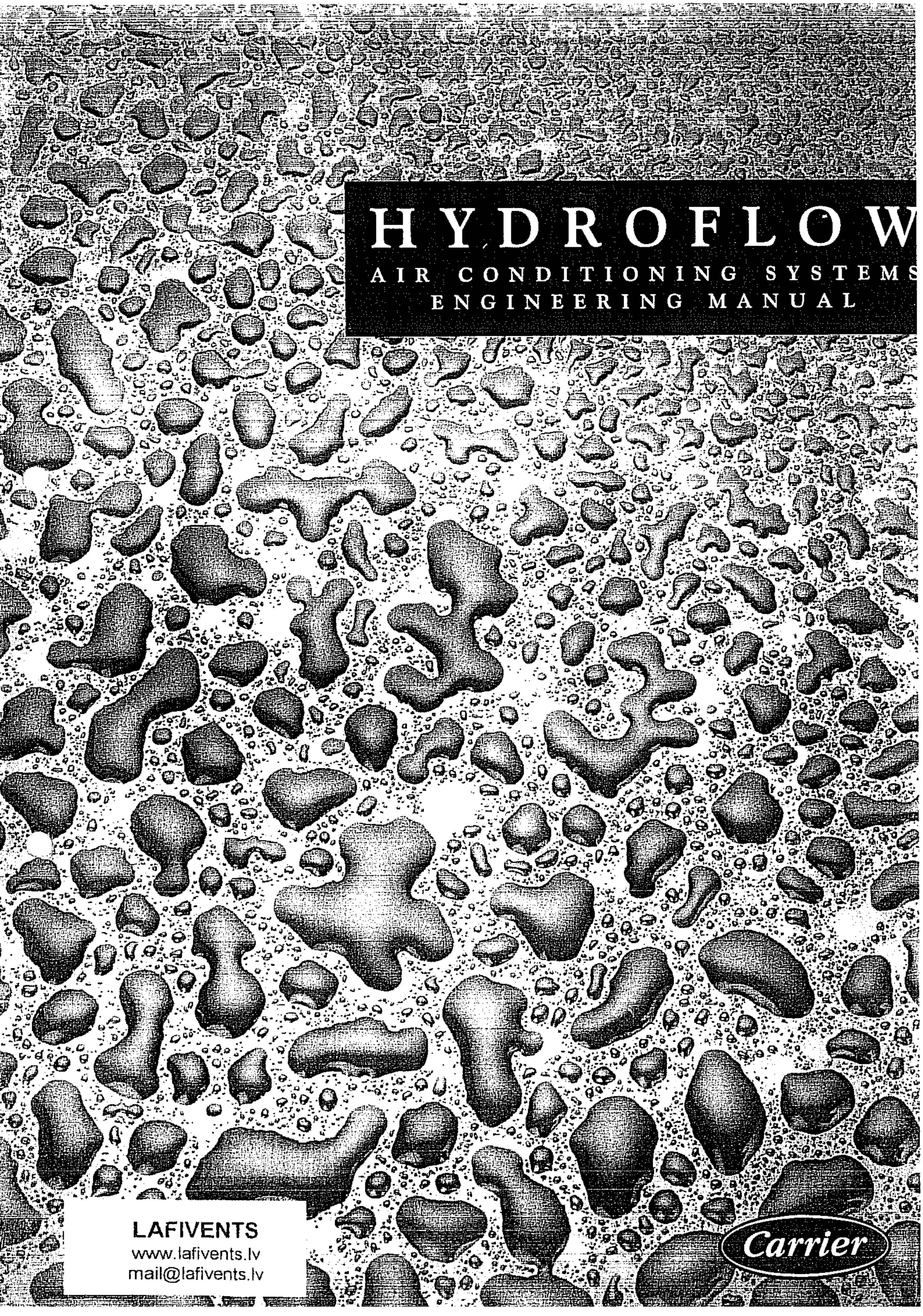


HYDROFLOW

AIR CONDITIONING SYSTEMS ENGINEERING MANUAL

Carrier

SECTION 1 - OVERVIEW

1.1 The Environmental Issue - the need for hydronics

Most people are aware of the implications of ozone depletion and global warming on the future of the planet. Now new areas above the North Pole have been identified where chlorine gases, particularly CFCs found in current refrigerants, are eating a hole into the protective ozone layer, and thus adding to the existing hole in the South Polar regions.

Global warming is also a problem due to the build-up of carbon dioxide and other gases in the upper atmosphere acting as the glass in a greenhouse and causing a gradual increase in the temperature of the planet. Air conditioning as a user of energy also contributes to this problem.

Modern man cannot live without refrigeration, and in many parts of the world finds it difficult to live without air conditioning. Consequently the air conditioning and refrigeration industries are in a state of flux as concern for the ozone layer mounts, and the urgent search for environmentally acceptable refrigerants continues.

Fig. 1.1 shows the ozone depletion potential of commonly used refrigerants. It should be noted that most of the air conditioning systems installed today use low ozone depletion HCFCs and not CFCs. However, even HCFCs will be phased out by 2005 and in Germany and Sweden the objective is to phase out HCFCs by the year 2000!

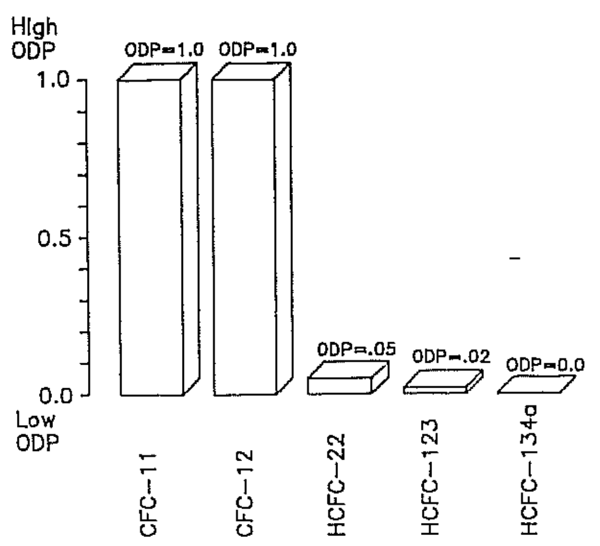


Fig. 1.1 - Ozone depletion potential (ODP) of commonly used refrigerants

In view of the foregoing, it can be seen that it is environmentally responsible and economically prudent to reduce dependence on man-made refrigerants. Whilst Carrier offer a range of 'close coupled' direct expansion systems for the smaller air conditioning requirement, in recognition of the concerns relating to environmental issues the decision was made to regenerate a greater awareness of the benefits offered by chilled water or "hydronic" systems in minimising the problems.

1.2 Hydroflow Systems - a brief description

Carrier Hydroflow systems are electrically powered water-based air conditioning systems, which eliminate the need for large quantities of refrigerant contained within the extensive and costly refrigerant pipework runs associated with split direct expansion systems. The small amount of low ozone depletion R-22 used in hydronic systems is safely and remotely sealed away within the chiller.

Another major advantage of hydronic systems is that they comply fully with the requirements of British Standard 4434 which recommends limitations as to the amount of refrigerant which can be used within the occupied spaces. Hydronic chillers use small amounts of refrigerant and this is kept well away from occupied spaces.

Chilled water or hydronic systems offer a viable, environmentally friendly, and cost effective option for any type of application. Utilising less expensive and user-friendly water pipework with a packaged Carrier hydronic chiller (incorporating a chilled water pump fill system and expansion tank), fan coil units and/or cassettes, and with fully integrated controls, hydronic systems can be applied in every situation from a single zone application upwards.

Chillers are available in heat pump or cooling only models and together with two- or four-pipe fan coil units, the hydronic systems that Carrier offers can replace an existing boiler system, or upgrade that system to incorporate full air conditioning.

Schematics showing various types of hydronic systems are shown in Figs. 1.2 and 1.3. These systems can vary from the traditional four pipe system with a chiller providing cold water and a boiler providing hot water to room fan coil units, ceiling mounted cassettes, large fan coils with distribution ductwork or Carrier's sophisticated zonal air treatment modules for individual air control.

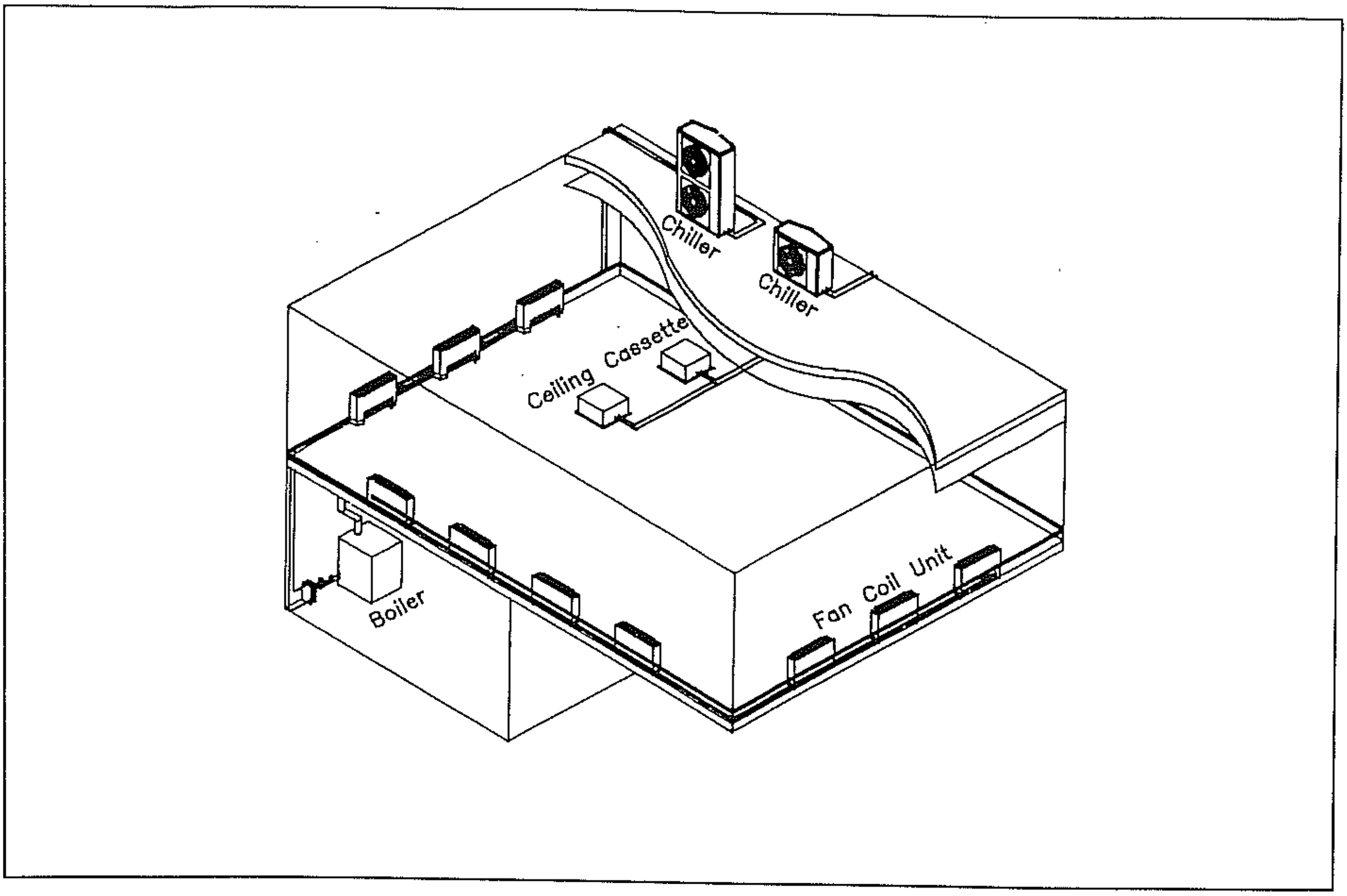


Fig. 1.2 - Four pipe system - hydronic chillers and boiler serving room fan coil units and ceiling cassettes

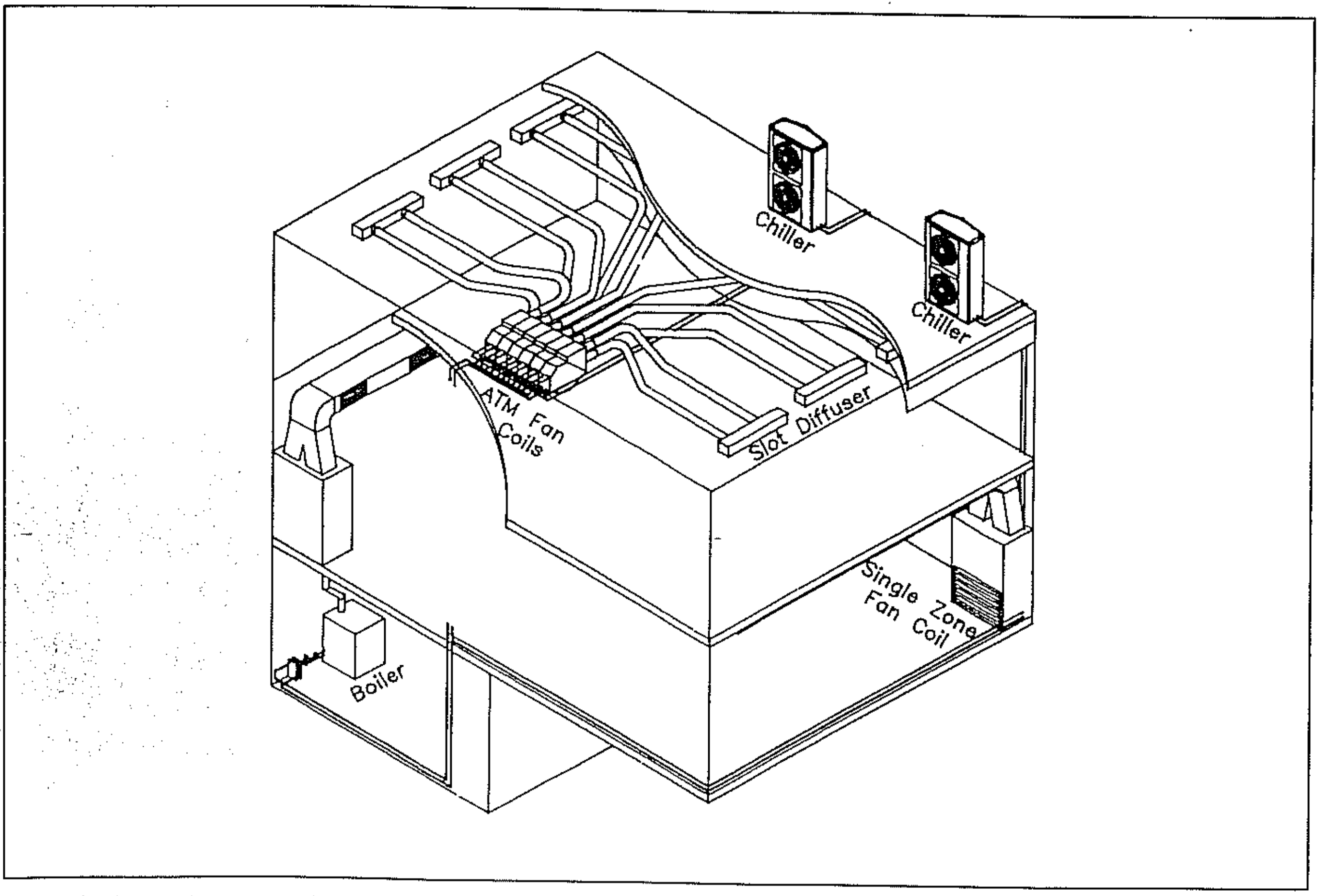


Fig. 1.3 - Four pipe system hydronic chillers and boiler serving large ducted fan coil units and Carrier's unique ATM units

1.3 Hydroflow System Hardware

Carrier hydronic chillers and heat pumps are provided complete with multi-speed water circulating pump, expansion tank and pressurisation system. All of this equipment is contained within a common housing as a single package, fully wired and ready for installation.

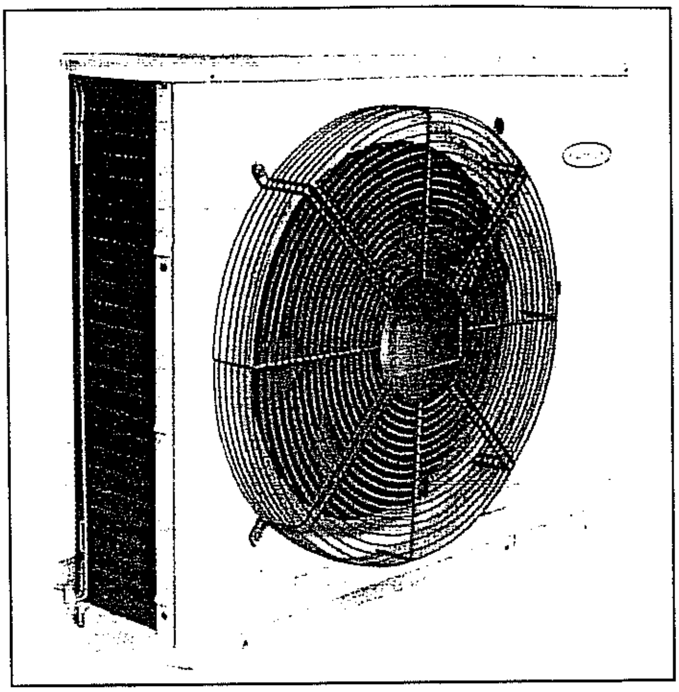


Fig. 1.4 - Hydronic chiller with internal pump, pressurisation system and expansion tank

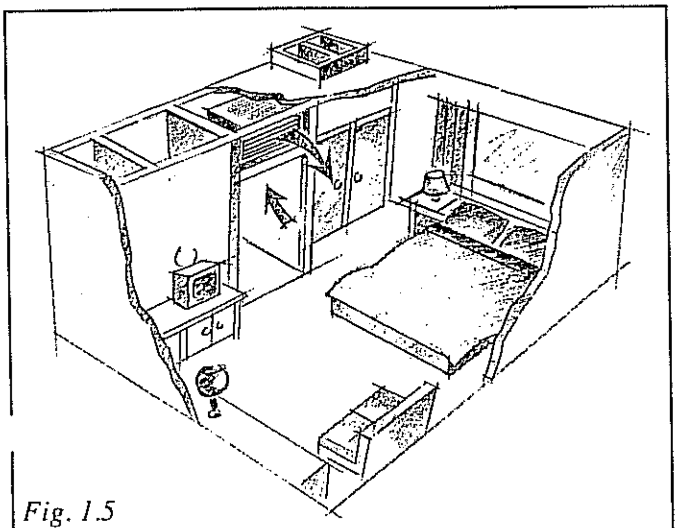


Fig. 1.5

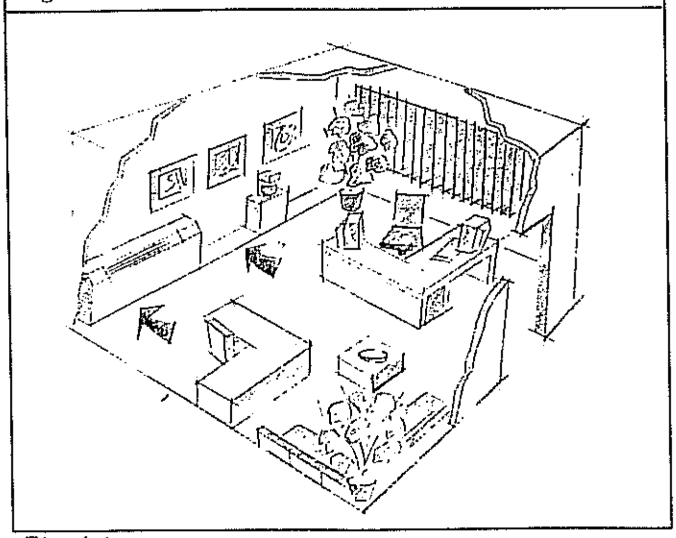


Fig. 1.6

A variety of fan coil units are offered to suit most applications. The conventional floor-/wall-mounted unit can be supplied complete with casing or as a furred-in unit within an architect's facade provided by others. These same units can be horizontally-mounted with cabinet at ceiling level or without cabinet above a false ceiling. They supply air to the occupied space via short lengths of supply and return ductwork with ceiling diffuser and return air grille.

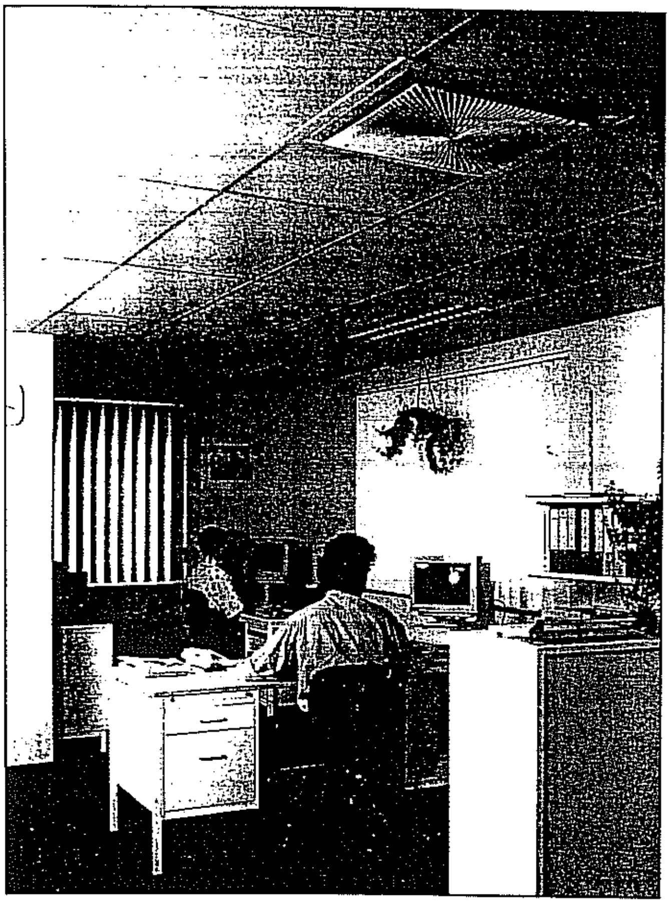


Fig. 1.7

Another type of fan coil unit is the ceiling cassette suitable for use above a false ceiling and incorporating a common supply and return air grille/diffuser.

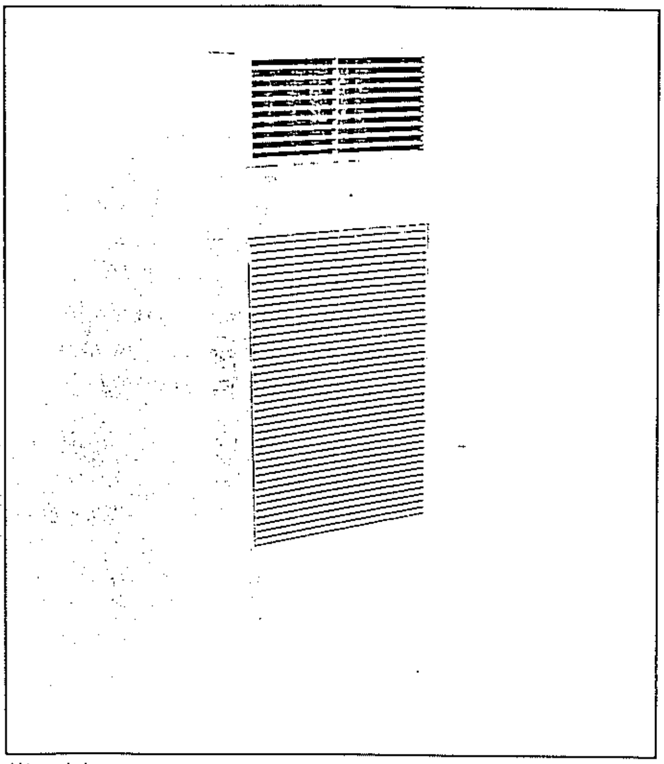


Fig. 1.8

Carrier package units can be mounted within the occupied space without ductwork to provide a low-cost alternative.

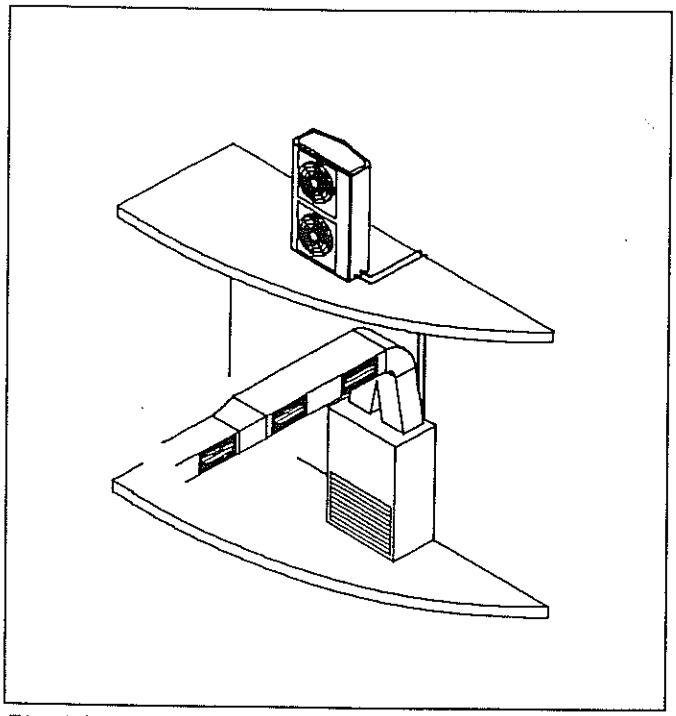


Fig. 1.9

For large areas such as open-plan offices or many offices within a common zone Carrier air handling units are used within a plant room supplying air via a system of ductwork to the conditioned areas.

On more specialised projects where space is of major concern and individual control is important, the Carrier zonal fan coil system known as ATM (Air Treatment Module) can be used. These units can be mounted in plant rooms away from the occupied space so that maintenance need not be carried out within the conditioned areas.

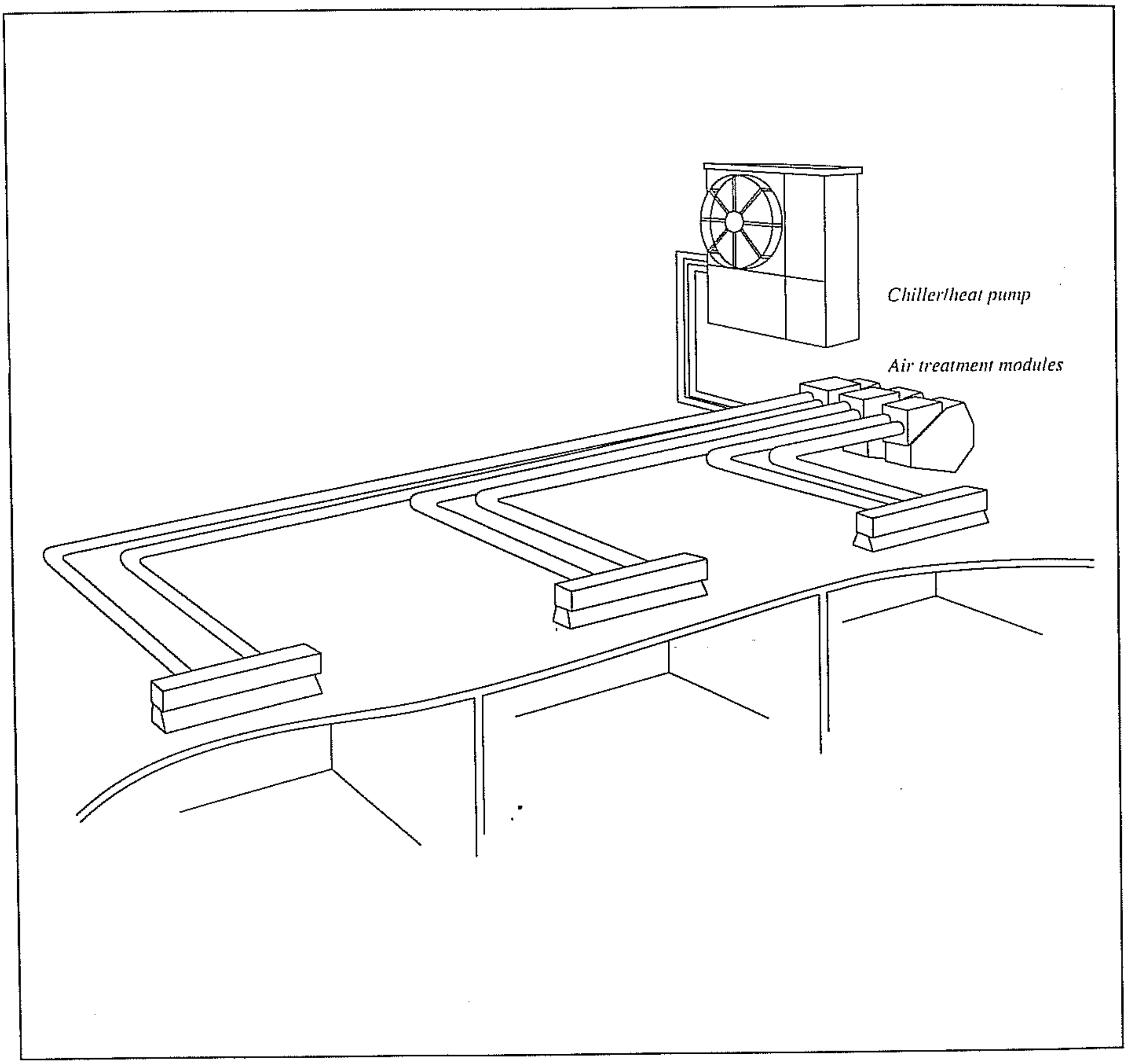


Fig. 1.10

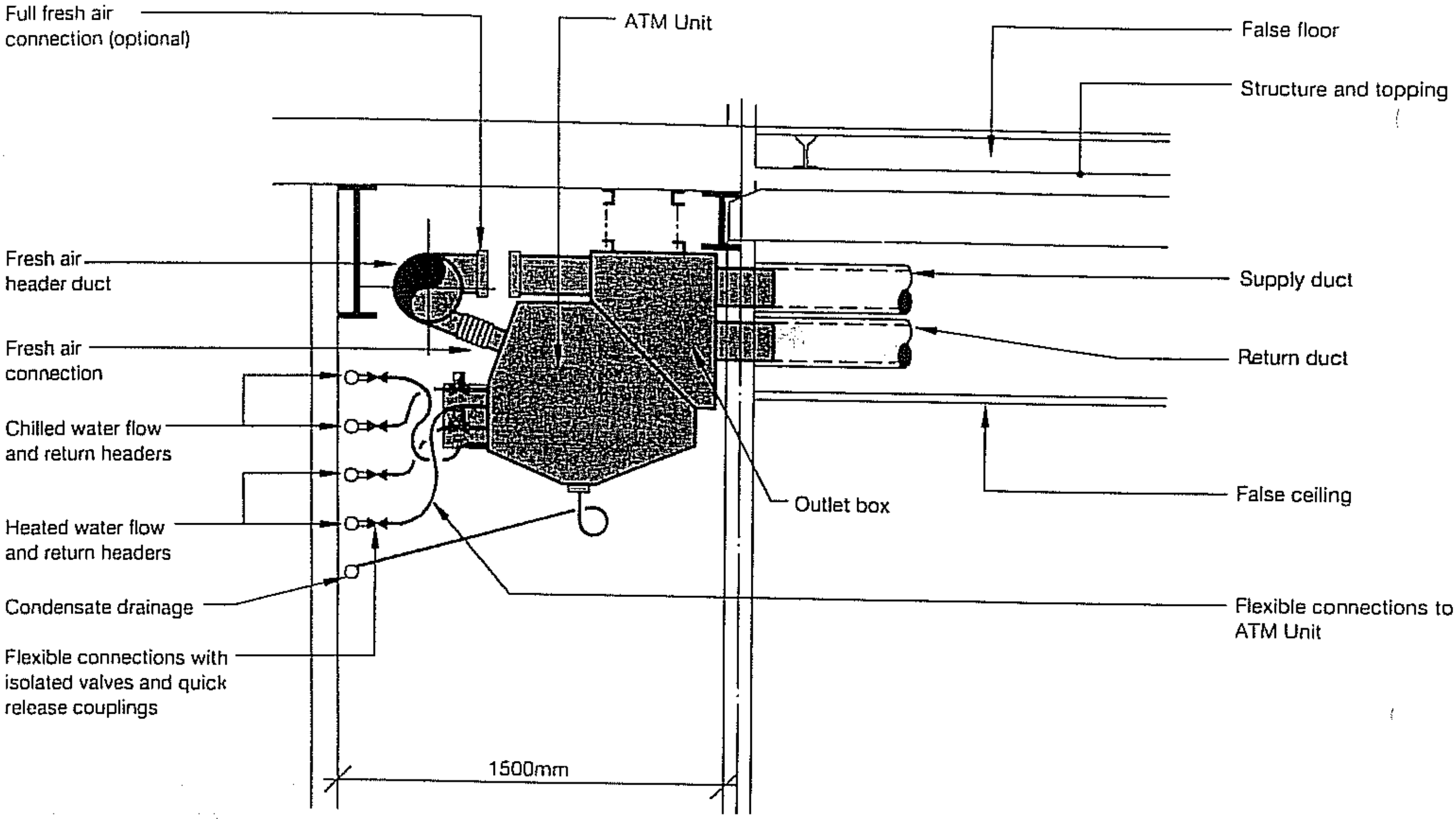

Full fresh air connection (optional)
ATM Unit
False floor
Structure and topping
Fresh air header duct
Supply duct
Fresh air connection
Return duct
Chilled water flow and return headers
Heated water flow and return headers
Outlet box
False ceiling
Condensate drainage
Flexible connections to ATM Unit
Flexible connections with isolated valves and quick release couplings
1500mm

Fig. 1.11

1.4 Hydroflow System Types

1.4.1 Two-pipe system cooling only

The diagram (Fig. 1.12) shows a conventional cooling only air-cooled chiller serving room-mounted fan coil units with chilled water on a two-pipe application. Typically the water temperature would be around 6°C entering temperature with 11°C leaving water to achieve the best performance from the fan coil units. The heating on a system of this sort would be provided by a separate and independent heating system. Thus an air conditioning system of this sort would be used to upgrade an existing heating only building. Note that care has to be taken to ensure that the air conditioning system is off when the heating is on and vice versa, otherwise the two systems will fight each other.

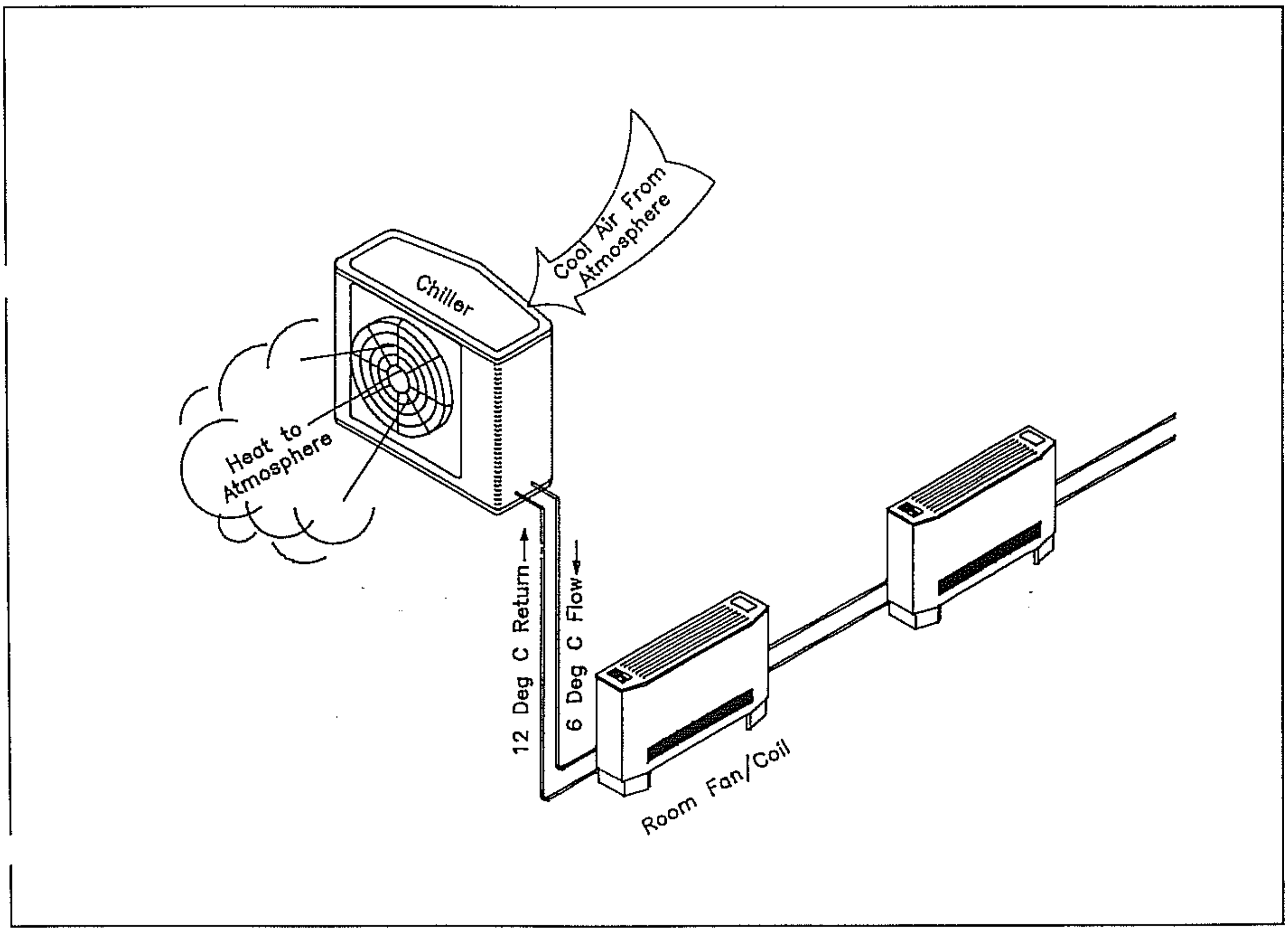


Fig. 1.12 - Two pipe system - cooling only

1.4.2 Two-pipe cooling only with electric heat

Here (Fig. 1.13) the fan coil units are provided with electric resistance heaters. A thermostat in the fan coil unit senses if cooling or heating is required and adjusts the unit accordingly. As electric heat is relatively expensive this system is normally only used for internal zones with very small heat loads that only occur in severe weather conditions; or alternatively those jobs where the cost of other types of heating are not warranted.

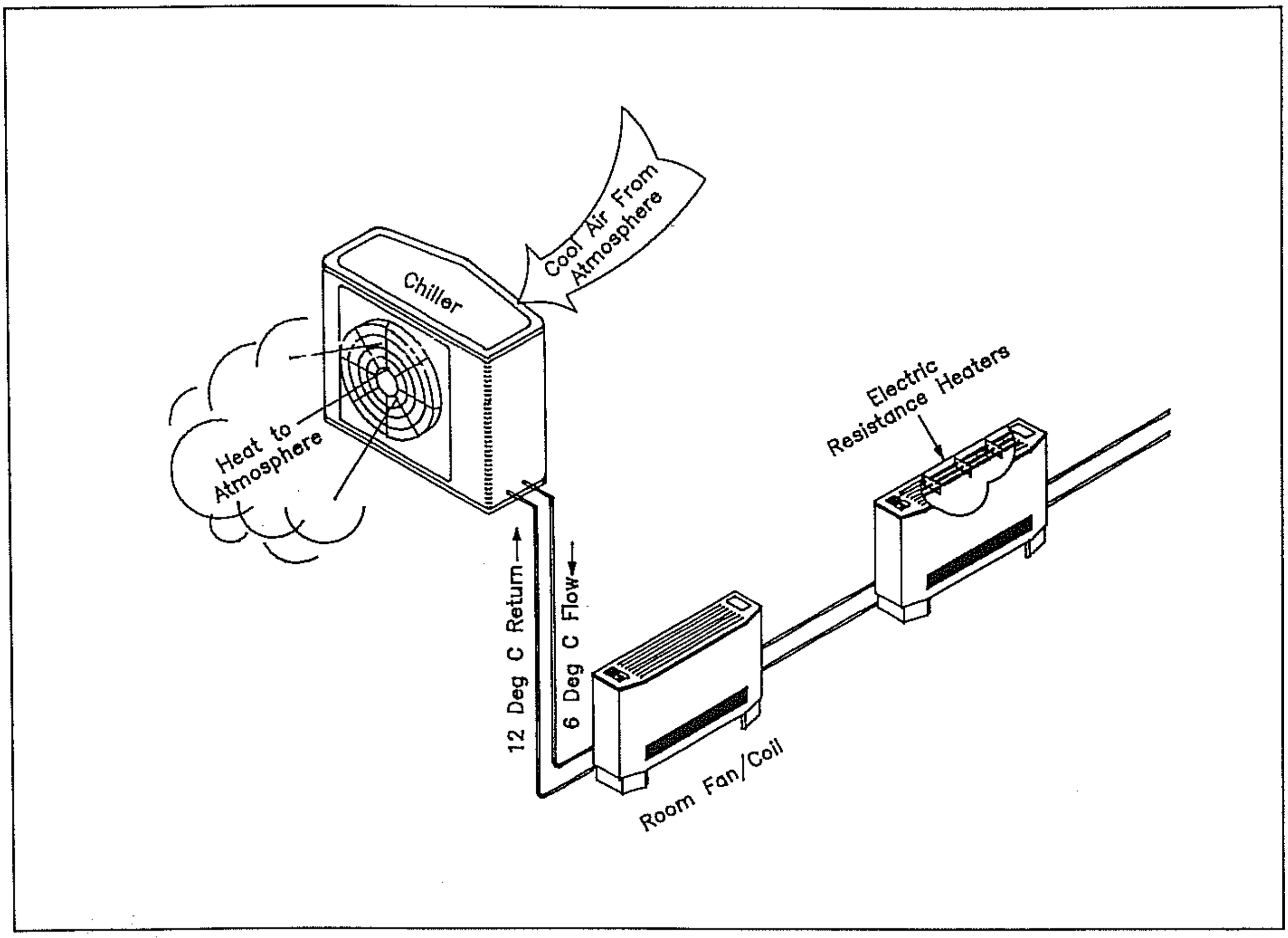


Fig. 1.13 - Two-pipe system - cooling with electric heat

1.4.3 Two-pipe cooling and heating using heat pump

An alternative to the previous schemes is a two-pipe heat pump system where the outdoor unit is capable of providing either chilled or warm water to the fan coil units. As a heat pump can provide either cooling or heating, but not both simultaneously, the area served must be zoned very carefully so that all the fan coils call for either cooling or heating at any one time. See Fig. 1.14. If this is not done, it is possible for a situation to arise where the building calls for a rapid change from heating mode to cooling mode. Return water in the system would still be at 45°C, which would cause excessive pressures within the refrigeration system. If the heat pump were to be in cooling mode safety devices within the unit would prevent this and the heat pump would be prevented from running until the residual heat within the pipework was dissipated.

To achieve simultaneous heating and cooling using this system, the building being served must be carefully zoned such that each zone is served by a dedicated heat pump. In this way a north/south facing building can have its south face served by a heat pump in cooling mode whilst its north face is being heated by a heat pump in heating mode.

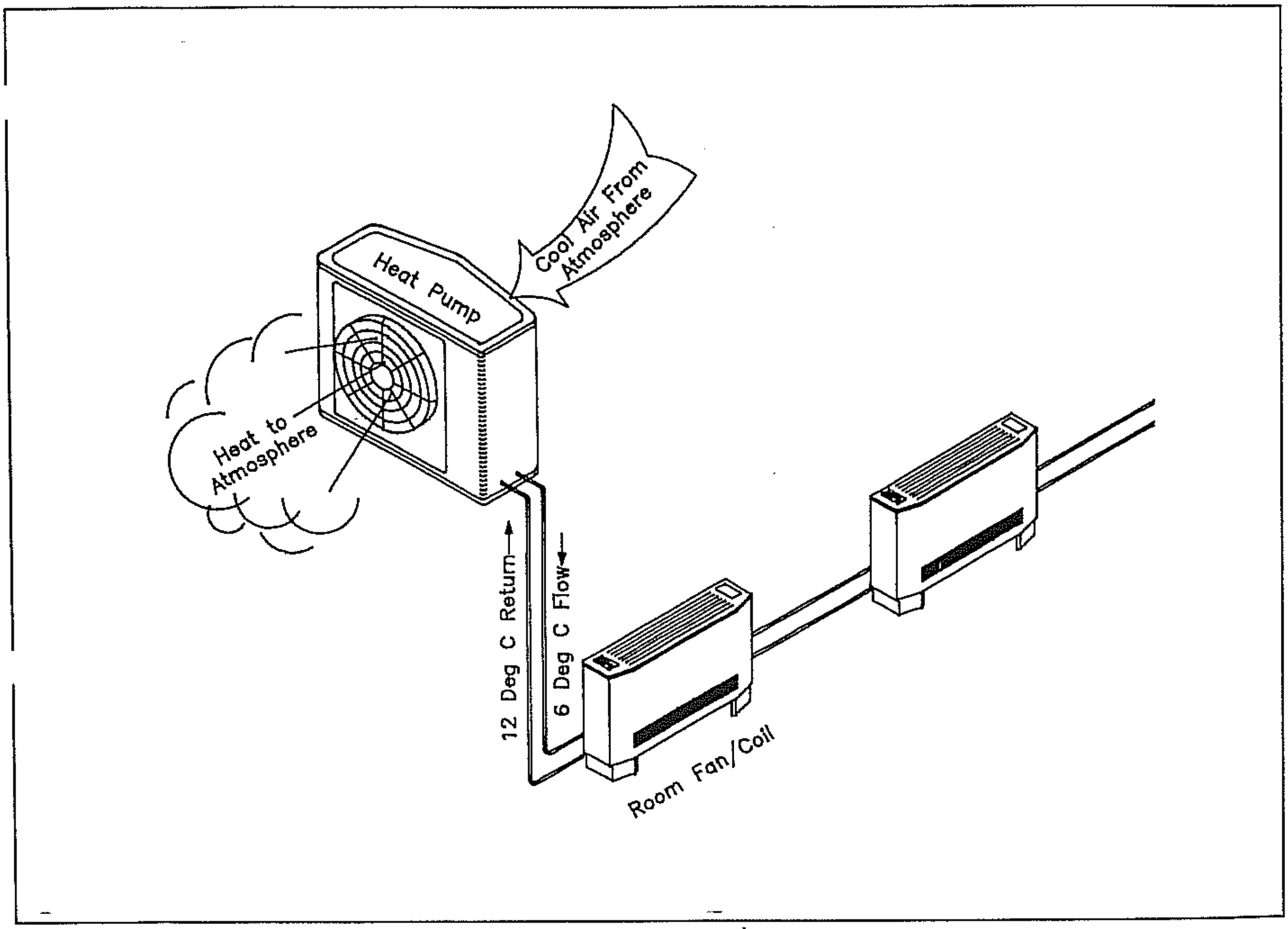


Fig. 1.14 - Two-pipe system - heat pump in cooling mode

When hydronic air-to-water heat pumps operate in heating mode they extract heat from the atmosphere and discharge it via fan coil units into the occupied spaces. Therefore, when outdoor conditions are cold and not much heat is available to be extracted from the atmosphere by the heat pump its ability to provide heat falls off. One way around this problem is to provide the fan coil units with electric heaters to boost the air supplied to the occupied spaces. However, despite the fall off in heating capacity suffered by heat pumps at low ambient conditions, they remain a very cost effective way of providing heat to a building, especially when combined with other forms of heating.

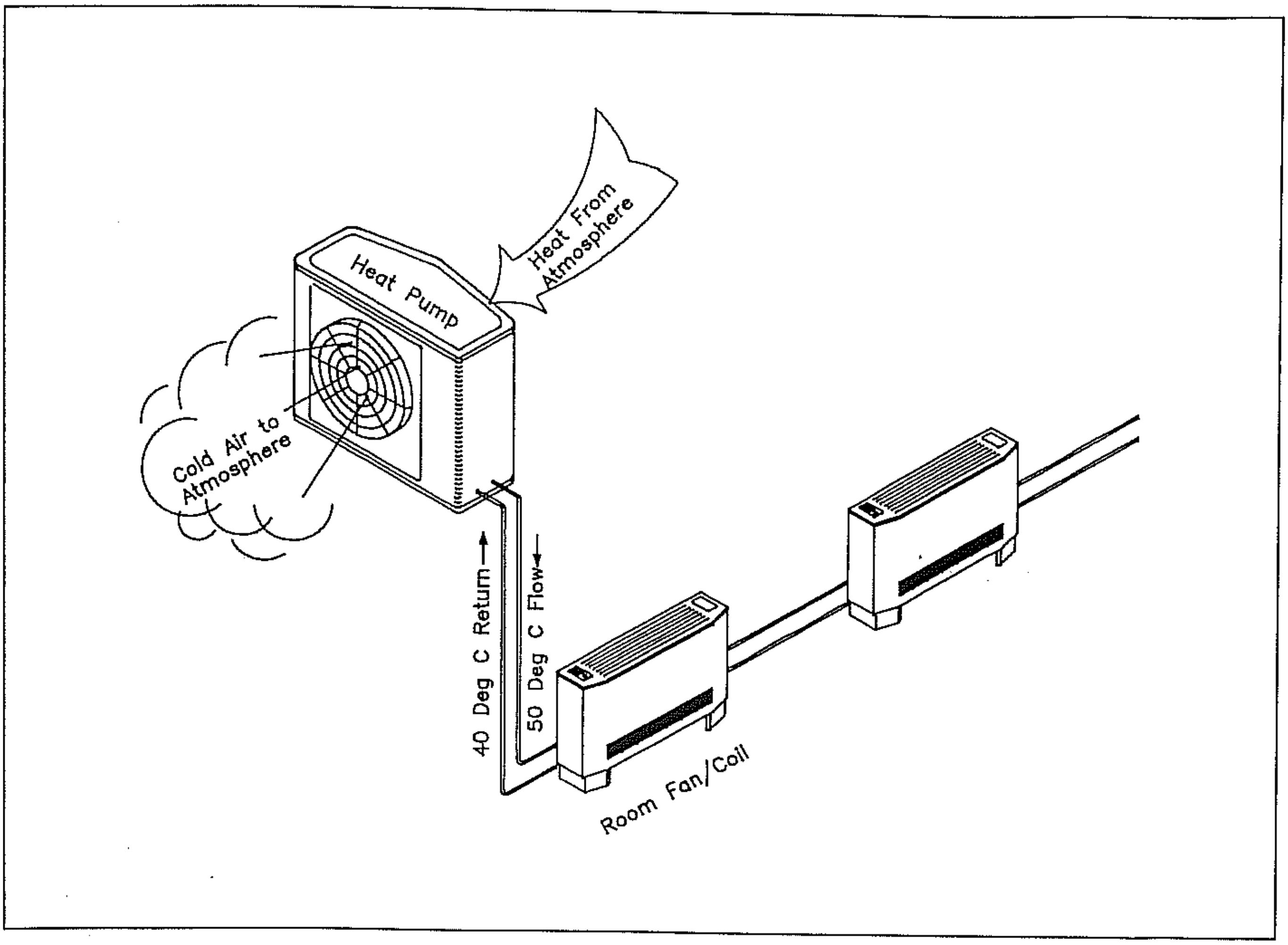


Fig. 1.15 - Two-pipe system - heat pump in heating mode

1.4.4 Two-pipe system - heat pump or boiler

One way around the problem of reduced heating capacity from a heat pump during cold spells is to increase the size of the heat pump. However, this is not cost effective as the unit is then oversized when operating in cooling mode. It is therefore common practice to select heat pumps to satisfy the building cooling load and provide an additional means of providing extra heat from a boiler during very cold weather.

Fig. 1.16 shows a heat pump which would provide water at 50°C. During periods when the heat pump cannot cope and the supply water temperature falls below 50°C, the system controls switch off the heat pump and bring in a boiler. However, it is important to note that the boiler must be selected to supply water at the same temperature as the heat pump so as to prevent high temperature water from the boiler entering the heat pump and causing its safety controls to cut out. Note that heat pumps cannot provide water much above 50°C.

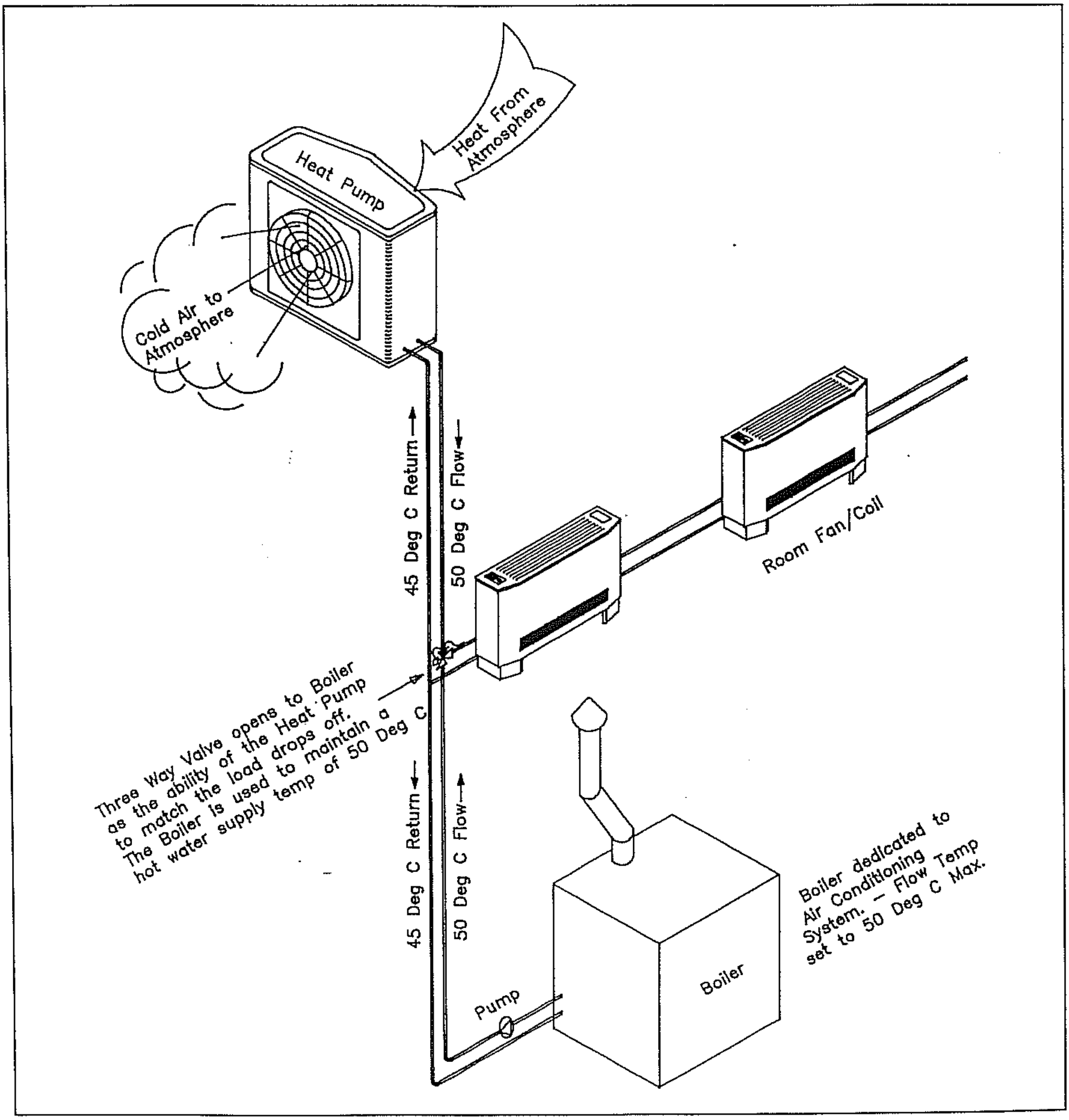


Fig. 1.16 - Two-pipe system - heat pump or boiler

1.4.5 Two-pipe system - heat pump with boiler boost

The system described on the previous page works well but suffers from the disadvantage of not making full use of the energy efficiency of the heat pump. Even in periods of cold weather, heat pumps still continue to extract heat at economical rates from the atmosphere. A way to make best use of this heat is to use a boiler to top up or boost the temperature of the low grade water provided by the heat pump.

In the system shown in Fig. 1.17 a heat pump and associated fan coils are selected based on a supply water temperature of 50°C, and the heat pump would satisfy the needs of the fan coils for the greater part of the heating season. At times when the supply water temperature from the heat pump falls below 50°C, a heat exchanger working with high grade hot water from a boiler provides the short fall. Note that even at conditions of 0°C outside ambient most hydronic air-to-water heat pumps will provide 2 kW of heat for every 1 kW of electrical input, and are thus still a viable source of cheap heat.

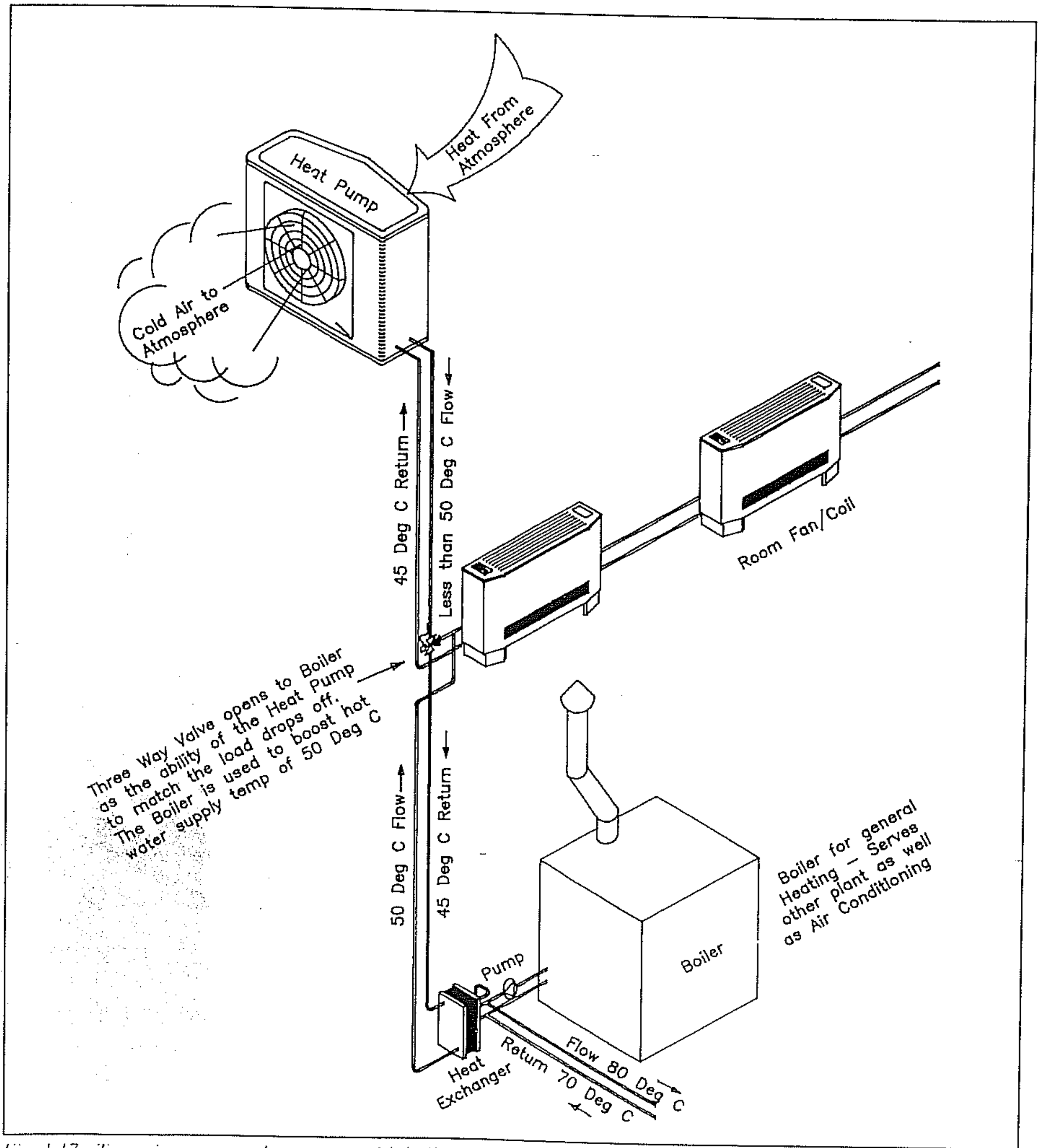


Fig. 1.17 - Two-pipe system - heat pump with boiler boost

1.4.6 Four-pipe system - chiller with boiler

The obvious advantage of two pipe systems is the low installation costs of pipework. However, they suffer from the disadvantage of having to be zoned very carefully. All fan coil units must require either heating or cooling at the same time. If the system cannot be easily zoned and units on a common system are likely to be simultaneously calling for both heating and cooling, a four-pipe system should be used. In this way a permanent source of both heating and cooling is provided to any fan coil unit which can in turn respond with cooling or heating to the occupied space. Each fan coil is provided with a separate heating and cooling coil which, via appropriate valves, responds to the demands of the individual room thermostats. See Fig. 1.18.

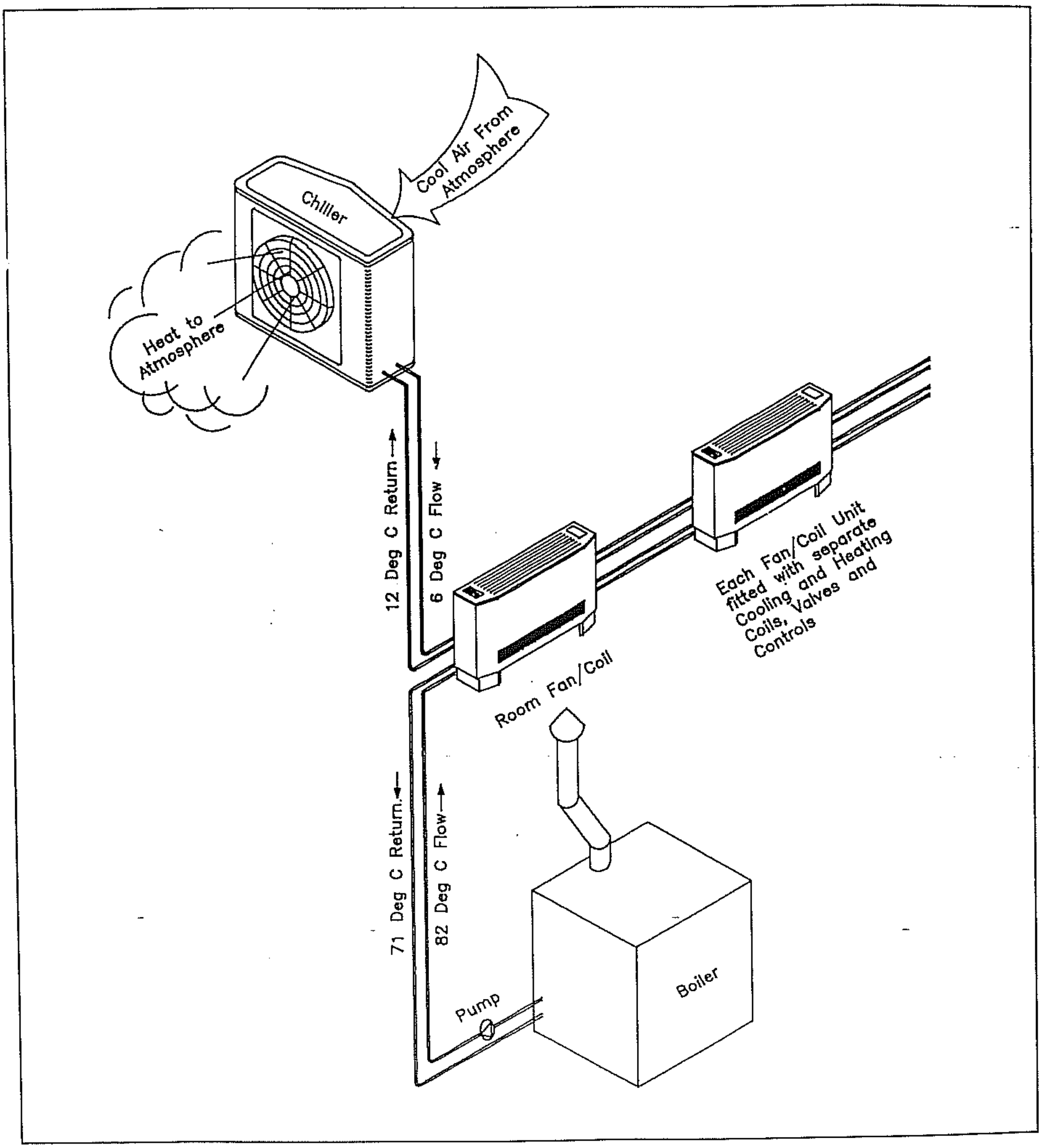


Fig. 1.18 - Four-pipe system - chiller and boiler

SECTION 2 - UNIT OPERATION

2.1 Hydronic Chillers

A hydronic chiller is an air-cooled package chiller comprising six major components.

* Circulating water pump with fill and pressurisation system
* Water-to-refrigerant heat exchanger or "evaporator"
* Refrigerant compressor
* Refrigerant-to-air heat exchanger or condenser
* Condenser fan and motor
* Electrical controls and safety devices

Hot high pressure refrigerant gas from the compressor at approximately 77°C is piped to the air-cooled condenser coil where relatively cool outside air provided by the condenser fan (normal UK summer outside air is taken as 30°C maximum) causes the hot refrigerant gas to condense into a liquid at approximately 42°C, thus giving up large amounts of latent heat plus a considerable amount of sensible heat. This heat is discharged into the atmosphere.

Cool liquid refrigerant at approximately 42°C then passes through a thermodynamic expansion valve where it is exposed to low pressure provided by the suction side of the compressor. This low pressure causes the liquid refrigerant to evaporate into a low pressure gas. The process of changing from a liquid to a gas absorbs a large amount of heat. The only place where this heat can come from is the water being pumped through the evaporator. Thus the water being circulated through the hydronic system is cooled from approximately 10°C to 5°C. See Fig. 2.1

Low temperature, low pressure refrigerant gas called "suction gas" is then returned to the compressor and the process is repeated over and over again. See Appendix A for a detailed description of the refrigeration process.

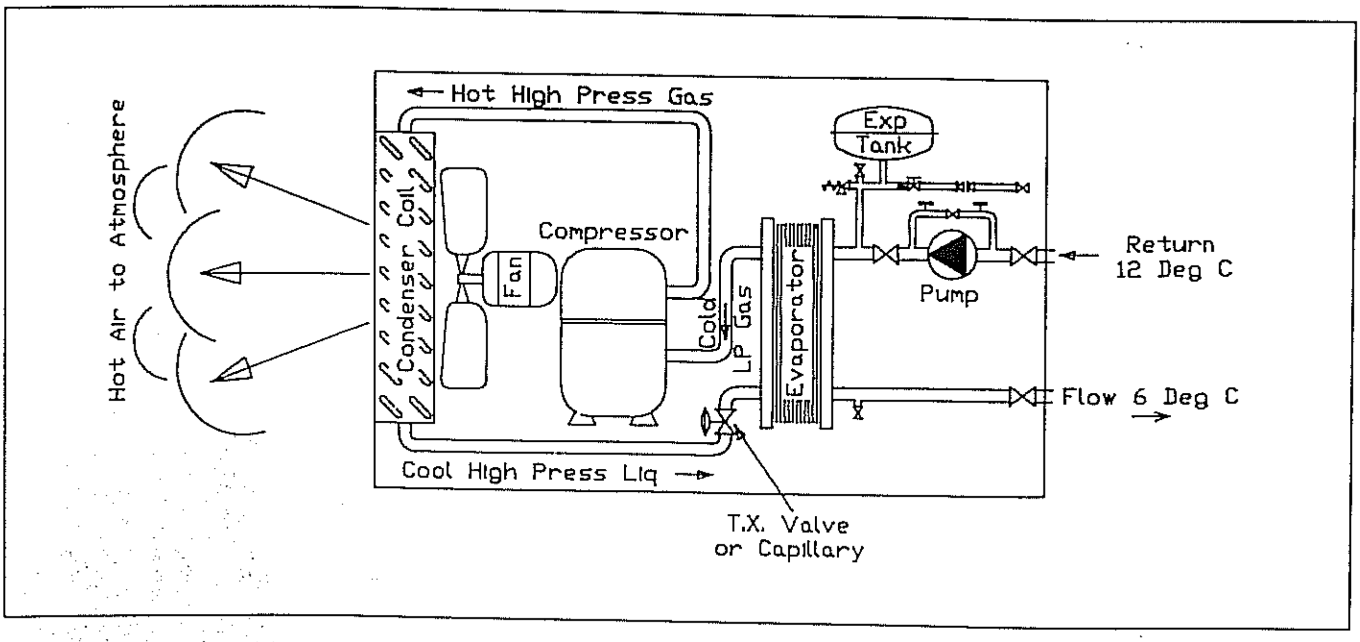


Fig. 2.1 - Hydronic chiller

2.2 Hydronic Heat Pumps

Hydronic heat pumps are similar to hydronic chillers but with the addition of a 4-way reversing valve situated in the refrigerant pipework at the compressor discharge. In cooling mode, a hydronic heat pump works in exactly the same way as a conventional chiller with the refrigerant-to-air heat exchanger acting as a condenser and the water-to-refrigerant heat exchanger acting as an evaporator. See Fig. 2.2.

In heating mode the solenoid operated 4-way mixing valve diverts hot gas to the refrigerant to water heat exchanger which now becomes a condenser and exhausts heat into the water circulating through the Hydroflow system. At the same time liquid refrigerant from the condenser, now flowing in the opposite direction, expands in the refrigerant to air heat exchanger which now acts as an evaporator cooling the outside ambient air and thus extracting heat from atmosphere. See Fig. 2.3.

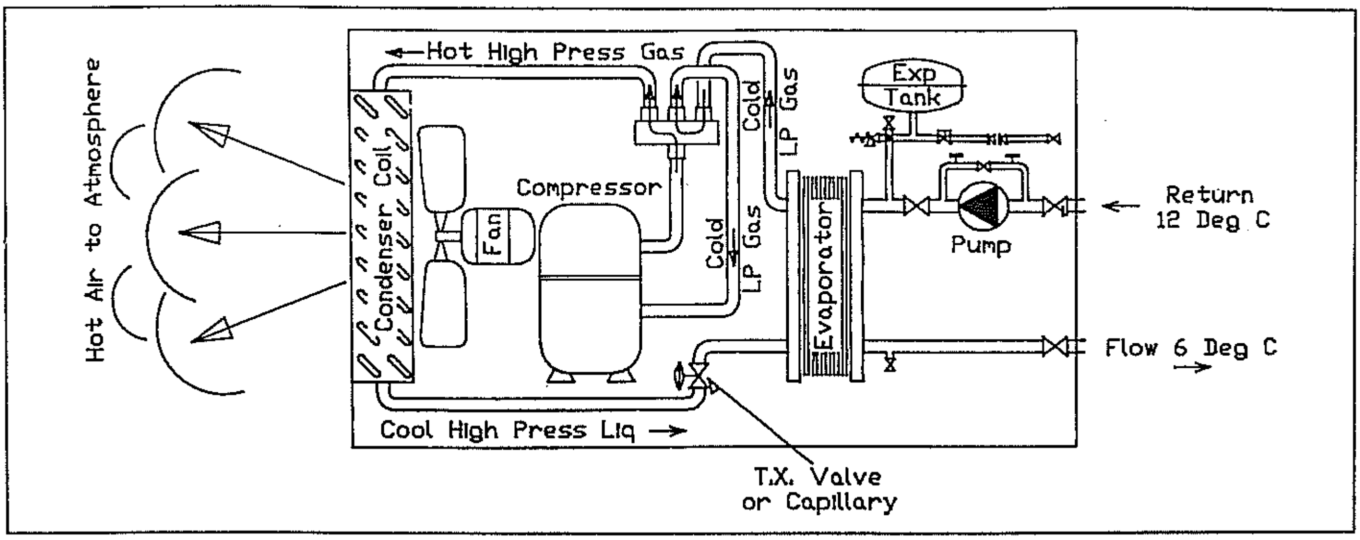


Fig. 2.2 - Hydronic heat pump in cooling mode

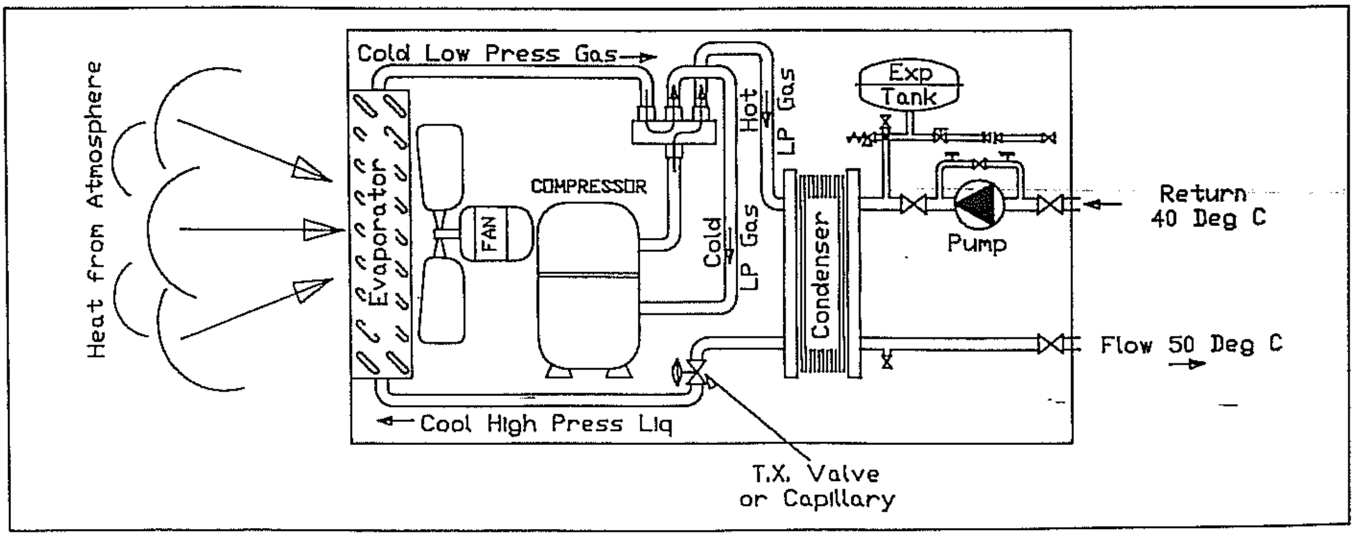


Fig. 2.3 - Hydronic heat pump in heating mode

SECTION 3 - LOAD ESTIMATING

3.1 Computerised Load Estimating

This section illustrates a method of calculating the cooling and heating loads for hydronic systems. A number of books are available describing in detail the laborious calculations involved in arriving at cooling and heating loads. Fortunately, Carrier can provide a number of computer programs ranging from the very sophisticated to the straightforward which enable the air conditioning design engineer to quickly and easily arrive at actual figures on which to base calculations and equipment selections. For hydronic system design we would recommend Carrier's "Block Load Lite" load estimating program. This program, complete with computer, keyboard, monitor and printer can be purchased by Carrier dealers from Carrier at reduced price, along with the program manual.

The 'Block Load Lite' program proceeds in a number of easy steps:

1. Selects weather data from a data base covering many countries and cities worldwide including ten UK cities. (This weather data can be modified by the user if necessary.)
2. Enters general data pertaining to the building being studied - occupancy hours, ventilation rate, room conditions, etc.
3. Enters data pertinent to each room within the building - room size, orientation, internal loads, etc.
4. Enters details of walls and windows, U factors, areas, etc.
5. Computer calculates cooling and heating loads for room being studied and provides a hard copy print out.
6. Steps 3 to 5 repeated for all other rooms.
7. Steps 3 to 5 repeated for building as a whole to establish the overall building diversified load.

Space Loads
Before calculating cooling and heating loads the building should be surveyed and the data required by the computer entered on input sheets similar to those shown below.

HVAC SYSTEM INPUT SHEET - S.I. METRIC UNITS
PAGE 1 OF 3

GENERAL SYSTEM DATA
System Name : ____________
System Type : ____________
System Start : ____________
Duration : ____________ hrs

SIZING SPECIFICATIONS
Supply : ____________
Ventilation : ____________
Direct Exhaust : ____________
Hot Water Delta-T : ____________K

FAN
Configuration : Draw-Thru Blow-Thru
Static, BHP, or kW: ____________

THERMOSTAT SETPOINTS
Cooling (Occupied) : ______C
Cooling (Unoccupied) : ______C
Heating : ______C

FACTORS
Cooling Coil Bypass : ______
Safety (Sensible) : ______%
Safety (Latent) : ______%
Heating Safety : ______%

RETURN AIR PLENUM ? Yes No
% Roof Load : ______%
% Lighting Load : ______%
% Wall Load : ______%

KEY:

System Types:
1. Cooling & Warm Air Heating
2. Cooling & Hydronic Heating
3. Cooling & Electric Heating
4. Cooling Only
5. Warm Air Heating Only
6. Hydronic Heating Only
7. Electric Heating Only

Supply Air Options:
1. L/s/sqm
2. L/s
3. Supply Temp (C)

Direct Exhaust Options:
1. L/s
2. % of Ventilation Air

Ventilation Air Options:
1. L/s/sqm
2. L/s
3. % of Supply Air
4. L/s/person

ZONE INPUT SHEET - SINGLE CONSTRUCTION TYPE - S.I. METRIC UNITS
PAGE 2 OF 3

ZONE NAME :

GENERAL ZONE DATA			PEOPLE		
Floor Area	:	sqm	sqm/person	:	sqm/person
Building Weight	:	kg/sqm	or Total People	:	People
Exposures	:		Unocc Diversity	:	%
Are Multiple			Activity Level	: 1 2 3 4 5 6	
..Wall,			Sensible Gain	:	W/person
..Roof,			Latent Gain	:	W/person
..or Glass			MISCELLANEOUS LOADS		
..Types Used	?	NO	Sensible	:	W
No. Partitions	:		Latent	:	W
LIGHTING			Unocc Diversity	:	%
Watts/sqm	:	W/sqm	INFILTRATION		
or Total Watts	:	Watts	Cooling L/s/sqm	:	L/s/sqm
Unocc Diversity	:	%	or Cooling L/s	:	L/s
Wattage Mult.	:		Heating L/s/sqm	:	L/s/sqm
Fixture Type	:		or Heating L/s	:	L/s
OTHER ELECTRIC			SLAB		
Watts/sqm	:	W/sqm	Area	:	sqm
or Total Watts	:	Watts	Perimeter	:	m
Unocc Diversity	:	%	Depth	:	m

KEY:

People Activity Levels:
1. Seated at Rest..(67.4-S/ 35.2-L)
2. Office Work.....(71.8-S/ 60.1-L)
3. Sedentary Work..(82.1-S/ 79.1-L)
4. Medium Work.....(86.5-S/133.4-L)
5. Heavy Work......(153.9-S/271.1-L)
6. User-Defined

Lighting Fixture Types:
1. Recessed, not vented
2. Recessed, vented
3. Free Hanging

ZONE INPUT SHEET - SINGLE CONSTRUCTION TYPE - S.I. METRIC UNITS
PAGE 3 OF 3

ZONE NAME :

WALL, ROOF & GLASS DATA

Item	WALL	ROOF	GLASS	
U-Value (W/sqm/K)			U-Value	
Weight (kg/sqm)			Glass Factor	
Color	L M D	L M D	Internal Shades ?	Yes No

EXTERNAL SHADING DATA					
Window Height	=	m	Overhang Height	=	mm
Window Width	=	m	Overhang Extension	=	mm
Reveal Depth	=	mm	Fin Separation	=	mm
			Fin Extension	=	mm

WALL EXPOSURE	Gross Area (sqm)	Glass Area (sqm)	WALL/ROOF EXPOSURE	Gross Area (sqm)	Glass Area (sqm)
NE Wall			W Wall		
E Wall			NW Wall		
SE Wall			N Wall		
S Wall			Roof (Horiz)		
SW Wall					

PARTITION DATA	Partition 1	Partition 2	Partition 3
Net Area (sqm)			
U-Value (W/sqm/K)			
Adj. Region Temp (Cooling) (C or %)			
Adj. Region Temp (Heating) (C or %)			

The building shown in Fig. 3.1 is an example of an application that could easily be air conditioned using a Hydroflow system. It is a single-storey building with solid brick walls and a pitched roof having 100 mm of loft insulation. Windows are double glazed using reflective glass.

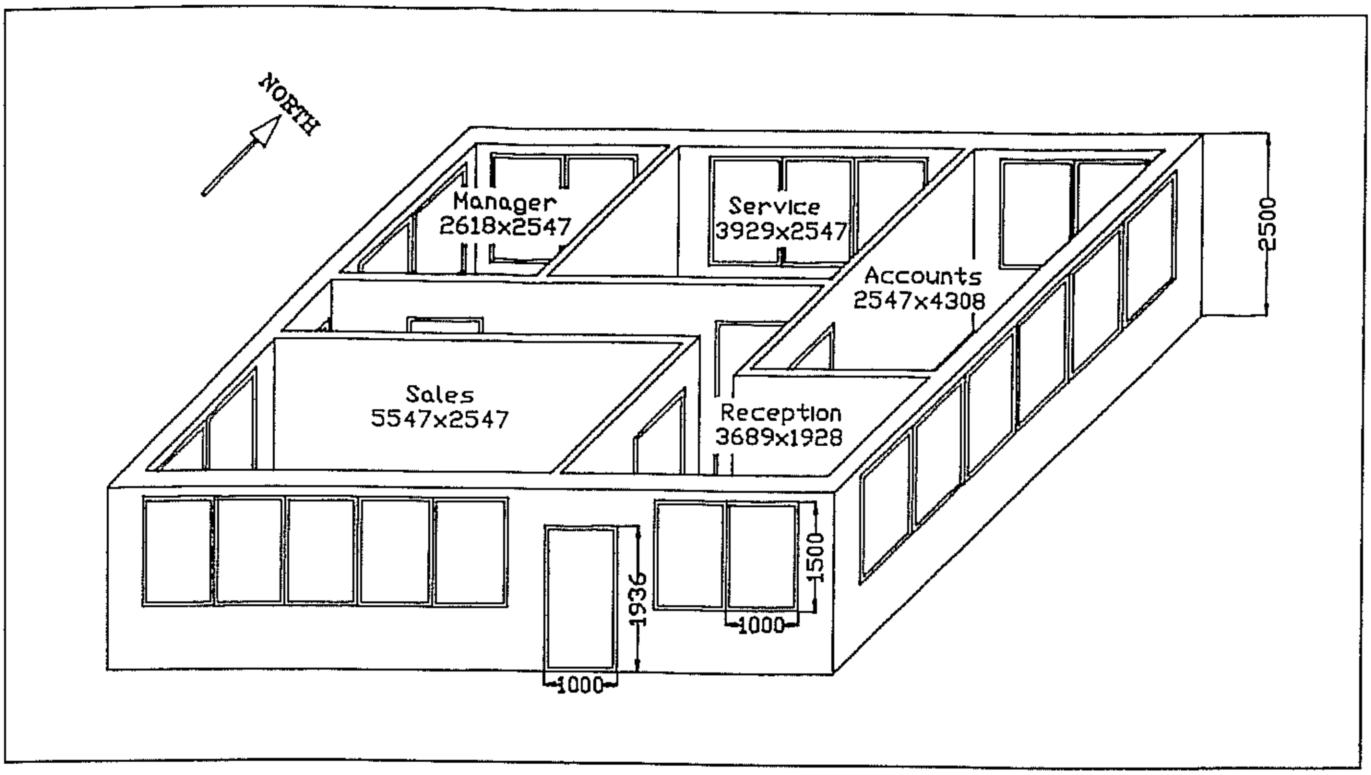


Fig. 3.1 - Sample building

Having selected weather data applicable to London, the program is instructed to calculate peak cooling and heating loads for each office within the building. See Fig. 3.2.

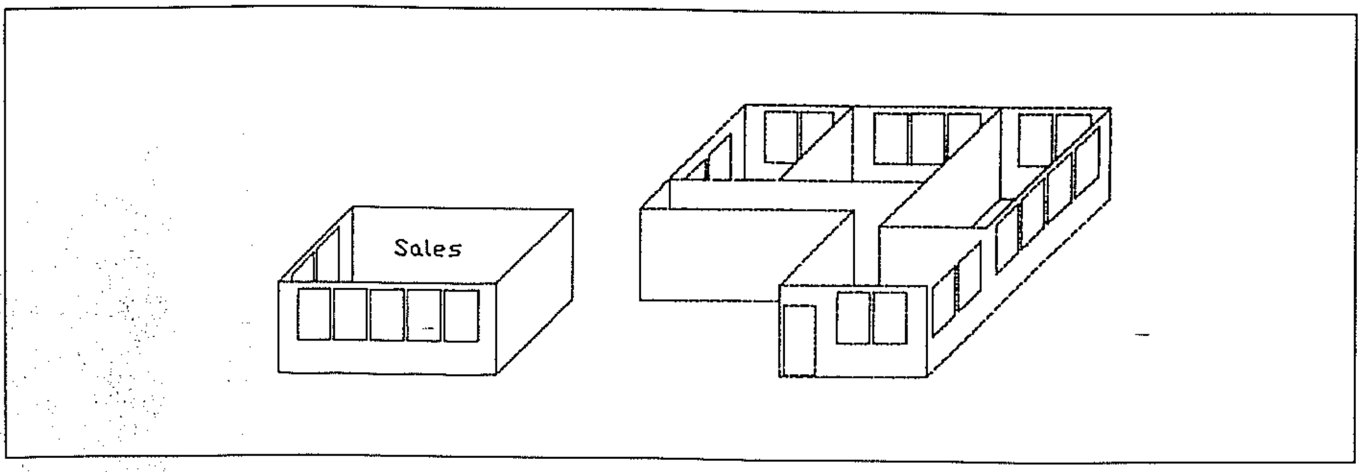


Fig. 3.2 - Sales office

Fig. 3.3 entitled "Building Sizing Summary" is the print out obtained for the Sales Office. The first part of the print out "Table 1" is the weather data for London. "Table 2" is a summary of the input data for the building as a whole. "Table 3" is a detailed list of output cooling data relating to the Sales Office and "Table 4" is a detailed list of output heating data for the Sales Office.

```
                BUILDING SIZING SUMMARY
Building Name : SALES OFFICE                                  23-12-93
Location      : London, United Kingdom            Block Load Lite v1.00
Prepared By : Carrier Air Conditioning                       Page 1 of 1
*************************************************************************

TABLE 1. INPUT DATA -- WEATHER
-------------------------------------------------------------------------
City           = London                       Summer dry-bulb     =  27.9 C
State          = United Kingdom               Coincident wet-bulb=   19.0 C
Data Source    = Original Data                Daily Range         =   8.9 K
Latitude       =    51.5 deg.                 Winter dry-bulb     =  -4.0 C
Elevation      =     5.0 m                    Atmos. Clear. Num.  =  1.00
-------------------------------------------------------------------------

TABLE 2. INPUT DATA -- BUILDING
-------------------------------------------------------------------------
System Type         : Clg & Hydronic Htg        THERMOSTAT SETPOINTS
System Start        :        800                  Cooling (Occ)     :   21.0 C
Duration            :         10 hrs              Cooling (Unocc)   :      N
                                                  Heating           :   20.0 C
SIZING SPECIFICATIONS                           FACTORS
  Supply            :       12.0 C                Coil Bypass       :  0.200
  Ventilation       :      10.00 L/s/person       Safety (Sens)     :      0 %
  Exhaust           :          0 L/s              Safety (Latent)   :      0 %
  Delta-T           :       10.0 K                Heating Safety    :      0 %
FAN                                             RETURN AIR PLENUM   :      N
  Configuration     : Blow-Thru
  Static Pressure   :       0.00 Pa.
-------------------------------------------------------------------------

TABLE 3. SIZING DATA -- COOLING
-------------------------------------------------------------------------
Total coil load      =    3,719 W       Load occurs        @      Oct 1400
Sensible coil load   =    3,387 W       Outdoor Db/Wb      = 25.2/ 17.5 C
Total sensible       =    3,236 W       Coil Conditions:
Supply temperature   =     12.0 C         Entering Db/Wb   = 21.4/ 14.9 C
Supply air (actual)  =      298 L/s       Leaving Db/Wb    = 12.0/ 10.8 C
Supply air (std)     =      298 L/s       Apparatus dewpoint=        9.6 C
Ventilation air      =       30 L/s       Bypass factor    =       0.200
Direct exhaust air   =        0 L/s     Resulting RH       =        50.2 %
Reheat required      =        0 W

 Floor area (sqm )      =        14   Total coil load      =     3.72 kW
 Overall U-value        =     1.424   Sensible coil load   =     3.39 kW
 Vent air L/s/sqm       =      2.12   SQM/kW               =     3.80
 Vent air L/s/person    =     10.00   Cooling    W/sqm     =   263.21
                                      Cooling L/s/sqm      =    21.09
-------------------------------------------------------------------------

TABLE 4. SIZING DATA -- HEATING
-------------------------------------------------------------------------
Heating coil load    =    2,561 W        Heating    W/sqm      =   181.27
Ventilation load     =      869 W        Heating L/s/sqm       =     0.02
Total load           =    1,692 W        Floor area (sqm )     =       14
Ventilation airflow=         30 L/s      Overall U-value       =    1.424
Water flow           =     0.04 L/s      Vent air L/s/sqm      =     2.12
Preheat water flow   =     0.02 L/s      Vent air L/s/person   =    10.00
Hot water delta-T    =     10.0 K
-------------------------------------------------------------------------
*************************************************************************
```

Fig. 3.3 - "Building Sizing Summary" print out

Fig. 3.4 entitled "Detailed Building Load Report" is the second page of the print out for the Sales Office. "Table 1" is a breakdown of the individual components of the heating and cooling loads, enabling the design engineer to identify areas of excess load and take remedial action if necessary. "Table 2" breaks down even further the cooling load and heating load through walls and windows.

DETAILED BUILDING LOAD REPORT

Building Name : SALES OFFICE — 23-12-93
Location : London, United Kingdom — Block Load Lite v1.00
Prepared By : Carrier Air Conditioning — Page 1 of 1

TABLE 1. LOAD COMPONENT SUMMARY for Oct 1400 (25.2/ 17.5 C)

Load Component	Details	Design Cooling Loads Sensible (W)	Latent (W)	Design Heating (W)
Solar Loads	11 sqm	2,380	-	-
Wall Transmission	10 sqm	136	-	352
Roof Transmission	14 sqm	75	-	119
Glass Transmission	11 sqm	76	-	706
Skylight Transmission	0 sqm	0	-	0
Partitions	0 sqm	0	-	0
Lighting	20.00 W/sqm	273	-	-
Other Electric	10.00 W/sqm	124	-	-
People	3 people	155	180	-
Infiltration		13	12	78
Miscellaneous		0	0	-
Slab	14 sqm	-	-	439
Pulldown/Warm-up		4	-	-
Safety Factor	0/ 0/ 0 %	0	0	0
Total Loads		3,236	193	1,692
Ventilation Load	30 L/s	151	139	869
Supply Fan Load	298 L/s	0	-	-
Plenum Load Thru Wall	0 %	0	-	-
Plenum Load Thru Roof	0 %	0	-	-
Plenum Load - Lights	0 %	0	-	-
Reheat Load		0	-	-
Total Coil Loads		3,387	332	2,561

TABLE 2. WALL AND GLASS BREAKDOWN

Component		Total Net Area (sqm)	Cooling Transmission (W)	Cooling Solar Load (W)	Heating Transmission (W)
Walls	: NE	0	0	-	0
	E	0	0	-	0
	SE	0	0	-	0
	S	6	131	-	229
	SW	0	0	-	0
	W	3	4	-	122
	NW	0	0	-	0
	N	0	0	-	0
Glass	: NE	0	0	0	0
	E	0	0	0	0
	SE	0	0	0	0
	S	7	54	2,006	504
	SW	0	0	0	0
	W	3	22	374	202
	NW	0	0	0	0
	N	0	0	0	0
	Hor	0	0	0	0

Fig. 3.4 - "Detailed Building Load Report" print out

In a similar fashion a print out for the Manager's Office, Service Department, Accounts Department and Reception Area are secured and used to select the appropriate fan coil units on an office by office basis.

Area	Total Cooling Load kW	Cooling Load Peaks at	Total Heating Load kW
Sales	3.719	Oct. 14.00 hours	2.561
Manager	1.752	June 17.00 hours	1.073
Service	1.272	June 15.00 hours	1.264
Accounts	3.906	June 08.00 hours	2.410
Reception	1.788	June 08.00 hours	1.105
	12.437		8.413

Diversified Load

From the table above listing individual room loads it can be seen that, due to their orientation relative to the sun, the various rooms have peak cooling loads occurring at different times of the year and at varying times of the day. Thus the total cooling load for the building as a whole is less than the sum of the peak cooling loads for each room. For this reason the "Block Load Lite" program is used again to look at the total building to establish the size of hydronic chiller or heat pump required. See Fig. 3.5 entitled "Diversified Load".

```
                    BUILDING SIZING SUMMARY
Building Name :DIVERSIFIED LOAD                              23-12-93
Location      : London, United Kingdom             Block Load Lite v1.00
Prepared By : Carrier Air Conditioning                     Page 1 of 1
**********************************************************************

TABLE 1. INPUT DATA -- WEATHER
----------------------------------------------------------------------
City           = London                   Summer dry-bulb    =  27.9 C
State          = United Kingdom           Coincident wet-bulb=  19.0 C
Data Source    = Original Data            Daily Range        =   8.9 K
Latitude       =    51.5 deg.             Winter dry-bulb    =  -4.0 C
Elevation      =     5.0 m                Atmos. Clear. Num. =  1.00
----------------------------------------------------------------------

TABLE 2. INPUT DATA -- BUILDING
----------------------------------------------------------------------
System Type          : Clg & Hydronic Htg      THERMOSTAT SETPOINTS
System Start         :        800                Cooling (Occ)   :   21.0 C
Duration             :         10 hrs            Cooling (Unocc) :      N
                                                 Heating         :   20.0 C
SIZING SPECIFICATIONS                          FACTORS
  Supply             :       12.0 C              Coil Bypass     :  0.200
  Ventilation        :      10.00 L/s/person     Safety (Sens)   :      0 %
  Exhaust            :          0 L/s            Safety (Latent) :      0 %
  Delta-T            :       10.0 K              Heating Safety  :      0 %
FAN                                            RETURN AIR PLENUM :      N
  Configuration      : Blow-Thru
  Static Pressure :          0.00 Pa.
----------------------------------------------------------------------

TABLE 3. SIZING DATA -- COOLING
----------------------------------------------------------------------
Total coil load      =    10,851 W      Load occurs         @      Aug 1500
Sensible coil load =       9,391 W      Outdoor Db/Wb       = 27.9/ 19.0 C
Total sensible       =     8,469 W      Coil Conditions:
Supply temperature =        12.0 C        Entering Db/Wb    = 22.0/ 15.4 C
Supply air (actual)=         780 L/s      Leaving Db/Wb     = 12.0/ 10.8 C
Supply air (std)     =       780 L/s      Apparatus dewpoint=        9.5 C
Ventilation air      =       110 L/s      Bypass factor     =     0.200
Direct exhaust air =           0 L/s    Resulting RH        =       50.8 %
Reheat required      =         0 W

  Floor area (sqm )       =          70  Total coil load        =    10.85 kW
  Overall U-value         =       1.283  Sensible coil load     =     9.39 kW
  Vent air L/s/sqm        =        1.57  SQM/kW                 =     6.45
  Vent air L/s/person     =       10.00  Cooling    W/sqm       =   155.02
                                         Cooling L/s/sqm        =    11.14
----------------------------------------------------------------------

TABLE 4. SIZING DATA -- HEATING
----------------------------------------------------------------------
Heating coil load    =     9,272 W         Heating    W/sqm        =   132.45
Ventilation load     =     3,185 W         Heating L/s/sqm         =     0.02
Total load           =     6,087 W         Floor area (sqm )       =       70
Ventilation airflow=         110 L/s       Overall U-value         =    1.283
Water flow           =      0.15 L/s       Vent air L/s/sqm        =     1.57
Preheat water flow =        0.08 L/s       Vent air L/s/person =       10.00
Hot water delta-T           10.0 K
----------------------------------------------------------------------
```

Fig. 3.5 - "Building Sizing Summary" for whole building - diversified load

From the diversified load calculations the total cooling load for the hydronic chiller/heat pump is calculated to be 10.851 kW compared with the sum of individual peak room loads of 12.637 kW. Note that the total heating load obtained from the diversified load calculations at 9.272 is bigger than the sum of the individual room heating loads. This is because the diversified calculation has taken the corridors into account, whereas the corridors were omitted from the individual room by room calculations. (Note: diversity is not taken into account for heating load calculations!)

General

It should be appreciated that the above is an illustration of the way to go about establishing hydronic cooling and heating loads and probably raises more questions that it gives answers. For this reason, Carrier holds regular training seminars for hydronic installers where these matters are gone into in detail and students are given examples to work out under the supervision of a tutor. Training seminars for Carrier's E20-II computerised programs are free of charge to licensed users and approved hydronics installers.

SECTION 4 - WATER PIPING SYSTEMS AND PUMPS

4.1 Introduction

In hydronic air conditioning work, water is used to carry heat from the point of generation, such as a cooling coil, to the point where it can be rejected to the refrigerant in a water chiller. The water is recirculated so that the pick up and rejection of heat is a continuous process.

The piping and pumping systems used to transport the water to and from the various heat exchangers are usually relatively simple and straightforward, and are complete in themselves, i.e. they do not function as part of a bigger piping network. The water is usually at temperatures between 5°C and 10°C in summer and 40°C and 50°C in winter, although four-pipe systems may use hot water at 70°C to 80°C in winter. The motive force for circulating the water through the piping system is almost invariably supplied by a centrifugal pump.

This part of the manual will review overall design considerations, with emphasis on those points which are considered especially applicable to the piping and pumps used in hydronic air conditioning work.

Formula
The basic and most important formula to remember is:

$$M = \frac{Q}{C \times \Delta t}$$

Where:
M = The flow rate of water (l/s) or (kg/s)
Q = Cooling or heating capacity (kW)
C = The specific heat capacity of water (kJ/kg K)
Δt = Difference between flow and return temperature (K)

One litre of water is equal to one kilogram, so that l/s and kg/s of water are one and the same thing.

The specific heat capacity of water is 4.186 kJ/kg °C. That is, a heat input of 4.186 kilojoules is required to raise the temperature of 1 kilogram of water by 1°C.

Present design practice uses a chilled water temperature change of about 5 K. This value is assumed to result in reasonable economic balance among first cost, operating costs, and energy requirements. Higher temperature changes result in lower water flow rates, smaller pipe sizes, lower operating costs, and lower energy requirements. For instance, chilled water temperature changes of 10 K or more can be used without incurring any great problem in the selection of water chillers and water-cooled coils.

4.2 Types of Piping Systems

For hydronic air conditioning purpose, water piping systems can be classified as being of the closed recirculating type, where water is simply circulated through a closed system of piping and equipment, without coming in close contact with air.

Recirculating piping systems can be further classified as either direct return or reverse return. A direct return system is illustrated in Fig. 4.1. The same units are shown on the right piped with a reverse return system.

If the pressure drops, though the units are identical, then in the case of the direct return system, each of the first five units will require a balancing valve as a means to measure flow plus balancing time to ensure the same flow through all units. In the reverse return system, however, the pressure difference from supply line through the unit to return line is the same for all units. Each unit will, therefore, take an equal share of the total flow and no balancing is required. The cost of the extra length of return pipe is probably less than the cost of valves and balancing, and much time and trouble will be saved. A reversed return should always be used in a multi-room system which uses a large number of identical units.

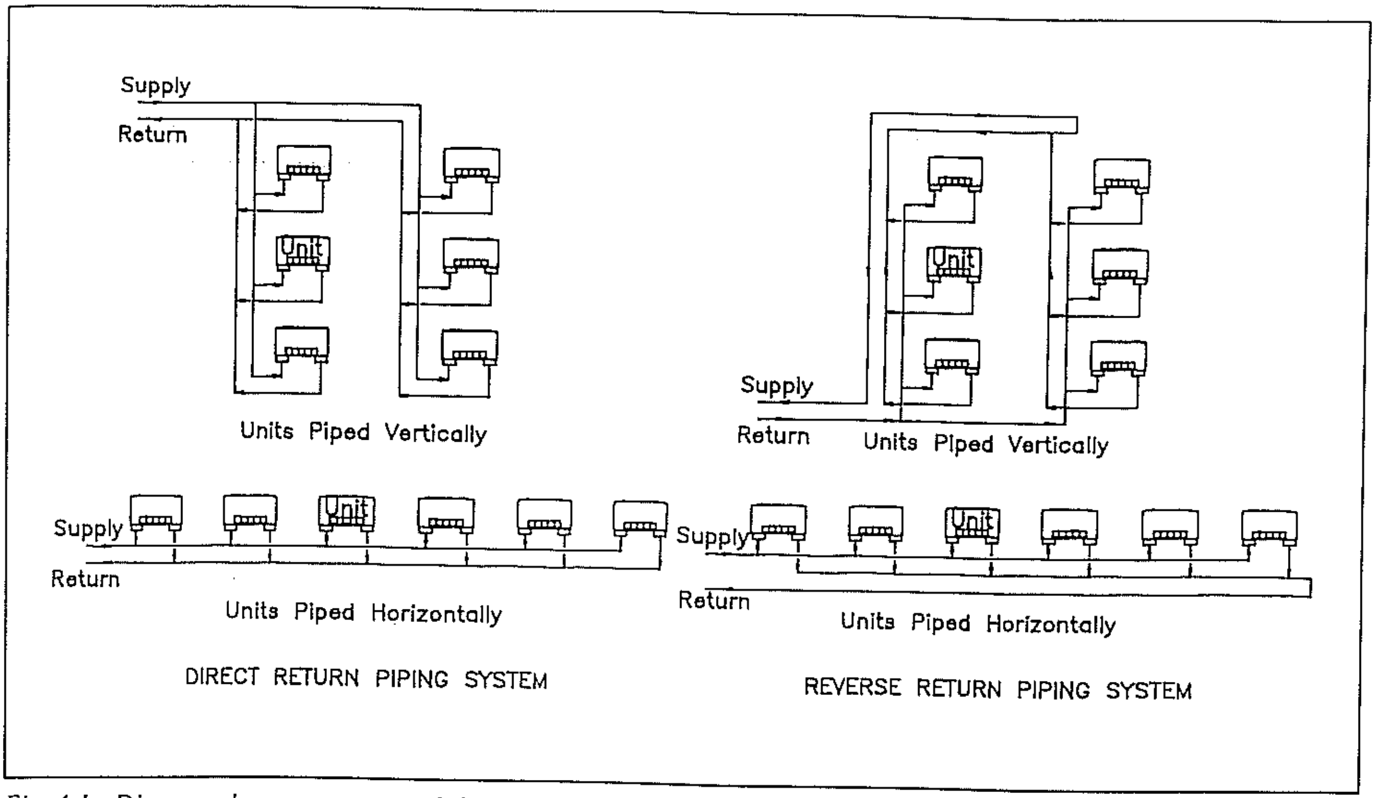


Fig. 4.1 - Direct and reverse return piping

4.3 General Considerations

Water piping systems should be as direct and uncomplicated as possible. Offsets, bends, and changes in elevation should be kept to a minimum. Any fitting or valve that is omitted, represents a reduction in first cost, operating cost and maintenance cost.

Hydronic pipework, especially two-pipe systems, is subjected to temperature changes ranging from 6°C to 50°C and is therefore subject to expansion and contraction. Pipework supports should be located in such a way as to allow for this, and 'U' bends should be installed in long lengths of straight pipe run.

On the other hand, cooling coils, control valves and pumps will eventually require repair or servicing. All of these operations must be preceded by draining the water out of the equipment involved. It is convenient and economical to be able to isolate such parts by means of shut off or isolating valves so that the entire system does not have to be drained and refilled. It may also be important that any piece of equipment can be isolated and worked on while the remainder of the system continues to operate normally. In addition to shut off valves, unions are required at strategic locations so that the piping can be easily dismantled for the possible removal of such things as coils, and control valves. Judgement and imagination are needed to balance convenience in servicing against first cost and maintenance cost of the system.

4.4 Equipment Selection

The main chilling plant and the individual fan coil units are selected using Carrier Product Data Digests to match the heat gains and heat losses. In the case of the room fan coil units, these will be selected to match the maximum gain or loss for the area in which the unit is mounted whilst maintaining a reasonable sound level (see section on sound). The main plant will have been selected to match the maximum collective gain or loss at any one time. Water flow rates for each item of plant are obtained from these Product Data Digests.

Remember when selecting units that even with well insulated pipework some heat gains or losses will occur in the distribution pipework and that the water arriving at the fan coil will always be slightly higher or lower (cooling and heating) than that leaving the main plant. In practice this rise or fall should not exceed 5% but the effect means that fan coil units should not be selected right on their limit of capacity.

4.5 Pipe Sizing

After a piping system has been laid out and the flow rate calculated it becomes necessary to size the pipe and determine the total resistance in the system so as to know what head the pump must work against.

Pipe size is limited by the maximum velocity permissible. The following table gives some recommended water velocity limits, based on noise considerations and the effect of water and entrained air wearing away or eroding the pipe.

Table I

Service	Velocity Range (m/s)
Pump Discharge	1.2 - 1.8
Pump Suction	0.6 - 1.0
Drain Line	0.6 - 1.0
Header	0.6 - 1.0
Riser	0.4 - 1.5
General Service	0.75 - 1.5
Mains Water	0.4 - 1.0

Erosion is, of course, increased with high velocity but it is also affected by the number of hours of operation per year. The following table gives some recommended velocity limits, which are based on experience and are designed to give a good balance between pipe size (or cost) and a reasonable life before the pipe is eroded away.

Table II

Normal Operation hour/year.	Water Velocity (m/s)
1500	2.3
2000	2.1
3000	2.0
4000	1.8
6000	1.5
8000	1.2

Pipe velocity may also be limited by the total pump head available or desirable. Note hydronic chillers are provided with a pump so the maximum pump head is a finite value which cannot be exceeded. In practice a good all round pipe velocity for hydronic pipework is 0.7 m/s.

Friction loss rate in pipes may be found from the graph shown in Fig. 4.2. These tables apply to new, smooth, clean standard weight pipe and can be used to determine the friction loss rate in a closed piping system, such as a chilled water recirculating system.

Copper tubing is normally used in Hydroflow systems and can be expected to stay clean throughout its normal life, so corrections for fouling are not normally made.

In a closed system, friction is the only loss or head which the pump has to overcome. The head of water on the suction side of the pump is always exactly equal to the height on the discharge side. The total head on the pump will consist of the following: pipe friction head, including entrance and exit losses; losses through fittings, valves, and accessories; pressure losses through equipment, such as coolers, cooling coils, etc.

Once plant has been selected and system laid out, the flow rates may be added back in order to determine the various pipe sizes within the system. The graph in Fig. 4.2 shows pressure drops between 10 and 7000 Pa/metre which will give reasonable practical pipe sizes and also will result in acceptable water velocities within the system.

4.6 Pump Selection

In order to select a circulating pump for a system it is necessary to know the total water quantity to be circulated and the circulating pressure required. The total water quantity will be easily determined from the individual unit selections.

The frictional resistance of the circuit will be mainly derived from the pressure drop through the chiller, the pressure drop through the furthest fan coil unit and the pressure drop through the selected control valve on the fan coil unit. The remainder of the frictional resistance is in the pipework distribution system. The longest (index) circuit within the system should be selected and measured for both flow and return travel. This is actual pipe length, plus the added equivalent length resistance for bends, branches, valves, etc., within that index run. When actual piping layouts have not been finalised, a rough estimate of equivalent length can be obtained by measuring the length of the circuit to the unit with the highest pressure drop and multiplying that length by a factor of 1.3. This factor then provides an allowance for the valves and fittings within the pipework. This method should be used as a guide only and a full hydraulic calculation should eventually be carried out.

See Figs. 4.3, 4.4 and 4.5 for equivalent length of common pipe fittings (screwed, flare or Yorkshire).

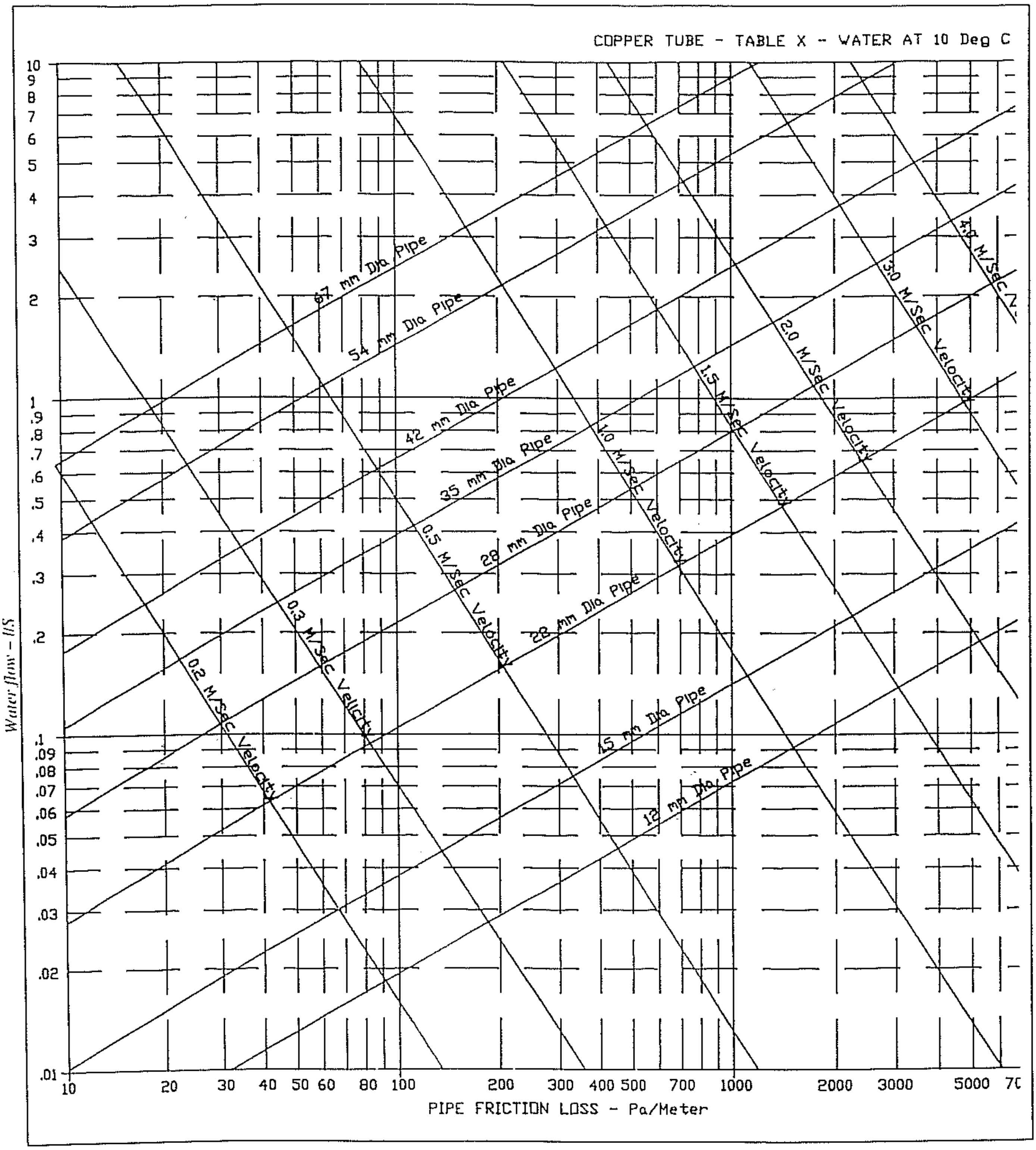
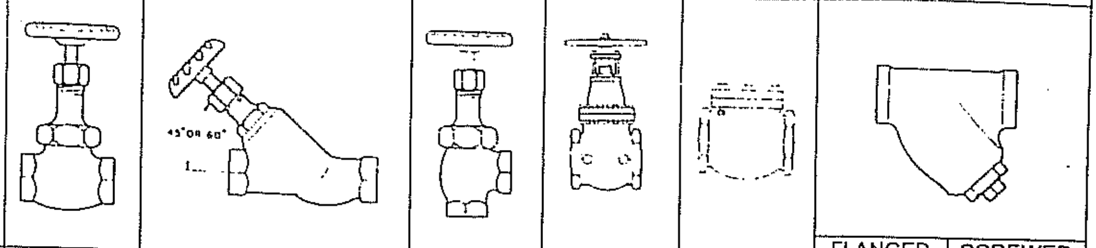


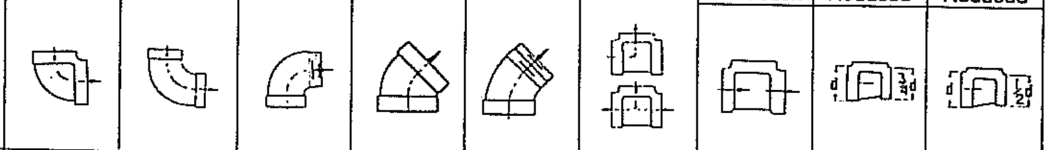
Fig. 4.2 - Friction loss for closed piping systems



NOMINAL PIPE DIA mm	GLOBE	60 Deg - Y	45 Deg - Y	ANGLE	GATE	SWING CHECK	Y - TYPE STRAINER FLANGED	Y - TYPE STRAINER SCREWED
12	5.2	2.4	1.8	1.8	0.2	1.5	---	---
15	5.5	2.7	2.1	2.1	0.2	1.8	---	0.9
22	6.7	3.4	2.7	2.7	0.3	2.4	---	1.2
28	8.8	4.6	3.7	3.7	0.3	3.0	---	1.5
35	11.6	7.3	4.6	4.6	0.5	4.3	---	2.7
42	13.1	9.1	5.5	5.5	0.5	4.9	---	3.0
54	16.8	10.7	7.3	7.3	0.7	6.1	8.2	4.3
67	21.0	13.1	8.8	8.8	0.9	7.6	8.5	6.1

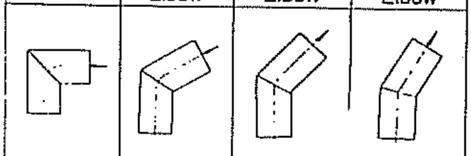
Losses are for valves in the fully open position.
Globe and Angle valve losses do not apply to valves with needle point seats.
For regular and short Plug cock valves in the open position, use data for Gate valves.

Fig. 4.3 - Valve losses in equivalent metres of pipe



NOMINAL PIPE DIA mm	SMOOTH BEND ELBOWS 90 Deg Std	90 Deg Long Rad	90 Deg Street	45 Deg Std	45 Deg Street	Flow-Thru Branch	SMOOTH BEND TEES Straight - Thru Flow No Reduction	25% Reduced	50% Reduced
12	0.4	0.3	0.7	0.2	0.3	0.8	0.3	0.4	0.4
15	0.5	0.3	0.8	0.2	0.4	0.9	0.3	0.4	0.5
22	0.6	0.4	1.0	0.3	0.5	1.2	0.4	0.6	0.6
28	0.8	0.5	1.2	0.4	0.6	1.5	0.5	0.7	0.8
35	1.0	0.7	1.7	0.5	0.9	2.1	0.7	0.9	1.0
42	1.2	0.8	1.9	0.6	1.0	2.4	0.8	1.1	1.2
54	1.5	1.0	2.5	0.8	1.4	3.0	1.0	1.4	1.5
67	1.8	1.2	3.0	1.0	1.6	3.7	1.2	1.7	1.8

Fig. 4.4 - Fitting losses in equivalent metres of pipe



NOMINAL PIPE DIA mm	MITRE ELBOWS 90 Deg Elbow	60 Deg Elbow	45 Deg Elbow	30 Deg Elbow
12	0.8	0.3	0.2	0.1
15	0.9	0.4	0.2	0.1
22	1.2	0.5	0.3	0.2
28	1.5	0.6	0.3	0.2
35	2.1	0.9	0.5	0.3
42	2.4	1.0	0.5	0.3
54	3.0	1.4	0.7	0.4
67	3 7	1.6	0.9	0.5

Fig. 4.5 - Fitting losses in equivalent metres of pipe

In modern practice pipe sizing and pump head evaluation is computerised and these lengthy calculations are done in minutes.

Many Hydroflow systems consist of a number of sub-circuits and in practice the length of the sub-circuits may vary considerably. Some means must be found therefore to equalise the frictional resistance of all circuits carrying their proper load in order to prevent a higher than required flow rate through the lower resistance circuits. Balancing valves are therefore required in all sub-circuits. With this type of system the majority of the resistance will be in the index-run with main plant items and so final balancing of the sub-circuits will be carried out using these balancing valves.

4.7 System Layout

The general system configuration should be as shown in the sample component diagram Fig. 4.6. In hydronic chillers, Carrier provides the pump, water pressurisation system and expansion vessel as an integral part of the chiller package. However, for standard chillers, the pump should always be located on the inlet to the chiller unit and in order to maintain a positive overall system pressure, the connection between the expansion tank/make up system should always be on the pump suction.

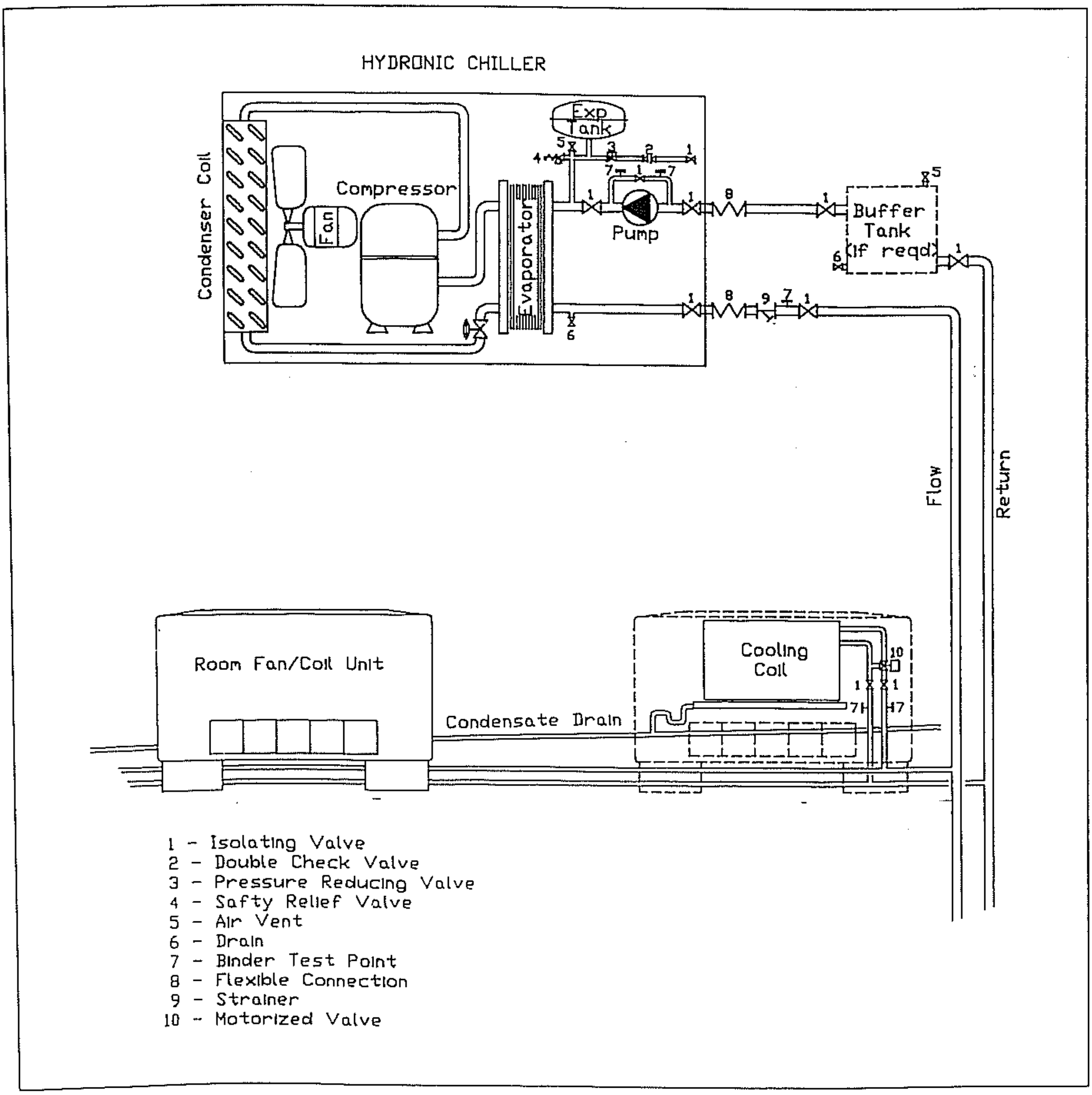


Fig. 4.6 - System layout

4.8 Pipe Grading - venting and draining

Unlike refrigerant systems it is essential that all distribution pipework be installed to ensure correct and continuous rises and falls to ensure that air can be released and when required the pipework drained.

Air trapped within distribution pipework in any quantity can and will be likely to prevent or limit circulation.

If high points in the system are unavoidable then provision for release of air by way of air venting points must be made. Such air release points should incorporate an air bottle where the air can initially collect without inhibiting circulation. The air release device may either be a manual aircock or an automatic air vent.

With a closed hydronic system, unless automatic water make up facility is provided, automatic air vents should not be used. In Figs. 4.7 and 4.8 details of venting and draining requirements are shown. Fig.4.7 shows an ideal circuit which will both vent and drain with the minimum of provision. Fig. 4.8 shows a circuit which, unless some additional air venting provision is made will not circulate.

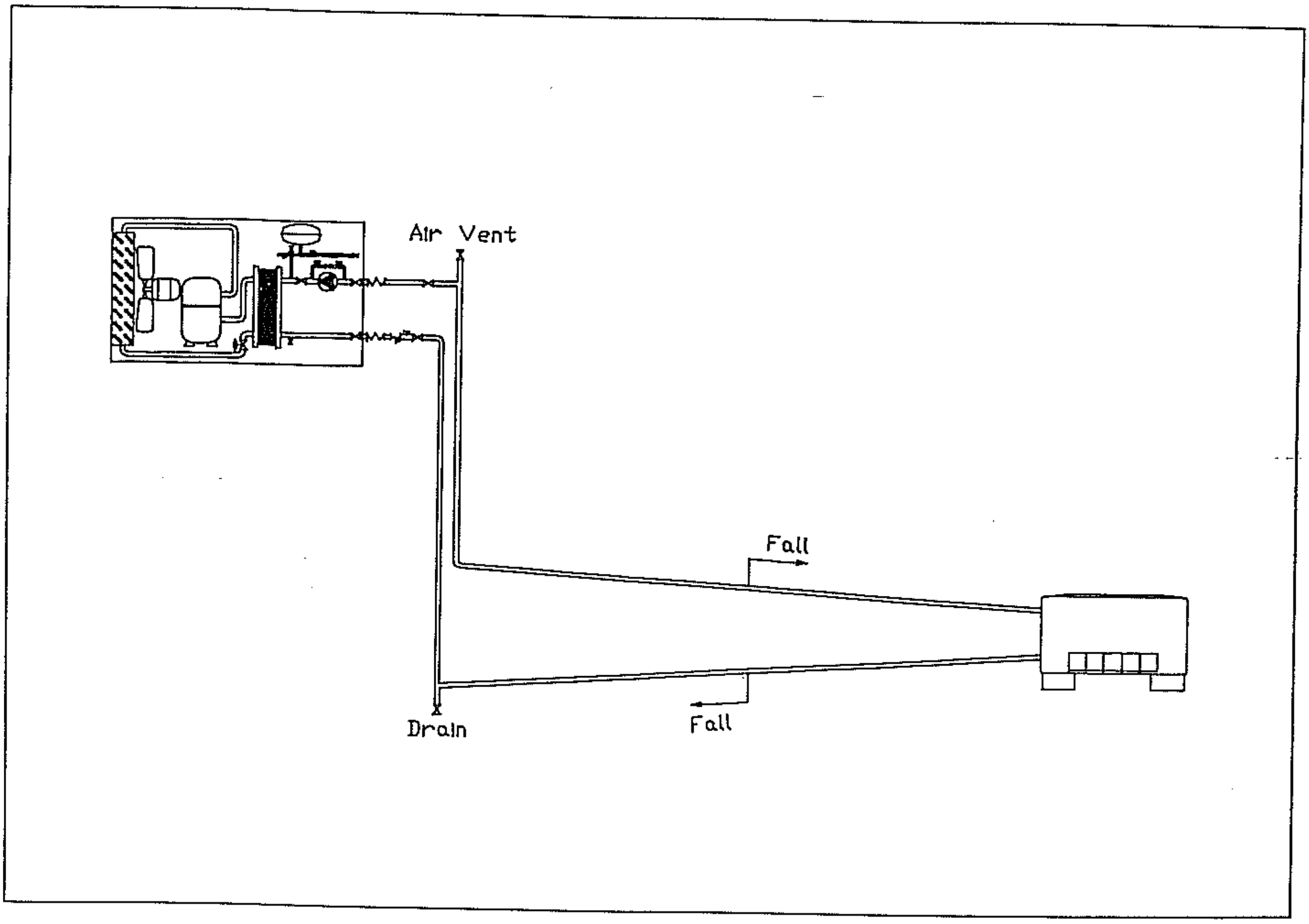


Fig. 4.7 - System that will vent and drain

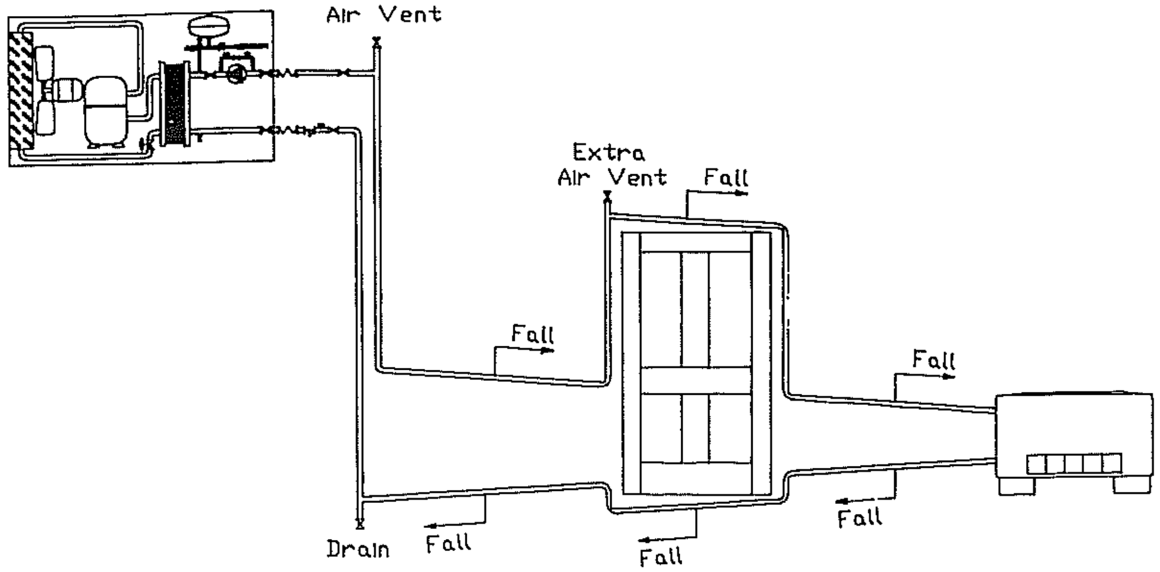


Fig. 4.8 - System that will not vent unless extra vent point is added

Clearly the circuit as drawn will airlock in the section of pipework over the doorway and the section of the pipework run under the doorway will not drain. To clear the airlock problem an additional air vent must be installed above the door.

Similarly, a second drain must be installed below the door to facilitate draining of the low section. The original drain shown should be left in position to allow draining of main plant when isolated. Every high or low point within the system which will not vent or drain naturally must be similarly treated.

4.9 Insulation

All chilled water pipework, fittings, valves, pumps, etc. must be adequately insulated and the insulation vapour sealed if problems with condensation forming on cold surfaces are to be avoided. Where pumps and any other items which require service and maintenance are insulated then insulation must be readily removable for the maintenance to be carried out. At every bracket position it is necessary to ensure, by the provision of an insulating block, that conduction of low temperature to the exposed part of the bracket does not occur otherwise problems will be experienced with condensation. See Fig. 4.9.

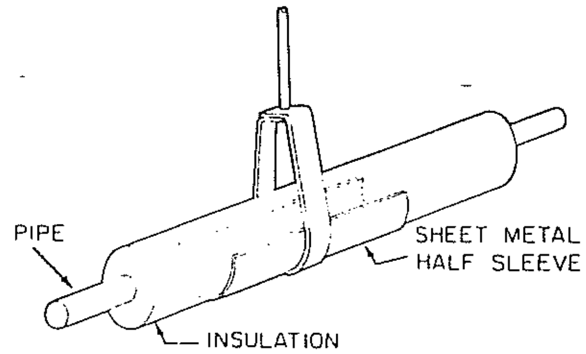


Fig. 4.9 - Insulated pipe hanger

4.10 Isolating Valves

In addition to the regulating valves installed within each sub-circuit for balancing purposes every item of plant or main sub-circuits must be fitted with isolating valves to facilitate the removal of individual items of equipment without the need to drain the whole installation.

4.11 Expansion Vessel/System Filling and Make Up

Provision must be made to accommodate the change in volume of the water due to the change in temperature and also to both initially fill the system, and make up the inevitable losses of water which occur.

Carrier hydronic chillers incorporate a filling and pressurisation system comprising check valves and pressure reducing valve for pressurising and filling direct from mains. However, as most hydronic systems contain glycol and inhibitors they should not be left permanently connected to the mains.

4.12 Buffer Tank

It is sometimes found that chilled water systems with short pipe runs and low water contents can cycle excessively on the water temperature control thermostat and this can cause nuisance trips and shorten the plant life.

For this reason, it is advisable to install chillers which are not oversize for the duty and to consider methods of capacity reduction for part load duty.

A method of helping to minimise cycling involves the use of a water buffer vessel which increases the system water content. In general, Carrier recommends that the water content of the system should be at least 5 litres for each kW of chiller cooling capacity. If total system capacity is less then a buffer tank should be installed to make up the difference. This minimum system volume is for comfort air conditioning applications and is increased to 7.5 litres/kW for process cooling applications.

4.13 Condensate Pipework

When the Hydroflow system is in the cooling mode, moisture may be removed from the air. This moisture forms as condensate on the cooling coil and must be collected and carried away to a drain. For this purpose, drain pans are provided under the indoor cooling coils. Clear flexible hoses, at least 400 mm in length and of diameter to match the unit drain connection, are used to connect the drain pans to the building's main condensate drainage system.

Under normal operating conditions, the condensate is subjected to pressure conditions slightly above or slightly below atmospheric pressure. It is, therefore, necessary to provide a trap in the condensate connection at the unit. This trap prevents conditioned air from entering the drain line when the condensate is under positive pressure, as in a blow-through unit. When the system is under a negative pressure, as in a draw-through unit, the trap prevents condensate being held back in the drain pan.

Fig. 4.10 illustrates the trapping of a drain line from the drain pan using a conventional pre-built trap. The height of the water seal or trap depends on the magnitude of the positive or negative pressure at the drain pan. For instance, a 25 mm H_2O negative fan pressure requires a 25 mm water seal. The rule is 1 mm of trap for each mm H_2O of negative pressure on the unit.

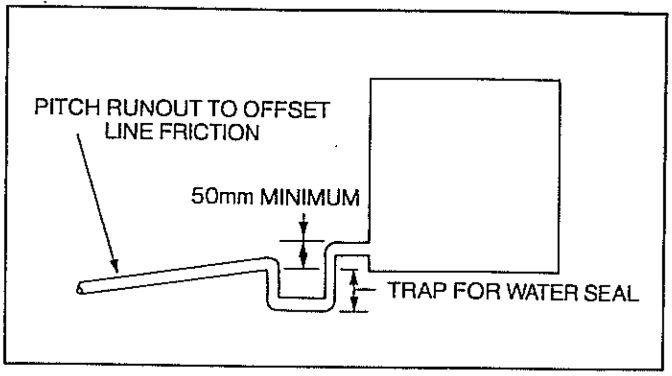


Fig. 4.10 - Condensate trap

Condensate traps can also be accomplished by looping the flexible connection pipe, the diameter of the loop being equal to the required height of the trap (Fig. 4.11). The drain line run out should be pitched to offset the line friction and allow the condensate to drain under gravity. The size of the drain lines must allow for the possible high room humidity at start-up for which a flow rate of 0.0001 l/s for each kW of total cooling load should be allowed. The lines should be designed and installed in accordance with good drainage practice. The flow rate and available head are used with a friction chart for open piping systems to determine the pipe size. See the Carrier System Design Manual, Part III, Piping Design. For estimating purposes, use open system pressure losses 50% greater than those of closed systems.

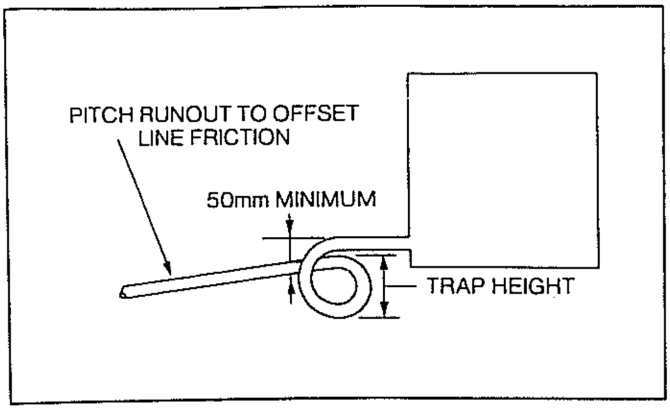


Fig. 4.11 - Loop type condensate trap

The header and riser diameters should never be sized smaller than the drain pan connections and the run outs must be fitted at a level below the units. Traps are not effective in preventing odours because they can easily dry out. The drain system should not therefore be connected to a foul drain or gully. Each system should be investigated to determine the need for drainage fittings and clean-out plugs. The use of flexible pipework connections for the condensate facilitates removal of the unit if it becomes necessary. As stated earlier in this section the use of clear flexible hose is recommended.

Where poor filtration is used in the air system, sediment and airborne impurities can collect in the drain pans, eventually finding their way into the condensate pipework. This pipework must therefore be cleaned out periodically to prevent blockages.

Condensate drainage from above ceiling fan coil units and from ceiling cassette units can caused problems particularly if long condensate pipe runs are required to the edge of the ceiling. For this reason Carrier ceiling cassette units are provided with a lifting device to provide a small additional head. Fan coil units installed above a false ceiling should be drained to a small reservoir which in turn should be provided with a condensate pump.

4.14 Frost Protection

It will be appreciated that a risk exists of freezing the water in a chilled water system, particularly the external pipework connecting to the chiller. See section on water treatment.

4.15 Checking of Water Flow Rates

Water flow rates in a chilled water system are of prime importance, particularly relating to the chiller. For this reason, methods of checking flow rates must be incorporated.

This can be done in a number of ways, but we suggest the following:

a. Chiller

If binder points are inserted in the flow and return tappings, the pressure drop can be compared to Carrier's tabulated data and flow rates checked by this method. The test plugs can also be used for temperature checks.

b. Pumps

Test plugs can be fitted in the pretapped connection on the pumps and the developed pressure can be checked and related to flow against pump manufacturer's pressure/flow curves or tabulated data.

c. Fan Coils

We suggest that "Taco Setter" valves are installed on each fan coil. These give an indication of flow and a means of balancing. Taco Setters are used in addition to the normal isolating valves so that the set levels do not need to be disturbed in the event of unit isolation.

SECTION 5 - FRESH AIR - INFILTRATION AND VENTILATION

For air conditioning systems to control properly, the external windows should be kept closed. However, closing the windows can result in insufficient ventilation to the occupied space, causing an increase in CO_2, odours and humidity levels.

5.1 Infiltration

Natural ventilation is caused by the effects of wind and temperature difference between the inside and outside of a building. In the past, minimum ventilation rates (even with closed windows) could often be provided by natural ventilation but modern buildings are often carefully sealed and this naturally occurring infiltration can no longer be relied upon to provide sufficient dilution. The infiltration rate of modern buildings can be assumed to be 0.19 litres per second of outside air per square metre of floor area.

5.2 Ventilation

Ventilation is the forced introduction of a limited amount of outside air into a building. The amount of ventilation is governed by the use to which the building is put and is affected by the activity of the occupants and whether smoking is permitted or not. Recommended ventilation rates are listed in the CIBSE Guide section A1-9.

Carrier room fan coil units and ceiling cassettes are provided with facilities for the provision of forced ventilation. Room fan coil units can be provided with a damper to regulate the amount of fresh air which can be drawn through an opening in the outside wall specially provided for the introduction of fresh air. Ceiling cassettes have a knock-out panel which can be used to draw air from a ventilated ceiling void or from a system consisting of fan plus ventilation ductwork. Larger fan coil units and Carrier's ATM (air treatment modules) are usually provided with fresh air from an outside air fan with distribution ductwork.

Whatever system of ventilation is used (natural or forced) the introduction of outside air must be taken into account when calculating the cooling load in summer or heating load in winter of the air conditioning plant.

SECTION 6 - WATER TREATMENT AND FREEZE PROTECTION

Water quality varies from location to location and job to job. Water will almost always include impurities and hardness which must be removed. The degree of treatment required will depend entirely on the original water quality as well as type of system.

6.1 Water Problems

Water problems fall into three categories. These problems and appropriate treatment measures are discussed in detail in the Carrier System Design Manual. Part V - Water Conditioning.

1. Scale formation, caused by hard water, reduces the heat transfer and increases the water pressure drop through heat exchangers. As water is heated, minerals and salts are precipitated from a solution, and deposited on the inside surface of pipes or tubes.

2. Corrosion can be caused partly by absorption of gases from the air into water so that an aggressive condition is created when the water attacks exposed metal. The condition is prevalent in areas of high pollution using open systems. Corrosion is also common in salt water areas. This is not normally a problem in closed hydronic systems.

3. Organic growths of slime and algae which form under certain environmental conditions can reduce the heat transfer rate by forming an insulating coating on the inside of tube surfaces. Algae can also promote corrosion by pitting - also not normally a problem in closed circuit hydronic systems.

6.2 Water Characteristics

The constituents of or impurities in water can be classified as dissolved solids, liquids or gases, and suspended matter. An example of a dissolved solid is sodium chloride in solution. Dissolved materials cannot be removed by filtration. An example of a suspended matter which can be removed by filtration is mud, clay or silt. Several characteristics of water such as pH value, alkalinity, hardness and specific conductance are of particular importance in water treatment as follows:

1. pH value is one of the most important control factors in water treatment. It is an arbitrary symbol adopted to express the degree of acidity or alkalinity in a water sample. Neutral water has a pH of 7.0. Values below 7.0 and approaching 0.0 are increasingly acidic, whilst values from 7.0 to 14.0 are increasingly alkaline. Most natural waters have a pH of 6.0 to 8.0. Water containing free mineral acids may have pH values below 4.5. A pH below 7.0 may cause corrosion of equipment which comes into contact with water. When the pH is high (above 7.5 or 8.0) calcium carbonate scale is deposited more readily.

2. Alkalinity is the most important characteristic of a water when determining the scale-forming tendency. Generally, alkalinity is a measure of the acid neutralizing power of a water, and is determined by titration of a standard acid to the point of colour change of an indicator. Alkalinity can be classified either as a measure of carbonate and caustic ions or as the total of all alkaline substances.

3. Hardness is represented by the sum of calcium and magnesium salts in water although it may include aluminium, iron, manganese, or zinc. Water hardness may be classified as follows:

Table III - Water Hardness Classification

Hardness (ppm as $CaC0_3$)	Classification
Less than 15	Very soft
15 to 50	Soft
50 to 100	Medium hard
100 to 200	Hard
Greater than 200	Very hard

Carbonate (temporary) hardness is attributed to carbonates and bicarbonates of calcium and/or magnesium expressed in parts per million (ppm) as $CaCO_3$. The remainder of the hardness is known as non-carbonate (permanent) hardness which is due to the sulphates, chlorides, and/or nitrates of calcium and/or magnesium expressed in ppm as $CaCO_3$. Non-carbonate hardness is not as serious a factor in water conditioning because it has a solubility which is approximately 70 times greater than the carbonate hardness.

4. Specific conductance is a measure of the ability of water to conduct an electric current. It is expressed in micro ohms per cubic centimetre. The specific conductance of a water indicates whether galvanic corrosion may be a problem.

In most commercial applications, hydronic systems use copper flow and return pipes. Where water contains pH, alkalinity, hardness or other contaminant values outside recommended standard limits, water treatment should be applied to correct the undesirable water condition.

Water problems and water conditioning in general are explained in depth in the Carrier System Design Manual, Part V - Water Conditioning.

6.3 Appraisal and Treatment of Water Systems

Scaling or slime and algae seldom cause problems in these hydronic systems. A problem that can occur with closed recirculating systems is galvanic corrosion. Galvanic corrosion occurs when dissimilar metals come into contact with each other, such as steel with copper, or copper with galvanised fittings. Zinc and galvanised metals should never be used in the same system.

Since closed recirculating systems require little water make-up, water problems once solved rarely recur.

6.4 Initial Cleaning

Initial flushing and cleaning of the water loop in a hydronic system is extremely important. Recommendations are made in manufacturer's installation instructions. Left uncleaned, initial construction matter can remain in the piping system, eventually becoming lodged in evaporators.

Table IV - Summary of Water Treatment Control

Scale Control	No control required in the hydronic water loop
Corrosion Control	Corrosion inhibitors in high concentrations (200-500 ppm) Proper materials of construction
Slime and Algae Control	No control required in hydronic water loops

6.5 Freeze Protection

Hydronic systems (particularly chillers and heat pumps) and associated pipework exposed to outdoor ambient temperature below freezing (0°C) must be protected. This can be accomplished by several methods:

1. Ethylene glycol solutions - the most common method of protecting water systems from freezing is mixing ethylene glycol concentrations with the water. The resultant glycol-water solution has a freezing point lower than the freezing point of water alone. While ethylene glycol solutions are necessary to prevent equipment and pipe damage, they are often over-used. Glycol concentrations of greater than 25% (-12°C freezing) by weight are almost never required since external conditions in much of the UK seldom go below -10°C. Carrier chillers and heat pumps located outside the building often have antifreeze protection heaters installed to protect pipework within the chiller.

It should be noted that ethylene glycol is poisonous and should never be used in food processing work, nor should pipes containing ethylene glycol be run through food preparation or storage areas.

Ethylene glycol concentrations of greater than 25% are rarely required. Although 25% ethylene glycol, for example, will begin freezing below -12°C outdoor ambient, solutions will not cause damage until temperatures are reached far below design. As water in glycol solutions begins to freeze, frozen water droplets drop out of the solution. Resultant glycol concentrations remaining in the water become much higher than the original 25%, lowering the freezing point of the solution. As the lower freezing point is again reached, water droplets begin to freeze, again causing higher glycol concentrations. Eventually at extremely low temperatures a "slush" begins to form, which does not cause damage to piping systems.

Glycol concentrations above 30% by weight are seldom required in the UK, and it is important not to go for overkill in the amount of ethylene glycol used as:

a. Heat pump and chiller performance suffers drastically with high concentrations of glycol and other antifreeze solutions.

b. Piping pressure losses increase resulting in reduced flow rates with consequent effects on fan coil unit performance.

c. Because of the higher solution viscosity, excess corrosion and wear of the entire system, including units and piping, will occur.

d. As glycol solutions break down with time, organic acids are formed, resulting in glycol-water conditions. The acidity of the water is then greatly increased, promoting corrosion.

e. Glycol promotes galvanic corrosion in systems of dissimilar metals. In this case, a form of battery reaction will occur. The dissimilar metals act as electrodes while the glycol solution performs as battery acid. The result is a corrosion of one metal by the other, eventually producing a leak.

   Systems requiring greater than 15% glycol concentrations should be thoroughly examined for actual operating requirements and the glycol kept to a minimum.

f. Zinc and zinc-based metals cannot be used because glycol attacks zinc.

g. The increased viscosity of glycol solutions gives increased leakage at the glands of pumps and valves.

6.6 Correcting for Glycol Concentration

As stated above, ethylene glycol is often used to protect hydronic systems against winter freeze-up. However, it must be understood that manufacturer's performance data is based on zero glycol concentration and must be corrected for the percentage of glycol to be added to the system. Fig. 6.1 gives correction factors to be applied to chiller capacity, pump flow rate and chiller head loss (also total pump head) for various concentrations of ethylene glycol. Also shown on the right hand Y axis scale of the chart is the solution freezing point.

The disadvantage of glycol protection is that it is expensive. It can be diluted when parts of the system are drained during maintenance, and that it deteriorates over time. Consequently other forms of freeze protection are often used.

6.7 Non-aqueous Systems (chemical freeze protection)

Non-aqueous systems (chemical freeze protection) can be used in place of glycol systems for freeze protection. However, with the type of duty typically seen by a hydronic system non-aqueous systems are generally impractical. They involve chemicals, with resulting solutions much higher in viscosity, causing greatly increased friction rates and pumping costs. In addition to the higher first cost, non-aqueous solutions are normally designed for extremely high operating temperatures.

6.8 Trace Heating

Carrier chillers and heat pumps contain heating elements within the water pipework inside the unit to provide protection against winter freeze-up when the pump is not running. However, these heating elements are of limited capacity, and can only provide protection to the small amount of pipework actually within the chiller/heat pump itself. Additional trace heating should be provided for the pipework external to the chiller/heat pump that may be exposed to outdoor winter conditions. This trace heating should be wrapped around the pipework and protected by a minimum of 25 mm insulation.

Note that electrical trace heating should not be relied upon as absolute protection against freeze-up as it would obviously not work in the event of a power failure or a power disconnect. However, a prolonged power failure would be necessary for freeze-up to occur provided that adequate lagging is provided for external pipework.

An additional protection is to energise the chilled water circulating pump if the water in external pipework falls below, say, 2°C. Pipework within the building will be reasonably warm due to heat pick up from the central heating system and this is used to offset losses from external pipework.

6.9 Winter Drain Down

Cooling only systems can be protected against freeze-up by the simple expedient of draining down at the end of the cooling season. However, this is not recommended as it fails to provide against an unexpected and unseasonal cold snap or against error on the part of the maintenance engineer in neglecting to drain the system.

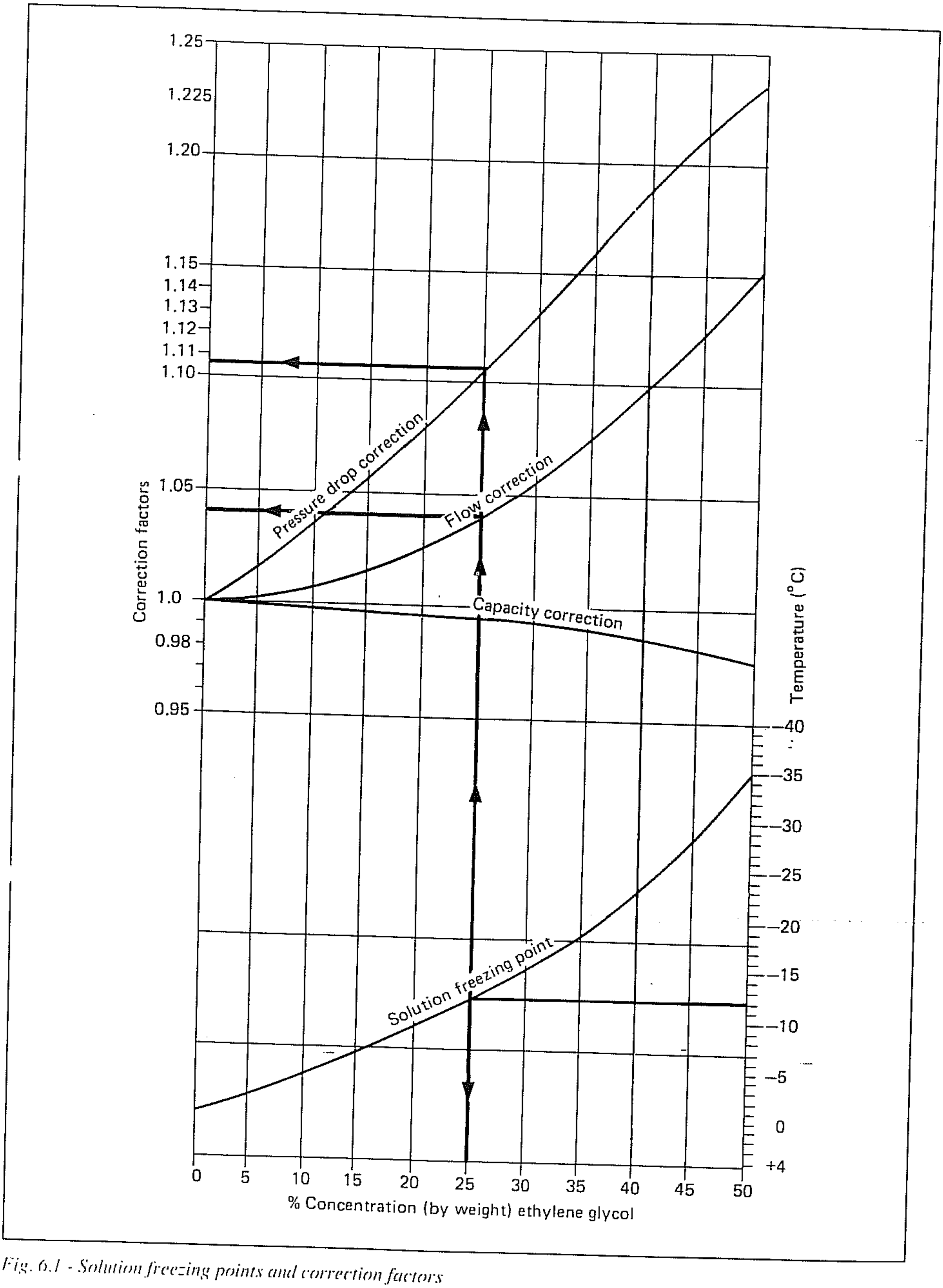


Fig. 6.1 - Solution freezing points and correction factors

SECTION 7 - SOUND CONSIDERATIONS

7.1 Introduction

For those unaccustomed to installing fan coil units within an occupied space, the amount of noise produced by the circulating fan within the unit can come as an unpleasant surprise. The effects of noise from hydronic fan coil units should therefore be carefully considered.

This chapter provides a description of sound, how it is produced and the relationships of its various components. A knowledge of the relationship between sound and noise will reduce or eliminate potential sound problems in hydronic system design.

7.2 Sound Power (Lw)

Sound is a form of energy and its propagation is a form of power. Conversely, when sound gives up power, it does work. The act of hearing sound is a form of sound doing work on a person's eardrum. While sound can be good or bad, it is most often thought of as a problem when associated with fan coil units. Like any potential problem associated with air conditioning equipment, sound must be provided for and avoided at the design stage.

As with other forms of power, sound is commonly measured in units of watts. Expressed in watts, sound power from various sources represent a wide range of magnitudes. For example, the sound power of a jet aeroplane is approximately 10,000 watts. The sound power of a car travelling approximately 45 miles per hour would be something of the magnitude of 0.1 watts. A three horsepower compressor has a sound power of 0.0001 watts while a whisper is approximately 0.000000001 (10^{-9}) watts. In order of magnitude, a jet aeroplane produces sound power 100,000 times that of a car, and a car produces sound power 100 million times that of a whisper. Clearly this wide range in numerical values makes expression of sound power in watts cumbersome, and acoustic engineers have therefore adopted a more appropriate system of measurement based on the decibel. See Table V.

To better express and measure sound power, a unit of measurement known as the decibel (dB) is most commonly used. This is a sound power level (Lw) and is calculated by the following formula:

Lw = 10 log 10 x (W1/W0)
W1 = Measured Sound Power (in watts)
W0 = 10-12 watts (reference)

Sound power (Watts)	Sound power level db	Source
25 to 40 000 000	195	Saturn rocket
100 000	170	Ram jet
10 000	160	Turbo jet engine 3200 kg thrust
1 000	150	4 propeller airliner
100	140	
10	130	75 piece orchestra
1	120	Large chipping hammer
0.1	110	Blaring radio
0.01	100	Car on motorway
0.001	90	Axial ventilating fan (695 l/s) Voice shouting
0.0001	80	
0.00001	70	Voice - conversational level
0.000001	60	
0.0000001	50	
0.00000001	40	
0.000000001	30	Voice - very soft whisper

Table V

Using the above formula and converting the watts in the previous example to sound power levels, the corresponding value for a jet would be 160 dB with the values of a car, compressor and whisper being 110, 80 and 30 respectively. Because decibels are logarithmic, increasing the sound power by a multiplier of 10 increases the sound power level by 10 dB. Each time sound power is doubled, the resulting sound power level is increased by 3 dB.

If two sources of equal sound power are measured side by side simultaneously, the net resultant sound power level will be 3 dB higher than either one alone.

The addition of sound power levels for two or more units and the calculation of the resultant sound power level is dependent on factors other than just individual sound power levels. The increase in sound power levels resulting from the addition of two unequal sound levels is a function of the difference between those two sound levels. The greater the difference, the less the amount added to the higher of the two sounds. The addition of a relatively low level source has little effect on a source of high magnitude. Net increases in sound power levels by the addition of two sources are shown in Table VI.

Table VI

	Addition of Sound Sources											
dB Difference	0	1	2	3	4	5	6	7	8	9	10	>10
dB to be added to higher value	3.0	2.5	2.0	1.5	1.5	1.5	1.0	1.0	1.0	0.5	0.5	0

7.3 Sound Pressure (Lp)

The energy the human ear perceives to be sound is actually a pressure wave. The relationship between sound power and this sound pressure wave is similar to dropping a stone in a pool of water. The stone, as it strikes the surface, represents sound power. The waves that radiate outward from the point of impact represent sound pressure. With sound, however, the waves are three dimensional rather than two dimensional as is the case with the surface of a pool of water. In a free field sound waves radiate outwardly in the form of a sphere from a source.

Sound waves behave like light rays as they radiate away from their source. With no obstructions, a sound wave will travel indefinitely and evenly in all directions, diminishing in intensity as a function of the square of the distance. As a result, doubling the distance from a source gives a 6 dB reduction in intensity. When obstructions are placed in its path, sound will either be absorbed, reflected or diffracted as is the case with light waves. Behind the obstruction, the intensity of the energy is greatly diminished. When an object is placed in the path of a sound wave to either absorb or usefully reflect that wave, sound reduction is achieved.

In summary:

1. Sound power levels represent the sound as it is produced by the source with no regard to attenuation between the source and the space receiver.

2. Sound can be diminished by increasing distance between the object and the space. For each doubling of the distance, the sound pressure level will be decreased by 6 dB.

3. Two identical fan coil units placed side by side in a room can never increase sound pressure by more than 3 dB.

7.4 Acoustic Design Goals (NC and NR Curves)

Acoustic design goals are the sound pressure levels desirable within a given conditioned space. These acoustic goals represent sound as perceived by the human ear as opposed to strict numerical values. For example, at equal sound pressure levels, a high frequency noise sounds much louder to the human ear than a low frequency noise. High frequency sounds are easiest to hear and must be attenuated the most. However, low frequency sounds are the hardest to attenuate and produce the most problems.

Acoustic design goals are necessary to provide spaces where people can be comfortable and communicate effectively over the background noise of the air conditioning system and other background noise sources. Thus, an upper limit must be set on the permissible loudness of the background noise level.

However, a lower limit requirement also exists with background noise levels. Those levels must be high enough so that, at reasonable distances, acoustic privacy is maintained. In the acoustic spectrum a reasonable balance is desired between high and low frequency sounds.

These criteria have been studied and combined in various ways in the past and the development of better design criteria is continuing. The NC (noise criteria) curves most commonly used are shown in Fig. 7.1 and tabulated in Table VII and represent the common acoustic design criteria currently in use. NR (Noise Rating) values are also in use and are virtually the same as NC values for mid frequencies; NC values being about 1 or 2 dB higher than NR values at 1000 Hz. At other frequencies the differences are greater. The NC levels represent a peak over a full spectrum of frequencies. A high value in a low frequency band has the same effect on NC level as a lower value in a high frequency band. It is important that sound levels be balanced over the entire spectrum relative to the NC curve.

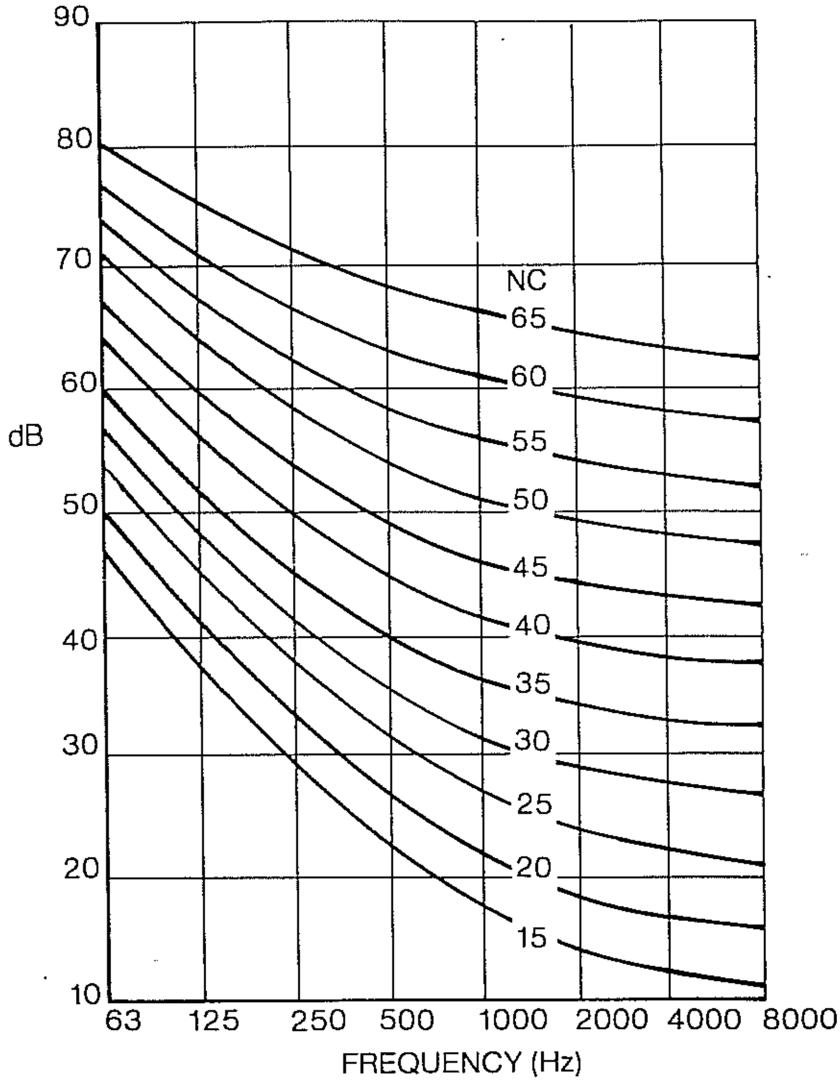


Fig. 7.1

Since the NC curves evolved from a desire for a balanced sound spectrum and the need for not too much or too little background noise, it is apparent that different spaces require different design criteria. Air conditioning design engineers recognise this and use a range of NC values for given spaces as shown in Table VIII.

Noise Criterion Curves	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
NC-15	49	36	26	17	17	14	12	11
NC-20	52	41	33	27	22	19	17	16
NC-25	54	45	38	31	27	24	22	21
NC-30	58	49	41	36	31	29	28	27
NC-35	61	53	45	40	36	34	33	32
NC-40	64	57	50	45	41	39	38	37
NC-45	67	61	54	49	46	44	43	42
NC-50	71	64	58	54	51	49	48	47
NC-55	74	68	63	58	56	54	53	57
NC-60	77	71	67	63	61	59	58	57
NC-65	80	75	71	68	66	64	63	62

Table VII - Octave Band Sound Pressure Levels (Lp) associated with NC curves

Table VIII - Ranges of Indoor Design Goals for Air Conditioning System Sound Control

Type of Area	Range of NC Criteria Curves
Residences	
Private homes (rural and suburban)	20-30
Private homes (urban)	25-35
Apartment houses, 2 and 3 family units	30-40
Hotels	
Individual rooms or suites	30-40
Ballrooms, banquet rooms	30-40
Halls and corridors, lobbies	35-45
Hospitals and Clinics	
Private rooms	25-45
Operating rooms, wards	30-40
Laboratories, halls and corridors	35-45
Lobbies and waiting rooms	35-45
Offices	
Board room	20-30
Conference rooms	25-35
Executive office	30-40
Supervisor office, reception rooms	30-45
General open offices, drafting rooms	35-50
Tabulation and computation	40-60
Churches and schools	
Libraries	30-40
Schools and classrooms	30-40
Laboratories	45-45
Recreation halls	35-50
Corridors and halls	35-50
Public buildings	
Libraries, museums, court rooms	30-40
Post offices, general banking, public areas	35-45
Lobbies	35-45
Restaurants, cafeterias, lounges	
Restaurants	35-45
Cocktail lounges	35-50
Night clubs	45-45
Cafeterias	40-50
Stores, retail	
Clothing stores	35-45
Department stores (upper floors)	35-45
Department stores (main floor)	40-50
Small retail stores	40-50
Supermarkets	40-50

7.5 Sound Power Level (Lw) Testing Methods

All sound power level (Lw) data are not the same. When comparing various manufacturers' sound power data, be sure like data are being compared. There are various testing methods and they give different data. The method for testing units can dramatically affect the resulting base data.

7.6 Converting Sound Power to Sound Pressure to Noise Criteria

Setting the acoustic design goal for the background noise level in a space is done to meet an NC requirement. Thus, it is important to know how to predict noise criteria from the unit ratings that are in terms of sound. This conversion depends on the specifics of the acoustical environment of the installation. Some of the factors that affect the conversion of sound power levels first to sound pressure levels and then, subsequently, to noise criteria values include:

1. Type of acoustical ceiling.
2. Thickness of carpets and curtains.
3. Distance from unit to listener.
4. Open or closed layout plan.
5. Unit located in space or above ceiling.
6. Orientation of unit to occupant.
7. Size of the room.
8. Location of unit in room.

The total of the above factors is sometimes called the room effect, which is subtracted from sound power to arrive at sound pressure within the room.

7.7 Attenuation

Most fan coil units are located directly within the occupied space and there is little facility for the application of any attenuating techniques.

Remote mounted fan coils supplying air via a system of ductwork are sometimes used and here there is some scope for attenuation. Unlined sheet metal duct has little sound attenuation value. Lined sheet metal duct may have considerable attenuation value depending on duct size. Typical attenuation values for 3 m of lined duct are: as little as 1.0 dB and 1.5 dB in the 125 and 8000 Hz frequency bands but as high as 9.5 dB in the mid frequency (2000 Hz) band, depending on the thickness of lining and the duct cross-section. Acoustic specialists should be contacted for advice for attenuation from ductwork.

Sound generation above a ceiling will be partially absorbed as it proceeds through the ceiling into the occupied space. This value varies with different types and makes of ceilings, but most manufacturers standardise with either 8 or 10 dB reduction in the highest octave bands (small attenuations occur in the lower bands). Openings between ceiling tiles and at luminaires may provide noise flanking paths and reduce the attenuation considerably. Seek help from a specialist for advice on ceiling attenuation.

The amount of sound absorbed in the occupied space is referred to as room attenuation or room effect. This occurs as a result of room, wall, floor and furniture design and room size. Specific values for specific sizes and types of rooms can be calculated from the CIBSE guide.

7.8 Unit Sound Power Levels

Carrier publishes certified sound power level data for each size and speed of its fan coil units offered (see following examples). This data should be passed to an acoustic specialist along with details of the air conditioned space for analysis of the resultant room NC level. However, as an approximate guide, the sound power levels have been converted to NC levels for various sizes of office. This assumes one fan coil per office (see correction for more than one unit), room reverberation time equivalent to a normal office and a distance of 1.5 metres from the fan coil unit to the listener.

42WK HYDRONIC CASSETTE FAN COIL UNITS - 220 VOLT SUPPLY

UNIT FAN SOUND POWER LEVELS RE 10 -12 WATTS

MODEL NUMBER	FAN SPEED	FREQUENCY - Hz 125	250	500	1K	2K	4K	8K
42WK 004	HIGH	44	48	47	46	35	21	18
	MEDIUM	38	41	43	39	26	16	13
	LOW	41	35	34	30	21	15	12
42WK 008	HIGH	43	46	47	47	41	33	28
	MEDIUM	42	43	44	44	38	30	25
	LOW	35	38	36	33	24	17	14
42WK 010	HIGH	50	52	52	52	46	36	28
	MEDIUM	46	47	48	48	42	34	27
	LOW	40	41	42	42	36	29	23
42WK 016	HIGH	54	51	50	50	44	34	26
	MEDIUM	52	49	47	45	38	28	24
	LOW	47	44	39	35	29	20	18
42WK 020	HIGH	57	60	56	56	53	48	41
	MEDIUM	53	55	51	51	47	41	33
	LOW	49	49	46	45	40	33	24

42WK HYDRONIC CASSETTE FAN COIL UNITS WITH CENTRIFUGAL FAN

APPRIXIMATE ROOM NOISE CRITERIA - ONE FAN COIL UNIT ONLY

MODEL NUMBER	FAN SPEED	NOM COOLING CAPACITY - KW	ROOM VOLUME - CUBIC METERS 10	20	30	40	50	60	70	80	90	100	150	200	250	300	350	400	450
42WK 004	HIGH	1.52		**44**	**43**	**42**	42	42	41	41	41								
	MEDIUM	1.37	40	**37**	**36**	**35**	35	35	34	34	34								
	LOW	1.22	31	**27**	**26**	**25**	25	25	24	24	24								
42WK 008	HIGH	2.85		45	44	**43**	**43**	**43**	**42**	**42**	**42**	42	41	41	40	40			
	MEDIUM	2.57	45	42	41	**40**	**40**	**40**	**39**	**39**	39	39	38	38	37				
	LOW	2.28	34	31	**30**	**28**	**28**	**28**	**27**	27	27	27	26	26					
42WK 010	HIGH	3.85													45	45	45		
	MEDIUM	3.46			45	44	**44**	**44**	**43**	**43**	**43**	**43**	42	42	41	41	41		
	LOW	3.08	43	40	39	**38**	**38**	**38**	**37**	**37**	**37**	37	36	36	35	35	35		
42WK 016	HIGH	5.89							45	**45**	**45**	**45**	**44**	44	43	43	43	43	43
	MEDIUM	5.30		43	42	41	41	41	**40**	**40**	**40**	**40**	**39**	39	38	38	328	38	
	LOW	4.71	37	34	33	32	32	**32**	**31**	**31**	**31**	**31**	**30**	30	28	28	28	28	
42WK 020	HIGH	7.66																	
	MEDIUM	6.89											**45**	**45**	44	44	44	44	44
	LOW	6.13			42	41	41	41	40	**40**	**40**	**40**	**39**	39	38	38	38	38	38

NOMINAL COOLING CAPACITY IS AT 6 Deg C ENTERING CHILLED WATER, 5 Deg C WATER RISE & 15 Deg C AIR ENTERING WET BULB TEMP

FAN COIL UNIT MOUNTED ABOVE CELING DISCHARGING INTO OCCUPIED SPACE

DISTANCE TO LISTENER IS 1.5 METERS

ROOMS 10 TO 50 CUBIC METERS HAVE .5 SEC REVERBERATION TIME

ROOMS 60 TO 150 CUBIC METERS HAVE .7 SEC REVERBERATION TIME

ROOMS 200 TO 350 CUBIC METERS HAVE .8 SEC REVERBERATION TIME

ROOMS 400 TO 450 CUBIC METERS HAVE .9 SEC REVERBERATION TIME

SHADED AREAS INDICATE THAT ROOM NC LEVEL IS ABOVE NC45

FAN SPEEDS AND SOUND CORRESPOND TO 220 VOLT SUPPLY

FOR TWO IDENTICAL UNITS IN OCCUPIED SPACE ADD 3

FOR THREE IDENTICAL UNITS IN OCCUPIED SPACE ADD 5

FOR FOUR IDENTICAL UNITS IN OCCUPIED SPACE ADD 6

UNDERLINED BOLD TYPE INDICATES RANGE OF NORMAL UNIT OPPERATION (FROM .08 TO .19 KW PER SQ METER FLOOR AREA)

42X FAN COIL UNIT WITH CENTRIFUGAL FAN – 220 VOLT SUPPLY
UNIT FAN SOUND POWER LEVELS RE 10 – 12 WATTS

MODEL NUMBER	FAN SPEED	FREQUENCY - Hz 125	250	500	1K	2K	4K	8K
42X 01	HIGH	39	45	42	38	33	25	20
	MEDIUM	36	42	38	34	28	23	19
	LOW	32	37	34	29	24	19	15
42X 02	HIGH	43	49	46	42	38	30	22
	MEDIUM	39	45	42	38	33	25	20
	LOW	32	37	34	29	24	19	15
42X 03	HIGH	48	51	50	46	42	33	23
	MEDIUM	40	44	41	35	27	20	14
	LOW	34	38	33	24	18	14	10
42X 04	HIGH	52	55	53	50	48	41	29
	MEDIUM	40	44	41	35	27	20	14
	LOW	34	38	33	24	18	14	10
42X 05	HIGH	60	62	60	57	54	49	39
	MEDIUM	52	55	53	50	48	41	29
	LOW	40	44	41	35	27	20	14
42X 06	HIGH	58	57	59	54	50	42	36
	MEDIUM	56	55	56	51	44	37	31
	LOW	48	44	42	35	30	24	17
42X 07	HIGH	61	61	62	58	53	47	39
	MEDIUM	48	44	42	51	44	37	31
	LOW	61	61	62	35	30	24	17
42X 08	HIGH	53	56	55	51	47	38	26
	MEDIUM	51	54	52	48	44	34	23
	LOW	45	49	46	42	37	26	15
42X 10	HIGH	55	59	57	53	49	42	32
	MEDIUM	51	54	52	48	44	34	23
	LOW	45	49	46	42	37	26	15
42X 12	HIGH	58	63	60	57	55	45	41
	MEDIUM	55	57	55	51	45	42	32
	LOW	43	46	46	41	37	27	18

42X ROOM FAN COIL UNITS WITH CENTRIFUGAL FAN
APPROXIMATE ROOM NOISE CRITERIA – ONE FAN COIL ONLY

MODEL NUMBER	FAN SPEED	NOM COOLING CAPACITY – KW	ROOM VOLUME – CUBIC METERS 10	15	20	25	30	35	40	45	50	60	70	80	90	100	150	200	250	300
42X 01	HIGH	0.5	**39**	**37**	36	36	35	35	34											
	MEDIUM	0.45	**35**	**33**	32	31	31	31	30											
	LOW	0.38	**31**	28	27	26	26	26												
42X 02	HIGH	0.94	**41**	**41**	**40**	**40**	**39**	39	38	38	38	38								
	MEDIUM	0.85	**37**	**37**	**36**	**36**	35	35	34	34	34									
	LOW	0.71	**28**	**28**	27	26	26	26	25	25										
42X 03	HIGH	1.15		**44**	**44**	**44**	**43**	**43**	42	42	42	42	41							
	MEDIUM	1.04	38	**36**	**35**	**35**	**34**	34	33	33	33	33								
	LOW	0.86	**30**	**27**	**26**	**26**	25	25	24	24	24									
42X 04	HIGH	1.43													45					
	MEDIUM	1.29	38	**36**	**35**	**35**	**34**	**34**	**33**	33	33	33	32	32						
	LOW	1.07	30	**27**	**26**	**26**	**25**	**25**	24	24	24	24	23							
42X 05	HIGH	2.05																		
	MEDIUM	1.85													45	45	45			
	LOW	1.54	38	36	**35**	**35**	**34**	**34**	**33**	**33**	**33**	33	32	32	32	32				
42X 06	HIGH	2.48											**45**	**45**	45	44	43	43	42	
	MEDIUM	2.23	45	42	41	41	**40**	**40**	**39**	**39**	**39**	**39**	**38**	38	38	38	37	37		
	LOW	1.86	33	31	30	**30**	**28**	**28**	**27**	**27**	**27**	**27**	26	26	26	26	25			
42X 07	HIGH	3																	45	45
	MEDIUM	2.70	45	42	41	41	40	**40**	**39**	**39**	**39**	**39**	**38**	**38**	38	38	37	37	36	–
	LOW	2.25	33	31	30	30	**28**	**28**	**27**	**27**	**27**	**27**	**26**	26	26	26	26	25		
42X 08	HIGH	3.4																	45	45
	MEDIUM	3.06							**45**	**45**	**45**	**45**	**43**	**43**	**43**	43	42	42	41	41
	LOW	2.55	43	41	40	40	**39**	**39**	**38**	**38**	**38**	**38**	**37**	**37**	37	37	36	36	35	
42X 10	HIGH	3.48																		
	MEDIUM	3.13							**45**	**45**	**45**	**45**	**43**	**43**	**43**	**43**	42	42	41	41
	LOW	2.61		41	40	40	39	**39**	**38**	**38**	**38**	**38**	**37**	**37**	**37**	37	36	36	35	35
42X 12	HIGH	4.6																		
	MEDIUM	4.14																	45	45
	LOW	3.45					39	49	38	38	38	**38**	**37**	**37**	**37**	**37**	**36**	36	35	35

NOMINAL COOLING CAPACITY IS AT 6 Deg C ENTERING CHILLED WATER, 5 Deg C WATER RISE & 15 Deg C AIR ENTERING WET BULB TEMP
FAN COIL UNIT MOUNTED INSIDE OCCUPIED SPACE
DISTANCE TO LISTENER IS 1.5 METERS
ROOMS 10 TO 50 CUBIC METERS HAVE .5 SEC REVERBERATION TIME
ROOMS 60 TO 150 CUBIC METERS HAVE .7 SEC REVERBERATION TIME
ROOMS 200 TO 300 CUBIC METERS HAVE .7 SEC REVERBERATION TIME
SHADED AREAS INDICATE THAT ROOM NC LEVEL IS ABOVE NC45
FAN SPEEDS AND SOUND CORRESPOND TO 220 VOLT SUPPLY
UNDERLINED BOLD TYPE INDICATES RANGE OF NORMAL OPERATION
FOR TWO IDENTICAL UNITS IN OCCUPIED SPACE ADD 3
FOR THREE IDENTICAL UNITS IN OCCUPIED SPACE ADD 5
FOR FOUR IDENTICAL UNITS IN OCCUPIED SPACE ADD 6

42X FAN COIL UNIT WITH TANGENTIAL FAN – 220 VOLT SUPPLY UNIT FAN SOUND POWER LEVELS RE 10 – 12 WATTS								
MODEL NUMBER	FAN SPEED	FREQUENCY - Hz						
		125	250	500	1K	2K	4K	8K
42X 01	HIGH	38	44	39	34	25	19	15
	MEDIUM	37	42	34	27	20	18	12
	LOW	35	32	25	20	17	16	10
42X 02	HIGH	41	48	47	44	36	26	20
	MEDIUM	37	42	34	27	20	18	12
	LOW	35	32	25	20	17	16	10
42X 03	HIGH	40	45	44	40	30	22	16
	MEDIUM	38	40	36	32	24	18	13
	LOW	35	36	32	27	21	15	11
42X 04	HIGH	45	49	49	45	37	30	23
	MEDIUM	40	45	44	40	30	22	16
	LOW	35	36	32	27	21	15	11
42X 05	HIGH	47	50	52	49	42	37	30
	MEDIUM	45	48	49	46	38	32	26
	LOW	43	42	40	35	27	20	15
42X 06	HIGH	53	54	57	52	47	37	25
	MEDIUM	52	53	55	50	44	33	21
	LOW	41	46	41	35	29	20	9
42X 07	HIGH	56	57	59	56	50	41	29
	MEDIUM	52	53	55	50	44	33	21
	LOW	41	46	41	35	29	20	9

42X ROOM FAN COIL UNITS WITH TANGENTIAL FAN APPROXIMATE ROOM NOISE CRITERIA – ONE FAN COIL ONLY																				
MODEL NUMBER	FAN SPEED	NOM COOLING CAPACITY – kW	ROOM VOLUME – CUBIC METERS																	
			10	15	20	25	30	35	40	45	50	60	70	80	90	100	150	200	250	300
42X 01	HIGH	0.5	**36**	**34**	*33*	*32*	*32*	*32*	*31*											
	MEDIUM	0.45	**33**	**31**	*30*	*28*	*27*	*27*	*27*											
	LOW	0.38	**21**	*19*	*19*	*18*	*17*	*17*												
42X 02	HIGH	0.94	**45**	**43**	**42**	**42**	**41**	*41*	*40*	*40*	*40*	*40*								
	MEDIUM	0.85	**33**	**31**	**30**	**28**	*27*	*27*	*27*	*27*	*27*									
	LOW	0.71	**21**	**19**	*19*	*18*	*17*	*17*	*17*	*17*										
42X 03	HIGH	1.15	*41*	**39**	**38**	**38**	**37**	**37**	*36*	*36*	*36*	*36*	*35*							
	MEDIUM	1.04	*33*	**31**	**30**	**30**	**28**	*28*	*27*	*28*	*27*	*27*								
	LOW	0.86	**28**	**26**	**25**	**25**	*24*	*24*	*23*	*24*	*23*									
42X 04	HIGH	1.43		*45*	**43**	**43**	**42**	**42**	**41**	**41**	*41*	*41*	*40*	*40*	*40*					
	MEDIUM	1.29	*41*	**39**	**38**	**38**	**37**	**37**	**36**	*36*	*36*	*36*	*35*	*35*						
	LOW	1.07	*28*	**26**	**25**	**25**	**24**	**24**	*23*	*23*	*23*	*23*	*22*							
42X 05	HIGH	2.05				**45**	**45**	**45**	**45**	**45**	**45**	**45**	*44*	*44*	*44*	*44*	*43*			
	MEDIUM	1.85		*45*	**44**	**44**	**43**	**43**	**42**	**42**	**42**	**42**	*41*	*41*	*41*	*41*	*40*			
	LOW	1.54	*37*	*35*	**34**	**34**	**33**	**33**	**32**	**32**	**32**	*32*	*31*	*31*	*31*	*31*				
42X 06	HIGH	2.48																		
	MEDIUM	2.23											**45**	*45*	*45*	*45*	*43*	*43*		
	LOW	1.86	*40*	*38*	*37*	**37**	**36**	**36**	**35**	**35**	**35**	**35**	*34*	*34*	*34*	*34*	*33*			
42X 07	HIGH	3																		
	MEDIUM	2.70											**45**	**45**	*45*	*45*	*43*	*43*	*42*	
	LOW	2.25	*40*	*38*	*37*	*37*	**36**	**36**	**35**	**35**	**35**	**35**	**34**	*34*	*34*	*34*	*33*	*33*		

NOMINAL COOLING CAPACITY IS AT 6 Deg C ENTERING CHILLED WATER. 5 Deg C WATER RISE & 15 Deg C AIR ENTERING WET BULB TEMP
FAN COIL UNIT MOUNTED INSIDE OCCUPIED SPACE
DISTANCE TO LISTENER IS 1.5 METERS
ROOMS 10 TO 50 CUBIC METERS HAVE .5 SEC REVERBERATION TIME
ROOMS 60 TO 150 CUBIC METERS HAVE .7 SEC REVERBERATION TIME
ROOMS 200 TO 300 CUBIC METERS HAVE .7 SEC REVERBERATION TIME
SHADED AREAS INDICATE THAT ROOM NC LEVEL IS ABOVE NC45
FAN SPEEDS AND SOUND CORRESPOND TO 220 VOLT SUPPLY
UNDERLINED BOLD TYPE INDICATES RANGE OF NORMAL OPERATION
FOR TWO IDENTICAL UNITS IN OCCUPIED SPACE ADD 3
FOR THREE IDENTICAL UNITS IN OCCUPIED SPACE ADD 5
FOR FOUR IDENTICAL UNITS IN OCCUPIED SPACE ADD 6

SECTION 8 - CONTROLS

8.1 Chillers and Heat Pumps

Carrier chillers and heat pumps are supplied as a single package complete with all necessary equipment to start and stop the unit and all necessary safety devices. Although the control systems used can vary from model to model, and some units include features that others do not, in general they follow the logic detailed below.

8.1.1 Electrical supply

All chillers require a fused three phase plus neutral electrical supply terminating in a field-supplied isolator located on or adjacent to the chiller or heat pump.

8.1.2 Power components

All hydronic chillers and heat pumps will contain a three phase compressor/s, one or three phase condenser fan/s and one single phase circulating pump and compressor crankcase heater/s. The need for these power components is obvious, with the exception of the crankcase heaters, which may need some explanation.

8.1.3 Crankcase heaters

The oil used to lubricate a refrigerant compressor circulates around within the refrigerant system passing from compressor to condenser to evaporator and back again to the compressor. To improve circulation and ensure that oil returns to the compressor the oil used is specially designed to have an affinity for the refrigerant used. It is therefore possible for the oil within the sump of a compressor to have large quantities of refrigerant dissolved within it. If nothing is done to remove this dissolved refrigerant, it will cause the oil to foam at compressor start up. Quantities of refrigerant/oil foam can be pumped away by the compressor resulting in oil starvation and compressor damage. To prevent this, each compressor sump is fitted with a crankcase heater to gently boil off dissolved refrigerant from within the oil. This crankcase heater is energised when the compressor switches off. Care has to be taken to energise the crankcase heaters for at least 24 hours prior to starting a chiller or heat pump that has been switched off for an extended period. It must also be noted that a chiller or heat pump that is apparently isolated can contain live crankcase heater terminals.

8.1.4 Compressor motor cooling

To minimise the possibility of refrigerant leakage through glands around shafts, hydronic chillers and heat pumps are provided with hermetic or semi-hermetic compressors. This means that the compressor motor is an integral part of the compressor housing and must therefore be provided with cooling. This is achieved by passing the cold suction gas returning from the evaporator over the motor windings prior to the gas reaching the compressor.

8.1.5 Safety devices

A chilled water flow switch or water differential pressure switch prevents the chiller from starting if the circulating pump is not running. This should be field-supplied if not fitted as part of the unit.

Minimum water temperature safety stat switches the unit off if chilled water gets below 3°C - normally auto reset.

Chilled water thermostat used to cycle the chiller on and off to maintain a constant water supply temperature.

Hot water thermostat used to control the hot water temperature in a heat pump.

Antifreeze thermostat brings in the antifreeze heaters if water temperature drops below 3°C.

Compressor motor klixon cuts power to the compressor when the temperature of the compressor motor windings exceeds set limits - auto reset.

High pressure switch cuts out the compressor if the compressor discharge pressure gets too high - generally manual reset.

Low pressure switch cuts off the compressor if the suction pressure becomes too low - manual reset.

Defrost control - heat pumps operating in heating mode in very cold weather can suffer from a build up of frost and ice on the outside air coil. A thermostat detects this build up and switches the unit into cooling mode for a short time thus passing hot discharge gas from the compressor through the outside air coil to melt this frost. The unit then reverts to heating mode.

Compressor anti-short cycle relay provides a minimum time delay of about six minutes between compressor starts to prevent the compressor motor from overheating.

Heat pump four-way valve to divert the discharge gas from the outside air coil to the refrigerant/water heat exchanger and back again as the heat pump switches from cooling to heating mode and vice versa.

Optional head pressure controller used in cooling only chillers that have to operate during winter - cycles or speed controls a condenser fan to maintain a minimum condensing pressure.

8.2 Room Terminals - general

These are provided with three speed supply fans. In addition, ceiling cassette units have a condensate pump fitted. All units are available with or without water control valve packages. Room fan coil units can be provided with unit- or remote-mounted thermostat and fan speed controls. Ceiling cassettes must have remote-mounted thermostat.

8.2.1 Electrical supply

Both ceiling cassette and room fan coil units require a single phase electrical supply, which is usually provided by means of a switched spur adjacent to the unit.

8.2.2 Fan coil unit temperature controls

Two-Pipe Systems

Cooling only
Each unit will be supplied with either a unit-mounted or wall-mounted temperature controller. This controller will have the following functions:

Room temperature control
The controller will turn on/off the unit cooling valve based on the user setpoint which is adjustable on the controller.

Fan speed
The controller will have a three position switch which will be user adjusted to select their required fan speed.

On/off
The controller may have a manual on/off switch.

Changeover system
In a two-pipe changeover system the fan coil units will be supplied with hot or cold water from the central plant. This plant would either be a heat pump unit or a cooling only unit with a gas boiler.

Each unit will be supplied with either a unit-mounted or wall-mounted temperature controller. This controller will have the following functions:

Room temperature control
The controller will control the room temperature based on the user's setpoint which is adjustable on the controller. The controller will control its valve in either heat or cooling mode based on one of the following:

a. Heat/cool select switch on the controller
b. A clamp-on pipe thermostat which based on the water temperature in the pipe changes the mode of the controller.

Fan speed
The controller will have a three position switch which will be user-adjusted to select their required fan speed.

On/off
The controller may have a manual on/off switch.

Four Pipe Systems

In a four-pipe fan coil system both hot and cold water is supplied to the fan coil unit via the main plant.

Each unit will be supplied with either a unit-mounted or wall-mounted temperature controller. This controller will have the following functions:

Room temperature control
The controller will control the room temperature based on the user's setpoint which is adjustable on the controller. It will turn on or off its heating or cooling valve to maintain its room temperature setpoint.

Fan speed
The controller will have a three position switch which will be user adjusted to select their required fan speed.

On/off
The controller may have a manual on/off switch.

8.2.3 System controls - general

Automatic timeclock control

In section 8.2.2 all the unit types can be turned on/off via a manual switch on the controller. If automatic timeclock control is required a separate timeclock must be provided. This timeclock would, via relays and contactors, be able to switch the units and the main plant on and off to the user's requirements.

System changeover

On two-pipe changeover systems the main plant must be changed over from heating to cooling manually.

On a heat pump this would be done via a heat/cool selector switch.

8.2.4 Frost protection

Building frost protection, if required, would be controlled by an outside air thermostat. If the temperature outside is cold enough to make the thermostat then the main plant pumps would be started and the heat pump started in heating mode, or if a gas boiler is used it would be started.

All externally exposed pipework should be trace heated, controlled by an outside air thermostat.

8.2.5 Optimization

An optimizer is used to ensure that the building is up to its required temperature by occupancy.

Note: If optimization is required then an automatic timeclock is required.

8.2.6 Compensation

If a gas boiler is used, a compensator can be used to adjust the flow temperature to the fan coil units based on outside air temperature.