AIR CONDITIONING DATA AND PRACTICE FOR THE PALO ALTO AREA

STANFORD LINEAR ACCELERATOR
STANFORD UNIVERSITY SUBCONTRACT 8-128

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4. INTRODUCTION

The following report is submitted in compliance with a request by Project H for a study to develop technical data and information on general practice in the area for evaluating possible air conditioning design problems for the buildings to be constructed for the Stanford Linear Accelerator.

Air conditioning of building spaces is to be considered within the limits and scope of the Atomic Energy Commission AE Manual, Volume 6000, which establishes air conditioning under the following conditions. (Paragraph 6302-d5)

Air conditioning is applicable only to those buildings where it is essential for operating or highest requirements, or to maintain efficiency among auxiliary workers under severe climatic conditions over prolonged periods of time. Such spaces as office, meeting rooms, laboratories and the like may be considered in this class. It may be impracticable to air condition offices in some locations. Where air conditioning is deemed justified by the foregoing conditions, it should be taken into consideration in the initial planning stage as permitting lesser occupancy, greater distances from outside walls, larger spans, etc. This will often result in enough savings to pay for the air conditioning installation.

It is further stated in paragraph 6306-c1, "Air conditioning should not be considered where ventilation or evaporative cooling will more economically accomplish a satisfactory result."

This study includes an analysis of the conditions that may be expected in the buildings planned by Project H, the temperatures and humidities recorded at the site by the U.S. Geodetic Survey during the summer of 1950, the comparative costs of adequate ventilation versus air conditioning, and the policies of manufacturing, commercial, and research establishments in the Palo Alto - Menlo Park area with regard to air conditioning.
E. COMMENTS

The technical designs of the buildings for Project N contemplate the most economical use of available space. In areas assigned to offices, laboratories, and engineering (principal locations), the buildings are designed to accommodate the buildings so that substantial areas are more efficiently used to permit natural ventilation.

The buildings will have high lighting levels, compact personnel groupings, and electrical and environmental equipment such as copy machines, and data processing equipment, and similar items, all of which add to the heat release in the office, engineering, and laboratory areas. The estimated temperature rise of the air which would be supplied to the above areas, in order to control the temperature, attributed to the various heat sources in 30 follows:

<table>
<thead>
<tr>
<th>Heat Source</th>
<th>Temperature Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lights, 6 watts/ft² (200 foot candle)</td>
<td>2°F</td>
</tr>
<tr>
<td>Office machines, 1 watt/ft²</td>
<td>1°F</td>
</tr>
<tr>
<td>Personnel, 3 per 100 ft²</td>
<td>1.5°F</td>
</tr>
<tr>
<td>Building conduction</td>
<td>6.5°F</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20.0°F</strong></td>
</tr>
</tbody>
</table>

A large part of the building conduction load is solar heat, some of which is transmitted even at relatively low ambient temperatures. One of the heat load is internal. All of this heat must be disposed of to maintain comfortable conditions.

Air conditioning systems normally are designed to provide about ten air changes per hour, with the supply air about 30 degrees cooler than the room temperature, as indicated above. Higher temperature differentials cause drafts due to the
Conduction through the cool supply air, and cause other undesirable effects. Increasing the ventilation rate appreciably above ten air changes per hour, as would have to be done unless refrigerated air conditioning were provided, also causes drafts in the areas which are difficult to control. With a good air distribution system the ventilation rate may be as high as fifteen air changes per hour before drafts become really objectionable. This is about the limit of the quantity of ventilation air that can be used in office spaces to offset heat gains. Even with this amount of air it must be supplied 20 degrees cooler than the desired room temperature to bring down the estimated heat load. The spaces then cannot be kept comfortable with the auxiliary cooling when the outside air temperature rises much above 90°F. With a good ventilating system. This has not necessarily been true of older buildings which have low lighting intensity and high thermal capacity because of heavy construction, but it is true of most of the buildings contemplated for Project H.

6. TEMPERATURES ON THE GROUND

Starting in 1962 the S. S. Sandstone Survey recorded the temperatures and humidities at their Sand Hillaisal Station, which adjoins the enclosure site. The dry bulb temperatures and relative humidities recorded for the months June, July, August and September, 1960, were made available to Project H. The results of an analysis of the temperatures are shown graphically on SK-HV-5-12, and SK-HV-6-2.

The top curve on SK-HV-5-12 shows the average number of days in which a given temperature was exceeded. The highest temperature recorded during the year 1960 period was 106°F. The highest temperature which was exceeded every day during the summer was 65°F.

The middle curve shows the number of hours during the average day in which a temperature was exceeded. The temperature of 70°F was exceeded 6 hours in the average day. The temperature of 60°F was exceeded during 15 hours of the average
day. In general, peak daily temperatures occurred at approximately 2 P.M.

The temperature which was exceeded on 3/2% per cent of the total hours during the period in the F. P. This temperature, when corrected by averaging over a five year period, becomes the air conditioning design temperature for the location.

(Pimentel and Eddy, p. 178)

The bottom curve shows the total number of hours during the four month period in which a certain temperature was exceeded. It should be noted that most of these hours occurred during the warmest week periods and, as pointed out in the previous section of this report, ambient air with the temperatures shown on the chart cannot be used efficiently to offset the heat loads imposed by lights, personnel and equipment in a studio office.

B. EVAPORATIVE COOLING

Evaporative cooling has been tried many times in the area with unsatisfactory results. The reduction in dry bulb temperature is obtained at the expense of an increase in relative humidity. If humidity is permitted to rise in the occupied space, human comfort conditions deteriorate rapidly. The results of tests conducted by the American Society of Heating, Refrigeration and Air-Conditioning Engineers, which are shown graphically in Figure 20, Page 72 of the 1960 Guide, show that 5% of the test subjects were comfortable at 80°F when the relative humidity (RH) was 30%, 70% were comfortable at 50% RH, and less than 30% were comfortable at 70% RH. A design objective of 80°F, 50% RH, aimed at keeping only 10% of the occupants comfortable, is certainly the minimum condition allowable to subject to criticism. However, for the purposes of this discussion it is assumed to be satisfactory.

The dry bulb temperatures and relative humidities recorded on the site in the summer of 1960 have been analyzed. The results are shown graphically on Figure 2.
The charts show the average and median relative humidities and the corresponding wet bulb temperatures which prevailed at the site at the peak daily dry bulb temperatures. Horizontal lines on the top chart indicate the maximum wet bulb temperatures at which evaporative cooling would be effective in maintaining the optimum condition of 75°F and 50% RH and also the barely satisfactory condition of 80°F and 50% RH in the occupied space. Heat loads, as discussed under "Design Considerations," and a high rate of 15 air changes per hour were assumed.

The chart shows that optimum conditions are not attainable with evaporative cooling even when the outside dry bulb temperature is as low as 66°F. Satisfactory conditions may be attained on the average when the outside dry bulb temperature is 73°F or below. Reference to the middle chart of RL-M-5-12 shows that this temperature was exceeded an average of over four hours a day during the summer of 1960. On 31 days during the summer the temperature exceeded 75°F at least 8 hours of the day. This is too great a percentage of the working hours to warrant consideration of evaporative cooling for maintaining comfort conditions.

8. PERSONNEL CONSIDERATIONS

The basic economic consideration which motivates management to decide on comfort air conditioning is that it is an important factor in the performance of personnel. Comfort air conditioning is an expense that can best be justified by increased efficiency. For any establishment, be it industrial, commercial, or engineering in nature, the most important function of its housing structure is to provide an atmosphere which will contribute to the ability of the personnel to do their assigned tasks efficiently. The cost of comfort air conditioning, as well as other necessary inputs to the task, whether capital investment, payrolls, or other costs, should always result in a commensurate output. In this sense all dollars are spent to buy efficiency. Efficiency depends on the quality of the personnel in terms of experience, judgment and enthusiasm, and also on the quality of the environment.
In fostering a condition conducive to concentration on the task. The best environment for concentration is one that is quiet and comfortable, one of which an individual is not conscious.

Subject N must be able to compete with other research institutions and scientific firms for the talent needed to prosecute its research programs. It has attracted and must continue to attract personnel of the highest caliber. These include not only the highly trained and dedicated physicists, but also the administrative people whose decisions may be just as vital to the project and whose talents are also sought after by many companies. The people in demand are those who take pride in doing their work efficiently. These are more and more frequently demanding a better environment in which to work. Control of the air temperature and quality is an essential part of the required good working environment. The cost is small when related to other investments and expenses which are necessary to accomplish the task.

The fact that work efficiency is increased by air conditioning is shown by the results of a test under controlled conditions, conducted by the General Services Administration in the summer of 1957. On page 8 of the report on this test entitled "Influence of Air Conditioning on Work Production," Research Division, Sandia
Bulletin 552-161, the conclusions are listed as follows:

"On the basis of the evidence, it would seem fair to conclude that the air conditioning resulted in:

1. A substantial average increase in work production (2.5 percent).
2. A slight decrease in errors (0.9 percent).
3. A measurable decrease in absenteeism (2.3 percent).
4. A measurable decrease in employee's living expenses (savings on cleaning bills, hairdos, make-up, etc.).
5. An important contribution to employee comfort and morale.

It is safe to assume that in other types of scientific research and other production in not standardized, or where no minimum equipment isn't kept
It is safe to assume that in any other type of office work, where the rate of production is not standardized, or where no minimum requirement must be met consistently, the increase in productivity will be more than enough to pay for air conditioning through savings in employees salaries."

On page 6 of the report, which sets forth the results of the study, it is stated:

"We know, from our previous studies, that a seven-minute saving in time per employee per day will save more than pay for the expense of an air conditioning system. In other words, if work production increases only 1.5 percent per year, the system will pay for itself through savings in salaries. We feel certain that the increase in production will never drop below this value."

On the basis of the above it may be concluded that air conditioning will not only pay for its expenses but will actually show a net savings of over eight percent of the payroll. If the investment for air conditioning is assumed to be two dollars per square foot, and the payroll equal to $50 per square foot per year, then the cost of the investment for air conditioning will be returned in less than six months because of these savings.

F. RELATIVE COST

A good ventilation or evaporative cooling system for an office building has all the elements of an air conditioning system except the refrigerating equipment. The other chief difference is that more air is generally supplied during hot summer than is required for air conditioning. This is an effort to decrease the inside temperature and approach the ambient temperature. The greater quantity of air requires larger ducts, diffusers, fans, filters, heating coils, and higher fan horsepowers. Provisions must be made for all the ventilation air to be conditioned since air cannot be recirculated in the summer season. Ventilation air quantities
are too high for the winter time as provisions must be made for decreasing the amount of supply air and adjusting the throw of diffusers. It is often necessary to increase the building height by several inches per floor to accommodate the larger ducts. All of these factors reduce the difference in cost between a good ventilation system and air conditioning. In buildings where extensive ductwork is required, the cost of a ventilating system may be approximately the same as the cost of air conditioning.

For comparison the cost of air conditioning ranges from about $1100 per square foot of conditioned space for a system using packaged air conditioners with minimum ductwork, to about $3.00 per square foot for a system using chilled water and heating extensive ductwork. Heating and ventilating costs range from about $0.60 per square foot to about $1.50 per square foot. If the building design is such that excessively long ventilating ducts are required to deliver the outside air to the space and return it to the outside, then it may be more economical to use packaged air conditioners which permit recirculation of approximately 90% of the air. In most cases a ventilating system will be cheaper than an air conditioning system. But the ventilating system can maintain satisfactory conditions less than half of the working hours during the summer season. The rest of the time worker efficiency suffers and full value cannot be realized from the investment in real property and equipment, costs of payroll, and the expenses associated with maintaining the work space.

G. SURVEY OF LOCAL PRACTICES

In order to determine the practice of the plants in the Palo Alto - Sunnyvale area with regard to comfort air conditioning a number of firms were contacted. These included an architectural firm, a firm of consulting engineers, a company which has built several buildings for lease, and four manufacturing plants, including the Lockheed plant at Sunnyvale (under Air Force contract). The architectural and consulting engineering firms have designed or are otherwise familiar with the design of a large part of the buildings in Stanford Industrial Park and many buildings
In the Palo Alto area. It was stated that to the extent of their knowledge all of
the large industrial and commercial buildings built or planned in this area within
the last eighteen months have provided air conditioning in their offices and
engineering areas. Of the industrial plants contacted, two now have air condition-
ing in all offices, laboratories, cafeterias and auditoriums. The third has only
ventilation in existing offices and laboratories but has an air conditioned
cafeteria. However, a new office building now under construction for this plant,
and all planned future construction is to have air conditioned offices. In two of
the buildings which were constructed for lease the lessors failed to provide for
air conditioning in the offices. One of these is now planning to install a complete
air conditioning system because of unsatisfactory environment. The other has an
unusually large window area arranged for a maximum amount of area ventilation.
This plant is the only one of the sixteen covered by the survey which does not
(1) have air conditioned offices or (2) have plans to air condition their offices
in the near future.

These lockheed plant office buildings not originally air conditioned are now
being converted. Stanford University has provided air conditioning in all offices
and laboratories in the new physics building now under construction on the campus.

The survey shows conclusively that the companies in the area have found that
air conditioning is necessary for their office operations.

H. CONCLUSIONS

The offices, laboratory and engineering spaces in Project H buildings will have
high heat loads resulting from high lighting intensities, compact grouping, and
considerable electrical equipment. Ventilation alone is inadequate to take care
of these loads when the ambient temperature exceeds 65°F. This occurs an average
of 9.5 hours a day in the summer. Evaporative cooling is not satisfactory for this
area. Calculations show that a wet bulb temperature not over 56°F. is required to
maintain room conditions at 75°F. and 50% relative humidity with evaporative
cooling. The temperature - humidity records show that the wet bulb temperatur
At the site are such that evaporative cooling of the buildings is not feasible. Ventilation is less expensive to install and maintain than air conditioning but can maintain satisfactory conditions less than half of the working hours during the summer season.

Air conditioning of offices, laboratories and engineering spaces is considered necessary by the local research and scientific firms for the efficient performance of their employees and as a requirement to attract the type of employee needed. Project H must also be able to offer a suitable work environment in order to compete with these organizations for the necessary talent.

Employee efficiency in air conditioned space has been shown to be substantially above that in non-air conditioned space. The savings in salaries is more than enough to pay the expenses and to amortize the investment for air conditioning.