentage that contacts the absorbing medium and, two, the vapor pressure difference between the odor that exists in the air and its pressure over the absorbing medium.

C. J. Fuccella, Procter & Gamble: Have any studies been made of the effect on absentee rate of varying bacteria environments in buildings?

Mr. Greene: In schools, yes. In 1936 or '37 in the school system in Pennsylvania some of this work was carried on by Dr. Wells, but I don't know of any other work done in recent years with some of our more modern sampling techniques.

J. R. Higgins, Gustin-Bacon Mfg. Co.: Some acoustical experts claim that an extremely quiet ambient noise level is not desirable. Is there any evidence that completely odor free air is unpleasant?

Mr. Barnebey: There has been much discussion about it, but there actually is no evidence, that I know of, that indicates the complete absence of odor is bad. In fact, what evidence we have is to the contrary. There is a general feeling that there may be fragrances that give you a psychological or physical lift, but I don't think it's been shown that the complete absence of odor is bad.

C. M. Sanders, Minneapolis-Honeywell: What effect does the liquid in the air cleaner that you described have on bacteria that it collects?

Mr. McGrath: The material, like glycerin, comes into equilibrium with the air. That is, it absorbs moisture from the air up to a certain point; in normal usage that would be 80-90%. This has a very sharp desiccating action on any kind of microbial life, and thus these materials are used to inhibit the growth of molds and funguses.

Unsigned question: You showed high bacteria removal by media filters. These media filters are also very efficient in dust removal. Some viscous impingement panel filters are only about 50-75% efficient in dust removal. Insofar as bacteria elimination is concerned, will it make any difference if a germicide is applied to the filter?

Mr. Greene: According to what I know about germicides, to be really effective they require a clean surface. They have to come into intimate contact with the microbes. There is no hypnotic effect, and there is no action at a distance. The bacteria would have to be exposed directly. The surface of the organism would have to come into contact with the molecule which was going to do the killing. These viscous impingement filters, being of an oily or mucilaginous nature, might protect the organism from the chemical. If we can develop a germicide which, in itself, is viscous enough to work, then it probably won't kill the bacteria. However, all known germicides have their activity or germicidal potential diminished by the presence of organic matter. I would have to qualify that answer again by asking what quantity and what kind of dirt is this filter tracking? As a rule, it's fungal. If you're removing about 57% of the dust (and the dust you are measuring is down to about .7 microns in size) you will be removing approximately that same proportion of the bacteria, if not more. A large proportion of the dust we see in the air is sterile or uncontaminated dust. In fact, the ratio of dust to bacteria is an interesting problem and we are trying to study it now. Not all dust is contaminated and, if we remove about 57% of all the dust, we will probably remove about 60-65% of the bacteria at the same time.

Mr. Barnebey: As I see it, there are at least two questions involved. One is what percentage of the bacteria is mechanically removed from the air stream by the filter, and two, how much of what is removed is filtered? These two questions should not be confused. The fact that a filter contains a germicide won't cause it to pick up any more bacteria. The efficiency of removing bacteria from the air is not increased because the filter has a germicide. However, having this germicide, it will more effectively kill the bacteria once they are trapped.

J. H. Stuart, Merck Sharp & Dohme: What is the relation of bacteria counts per cubic foot and plate counts per 20 minutes exposure?

Mr. Greene: The plate count for any period of time is a nonquantitative measurement. The bacteria will sediment onto these plates at different rates, depending on what they are attached to. A great deal of work has been done on the sedimentation plate. It is not quantitative and there is no relationship, whatsoever, between a bacteria count per cubic foot and the actual sedimentation value.

Mr. Stuart: What do you think of Beta Propiolactone as a bacteriacide?

Mr. Greene: It's an excellent bacteriacide, but it is toxic to human beings, also. It is used very effectively for sterilizing materials which are heat labile, which can't take autoclaving or dry heat. Unfortunately, you cannot do this in a room which contains human beings. Beta Propiolactone is very efficient if you want to terminally sterilize a room, i.e., after an infected patient has left you can seal off the door and windows and prevent all exfiltration and infiltration. Some of the other gases, ethylene oxide and some glycols, are very effective in that regard, but they cannot be used successfully in an occupied space.

Unsigned question: Could you discuss the particle size of airborne bacteria? What portion of airborne bacteria are "riding piggyback" on dust particles?

Mr. Haines: We don't know what proportion of the bacteria are taking a "piggyback ride" and how many travel by themselves. We would like to find that out. The particle size of bacteria has been determined by a British research worker to be between 2 and 3 microns, containing about 2.5 bacteria per clump. However, some people have stated that these figures are based on erroneous assumptions.

Future Research Needs

Comments by the Conference Speakers

Mr. Barnebey: Considerable research is being done on odors and their control, and more is needed. We need more facts on the effect of odors on working personnel under various conditions. It is generally thought that odors, particularly at high level, decrease a worker's efficiency. We need proof of this and knowledge of the extent to which efficiency is decreased. This is important in industry, and also in connection with tightly enclosed spaces on submarines, in collective protection shelters, and in vehicles for space flights. We need true facts on some of the so-called odor removing devices now on the market. Many of them are worthless and others are of limited benefit. This knowledge should be obtained and made available to the public. The ASHRAE laboratory in Cleveland has an active, long-range program on odors and is currently conducting a series of evaluations of odor control methods. Our Government is doing research work on odors in submarines and space craft. Odor elimination is an important part of atmosphere control for closed spaces. We also need a better dissemination of knowledge obtained from research work already completed. There are many things about odor and its control that are already known but have not been put to use.

Mr. Larsen: Odor control is the field which we know least about in the entire air conditioning problem. This is an area in which we definitely need basic understanding, basic research, and greater development of fundamental knowledge. We must approach it in this manner if we are going to obtain answers that are really meaningful.

Mr. Greene: In the hospital building program, a great deal of research is needed by a great many different disciplines. Most of the time, when you see a hospital being built and ask the architect why he did a certain thing, why he used a certain material, or why he designed it in a certain way, the answer will be that this is the form which drew the least number of complaints--a rather negative attitude. We suggest that a truly integrated research program be undertaken in the hospital field encompassing design, materials, engineering, ventilation, administration, and housekeeping problems. Most of the traditional design of hospitals dates back to a period when the science of medicine and hospitalization were very new. Today we know a great deal more about hospitals. Earlier I discussed the type of traffic encountered in a hospital. As far as is known, we are the first to have actually counted the number of people who walked by a nursing station within a given period. The results showed that 343 different people were making motions of importance not only from a bacteria viewpoint but also from an administrative viewpoint. I have included administration because in many cases the patient has to be awakened at all hours and given sleeping pills, etc. In England the nurses no longer wear skirts in operating rooms, because it's hygienically unsound. Why do we allow nurses to launder their own uniforms, when we can provide them with lint free clothing? Look at laundry and trash chutes in hospitals. I know of one hospital recently built in Minneapolis where the whole system of waste disposal has been reorganized so that there is no need for laundry chutes and trash chutes. They collect the unwanted material in carts and take it down a special elevator to eliminate any cross-contamination or infection, and still there are great, big laundry chutes in that hospital, because the architect didn't think it would be a hospital without a laundry chute. This is why we suggest a serious program, perhaps to be sponsored by an organization like the NAS-NRC, in association with architects, engineers, the American Hospital Association, the American Medical Association, etc. There is a great deal of knowledge which should be organized and made available to the people who design and build hospitals.

Mr. McGrath: A study is certainly indicated, even beyond the design of hospitals on the question of air purification. Certainly high on the list would be the question of school buildings where there is a very important level of bacteria activity. This could be very important because we can easily do something about it, but the problem is to determine what the benefits are. The second area where we lack knowledge is the extent to which it is desirable in contaminated urban areas, to provide for removal of noxious gases, etc. I feel there are equipment and techniques available for eliminating these pollutants, but we don't even know what the problem is. I don't think anyone knows how much of this gets into the buildings, and this is a subject that ought to be explored. And, of course, to get back to the ions again, I would love to know whether they would do any good or not.

Mr. Greene: I would like to ask Dr. Larsen a question about the space vehicle. Are they going to put these people in quarantine before they put them into the space vehicle, to preclude any chance of their incubating some type of disease and then spreading it to each other while they are in the space vehicle?

Mr. Larsen: This has not been planned as yet. There was a trial run of two weeks and the men simply were subjected to a medical examination by a competent M.D., but that is the only precaution that has been taken thus far.

APPENDIX I

Current Problems in Hospital Air Conditioning

By C. P. Yaglou*

(Editor's Note: This paper was not presented at the BRI Conference on Cleaning and Purification of Air in Buildings, but is included here as a further contribution of data pertinent to the subject matter. It was prepared for the Subcommittee on Thermal Factors in Environment of the Committee on Sanitary Engineering and Environment of the Division of Medical Sciences, National Academy of Sciences-National Research Council, and was subsequently approved by the Committee on June 7, 1960. The Building Research Institute is indebted to the Division of Medical Sciences for permission to reproduce this paper.)

The conventional standards and practices for designing hospital air conditioning systems in the United States, have been reviewed adequately by Gaulin in a recent issue of the "Journal of the American Hospital Association."(1) Two important problems today on which information is limited are:(a) the definition of healthful air conditions for optimum design of air conditioning systems, and (b) the control of aerial transmission of pathogenic organisms, specifically the antibiotic resistant staphylococci now held responsible for many hospital infections. This paper summarizes the present state of knowledge on these two problems, and points out areas in which additional research is needed.

OPTIMUM AIR CONDITIONS FOR HEALTH

Thermal environments are better known for their effects on comfort than on health. There is no information to tell whether a room temperature of 68°, for instance, is in the long run better or worse than one of 72° or 75° for normally healthy persons. The same holds true regarding humidity within the comfort range, excluding disease conditions.

Controlled studies of possible effects of ordinary room conditions on health have been made by the Metropolitan Life Insurance Company,(2) the Bell Telephone Company of New York,(3) and the Detroit Edison Company,(4) using incidence of illness as a criterion of health. The Metropolitan studies comprised 10,500 clerical employees, one half of them worked in a new completely air conditioned building and the other half (control group) working in an older building ventilated by natural means, without artificial humidification in the wintertime and without cooling in warm weather. Test and control groups were

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*YAGLOU, CONSTANTINE P., M.D., died June 3, 1960; was Professor of Industrial Hygiene, Harvard School of Public Health; Chairman, Subcommittee on Thermal Factors in Environment, Committee on Sanitary Engineering and Environment, NAS-NRC; Member, American Public Health Association, American Industrial Hygiene Association; authored more than 150 articles and papers on ventilation, air conditioning and air hygiene.

1) Numbers in parentheses refer to list of references at end of paper.

comparable in all respects. The illnesses studied were common colds lasting 1-3 days, severe colds or grippe lasting 4-6 days, and severe upper respiratory illness of longer than six days duration. Diagnosis was made by the patients' physician or by an interviewing nurse at the home office.

After 47 months of study, no significant difference could be found in the number of days lost per clerk between the test group working in the air conditioned building and the control group working in the nonconditioned building.

In the Bell Telephone Company studies, a comparison was made of the incidence, character, and duration of illness between two comparable groups of female telephone operators having more than two years of service. A test group, comprising about 1000 girls, worked in air conditioned rooms, and a comparable control group worked in similar quarters in the same building but without air conditioning. The illnesses reported were those lasting more than seven days, certified by a physician. During 33 months of study, the group working in the air conditioned quarters had as much respiratory illness, or illness from all causes, as the group working in nonconditioned quarters. The duration of illness in the two groups was also the same.

Substantially similar results were obtained by the Detroit Edison Company in a two-year study with a test group of 875 men working in an air conditioned office building of the company, and a comparable control group working in an adjoining nonconditioned building.

The conclusion to be drawn from these studies is that exposure to comfortably conditioned office quarters for seven to eight working hours a day has no measurable effects on the incidence or duration of upper respiratory infections, or on nonrespiratory illness. Re-evaluation of the problem for continuous exposure to conditioned air, or on the basis of some more suitable health criterion than respiratory illness, might perhaps prove more successful in defining optimum air conditions for health, but a broad scale effort would be required.

While the benefits of air conditioning as an adjunct in the treatment of patients suffering from certain diseases are well recognized, it is even more difficult, than in the case of healthy persons, to establish optimum air conditions for various types of patients and medical procedures. Response of some patients to a given thermal environment can differ enough to require treatment of the individual patient himself, rather than the disease. These facts recently have been reviewed by Burch and De Pasquale(5) for patients suffering from circulatory and respiratory conditions.

In the absence of health criteria, the best guide for engineering design today is the empirical experience of clinicians based on patients' needs for comfort, which in turn can be considerably modified by adjustments of bed clothes. It seems unlikely that the engineers will ever obtain from the medical profession the exact specifications they are seeking.

CONTROL OF AERIAL DISSEMINATION OF INFECTIOUS ORGANISMS

Air as a Vehicle of Infection. Normally, the air is not considered a very important route of infection when the skin and respiratory membranes are unbroken, except perhaps in highly susceptible individuals exposed to heavily contaminated air. Extensive studies in barracks, hospitals, and industries during World War II have failed to show any significant relationship between the concentration of infective agents in the air and the incidence of infection from person to person. Spread of infectious diseases by direct contact or by short range droplets ejected from the mouth or nose was then believed to present the most serious risk. The picture may have changed with the emergence of the resistant staphylococci but there is as yet no convincing evidence to that effect.

The problem of airborne infection assumes a greater significance in operating rooms where open wounds are exposed to contaminated air. The primary sources of air infection are the respiratory passages, skin and clothing of apparently uninfected patients and surgical staff. There is no clear evidence as to how much of the incidence of clean wound infections is due to contaminated operating room air and how much to other recognized routes of transmission. Nevertheless, control of the bacterial content of air is generally believed desirable as a good hygienic measure, even though it is unlikely by itself to prevent infection.

Suggested Bacteriological Standards of Air Purity. The maximum safe concentration of airborne pathogens has not been determined. The following minimum standards have been suggested by investigators in Great Britain in terms of total bacteria colonies grown in blood serum agar, or serum agar after incubation at 37° C for 24 hours:[6, 7]

	Colonies/cu. ft.
Ordinary living and working spaces	50
Minor operations, dressing of small wounds	20
Major operations	10
Long operations on easily infected tissues	2.0-0.1

The use of total counts, rather than the count of the specific organism responsible for the disease, has been suggested because of the difficulties involved in recovering pathogenic organisms from the air.

Disinfection of Hospital Air Supplies. Aside from cost, there are no insurmountable difficulties in supplying nearly sterile air for hospital uses. In clean locations, air taken in from points well above the roof seldom contains pathogenic organisms. Although bacteria in the free state are microscopic in size (0.2-10μ), most of them normally are associated with dust particles or aerosol droplets larger than themselves. It is therefore not too difficult to remove up to 90% of them from the air along with dust by means of properly designed and operated electrostatic filters, giving air that is clean enough for most hospital purposes, at a pressure drop of only 0.1" H_2O when clean and 0.5" H_2O when dirty. For operating rooms and other critical areas, higher cleaning efficiencies can be obtained, if necessary, by the use of fine glass-asbestos fiber filters capable of removing from 95 to 99% of the bacteria, at pressure drops of 0.5 to 3.0" H_2O. However, the maintenance of filters of any kind is a problem in many hospitals.

Bactericidal aerosols, or ultraviolet lights installed inside the supply duct are relatively inefficient for dust-borne organisms and impractical from the maintenance standpoint.

Although the airborne transmission of viral particles will not be considered in detail, current opinion regarding many viral agents is that they too are transmitted by means of dust particles or aerosol droplets larger than the viral particles.[8] Accordingly, much of the discussion to follow will apply to viral as well as bacterial agents.

Control of Bacterial Pollution of Air Inside Operating Rooms. Real difficulties are encountered in preventing contamination of the operating room air by activities of the surgical team over which the air conditioning engineer has no control. He has to cope with situations as he finds them by supplying enough filtered air to prevent accumulation of bacteria. Unfortunately the amount of contamination varies so much with different operating procedures and personnel, that it is impossible to estimate the quantity of air required for dilution on a rational basis. Safe bacteriological standards of air purity cannot be fixed. Until recently the recommended clean air supply to operating rooms by plenum systems has been 8 to 12 changes per hour, based largely on thermal requirements for maintaining temperatures of 75° to 80° with 55% relative humidity in hot weather without recirculation. The recommended capacity of the exhaust system has been 75% of the air supplied.

Another significant source of air contamination in operating rooms is the entrance of unsterile air from corridors and other access areas. This is particularly important where operating rooms are ventilated by exhaust systems, as in many British and European hospitals. The difficulty is now met abroad by pressurizing the operating room in order to create an outward leakage at all times. The air flow required for effective pressurization (0.06-0.08" H_2O) is placed at between 15 and 30 changes per hour.(9)

Some American hospitals are equipped with central corridor exhaust systems which reduce the need for pressurizing operating rooms, and at the same time prevent accumulation of bacteria in the corridors and adjacent rooms.

Disinfection of operating room air with tolerable levels of ultraviolet radiation has not proved very effective. However, good results have been reported by Hart(10) using strong radiation directed over the operating table from above, with eyes and skin of the surgical staff and patient protected by shading or covering with suitable material.

A study of the effectiveness of ultraviolet radiation in disinfecting air and in preventing postoperative surgical wound infections, is now in progress at five university hospitals. This study is financed by a research grant from the National Institutes of Health. Statistical support and coordination are provided by the Follow-Up Agency of the Division of Medical Sciences, National Academy of Sciences-National Research Council, and epidemiological assistance is furnished by the Communicable Disease Center of the U. S. Public Health Service.

BACTERIOLOGICAL PERFORMANCE OF VENTILATING SYSTEMS

British Investigations. Blowers(11) studied the efficiency of positive pressure systems versus simple exhaust systems in removing bacteria from the air of operating rooms in British hospitals (Fig. 1). A mechanical exhaust system removing air at a rate of 15 changes/hr. resulted in a total bacterial count of 15 to 45/c. f. of air (by slit samplers) under actual surgical procedures, when doors were opened as many as 55 times during the operation, for various unexplained but presumably good reasons. The highest counts coincided with periods of maximum activity preceding and immediately following the operation. The lowest counts were obtained during the operation when activity was at a minimum.

With pressure ventilation, and a comparable air flow, slit sampler counts ranged between 3 and 13 organisms per cu. ft. of air, when doors were opened 47 times during the operation, and between 1 and 3 organisms per cu. ft. when the doors were kept closed.

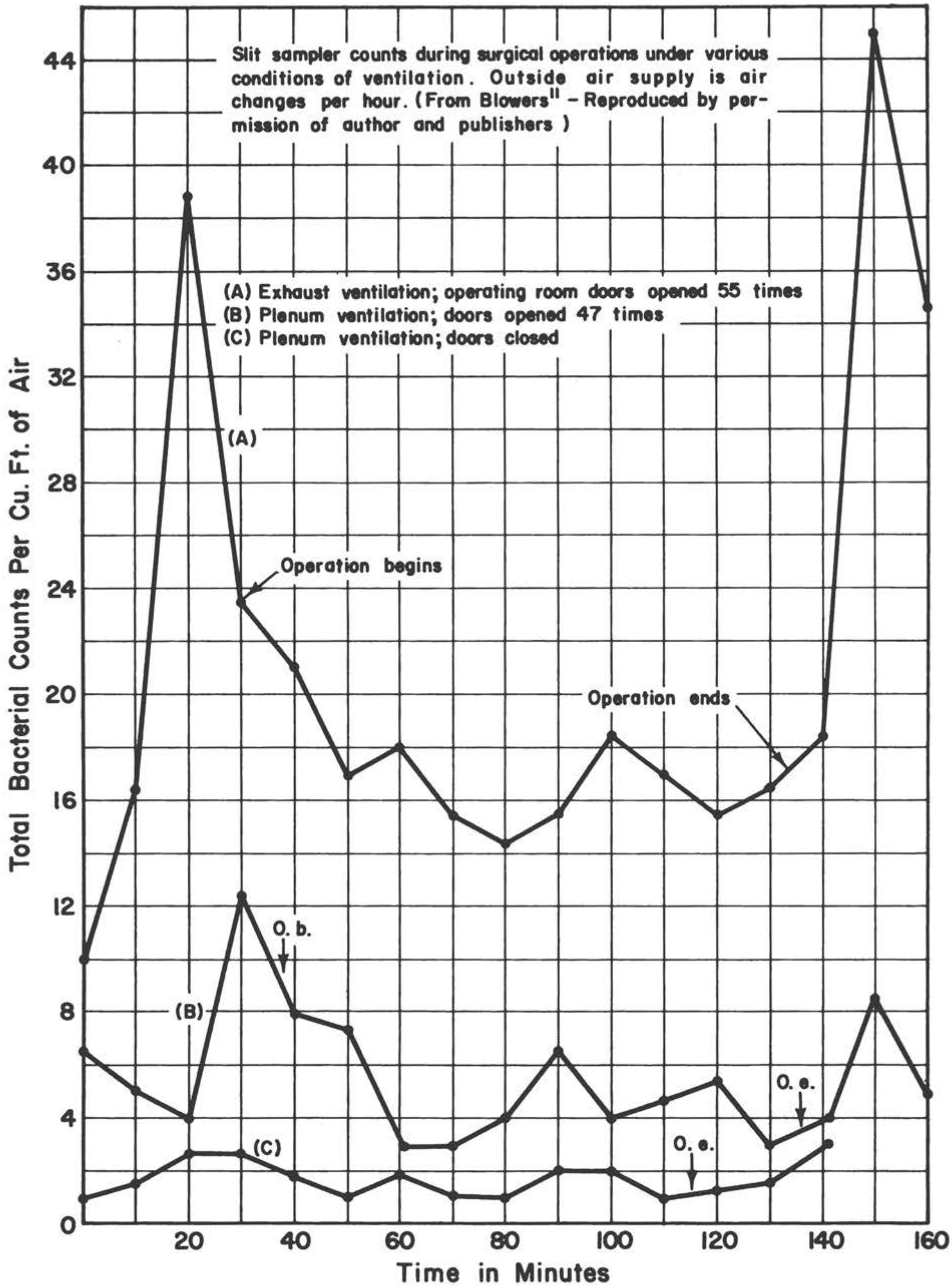
Slit sampler counts during surgical operations under various conditions of ventilation. Outside air supply is air changes per hour. (From Blowers[11] - Reproduced by permission of author and publishers)
(A) Exhaust ventilation; operating room doors opened 55 times
(B) Plenum ventilation; doors opened 47 times
(C) Plenum ventilation; doors closed
(A)
(B)
(C)
Operation begins
Operation ends
O. b.
O. e.
O. e.
Total Bacterial Counts Per Cu. Ft. of Air
Time in Minutes
0
4
8
12
16
20
24
28
32
36
40
44
20
40
60
80
100
120
140
160

Figure 1

Sedimentation counts by Petri dishes exposed from the time of the first incision until the tying of the last stitch were 11.08 colonies per sq. ft. of exposed surface per minute with simple exhaust ventilation, but only 0.48 colonies/sq. ft./min. with positive-pressure ventilation and closed doors. These counts refer to total bacterial colonies grown on nutrient agar after 24 hours of incubation at 37° C. The pathogens comprised only a small part of the total colony count.

Another important measure for maintaining low bacterial counts was the reduction of air movement from all sources to less than 50 fpm, the threshold air current capable of dislodging dust particles from the floor, equipment, etc. In laboratory studies, Lidwell[9] found that the use of a perforated ceiling greatly reduced disturbances of air due to ventilation, and nearly doubled the effective bacterial clearance rate.

High-velocity ceiling-supply outlets of the induction type with high entrainment ratio, were found unsatisfactory because of the disturbances they created and their recirculating action resulting in entrainment of dirty air. Streams of air from side walls directed toward the operating table did not reduce the bacterial count in the vital zone and produced unpleasant drafts. On the other hand, multiple, low-velocity, non-diffusing supply-air outlets, imparting a horizontal velocity to the entering air, produced satisfactory results, although inferior to those obtained with the perforated ceiling.[9,11]

Air movement produced by the walking of the operating staff was found to be of the order of 40-60 fpm[9] and to play an important role in increasing bacterial counts. Convectional currents set up by the surgical lights opposed the downward flow of clean air and reduced the effective ventilation rate by about five air changes under simulated operating room conditions.[9] Uninsulated cold walls, and direct hot water radiators also were found objectionable by contributing to the general air turbulence inside the operating room.

Positive pressure ventilation with gravity exhaust to the corridor through hinged louver outlets yielded better results than positive pressure ventilation with 25% mechanical exhaust, because the louvers instantly closed when the theater door was opened and all the ventilation air passed out through the door with no back-flow from the corridor.[9] It should be pointed out that corridor venting is not permitted in the United States by regulations of the National Board of Fire Underwriters, and is specifically forbidden, or tacitly ruled out, by law in many States.

The common British and American practice of exhausting operating room air through the sterilizer room in the interest of economy is disapproved by the British investigators because of the possibility of contaminating sterile instruments under certain conditions. Some of the investigators feel that the clean and dirty areas adjacent to operating rooms should be separated by air locks to prevent direct opening of dirty areas to the operating and sterilizing room.

Other British recommendations are the use of separate air conditioning systems for each operating room to meet individual likes or dislikes of surgeons, segregation of infected and susceptible patients, and maintenance of scrupulous cleanliness not only in operating rooms but in all hospital areas.

CONTAMINATION OF HOSPITAL AIR BY POORLY MAINTAINED AIR CONDITIONING SYSTEMS

The spray type air conditioner used for humidifying operating rooms in cold weather, can be an effective incubator for bacteria, or an efficient purification measure depending upon cleanliness and maintenance. Experiments have shown that commercial humidifiers using fresh clean water are capable of removing from 60 to 80% of room type bacteria from the air being humidified.[12,13] However, failure to change the recirculated spray water frequently, results in rapid growth and accumulation of bacteria, molds, and spores, which can contaminate the air.[14] It is important that the water be changed daily, and the slime scrubbed and flushed out at least once a week.

The cooling coils, fans, air filters, and ducts, also offer conditions favorable to growth and accumulation of microorganisms. Massive contamination may result when dried fomites are dislodged from surfaces of the apparatus and blown into the conditioned space by the fan. It is therefore essential to provide clean-out openings for cleaning the whole system periodically. Judging from the broad experience of Walters,[15] it would seem that the maintenance required of air conditioning systems is beyond the capabilities of many hospitals.

There is a great need for the development of a germicide that would insure sterility of the spray water and of condensing cooling coils, without harming humans. Most of the known germicides cannot be used because of their odor, irritation to upper respiratory mucosa, or corrosive action on metal parts of the apparatus.

JUSTIFICATION FOR HIGH COST OF HOSPITAL AIR CONDITIONING SYSTEMS

In some of the latest American installations designed to meet the challenge of staphylococcal infections, the outside air taken in undergoes a most elaborate treatment to remove microorganisms and dust. It is passed first through a coarse prefilter, then through en electrostatic filter, or glass-asbestos fiber filters, to remove fine dust, next through an ultraviolet plenum chamber, followed by a humidifier or dehumidifier and heating of cooling coils, before the conditioned air is admitted to operating rooms or to other critical areas. In addition to the inordinate initial investment, the operating and maintenance costs are excessively high because of the large quantities of air to be treated without recirculation. Justification for the high cost depends largely on the relative importance of airborne infection in comparison with other recognized sources of infection, as well as upon maintenance of the system. Obviously there is no justification for elaborate air disinfection measures unless good maintenance service is provided. Hospital authorities should be made aware of these limitations before embarking on such expensive projects.

There is real need for systematic bacteriological and epidemiological evaluation of air conditioning measures used in American hospitals with a view to simplifying systems, improving their efficiency and safety, and reducing costs.

LIST OF REFERENCES

1) Gaulin, R. P., Air conditioning the hospital, J.A.M.A. 31:43, January, 1957.

2) McConnell, W. J., et al., Some observations on the health aspects of air conditioning, Metropolitan Life Ins. Co., N.Y., October, 1937.

3) Bristol, L. D., Air conditioning and industrial health, J.A.M.A. 110:2142, June 5, 1938.

4) McCord, C. P., Diseases of the respiratory tract and air conditioning, J.A.M.A. 116:1360, March 29, 1941.

5) Burch, G. E., and DePasquale, N., Influence of air conditioning on hospital patients, J.A.M.A. 170:160, May 9, 1959.

6) Bourdillon, R. B., et al., Studies in air hygiene. Med. Res. Council (London) Spec. Rep. Series No. 262, 1948.

7) Bourdillon, R. B., and Colebrook, L., Air hygiene in dressing rooms for burns or major wounds, Lancet i:561, 1946.

8) Smadel, J. E., General aspects of viral and rickettsial infection. Chapter in Rivers, T. M., and Horsfall, F. L., Jr.: Viral and rickettsial infections of man, 3rd Ed., Lippincott, p. 8, 1959.

9) Discussion on ventilation of operation theatres. Jour. Inst. of Heating and Ventilating Engineers (London) 27:257, January, 1959.

10) Hart, D., Bacteriological ultraviolet radiation in the operating room, J.A.M.A. 172:1019, March 5, 1960.

11) Blowers, R., Wound infections in operation theatres, Medical Annual, (London) 1958.

12) Yaglou, C. P., and Wilson, Ursula, Disinfection of air by air conditioning processes. A.A.A.S., Publication No. 17, p. 129, 1942.

13) Carswell, T. S., et al., Studies on bacterial control in air conditioning, Heating, Piping and Air Conditioning, 10:279, April, 1938.

14) Wells, W. F., et al., An investigation of the bacteria contamination of the air of textile mills with special reference to the influence of artificial humidification, Jour. Industr. Hyg. and Toxicol, 19:513, 1937.

15) Walters, C. W., Environmental sepsis, Modern Hospital 91:69, 1958.

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