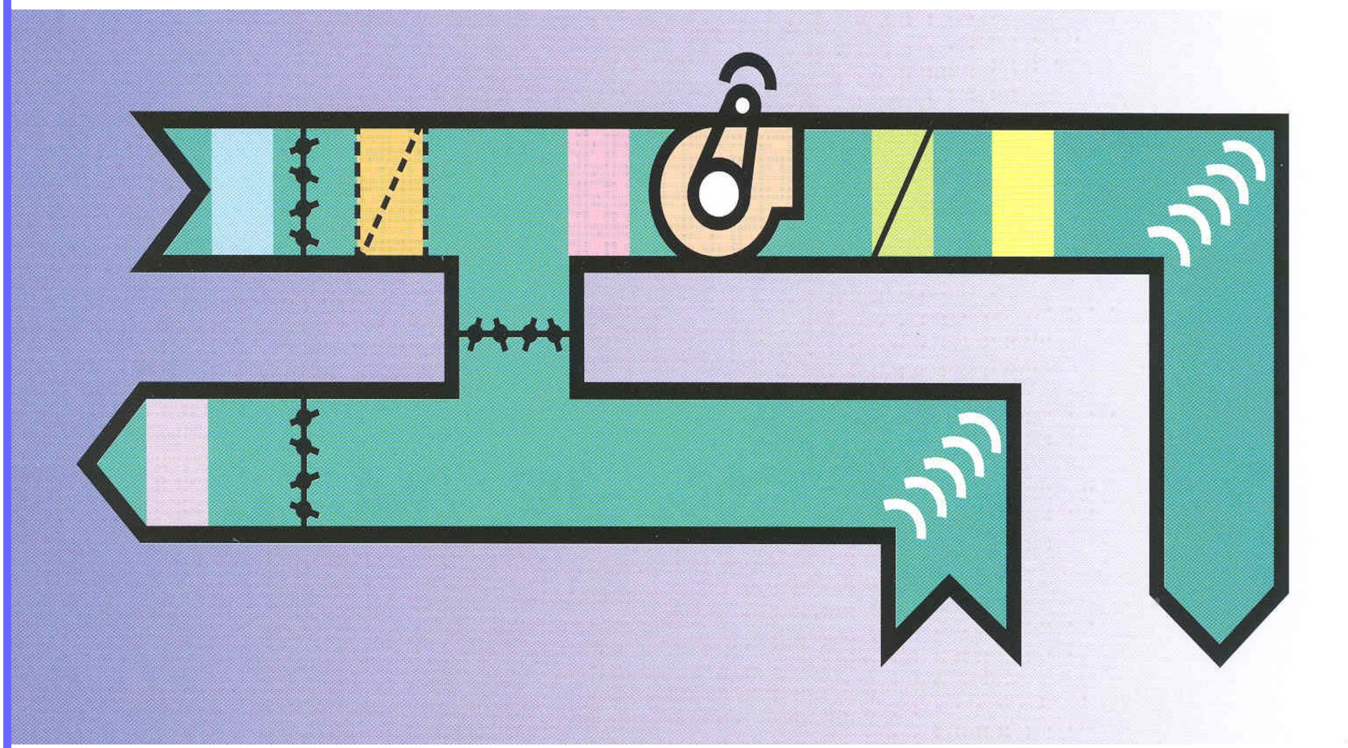
Guidelines on

Energy Efficiency of Air Conditioning Installations

2007 EDITION

the Supplement to the *Code* document



EMSD

Preface

The Code of Practice for Energy Efficiency of Air Conditioning Installations (AC Code) developed by the Electrical & Mechanical Services Department (EMSD) aims to set out the minimum design requirements on energy efficiency of air conditioning installations. It forms a part of a set of comprehensive *Building Energy Codes* (BEC) that addresses energy efficiency requirements in building services installations. The set of comprehensive BEC covers the AC Code, the Codes of Practice for Energy Efficiency of Lighting Installations, Electrical Installations, and Lift & Escalator Installations, and the Performance-based Building Energy Code.

As a supplement to the AC Code, the EMSD has developed this handbook of Guidelines on Energy Efficiency of Air Conditioning Installations (Guidelines). The intention of the Guidelines is to provide guidance notes to compliance with the AC Code and draw attention of air conditioning designers & operators to general recommended practices for energy efficiency and conservation on the design, operation & maintenance of air conditioning installations. The Guidelines seek to explain the requirements of the AC Code in general terms and should be read in conjunction with the AC Code. It is hoped that designers will not only design installations that would satisfy the minimum requirements stated in the AC Code, but also pursue above the minimum requirements.

The Guidelines were first published in 1998. With the AC Code upgraded to its 2005 edition, an addendum for the Guidelines was issued in 2005. The Guidelines are amended in 2007 to suit the 2007 edition of the AC Code.

To promote the adoption of the BEC, the Hong Kong Energy Efficiency Registration Scheme for Buildings was also launched. The Registration Scheme provides the certification to a building complying with one or more of the BEC.

The Building Energy Codes, corresponding Guidelines and Registration Scheme documents are available for download at http://www.emsd.gov.hk/emsd/eng/pee/eersb.shtml
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(a) INTRODUCTION

The primary objective of the Code of Practice for Energy Efficiency of Air Conditioning Installations (AC Code), published by the Electrical and Mechanical Services Department (EMSD), is to set out the minimum energy-efficient design standards for air conditioning installations without imposing any adverse constraint on building functions, nor hindrance to comfort or productivity of the building occupants. The Guidelines on Energy Efficiency of Air Conditioning Installations (Guidelines) is a supplement to the AC Code. The intention of the Guidelines is to explain the principles behind relevant requirements in the AC Code and provide guidance on Code compliance. The Guidelines also provide the recommended general practices for energy efficiency and conservation on the design, operation & maintenance of air conditioning installations. Whilst focusing on energy efficiency aspects, the Guidelines are not to provide a comprehensive set of guidance notes in air conditioning design.

The AC Code's requirements are "minimum" performance standards only, and designers should not rely on them but try to exceed these standards in their designs. The AC Code's control parameters are adopted based on a simple and easy to follow principle, and the data needed for compliance verification can either be readily obtained from the air conditioning equipment suppliers or through simple calculations.

The direction to achieve energy efficient air conditioning depends on both the technological factors and the operational factors of the air conditioning system. Among them, the operational factors should prevail the technological factors, and should be considered by building owners as first priorities because the effort or cost for implementing good house keeping measures is usually lower than that for implementing the technological measures. On the other hand, the advantages of energy efficient design and equipment may be easily offset by improper operation & maintenance of the original system. For existing installations, new technologies have provided plenty of options to retrofit into more energy efficient installations with attractive payback periods. Decision makers should always discern that money to be spent on improving energy efficiency is an investment rather than a cost.

(a) CODE COMPLIANCE

2.1 Scope of Control

The AC Code has specified the applicable scope of coverage on the types of buildings and the natures of installations, and the types or natures outside the scope are not controlled by the Code. Having excluded domestic or residential buildings, the Code is applicable to hotels and hostels, which are of a commercial nature and are for human comfort.

The control parameters in the AC Code are as follows.

<u>System Load Design</u>

This is to avoid over design of system and equipment, by stipulating limits of the outdoor design temperatures and indoor design temperatures, and by requiring designs to be based on recognized procedures. There are many varying factors which would affect the accuracy of load calculation for each application, one possible means to control the plant sizing is to require the use of internationally ecognized methods and procedures for calculations of AC loads.

<u>Separate Air Distribution System</u>

Zones having special process temperatures other than for comfort only usually serve equipment that demand cooler and/or warmer than human comfort supply air conditions. The Code calls for a separate distribution system or supplementary control in the zone. This is to avoid the over cooling or over heating in the entire zone, which shall be broken down into two smaller zones instead. Each of the two zones will have an independent air side system or control, such that the zone temperatures could be adjusted to suit the different occupancies, thus avoiding unnecessary over cooling or heating. Small systems, generally associated with lower energy consumption and thus limited energy wastage, are exempted from the requirement.

Air Leakage Limit

While air leakage on ductwork is unavoidable, the Code tries to put a limit to the leakage to avoid unnecessary wastage on both the fan power as well as the thermal energy in the previously cooled/warmed up but leaked air.

Fan System Power

The Code calls for thresholds to the fan power, which is a result of the duct length, duct frictional loss, fan efficiency, driving motor efficiency etc. To meet the requirement, the designer should adopt a reasonably duct equivalent length, reasonably large duct crossection, fan with high efficiency and fan motor with high efficiency. For purpose of good indoor air quality, a certain exemption is granted to the power to overcome in-duct air treatment or filtering system. Small systems, generally associated with lower energy consumption and thus limited energy wastage, are exempted from the requirement; fan coil systems having short duct lengths and thus demanding lower fan power are also exempted. Also exempted from the requirement are systems for safety or health purposes. For VAV system over a certain size, there is an additional requirement on fan power, which is not to exceed 55% of design wattage at 50% of design air flow. This carries the implication of a VAV to adopt a variable frequency motor drive, which is likely the only type of drive that can meet the requirement.

Pump Power

The Code sets limit to the pump power, which is a result of the piping configuration, pipe length, pipe frictional loss, pump efficiency, driving motor efficiency etc. This is done by restricting the pipe frictional loss to a certain value per unit pipe length, and imposing a variable flow requirement. To comply with the friction requirement, the designer should adopt a reasonably large pipe size. For the variable flow requirement, a piping configuration enabling a reduction of flow should be adopted. Basically this means that two-way rather than three-way control valves should be used. The flow reduction could be exempted for systems absolutely necessitating a full flow and systems that could reduce energy consumption through water temperature reset.

Control

The Code stipulates requirements on the controls in a system, without which the system could not operate in an efficient manner.

(a) Thermostatic control An air conditioning system shall be individually controlled by a thermostat sensing the temperature in the serving space, and the thermostat shall have the provisions for high temperature settings in case of cooling and low temperature settings in case of heating. This is to enable the flexibility of a relative warmer (or cooler) operation should such condition be desired or required, and avoid the operation at the cooler (or warmer) condition unnecessarily consuming more energy as a result of a lack of the flexibility. The thermostat serving both cooling and heating shall have the dead band "deep" enough to distinguish the space conditions actually requiring cooling or heating. This is to avoid unnecessary heating (or cooling) due to transient temperate swing just above or below the space temperature set point. Naturally, the dead band requirement is not required for a thermostat with manual change-over.

(b) Humidity Control A space with specific humidity requirement has to be controlled by a humidistat with humidity settings in a range not too extreme to avoid excessive energy consumption.

(c) Zone control The importance and characteristics of the AC zone is emphasized, and the requirements to prevent unnecessary re-heat or re-cool is stipulated, with exemptions for small systems. For energy efficiency, the proper matching of zone to system is very influential.

(d) Off-hours control A system shall have automatic control to ensure no or low energy operation in the off-hours, with exception for small systems.

Insulation

Owing to the usual high humidity level in Hong Kong, the prime local consideration for insulation thickness is to prevent condensation. Relating energy to condensation, the values on minimum allowable insulation thickness are based on the equations to prevent condensation.

Equipment Efficiency

Equipment Efficiency is the most critical in AC energy consumption. The coefficients of performance for AC equipment, chillers in particular, are set based on equipment commonly used in Hong Kong.

2.2 Approach to Comply with Code

The Forms in the Code serve the purpose of step-by-step checking and are meant to be completed by the designer to demonstrate the compliance.

3. DESIGN CONSIDERATIONS

As a general principle, the design of air conditioning installation must take into account the following : -

- Nature of Building Construction
- Type of Application
- External Conditions, i.e. Weather
- Internal Conditions, i.e. Desired Space Conditions
- AC Load Patterns and Characteristics

It is obvious that these elements would critically determine the selection of AC equipment, type of systems and the associated control methods. A suitably designed system incorporated with elements for minimizing the use of energy or opportunities of energy conservation such as heat recovery, etc. can always lead to good overall energy efficiency for the whole air conditioning installation.

It is the objective of the AC Code that air conditioning systems should be designed for optimum energy use as far as practicable. The design should take into account the building characteristics and load profile so as to yield good efficiencies at both maximum and part loads. Care should be exercised to consider based on the merits of a project the adoption of modular systems and small units rather than large systems or units running at part loads. The provisions for monitoring and control facilities should be considered in the design stage. It is preferable to carry out computer simulations of the sketch systems in consideration at the early stage, so that the energy consumptions could be identified.

3.1 Load Calculation

Oversized equipment not only increases capital cost, but also usually operates at less efficient conditions. It may also lead to poor comfort control due to lack of humidity control and fluctuating temperature from short-cycling. Undersized equipment not only fails to meet the load requirement, but also needs to operate longer hours to pre-cool the building.

According to surveyed results, it was found that several popular AC load computation methods - e.g. ASHRAE Method and CIBSE Method - are widely adopted by designers in Hong Kong. Depending on many other factors, e.g. plant sizes, building complexities and usage, each method has its own merits, designers' experience and assumed design factors etc., there is no single method being superior to others at all conditions. The varying thermodynamic performance of buildings and AC systems is so complicated that all calculation methods and computer software must have simplifying assumptions embedded within them to make them practical to use. Therefore, the Code would allow designers to use any internationally recognised methods without imposing unnecessary constraint on designers' choices.

The AC load pattern and profile of the building should be analyzed and developed so that suitable equipment systems can be selected and appropriate systems can be designed for the particular application yielding optimum efficiencies against the possible varying loads. Separate systems should be provided for different areas with different AC requirements, cooling load characteristics and operation patterns.

Control and monitoring facilities should be allowed for and incorporated in the systems during the design stage. Adequate monitoring and control enable regulation and tuning of AC systems to operate at optimum efficiencies with minimum energy consumption.

3.2 Design Conditions

The indoor and outdoor design conditions stipulated have a direct effect on the results of the AC load computation. The requirement limits set in the AC Code are mainly based on the results of a survey conducted on the indoor & outdoor conditions normally adopted in Hong Kong. For outdoor conditions, data from Hong Kong Observatory are also referenced. There are some suggestions that higher outdoor temperature, e.g. 34°C, 35°C or above should be used for summer. However, as the Observatory's data have shown that these conditions are below 0.5% of total hours during the months of June through September, these higher values have not been adopted.

3.3 Air Side

The Code has not focused on ductwork construction details and workmanship. The requirement on air leakage rate is set on the basis of some international standards. Tests may be made for only representative sections provided these sections represent at least 25% of the total installed ductwork area for the tested pressure class.

The limits on power consumption in the Code refer to the actual power inputs to fan motors, i.e. the power drawn by the motors and not the power rating on motor nameplates.

The Code requires that any individual VAV supply fan with a motor power of 5kW or above should demand no more than 55% of design wattage when operating at 50% designed air flow. This requirement would prohibit the use of inefficient control methods, e.g. volume control dampers and some inlet guide vane controls with improper selection of fans. Variable speed drives or frequency inverters for motors of air handling units are recommended to cope with the varying part load situation.

3.4 Water Side

High friction loss of water pipes not only causes energy wastage, but also leads to pipe noise and erosion problems. Therefore, the maximum pipe friction loss is set to be 400 Pa/m after considering practical installations and the recommended figures used by some international standards. In fact, the general range of pipe friction loss used for design of common hydronic systems lies between 100 and 400 Pa/m; and so 250 Pa/m represents the mean value of friction loss to which most systems are designed.

3.5 Insulation

The limiting condition for formation of condensation on the surface of an insulating material occurs when the surface temperature equals to the dew point temperature. Equation 8-1 will give the provisional thickness, which is then used in iteration with equation 8-2, taking into account the diameter of the pipe, to find the actual minimum insulation thickness required. Equation 8-3 implies that the calculated value from equation 8-1 is already the actual minimum thickness of insulation for ductworks or AHU casings. Sample calculations for minimum thickness of insulation for both chilled water pipe and air duct are shown in the Appendix of the Code.

3.6 System Control

Control is required because AC systems generally do not operate at full capacity all the time. Effective control automatically adjusts the plant capacity to meet the varying load. In so doing, the power input to the system is modulated and regulated according to load demand instead of full power being constantly drawn by the system.

Where both heating and cooling are provided to a zone, the controls should not permit heating of previously cooled air, cooling of previously heated air or simultaneous heating and cooling of air, which inevitably would result in wastage of energy. Furthermore, the control system should be capable of reducing energy consumption by means of control setback or equipment shutdown during the period when the air-conditioned space is not occupied.

Where space humidity control is used for comfort purpose, the humidistat should be capable of preventing energy use for increasing R.H. above 30% during humidification or for decreasing R.H. below 60% during dehumidification. The conditions has certain deviations from the optimal design value of 50% RH, which is mainly for equipment sizing purpose, and these conditions are still within the relevant comfort zone of the human body. The use of energy to go beyond these limiting conditions would normally waste energy with no apparent benefit.

To properly reflect the space conditions, the temperature & humidity sensors should be positioned at such locations that they can detect the conditions representative of the entire controlling zone.

3.7 Equipment Efficiency

Based on survey results and with the help from the Air Conditioning and Refrigeration Association of Hong Kong, standard rating conditions are set for various AC equipment. All specified values of minimum COP for AC equipment are based on these standard rating conditions.

The minimum COP requirements are formed on the basis of the survey on AC equipment of different manufacturers/suppliers and other international standards as well. It is considered not suitable, for the time being, to specify part-load COP for AC equipment. The formation or proportion of part load COP is controversial. Even in U.S., there are also arguments over the accuracy of adoption of one single integrated part load values (IPLV) for all building types. Besides, very little data on part-load COP are available from manufacturers. It is therefore unable to formulate part-load COP requirements based on the survey. Under such circumstances, part-load COP is not recommended in the Code for the time being.

Minimum COP values under stipulated standard rating conditions are listed in the AC Code for unitary air conditioners (including single package units and split type units but excluding room coolers) and water chillers (with reciprocating, centrifugal, screw or scroll compressors). Other AC equipment not listed in this section of the AC Code have no requirement for minimum COP at the present stage.

3.8 Outdoor Air

Except where additional outdoor air intake is required to operate air economizer, to make up for process exhaust systems or for other special requirements, the AC installations should be supplied only with the minimum outdoor air quantity in accordance with relevant standards and health requirements. Attention should be paid to the intake location for outdoor air, which will affect intake air quality.

One of the best ways to minimize energy usage and still maintain high quality indoor air conditions is to minimize the source of pollutants. This can be achieved by specifying materials for furnishings, carpeting, etc. that do not liberate objectionable volatile organic compounds. If sources cannot be limited, they can often be controlled. For persistent sources, such as copying machines, exhaust hoods can be installed over the source to reduce the amount of pollutants that escape into the conditioned space.

The AC Code does not specify any requirement for outdoor air intake rate since surveys show that almost all designers are using ventilation rates much lower than the current standard of ASHRAE Standard 62-1989. It means that energy wasted on ventilation is uncommon whereas to set maximum values might mislead designers of being encouraged to spend more energy on ventilation and the minimum rate should be left to other health related requirements.

3.9 Ventilation Effectiveness

Intake outdoor air must be effectively mixed with the air in occupied spaces. Poorly selected, sized or placed air outlets can reduce ventilation effectiveness. To mitigate air outlet performance, outside air intake rates are often increased, or overall circulation rates are increased to improve air outlet performance. Both of these options will increase energy usage.

Ventilation effectiveness can be improved for less energy usage by the following measures : -

- Use supply air outlets that have high aspiration ratios, such as slot diffusers or light troffer diffusers. The air pattern a few feet from a well designed outlet supplied with a small amount of air can be identical to the pattern that results from a poor outlet supplied with a higher air quantity.

- Distribute air outlets well around each space; avoid using one large outlet when several small outlets will distribute air more evenly.

- Do not oversize outlets, which reduces their throw and aspiration ratio. This is particularly important for VAV systems, which will operate at less than full flow most of the time.

- Locate air returns where they will not short-circuit supply air. With properly sized outlets, the location of the return will generally not affect space mixing unless the return is located too close to the supply. Take extra care when using light fixtures for air returns since they are often close to air supplies and their location is not under the control of the HVAC designers; ensure that fixtures located close to supplies are blanked off.

3.10 Seasonal Ventilation

In Hong Kong, free air cooling can be applied during the cold season from November to March when additional outdoor air will result in cooling effect to balance internal loads from lighting, people and equipment.

3.11 Intermittent High-occupancy

For spaces that have high peak occupancies but only intermittently, such as seminar rooms, ballrooms, meeting rooms and theatres, etc. the outside air can be varied corresponding to the actual situation rather than constantly maintaining the high rates needed for the peak occupancy.

For spaces with peak occupancy shorter than certain period, local statutory requirements or international standards, such as ASHRAE 62, can be referred to determine the reduced ventilation rates.

For spaces that are people load dominated, such as movie theatres or ballrooms, use of VAV supply air in response to the cooling load and therefore indirectly to people density, can provide effective ventilation demand control.

For other applications, a control system that modulates outside air intake to maintain a maximum allowable space CO_2 concentration is recommended. CO_2 concentration is indicative of indoor air quality for spaces whose primary sources of indoor pollution are the occupants themselves.

Readily accessible bypass timer can also be installed to allow the minimum outdoor air quantity.

3.12 Transfer Air

Provision of outdoor air can be met by transferring air from adjacent spaces for some spaces, such as kitchens and toilets. These areas are usually with a higher room design temperature and can often be cooled by transferring exhaust air through door louvers by means of differential air pressure from adjacent air-conditioned spaces.

3.13 VAV Air Return

Return fans should be avoided in VAV systems because good control of return fans is difficult and involves sophisticated hardware. Return fans also require more energy than exhaust fans due to higher friction loss of control dampers required in return air paths if returns fans are used. However, if a return fan is absolutely essential for a particular application, it must be properly controlled to minimize pressure fluctuations and increase energy efficiency. The simplest method is to use the output from the supply duct static pressure controller to also modulate the return fan. It is most effective if both the fans are properly set up at full flow to provide the right difference between the supply and return airflow and if both fans have similar part-load performance characteristics. A more effective but more complicated scheme is to measure the supply and return fan airflow rates with a flow-measuring device and use these flows as inputs to the return fan and controller.

3.14 Variable Water Flow

For hydronic variable flow systems, flow rate of systems using two-way valves will vary with load. Therefore, to save pumping energy, two-way valves instead of three-way valves are recommended to be used for variable flow systems.

3.15 Off Hours Control

Since most AC systems serve spaces on a regular intermittent basis, proper design of off hours control according to application needs can reduce energy wastage during period of non-use. The followings are some off hours control methods that can be adopted by designers to suit operation needs of their designed space.

Automatic Shutdown

(a) Automatic programmable timer control to start and stop the system under different schedules according to requirements.

(b) Adjustable manually-operated timer to operate the system to suit required schedules.

(c) Occupancy sensors to start and stop the system.

Setback Controls

During hours when a building is unoccupied or during periods when less demand is acceptable, reduction of cooling can be done by raising the set point whereas reduction of heating can likewise be achieved by lowering the set point.

Damper Controls

Both outdoor air supply and exhaust systems can be equipped with motorized dampers that will automatically shut when the systems or spaces served are not in use. These air dampers should be controlled to shut off during pre-cooling, building initial warm-up, or setback.

Zone Isolation

AC systems serving areas that are expected to operate or be occupied at different time schedules can be divided into isolated zones. Each zone should be equipped with isolation devices capable of automatically shutting off the supply of conditioned air, outside air, and exhaust air to the isolated zone. Each zone should be controlled independently by a device meeting the requirements of automatic shutdown. For central systems and plants, control devices should be provided to allow stable system and equipment operation for any length of time while serving one or more isolation areas.

3.16 Temperature Reset Control

Supply Air Temperature Reset Control

Air distribution systems serving multiple zones may include controls that automatically reset supply air temperature by representative building loads or by outside air temperature to reduce energy consumption. The representative load means the load of a zone requiring the lowest supply air temperature (for cooling systems) or the highest supply air temperature (for heating systems).

Water Temperature Reset Control

To respond to actual load requirements, chilled and hot water systems can include controls that automatically reset supply water temperatures by representative building loads or by outside air temperature.

3.17 Variable Speed Drives

Variable speed drives or frequency inverters are solid-state devices and save energy whenever electric motors run at less than full power. It must be noted that the power demand of motor varies with the cube of the motor speed, i.e. power α $(\text{speed})^3$. This means that a reduction of speed by 20% will result in reduction of power consumption by a half, i.e. 50% saving. Since most HVAC equipment seldom runs at full power, significant energy savings can be made with these variable speed drives. The use of variable speed drives for air handling units, pumps and compressors has increased as they can now be available from the market at reasonable price. They can be added on to conventional equipment or can now be part of the factory-supplied equipment as some manufactures do provide, such as for air handling units and water pumps.

Air Flow Control

Comparing the usual ways of controlling air flow - dampers, guide vanes, and couplings, it has been verified that speed control by means of variable speed drives or frequency inverters is the most energy efficient way and is recommended to replace the other three methods wherever applicable. The table below shows the comparison of respective power consumed by the different methods of flow control. For example, the power requirement at 80% air flow with damper is 93%, with guide vane is 70%, with coupling is 67%, whereas with variable speed drive, the power demand is only 51%, i.e. a reduction to about half of that required for full flow.

Air Flow	Damper	Guide Vane	Coupling	Variable Speed Drive
Full Flow	100 %	100 %	100 %	100 %
80 % Flow	93 %	70 %	67 %	51 %
50 % Flow	73 %	49 %	29 %	15 %

Water Flow Control

Water flow is traditionally controlled by using valves and it has been shown that up to 30% wastage is incurred due to bypass of the pumped water. Reducing the water flow from full flow to 80% flow by turning the valves only reduces energy consumption by about 3%. Considering the wastage of water flow through bypass, it even increases the cost per litre the less water flow is running. However, by changing the speed of the pump/motor to deliver 80% flow, the energy consumption is halved as it is proportional to the third power of speed mentioned above. Therefore, it is recommended to use variable speed drives to vary the water flow in accordance with the actual load requirements.

It must be noted, nevertheless, that variable speed drives or frequency inverters, like all other solid-state equipment, are sensitive to phase imbalance or difference in phase loads and usually induce harmonic currents due to their non-linear nature. Hence it is necessary to ensure that phase differences are no more than 10% on circuits incorporating these devices and the system do not give rise to excessive harmonic contents.

3.18 Water Cooled System

In general, AC system employing water-cooled method of heat dissipation consumes less energy than that using air for heat rejection. For example, a cooling tower will give a lower condensing pressure than an air-cooled condenser resulting in a better coefficient of performance, in other words more energy efficient. Studies have found that the saving of using water-cooled system instead of air-cooled system ranges from 25% up to 40%, depending on the complexity and the types of AC systems.

3.19 Energy Saving Systems

There are many other systems or equipment which are specifically energy efficient to certain types of AC installations and the followings are some examples which designers of air conditioning systems are encouraged to adopt or incorporate into their designed installations wherever applicable.

<u>Air Economizer</u>

This is a ducting/damper arrangement with automatic control system for the supply air system that modulates the quantity of outdoor air supplied for the purpose of space conditioning in order to reduce or eliminate the need of refrigeration energy for cooling during mild or cold weather.

<u>Water Economizer</u>

This is a system by which the supply air of an air conditioning system is cooled directly or indirectly by evaporation of water or other appropriate fluid in order to reduce or eliminate the need of refrigeration energy for mechanical cooling.

<u>Thermal Wheel</u>

This is basically a heat transfer device with a rotating wheel, one half of which in one air stream and the other half in another air stream. The wheel is generally made of open mesh material and when it rotates, it picks up heat from the warm air stream and transfers it to the cold air stream. This type of installation can be applied to AC system where the fresh air demand is large and exhaust air is used to either preheat or precool (winter or summer respectively) the outside fresh air intake. Thermal wheel requires low cost to run or maintain and can give sensible and latent heat transfer depending on unit being selected for the system load. Thermal wheel saves electricity because it requires lower electric power and significantly reduces the chiller or DX cooling capacity allocated for conditioning the outdoor air.

VRV System

This is a kind of multi-split HVAC system which one external condensing unit / heat pump is connected by refrigerant pipework to several indoor cooling / cooling and heating units. It uses refrigerant as the cooling / heating medium rather than chilled water / hot water as used in conventional hydraulic system circulated by pumps. VRV system is able to provide total versatility as each indoor unit can cool / heat independently of each other. If part of a building requires cooling and other areas require heating the heat rejected for the required cooling contributes or is recovered to provide heating in the other area. This system is also possible to provide separate control to each indoor unit. For the example of cooling, if the temperature in a specific zone is lower than the set point temperature, the indoor unit will shut down and the load of outdoor unit can be reduced. Besides, cooling / heating for a specific zone can be supplied by running the related outdoor unit only instead of the whole system.

Hydronic Cooling System

Hydronic cooling systems supply chilled water to conditioning systems or equipment with circulation pumps, whilst air systems supply cooled air with fans to meet the load requirements. In comparing with air systems, hydronic cooling usually requires much less energy for cooling delivery because water has a much higher heat transport capacity than that of air. It is estimated that a hydronic system can transport a given amount of cooling with less than 5% of the energy required to deliver cool air with fans.

Automatic Self-cleaning System

The efficiency of condenser and heat exchanger can be seriously deteriorated by the debris and foulants accumulated in the tubes of condensers and heat exchangers. Unwanted deposits on tubes surfaces can cost up to 30% or more in energy consumption. Conventional techniques for cleaning makes it necessary to take the equipment out of service and manual tube cleaning is labour intensive and costly. They also incur equipment downtime and the cleaning has to be repeated periodically. In fact, the heat transfer across the tubes starts declining almost immediately after start-up. It is therefore advisable to employ some developed automatic tube cleaning systems such as (a) automatic tube brushing system or (b) automatic tube cleaning system using spongy spheres running through the tubes constantly. These automatic systems clean the condenser and heat exchanger tubes while the plant is operating under load condition and do not necessitate shutdown of the plant. They virtually eliminate tube fouling by removing debris from tube surfaces as often as they are deposited. This enables the condensers and heat exchangers to operate at 100% of rated capacity at each load condition and can achieve substantial energy saving. These systems can be applied to both existing and new installations.

Desiccant Dehumidifier

Desiccants are porous crystals that are highly hygroscopic and readily absorb water vapour molecules from the air. Desiccant dehumidifier is usually applied in the form of wheel, impregnated with desiccant material, which rotates as in thermal wheel picking up heat and moisture from the incoming air. It precools and dehumidifies fresh air supplied to the building by using the energy contained in the air exhausted from the occupied spaces. This eliminates the conventional overcooling and reheating. Desiccant wheel and thermal wheel can be applied in series to pretreat and subsequently deliver the air at design conditions as required by the occupied space. Desiccant dehumidifiers are particularly applicable to manufacturing processes and plants where low humidity condition is essential.

4. OPERATION & MAINTENANCE CONSIDERATIONS

4.1 General

Effective and efficient procedures for operation and maintenance of air conditioning installations can be an essential element for successful energy management of a building. Proper operation and maintenance of AC plants and equipment will enable systems and installations to operate at best efficiency and with least possible energy consumption. In general, manufacturers of equipment and machinery usually provide manuals of established practices for operation and maintenance of their products leading to their optimum performance and working life span. It is therefore recommended that plant operators and maintenance personnel should follow the recommendations and provisions stipulated in the O&M instruction manuals issued by the individual equipment and plant components as far as practicable. However, each building may be unique in nature, occupancy type, air conditioning load profile, etc. Energy efficient operation principles and procedures, developed with professional engineering knowledge, should be tailored for the AC systems of the building involved to suit the specific requirements and characteristics of a particular AC load profile. The guidelines set out in this handbook are for general application of operation and maintenance leading to achieving energy efficiency of the AC systems and installations.

4.2 Energy Efficient Operation of Air Conditioning Installations

4.2.1 It is essential that plant operators maintain daily logs and records of plant operation to enable close monitoring of plant performance and operating conditions of equipment so as to ensure effective and efficient supply of air conditioning to the occupants.

4.2.2 The Guidelines are not describing or detailing how to start up or shut down each piece of AC equipment as all O&M instruction manuals already have spelled out the steps in details for doing so. Instead, the guidelines herein are trying to give the plant operators and other related personnel the ideas, principles and ways of achieving energy saving or consuming less energy while the AC plants, systems and equipment are operating to provide the necessary air conditioning supply to the occupants.

4.3 Operational Control and Parameters

The following are general guidelines on principles of operational control and operational parameters, which if adopted, may often achieve significant energy savings.

4.3.1 Precooling should be avoided or minimized as far as possible. If necessary, precool to around 28^{o}C by the time the occupants arrive.

4.3.2 Complete cool down without introducing outside air during the first hour of occupancy if the indoor air quality is acceptable, i.e. complying international health standards and statutory requirements.

4.3.3 Set the room temperature of office areas to 24^{o}C and allow relative humidity to vary from 35% to 65% when occupied and turn off cooling immediately when unoccupied.

4.3.4 Reduce the use of AC systems in spaces, which are not used frequently, or only for short periods of time.

4.3.5 Do not turn on reheat except it is absolutely necessary for humidity control.

4.3.6 Check regularly the control parameters and set points. Readjust improper control parameters and set points as well as rebalance the systems to avoid overcooling, poor distribution and poor zoning.

4.3.7 For multiple chiller installation, always operate one chiller at its full load condition rather than operate two or more chillers with each unit running at part load condition. It is also important to check that the chillers are correctly sequence-controlled.

4.3.8 Operate only those chilled water pumps and cooling tower fans that are necessary to match the chiller operation or load requirements.

4.3.9 Most buildings operate with chilled-water supply temperature at 5 to 9^{o}C. When the load conditions permit, operate the system at higher temperatures of chilled water supply, such as 8/9^{o}C or above. Raising the chilled water temperature 1^{o}C saves about 3% of energy use in chiller operation.

4.3.10 Operate the condenser water system at lower temperature and the evaporator at higher temperature will have energy savings. It is recognized that raising the evaporator temperature 1^{o}C decreases energy consumption by about 2.5%, whereas lowering the condensing temperature 1^{o}C produces about 1.5% saving.

4.3.11 The use of BAS (Building Automation System) can serve the purpose of monitoring and optimization of control system. In addition to providing programme for maintenance, security and fire control, BAS can also reduce operating costs. AC installations incorporated with a sophisticated and well developed BAS can always achieve substantial energy saving as compared to AC system without BAS. However, it must be noted that the BAS must be well attended and the conditions and function of the probes and sensors of the system must be checked regularly and repaired or replaced if necessary.

4.4 Operation of Air Conditioning Installations

The following paragraphs provide the recommendations on operation of air conditioning plants. Focus is on plants with operators or plant attendants, on the basis of daily and weekly routines. Plant operators are encouraged to follow the recommended guidelines of procedures to enable satisfactory operation of the AC plants and energy efficient performance of the equipment.

4.4.1 General

From the date of commencement of operation of the plants and equipment, the owner or management shall immediately provide operators, with sufficient technical knowledge, experienced and well trained, to undertake the operation duties at the attended plants as described. They must be able to control and operate the plants efficiently, economically and safely according to the manufacturers' recommendations or according to good practice and established operational sequences. These operators will run the plants during the plant operating hours as scheduled.

4.4.2 Records

Daily log sheets shall be provided to each plant to record all the fundamental operating parameters on an hourly basis. Responsible engineer should check the log sheets to assess the performance of the plants and equipment at least at monthly interval.

4.4.3 Daily Routine Operation and Maintenance Duties

The following duties are to be carried out daily by operators assigned to the attended plant :

4.4.3.1 General Daily Operation Routines and Service Duties

(a) Start up and shut down the plants at times according to scheduled programme and ambient conditions. Detailed steps and procedures for start up and shut down of individual equipment and components should be followed in accordance with manufacturers' operation manuals.

(b) Log the operating parameters in the daily log sheet.

(c) Log all the maintenance activities relating to operation and routine maintenance of the plants in the log book.

(d) Conduct routine checks on all components of the plants and, where there is evidence of a fault indicated by poor performance, leakage, vibration or any other signs, locate the faults or defects and rectify.

(e) Carry out testing as required.

(f) Record any other data and information required.

(g) Report immediately any abnormality of performance and/or breakdown of equipment.

4.4.3.2 Chillers and Refrigerant Compressors

Daily Routines

(a) Start up and shut down the chillers at the appointed times, according to established sequences as recommended by the manufacturer.

(b) Check the operating conditions of the equipment at least once per shift. These conditions include vibration, noise, bearing temperatures if accessible, conditions of lubrication, conditions of auxiliary equipment, e.g. any loose parts, etc., oil level, purge unit operating conditions, refrigerant level at sight glass, operating conditions of the inlet guide vane for a centrifugal compressor, conditions of loading and unloading devices, etc.

(c) Check for any sign of water leakage from the chiller and any damage of the lagging. Repair as required.

(d) Check for sign of blockage of the water circuits. Repair and rectify as required.

Weekly Routine

(a) Check for sign of refrigerant leakage around the chillers and compressors. Repair as required.

(b) Carefully observe the response of the control instruments.

(c) Rotate the operations of chillers alternately if possible.

4.4.3.3 Air-Cooled / Water-Cooled Condensers

Daily Routines

(a) Check for sign of water leakage for water-cooled condensers. Re-tighten and fix as required.

(b) Observe the operating condition of both types of condensers, e.g. vibration, noise, etc. Repair as required.

Weekly Routines

(a) Check for signs of blockage on the water side and air side fixtures. Clean as required with effective chemicals. Pay particular attention to the cooling fins while doing so. Repair as required.

4.4.3.4 Condenser Water Pumps/Chilled Water Pumps/Feed Water Pumps

Daily Routines

(a) Check the condition of bearings, oil and grease if necessary.

(b) Maintain a small quantity of water leaking from the glands. Readjust and renew the packings as necessary.

(c) Check for pump vibration and pay attention to abnormal noise generated.

(d) Vent the pump as required.

(e) Clean the pump externals. Repaint with approved paint as required.

Weekly Routines

(a) Remove the pump coupling safety cover and check the condition of couplings. Observe any sign of misalignment.

(b) Note the running currents and observe any abnormal changes to the figures.

(c) Rotate the operation of the standby pumps.

(d) Check and re-tighten any loose bolts and nuts in proper sequence.

4.4.3.5 Air-Handling Units

Daily Routines

(a) Visually inspect each of the air handling units at least once a day.

(b) Check for abnormal noise.

(c) Observe the running current and check for deviation.

Weekly Routine

(a) Clean the air handling units and their rooms once as required.

(b) Clean the fresh air and return air louvres.

(c) Check the condition of air filters. Wash and clean if necessary with effective chemicals. Replace if required with appropriate type.

(d) Check the operation of the filter indicator. Repair as required.

(e) Check the fresh air intake filters if available. Clean and replace as required.

(f) Observe the chilled water temperature drop across the cooling coils.

4.4.3.6 Electric Motors and Associated Control Panels

Daily Routine

(a) Inspect and check the bearing temperatures.

(b) Check for vibration and abnormal noise generated.

Weekly Routines

(a) Clean the motors outer casings.

(b) Oil and grease the bearings if applicable and necessary.

(c) Observe the operating current for motors.

4.4.3.7 Cooling Towers

Daily Routines

(a) Inspect the equipment including fans, motors and accessory parts for abnormal operating conditions.

(b) Check for sign of corrosion on all parts. Repaint as necessary.

(c) Check the bearing temperature as required.

Weekly Routines

(a) Oil and grease the bearings if necessary.

(b) Turn the valves from full-open to full-closed position and finally reset them at operating condition. Grease the spindles.

4.4.3.8 Expansion Tanks and Cooling Water Storage Tanks

Daily Routines

(a) Check the incoming fresh water supply availability.

(b) Check the operation of the ball float valve.

Weekly Routine

(c) Turn and reset all the isolating valves once.

(d) Check for blockage of vent.

(e) Check for signs of corrosion and repaint if necessary.

4.5 Maintenance of Air Conditioning Installations

4.5.1 It is obvious that good maintenance will ensure efficient operation of equipment and systems as well as sustaining long usable life. In fact, effective maintenance is also one of the most crucial items in gaining success in the implementation of energy management programme. The frequency and timing for implementing maintenance procedures is essential and vital for efficient running of plants and equipment.

4.5.2 Consideration should be given at the design stage to provide the requirements of space, position, access and facilities for maintenance of the AC plants and equipment.

4.5.3 The recommendations in the following paragraphs are maintenance guidelines for items of equipment commonly in use in air conditioning systems and installations.

4.5.4 Monthly Routine Service and Repair

4.5.4.1 General

(a) Check the general condition of the plants and equipment such as chillers, compressors, condenser coils, chilled water pumps, make up water tanks, air handling units, fan coil units, all motors, water treatment equipment and the associated electrical, electronic & mechanical controls and circuit boards to ensure that the plant and equipment are operating satisfactorily within designed conditions.

(b) Check and record on log sheets and where appropriate on system performance sheets the following, after maintenance work is completed : -

i. the temperature and humidity readings of the ambient space, and at designed locations within the air-conditioned area;

ii. the refrigerant compressor suction and discharge pressure, chiller water inlet and outlet temperature, condenser air inlet and outlet temperature, ampere of motors;

iii. the air handling units operating conditions including motor ampere, chilled water inlet and outlet temperatures, return and delivery air temperatures;

iv. water pump suction and discharge pressure and motor ampere, items of equipment checked and whether they are operating satisfactorily;

v. any particular observations/remarks and works carried out.

(c) Repair and replace defective components of the plant.

(d) Drain and clean the pre-filler and after-filter of the pneumatic control system (if any); clean the refrigerant drier and aftercooler (if installed).

(e) Check the lubricating system of all running pumps, cooling fans, motors, fan blowers, compressors, control mechanisms and any other running parts; cleaning, greasing and oiling where necessary.

(f) Check the performance of the controls and safety cutouts and check all control panel indication lamps, rectify as required.

(g) Clean the electrical panels including wiring terminals/connection points.

(h) Touch up with finish-coating where there is any rust or sign of corrosion of the equipment after first removing the rust or corrosion.

(i) Check any water leakage from the pipework and repair if required.

(j) Keep all supply and exhaust grilles and louvres clean.

(k) Check and adjust, if necessary, the air flow rate in the air-duct system.

(l) Check the corrosion of metal surface, frame work and supporting/mounting brackets, etc., and reinstate the surface by removing rust and repaint if necessary or as directed by Engineer's Representative.

4.5.4.2 Refrigerant Compressors

(a) Check for proper operation of the refrigerant compressor and related controls and control circuits, paying particular attention to any abnormal noise and vibration, repair or adjust as necessary.

(b) Check the operating refrigerant condition, liquid level, operating pressures (suction pressure, discharge pressure and oil pressure), operating temperatures, and lubrication level, refill or renew as necessary.

(c) Examine the condition of joints, stop valves, covers and seals for leaks, repair and replace if necessary.

(d) Remove debris and maintain the compressor in clean and tidy condition.

(e) Check driving belts for proper tension and correct alignment, adjust and renew belts if required, lubricate bearings as required.

4.5.4.3 Water Chillers (Evaporators) and Condensers

(a) Check for proper operation of chiller, condenser and related controls and control circuits, paying particular attention to water inlet and outlet temperatures.

(b) Check the operating pressure, pressure drop and flow rate.

(c) Examine the condition of joints, stop valves, covers and seals for leaks, repair and replace if necessary.

(d) Ensure cleanliness of water-side heat transfer surfaces. Chemical cleaning should be applied if necessary.

(e) Carry out water treatment as required.

4.5.4.4 Cooling Towers

(a) Check for proper operation of cooling tower and related controls and control circuits, paying particular attention to water inlet and outlet temperatures.

(b) Ensure tower cleanliness to minimize resistance of both water-side and air-side components such as tower-fill, packing, water nozzles, water distribution system, tower basin, water strainers and air intake screens, etc.

(c) Check for leakage in water piping circuits, repair or replace if necessary.

(d) Check the water levels and ensure correct control of bleed-off.

(e) Check for proper operation of fans including speed, running current, fan noise/vibration and rectify if necessary.

(f) Ensure that air flow discharge of fan is not obstructed and avoid short circuit back to air intake.

(g) Implement effective water treatment.

4.5.4.5 Motors for All Motorized Devices and Equipment

(a) Check the electricity supply voltage and the phase balance conditions.

(b) Clean the motor casing, grease and lubricate if necessary.

(c) Check and report any abnormal running noise and vibration. Replace the bearings, megger test the motors and repair as necessary.

(d) Check, adjust and rectify defect if required for circuit protective devices including starters, control relay and indicators.

(e) Check electrical circuits and attend to any loose connections or bad contacts found.

(f) Check motor cooling or ventilation to avoid overheating.

(g) Check motor drive and if necessary, tighten belts and pulleys, replace worn out bearings and ensure correct drive alignment.

4.5.4.6 Pumps

(a) Visually inspect the pumps, check for abnormal running noise and repair if necessary.

(b) Check condition of gland for excessive wear. Replace if required.

(c) Ensure that the drain pipes are not choked and rectify if necessary.

(d) Check the pump bearings and bearing temperature, and repair if necessary.

(e) Observe and rectify any abnormal running noise and vibration. If necessary, replace the bearings, megger test the motors and repair as necessary.

(f) Check and operate the vent valves.

(g) Check for proper operation of the flow switch control system and safety device. Rectify if necessary.

(h) Clean suction strainer.

(i) Check for proper function of the make up system to the chilled water circuit and rectify if necessary.

(j) Check for correct alignment of the motor and pump, tighten belts and pulleys, and rectify if necessary.

4.5.4.7 Air Handling Units

(a) Check that the air handling units and related controls and control circuit (including volume control devices) are operating properly, repair or renew if required.

(b) Check condensate drain pan, drain pipe and floor drains to ensure no choking and flooding. Rectify if necessary.

(c) Check unit casing, air filters and passage around coils for any air leakage and rectify where necessary.

(d) Clean or renew air filter as required.

(e) Check and rectify any abnormal running noise and vibration. If necessary, replace the bearings, megger test the motors and repair as necessary.

(f) Check the insulation, repair or replace if necessary.

(g) Check the belt drives for proper tension and correct alignment, adjust and renew belts and lubricate the bearings as required.

(h) Check the operation of control valves and isolating valves, rectify if required.

(i) Clean the fresh air inlet, exhaust air louvres, air dampers, accessible ductwork and fan blades.

(j) Check the heaters for proper operation and rectify if required.

4.5.4.8 Fan Coil Units

(a) Check that the fan coil unit and its control/sensing devices are functioning properly.

(b) Inspect and clean if required the condensate drain pan and drain pipes to ensure no choking, leaking and flooding. Rectify if necessary.

(c) Clean the supply and return air grilles and filters.

(d) Check heaters and their control/protection devices for proper operation and rectify if required.

(e) Check and rectify any abnormal running noise and vibration. If necessary, replace the bearings, megger test the motors and repair as required.

(f) Check all applicable items as for air handling units.

4.5.4.9 Fans

(a) Check that the fans and related controls and control circuit (including volume control devices) are operating properly, repair or renew if required.

(b) Check the belt drives for proper tension and correct alignment. Adjust and renew belts and lubricate the bearings as required.

(c) Ensure cleanliness of fan blades, fan casing and interior.

(d) Check and rectify any abnormal running noise and vibration. If necessary, replace the bearings, megger test the motors and repair as required.

4.5.4.10 Calorifiers

(a) Inspect all joints and connections for leakage, and repair as necessary.

(b) Examine all mountings (gauge, pressure relief valve, etc.,) to see that they are not damaged or leaking and that they are in working order.

(c) Check the temperature settings and functioning of the controls and ensure compliance with manufacturers' details.

(d) Check the insulation and repair or replace if necessary.

4.5.5 Half Yearly Service and Maintenance

In addition to the monthly service, repair and maintenance work, half yearly service and maintenance are necessary and shall include the following items : -

4.5.5.1 Air Cooled Condenser

Carry out cleaning of all the air cooled condenser coils by high water pressure or steam jet once every six months with appropriate cleaning detergent to ensure that high heat transfer efficiency is maintained.

4.5.5.2 Cooling/Heating Coils

Clean the cooling/heating coils by high pressure, water pressure or steam jet with effective cleaning detergent to ensure that high transfer efficiency is maintained.

4.5.5.3 Automatic Control and Temperature Sensing Devices

Examine, test and re-calibrate or replace if necessary all thermostats, sensors and gauges.

4.5.6 Annual Overhaul

Annual overhaul should include the service work under Section 4.5.4 "Monthly Routine Service and Repair", Section 4.5.5 "Half Yearly Service and Maintenance" and the following items of work : -

4.5.6.1 General

(a) Inspect the condition of pipe-fittings, supports, duct, hangers, etc., for sign of corrosion and leakage. Derust and repaint with primer and finish coating as necessary.

(b) Check condition of pipework and ductwork. Recondition and if necessary, replace the deteriorated portion in accordance with acceptable engineering practice and standard.

(c) If necessary, refit the isolating valves, change the valve gland and gasket, and recondition the globe valves, etc.

(d) Examine, check and maintain the proper operation of associated switchboard in the plant room. Repair and renew as appropriate.

(e) Check, test, recalibrate or replace if required, all control and safety devices.

(f) Check inlet guide vanes of centrifugal compressors.

(g) Check, test, adjust, clean dirt/dust, and repair/rectify defects if necessary for all electronic circuit boards, components and control/sensing/detection devices including building automation system if available in the system.

4.5.6.2 Refrigerant and Chilled Water System

(a) Check, test, recalibrate or replace if necessary, in accordance with manufacturers' instructions or designed values all safety and control units including chilled water low temperature cutout, and recycle switches, timers, refrigerant low temperature cutout, low oil pressure cutout, refrigerant low and high pressure cutout, water flow switch, etc.

(b) Check the pipework for leaks, operate all valves and grease the spindles and repair if necessary.

(c) Dismantle, check and clean in accordance with manufacturers' instructions all associated equipment; repair or renew the relevant parts showing signs of wear, tear or damage. All equipment after re-conditioning and overhauling shall be restored to an efficient working condition.

(d) Inspect condition of coupling, repair or renew as necessary, and realign motors and compressors.

4.5.6.3 Air Cooled Condensers

(a) Dismantle fan blades and repaint after removal of rust and cleaning.

(b) Check and renew bearings and fan belts as required.

(c) Check and clean condenser coils as in Item 4.5.4.3.

4.5.6.4 Pumps

(a) Overhaul pumps as detailed in Item 4.5.4.6.

(b) Check, repair or renew as required all associated controls.

(c) Open up pump casings and check condition of pump shafts, impellers, sleeves, bearings and casings for wear and corrosion. Derust, refit, repair or replace as necessary or as instructed. Repaint the pump internals and external casings with suitable protective paint of approved colour.

(d) Check, repair and renew if necessary, pumps and motor couplings.

(e) Renew and replace grease, oil and gland packing and other parts as necessary.

4.5.6.5 Motors for All Motorized Devices and Equipment

(a) Overhaul motors and related controls as detailed in Item 4.5.4.5 including removal of dust, oil or grease from motor windings and interiors of motors by using carbon tetrachloride solution or other effective chemical solutions. Check winding insulation by megger test. Check cable terminals and cables for damage or deterioration. Replace motor bearings, windings, and cable terminals as necessary.

(b) Check the associated circuit protection devices, electrical starter and equipment for good working condition; renew contacts and other worn or defective parts as required.

4.5.6.6 Air Handling Units

(a) Test the operation of the unit, including checking the flow rate, temperature, controls and sensors. Adjust and renew any component as required.

(b) Overhaul motors and related controls as detailed in Item 4.5.4.5.

(c) Check and adjust tension of belt drive; replace the fan belt if required.

(d) Clean cooling coils by steam or high pressure water jet cleaners and effective cleaning detergent.

(e) Check and clean condensate drain pan and pipe to ensure no choking, leaking and flooding. Derust and repaint with primer and finish coating.

(f) Examine the fan blades, derust and repaint as necessary to renew grease or oil and renew defective bearing as required.

(g) Clean control linkage and associated instruments.

(h) Dismantle and remove the electric duct heater bank for cleaning and carry out megger test, repair or renew if required.

(i) Clean accessible portion of ductwork and dampers.

4.5.6.7 Fan Coil Unit (Direct Expansion and Chilled Water Type)

(a) Test the operation of the unit, including checking the flow rate, temperature, controls and sensors. Adjust and renew any component as required.

(b) Dismantle blower fan and motor assemblies for cleaning, oiling and overhaul of electrical motors in accordance with Item 4.5.4.5.

(c) Clean the filters, supply and return air grilles; and renew air filters if necessary.

(d) Clean cooling coils by water jet cleaners and effective cleaning detergent.

(e) Dismantle and remove the duct heater for cleaning and carry out megger test, repair or renew if required.

(f) Check and clean condensate drain pan and pipe to prevent choking, leaking and flooding. Derust and repaint with primer and finishing coat.

(g) Check for leaks in refrigerant pipes.

(h) Check conditions of drain pumps, if any.

4.5.6.8 Calorifiers

(a) Clean off all scale or deposit from inner heater and inspect for corrosion and/or pitting.

(b) Remove any sludge from inside the calorifier shell and inspect for corrosion, etc.

(c) Clean the mating surface and fit a new joint ring before bolting up.

(d) Replace or repair as necessary any lagging which has been removed or damaged.

(e) Apply coats of paint in accordance with colour codes to the plants.

(f) Arrange for survey by a registered surveyor as called for under the Ordinance.

(g) Submit relevant certificate according to Government regulations.

4.5.7 Biennial Overhaul

The following work is recommended to be carried out biennially in addition to the routine service.

4.5.7.1 Open-type and Semi-hermetic Type Reciprocating Compressors

Overhaul open-type and semi-hermetic type reciprocating compressors (excluding hermetic compressors). In the course of overhauling the open-type compressors, the following steps are suggested. Nevertheless, all overhaul work should be carried out in accordance with the procedures and details as described in the manufacturers' instruction manuals whenever available.

(a) Withdraw all refrigerant from the system if the stop valves of the compressor are leaking.

(b) Evacuate the oil from the crankcase.

(c) Dismantle protecting guards.

(d) Dismantle belt flywheel or direct coupling.

(e) Dismantle interior parts of the compressor.

(f) Check clearance of crankshaft flow and take out crankshaft.

(g) Clean all parts with kerosene.

(h) Dismantle the oil pump and examine internal parts.

(i) Clean the metal deposits from the magnetic plug on the crankshaft.

(j) Dismantle the unloader and examine internal parts.

(k) Examine clearance of all moving and rotating parts.

(l) Grind carbon and steel ring of the shaft seal and valve plate.

(m) Examine internal safety relief valve.

(n) Renew all gaskets.

(o) Examine all stop valves and replace packing if necessary.

(p) Reassemble all components in good working order and test the operation of the unloader with oil pressure.

(q) Reassemble all access doors, shaft seals and cylinder head.

(r) Reassemble flywheel, belt or direct coupling and make alignment.

(s) Draw air out, re-fill lubricating oil and leak test.

(t) Dismantle oil separator and check float valve and clean.

(u) Replace filter drier.

4.6 Maintenance of Ventilation Installations

4.6.1 Monthly Routine

(a) Clean fan blades and examine blades for wear or damage.

(b) Check and if necessary lubricate fan and motor bearings.

(c) Check the fan belt, if any. Adjust as required and replace if necessary.

(d) Inspect flexible connections and anti-vibration mountings. Ensure that they are securely bolted, free to move, and function properly.

(e) Clean the air filters, supply and return air grilles. Renew air filters if necessary.

4.6.2 Half Yearly Routine

(a) Check the operation of the control and function of individual parts.

(b) Check all electrical wiring and connections and circuit protection devices including switchgears and starters. Rectify or replace if required.

(c) Thoroughly clean the exhaust hood with suitable detergent.

4.6.3 Annual Maintenance

(a) Clear the vanes in the air ducts.

(b) Check and re-tighten any loose bolts and nuts in proper sequence.

(c) Check the corrosion of the metal components. Derust and repaint with primer and finishing paint if necessary.

(d) Overhaul the fan motor, wiring and associated electrical equipment as detailed in Item 4.5.4.5.

(e) Take down the fan, replace the fan bearings if required and repaint the fan blades, fan casings, wire guards, etc.

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