ORIGINAL COMMUNICATIONS.

NOTES ON AIR CONDITIONING IN THE TROPICS.

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AND

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WITH A FOREWORD
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FOREWORD.

The subject of air conditioning is receiving widespread attention in tropical countries where plants have been installed in hospitals, offices, hotels, theatres, etc., and I have recently had an opportunity of studying two plants in London—one at the Empire Theatre and one at the London School of Hygiene and Tropical Medicine.

So far as I am aware no such plant has yet been tried in any of our military hospitals, either in the tropics or sub-tropics, and I think the time has come when a trial should be made of air conditioning in, say, two wards and an operating theatre in one of our large military hospitals in India. Such wards would enable us to depart from our present primitive and unscientific methods of treating hyperpyrexia and would provide a natural physiological method of treating not only heat-stroke cases, but any case suffering from high temperature, and would also be of inestimable value in treating post-operative cases.
The advantages of air conditioning in an operating theatre in the tropics appear to be self-evident.

The cost of these installations, though at present high, will doubtless be reduced as the demand increases.

Considerable information in regard to air conditioning will be found in recent Crown Agents' Bulletins.

The articles which follow have been prepared at my request.

NOTES ON AIR CONDITIONING IN THE TROPICS.

By MAJOR R. A. ANDERSON,
Royal Army Medical Corps.

At the request of the Hygiene Directorate, War Office, the following report on air conditioning is submitted.

The problem of cooling the atmosphere in hot, dry climates with low relative humidity is, generally speaking, an easy one. All that is necessary is to pass the incoming hot, dry air through sprays of water so that by the rapid evaporation of the water the temperature of the air is reduced and its relative humidity raised to a more comfortable degree. In various parts of India this is generally carried out by the well-known system of "Khus khus tatties." These consists of furze or brushwood screens placed in open windows or doors. Water is allowed to percolate down the screen and air passes through naturally or is driven or drawn through by means of fans. This system is simple and efficacious, but it is useless for dealing with hot, moist atmospheres where the relative humidity is high.

In hot, moist climates with high relative humidity, not only the temperature of the air but also the relative humidity must be reduced. This process has come to be known as "air conditioning" and it is with this subject that these notes chiefly deal.

Air conditioning, as it is called, is accomplished as follows. If the outside air is 90° F. with relative humidity eighty per cent, and we wish to reduce it to a temperature of 75° F. with a relative humidity of sixty per cent, the air is drawn through a layer of fine water jets, the temperature of which has been reduced to 60° F. by a cooling plant, the air passing through these jets is brought to 60° F. and leaves saturated with moisture, the excess moisture representing eighty per cent relative humidity at 90° F. being removed. This air is then taken through ducts and delivered into the rooms. During its passage through the ducts the air will become heated and will actually diffuse through the room at a temperature of 75° F. It contains the same amount of moisture as it did at 60° F. and this represents at 75° F. a relative humidity of sixty per cent. The air is drawn out at floor level of the room or hall by means of outlets and is led back to the cooling machine where it can be used again in a continuous cycle. The above description illustrates the principle. In most apparatus, provision is made for the admixture of about twenty to twenty-five per cent.
of fresh air during each cycle. The fresh air is drawn in through a separate
duct from which mosquitoes, flies and a certain number of organisms can be
eliminated by means of wire gauze and textile screens, and at the same time,
disinfectants and deodorants can be added. This fresh air is also passed
through the cooling apparatus after it has been mixed with the constantly
circulating air.

There is thus a constant circulation of air; heated air is continually
being drawn off and returned again in the form of cool, fresh air. There
is no risk of chills.

The subject of air conditioning is becoming more and more popular in
China, principally with regard to places of amusement in the large seaport
towns.

All along the China coast the relative humidity varies between 80 and
100 per cent during seven months of the year in the hot weather; at times
the relative humidity is 98 per cent with a maximum temperature as low as
74. Even during the winter the relative humidity has been 93 per cent with
a maximum temperature of 69°. This makes the climate during the hot
weather almost unbearable.

Great enterprise is being shown by many firms and cinema companies
in the installation of air-conditioning plants. In Shanghai air-conditioning
plants have been installed in the Hong Kong and Shanghai Bank, in
Malcolm's Engineering Offices, on the eighth floor of the Cathay Hotel, and
in at least two cinema theatres.

During my inspection tour I took the opportunity of studying the
plants in the first three places. Time was not available to carry out
any experiments. My inspection tour coincided with the hot weather.
As the plants are the same in principle as that installed in the King's
Theatre in Hong Kong, which is described in full later, it is not proposed
to comment on them here.

The apparatus installed in the Hong Kong and Shanghai Bank cost
roughly about 78,000 taels (about £6,000), that in Malcolm's building
50,000 taels (about £4,500).

The sensation on entering the bank from the hot sticky atmosphere
outside was one of delight and comfort. It is difficult to describe the
sensation accurately; there is immediate relief and a feeling of coolness, so
much so that one had the sensation of dampness although the relative
humidity of the air is considerably reduced. The air gives the impression
of mustiness; whether this is due to staleness is commented on later. I think
the simplest way to describe the sensation is to say that it was very similar
to that of entering an underground or very shaded cave. The first sensa-
tion passes off very quickly and one is left with the feeling of comfort.
This may be due to the rapid accommodation of the body to different
atmospheric conditions. The longer one spends in this atmosphere
the more reluctant one feels to leave it. The sensation after leaving
the bank is much more easily described. It is immediate: the heat
and the glare hit you at once. It must be like a sudden transference to Dante's Inferno or like putting one's head into a hot oven.

From inquiries I made from the staff I was informed that they appreciated the conditioned air very much, and as they were working in the atmosphere all day they did not have to suffer the unpleasantness experienced on leaving it.

Further inquiries elicited the fact that since the installation there has not been any increase in the sick rates of the staff, but if anything rather the reverse. There is no evidence of any increase in chest complaints. This, we must assume, is due to the uniformity of the atmosphere.

I am unable to say what the effect on the human system would be in the case of individuals who, of necessity, have to keep continually passing from this atmosphere into outside conditions. I should think it must be deleterious. Admitted the human body has wonderful powers of adapting itself to altered conditions of climate, there must come a time when the powers of adaptation would become exhausted if exposed to such excessive and repeated sudden changes.

With regard to the eighth floor of the Cathay Hotel, this floor contains the dining rooms and the ball rooms. It is only necessary to remark that from personal experience, physical exertion (in the form of dancing) in this atmosphere did not appear to have any deleterious effects. There was no undue tiredness or after-effects. It would have been interesting had it been possible to have ascertained whether energy expenditure was higher in an atmosphere of this type, as compared with ordinary conditions.

There is only one air-conditioning plant in Hong Kong. This is installed in the King's Theatre Cinema, and naturally I have had more opportunity of studying it. I propose to describe it in greater detail.

The apparatus is worked during the hot weather and closes down during the winter. I have carried out certain investigations, but unfortunately they were not completed to my own satisfaction before the closing down. I propose therefore to complete the investigations during the next hot weather, so as to enable me to come to more definite conclusions.

The chief difficulty experienced up to date with regard to the subject has been the inability to obtain any literature concerning it. Apparently one is dealing with a subject which has lacked investigation. There are many points on which I wish to refer to our expert chemist at the Royal Army Medical College (Major Elliott), whose advice and aid would be of great help. The distance between us of course means considerable delay.

In Hong Kong, opposite the King's Theatre Cinema, there is a similar large cinema, called the Queen's Theatre. The advertisements regarding these two cinemas in the past have been very amusing.

The King's Theatre:—"The only air-cooled Theatre in Hong Kong."

The Queen's Theatre:—"The Theatre where you do not have to breathe used air." "Only fresh air supplied."
The owners of the Queen's Theatre have now decided to install an air-cooling system—work on which has begun.

The plant installed in the King's Theatre in Hong Kong is designed to supply clean air throughout the house so that when it is filled with people the average temperature will be about 75° F. and the relative humidity about 60 per cent.

Local weather records of Hong Kong for the past twenty years indicate that the temperature range could be expected to vary from 94° to 78° F. with a general average of 80° F. The relative humidity was found to be about 81 per cent at the average temperature of 80° F.

The aim therefore of the plant was to supply a cold dry atmosphere which would have only about one third as much moisture in it as that contained in the outside air. To purify, dry and cool the air, a complete plant has been installed. The essential units are the ammonia compressors, condenser, brine cooler, air washer, and circulating fan, all electrically controlled.

In practice cold brine is rapidly circulated through a series of tubes over which the incoming air is drawn by a fan. Jets of water spray on this air, washing out of it all dust and impurities. Its passage over the chilled coils cools it to a point where the water vapour condenses out. It is then drawn through the fan and forced into the duct system, which is installed above the ceiling of the main portion of the theatre and above the seats under the balcony.

The cool air passes downwards, being heavier, and is finally returned to the washer through the outlets or mushrooms under the seats on the floor.

After repeated changes and washings the entire atmosphere inside the theatre will be brought to about the same temperature and humidity. Sudden changes in the outside air, some of which is constantly being introduced into the system, such as increase in moisture content, or rise in temperature, will be taken into account and the compensating allowances made in the system to establish again a uniform inside atmosphere.

Some facts about the equipment may be of interest.

When nearly 1,100 people are together in a single large hall, a very definite amount of heat and products of breathing are given off. Each individual must be supplied with a certain amount of pure fresh air per minute, otherwise the hall soon becomes stuffy. In this design a total of 39,000 cubic feet of conditioned air will be supplied to the ducts overhead which will give every person in the house about 38 cubic feet of air per minute. This is a very liberal supply for a picture house—2,280 cubic feet per hour.

To purify and cool this amount of air requires the circulation of a very large amount of chilled brine. This is accomplished in a twelve-foot horizontal brine cooler. The brine circulates through the brine pipes in the air washer and back through the cooler. The cooling of the brine is
brought about by liquid ammonia evaporating inside the cooler around the brine tubes. As the ammonia evaporates, taking away the heat from the brine, the vapour is drawn into one or two ammonia compressors of the latest design, driven by directly connected synchronous motors, taking power from the incoming current at 350 volts.

The two compressors are single acting machines 8 feet by 8 feet and 9 feet by 9 feet running at 300 revolutions per minute. The smaller compressor is driven by a 75 h.p. motor and the larger by a 100 h.p. motor.

The brine circulating pump is rated at 500 G.P.M. against a 50 foot head thus giving about 25 pounds pressure through the brine cooler and coils of the washer. It is directly connected to a 16 h.p. induction motor running at 1,450 revolutions per minute. The water used in the spray system for purifying and cooling the air is circulated by a pumping unit similar to the brine pump described above; it is pure water drawn from the Colony’s water system.

The circulating fan for the house is a positive acting low pressure blower, horizontally mounted and running at 875 revolutions per minute. It is driven by three “\(V\)” type rubber belts from a 20 h.p., 3 phase, 350 volts, 1,450 revs. per minute motor.

The cooling of the ammonia vapour in the ammonia condenser requires a relatively large amount of cold water. Study was first made to see if water from the local mains could be used and then recooled by means of a cooling pond or tower, but it was found that the amount required and the cooling area necessary entailed prohibitive costs. It was therefore decided to use sea-water for cooling the condenser. A pump house was built near Blake Pier. A directly connected centrifugal pump rated at 400 G.P.M. at a 65 foot head, driven by a 20 h.p. motor, puts sea-water through 1,100 feet of 6-inch pipes to the condenser, from whence it flows back to the sea through the nullah which runs through Pedder Street.

Some interesting points struck me. The whole of the air in the theatre passes through the apparatus in eight minutes. There is no arrangement in the apparatus for taking tobacco smoke out of the air; the mere passing the air over the coolers and through the washer does not remove the smoke. The system adopted for this purpose in the King’s Theatre consists of exhaust fans placed in the roof with exits which can be opened when necessary. The smoke which accumulates in the upper strata of the atmosphere is removed by opening the exits and running the exhaust fans for two, three or four minutes. This, of course, interferes with the air conditioning and temporarily raises the temperature and relative humidity because outside air is to a certain extent drawn in from the doors.

The apparatus has to be run for two and a half to three hours before the first performance opens, so as to get the air in the theatre to the required condition. The cost of running the apparatus amounts to $130 per day (about £8). This is certainly expensive, combined with the initial outlay of a costly plant.
It is interesting to note that the apparatus to be installed in the Queen's Theatre Cinema will bring about the reduction of temperature by means of ice instead of the brine cooling plant. I understand one ton of ice will be used per day for cooling the water used for spraying and for cooling coils. It is said that this will avoid a large outlay on plant and the daily cost will be less than with the apparatus installed in the King's Theatre.

The purification of the air is relative; it certainly is not complete. Admitted that the chilling of the air will tend to inhibit growth of organisms, and that the washing removes dust and a large proportion of the organisms and some of the chemical impurities, yet it cannot remove them all.

The water which is used for washing the air is in constant circulation: in its cycle it sprays the air and takes part of the heat out; its temperature rises, it returns to be reduced in temperature again and goes back to the washing chamber.

Some of the investigations which I wish to carry out are as follows:

(a) How far does the repeated chilling of this water affect the growth of organisms which it is continually removing from the air?

Are they killed? Theoretically, it would appear that droplets are removed.

(b) It is presumed that this water removes from the air some of the excess carbon dioxide which is continually being added to during the time the air is breathed. Does not the water reach a point where it becomes unable to take up more carbon dioxide?

(c) To what extent is the percentage of oxygen in this conditioned air reduced, say towards the end of the third or fourth performance? It must be borne in mind that some 20 per cent of fresh air from outside is continually being added to used air in its cycle as it passes through the apparatus.

Although we are accustomed nowadays to judge the atmosphere in a room from a point of view of maintenance of health, more from its cooling effect on the body surface rather than upon its chemical composition, there still remain certain standards.

The very limited practical investigations which I was able to carry out consisted in ascertaining the percentage of carbon dioxide in the conditioned air, and taking Kata thermometer readings inside the air-conditioned theatre, at the same time carrying out a similar investigation in the Queen's Theatre Cinema opposite. The Queen's Theatre is a very well ventilated theatre with a very large number of rotatory fans in the ceiling, and other fans ensuring very good air movement.

After many attempts to arrange matters with the managers of the theatres concerned, most of an afternoon and evening was spent in the two theatres. It was unfortunate that on the particular day chosen the temperature and relative humidity were both low.

The following table gives the averages of the Kata readings and the average percentage of carbon dioxide in the various samples taken:—
### Notes on Air Conditioning in the Tropics

<table>
<thead>
<tr>
<th>Time</th>
<th>Temp. F.</th>
<th>Relative humidity per cent.</th>
<th>Dry Kata reading</th>
<th>Wet Kata reading</th>
<th>Percentage of CO₂</th>
<th>Organisms falling per sq. metre per minute</th>
<th>No. of colonies grown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queen’s Theatre — Air: 2.30 p.m.</td>
<td>76</td>
<td>65</td>
<td>3.15</td>
<td>7.38</td>
<td>0.064</td>
<td>182</td>
<td>336</td>
</tr>
<tr>
<td>Queen’s Theatre — Air: 9 p.m.</td>
<td>76</td>
<td>65</td>
<td>3.15</td>
<td>7.38</td>
<td>0.064</td>
<td>182</td>
<td>336</td>
</tr>
<tr>
<td>King’s Theatre — Air: before washing</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>King’s Theatre — Air: after washing</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>In Barracks</td>
<td>81</td>
<td>79</td>
<td>3.40</td>
<td>9.27</td>
<td>0.089</td>
<td>142</td>
<td>2,560</td>
</tr>
<tr>
<td>King’s Theatre — 2.30 p.m...</td>
<td>76</td>
<td>65</td>
<td>4.78</td>
<td>9.46</td>
<td>0.089</td>
<td>142</td>
<td>2,560</td>
</tr>
<tr>
<td>King’s Theatre — 9 p.m. ...</td>
<td>71</td>
<td>65</td>
<td>3.01</td>
<td>7.84</td>
<td>0.098</td>
<td>38</td>
<td>1,040</td>
</tr>
</tbody>
</table>

It will be noted that the temperature inside the King’s Theatre is kept at about 71° F., with relative humidity of sixty-five per cent. In the Queen’s Theatre the temperature remained fairly constant at 79° F. The Kata readings show very little difference between the outside air of an ordinary barrack room, the King’s Theatre and the Queen’s Theatre. The cooling power per square metre body surface is low when it is considered that a satisfactory standard is one which gives a dry Kata reading of about 6 and a wet Kata reading of 18.

The percentage of CO₂ is higher in the King’s Theatre than in the Queen’s: this, theoretically, I expected to find. Oxygen percentage was not tested; it is hoped to do this during the next hot weather. The number of colonies grown on plates exposed inside both theatres for the same length of time shows very little difference.

It is interesting to note that with regard to the number of colonies grown on plates exposed for three seconds in the air ducts, where the air is moving very rapidly, just before the air passes through the conditioning plant, and immediately after it leaves it, there are only half the number of colonies grown after it has passed through the plant.

It is realized that a very large number of analyses and considerable more work is necessary before one could become dogmatic and arrive at any sort of definite conclusions. It is hoped that other observers in the Corps will assist by giving their views and suggestions.

The following tentative conclusions have been arrived at with regard to the possible use of air conditioning in barracks:

1. Undoubtedly the ideal system of air conditioning would be one in which fresh air is taken from the outside, conditioned, and then passed into the building and, after use, removed into the open air by exhaust fans; in other words, where there is a constant circulation of fresh conditioned air through the building. I understand that the cost of this would be absolutely prohibitive.

2. For the soldier, the provision of air-conditioned barracks in the tropics does not appear feasible; firstly on account of cost, secondly owing to the fact that during the day he is constantly in and out of barracks for parades, recreation, etc.

3. The only place in the China Command where air conditioning would
be of great use is in the hospital at Shanghai. In Shanghai very severe hot weather is experienced, reaching its maximum in July and August, when a number of military cases of heatstroke and heat exhaustion, some of which prove fatal, occur.

In addition, the surgical specialist there reports that, owing to the fact that after major operations a very considerable fall of blood-pressure occurs in his patients during the hot weather, he is only able to perform urgent operations. All other routine work has to be kept over until the hot weather is finished. He further reports that the strain on the theatre staff during this period, owing to the conditions inside the theatre, is considerable, although only urgent operations are performed.

I am therefore of opinion that the operating theatre and an adjoining small ward of four or six beds, should be air conditioned. It would be useless for the operating theatre to be air conditioned alone, because most of the collapse takes place after the operation. Furthermore, there would be a decided risk of an increase in post-operative chest complaints.

The small ward would also supply an admirable place in which to treat heatstroke and heat-exhaustion cases, and, in my opinion, would afford them a much better chance of recovery.

A plant sufficient for the operating theatre and the small ward could be installed for about £500.

Although I can find no literature on experimental work with regard to air conditioning, and there appear to be many points regarding it which require elucidation, I think I am justified even at this stage in recommending it, because so far as I can ascertain no ill-effects appear to be produced, or follow, among individuals frequenting air-conditioned places.

With regard to chemical purity of an atmosphere, we must bear in mind that individuals in submarines are able to carry on when submerged in an atmosphere which cannot be considered pure, as judged by chemical standards.

I am indebted to Major W. E. Tyndall, M.C., Royal Army Medical Corps, D.A.D.P., China Command, and to Corporal G. Fawcitt, Royal Army Medical Corps, of the Command Laboratory, for their assistance and help in carrying out the analyses for me.

REPORT ON AN AIR COOLING PLANT INSTALLED IN THE HAFFKINE INSTITUTE, PAREL, BOMBAY, AND THE CARRIER COOLING PLANT INSTALLED IN THE NEW COUNCIL HALL, BOMBAY.

By Major J. C. Sproule, O.B.E.,
Royal Army Medical Corps.

The Frigidaire Company manufacture two types of air conditioning cabinets, one being fitted with cooling and heating coils, which may be used for places which are very cold in winter and hot in summer, and the other fitted with cooling coils only. In the former the heating is carried
out by hot water or steam and in both the cooling is obtained by a compressor and refrigerant.

As the climate of Bombay seldom falls below 70°F., room coolers only are installed in the Haffkine Institute.

The room in which these coolers are installed is 23 feet 10 inches long and 18 feet 11 inches wide, with a total floor area of approximately 450 square feet. There are two large windows on the south side, and two doors, one on the east and the other on the west side of the room. One of these doors is permanently closed and the other is shut immediately after any person has used it. There are no fans or air extractors in the room.

It is stated that one standard room cooler is capable of dealing with a room of about 250 square feet floor area. The height of the room itself is immaterial since the room cooler will produce a layer of about 8 feet of cold air from the floor. The rest of the air above 8 feet from the floor will not be cooled. This is claimed to be an economy since the lower 8 feet of cooled air should be sufficient for practical purposes and the large volume of air above that height has not to be cooled.

The plant installed in the Haffkine Institute consists essentially of:
(1) Two room cooler cabinets and two screens; (2) two refrigerating compressors.

Each room cooling cabinet consists of a series of cooling coils and a circulating fan, or blower. The cooling cabinets are placed in the room in which the air is to be conditioned. In front of each cabinet is placed a small screen to prevent direct draught from the cooling cabinet.

The refrigerating compressors are placed in an adjoining room, but could be placed in a basement or outside shed. These are driven by electric motors.

**Principle of Operation.**

Warm air from the room is drawn in at the bottom of the cabinet by the fan operating therein. The air then passes over the cooling coil, where it is cooled below its dew point and so gives up a certain quantity of its moisture. It is then forced into the room through the upper part of the cabinet at a rate stated to be 450 cubic feet per minute. Moisture so removed from the air passes through a pipe into a drain in the corner of the room.

The cold air readily mixes with the warmer air in the room and the resultant mixture has a lower temperature, and lower absolute and relative humidity than the original. There is also a slight fanning effect.

When the apparatus was first installed it was found that a drop of 10°F. in temperature, as specified originally, was too much, as the atmosphere felt positively chilly. It was also found that a pleasant effect was reached by the following figures:
Reduction in the dry bulb 6° F.
Reduction in the wet bulb 10° to 12° F.
Eventually the machines were set so that the drop in temperature would not exceed 8° F.

The compressors have automatic switches which will stop them if an undesirably low temperature is reached. For special purposes an automatic control can be arranged for starting and stopping the plant at any desired time.

Cost of Plant.

At the present moment the cost of one cabinet cooler and one compressor, complete, would be approximately Rs. 2,600, so that under normal circumstances the total installation would come to about Rs. 3,000. This would include the cost of wiring, and other incidental charges. Duty at present on this type of machinery entering India is extraordinarily high, and may be reduced somewhat in the future.

Cost of Running.

The cost of running will depend on the cost of electric current in the particular place. To ascertain the actual cost of running, the plant was allowed to work for two hours, the meter readings being taken at the beginning and end of this time. It was found that where electricity costs one anna per unit the cost of running one compressor for one hour is three quarters of an anna. This is very low and the local agents consider that in general the electricity used will amount to somewhere about one and a half to two units per hour.

The room cooler will be able to bring the temperature down to the desired figure in about two hours, and thereafter it is kept running as long as it is necessary.

The cost of running the plant increases directly as the work increases; in other words, it would cost more to run the plant on a very hot day than it would on a day with a moderate temperature.

To test the efficiency of the plant four persons went into the room and remained in it for one hour. The dry and wet bulb readings did not change during this time. The doors were opened several times and people from outside came into the room on many occasions.

Inside readings at 11.30 a.m. and 12.30 p.m.
Dry bulb 80° F.; wet bulb 72° E. Relative humidity 65.
The outside readings taken during this time were:
Dry bulb 82° F.; wet bulb 78° F. Relative humidity 82.6.

Conclusions.

This is a type of machine which could be used in operating rooms or in wards.

As the air entering the cabinets comes from the room itself and not from outside, as in some of the larger types of air-conditioning plants, it is
considered that if used in operation rooms the air of the room would, after a time, become saturated with the anaesthetic being used.

To obviate this an extractor fan might be fitted high up in the operation room. This would entail the cooling of a larger total quantity of air. As the cabinet cooler is stated to be capable of producing a maximum drop of temperature of 12° or 15° F., and when actually seen working a drop of only 2° F. was recorded, it is considered that it would be capable of doing this.

However, trials would require to be made in places with a higher temperature than Bombay before this could be definitely ascertained.

The Director of the Haffkine Institute informed me that the greatest advantage of these cabinet coolers is felt when the temperature rises above 90° F., with a high relative humidity, and work appears to be impossible.

In conclusion, my thanks are due to Lieutenant-Colonel J. Taylor, D.S.O., M.D., D.P.H., Director of the Haffkine Institute, for his kindness in allowing me to see and experiment with this plant. Also to Mr. R. Schuepp of Messrs. Volkart Bros., Bombay, who supplied copious notes on the working of the plant and helped me with the various tests to which the plant was subjected.

THE CARRIER COOLING PLANT INSTALLED IN THE NEW COUNCIL HALL, BOMBAY.

The climate of Bombay, although equable, is warm and sticky. The coolest months of the year are December, January and February. The temperature seldom rises above 95° F. while in the so-called "cold months" of the year, the day temperature may fall to 75° F.

In 1929 the Carrier Engineering Company, of London and New York, installed a cooling and ventilating plant in the New Council Hall, Bombay.

The plant installed is known as the Carrier "downward diffusion" system, so-called because the conditioned air enters the building at a high level and, on account of its density, falls to the floor where it is removed. Invented and used originally for theatres it is stated to be eminently suitable for all buildings with high ceilings, obviating the need for air inlets around the walls.

OBJECT OF INSTALLATION.

The object of the installation is to give comfort to the occupants of the Council Hall by supplying them with air which is pure, cool and dry. Ventilation accompanied by a reduction of temperature alone would not entirely effect this because any decrease in temperature would, through condensation, increase the relative humidity in the Hall, and it is this
factor which is the chief source of discomfort. The humidity within the Hall must also be reduced and the apparatus is capable of bringing this about.

**Principles of Operation.**

The manner in which this is achieved is as follows:—

Air is often drawn from outside into a chamber through two ducts, the amount of air being regulated by automatic valves. In this chamber gross impurities, such as leaves, &c., are removed.

The air now passes through baffle plates into two washing chambers or humidifiers. In these chambers the air passes through finely atomized sprays of water which remove all impurities, the air in its passage through this chamber having its moisture contents reduced by virtue of the lower dewpoint with which it leaves.

In a country where the air is dry no refrigerating plant is required, but in a place like Bombay with a moist climate a refrigerating plant is necessary. This is used to keep the water, used in the sprays, at the required temperature. Thus, by controlling the temperature of the water that of the air is simultaneously controlled, and this is maintained at a figure corresponding to the "dewpoint" required in the Council Hall.

The air, having been cooled and dehumidified, now passes over specially designed baffle plates which eliminate all free moisture, i.e., water in the form of droplets. It is then mixed with a small amount of air which comes from the Council Hall. The reason for this will be explained below under "prevention of draughts." The air then passes into the fan which has been drawing it along all the time and is propelled into ducts which lead to a void above the ceiling of the Council Hall. From here it is discharged through special openings arranged around the periphery of the ceiling, into the Hall. Ducts also conduct air from this void to the various galleries which surround the upper part of the hall.

**Prevention of Draughts.**

It has been found from experience that if air of a low temperature be admitted at a high level it will fall by virtue of its increased density, but will stratify or fail to diffuse with the air of the room into which it is descending. This will cause local or patchy cooling and set up unpleasant draughts. These are particularly noticeable with air entering at low temperatures, but disappear above certain limits.

By mixing some of the comparatively warm air from the Hall with the colder air from the dehumidifier the creation of draughts can be prevented.

The air on reaching floor level is gently extracted through hidden gratings by a suction fan. A certain portion of this extracted air is mixed with fresh air from outside and returns to the dehumidifier, thus re-commencing the cycle.

The air as it passes through the Hall absorbs heat and the volume admitted is so regulated as to maintain a comfortable temperature.
Notes on Air Conditioning in the Tropics

As a result of the humid exhalations of the persons present, the internal dewpoint would tend to rise and increase the humidity of the Hall, the entering air is therefore given a dewpoint which is predetermined and controlled to counteract this effect.

CONTROL OF INTERNAL CONDITIONS.

There are two controls, both of which are automatic: (1) Dewpoint control; (2) minimum temperature control.

(1) The dewpoint control is so arranged as to allow a constant temperature of the air leaving the dehumidifier. It consists of a thermostat, situated in the air leaving the machine, which reacts on a mixing valve, through which the refrigerated water proceeds to the dehumidifier. When the dewpoint tends to become too low, warm water, i.e., water at the Bombay temperature prevailing at the time, is permitted to mix with the cold water and conversely is shut off when the dewpoint show signs of rising.

Thus at all seasons of the year a constant dewpoint is maintained irrespective of the alterations of outside temperature and the personal idiosyncrasies of the attendants in charge of the apparatus.

(2) The minimum temperature control ensures that the temperature of the Hall does not fall below a predetermined point. It consists of a thermostat situated in the Council Hall which refers back to automatically operated dampers which close and prevent air passing through the dehumidifier when the Hall temperature falls below that for which it is set.

Both of the above controls use compressed air as the operating medium.

REFRIGERATING PLANT.

This plant was installed by the Lightfoot Refrigerating Company. It is their ordinary type and consists of water circulating over pipes containing ammonia.

CONDITIONS PRODUCED BY THE PLANT.

By the courtesy of the Public Works Department the Council Hall was visited and the plant was seen working. At the time of this visit the thermometer readings were as follows:

| OUTSIDE | Wet bulb .. 81°F. | Dry bulb .. 90°F. |
| INSIDE  | Wet bulb .. 74°F. | Dry bulb .. 86°F. |

It will be noted that the difference between the outside and inside dry bulb readings was only 4°F.

The atmosphere of the Council Hall was particularly clear, and little or no dust particles were noticed floating about in it. The air itself felt dry and was particularly invigorating and pleasant; no draughts were noticed.
in any part of the room; in fact, coming out of the steamy atmosphere of Bombay, it felt like being transported to some drier and cooler station. It is considered that the provision of an atmosphere such as this would be of the greatest benefit for hospital patients.

It was stated that the plant installed was much too powerful for the work it had to do as it could reduce the temperature to freezing point, whereas it was only required to reduce it by four or five degrees. When first installed the temperature was reduced by 12° F., but the members of the Council complained of feeling cold.

**Costs of Running the Plant.**

While the Council is sitting the plant normally works from 9 a.m. to 4.30 p.m.

The daily expenditure is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Rs.  a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>2</td>
</tr>
<tr>
<td>Mobiloil B.B.</td>
<td>0 4</td>
</tr>
<tr>
<td>Mobiloil A.</td>
<td>1 2</td>
</tr>
<tr>
<td>Arctic oil C.</td>
<td>0 8</td>
</tr>
<tr>
<td>Energy charges</td>
<td>30 0</td>
</tr>
<tr>
<td>2 Coolies @ annas 14 each</td>
<td>1 12</td>
</tr>
<tr>
<td>Ice mechanics</td>
<td>4 0</td>
</tr>
<tr>
<td>Miscellaneous expenses</td>
<td>0 6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40 0</strong></td>
</tr>
</tbody>
</table>

Interest and depreciation are not included. Maintenance is not included as the Carrier Engineering Company claim that none is required for the first ten years.

**Conclusions.**

Medical officers who have spent their lives in India are of opinion that a cooling and dehumidifying system of conditioning the air would be of great advantage in the treatment of the sick.

This is fully borne out by the work already done in this direction by the medical services of the Anglo-Persian Oil Company (*vide Transactions of the Royal Society of Tropical Medicine and Hygiene*, vol. xxiii, No. 6).

Not only would the stay in hospital be curtailed in many instances, but the patients could rejoin for duty without the necessity of leave, or being sent to a hill station to recuperate.

Surgical cases would be particularly benefited both during operations and in the immediate post-operative period. Operating surgeons in India have been clamouring for some air-conditioning apparatus for operating theatres (see “Surgery in the Tropics,” by F. P. Conner, pages 3, 6), and many instances can be quoted where surgeons, unlike their medical colleagues, have left India broken down in health.

It should be noted that much smaller and comparatively inexpensive installations, suitable for small rooms like operating theatres, are available.
Notes on Air Conditioning in the Tropics

In stations where heatstroke is prevalent, not only would the convalescence period and mortality be greatly reduced but the psychological effects on others, following such outbreaks, would be almost completely abolished.

The financial aspect of such an installation must always be an important consideration. It is suggested, however, that whereas large plants like that installed in the County Hall, Bombay, might prove to be expensive at the present juncture, it might be possible to instal smaller plants in hospitals which would supply conditioned air to the operating room and one ward at a small cost.

In conclusion, thanks are due to Mr. F. O. J. Roose, P.W.D., for valuable notes supplied to me on the working of this plant and for his kindness in having the plant operated during the period when the Council was not sitting.