6.3. Automation in air conditioning system

In general, an air-conditioning automatic system, which is a part of BAS, is manufactured and installed by Johnson, Honeywell company etc., according to the control requirements of the designer. Although the intellectualization of the buildings has been taken into consideration in Shanghai, and most of the investors and owners claim that their buildings are intelligent, we think only a few buildings can be taken as real intelligent buildings at present because of the high initial cost and the insufficient experience.

6.4 Designs of smoke control system comply with the Standards. It is necessary to employ positive pressure and exhaust smoke system.

7. Conclusion

The extent, number and speed of urban construction in China are unique in the world. Therefore, there are some problems in building services and construction management. The reasons are:

(1) Some problems are endured by renters and buyers because of the short development duration and limited investment. There is not enough concern about social impact or energy conservation.

(2) "Change of appearance" is the first and greatest concern of the governments. There is no advanced policy about energy planning and management. For example, the application of DHC and cogeneration is difficult to be carried out, standards about energy conservation for air-conditioning buildings have not been established yet.

(3) Designers are a bit shorthanded. They have not got enough time to test and sum up the projects in all respects, when the projects are finished. And they are not good at new technology, because they are so busy in making designs that they have no time in testing and analyzing the new methods.

(4) Only to seek for simplicity in operation and management, it is not helpful for the application of new systems and technology. To train managers in advance is essential. In addition, using new systems will provide good opportunities for training personnel and developing advanced technology management.

Although there are some problems, just as mentioned above, we think that it is not very easy for the designers to accomplish so many projects in such a short period. In the cooperation and interchange with foreign designers and engineers, and in the application of new technology and equipment, our engineering staff have greatly improved their abilities. When the high rise buildings come into operation in a few years, we will learn a useful lesson from them, and it will be helpful for designers to make high-rise designs.

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AIR CONDITIONING IN BUILDINGS: TWO WORDS OF CAUTION

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Abstract

Two specific areas are addressed: (1) The necessity for effective estimates of infiltration rates in buildings; and (2) The dependence of vapor compression air conditioning systems on refrigerant charge. It is shown that the estimate of air infiltration rates through simple tests such as "blower-tests" are not applicable. In addition, there may be measurable drops in the capacity of air conditioning systems (on the order of up to 10%) for non-insignificant variations in the refrigerant charge from the optimum value.

Introduction

Two somewhat unrelated aspects in building air conditioning are now addressed: (1) concerns with estimates of air infiltration, and (2) warnings about the dependence of capacity of air conditioners on refrigerant charge.

Part a: Infiltration Concerns

Background

In order to provide needed comfort and health building interiors require some air exchange with the outdoor ambient. Air exchange can be via intentional ventilation or through infiltration. The ventilation in turn may be forced (providing the greatest control through the proper selection, installation and operation of the ventilation system) or natural. Natural ventilation is the air flow through intentional openings in the building envelope. The air flow in natural ventilation is driven by wind or temperature-gradients Air infiltration is also driven by wind and/or temperature differences between the indoor and outdoor ambients; but unlike ventilation through intentional openings, it cannot be controlled as air flows through leakage paths in the building envelope.

Infiltration can have a measurable effect on the design load for air conditioning in buildings; in some instances, as high as 20% of the cooling load. What is unfortunate is that its estimate, without measurements, is still more of an art than a science.

The classical approach to measure air infiltration rates is known as the decay gas method. The decay gas method consists of releasing a tracer gas (such as sulfur hexafluoride, or, for unoccupied buildings carbon monoxide) whose concentration can be easily measured. The decrease in gas concentration is then measured and recorded within the building. Provided the measurements are taken under well mixed conditions, a measure of air infiltration in the form of air changes per hour can be obtained. Under constant ambient conditions, there will be a liner relationship between the logarithm of concentration and time.

With a proper estimate of the building interior volume, the corresponding volume flow rate of air due to infiltration can be determined, and from it together with the enthalpy difference between the outdoor air and the indoor air the impact on the cooling load due to infiltration can be obtained. Unfortunately, there is a dependence on ambient conditions (wind and temperature), and most recorded measures in the literature appear to completely ignore the need for recording these environmental conditions. Extensive and comprehensive testing is therefore necessary.

In order to simplify the testing procedure needed to effectively measure the air infiltration, a method to measure air leakage through pressurization of the building has become more popular. With the use of a large fan or blower, a large pressure difference between the indoor and the outdoor is imposed. A measure of the air flow to maintain a desired pressure drop can in turn be related to air leakage as well as to an effective leakage area.

Both methods have major fundamental shortcomings. First, the measurement with the blower test is never in the complete absence of wind or temperature differences, hence "smearing" the blower test data. Second, the blower test, in principle, induces a uniform pressure difference through all the external surfaces of the building, while the wind always induces positive differences in some surfaces and negative differences in others and is hence dependent on the geometry of the building (which the blower test is not). Third, and most important, the blower test by itself cannot account for the temperature driven "stack" effects as these depend not only on leakage areas but very strongly on the distribution of the leakage paths.

The blower test has become popular as it is simple and rapid. A number of authors address themselves to its use and some acknowledge its shortcomings. The major advantage of the blower test is that it is straightforward and readily permits a comparison of "leakage areas" for different buildings. In spite of that, its relationship to actual infiltration rates leaves a lot to question both impractical aspects as well as physical principles. The limitations of the blower test or the fan pressurization test, while clearly stated in the ASTM, standards are sometimes ignored in the published literature.

A model

As a matter of fact, infiltration takes place through small cracks and openings. This means that in general the flow through the envelope will be laminar - even though the external flow is turbulent. This flow into the building will then be driven by a pressure difference between the outside ambient and the indoors. A companion flow, with the same mass rate of flow (not necessarily the same volume rate of flow) out of the building must also take place. Due to external wake effects and lack of a uniform external pressure there will be regions in the envelope where the indoor pressure is higher than that outside (across a crack or small opening) and exfiltration will result. In essence, the indoor pressure would increase due to infiltration leading to an increase of exfiltration until mass conservation is satisfied. Any changes in wind (as well as temperatures) would in turn lead to a new internal pressure for equivalence between the infiltration and exfiltration.

The pressure on the surface of a building due to wind is the stagnation pressure of the wind. If $\overline{P}_o$ is the average stagnation pressure and $\overline{P}_a$ the average free stream pressure, then

$$\overline{P}_o - \overline{P}_a = \frac{1}{2}\left(\overline{\rho}\overline{C}_p\overline{W}^2\right) \tag{1}$$

where C_p is a pressure coefficient on the order of 0.65 for a wind-facing wall, ≅ 0.65 on the downwind wall, and ≅ 0.4 for the side walls (estimated for test data for rectangular cross section bluff bodies). The overbars in (1) indicate averaged quantities. The pressures P_o, P_a, and P_i (inside pressure) are all functions of height. The dependence of these pressures on height can be obtained assuming an adiabatic atmosphere, for which $\frac{P}{\rho^k}$ = constant. The relationship is then

$$\frac{P}{P_{H/2}} = \left[1 - \frac{k-1}{k}\frac{g}{RT}\left(h - \frac{H}{2}\right)\right]^{\frac{k}{k-1}} \tag{2}$$

where $P_{H/2}$ and T are measured at $H/2$ (half the height of the building). In (2), k is the specific heat ratio, R the universal gas constant, g gravitational acceleration, and T the temperature in absolute units. Owing to the fact that

$$\frac{k-1}{k}\frac{g}{RT}\left(h - \frac{H}{2}\right) << 1 \tag{3}$$

Equation (2) may be rewritten using the binomial expansion as

$$\frac{P}{P_{H/2}} \cong 1 - \frac{g}{RT}\left(h - \frac{H}{2}\right) \tag{4}$$

Integrating to find an average pressure gives $\frac{\overline{P}}{P_{H/2}} \cong 1$. Thus, $P_{H/2}$ may be taken as $\overline{P}$. The outside-inside pressure difference is then

$$\Delta P = P_o - P_i \cong \overline{P}_o - \frac{g\overline{P}_o}{RT}\left(h - \frac{H}{2}\right) - \overline{P}_i + \frac{g\overline{P}_i}{RT}\left(h - \frac{H}{2}\right) \tag{5}$$

or

$$\Delta P \cong \overline{P}_o - \overline{P}_i - \left(h - \frac{H}{2}\right)\left(\frac{g\overline{P}_o}{RT_o} - \frac{g\overline{P}_i}{RT_i}\right) \tag{6}$$

Inserting (1) for $\overline{P}_o$ gives

$$\Delta P \cong \overline{P}_a - \overline{P}_i + \frac{1}{2}\rho\overline{C}_p\overline{W}^2 - \left(h - \frac{H}{2}\right)\left[\frac{g}{R}\left(\frac{\overline{P}_a}{T_o} - \frac{\overline{P}_i}{T_i} + \frac{1}{2}\frac{\rho\overline{C}_p\overline{W}^2}{T_o}\right)\right] \tag{7}$$

Equation (7) may be rewritten as

$$\Delta P \cong \left(\overline{P}_a - \overline{P}_i\right)\left[1 - \frac{g}{RT_i}\left(h - \frac{H}{2}\right)\right] + \frac{1}{2}\rho\overline{C}_p\overline{W}^2\left[1 - \frac{g}{RT_o}\left(h - \frac{H}{2}\right)\right] - \frac{g\overline{P}_a\left(T_i - T_o\right)\left(h - \frac{H}{2}\right)}{RT_iT_o} \tag{8}$$

Or more simply

$$\Delta P \cong \overline{P}_a - \overline{P}_i + \frac{1}{2}\rho\overline{C}_p\overline{W}^2 - \frac{g\overline{P}_a}{RT_iT_o}\left(h - \frac{H}{2}\right)\left(T_i - T_o\right) \tag{9}$$

since

$$\frac{g}{RT}\left(h - \frac{H}{2}\right) << 1 \tag{10}$$

for all values of T under consideration.

Equation (9) gives an estimate of the pressure difference driving the infiltration process. It assumes adiabatic relationships for the air and gives the pressure difference as a function of height. It does not account for the pressure difference due to mechanical ventilation. With the pressure difference function known, the corresponding infiltration can be determined.

The flow through a crack can be approximated as laminar flow between two flat plates. In the limit as these plates become infinite, entrance and exit effects can be neglected. Flow is then given by

$$\frac{Q}{l} = \frac{y^3}{12\mu\Delta x}\Delta P \tag{11}$$

where Q/l is the volume flow rate per unit length of crack, y the crack width, Δx the length through the crack, μ the viscosity and Δp the inside-outside pressure difference across the crack given by (9). The flow can then be determined by integrating (9) and (11) over all of the cracks, and finding the value of $\overline{P}_a - \overline{P}_i$ ($= \Delta P_a$) such that mass is conserved.

For the sake simplicity the following substitutions will be made:

$$C_T = \frac{\overline{P}_a g\Delta T}{RT_iT_o}, \quad C_W = \frac{1}{2}\rho C_p W^2, \quad Y_{()} = \frac{y^3_{()}}{12\mu\Delta x} \tag{12}$$

where $\Delta T = T_i - T_o$. In order to proceed it is necessary to assume some crack distribution. For the purposes of demonstrations, consider the building as having a uniform crack distribution over the four walls (where $F = dl/L\ dh$; L = horizontal length of wall), and two cracks along the foundation-wall and roof-wall joints. The flow rate, Q, from the floor to the neutral level h_n (where $\Delta P = 0$), is given by

$$Q_1 = LFY_W\int_0^{h_n}\left(\Delta P_a + C_W - \frac{C_T}{2}\left(h - \frac{H}{2}\right)\right)dh \tag{13}$$

for each wall, or

$$Q_1 = LFY_W h_n\left(\Delta P_a + C_W - \frac{C_T}{2}\left(h_n - H\right)\right) \tag{14}$$

Similarly, Q above the neutral level becomes

$$Q_2 = LFY_W(H - h_n)\left(\Delta P_a + C_W - \frac{C_T}{2} h_n\right) \tag{15}$$

for each wall. In the above equations (14)-(15) L is the length of each wall of the building and Y_W is as defined in (12) using the crack width of the wall. The neutral pressure level, h_n, is given by

$$\Delta P = 0 = P_a + C_W - C_T\left(h_n - \frac{H}{2}\right) \tag{16}$$

or

$$h_n = \frac{\Delta P_a + C_W}{C_T} + \frac{H}{2} \tag{17}$$

when $0 < h_n < H$. If h_n is less than zero it is set to equal to zero, and if h_n is greater than H it is set equal to H.

In addition to the uniform crack on the wall of the building two cracks were assumed located around the perimeter of the building, one at the foundation-wall joint and one at the roof-wall joint. For the crack at the bottom,

$$Q_3 = Y_P L\left(\Delta P_a + C_W + C_T \frac{H}{2}\right) \tag{18}$$

For the crack at the top

$$Q_4 = Y_P L\left(\Delta P_a + C_W - C_T \frac{H}{2}\right) \tag{19}$$

Note that Q_1 through Q_4 must be evaluated for each since each wall has a different C_p value for wind. Y_P is defined in (12) using the perimeter crack width, Y_p.

The signs of Q_1, Q_2, Q_3, and Q_4 depend on the sign of ΔT, whether they are above or below the neutral level, and whether or not the area faces the wind. By properly summing all of the Q's over all of the walls, the value of ΔP_a can be determined such that $\rho_o Q^+ = \rho_i Q^-$ (Q^+ = flow into the home, Q^- = flow out of the building). With this criteria met the infiltration can be found by considering the sum of either the positive or negative terms by themselves.

While the procedure is cumbersome, there are important conclusions that are obvious (and most times neglected in studies of infiltration) when noting the form of Equations (12) and (14) through (19):

1. The infiltration rate is proportional to the square of the wind speed,
2. The infiltration rate is proportional to the temperature difference between the indoors and outdoors, and
3. The location (i.e. distribution of the cracks and openings can have a major effect on infiltration rates.

The implications of the third conclusion are that the pressurization tests by themselves are not sufficient estimators of air exchange. Two cracks, located near the neutral pressure level, will lead to widely different infiltration than the same two cracks located one near the foundation and the other near the roof.

Similarly, the first and second conclusions bring further uncertainty to any testing or estimate of infiltration not taking into account the outside temperature and wind. It is interesting to note that the expected relationships have been confirmed against actual field data. Figures 1 and 2 show data for comprehensive tests on two simple homes. The are seen to satisfy the relationship

Infiltration = A + B(absolute value for delta T) + C(wind speed square)

in accordance with the model.

Conclusions

Infiltration rate can have an effect on building cooling load, and is strongly dependent on ambient conditions. In order to properly estimate its effect it is necessary to account for distribution of cracks and openings along the building envelope. Strong dependence on elevation is noted, which could have an influence in tall buildings unless mechanical ventilation is controlled according to the total air exchange, including that to uncontrollable infiltration.

Part b: Refrigerant Charge effects

Background

Vapor compression systems are normally charged in such a manner so as to provide low superheat at the compressor inlet, and nominal subcooling. Changes from these desired conditions will compromise capacity and efficiency of the vapor compression system.

A set of test data are now presented and generalized to the extent possible. The purpose is to demonstrate that there may be a notable drop in capacity for undercharged as well as overcharged systems. This can place an interesting penalty to the building operator if maintenance is not properly handled.

Sample test data

Results of four different tests are presented, without any details of the procedures for testing or on the test data itself. These are all products of graduate research theses at Herrick Laboratories, with details presented elsewhere. Data for five different vapor compression systems are presented:

1. A heat pump in a cooling mode with capillary tube expansion;
2. Two different variable speed heat pumps in a cooling mode and with a thermal expansion valve;
3. A multiplex heat pump with an electronic expansion valve; and
4. A household refrigerator with a capillary tube.

All of these tests were conducted in psychrometric rooms (for the refrigerator this was a convenient way to maintain ambient temperatures).

(1) Heat pump in cooling with a capillary tube

Figure 3 presents the results. Both the EER and capacity are seen to reach a maximum at a charge of about 3.63 kg (8 lbm). The superheat decreases as this optimum charge is reached. The dependence on charge is notable.

(2) Variable speed heat pump in a cooling mode with a TXV

Figure 4 presents the dependence of capacity and efficiency on charge for different speeds for one of the tested heat pumps. Similar results were obtained under other conditions. The data are replotted in Figure 5 where a smooth curve is fit with the recognition of the zero capacity at no charge. Even though these had TXV expansion devices, which should be more "forgiving" to improper charging, the results show a notable dependence on charge.

(3) Multiplex in cooling with a TEV

This system had four different indoor units. The capacity measurements with two indoor units operating and for four units operating are shown in Figure 6. The results are consistent with the preceding plots.

Refrigerator (with a capillary tube)

Data were also obtained in a household refrigerator. Figure 7 shows the COP and capacity variations versus charge for five different refrigerants. What is relevant here is not the different values noted, but the repeatable trends.

Generalization of results

The results can all be replotted in terms of a dimensionless charge (actual charge divided by the optimum charge) and a dimensionless capacity (made dimensionless by dividing by the maximum capacity). What becomes most startling is that all of the data for the fixed expansion devices collapse onto the same curve, while all of the data for the active expansion devices collapse onto another distinct curve. Figure 8 presents the results. The actual data are not shown as they become indistinguishable from another. There is a notable charge dependence, that is dependent only on the type of expansion device.

Conclusions

- The performance of air conditioning (vapor compression) systems is strongly dependent on refrigerant charge. In general, systems with capillary tubes show that a 25% over or undercharge can lead to decreases in capacity as high as 25 to 35%. On the other hand, systems with thermal or with electronic expansion valves, for similar levels of under or overcharge will exhibit drops in capacity around 5 to 7%, a far-from-negligible amount.

Closure

Two effects, not always considered in air conditioning systems were addressed. It was noted that any estimate of air infiltration without consideration of distribution of openings along the height of the building, or without accounting for wind and temperature cannot be universally correct. In addition, the strong dependence (and somewhat universal trends) of capacity on refrigerant charge, demonstrate the need for careful measures when charging refrigeration systems in the field.

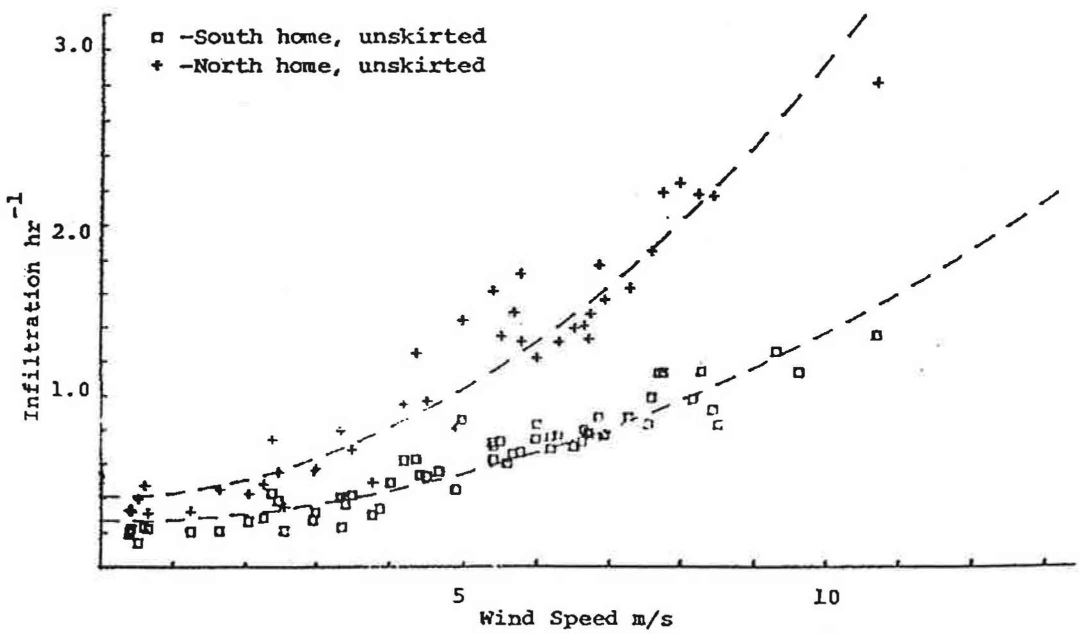

Figure 1.Infiltration vs. wind speed,30< ΔT <37℃.

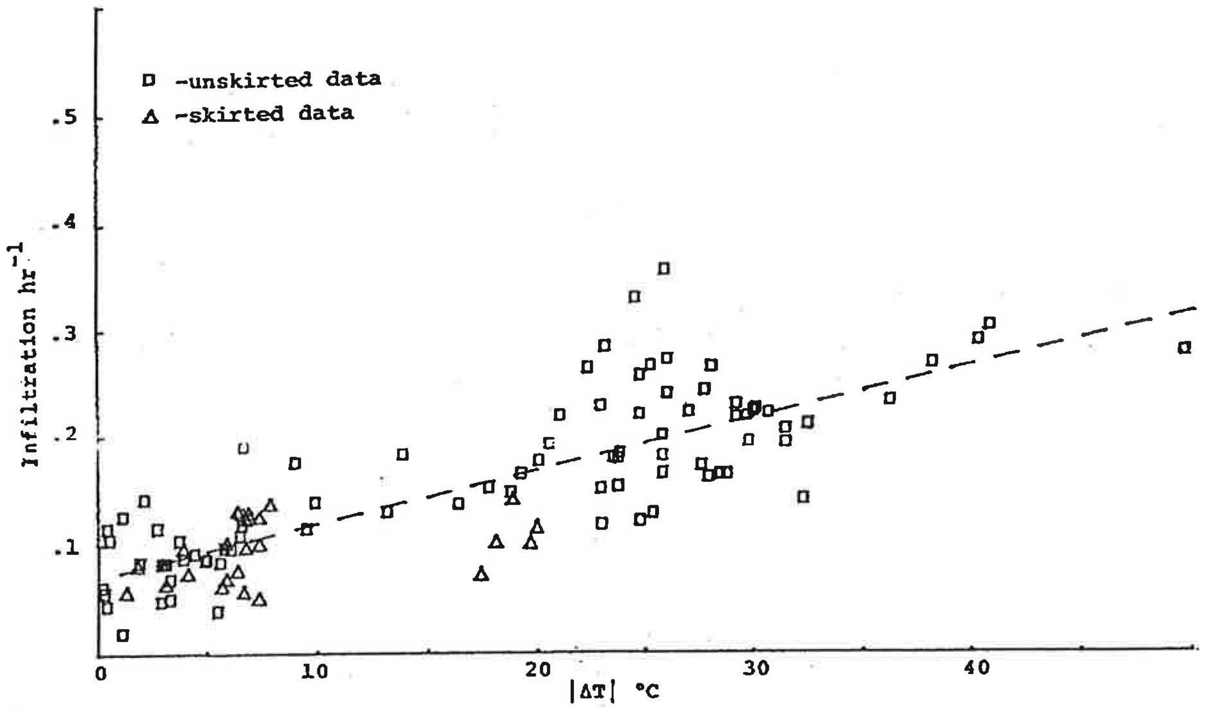

Figure 2.Infiltration vs. $|\Delta T|$ for W<1.4 m/s.

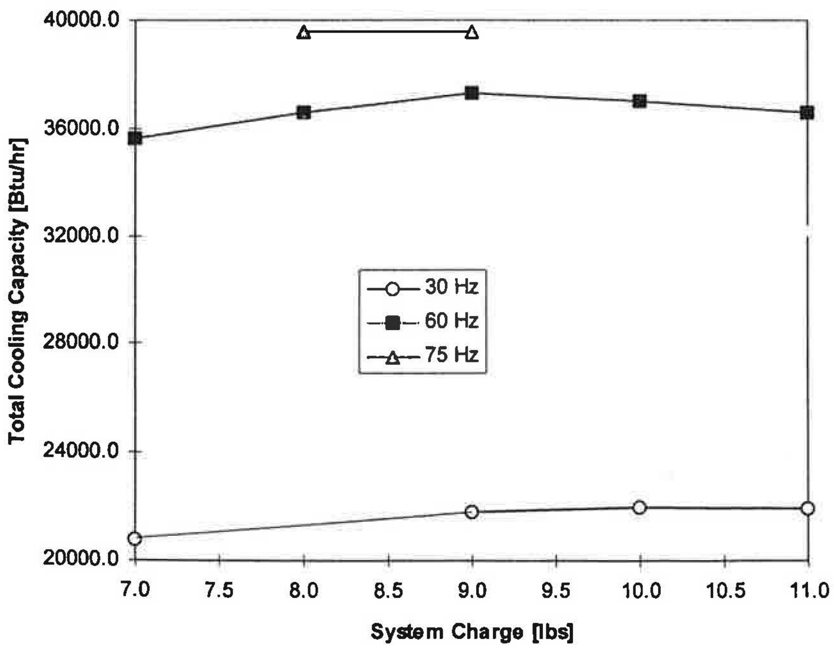

Figure 4. Total cooling capacity vs. total system charge for 30,60,and 75 Hz compressor speeds-VHP2.

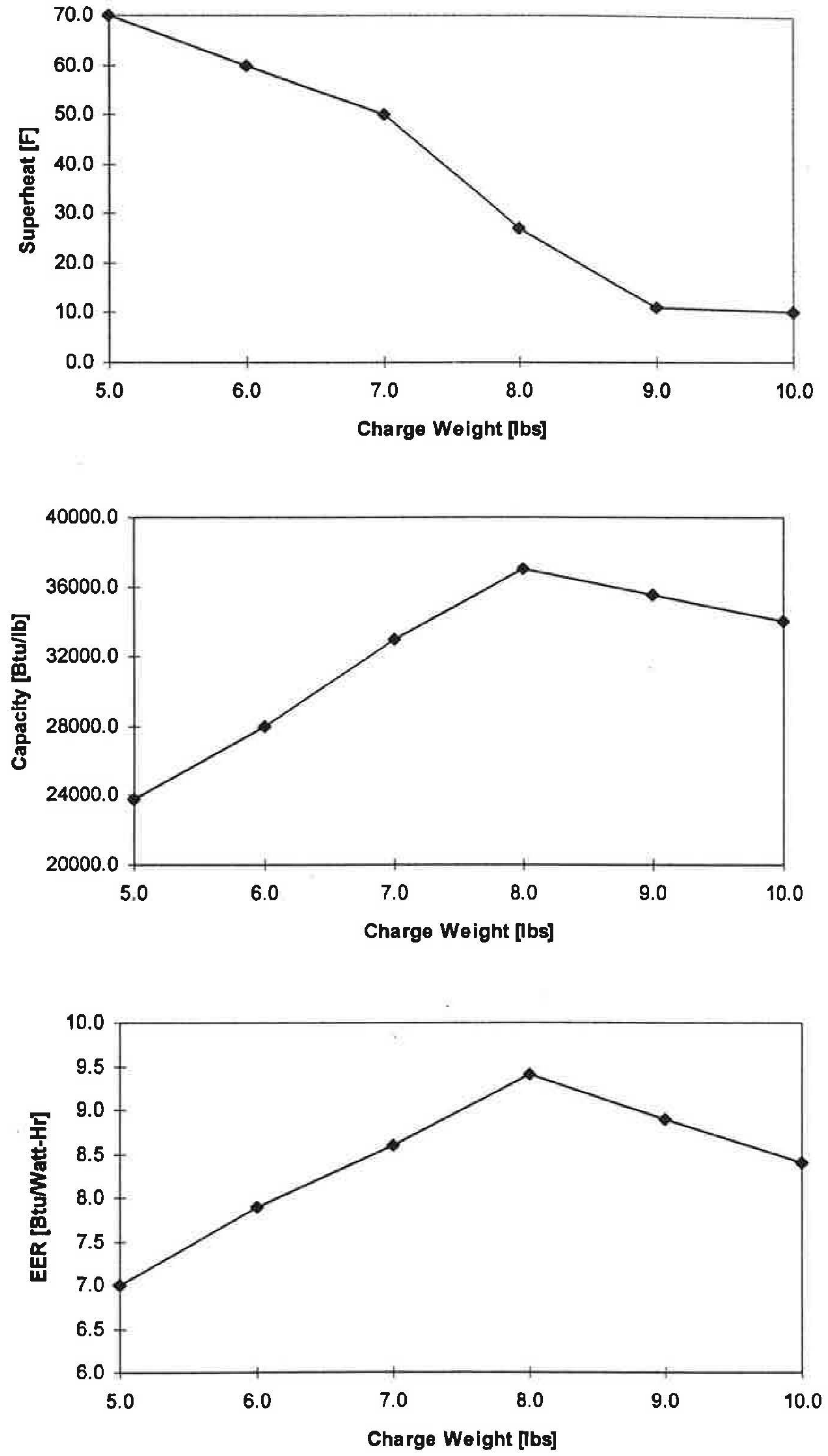

Figure 3.Unmodified systems: Cooling Performance vs. Charge.

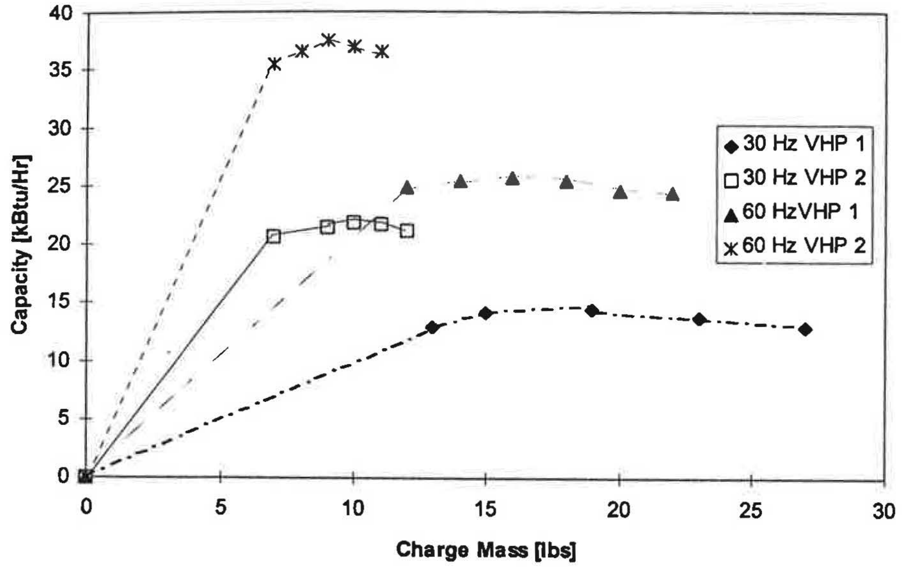

Figure 5.Data from Figure 4 replotted with zero capcity at zero charge. A notable dependence on charge is evident.

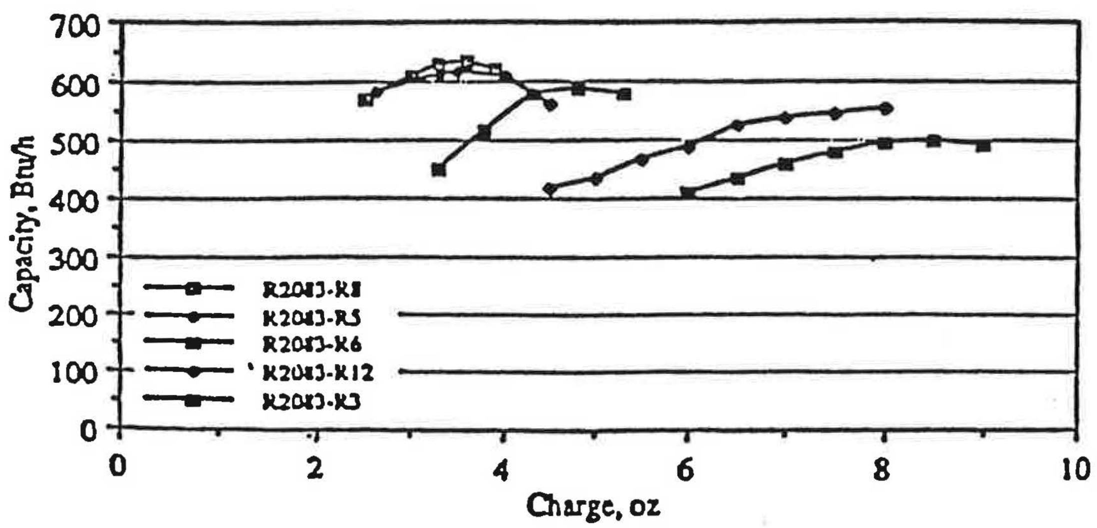

Figure 7.Capacity vs. charge for sample refrigerants.

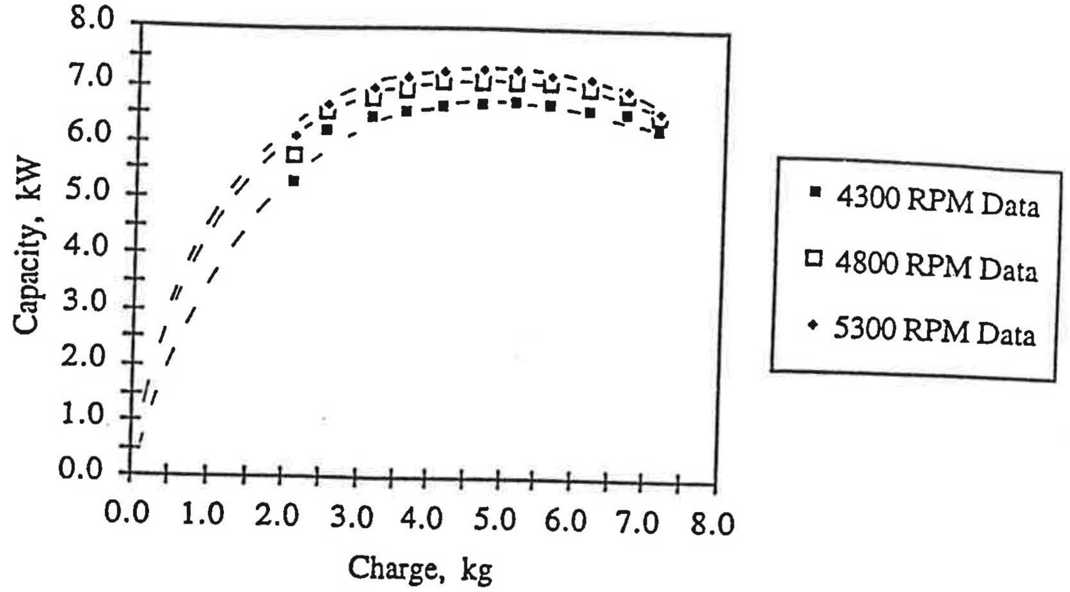

Figure 6a. Cooling capacity vs. refrigerant charge for four indoor units.

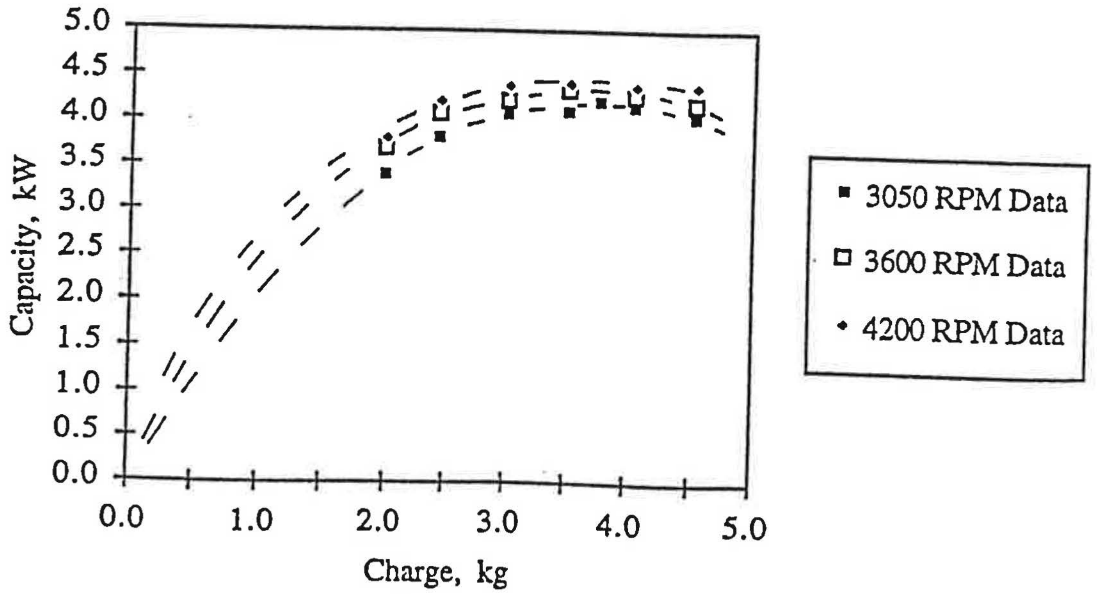

Figure 6b. Cooling capacity vs. Refrigerant charge for two indoor units.

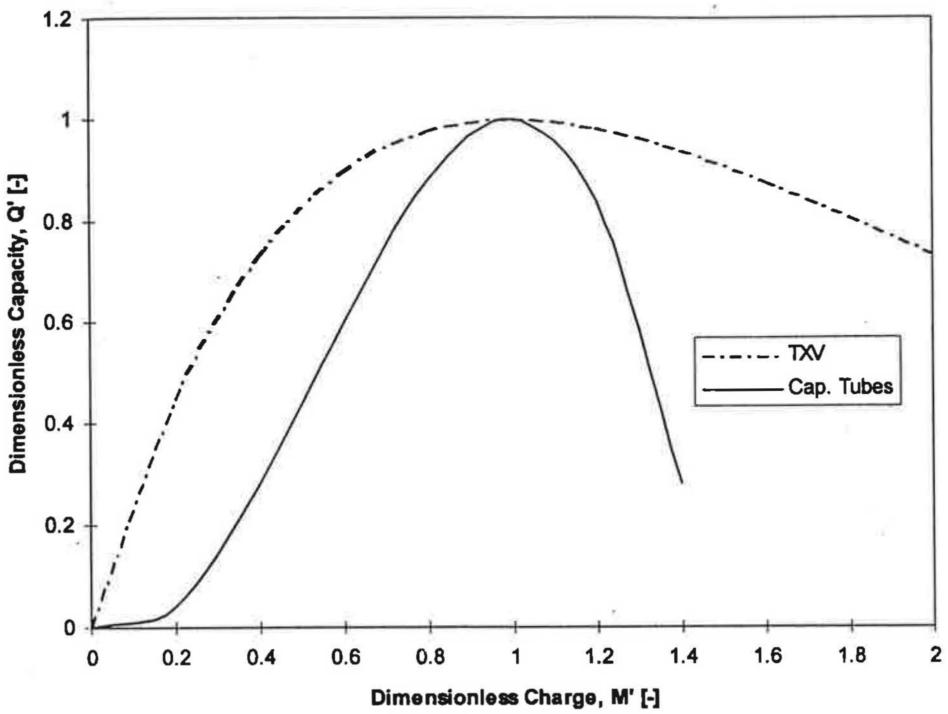

Figure 8. Replotted results from Figure 7 in terms of a dimensionless charge (actual charge divided by the optimum charge) and a dimensionless capacity (made dimensionless by dividing) by the maximum capacity. The data for the fixed expansion devices collapse onto the same curve, while all of the data for the active expansion devices collapse onto another distinct curve.

FAN COIL UNITS IN HIGH RISE BUILDING

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SUMMARY

In the paper an overview of the selection criteria for the air-conditioning of the high rise building is presented. The fan coil unit (FCU) design and performance has been described. Based on the present design of the FCU, the air conditioning system for high rise buildings is proposed. Using μP control units and remote controller, a flexible, user friendly and energy efficient four pipe FCU system with primary air for ventilation, pressurisation and smoke control is proposed.

1. INTRODUCTION

For the air conditioning of a high rise buildings different solutions are available p.e. all air system, air-water system with induction or fan coil units (FCU).

The designer is responsible for considering various systems and recommending one or two that will perform as desired. It is imperative that the designer (architect and mechanical engineer) and the owner collaborate on identifying and rating the goals of the design. Some of the criteria that may be considered are: performance, capacity and spatial requirement, first cost, operating cost, reliability, flexibility, maintenance etc.

Because these factors are interrelated, the owner and building designer must consider hoe each factor affects the others. Integrated building design is an imperative of today practices. Relative importance of these different factors differs with different owners and often change from one project to another.

Selection goals is in the first line providing the desired environment in the building, but designer must be aware of an account for other goals the owner may require such as: supporting the working process, increasing sales, net rental income, saleability of a property etc.

Typical concerns of owners include first cost compared to operating cost, the extent of maintenance (out and in occupied space), expected frequency of failure, his impact and duration. Each of these concerns has a different priority, depending on the owner's goals.

The owner can only make appropriate value judgements if the designer provides complete information on the advantages and disadvantages of each option. Owner does not usually know the performances of the selected system and the designer rarely knows all the owner's financial and functional goals. There fore it is important to involve owner in the selection of a system.