Palestine Polytechnic University

College of Engineering and Technology
Mechanical Engineering Department

Graduation Prpject

Design of an Air conditioning System for Abu-al-hassan Al-Qasem (Yatta) Governmental Hospital

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جامعة بوليتكنك فلسطين
فلسطين – الخليل
كلية الهندسة والتكنولوجيا
دائرة الهندسة الميكانيكية

اسم المشروع

Design of an Air Conditioning For Abu Al-Hassan Alqasim (Yatta) Hospital

أسماء الطلبة

فؤادشحدة عبد داود   عبد ا   زكي خلاوي

بناء على نظام كلية الهندسة والتكنولوجيا وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الميكانيكية، وذلك للوفاء بمتطلبات درجة البكالوريوس في الهندسة تخصص سيارات

توقيع المشرف

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توقيع اللجنة الممتحنة

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توقيع رئيس الدائرة

....

الشكر والتقدير

الى الاستاذ المشرف كاظم العسيلي لما بذله من جهد في مساعدتنا على اتمام هذا العمل واخراجه بهذه الصورة

الى الدكتور اسحق سدر على المشورة التي اسداها لنا اثناء جمعنا لمادة هذا المشروع

الى العاملين في مكتبتي جامعة بوليتكنيك فلسطين وبلدية الخليل لما قدموه لنا من مساعدة في الحصول على الكتب والمراجع بسهولة

الى المهندس طلعت عواد لمساعدته لنا في الحصول على المخططات المعمارية للمستشفى

الى جميع الطلبة الذين ساعدونا على انجاز هذا العمل

إهداء

إلى الزهرة التي لا تذبل ......نبع الحنان .... إلى أمي

إلى الماس الذي لا ينكسر.....نبع العطاء .... إلى والدي

إلى ملائكة الأرض ....شقائق النعمان...................إلي أشقائي

إلى قناديل الدرب..........الشموع التي لا تنطفئ .... إلى أساتذتي

إلى رفاق الدرب .... بناة المستقبل .... إلى أصدقائي
الى كل طالب علم................ احرق المحتل........................ كتابه

الى كل عجوز ....كسر المحتل....................... عكازة

إلى صناع الكرامة .... رايات المجد .... إلى شهدائنا

إلى من رفضوا الخضوع .... من طلبوا العزة ....إلى أسرانا

Chapter One

Introduction

Contents:-

(1) Introduction

The engineering area frequently referred to as thermal science includes thermodynamics and heat transfer, The role of heat transfer is to supplement thermodynamic analyses, which consider only systems in equilibrium, with additional laws that allow prediction of time rates of energy transfer.

These supplemental laws are based upon the three fundamental modes of heat transfer, namely conduction, convection, and radiation.

(1.1) Conduction

A temperature gradient within a homogeneous substance results in an energy transfer rate within the medium which can be calculated by

$$q = -KA\frac{\partial T}{\partial x} \qquad (1.1)$$

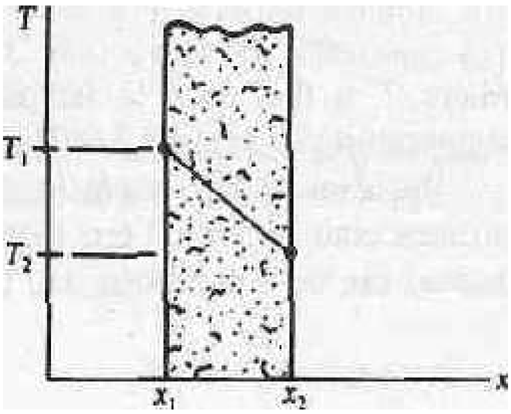


Fig. 1.1

Where is $\partial T/\partial x$ the temperature gradient in the direction normal to the area A , The thermal conductivity k is an experimental constant for the medium involved, and it may depend upon other properties, such as temperature and pressure, The units of k are W/m.K .

The minus sign in Fourier's law: (1.1), is required by the second law of thermodynamics: thermal energy transfer resulting from a thermal gradient must be from a warmer to a colder region.

If the temperature profile within the medium is linear (Fig. 1-1), it is permissible to replace the temperature gradient (partial derivative) with

$$\frac{\Delta T}{\Delta x}=\frac{T_2-T_1}{x_2-x_1} \qquad (1.2)$$

Such linearity always exists in a homogeneous medium of fixed k during steady state heat transfer, Steady state transfer occurs whenever the temperature

$$q_{(stored)}=mc_p\frac{\partial T}{\partial t} \qquad (1.3)$$

at every point within the body, including the surfaces, is independent of time. If the temperature changes with time, energy is either being stored in or removed from the body. This storage rate is

Where the mass m is the product of volume V and density ρ and t is time (second)

(1.2) Convection

Whenever a solid body is exposed to a moving fluid having a temperature different from that of the body, energy is carried or convected from or to the body by the fluid.

If the upstream temperature of the fluid is T_∞, and the surface temperature of the solid is T_s the heat transfer per unit time is given, by

$$q=hA(T_s-T_\infty) \qquad (1.4)$$

Which is known as Newton's law of cooling , This equation defines the convective heat transfer coefficient *h* as the constant of proportionalily relating the heat transfer per unit time and unit area to the overall temperature difference. The units of *h* are

$$hA(T_s-T_\infty)=-KA(\frac{\partial T}{\partial y})_s \qquad (1.5)$$

$W/m^2.K$, It is important to keep in mind that the fundamental energy exchange at a solid-fluid boundary is by conduction, and that this energy is then convected away by the fluid flow, by comparison of (1.1) and (1.4), we obtain, for y = x

Where the subscript on the temperature gradient indicates evaluation in the fluid at the surface .

(1.3) Radiation

The third mode of heat transmission is due to electromagnetic wave propagation, which can occur in a total vacuum as well as in a medium. Experimental evidence indicates that radiant heat transfer is proportional to the fourth power of the absolute temperature, whereas conduction and convection are proportional to a linear temperature difference. The fundamental Stefan-Boltzmann law is

$$q=\sigma A T^4 \qquad (1.6)$$

Where T is the absolute temperature. The constant σ is independent of surface, medium, and temperature; its value is 5.6697 X 10^{-8} $W/m^2 K^4$

The ideal emitter, or blackbody, is one which gives off radiant energy according to (1.6). All other surfaces emit some what less than this amount, and the thermal emission from many surfaces (gray bodies) can be well represented by

$$q = \varepsilon \sigma A T^4 \qquad (1.7)$$

Where ε the emissivity of the surface, ranges from zero to one.

(1.5) Plane wall

A plane wall of a uniform, homogeneous material a having constant thermal conductivity and exposed to fluid (at temperature T_i on one side and fluid at temperature T_o on the other sideis shown in Fig. (1.2)(a). Frequently the fluid temperatures sufficiently far from the wall to be unaffected by the heat transfer are known, and the surface temperatures T_i and T_o are not specified.
Applying (1.4) at the two surfaces yields

$$\frac{q}{A} = h_i (T_i - T_1) = h_o (T_2 - T_1) \qquad (1.8)$$

or

$$q = \frac{T_i - T_1}{1/h_i A} = \frac{T_2 - T_o}{1/h_i A} \qquad (1.9)$$

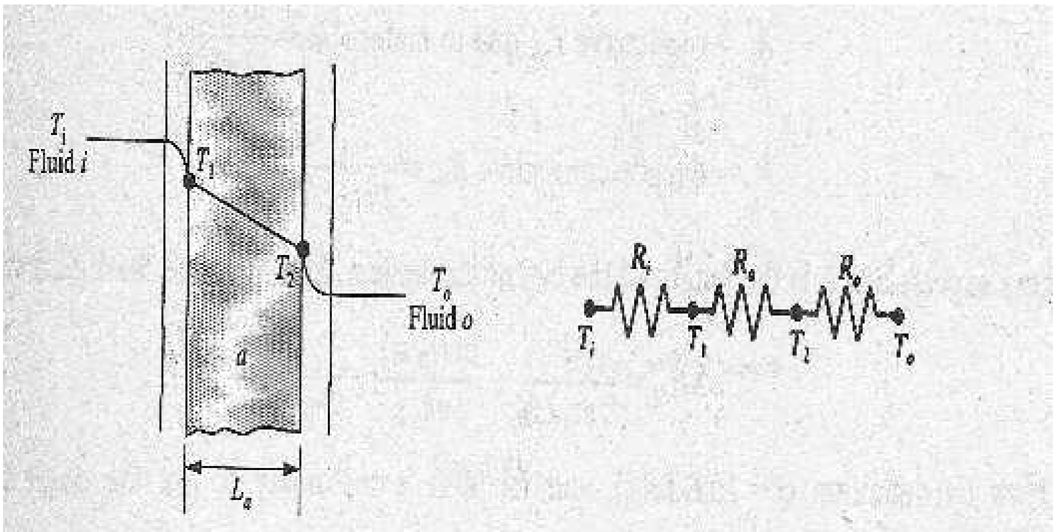


fig. 1.2b

1/hA can be thought of as a thermal resistance due to the convective boundary. Thus, the electrical analog to this problem is that of three resistances in series, Fig. (1.2)(b).

Here, $R_a = L_a/k_aA$ is the conductive resistance due to the .homogeneous material . Since the conductive heat flow within the solid must exactly equal the convective heat flow at the boundaries, ((1.8) and (1.9)) gives

$$\frac{q}{A} = \frac{T_i - T_o}{1/h_i + L_a/K_a + 1/h_o} = \frac{(\Delta T)_{overall}}{A\sum R_{th}} \qquad (1.10)$$

$$U = \frac{1}{A\sum R_{th}} \qquad (1.11)$$

U: overall heat-transfer coefficient.

for any geometry, we see that

$$\frac{q}{A} = U(\Delta T)_{overall} \qquad (1.12)$$

$$U = \frac{1}{1/h_i + L_a/K_a + 1/h_o} \qquad (1.13)$$

and for the plane wall of fig. (1.2)(a)

For a multi layered plane wall consisting of layers a, b, ...

$$U = \frac{1}{1/h_i + L_a/K_a + L_b/K_b + \cdots + 1/h_o} \qquad (1.14)$$

(1.6) Heat loss by temperature difference

The heat loss through walls ,ceiling roofs , windows , ground and doors is caused by the temperature difference between inside and the outside of the building. This heat is calculated from

$Q = U A (t_I - t_o)$ (1.15)

Where

Q : Heat load (W).

U : Over all heat transfer coefficient ($W/m^2.^oC$)
A : Surface area(m^2).
t_o : Out side temperature
t_I : Inside temperature

(1.7) Ventilation

Buildings in which people live and work must be ventilated to replenish oxygen, dilute the concentration of carbon dioxide and water vapor, and minimize unpleasant odors. A certain amount of air movement or ventilation ordinarily is provided by air leakage through small crevices in the building's walls, especially around windows and doors. Such haphazard ventilation may suffice for homes, but not for public buildings such as offices and theaters, or for factories.

$$Q_{ventilation} = \dot{V} \circ_{air} (h_o - h_i) \qquad 1.16$$

ρair: Density of air (kg/m3(
ho , hI : Enthalpy of dry air from psychometric chart (chart7)
ho = 10 K J/kg at 3 oC , ho=84 K J/kg at 35 oC, Φ = 50%
h I= 40 K J/kg at 21 oC, hI=48 K J/kg at 24 oC , Φ = 50%
Φ : Relative humidity

$$\dot{V} = No \times v \qquad 1.17$$

No : maximum number of person in the space
v : Volume of air that need for one person (l/s/person) from table A17

Chapter Two

Heating and Cooling loads:-

Contents:-

(2.1) Heat loss occurred by two (main) methods:-

1) Air-infiltration heat loss.
2) Heat transmission loss.

Natural air-infiltration is sufficient in the following conditions:-
1) Each person must have 4.65 m^2 (50 ft^2) of the floor area.
2) Each person must have 14.16 m^3 (500 ft^3) of the room air.
3) Windows openings must be at least 5% of the floor area.
4) The air must be renewed at a rate of 17 m^3 (600 ft^3)/hour per one person.

* Rules of air-infiltration are summarized in the following table:-

Number of external walls (subjected to air)	The value of air-infiltration
One wall	The sum of air-infiltration across walls and doors
Two walls	The larger value across the two walls
Three or four walls	The larger value of the following:- 1) the larger value of air infiltration of walls 1) half of the sum of air-infiltration of the walls

Table 2.1

* The following table explains the number of air renewals per hour:-

Number of walls exposed to air	Number of air renewals per hour
1	1.0
2	1.5
3	2.0
4	2.0
Reception	2.0
Bathroom	2.0
Store	3.0
Garage	12.0
Kitchen	25-30
Hospital operating rooms	20
Hospital treatment rooms	10
Smoking rooms	10-15

Table 2.2

(2.2) Dentist clinic room was taken as an example:-

(2.2.1) Data:-

Outside temperature = 3 °C (37.4 °F).

$$Volume = 4.77 \times 3.30 \times 3.64 m^3 (15.56 \times 10.38 \times 11.35 ft^3)$$

Inside temperature = 21 °C (69.8 °F).
Outside wind velocity = 3 m/s (6.71mile/hr).
Number of expected persons to be found = 3 persons.

Windows:-
Number of windows = 2; (each is composed of tow half's). double glassing.
.

$\text{dimensions} = 1.56 \times 1.20 \text{m}^2 \ (5.12 \times 3.94 ft^2)$
Doors:-
It has one wooden door opens to the sub wait.

$\text{dimensions} = 1.95 \times 1.00 \text{m}^2 \ (6.40 \times 3.28 ft^2$

(2.2.2) Walls:-

a) South-west wall; composed of the following layers:-

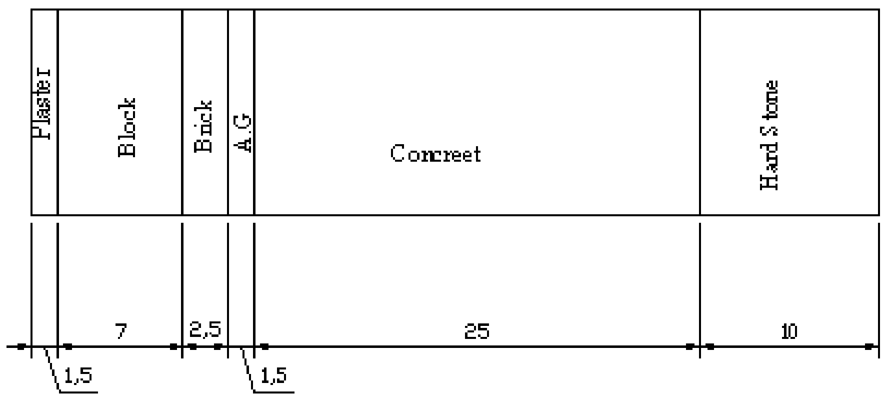


Fig.(2.1)

1) Hard stone (HS):
X = 0.1 m (0.328 ft),
K = 2.2 W/m. °C (table A7)

$$R_{(HS)} = \frac{X}{K} = \frac{0.1}{2.2} = 0.0455 \ m^2.°c / W \qquad (2.1)$$

2) Concrete (Con.):-
X = 0.25 m (0.82 ft).
K = 1.75 W/m. °C.

$$R_{(con)} = \frac{0.25}{1.75} = 0.143 \ m^2.°c / W$$

3) Air gap (AG.):-

X = 0.015 m (0.05 ft).
$R_{(A.G.)}$ = 0.18 m^2 .°C/ W. (table A4).

4) Brick (b):-
X = 0.025 m (0.082 ft).
K = 0.8 W/m. °C.

$$R_{(b)} = \frac{0.025}{0.8} = 0.0313 m^2.°c/W$$

5) Block (B):-
X = 0.07 m (0.23 ft).
K = 1.2 W/m. °C.
$R_{(B)}$ = 0.0683 m^2. °C/W.

6) Plaster (p):-
X = 0.015 m (0.05 ft).
K = 1.2 W/m. °C.

$$R_{(P)} = \frac{0.015}{1.2} = 0.0125 m^2.°c/W$$

b) South-east wall; composed only from three layers, it has neither insulating layers nor air gap; the other layers have the same dimensions and thermal conductivities as in the south-west wall, the three layers are-
1) Hard stone. 2) Concrete. 3) Plaster.

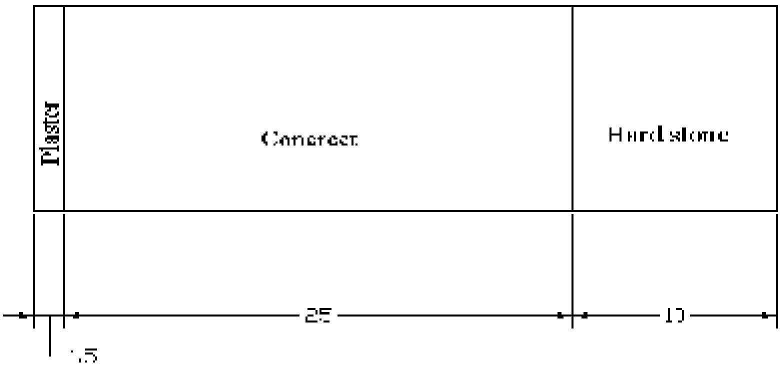


Fig.(2.2)

(2.2.3) Air-infiltration heat loss through south-west wall

The crack length method is used in the following calculations as it provides a considerable accuracy.
The perimeters for the two windows are estimated as follows:-

Perimeter = 2(3×5.12+2×3.94) = 46.5 ft (14.16 m).

From table A1 :-

$$\frac{6.71-5}{10-5}(108-52)+52=71.1 ft^3/hr/ft$$

So air-infiltration through the windows per hour = 46.5×71.1
= 3306.2 ft^3/hr (93.6 m^3/hr).

* South-east wall has neither windows nor doors, so air-infiltration through it is zero; the building is subjected to air from both sides, accordingly the number of air renewals is 1.5 times per hour, and the required volume of air is given by:-

$$V = No. \times v \qquad (2.2)$$

Where:-
V: Required volume of air.
No: number of air changes per hour; (table 2-1).
V: volume of the room.

$$V = 1.5(15.65\times10.38\times11.35) = 2766\, ft^3/hr\ (78.3\, m^3/hr)$$

* The value of air infiltration through windows per hour (93.6m^2/hr) must be larger than the required value (78.3m^3/hr), such that the ratio between the two values must not exceed 50%.

$$\text{i.e.} \frac{93.6-78.3}{78.3}\times100\% \le 50\%$$

The result is 20% and this value is acceptable.

The volume of air, which is required for thee persons V_{ap}
, is given by the following equation:-

V_{ap} = 17(No. of people) (2.3)

V_{ap} must be ≤ 93.6; otherwise, ventilated air must be used to ensure a person comfort.

V_{ap} = 17(3) = 51 m^3/hr

And this value occurs within our range.

$$\text{Area of the floor per one person} = \frac{4.77\times3.30}{3} = 5.3 m^2.$$

And the least required value per one person is 4.65 m^2.

$$\text{Volume of air per one person } \frac{4.77\times3.3\times3.64}{3} = 19.1m^3$$

And the least required volume is 14.2 m^3.

Windows openings ($Win_{op.}$) per floor area is

$$Win_{op.} = \frac{1.56\times1.2\times2}{4.77\times3.30}\times100\% = 24\%$$

And the least required ratio is 5%

Conclusion: natural air-infiltration (NAI) is sufficient and there is no need for forced air-ventilation, and the value for natural air infiltration is
3306.2 ft^3/hr (93.6 m^3/hr).

The winter outside temperature in yatta is 37.4°F (3°C), thus the amount of heat per pound of dry air (from table A3) is 9.4 Btu, while for the conditioned air (69.8°F, relative humidity =45%) , the amount of heat per pound (from westing house chart) is 24.9 Btu, and the specific volume is 13.7 ft^3/pound

The amount of heat, which is lost per one pound of air, is

24.9-9.4 = 15.5 Btu

Where:

$$W_{ai} = \frac{3306.2}{13.75} = 240.5lb/hr$$

W_{ai}: weight of air-infiltration.

Thus the air-infiltration heat loss (Q_{inf}) can be estimated as follows:-
Q_{inf} = 15.5(240.5) = 3727.8 Btu/hr (0.98 kw).

The air-infiltration heat loss may be calculated by using the law

$$Q_{inf} = CV\Delta T \tag{2.4}$$

Where:-

C: Constant from table A2.
V: Volume of the room.

Q_{inf} = 1×(4.77×3.30×3.64)×(21-3) = 1.03 kw

Note that both values are nearly equal, but the crack length method is more reliable.

(2.3) Heat transmission loss:-

As explained in chapter one, the value of heat transmission loss is given by the following equation:-

$Q = U A (t_I - t_o)$ **(2.5)**

Where

Q : Heat load(W).

U : Over all heat transfer coefficient ($W/m^2.^oC$).

$$U = \frac{1}{A\sum R_{th}} \quad (2.6)$$

A : Surface area(m^2).

t_o : Out side temperature.

t_I : Inside temperature .

(2.3.1) Overall heat transfer coefficient for the south-west wall

$$U = \frac{1}{R_{int} + R_p + R_B + R_b + R_{AG} + R_{con.} + R_{HS} + R_{ext}} \quad (2.7)$$

R_{int} and R_{ext} can be known from table A5 and table A6 respectively.

or it can be estimated using the laws :

$$R_{int} = \frac{1}{h_{int}} \quad (2.8)$$

$$R_{ext} = \frac{1}{h_{ext}} \quad (2.9)$$

$$h = 6 + 4(V) \quad (2.10)$$

Where

h_{int}: internal heat transfer coefficient.

h_{ext}: external heat transfer coefficient.

V: wind velocity.

h_{int}= 6+4(0.55) = 8.2 W/m^2.°C.

$$R_{int} = \frac{1}{8.2} = 0.121 m^2.°C$$

h_{ext}= 6+4(3) = 18 W/m^2.°C.

$$R_{ext} = \frac{1}{18} = 0.06 m^2.°C.$$

Note: the same results(nearly) can be obtained using the tables (table A5 and table A6).

$$U = \frac{1}{0.121 + 0.0125 + 0.0683 + 0.0313 + 0.18 + 0.143 + 0.0455 + 0.06}$$

=1.51 W/m^2.°C.

Q_{sw} = 1.51×(3.3×3.64)×(21-3) = 326.5 W

(2.3.2) Overall heat transfer coefficient for the southeast wall

The wall is composed only of three layers as explained before, thus the overall heat transfer coefficient can be calculated as follows:-

$$U = \frac{1}{0.12 + 0.0125 + 0.143 + 0.0455 + 0.06}$$

= 2.6 W/m^2.°C.

Q_{se} = 2.6×[4.77×3.64-2(1.56×1.2)]×(21-3) = 637.4 W.

Q_{wall} = Q_{sw}+Q_{se} (2.11)

Q_{wall} = 326.5+637.4 = 963.9 W.

U_{glass}= 3.2 W/m^2.°C. (table A8).

Q_{glass}= 3.2×2(1.56×1.2)×(21-3) = 215.6 W.

(2.4) Overall heat transfer coefficient for the roof and floor ($Q_{r\&f}$)

The roof and the floor composed from the following components:-

(Consider that the tow other stairs are not conditioned, and the temperature within them are 10°C.).

1) Tiles (burnt clay); K = 0.85 W/m. °C; X = 0.04 m.
   R_{tiles}= 0.047 m^2. °C/W.
2) Concrete. K = 1.75 W/m. °C; X = 0.08 m.
   $R_{Con.}$= 0.046 m^2. °C/W.
3) Block K = 1.2 W/m. °C; X= 0.24 m
   R_B = 0.2 m^2. °C/W.
4) Plaster. K = 1.2 W/m. °C; X = 0.015 m
   R_p = 0.0125 m^2. °C/W.

$$U = \frac{1}{0.2 + 0.0125 + 0.2 + 0.046 + 0.047 + 0.04}$$

=1.8 W/m^2.°C.

$Q_{(r\&f)}$ = 2×[1.8×(4.77×3.30)×(21-10)] = 623 W

(2.5) Heat gain from people and lights:-

Q_{people}= No.×($Q_{lat.}$+$Q_{sen.}$) (2.12)

No.: number of expected people = 3 (light work).

($Q_{lat.}$+$Q_{sen.}$): latent and sensible heat, from table A9.

Q_{people} = 3×(73.2+58.5) = 395.1 W.

Q_{light} = 30A (2.13)

A: room area.

Q_{light} = 30×(4.77×3.30) = 472.2 W.

Q_t = Q_{inf+} Q_{sw}+Q_{se}+Q_{glass} +$Q_{(r\&f)}$ -Q_{people}-Q_{light} (2.14)

Q_t = 980+326.5+637.4+215.7+623-395.1-472.2 = 1.92 kw.

Heating loads table:-

ame of the room	Area cm^2	NAI m^3/hr	Q_{inf} (W)	Q_{wall} (W)	Q_{win} (W)	$Q_{r\&f}$ (W)	Q_{people} (W)	Q_{light} (W)	Q_t (kW)
Dentistic Clinic	477×330	93.6	979.2	963.9	215.7	623	395.1	472.2	1.92
O.P. clinic	300×350	65.8	688	237.5	125.8	415.8	263.4	315	0.85
GP clinic	235× 350	51.5	538.9	173.1	125.8	325.7	137.1	246.8	0.75
Rotating	445×350	94.1	1020.5	861.3	215.7	616.8	548.4	462	1.65

Specialist									
Waiting Area	345×330	71.3	745.9	478.2	244.3	450.9	548.4	341.6	1.26
Chronic Disease Clinic	275×330	56.8	594.8	380.9	107.8	359.4	131.7	272.3	1.04
Disabled Toilet	185×270	31.3	327.3	315	62.9	197.8	131.7	149.9	0.62
Toilet Mal&fem	460×330	95.1	994.5	586.5	242.6	601.1	526.8	455.4	1.44
Waiting Area	423×853	1226.1	2364.1	514.5	302.7	1298.9	317	1082.5	2.10
Reception	340×720	153.3	1603.9	219.2	597.5	881.3	395.1	734.4	2.17
Rotating Specialist	330×333	68.8	718	474.6	107.8	395.6	263.4	329.7	1.10
Staff rest	340×333	71.1	741.8	404	215.7	407.6	526.8	339.7	0.90
Sub wait	370×750	174.3	1818.2	455.1	215.7	999	658.5	832.5	1.99
Maternal Clinic (1)	330×333	68.8	718	474.6	107.8	395.6	526.8	229.7	0.94
Maternal Clinic (2)	330×333	68.8	718	474.6	107.8	395.6	526.8	229.7	0.94
Baby clinic	328×333	68.6	715.6	471.1	107.8	390.2	395.1	227.8	1.06
Vaccination 1	340×333	71.1	741.8	491.6	107.8	407.6	395.1	339.7	1.11
vaccination 2	370×333	77.4	807.3	542.7	107.8	443.6	263.4	369.6	1.27
Child clinic	350×333	73.2	763.6	508.6	215.7	419.6	395.1	349.7	1.05
School health	340×333	71.1	741.8	971.3	179.7	407.6	1053.5	339.7	0.94
Family planning unit 1	300×483	91	949.4	365.1	179.7	413.7	263.4	434.7	1.21
Family planning unit 2	300×483	91	949.4	365.1	107.8	413.7	263.4	434.7	1.21
Toilet (m&f)	440×483	133.5	1392.4	593.2	107.8	765.1	526.8	637.6	1.78
Tel. room	200×483	16.7	173.9	253.1	107.8	347.8	131.7	289.8	0.46
Office 1	280×483	23.4	243.4	389.4	107.8	486.9	395.1	405.8	0.43
Office 2	280×483	23.4	243.4	389.4	107.8	486.9	395.1	405.8	0.43
Office 3	280×483	23.4	243.4	389.4	107.8	486.9	395.1	405.8	0.43
Office4	280×483	23.4	243.4	389.4	107.8	486.9	395.1	405.8	0.43
Office 5	280× 483	23.4	243.4	389.4	107.8	486.9	395.1	405.8	0.43
Office 6	300× 388	73.3	762.7	1084	107.8	419.1	526.8	349.2	1.50
Stairs	737× 245	113.7	1183.1	1509.5	307.3	650	526.8	541.7	2.58
Meeting room	483× 773	64.9	675.8	647.6	215.7	1344.1	790.2	1120.1	0.97
Pharmacy store	410× 773	54.8	570	523.2	215.7	1140.9	131.7	950.8	1.37
dispensary	570×210	75.3	784.3	443.2	143.8	430.1	0	359.1	1.44
Gate 2	380×773	185	1924.6	510	185	1057.5	1448.7	881.2	1.35
									41.12

Table 2.3

b) Cooling load:-

(2.6) Data:-

For the same room, which was taken as an example in heating loads; (Dentistic Clinic), most of data is the same except that of the following:-

Outside temperature = 35°C (95°F).
Inside temperature = 24°C (75.2°F).

$Q_{inf} = CV\Delta T$

$$Q_{inf} = 1 \times (4.77 \times 3.30 \times 3.64) \times (35 - 24) = 630.3W$$

$Q_{walls} = Q_{sw} + Q_{se}$

$$Q_{sw} = 1.51 \times (3.3 \times 3.64) \times (35 - 24) = 199.6W$$

$$Q_{se} = 2.6 \times (4.77 \times 3.64 - 2(1.56 \times 1.2) \times (35 - 24) = 389.8W$$

Q_{walls} = 199.6 + 389.8 = 589.4 W

$Q_{glass} = U_g A \Delta T$

$$Q_{glass} = 3.2 \times 2 \times (1.56 \times 1.2) \times (35 - 24) = 131.8W$$

$$Q_{(r\&f)} = 2 \times (1.8(4.77 \times 3.30) \times (35 - 30) = 283.4W$$

(Considering that the temperature is 30 in up stair and down stair).

$Q_{people} = No(Q_{per\ one\ person})$.

$$Q_{people} = 3 \times 131.7 = 395.1W$$

$Q_{light} = 30A$

$$Q_{light} = 30(4.77 \times 3.3) = 472.2W$$

(2.7) Solar heat

Heat gain by the sun can be estimated using the law:-

$Q_{sun} = UA\Delta T$

Where the temperature difference here is a special case in the law, and can be treated as follows:-

For east and west → $\Delta T = \Delta t + 2$ For roof → $\Delta T = \Delta t + 8$

For south → $\Delta T = \Delta t + 1$ For north → $\Delta T = \Delta t$

For the dentistic clinic Q_{sun} can be estimated as follows:-

$Q_{sun} = Q_{sun(sw)} + Q_{sun(se)} + Q_{sun(glass)}$

$$Q_{sun(sw)} = 1.51(3.3 \times 3.64)(35 - 24 + 2) = 235.8W .$$

$$Q_{sun(se)} = 2.6(4.77 \times 3.64) - 2(1.56 \times 1.2)(35 - 24 + 2) = 460.3W .$$

$$Q_{sun(glass)} = 3.2 \times 2(1.56 \times 1.2)(35 - 24 + 2) = 155.7W .$$

$Q_{sun} = 235.8 + 460.3 + 155.7 = 851.8$ W.

$Q_t = Q_{(inf)} + Q_{(wqlls)} + Q_{(glass)} + Q_{(r\&f)} + Q_{(people)} + Q_{(light)} + Q_{(sun)}$.

$Q_t = 630.3 + 589.4 + 131.8 + 283.4 + 395.1 + 472.2 + 851.8 = 3353$ W.

$= 3.35$ kW

Cooling loads table:-

Name of the room	**Q_{inf} (W)**	**Q wall (W)**	**Q windows and doors (W)**	**Q roof and floor (W)**	**Q people (W)**	**Q light (W)**	**Q sun (W)**	**Q_t (KW)**
Dentistic Clinic	630.3	589.4	131.8	283.4	395.1	472.2	851.9	3.35
O.P. clinic	420.4	145.1	76.9	189	263.4	315	262.4	1.67
GP clinic	329.3	79.9	76.9	148	137.1	246.8	215.9	1.23
Rotating Specialist	623.6	526.3	131.8	280.4	548.4	462	777.7	3.35
Waiting Area	455.8	292.2	149.3	205	548.4	341.6	221.8	2.51
Chronic Disease Clinic	363.5	232.7	65.9	163.4	131.7	272.3	353	1.58
Disabled Toilet	138.9	192.5	38.4	85.4	131.7	149.9	273.1	1.01
Toilet (Mal&fem)	607.8	358.4	148.3	263.2	526.8	455.4	598.8	2.97
Waiting Area	1444.7	314.4	185	590.4	317	1082.5	590.2	4.52
Reception	980.2	134	365.1	400.6	395.1	734.4	589.9	3.60
Rotating Specialist	438.8	290	65.9	179.8	263.4	329.7	420.6	1.99
Staff rest	453.3	246.9	131.8	185.3	226.8	339.7	447.6	2.33
Sub wait	1111.1	278.1	131.8	454.1	658.5	832.5	484.5	3.95
Maternal Clinic (1)	438.8	290	65.9	179.9	526.8	229.7	420.5	2.15
Maternal	438.8	290	65.9	179.9	526.8	229.7	420.5	2.15

Clinic (2)								
Baby clinic	437.3	287.9	65.9	177.4	395.1	227.8	418.1	2.1
Vaccination 1	453.3	300.4	65.9	185.3	395.1	339.7	432.8	2.17
Vaccination 2	493.4	331.7	65.9	271.1	1371	369.6	469.8	3.32
Child clinic	466.6	310.8	65.9	190.1	1371	349.9	445.2	3.15
School health	453.3	593.6	131.8	185.3	1053.5	339.7	857.3	3.61
Family planning unit 1	580.2	223.1	109.9	188	263.4	434.7	393.5	2.91
Family planning unit 2	580.2	223.1	109.9	188	263.4	434.7	393.5	2.19
Toilet (m&f)	850.9	362.5	115.7	347.8	226.8	637.6	665.2	3.21
Tel. room	106.3	154.7	65.9	158.1	131.7	289.8	260.7	1.17
Office 1	148.7	237.9	65.9	221.3	395.1	405.8	359.1	1.38
Office 2	148.7	238	65.9	221.3	395.1	405.8	359.1	1.38
Office 3	148.7	238	65.9	221.3	395.1	405.8	359.1	1.38
Office4	148.7	238	65.9	221.3	395.1	405.8	359.1	1.38
Office 5	148.7	238	65.9	221.3	395.1	405.8	359.1	1.38
Office 6	466.1	662.5	65.9	190.5	526.8	349.2	860.7	3.12
Stairs	723	922.5	187.7	295.5	526.8	541.7	1312.1	4.51
Meeting room	413	396	131.8	611	790.2	1120.1	623.5	4.09
Pharmacy store	348.6	319.7	131.8	518.6	131.7	950.8	533.7	2.93
dispensary	479.3	271	87.9	195.5	0	359.1	424.1	1.82
Gate 2	1196.1	311.7	113.1	480.7	1448.7	881.2	501.9	4.19
								89.66

Table 2.4

For enclosed rooms and spaces such as Col 1, the following empirical equations are used:-

$Q_{heating} = V×60$ kcal/hr. (2.15)

$Q_{cooling} = V×A_{floor}×700$ Btu. (2.16)

Col 1 was taken as an example:- A = (2 × 24) m^2
$Q_{heating}$ = (2 × 24) ×3.64 × 60 = 10483 kcal/hr (10.940 kW)

$Q_{cooling}$= (2 × 24)×3.64×(2 × 24)×700 = (5870592) Btu (4.9 kW)

The following table lists the heating loads for enclosed areas:

Name of the room	Area m^2	Q_t KW
Col 1	(2 × 24)	10.94
Col 2	(9.4×2)+(7.2×4.5)	11.6

Col 3	(30×2)	3.45
		26

Table 2.5

The following table lists the cooling loads for enclosed areas:

Name of the room	Area m^2	Q_t KW
Col 1	(2 × 24)	4.89
Col 2	(9.4×2)+(7.2×4.5)	5.6
Col 3	(30×2)	7.64
		18.13

Table 2.6

The total heating load is 41.12 + 26 = 67.12 kW

Total cooling load is 89.66 + 18.13 = 108 kW.

(2.8) Ventilation

Equation (1.16) and equation (1.17) can be used to estimate the value of ventilation. dentistic clinic room, was taken as an example:-

1) In winter:-

$Q_{ven(win)}$ = 1.2 × (3×12) × (40 - 10) = 1296 W.

2) In summer:-

$Q_{ven(sum)}$ = 1.2 × (3×12) × (84 - 48) = 1555.2 W.

Q_{ven} for other rooms are listed in the following table:-

Name of the room	# of people	$Q_{ven(sum)}$ (W)	$Q_{ven(sum)}$ (W)
Dentistic Clinic	3	1296	1555.2
O.P. clinic	2	864	1036.8
GP clinic	1	432	518.4
Rotating Specialist	4	1728	2073.6
Waiting Area	4	1728	2073.6
Chronic Disease Clinic	1	432	518.4
Disabled Toilet	1	432	518.4
Toilet (Mal&fem)	4	1728	2073.6
Waiting Area	2	864	1036.8
Reception	3	1296	1555.2
Rotating Specialist	2	864	1036.8
Staff rest	4	1728	2073.6
Sub wait	5	2160	2592
Maternal Clinic (1)	4	1728	2073.6

Maternal Clinic (2)	4	1728	2073.6
Baby clinic	3	1296	1555.2
Vaccination1	3	1296	1555.2
Vaccination2	1	432	518.4
Child clinic	1	432	518.4
School health	8	3456	4147.2
Family planning unit 1	2	864	1036.8
Family planning unit 2	2	864	1036.8
Toilet (m&f)	2	864	1036.8
Tel. room	1	432	432
Office 1	3	1296	1555.2
Office 2	3	1296	1555.2
Office 3	3	1296	1555.2
Office4	3	1296	1555.2
Office 5	3	1296	1555.2
Office 6	4	1728	2073.6
Stairs	4	1728	2073.6
Meeting room	6	2592	3110.4
Pharmacy store	1	432	518.4
dispensary	0	0	0
Gate 2	11	4752	5702.4

Table (2.7)

Chapter Three

Air conditioning system components

Contents:-

(3) Air conditioning system components:-

Air conditioning system composed from the following components:-

(3.1) Boiler (Steam generator):-

apparatus designed to convert a liquid to vapour. In a conventional steam power plant, a **boiler** consists of a furnace in which fuel is burned, surfaces to transmit heat from the combustion products to the water, and a space where steam can form and collect. A conventional **boiler** has a furnace that burns a fossil fuel or, in some installations, waste fuels. A nuclear reactor can also serve as a source of heat for generating steam under pressure.

Most conventional steam boilers are classed as either fire-tube or watertube types. In the fire-tube type, the water surrounds the steel tubes through which hot gases from the furnace flow. The steam generated collects above the water level in a cylindrically shaped drum. A safety valve is set to allow escape of steam at pressures above normal operating pressure; this device is necessary on all boilers, because continued addition of heat to water in a closed vessel without means of steam escape results in a rise in pressure and, ultimately, in explosion of the **boiler**. Fire-tube boilers have the advantage of being easy to install and operate. They are widely used in small installations to heat buildings and to provide power for factory processes. Fire-tube boilers are also used in steam locomotives.

In the watertube **boiler**, the water is inside tubes with the hot furnace gases circulating outside the tubes. When the steam turbogenerator was developed early in the 20th century, modern watertube boilers were developed in response to the demand for large quantities of steam at pressures and temperatures far exceeding those possible with fire-tube boilers. The tubes are outside the steam drum, which has no heating surface and is much smaller than in the fire-tube **boiler**. For this reason, the drum of the watertube **boiler** is better able to withstand higher pressures and temperatures. A wide variety of sizes and designs of watertube boilers are used in ships and factories.

The express **boiler** is designed with small water tubes for quick generation of steam. The flash **boiler** may not require a steam drum, because the tubes operate at such high temperatures that the feed water flashes into steam and superheats before leaving the tubes. The largest units are found in the central-station power plants of public utilities. Units of substantial size are used in steel mills, paper mills, oil refineries, chemical plants, and other large manufacturing plants.

(3.1.1) Fire-Tube Boiler

Evans's boiler consisted of two cylindrical shells, one inside the other; water occupied the region between them. The fire grate and flue were housed inside the inner cylinder, permitting a rapid increase in steam pressure. “Cornish” boiler. The first major improvement over Evans's and Trevithick's boilers was the fire-tube “Lancashire Boiler,” in which hot combustion gases were passed through tubes inserted into the water container, increasing the surface area through which heat could be transferred. Fire-tube boilers were limited in capacity and pressure and were also, sometimes, dangerously explosive.

(3.1.2) Water-Tube boiler

In the water-tube boiler, water flowed through tubes heated externally by combustion gases, and steam was collected above in a drum. This arrangement used both the convection heat of the gases and the radiant heat from the fire and the boiler walls. Wide application of the water-tube boiler became possible in the 20th century with such developments as high-temperature steel alloys and modern welding techniques, which made the water-tube boiler the standard type for all large boilers.

(3.1.3) chimney

structure designed to carry off smoke from a fireplace or furnace. A chimney also induces and maintains a draft that provides air to the. Most of the characteristic forms of modern chimneys originated in northern Europe, when masonry techniques were developed that allowed the construction of a hearth along a wall with a fireproof backstop and flue. Some medieval chimney stacks were tubular, and some had ingenious conical caps with hooded side vents to shield against rain.

An ordinary domestic chimney consists of three parts: the throat, the smoke chamber, and the flue. The throat is the opening immediately above the fire; it usually narrows to a few inches in width just below the damper, a door that can be closed when the furnace or fireplace is not in use. Above the damper is the smoke chamber. At the bottom of the smoke chamber is a smoke shelf formed by setting back the masonry at the top of the throat to the line of the back wall of the flue; its function is to deflect downdrafts that might otherwise blow smoke out into the room. The smoke chamber narrows uniformly toward the top; it slows down drafts and acts as a reservoir for smoke trapped in the chimney by gusts across the chimney top. The flue, the main length of the chimney, is usually of masonry, often brick, and metal-lined. Vertical flues perform best, though a bend is sometimes included to reduce rain splash; bends are also necessary when several flues are united in a common outlet.

Industrial chimneys are usually free-standing single flues with cylindrical cores of firebrick and outer jackets of steel, brick, or reinforced concrete, often with an insulating air space between to allow for differential expansion. Because the taller the chimney, the better the draft, some industrial chimneys are more than 300 feet (91.5 m) in height.

(3.2) Fan-coil units

Fan-coil units provide heating, cooling, or both to individual spaces. They may be mounted in freestanding cabinets, inside walls, in ceiling plenums, or in other locations. Fan-coil units usually discharge air directly from their enclosures, although some may be installed with short ducts.

The main components of fan-coil units are a fan and one or two coils. Units may have separate heating and cooling coils, or a single water coil may be used for both functions. The coils may operate with hot water, chilled water, electric resistance, or rarely, steam. (Units with refrigerant coils are considered to be part of "split systems,").

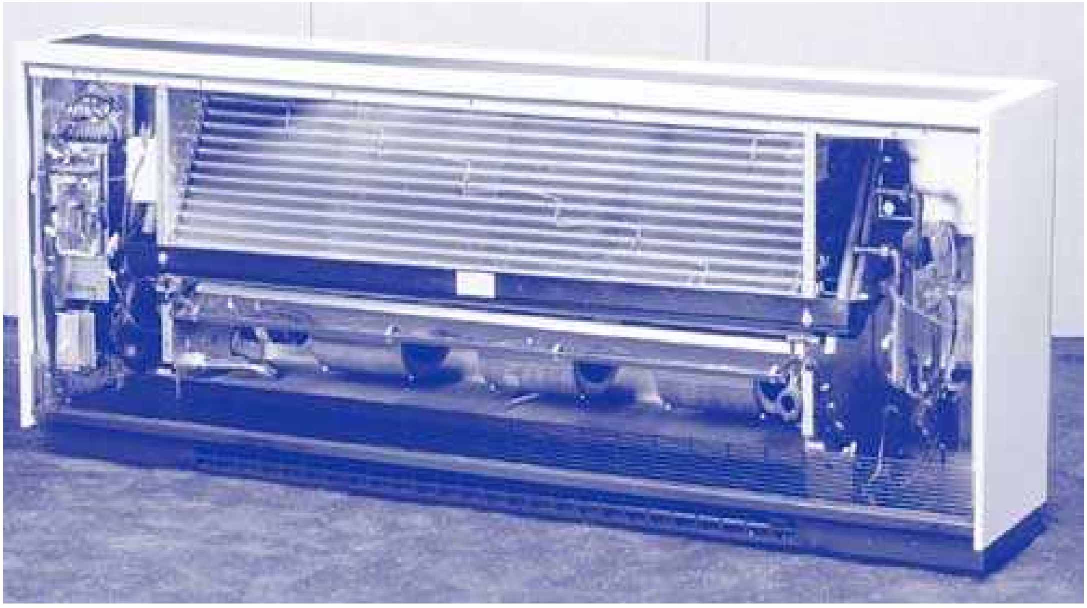


Fig.(3.1)

The output of a fan-coil unit can be controlled by cycling the fan, by controlling the speed of the fan, by throttling the flow of water in the coil, or by turning electric coils on and off. Units typically have control panels to allow occupants to select heating or cooling, to select the fan speed, and to control outside air ventilation, if any is available. Automatic controls may shut off flow through hydronic coils when the fan stops, and they may perform other functions. The fan-coil unit may have thermostatic controls that are entirely self-contained, or the fan-coil unit may have actuators that are powered by external thermostats.

Fan-coil units that are designed to provide a large amount of outside air ventilation are called "unit ventilators." Unit ventilators are combined with relief air fans to provide positive control of outside air intake, maximize ventilation capacity, and direct the air flow. The unit ventilator and its relief fan should function as an integral system.

The energy conservation measures explained here include the maintenance needed to maintain efficiency, methods to avoid wasting the energy of the discharged air, high-efficiency fan motors, more efficient thermostatic controls, and major system conversions. The latter include conversion from a 3-pipe systems to a 2-pipe, and conversion of a 3-pipe system to a 4-pipe system.

Fan Coil Boxes come in many flavours, 2 pipe, 4 pipe, electric heating, DX cooling, multi speed etc. Although a controller could be designed to cope with all options it would cost too much when used for some of the simpler applications. SeaChange have therefore developed a range of controllers to be able to closely match the controller to the needs of the plant thus providing a very cost effective solution in all cases.

Because it is modular and incorporates plug and play engineering, a SeaChange fan coil control system can be easily and inexpensively adapted to cope with additional zones, or fan coils reallocated to different zones when offices are re-arranged.

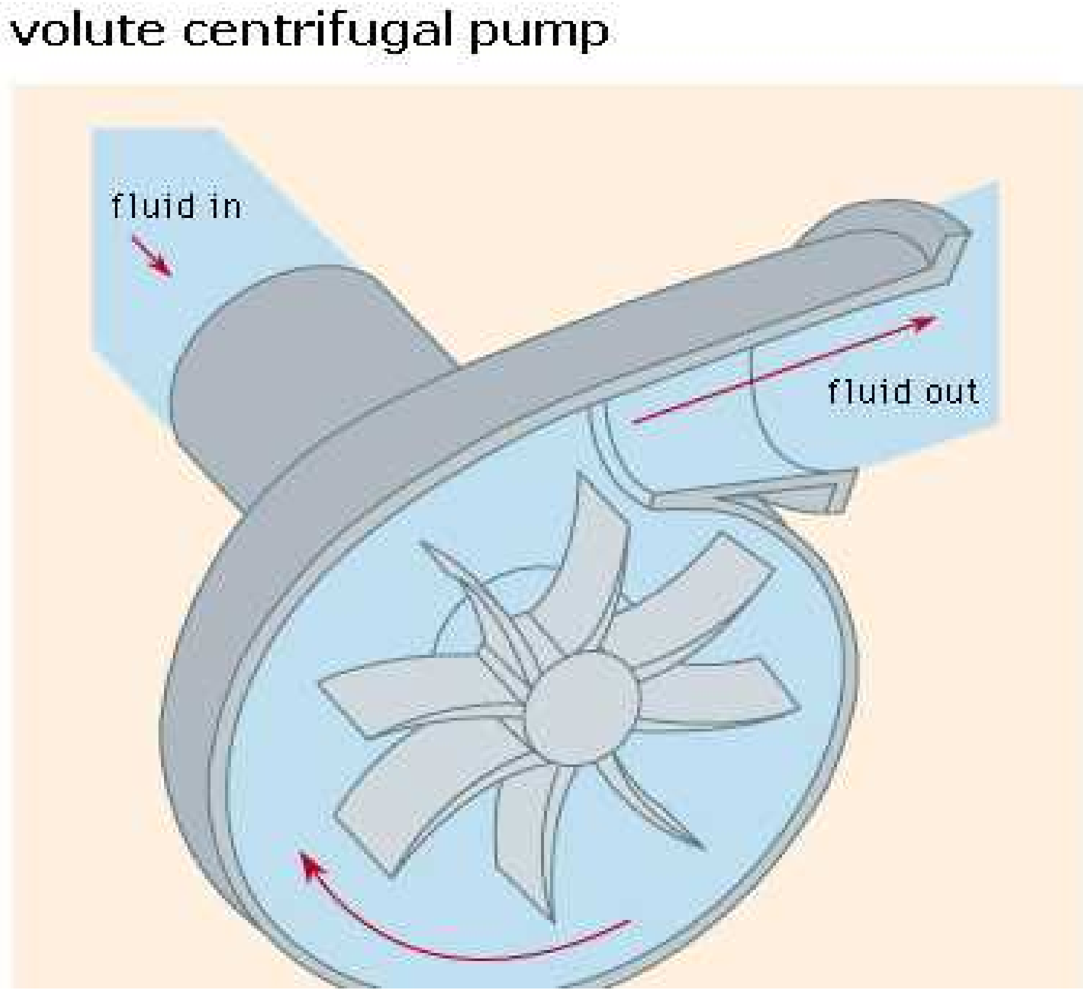
(3.3) Pump:-

Water Pump, device for moving water from one location to another, using tubes or other machinery. Water pumps operate under pressures ranging from a fraction of a pound to more than 10,000 pounds per square inch. Everyday examples of water pumps range from small electric pumps that circulate and aerate water in aquariums and fountains to sump pumps that remove water from beneath the foundations of homes.

Two types of modern pumps used to move water are the positive-displacement pump and the centrifugal pump. Positive-displacement pumps use suction created by a vacuum to draw water into a closed space. An example of this type of pump is the lift, or force, The lift pump is operated by raising a handle that is attached to a piston encased in a pipe. Lifting the piston creates a partial vacuum beneath it in the pipe, causing water to be drawn from a well below, through the pipe, and into a chamber in the pump. A one-way valve closes after water is pumped A into the chamber, keeping the water from flowing back down into the well. Subsequent pumps of the piston pull more water into the chamber, which eventually overflows, spilling water out of a spout.

Centrifugal pumps use motor-driven propellers that create a flow of water when they rotate. The blades of the propeller are immersed in the water to be pumped. As the propeller turns, water enters the pump near the axis of the blades and is swept out toward their ends at high pressure. An alternative, early version of the centrifugal pump, the screw pump, consists of a corkscrew-shaped mechanism in a pipe that, when rotated, pulls water upward. Screw pumps are often used in waste-water treatment plants because they can move large amounts of water without becoming clogged with debris.

Traditional hot water circulating systems use a hot water circulating pump to pump hot water from the water heater, through the hot water piping, and on back to the water heater through an additional length of pipe that runs from the furthest fixture back to the water heater.


volute centrifugal pump
fluid in
fluid out

Fig(3.2)

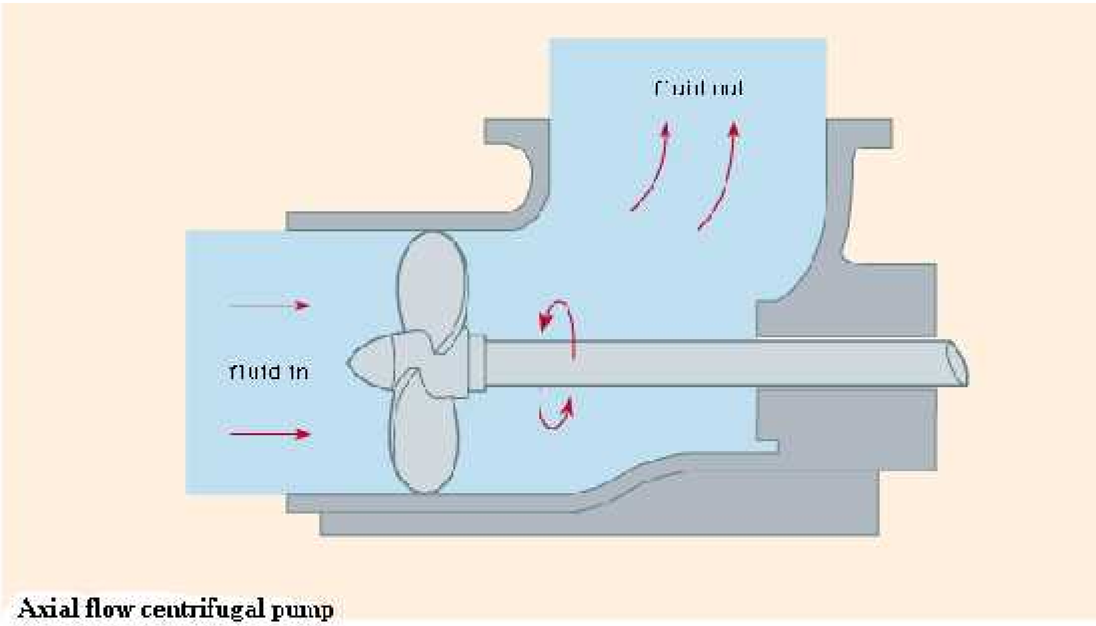

fluid in
Axial flow centrifugal pump

Fig.(3.3)

This type of hot water circulating system provides nearly instant hot water at the fixtures, but wastes a tremendous amount of energy through both the energy required to operate the hot water pump and the heat energy lost from the piping.

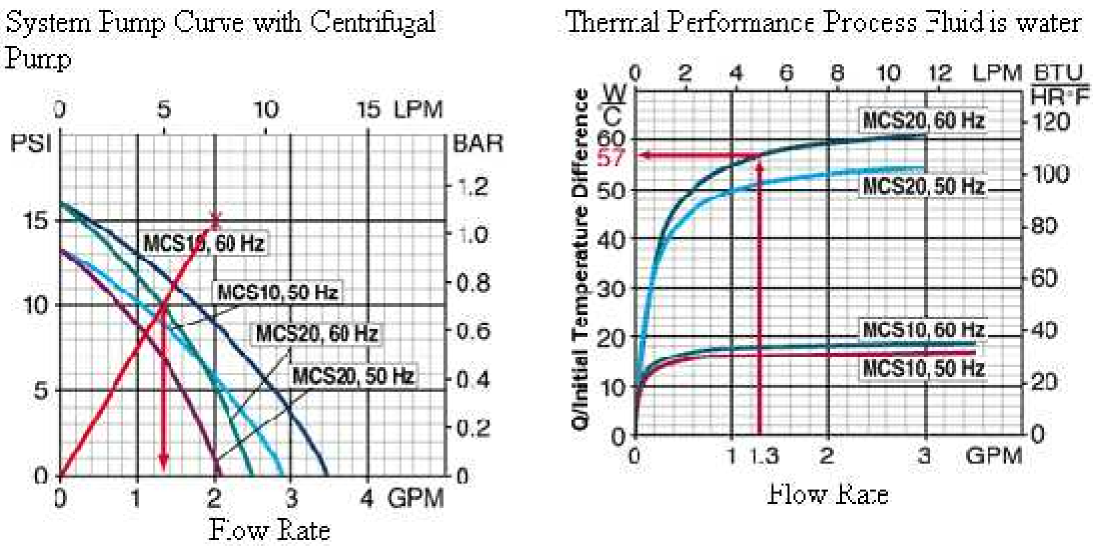


Fig.(3.4)

Several methods have been employed to reduce the energy waste associated with hot water pump circulating systems.

Timers are sometimes placed on the circulating pump so the system shuts the hot water pump off during hours that one one normally uses hot water such as from midnight to 6:00 a. m.

Sometimes the circulating pump is controlled by a temperature sensing circuit that shuts the hot water pump off once the water temperature reaches a pre-set temperature such as !40 degrees and then starts the pump back up when the water temperature in the pipe drops below a second set point such as 110 degrees. This type of system does little to reduce the energy losses because the lower set point is still high enough to cause continual large heat losses from the system, and the pump does not contribute nearly as much to the loss as the heat loss itself.

(3.4) Chiller

A chiller is a mechanical refrigeration device that cools a fluid (usually water), a “chiller” consists of a few major components. A compressor, an evaporator , a condenser, an expansion valve or two and some piping and controls are the basics. Compressors are usually of reciprocating, scroll, centrifugal, or rotary screw types. The evaporator heat exchanger is usually of shell & tube construction and is the exchanger where chilled water would be produced. The condenser heat exchanger can be either air-cooled, a coil or coils and a fan or fans, or water-cooled & tube heat.

Selecting a Recirculating Chiller

Selecting the proper recirculating chiller is a function of the following three factors:

1. The heat load generated by the device being cooled (Q)
2. The maximum acceptable temperature of the fluid exiting the heat source (T_{OUT})
3. Available fluid flow rate ($\dot{V}$)

If the Heat Load (Q) is known, but the Flow Rate is unknown, the following equation can be used to determine the required flow rate.

$$v = \frac{Q}{\circ\, C_p (T_{out} - T_{in})}$$

where:

= Fluid Rate

= Heat Load

= Fluid Density

= Fluid Specific Heat
p

= Maximum Fluid Temperature
OUT

= Fluid Temperature Exiting the Recirculating
IN Chiller

Chapter Four

Calculations

Contents:-

(4) Calculations:-

(4.1) piping system:-

Chart 4 gives a complete preview about the piping system used in the hospital

Calculations of pipes diameters:-

$$Q = \dot{m} C_p \Delta T \qquad 4.1$$

Q : total heat loss [kW]
m : mass flow rate [kg/s]
C_p :specific heat capacity at constant pressure
$C_{p\ water}$ =4.18 [kJ/kg ^{o}C]
ΔT : water temperature difference = 8˚C.

$$\dot{m} = \frac{Q}{C_p \Delta T} = \frac{Q}{4.18 \times 8}$$

$$\dot{m} = \frac{Q}{33.44} kg/s \qquad 4.2$$

$$\dot{m} = \rho_w VA \qquad 4.3$$

$\dot{m}$: mass flow rate [kg/s]
ρ_w :water mass density 1000 [kg/m^3]
V: water velocity in pipe 2 m/s.
A: cross-sectional area of pipe.

$$A = \frac{\dot{m}}{\rho_w V} \qquad 4.4$$

$$A = \frac{\dot{m}}{1000 \times 2} = \frac{\dot{m}}{2000} m^2 \qquad 4.5$$

$$A = \frac{\pi d^2}{4} \longrightarrow d = \sqrt{\frac{4A}{\pi}}\ m \qquad 4.6$$

Where:-
d = Pipe cross-sectional diameter.

1) Main pipe's diameter:-

Q_t = 108 kW;

$$\dot{m} = \frac{108}{33.44} = 3.23 kg/s$$

$$A = \frac{3.23}{2000} = 1.6 \times 10^{-3} m^2 .$$

$$d_{main} = \sqrt{\frac{4(1.6 \times 10^{-3})}{®}} = 0.045m .$$

Select d_{main} = 2 inch.

Pipe	**Q_t kW**	**$\dot{m}$ kg/s**	**A m^2**	**d m**	$d_{(selected)}$ inch
Main pipe	108	3.23	1.6×10^{-3}	0.045	2
Pipe A_1	5.56	0.166	8.30×10^{-4}	9.11×10^{-3}	0.5
Pipe A_2	16.53	0.490	2.47×10^{-4}	0.0177	0.75
Pipe A_3	23.1	0.690	3.45×10^{-4}	0.0209	1
Pipe A_4	31.71	0.940	4.74×10^{-4}	0.0245	1
Pipe A_5	40.53	1.212	6.06×10^{-4}	0.0277	1.25
Pipe A_6	56.55	1.544	7.72×10^{-4}	0.0313	1.25
Pipe B_1	13.1	0.391	1.96×10^{-4}	0.016	0.75
Pipe B_2	20.17	0.60	3.02×10^{-4}	0.019	0.75
Pipe B_3	27.72	0.828	4.14×10^{-4}	0.0229	1
Pipe B_4	39.74	1.188	5.90×10^{-4}	0.0280	1.25
Pipe C	6.76	0.200	1.01×10^{-4}	0.0113	0.5
Boiler pipe	67.12	2	1×10^{-3}	0.036	1.5

Table 4.1: Induction lines diameters

Diameters of pipes of rooms are given in the following table:-

Pipe of the room	**Q_t KW**	**$\dot{m}$ kg/s**	$d_{(selected)}$ inch
Dentist Clinic	3.5	0.105	0.50
O.P. clinic	1.67	0.050	0.50
GP clinic	1.23	0.037	0.50
Rotating Specialist	3.35	0.100	0.50
Waiting Area	2.51	0.075	0.50
Chronic Disease Clinic	1.58	0.042	0.50
Disabled Toilet	1.01	0.030	0.50
Toilet (Mal&fem)	2.97	0.089	0.50
Waiting Area	4.52	0135	0.50

Reception	3.6	0.108	0.50
Rotating Specialist	1.99	0.060	0.50
Staff rest	2.33	0.070	0.50
Sub wait	3.95	0.118	0.50
Maternal Clinic (1)	2.15	0.064	0.50
Maternal Clinic (2)	2.15	0.064	0.50
Baby clinic	2.01	0.060	0.50
Vaccination 1	2.17	0.066	0.50
Vaccination 2	3.32	0.099	0.50
Child clinic	3.15	0.94	0.50
School health	3.61	0.108	0.50
Family planning unit 1	2.19	0.066	0.50
Family planning unit 2	2.19	0.066	0.50
Toilet (m&f)	3.21	0.096	0.50
Tel. room	1.17	0.035	0.50
Office 1	1.38	0.0413	0.50
Office 2	1.38	0.0413	0.50
Office 3	1.38	0.0413	0.50
Office4	1.38	0.0413	0.50
Office 5	1.38	0.0413	0.50
Office 6	3.12	0.093	0.50
Stairs	4.51	0.135	0.50
Meeting room	4.09	0.122	0.50
Pharmacy store	2.93	0.088	0.50
dispensary	1.82	0.054	0.50
Gate 2	4.91	0.147	0.50

Table 4.2

(4.2) Flow through pipes

(4.2.1) Losses of head in pipes

1) Major loss of head due friction -

$$h_f = \frac{flv^2}{2gd} \qquad 4.7$$

Where:

h_f : Major loss of head due to friction.

v : Velocity of water = 2 m/s.

d : Pipe diameter.

f : Darcy coefficient.

$$f = 0.005(1+\frac{1}{12d})$$ For new and smooth pipes. 4.8

$$f = 0.01(1+\frac{1}{12d})$$ For old and rough pipes. 4.9

- The last tow equations (4.8 & 4.9); are empirical ones.

2) Minor loss due to:-

a) Loss of head at entrance $= \frac{0.5v^2}{2g}$.

b) Loss of head due to velocity of water at outlet $= \frac{v^2}{2g}$

Then the total loss of head in pipes is the sum of minor and major losses; and can be explained by the following Darcy formula.

$$h_{f(pipe)} = \frac{0.5v^2}{2g} + \frac{flv^2}{2gd} + \frac{v^2}{2g} \qquad 4.10$$

$$Q = vA \rightarrow A = \frac{Q}{v} \qquad 4.11$$

* in actual practice, the minor losses are neglected, one of the reasons, for this, is to make the calculation simple.

Losses of head in pipe A1:-

$l_{A1} = 6m$ $\qquad d_{A1} = 0.5inch = 0.0127m$

$h_{f(pipe)} = \frac{flv^2}{2gd}$; considering $f = 0.004$

$$h_{f(pipe)} = \frac{0.004\times 6\times 2^2}{2\times 9.81\times 0.0127} = 0.39m$$

The following table lists the losses of head in different pipes

Name of pipe	L (m)	d (Inch)	d (m)	h_f
Pipe A1	6	0.5	0.0127	0.39
Pipe A2	7	0.75	0.0190	0.3
Pipe A3	6	1	0.0254	0.19
Pipe A4	5	1	0.0254	0.16

Pipe A5	5	1.25	0.0317	0.13
Pipe A6	7	1.25	0.0317	0.18
Pipe B1	6	0.75	0.0190	0.26
Pipe B2	6	0.75	0.0190	0.26
Pipe B3	7	1	0.0254	0.23
Pipe B4	10	1.25	0.0317	0.26
Pipe C	5	0.5	0.0127	0.32
				2.68

Table 4.3

(4.2.2) Losses in fittings:-

a) In valves:-

The loss of head in valves can be estimated using equation (4.7), and the equivalent length of these valves can be obtained by using table A10.

In first floor there are 35 global valves (d=0.5inch= 0.0127m), so the equivalent length is:- (35*5.5) = 192.5 m.

$$h_{fg} = \frac{0.004 \times 192.5 \times 2^2}{2 \times 9.81 \times 0.0127} = 12.36m$$

The following table explains the different types of valves and the loss of head within them.

* The values of the following tables are listed only for one value.

Valve type	d inch	# valve	Equivalent length (for one valve) m	h_{fg} m (for one valve)
Globe	0.5	35	5.5	0.353
Gate	2	1	0.7	0.0112
Gate	1.25	2	0.5	0.013
Gate	0.75	2	0.3	0.013
				0.377

Table 4.4

b) Elbows:-

There are 100 elbows (long radius 90°), K=0.2, (see table A11).

$$h_{fe} = K\frac{V^2}{2g} = 100 \times 0.2 \frac{2^2}{2(9.81)} = 4.08m.$$

The following table lists the types of elbows which is used in the system, and the loss of head within them:-

Elbow type	# elbows	K	h_{fe} (for one elbow)
Long radius 90° flanged	100	0.2	0.041
Long radius 45°	35	1.5	0.306
Long radius 90° flanged	70	0.3	0.061
			0.408

Table 4.6

c) Tees connections:-

The same law is used to determine the loss of head in tees connections as explained in elbows, the following table explains several types of these connections.

Tee type	# Tees	K	h_{ft} (for one connection)
(Rounded) connection	1	1	0.21
Branch flow threaded	35	2	0.41
Square connection	1	0.9	0.18
			0.8

Table 4.7

d) Head loss due to sudden contraction:-

it can be estimated using the equation (4.7), as explained in valves, the results are listed in the following table:-

Diameter before contraction inch	d after contraction Inch	# connection	Equivalent length (for one connection)	h_{fR} (for one connection) m
1.25	1	2	0.3	5.7×10^{-3}
1	0.75	2	0.2	7.3×10^{-3}
0.75	0.5	1	0.2	0.01
				0.023

Table 4.8

(4.3) Selection of fan coils:-

The new 42E fan coil units combine advanced technology, they will enhance any surroundings, such as hotels rooms, shops, offices and private homes, they are either horizontal or vertical, most fan coils which are used is of horizontal type

The compact 42E fan coils units are available in ten sizes as illustrated in table A12

Fan coils which are selected to the hospital are listed in the following table:-

Name of the room	Q_t KW	Type of fan coil
Dentistic Clinic	3.35	42E05
O.P. clinic	1.67	42E02
GP clinic	1.23	42E02
Rotating Specialist	3.35	42E05
Waiting Area	2.51	42E03
Chronic Disease Clinic	1.58	42E02
Disabled Toilet	1.01	42E01
Toilet Mal&fem	2.97	42E04
Waiting Area	4.52	42E06
Reception	3.60	42E05
Rotating Specialist	1.99	42E02
Staff rest	2.33	42E03
Sub wait	3.95	42E05
Maternal Clinic (1)	2.15	42E03
Maternal Clinic (2)	2.15	42E03
Baby clinic	2.01	42E03
Vaccination 1	2.17	42E03
Vaccination 2	3.32	42E05
Child clinic	3.15	42E04
School health	3.61	42E05
Family planning unit 1	2.19	42E03
Family planning unit 2	2.19	42E03
Toilet (m&f)	3.21	42E04
Tel. room	1.17	42E01
Office 1	1.38	42E02
Office 2	1.38	42E02
Office 3	1.38	42E02
Office4	1.38	42E02
Office 5	1.38	42E02
Office 6	3.12	42E04
Stairs	4.51	42E05
Pharmacy store	2.93	42E03
Meeting room	4.09	42E05
dispensary	1.82	42E02
Gate 2	4.91	42E06
Col 1	4.89	42E06
Col 2	5.6	42E07
Col 3	7.64	42E10

Table 4.9

Ducts:-

For enclosed areas ducts had been used, Col 3 was taken as an example:-

L = 30 m → Number of grills $= \frac{30}{4} = 8$

Q = 7.64 kW → Fan coil = 42E10.
Air flow = 350 l/s (see table A12b).

Air flow = 21000 l/m = 742 cfm.

There are 8 grills, so air flow per one grill = $742/8 = 93$cfm/grill

→ Velocity = 415 fpm, d (for a rounded duct) = 6.5in, (see chart 5b).

Then the area for the duct is $\frac{® \times 6.5^2}{4} = 33.1 in^2$.

Select a cubic duct with 6×6 dimensions

Note: Area can be obtained using equation (4.11) as follows:

$$A = \frac{93}{415} = 0.2241 ft^2 = 33 in^2$$

Areas of grills are calculated as follows:-

$$A_1 v_1 = A_2 v_2 \rightarrow A_2 = \frac{A_1 v_1}{v_2}, \quad v_1 = 300\, fpm$$

$$A_{grill} = \frac{33 \times 415}{300} = 46 in^2.$$

The following table explains the specifications of ducts and grills for col. 3.

Duct	**Q** **cfm**	**V** **fpm**	**d** **Inch**	**A** **Inch^2**	**Selected Duct dimension Inch^2**	**A_{grill}** **Inch^2**
1	742	700	13.5	143	15x15	334
2	651	680	11.5	103	12x12	234
3	558	650	11.1	97	12x12	210
4	465	610	10.75	91	12x12	185
5	372	590	10.25	88	12x12	173
6	279	520	9.8	75	9x9	130
7	186	475	8.25	53.5	9x9	85
8	93	415	6.5	33.1	6x6	46

Table 4.10

Col. 2 is divided into two areas with the following dimensions:-

L_1 = 9.4 m, L_2 = 7.2 m.
Number of grills = 2 + 2 = 4 grills.
Q = 5.6→ fan coil = 42E07.
Air flow 300 l/s = 1800 l/m = 636 cfm
Air flow = 159 cfm/grill.

The following table explains the specifications of ducts and grills for col. 2.

Duct	Q cfm	V fpm	d Inch	A $Inch^2$	Selected Duct dimension In^2	A grill $Inch^2$
1	636	670	13.2	137	12x12	306
2	318	563	10.2	81.7	12x12	153
3	159	465	7.9	49.2	9x9	76
4	318	563	10.1	81.7	12x12	153
5	159	465	7.9	49.2	9x9	76

Table 4.11

For col 1 has the following specifications:-
L =24 m, Number of grills = 6, fan coil 42E06.
Air flow = 88.7 cfm/grill

The following table explains the specifications of ducts and grills for col. 1.

Duct	Q cfm	V fpm	d inch	A inch	Selected dimension $Inch^2$	A grill $Inch^2$
1	532	630	12.4	122	12x12	256.2
2	443.3	607	11.6	105	12x12	212.5
3	354.6	575	10.6	89	12x12	170.6
4	266	518	9.7	74	9x9	127.8
5	177.1	470	8.3	54	9x9	84.6
6	88.7	410	6.3	31	6x6	424

Table 4.12

Waiting area and Reception also has 2 grills as illustrated in the following tables:-

Duct	Q cfm	V fpm	d in	A In^2	Selected dimension In^2	A grill In^2
1	532	630	12.4	122	12x12	256.2
2	266	518	9.7	74	9x9	127.8

Table 4.13 (Waiting area)

duct	Q cfm	V fpm	d in	A In^2	Selected dimension In^2	A grill In^2
1	400	595	11.1	97	12x12	129
2	200	475	8.8	60.6	9x9	96

Table 4.14 (Reception)

The loss of head which occurred in fan coil, can be estimated by using the chart2, the mass flow rate for farthest room (Toilet (m & f)) is 0.089kg/s, from chart2;

the value of loss of head is obtained and equal 1.8 m, and this value is added to the total, loss of head.

* Diameter of return duct from each room equals the diameter of feeding duct to the room, and all are gathered in one large duct and then to the atmosphere.

(4.4) Selection of chillers: -

The 30SM compact water-cooled liquid chillers are ideal for numerous air conditioning and process cooling applications, two chillers are needed for the hospital.

The cooling load is 108 kW, so the most appropriate chiller is 30SM036, table A13 provides a complete specification about it, the mass flow rate is 2.681 kg/s, from chart 3, the head loss is 5.1 m.

$h_{total} = h_{fg} + h_{fe} + h_{ft} + h_{fr} + h_{chiller} + h_{fan\ coil.}$

$h_{total} = 0.377 + 0.408 + 0.8 + 0.023 + 5.1 + 1.8 = 8.51$ m.

(4.5) (Selection of pumps):-

Several charts had been made to describe several pumps; the pumps are selected according to the total loss of head (h_{total}), and to the mass flow rate ($\dot{m}$**),** the total loss of head in hospital is 8.51 m, and the total mass flow rate for boiler and chiller pipes are 2 kg/s and 3.2 kg/s respectively, chart 6 describes the pumps which are needed to the hospital (DN 50).

(4.6) (Selection of boilers):-

BONGIOANNI has been producing boilers for heating plants for over 80 years, this kind of boilers is suitable for the hospital as it provide high thermal efficiency (not below 90%), and large quantities of heat.

The total heating load is 67.12 kW, table A16 explains that (T 100 HR 7), is most appropriate boiler for the hospital, the table also lists the specifications of the boiler.

(4.7) Chimney:-

Table A14 explains the cross-sectional areas and height of chimneys according to the total load.

The hospital's total heating load is 67.12 kW, so the chimney's height is 15 m with cross-sectional area 365 cm^2.

(4.8) Expansion tank calculations:-

$\Delta V = V_{max} - V_{min}$

Where

ΔV : water difference volume m^3.

V_{max} :volume of water at max temperature.

V_{min} : volume of water at min temperature.

$V_{min} = m/\rho$

m : water mass, kg

ρ :density of water at min temperature.

$V = AL$

V: volume of water (m^3).

A: Cross-sectional area of the pipe (m^2).

L: Length of the pipe (m).

For pipe A6:-

L = 6 m d = 1.25 inch = 0.03175 m.

$$A = \frac{\text{®} d^2}{4} = \frac{\text{®} \times 0.03175^2}{4} = 7.9 \times 10^{-4} m^2.$$

$V_A = 7.9\times10^{-4} \times 6 = 4.8\times10^{-3}\ m^3$.

The following table includes information about all other pipes:-

Pipe	L m	d Inch	d m	A m^2	V m^3
Pipe A1	6	0.5	0.0127	1.3×10^{-4}	7.8×10^{-4}
Pipe A2	7	0.75	0.01905	2.9×10^{-4}	2.1×10^{-3}
Pipe A3	6	1	0.0254	5.1×10^{-4}	3.1×10^{-3}
Pipe A4	5	1	0.0254	5.1×10^{-4}	2.6×10^{-3}
Pipe A5	5	1.25	0.03175	7.9×10^{-4}	4.0×10^{-3}
Pipe A6	7	1.25	0.03175	7.9×10^{-4}	4.8×10^{-3}
Pipe B1	6	0.75	0.01905	2.9×10^{-4}	1.8×10^{-3}
Pipe B2	6	0.75	0.01905	2.9×10^{-4}	1.8×10^{-3}
Pipe B3	7	1	0.0254	5.1×10^{-4}	3.6×10^{-3}
Pipe B4	10	1.25	0.03175	7.9×10^{-4}	7.9×10^{-3}
Pipe C	15	0.5	0.0127	1.3×10^{-4}	6.5×10^{-4}
Main pipe	15	2	0.0508	2.1×10^{-3}	0.0304
Others	144	0.5	0.0127	1.3×10^{-4}	19×10^{-3}
					0.083

Table 4.15

So the total volume in pipes is ($83\times2 = 166$ L $= 166\times10^{-3}\ m^3$).

Expansion tank for the chiller

$\mathbf{V}_{chiller} = 15$ L $= 15\times10^{-3}\ m^3$.

V_{min} = 166×10^{-3} + 15×10^{-3} = 181×10^{-3} m^3 = 181 L.
m = $\rho_{low\ temp}$×V_{min}
m = 998×0.181 = 181 kg.

$$V_{max} = \frac{m}{\rho_{high\ temp}} = \frac{181}{970} = 0.19m^3.$$

ΔV = 0.19 – 0.18 = 0.01 m^3

Note:- For three stories the minimum required volume is 30 L.

Expansion tank for the boiler

V_{boiler} = 24.5 L = 24.5 ×10^{-3} m^3
V_{min} = 166 + 24 = 190 L.
m = 998×0.190 = 190 kg.
V_{max} = 0.20 m^3.

ΔV = 0.200 – 0.190 = 10 L (30 L For the three stories nearly).

(4.9) Insulations:-

Table A15 explains several types of insulators (such as armflex) and the minimum thickness for given pipe's diameters, accordingly; the following table explains the insulators for hospital's pipes.

Pipe	d Inch	d mm	Thickness of insulation mm	K $W/m^{2}°C$
Pipe A1	0.5	13	9	0.03
Pipe A2	0.75	19	9	0.03
Pipe A3	1	25	12	0.04
Pipe A4	1	25	12	0.04
Pipe A5	1.25	32	12	0.04
Pipe A6	1.25	32	12	0.04
Pipe B1	0.75	19	9	0.03
Pipe B2	0.75	19	9	0.03
Pipe B3	1	25	12	0.04
Pipe B4	1.25	32	12	0.04
Pipe C	0.5	13	9	0.03
Main pipe	2	51	12	0.04
Room pipes	0.5	13	9	0.03

Table 4.16

Conclusion

The preferred system for senior living community resident units is a four-pipe system. For single resident rooms, valance units are preferred, providing the optimum in occupant comfort, system operation, and energy efficiency. For apartment units, either four-pipe valance units or four-pipe fan coil units are preferred. But, the higher first cost of these systems is often a factor in their selection.

At the other end of the scale are packaged terminal heat pump/AC units. They provide the lowest in first cost, but are the poorest choice for occupant comfort, aesthetic appeal, long-term life and maintenance costs, and operating energy efficiency. As a compromise, two-pipe systems are frequently selected. These provide first cost savings over the four-pipe systems, but still provide some of the benefits of the central system (equipment life, energy efficiency, consolidation of equipment for maintenance).

But the owner should be aware of the limitations of these systems, primarily the loss of system control by not always having simultaneous heating and cooling available. When the system is in the heating water mode, cooling is not available. This can be a problem on warm winter days when cooling is needed, primarily in administrative and central service spaces with high internal heat gains. The problem is less severe in resident spaces. When the system is in the chilled water mode, heating is still available with the supplemental electric resistance heat, but the operational costs increase due to the higher cost of electric heat, thereby sacrificing system efficiency.

The water source heat pump system (like that used in hospital) offers another compromise that overcomes the control problems of the two-pipe system by providing year-round simultaneous heating and cooling. This system provides first cost savings over the four-pipe systems, but sacrifices operating efficiencies, equipment life, and maintenance cost savings which are available in the central chilled water/hot water systems. Another important consideration is the requirement for emergency heating. When emergency heating is required, the high cost of the emergency generator and feeder circuits for the two-pipe system and the water source heat pump system may offset the cost savings over a four-pipe system.

To decrease the loss of energy, we recommend the following:-

1) Use insulations for pipes and walls.
2) Use air gap in walls.
3) Good orientation for the building.
4) Using glass of low thermal conductivity.

مع تحيات: فؤاد داود
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Appendices:-

Appendix (A)

Abstract

The purpose of the project is estimation of cooling(summer) and heating(in winter) loads for Yatta governmental hospital to select the suitable and economical air conditioning system/s.

The hospital is located in the southern part of Yatta in Almintar village, at the road to Alsamoo'h town in hebron district in west bank in palestine.

The inside and outside design temperature:-

The summer is relatively hot in Yatta, the out side design temperature is taken 35^{o}C. The inside design temperature for human comfort is considered as 24 ^{o}C in summer. Which means the conditioning system was selected for cooling the rooms inside the building is to 24 ^{o}C.

The winter is relatively cold then the temperature in the out side is very low .By the Hebron climate station the temperature in the outside is taken 3 ^{o}C. The inside of the rooms was heated to 21 ^{o}C because it's a comfortable temperature in winter for people.

The ground floor of the hospital was estimated in our calculation, fan coil system also selected in our design, and the other floors wasn't taken in calculations.

The heating load is 67.12 kW

BONGIOANNI has been producing boilers for heating plants for over 80 years, this kind of boilers is suitable for the hospital as it provide high thermal efficiency (not below 90%), and large quantities of heat.

The cooling load is 108 kW

The 30SM compact water-cooled liquid chillers are ideal for numerous air conditioning and process cooling applications, two chillers are needed for the hospital.

Contents:- **Page**

(3) Air conditioning system components:-

(4)Calculations:-

Tables:-

Table A1: Air infiltration heat loss through windows and doors

(٣٠)	(٢٥)	(٢٠)	(١٥)	(١٠)	(٥)	سرعة الرياح (ميل/ساعة)
ft^3/hr	ft^3/hr	ft^3/hr	ft^3/hr	ft^3/hr	ft^3/hr	
١٠٤	٨٠	٥٩	٣٩	٢١	٧	نافذة خشبية بدلفين مركب بحالة متوسطة
٢٤٩	١٩٩	١٥٤	١١١	٦٩	٢٧	نافذة خشبية بدلفين مركب بحالة رديئة
٣٧٢	٣٠٤	٢٤٤	١٧٦	١٠٨	٥٢	نافذة معدنية بدلفين
٧٤	٦٠	٤٧	٣٣	١٨	٦	لمسكن ومركب بحالة جيدة
١٢٨	١٠٠	٧٦	٥٢	٣٢	١٤	**لمسكن ومركب بحالة متوسطة**
						الأبواب
٢٤٩	١٩٩	١٥٤	١١١	٦٩	٢٧	مركب بحالة جيدة
٤٩٨	٣٩٨	٣٠٨	٢٢٢	١٣٨	٥٤	مركب بحالة رديئة
٧٥٠	٦٠٠	٤٥٠	٣٠٠	٢٠٠	٨٠	لمخزن أو لحانوت يفتح كثيرا

Table A7: Thermal conductivity for materials

Material	Density Kg/m^2	Thermal conductivity $W/m.^oC$
Marble	2600	2.9
Hard stone	2500	2.2
Firm stone	2250	1.7
Tiles	1900	0.85
Normal concrete	2300	1.75
Bricks	1400	0.8
Plaster	2000	1.2
Iron (cast)	7400	47
block	1800	1.2

Table A9: Heat gain from people

Degree of activity	SenHG (W)	LatHG (W)	Total heat (W)
Seated at rest	60.5	42.5	103
Seated –very light work	73.2	58.5	131.7
Moderately active office work.	67.3	64.7	132
Standing light work ,walking slowly	69.6	77.8	147.4

Moderate work	77.1	143.3	220.4

Table A17 outside air required per person

Application	Smoking	Outside air L/s/person
Hotels room	Heavy	14-12
Offices,general	Some	7-5
Meeting rooms	Heavy	24-14
Restaurant	Some	7-5
Theaters	None	3.6-2.4
Hospital,wards	None	14-9
Offices private	None	12-7

Table A11: Minor Losses Coefficients

fitting	**K_m**	**Fitting**	**K_m**
Valves:		Elbows:	
Globe, fully open	10	Regular 90°, flanged	0.3
Angle, fully open	2	Regular 90°, threaded	1.5
Gate, fully open	0.15	Long radius 90°, flanged	0.2
Gate 1/4 closed	0.26	Long radius 90°, threaded	0.7
Gate, 1/2 closed	2.1	Long radius 45°, threaded	0.2
Gate, 3/4 closed	17	Regular 45°, threaded	0.4
Swing check, backward flow	infinity	Tees:	
		Line flow, flanged	0.2
180° return bends:		Line flow, threaded	0.9
Flanged	0.2	Branch flow, flanged	1.0
Threaded	1.5	Branch flow, threaded	2.0
Pipe Entrance (Reservoir to Pipe):		Pipe Exit (Pipe to Reservoir)	
Square Connection	0.5	Square Connection	1.0
Rounded Connection	0.2	Rounded Connection	1.0
Re-entrant (pipe	1.0	Re-entrant (pipe	1.0

juts into tank)		juts into tank)	

48	49	50	51	52
53	54	55	56	57
58	59	60	61	62
63	64	65	66	67
68	69	70	71	72
73	74	75	76	77
78	79	80	81	82
83	84	85	86	87
88	89	90	91	92
93	94	95	96	97
98	99	100	101	102
103	104	405	106	107
108	109	110	111	112
113	114	115	116	117
118	119	120	[illegible]	

Appendices:-

Appendix (A)

Table A1: Air infiltration heat loss through windows and doors

(30)	(25)	(20)	(15)	(10)	(5)	سرعة الرياح (ميل/الساعة)
ft^2/hr	ft^3/hr	ft^3/hr	ft^3/hr	ft^3/hr	ft^3/hr	
104	80	59	39	21	7	نافذة خشبية بدلفين مركب بحالة متوسطة
249	199	154	111	69	27	نافذة خشبية بدلفين مركب بحالة رديئة
372	304	244	176	108	52	نافذة معدنية بدلفين
74	60	47	33	18	6	لمسكن ومركب بحالة جيدة
128	100	76	52	32	14	لمسكن ومركب بحالة متوسطة
						الأبواب
249	199	154	111	69	27	مركب بحالة جيدة
498	398	308	222	138	54	مركب بحالة رديئة
750	600	450	300	200	80	لمخزن أو لحانوت يفتح كثيرا

Table A2: Natural air infiltration for heat losses

Room or Building	Air Change per hour	Ventilation Loss ($W/m^3 K$)
Large spaces (e.g. Factories, Assembly Halls, Churches Canteens)		
Solid Construction		
up to 5000 m^2	1	0·3
5000 to 25 000 m^2	½	0·2
over 25 000 m^2	¼	0·1
Light Construction		
up to 5000	3	1·0
5000 to 25 000 m^2	1½	0·5
over 25 000 m^2	¾	0·3
Living spaces, offices, libraries		
Windows exposed one side	1	0·3
Windows exposed two sides	1½	0·5
Windows exposed more sides (if windows are weather-stripped, halve the above rates.)	2	0·7
Circulating Spaces Generally	2-3	0·7-1·0
Lavatories	2	0·7
Laboratories	3	1·0
Hospitals, Schools etc See Department of Health and Social Security, Ministry of Education and Science publications setting standards		

NOTE: This Table refers to air-change rates for heat loss calculations. Where mechanical inlet and extract ventilation is provided, heat for additional air-change must be added.

Table A3: خواص الخليط من الهواء الجاف وبخار الماء

شروط التشبع			وزن بخار التشبع		الحجم بالقدم المكعب		كمية الحرارة في الرطل		
درجة الحرارة ف	الضغط المطلق: رطل على البوصة المربعة	الضغط المطلق: بوصة من عامود الزئبق	في القدم المكعب (الوزن النوعي): رطل	في القدم المكعب (الوزن النوعي): قمحة	للرطل من الهواء الجاف	للرطل من الهواء الجاف + بخار التشبع	من الهواء الجاف	من البخار	من الهواء المشبع
٢٥	ر٠٦٤١	ر١٣٠٤	ر٠٠٠٢٢٢	١ر٥٥٨	١٢ر٣١	١٢ر٣٦	٦ر٠٠٠	١٠٧٠ر٥٥	٨ر٩١٢
٢٦	ر٠٦٧١	ر١٣٦٦	ر٠٠٠٢٣٣	١ر٦٢٩	١٢ر٣٣	١٢ر٢٩	٦ر٢٤٠	١٠٧٠ر٠٩	٩ر٢٩٣
٢٧	ر٠٧٠٣	ر١٤٣٢	ر٠٠٠٢٤٣	١ر٧٠٤	١٢ر٢٦	١٢ر٣٢	٦ر٤٨٠	١٠٧١ر٥٤	٩ر٦٨٢
٢٨	ر٠٧٣٧	ر١٥٠٠	ر٠٠٠٢٥٤	١ر٧٨١	١٢ر٢٨	١٢ر٣٤	٦ر٧٢٠	١٠٧١ر٩٨	١٠ر٠٧٥
٢٩	ر٠٧٧٢	ر١٥٧١	ر٠٠٠٢٦٦	١ر٨٦٢	١٢ر٣١	١٢ر٣٧	٩ر١٦٠	١٠٧٢ر٤٣	١٠ر٤٧٧
٣٠	ر٠٨٠٨	ر١٦٤٥	ر٠٠٠٢٧٨	١ر٩٥	١٢ر٣٣	١٢ر٤٠	٧ر١٩٧	١٠٧٢ر٧٧	١٠ر٨٩٠
٣١	ر٠٨٤٦	ر١٧٢٢	ر٠٠٠٢٩٠	٢ر٠٣	١٢ر٣٦	١٢ر٤٣	٧ر٤٣٧	١٠٧٣ر٢٢	١١ر٣٠٠
٣٢	ر٠٨٨٦	ر١٨٠٣	ر٠٠٠٣٠٣	٢ر١٢	١٢ر٣٨	١٢ر٤٦	٧ر٦٧٧	١٠٧٣ر٦٦	١١ر٧٣٠
٣٣	ر٠٩٢٣	ر١٨٧٩	ر٠٠٠٣١٥	٢ر٢٠	١٢ر٤١	١٢ر٤٩	٧ر٩١٧	١٠٧٤ر١١	١٢ر١٤٠
٣٤	ر٠٩٦١	ر١٩٥٧	ر٠٠٠٣٢٧	٢ر٢٩	١٢ر٤٣	١٢ر٥١	٨ر١٥٧	١٠٧٤ر٥٥	١٢ر٥٦٠
٣٥	ر١٠٠٠	ر٢٠٣٦	ر٠٠٠٣٣٩	٢ر٣٨	١٢ر٤٦	١٢ر٥٤	٨ر٣٩٧	١٠٧٥ر٠٠	١٢ر٩٨٠
٣٦	ر١٠٤٠	ر٢١٢٠	ر٠٠٠٣٥٢	٢ر٤٧	١٢ر٤٨	١٢ر٥٧	٨ر٦٣٦	١٠٧٥ر٤٤	١٣ر٤١٠
٣٧	ر١٠٨٠	ر٢٢٠٥	ر٠٠٠٣٦٦	٢ر٥٦	١٢ر٥١	١٢ر٦٠	٨ر٨٧٦	١٠٧٥ر٨٩	١٣ر٨٥٠
٣٨	ر١١٣٠	ر٢٢٩٢	ر٠٠٠٣٨٠	٢ر٦٦	١٢ر٥٣	١٢ر٦٣	٩ر١١٦	١٠٧٦ر٣٣	١٤ر٢٩٠
٣٩	ر١١٧٠	ر٢٣٨٤	ر٠٠٠٣٩٤	٢ر٧٦	١٢ر٥٦	١٢ر٦٦	٩ر٣٥٦	١٠٧٦ر٧٨	١٤ر٧٤٠
٤٠	ر١٢٢٠	ر٢٤٧٨	ر٠٠٠٤٠٩	٢ر٨٦	١٢ر٥٩	١٢ر٦٩	٩ر٥٩٦	١٠٧٧ر٢٢	١٥ر١٩٠
٤١	ر١٢٧٠	ر٢٥٧٦	ر٠٠٠٤٢٤	٢ر٩٧	١٢ر٦١	١٢ر٧٢	٩ر٨٣٦	١٠٧٧ر٦٧	١٥ر٦٦٠
٤٢	ر١٣٢٠	ر٢٦٧٧	ر٠٠٠٤٤٠	٣ر٠٨	١٢ر٦٤	١٢ر٧٥	١٠ر٠٨٠	١٠٧٨ر١١	١٦ر١٣٠
٤٣	ر١٣٧٠	ر٢٧٨٣	ر٠٠٠٤٥٧	٣ر٢٠	١٢ر٦٦	١٢ر٧٨	١٠ر٣٢٠	١٠٧٨ر٥٦	١٦ر٦٢٠
٤٤	ر١٤٢٠	ر٢٨٩١	ر٠٠٠٤٧٤	٣ر٣٢	١٢ر٦٩	١٢ر٨١	١٠ر٥٦٠	١٠٧٩ر٠٠	١٧ر١١٠
٤٥	ر١٤٨٠	ر٣٠٠٣	ر٠٠٠٤٩١	٣ر٤٤	١٢ر٧١	١٢ر٨٤	١٠ر٨٠٠	١٠٧٩ر٤٥	١٧ر٦١٠
٤٦	ر١٥٣٠	ر٣١١٩	ر٠٠٠٥٠٩	٣ر٥٦	١٢ر٧٤	١٢ر٨٧	١١ر٠٤٠	١٠٧٩ر٨٩	١٨ر١٢٠
٤٧	ر١٥٩٠	ر٣٢٣٩	ر٠٠٠٥٢٧	٣ر٦٩	١٢ر٧٦	١٢ر٩٠	١١ر٢٨٠	١٠٨٠ر٣٤	١٨ر٦٤٠
٤٨	ر١٥٦٠	ر٣٣٦٤	ر٠٠٠٥٤٧	٣ر٨٢	١٢ر٧٩	١٢ر٩٣	١١ر٥٢٠	١٠٨٠ر٧٨	١٩ر١٦٠
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	١٢ر٨١	١٢ر٩٦	١١ر٧٦٠	١٠٨١ر٢٣	١٩ر٧٠٠

درجة الحرارة ف	شروط التبخير – الضغط المطلق: رطل على البوصة المربعة	شروط التبخير – الضغط المطلق: بوصة من عامود الزئبق	وزن بخار التشبع في القدم المكعب (الوزن النوعي): رطل	وزن بخار التشبع في القدم المكعب (الوزن النوعي): قمحة	الحجم بالقدم المكعب: للرطل من الهواء الجاف	الحجم بالقدم المكعب: للرطل من الهواء الجاف + بخار التشبع	كمية الحرارة في الرطل: من الهواء الجاف	كمية الحرارة في الرطل: من البخار	كمية الحرارة في الرطل: من الهواء المشبع
٥٠	ر١٧٨	ر٣٦٢٤	ر٠٠٠٥٨٧	٤ر١١	١٢ر٨٤	١٢ر٩٩	١٢ر٠٠	١٠٨١ر٧	٢٠ر٢٥
٥١	ر١٨٥	ر٣٧٦٢	ر٠٠٠٦٠٨	٤ر٢٦	١٢ر٨٦	١٣ر٠٢	١٢ر٢٣	١٠٨٢ر٢	٢٠ر٨٠
٥٢	ر١٩٢	ر٣٩٠٥	ر٠٠٠٦٣٠	٤ر٤١	١٢ر٨٩	١٣ر٠٦	١٢ر٤٧	١٠٨٢ر٦	٢١ر٣٨
٥٣	ر١٩٩	ر٤٠٥٠	ر٠٠٠٦٥٢	٤ر٥٦	١٢ر٩١	١٣ر٠٩	١٢ر٧١	١٠٨٣ر١	٢١ر٩٥
٥٤	ر٢٠٦	ر٤٢٠٠	ر٠٠٠٦٧٥	٤ر٧٢	١٢ر٩٤	١٣ر١٢	١٢ر٩٥	١٠٨٣ر٥	٢٢ر٥٥
٥٥	ر٢١٤	ر٤٣٥٧	ر٠٠٠٦٩٨	٤ر٨٩	١٢ر٩٦	١٣ر١٥	١٣ر١٩	١٠٨٤ر٠	٢٣ر١٥
٥٦	ر٢٢٢	ر٤٥١٨	ر٠٠٠٧٢٣	٥ر٠٦	١٢ر٩٩	١٣ر١٩	١٣ر٤٣	١٠٨٤ر٤	٢٣ر٧٧
٥٧	ر٢٣٠	ر٤٦٨٣	ر٠٠٠٧٤٨	٥ر٢٣	١٣ر٠١	١٣ر٢٢	١٣ر٦٧	١٠٨٤ر٩	٢٤ر٤٠
٥٨	ر٢٣٨	ر٤٨٥٤	ر٠٠٠٧٧٤	٥ر٤٣	١٣ر٠٤	١٣ر٢٥	١٣ر٩١	١٠٨٥ر٣	٢٥ر٠٥
٥٩	ر٢٤٧	ر٥٠٣١	ر٠٠٠٨٠٩	٥ر٦٠	١٣ر٠٦	١٣ر٢٩	١٤ر١٥	١٠٨٥ر٨	٢٥ر٧٠
٦٠	ر٢٥٦	ر٥٢١٤	ر٠٠٠٨٢٨	٥ر٨٠	١٣ر٠٩	١٣ر٣٢	١٤ر٣٩	١٠٨٦ر٢	٢٦ر٣٧
٦١	ر٢٦٥	ر٥٤٠٤	ر٠٠٠٨٥٦	٥ر٩٩	١٣ر١١	١٣ر٣٥	١٤ر٦٣	١٠٨٦ر٧	٢٧ر٠٦
٦٢	ر٢٧٥	ر٥٥٩٧	ر٠٠٠٨٨٥	٦ر٢٠	١٣ر١٤	١٣ر٣٩	١٤ر٨٧	١٠٨٧ر١	٢٧ر٧٦
٦٣	ر٢٨٥	ر٥٧٩٩	ر٠٠٠٩١٥	٦ر٤١	١٣ر١٦	١٣ر٤٢	١٥ر١١	١٠٨٧ر٦	٢٨ر٤٨
٦٤	ر٢٩٥	ر٦٠٠٤	ر٠٠٠٩٤٦	٦ر٦٢	١٣ر١٩	١٣ر٤٦	١٥ر٣٥	١٠٨٨ر٠	٢٩ر٢١
٦٥	ر٣٠٥	ر٦٢١٨	ر٠٠٠٩٧٨	٦ر٨٥	١٣ر٢١	١٣ر٤٩	١٥ر٥٩	١٠٨٨ر٥	٢٩ر٩٦
٦٦	ر٣١٦	ر٦٤٣٨	ر٠٠١٠١١	٧ر٠٧	١٣ر٢٤	١٣ر٥٣	١٥ر٨٣	١٠٨٨ر٩	٣٠ر٧٣
٦٧	ر٣٢٧	ر٦٦٦٤	ر٠٠١٠٤٤	٧ر٣١	١٣ر٢٦	١٣ر٥٧	١٦ر٠٧	١٠٨٩ر٤	٣١ر٠١
٦٨	ر٣٣٩	ر٦٨٩٨	ر٠٠١٠٨٢	٧ر٥٧	١٣ر٢٩	١٣ر٦٠	١٦ر٣١	١٠٨٩ر٨	٣٢ر٣١
٦٩	ر٣٥١	ر٧١٣٨	ر٠٠١١١٤	٧ر٨٠	١٣ر٣١	١٣ر٦٤	١٦ر٥٥	١٠٩٠ر٣	٣٣ر١٣
٧٠	ر٣٦٣	ر٧٣٨٧	ر٠٠١١٥١	٨ر٠٦	١٣ر٣٤	١٣ر٦٨	١٦ر٧٩	١٠٩٠ر٧	٣٣ر٩٦
٧١	ر٣٧٥	ر٧٦٤٣	ر٠٠١١٨٨	٨ر٣٢	١٣ر٣٧	١٣ر٧١	١٧ر٠٣	١٠٩١ر٢	٣٤ر٧٣
٧٢	ر٣٨٨	ر٧٩٠٦	ر٠٠١٢٢٧	٨ر٥٩	١٣ر٤٠	١٣ر٧٥	١٧ر٢٧	١٠٩١ر٦	٣٥ر٧٠
٧٣	ر٤٠٢	ر٨١٧٧	ر٠٠١٢٦٧	٨ر٨٧	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

شروط التبخير			وزن بخار التشبع		الحجم بالقدم المكعب		كمية الحرارة فى الرطل		
درجة الحرارة ف	الضغط المطلق		فى القدم المكعب (الوزن النوعى)						
	رطل على البوصة المربعة	بوصة من عامود الزئبق	رطل	قمحة	للرطل من الهواء الجاف	للرطل من الهواء الجاف + بخار التشبع	من الهواء الجاف	من البخار	من الهواء المشبع
٧٥	٫٤٣٠	٫٨٧١٥	٫٠٠٢١٥٠	٩٫٤٥	١٣٫٤٧	١٣٫٨٧	١٧٫٩٩	١٠٩٣٫٠	٣٨٫٤٦
٧٦	٫٤٤٤	٫٩٠٤٠	٫٠٠١٣٩٣	٩٫٧٥	١٣٫٤٩	١٣٫٩١	١٨٫٢٣	١٠٩٣٫٤	٣٩٫٤٢
٧٧	٫٤٥٩	٫٩٣٤٥	٫٠٠١٤٣٧	١٠٫٠٦	١٣٫٥٢	١٣٫٩٥	١٨٫٤٧	١٠٩٣٫٩	٤٠٫٤٠
٧٨	٫٤٧٤	٫٩٦٥٩	٫٠٠١٤٨٣	١٠٫٣٨	١٣٫٥٤	١٣٫٩٩	١٨٫٧١	١٠٩٤٫٣	٤١٫٤٣
٧٩	٫٤٩٠	٫٩٩٨٣	٫٠٠١٥٣٠	١٠٫٧١	١٣٫٥٧	١٤٫٠٣	١٨٫٩٥	١٠٩٤٫٧	٤٢٫٤٦
٨٠	٫٥٠٧	١٫٠٣١٦	٫٠٠١٥٧٨	١١٫٠٤	١٣٫٥٩	١٤٫٠٨	١٩٫١٩	١٠٩٥٫٢	٤٣٫٥١
٨١	٫٥٢٤	١٫٠٦٦١	٫٠٠١٦٢٧	١١٫٣٩	١٣٫٦٢	١٤٫١٢	١٩٫٤٣	١٠٩٥٫٧	٤٤٫٦١
٨٢	٫٥٤١	١٫١٠١٣	٫٠٠١٦٧٨	١١٫٧٥	١٣٫٦٤	١٤٫١٦	١٩٫٦٧	١٠٩٦٫١	٤٥٫٧٣
٨٣	٫٥٥٩	١٫١٣٧٧	٫٠٠١٧٣٠	١٢٫١١	١٣٫٦٧	١٤٫٢١	١٩٫٩١	١٠٩٦٫٦	٤٦٫٨٨
٨٤	٫٥٧٧	١٫١٧٥٣	٫٠٠١٧٨٤	١٢٫٤٩	١٣٫٦٩	١٤٫٢٦	٢٠٫١٥	١٠٩٧٫٠	٤٨٫٠٥
٨٥	٫٥٩٦	١٫٢١٣٥	٫٠٠١٨٣٩	١٢٫٨٧	١٣٫٧٢	١٤٫٣٠	٢٠٫٣٩	١٠٩٧٫٥	٤٩٫٢٤
٨٦	٫٦١٥	١٫٢٥٢٧	٫٠٠١٨٩٥	١٣٫٢٧	١٣٫٧٤	١٤٫٣٤	٢٠٫٦٣	١٠٩٧٫٩	٥٠٫٤٧
٨٧	٫٦٣٥	١٫٢٩٣٣	٫٠٠١٩٥٣	١٣٫٦٧	١٣٫٧٧	١٤٫٣٩	٢٠٫٨٧	١٠٩٨٫٤	٥١٫٧٤
٨٨	٫٦٥٦	١٫٣٣٤٦	٫٠٠٢٠١٢	١٤٫٠٨	١٣٫٧٩	١٤٫٤٤	٢١٫١١	١٠٩٨٫٨	٥٣٫٠٢
٨٩	٫٦٧٧	١٫٣٧٧٤	٫٠٠٢٠٧٢	١٤٫٥١	١٣٫٨٢	١٤٫٤٨	٢١٫٣٥	١٠٩٩٫٣	٥٤٫٣٥
٩٠	٫٦٩٨	١٫٤٢١١	٫٠٠٢١٣٤	١٤٫٩٤	١٣٫٨٤	١٤٫٥٣	٢١٫٥٩	١٠٩٩٫٧	٥٥٫٧٠
٩١	٫٧٢٠١	١٫٤٦٦١	٫٠٠٢١٩٨	١٥٫٣٩	١٣٫٨٧	١٤٫٥٨	٢١٫٨٣	١١٠٠٫٢	٥٧٫٠٩
٩٢	٫٧٤٢٩	١٫٥١٢٥	٫٠٠٢٢٦٣	١٥٫٨٤	١٣٫٨٩	١٤٫٦٣	٢٢٫٠٧	١١٠٠٫٦	٥٨٫٥٢
٩٣	٫٧٦٦٢	١٫٥٦٠٠	٫٠٠٢٣٣٠	١٦٫٣١	١٣٫٩٢	١٤٫٦٨	٢٢٫٣٢	١١٠١٫١	٥٩٫٩٩
٩٤	٫٧٩٠٢	١٫٦٠٨٨	٫٠٠٢٣٩٩	١٦٫٧٩	١٣٫٩٤	١٤٫٧٣	٢٢٫٥٦	١١٠١٫٥	٦١٫٥٠
٩٥	٫٨١٤٩	١٫٦٥٩١	٫٠٠٢٤٧٠	١٧٫٢٨	١٣٫٩٧	١٤٫٧٩	٢٢٫٨٠	١١٠٢٫٠	٦٣٫٥٠
٩٦	٫٨٤٠٣	١٫٧١٠٨	٫٠٠٢٥٤٣	١٧٫٨٠	١٣٫٩٩	١٤٫٨٤	٢٣٫٠٤	١١٠٢٫٤	٦٤٫٦٣
٩٧	٫٨٦٦٣	١٫٧٦٣٨	٫٠٠٢٦١٦	١٨٫٣١	١٤٫٠٢	١٤٫٩٠	٢٣٫٢٨	١١٠٢٫٩	٦٦٫٢٥

Table A4: Cavity thermal resistance

Air-gap		Cavity Thermal Resistance	
Gap width [mm]	Kind of material	Vertically or upward heat flow	Downward heat flow
5	Building materials	0.11	0.11
5	Metals	0.18	0.18
20 or more	Building materials	0.18	0.2
20 or more	Metals	0.35	1.06

Table A5: Inside surface thermal resistance

Element	Direction of thermal flow	Kind of material	Inside Surface Thermal Resistance
Walls	Vertically	Building materials	0.12
		metals	0.31
Ceilings & floors	Upward	Building materials	0.1
		metals	0.21
	Downward	Building materials	0.15

Table A6: Outside surface thermal resistance

Degree of exposure		Sheltered	Normal	Sever
Wind speed (m / s)		Less than 0.5	0.5 - 5	More than 5
Element	Kind of material	Outside Surface Thermal Resistance		
Walls	Building materials	0.08	0.06	0.03
	Metals	0.1	0.07	0.03
Ceilings	Building materials	0.07	0.04	0.02
	Metals	0.09	0.05	0.02
Exposure floors	Building materials	0.09	-------	-------

Table A7: Thermal conductivity for materials

Material	Density Kg/m^3	thermal conductivity W/m.°C
Marble	2600	2.9
Hard stone	2500	2.2
Firm stone	2250	1.7
Tiles	1900	0.85
Normal concrete	2300	1.75
Bricks	1400	0.8
Plaster	2000	1.2
Iron (cast)	7400	47
block	1800	1.2

Table A8: Glass thermal resistance

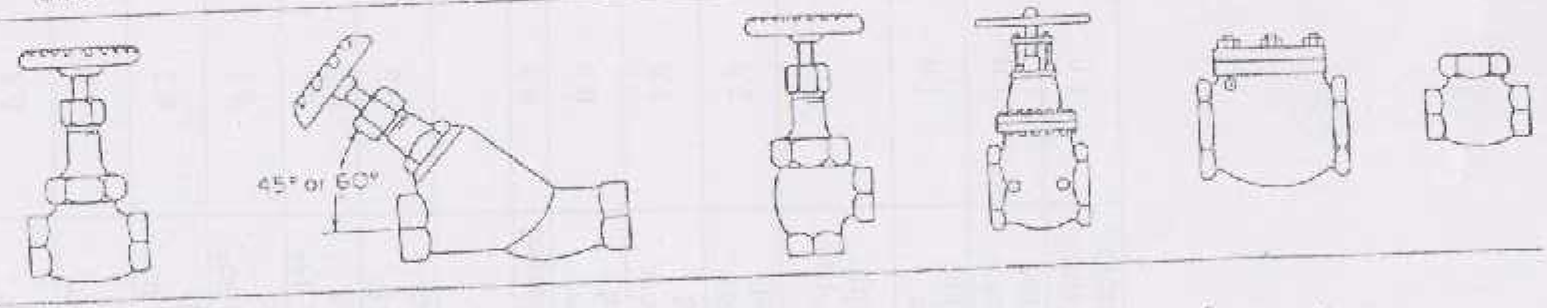
Kind of materials for openings	Doors	Windows					
		Single glazing			Double glazing		
		Sheltered	Normal	Sever	Sheltered	Normal	Sever
Wood	3.5	5	4.3	3.8	2.7	2.5	2.3
Aluminium	7	6.7	5.6	5	3.5	3.2	3
Steel	5.8						
PVC	---	5	4.3	3.8	2.7	2.5	2.3

Table A9: Heat gain from people

Degree of activity	SenHG (W)	LatHG (W)	Total heat (W)
Seated at rest	60.5	42.5	103
Seated –very light work	73.2	58.5	131.7
Moderately active office work.	67.3	64.7	132
Standing light work ,walking slowly	69.6	77.8	147.4
Moderate work	77.1	143.3	220.4

Table A10: Valve losses in equivalent feet (meters) of pipe

Screwed, welded, flanged, and flared connections



Nominal pipe or tube size		Globe†		60° Y		45° Y		Angle†		Gate‡		Swing check§		Lift check
in	mm	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	
3/8	10	17	5.2	8	2.4	6	1.8	6	1.8	0.6	0.2	5	1.5	Globe and vertical lift same as globe valve¶
1/2	12	18	5.5	9	2.7	7	2.1	7	2.1	0.7	0.2	6	1.8	
3/4	20	22	6.7	11	3.4	9	2.7	9	2.7	0.9	0.3	8	2.4	
1	25	29	8.8	15	4.6	12	3.7	12	3.7	1.0	0.3	10	3.0	
1 1/4	32	38	11.6	20	6.1	15	4.6	15	4.6	1.5	0.5	14	4.3	
1 1/2	40	43	13.1	24	7.3	18	5.5	18	5.5	1.8	0.5	16	4.9	
2	50	55	16.8	30	9.1	24	7.3	24	7.3	2.3	0.7	20	6.1	
2 1/2	65	69	21.0	35	10.7	29	8.8	29	8.8	2.4	0.9	25	7.6	
3	80	84	25.6	43	13.1	35	10.7	35	10.7	3.2	1.0	30	9.1	
3 1/2	90	107	32.6	50	15.2	41	12.5	41	12.5	4.0	1.2	35	10.7	
4	100	120	36.6	58	17.7	47	14.3	47	14.3	4.5	1.4	40	12.2	
5	125	140	42.7	71	21.6	58	17.7	58	17.7	6	1.8	50	15.2	
6	150	170	51.8	88	26.8	70	21.3	70	21.3	7	2.1	60	18.3	
8	200	220	67.1	115	35.1	85	25.9	85	25.9	9	2.7	80	24.4	
10	250	280	85.3	145	44.2	105	32.0	105	32.0	12	3.7	100	30.5	Angle lift same as angle valve
12	300	320	97.5	165	50.3	130	39.6	130	39.6	13	4.0	120	36.6	
14	350	360	109.7	185	56.4	155	47.2	155	47.2	15	4.6	135	41.1	
16	400	410	125.0	210	64.0	180	54.9	180	54.9	17	5.0	150	45.7	
18	450	460	140.2	240	73.2	200	61.0	200	61.0	19	5.8	165	50.3	
20	500	520	158.5	275	83.8	235	71.6	235	71.6	22	6.7	200	61.0	
24	600	610	185.9	330	100.6	265	80.8	265	80.8	25	7.6	240	73.2	

*Losses are for all valves in fully open position.
†These losses do not apply to valves with needlepoint type seats.
‡Regular and short pattern plug cock valves, when fully open, have same loss as gate valve. For valve losses of short-pattern plug cocks above 6 in. check manufacturer.
§Losses also apply to the in-line, ball type check valve.
¶For Y pattern globe lift-check valve with seat approximately equal to the nominal pipe diameter, use values of 60° Y valve for loss.

Table A11: Minor Losses Coefficients

fitting	K_m	Fitting	K_m
Valves:		Elbows:	
Globe, fully open	10	Regular 90°, flanged	0.3
Angle, fully open	2	Regular 90°, threaded	1.5
Gate, fully open	0.15	Long radius 90°, flanged	0.2
Gate 1/4 closed	0.26	Long radius 90°, threaded	0.7
Gate, 1/2 closed	2.1	Long radius 45°, threaded	0.2
Gate, 3/4 closed	17	Regular 45°, threaded	0.4
Swing check, backward flow	infinity	Tees:	
		Line flow, flanged	0.2
180° return bends:		Line flow, threaded	0.9
Flanged	0.2	Branch flow, flanged	1.0
Threaded	1.5	Branch flow, threaded	2.0
Pipe Entrance (Reservoir to Pipe):		Pipe Exit (Pipe to Reservoir)	
Square Connection	0.5	Square Connection	1.0
Rounded Connection	0.2	Rounded Connection	1.0
Re-entrant (pipe juts into tank)	1.0	Re-entrant (pipe juts into tank)	1.0

Table A12a: Cooling capacities of fan coils

Cooling capacities

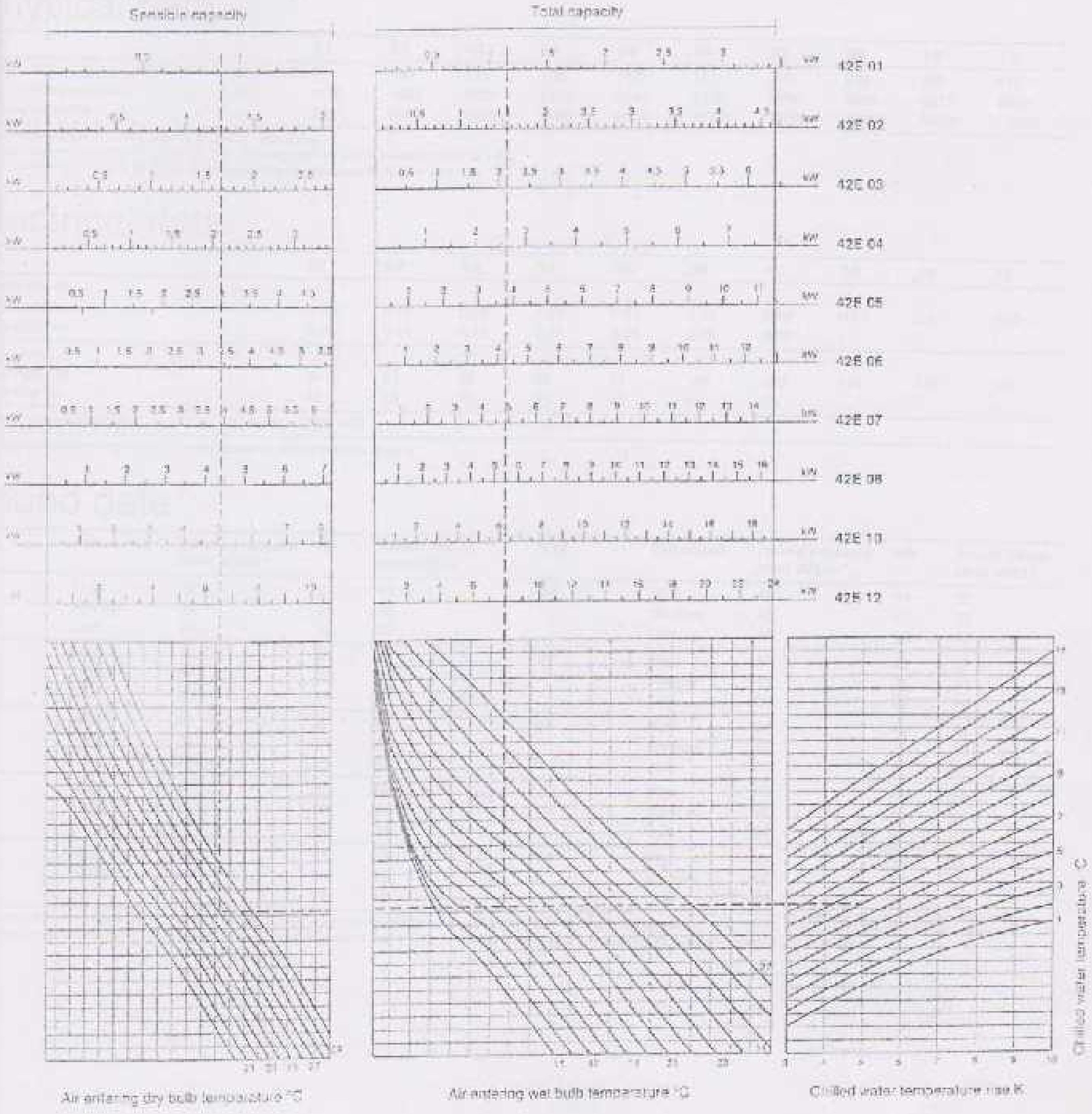


Table A12b: Fan coils data

Physical data

[illegible]		01	02	03	04	05	06	07	08	10	12
[illegible] flow	l/s	74	100	133	159	149	251	300	319	350	472
[illegible] cooling capacity	W	1130	1560	2030	2350	3630	4200	4900	5590	6215	5030
[illegible] ting capacity	W	2500	3880	4570	6300	8900	10100	11600	12200	14800	19500

[illegible] at high fan speed and:
[illegible] entering chilled water temperature 7°C, Δt = 5 K
[illegible] entering hot water temperature 70°C, Δt = 10 K

Electrical data

[illegible]		01	02	03	04	05	06	07	08	10	12
[illegible] rent drawn	A										
[illegible] trifugal fan		0.15	0.16	0.28	0.30	0.31	0.49	0.54	0.53	0.61	0.82
[illegible] gential fan		0.09	0.11	0.13	0.17	0.20	0.28	0.32	-	-	-
[illegible] er input	W										
[illegible] trifugal fan		34	40	55	63	71	106	120	121	139	167
[illegible] gential fan		16	23	28	33	43	52	73	-	-	-
[illegible] inal power supply	V-ph-Hz	230-1-50									

[illegible] electric motors with permanent capacitor, IP20 protection, class B.

Sound data*

[illegible]	Fan speed	Sound pressure level dB(A)**	NR	Sound power level dB(A)
	High	32	27	40
	Medium	28	24	36
	Low	20	15	28
	High	40	36	48
	Medium	32	27	40
	Low	20	15	28
	High	38	32	44
	Medium	29	24	37
	Low	25	20	33
	High	41	37	49
	Medium	36	32	44
	Low	25	20	33
	High	45	41	53
	Medium	42	38	50
	Low	32	28	40

42E	Fan speed	Sound pressure level dB(A)**	NR	Sound power level dB(A)
06	High	48	44	56
	Medium	45	41	53
	Low	34	25	42
07	High	49	45	57
	Medium	45	41	53
	Low	34	29	42
08	High	48	43	56
	Medium	45	40	53
	Low	39	34	47
10	High	50	45	58
	Medium	45	40	53
	Low	39	34	47
12	High	59	54	67
	Medium	51	47	59
	Low	43	39	51

[illegible] for floor-mounted fan coil units with cabinet. Values refer to units with tangential fan for sizes 01-07, and centrifugal fan for sizes 08-12. Values given are for a typical installation.
[illegible] pressure levels dB(A). NR measured in a room of 100 m³ volume and 0.5 sec. reverberation time (e.g. living room with wall-to-wall carpet and curtains).

Table A13: Physical data of 30SM chillers

hysical data

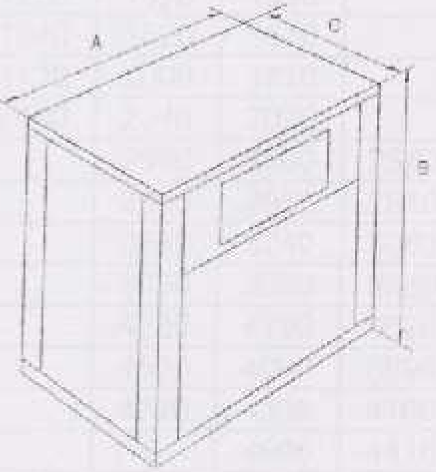
		004	005	006	007	009	011	018	024	027	036
al cooling capacity*	kW	13.2	16.5	21.5	25.0	31.1	34.7	53.2	79.7	00.1	110.5
ating weight	kg	125	125	132	154	173	188	444	492	504	543
gerant charge	kg	2.90	3.00	3.30	3.65	4.10	4.25	7.4	9.2	9.2	10.5
pressor		One... Hermetic						One... Semi-hermetic			
arge	l	1.92	1.92	1.92	4.0	4.0	4.0	5.83	8.99	8.99	8.99
r		One... Plate heat exchanger									
ater volume	l	1.24	1.24	1.90	1.90	2.26	2.65	7.50	10.00	11.25	15.00
design working pressure	kPa										
gerant side		3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
r side		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
r connection MPT gas											
Outlet	in.	1	1	1	1	1	1	1-1/2	1-1/2	1-1/2	1-1/2
enser		One... Plate heat exchanger									
ater volume	l	0.95	0.95	1.5	1.6	1.9	2.20	6.25	7.5	8.75	11.25
design working pressure	kPa										
gerant side		3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
r side		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
r connection MPT gas											
Outlet	in.	1	1	1	1	1	1	1-1/2	1-1/2	1-1/2	1-1/2

...water entering evaporator at 12°C, leaving evaporator at 7°C, water entering condenser at 30°C and water leaving condenser at 35°C

mensions/clearances

	A	B	C
	780	840	580
	780	840	580
	780	840	580
	780	840	580
	780	840	580
	780	840	580
	1007	900	910
	1007	900	910
	1007	900	910
	1007	900	910

...ensions are given in mm.



area

	units 004-011 - 500 mm
	units 018-036 - 1000 mm
and rear:	units 004-011 - 300 mm
	units 018-036 - 500 mm

Table A14:

Chimney Dimensions For Natural Draught

Boiler output [Kw]	Chimney height [m]							
	6	8	10	12	15	20	30	40
	Suitable cross-sectional area [cm²]							
25	125	125	125					
35	210	200	190	185				
45	330	300	285	280	275			
60	380	350	330	320	315			
70	430	400	380	370	365			
80	475	445	425	415	410			
90		490	470	460	455	440		
105		335	515	505	495			
115		580	560	545	535	520		
175		810	775	760	750	730		
230			1000	985	960	925		
290			1230	1200	1160	1100		
350				1400	1340	1290		
400				1610	1550	1480	1360	
465					1750	1670	1530	
525					1940	1820	1670	
580					2130	2000	1810	
700					2490	2340	2070	
930						2990	2660	2540
1050						3310	2950	2810
1160						3630	3240	3080
1280						3930	3520	3360
1400						4230	4790	3620
1500						4520	4060	3890
1630						4820	4336	4160
1750							4600	4410
1850							4860	4670
1975							5120	4920
2090							5390	5180
2200							5660	5440
2325							5920	5700
2900							7220	6920

Table A15:

Minimum Thickness Of Thermal Insulation For Hot Surfaces

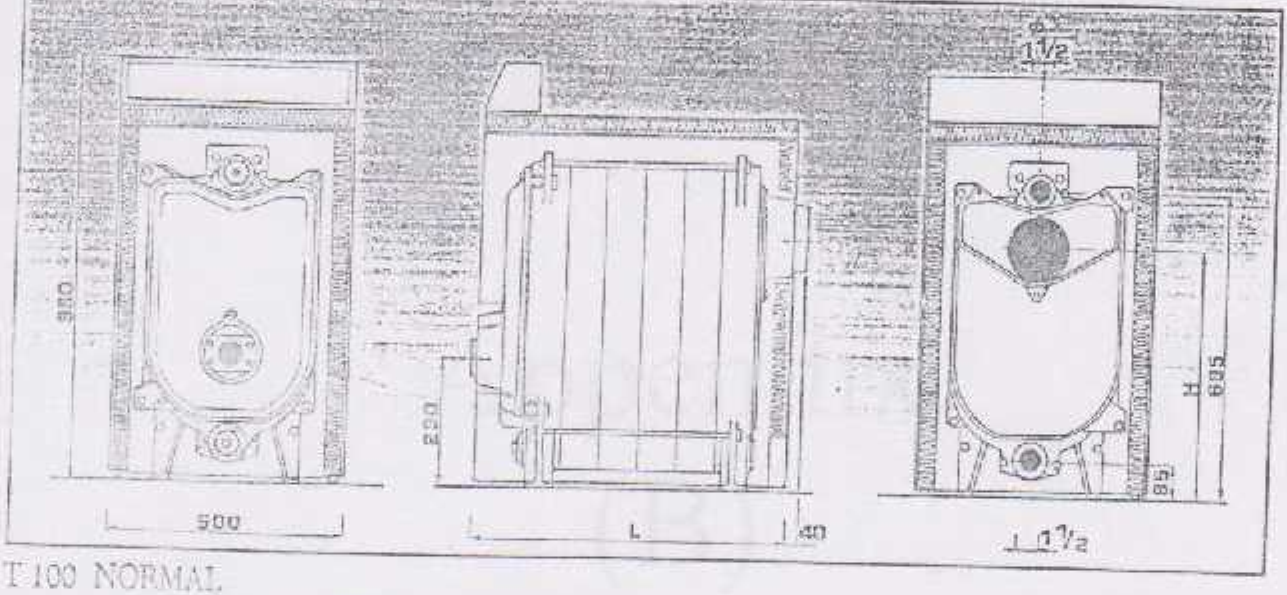
Nominal diameter of the pipe [mm]	Insulation thermal conductance [W/m^2 °C]				
	0.03	0.04	0.05	0.06	0.07
	Minimum Thickness [mm]				
Less than 20	8	12	17	22	31
20 to 80	11	16	23	30	39
80 to 200	16	23	31	38	49
More than 200	22	31	40	48	59

TECHNICAL DATA

T 100 HR

Table A16: Technical data of T 100 HR boilers

Boiler model	Nr of sections	Rated thermal delivery of the comb. chamb. cal/h	kw	Rated thermal capacity cal/h	Useful thermal cap. kw	Water contents L	Length with casing mm	Ø Flue outlet mm	Onflow conn.	Backflow conn.	Weight
T 100 HR 3	3	22.000	24.1	19.000	22.1	10.5	440	150	1 1/2"	1 1/2"	126
T 100 HR 4	4	29.900	34.8	27.000	31.4	14	520	150	1 1/2"	1 1/2"	155
T 100 HR 5	5	40.900	47.6	37.000	43.0	17.5	600	150	1 1/2"	1 1/2"	183
T 100 HR 6	6	51.900	60.3	47.000	54.7	21	680	150	1 1/2"	1 1/2"	212
T 100 HR 7	7	63.100	73.4	57.000	66.3	24.5	760	180	1 1/2"	1 1/2"	243
T 100 HR 8	8	73.300	85.1	66.000	76.7	28	840	180	1 1/2"	1 1/2"	272
T 100 HR 9	9	83.300	96.7	75.000	87.2	31.5	920	180	1 1/2"	1 1/2"	300



T 100 NORMAL

Boiler model	Nr of sections	Rated thermal delivery of the comb. chamb. cal/h	kw	Rated thermal capacity cal/h	Useful thermal cap. kw	Water contents L	Length with casing mm	Ø Flue outlet mm	Onflow conn.	Backflow conn.	Weight
T 100/N 3	3	28.400	33.0	25.000	29.1	10.5	440	150	1 1/2"	1 1/2"	126
T 100/N 4	4	40.900	47.6	36.000	41.9	14	520	150	1 1/2"	1 1/2"	155
T 100/N 5	5	53.400	62.1	47.000	54.7	17.5	600	150	1 1/2"	1 1/2"	183
T 100/N 6	6	66.000	76.7	58.000	67.4	21	680	150	1 1/2"	1 1/2"	212
T 100/N 7	7	78.600	91.4	69.000	80.2	24.5	760	180	1 1/2"	1 1/2"	243
T 100/N 8	8	91.100	105.9	80.000	93.0	28	840	180	1 1/2"	1 1/2"	272

Table A17 outside air required per person

Application	Smoking	Outside air L/s/person
Hotels room	Heavy	14-12
Offices,general	Some	7-5
Meeting rooms	Heavy	24-14
Restaurant	Some	7-5
Theaters	None	3.6-2.4
Hospital,wards	None	14-9
Offices private	None	12-7

Appendix (B)

Chart 1: حساب أقطار المواسير

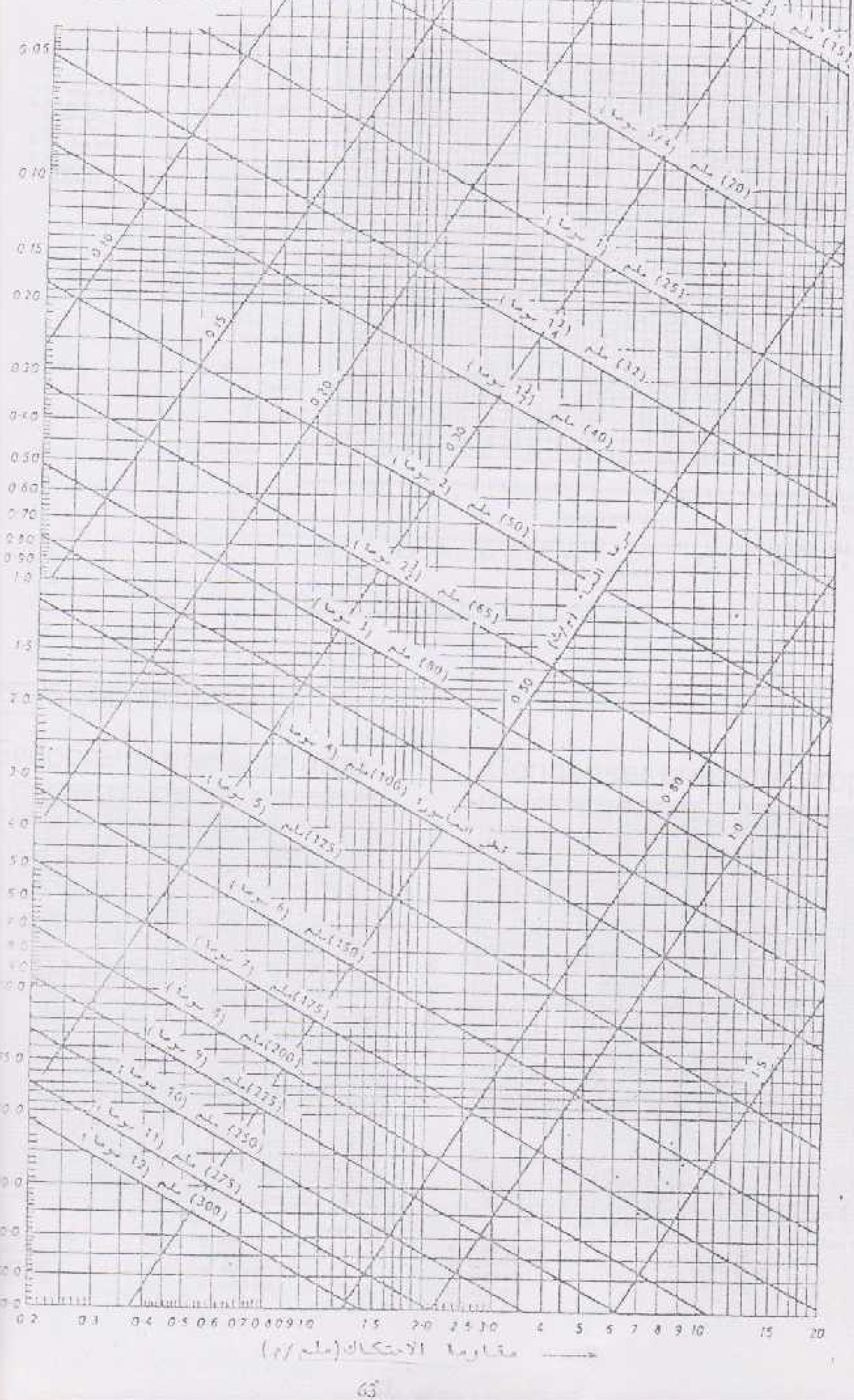
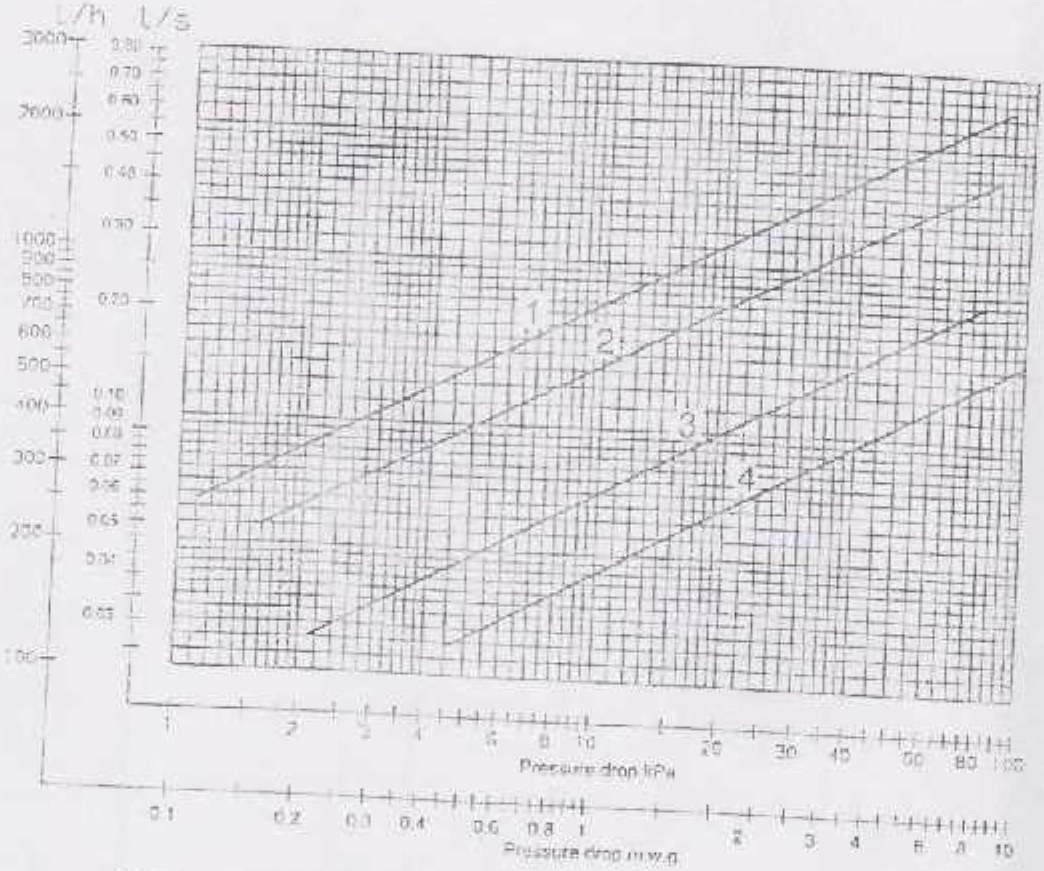


Chart 2: Carrier fan coil head loss

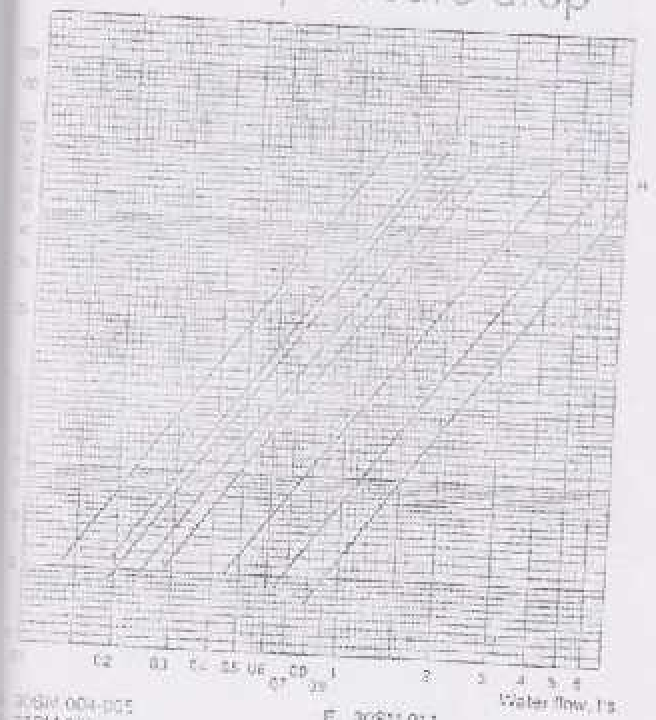
1. 3/4" valve, open
2. 3/4" valve, bypass open (3-way only)
3. 1/2" valve, open
4. 1/2" valve, bypass open (3-way only)



Pressure drop values are based on a water temperature of 20°C.
For other water temperature values use a correction factor of 0.4% per °C.

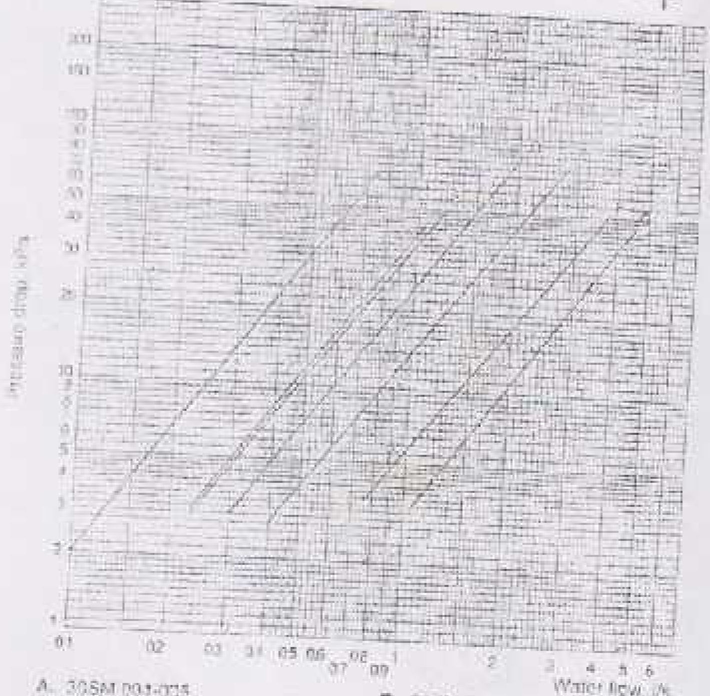
Chart 3: Carrier chiller head loss

Evaporator pressure drop



A. 30SM 004-005
B. 30SM 006
C. 30SM 007
D. 30SM 009
E. 30SM 011
F. 30SM 018
G. 30SM 024-027
H. 30SM 036

Condenser pressure drop



A. 30SM 004-005
B. 30SM 006-007
C. 30SM 009
D. 30SM 011
E. 30SM 018
F. 30SM 024-027
G. 30SM 036

Chart 5a: لوحة وستنجهاوس

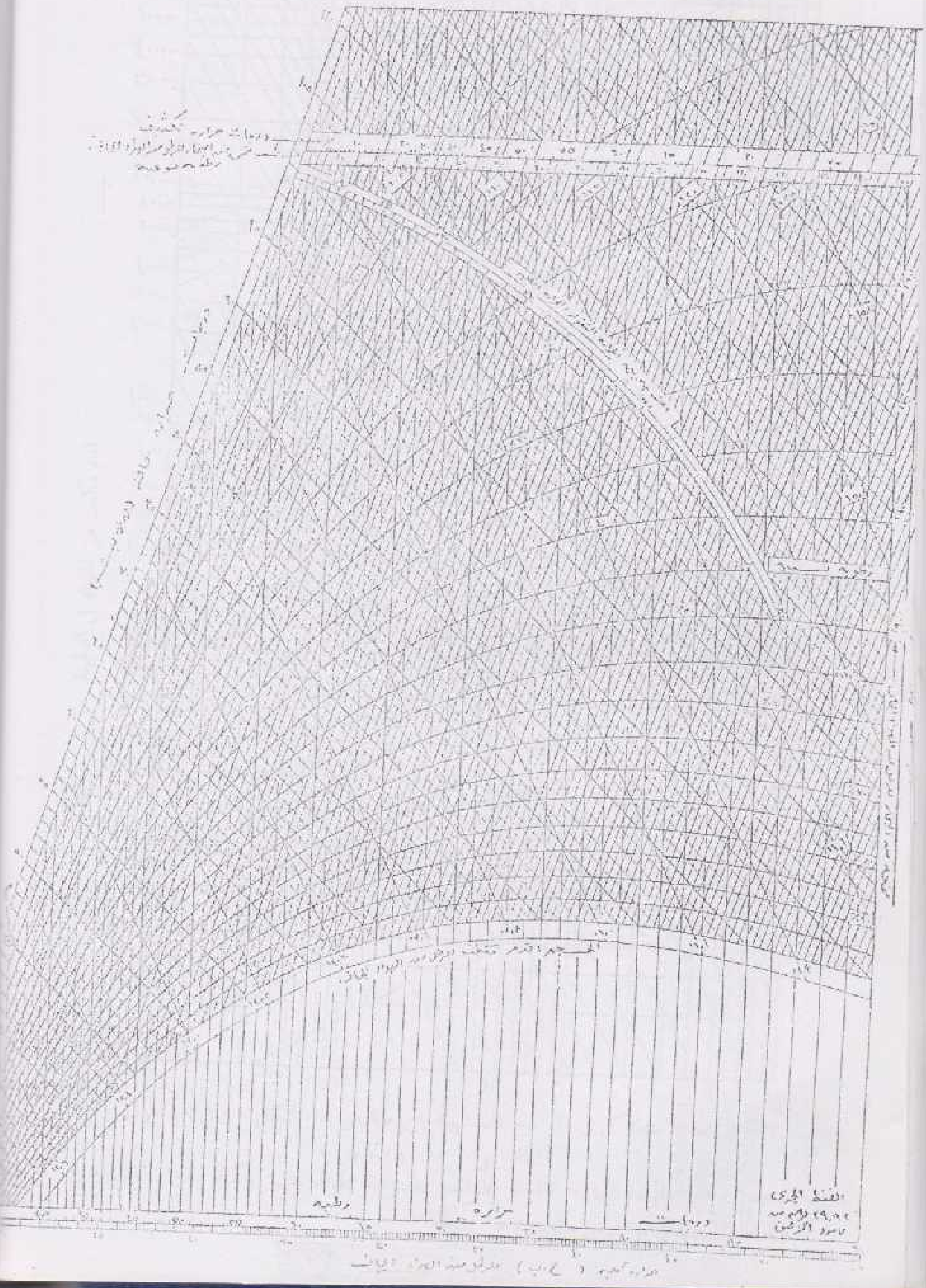
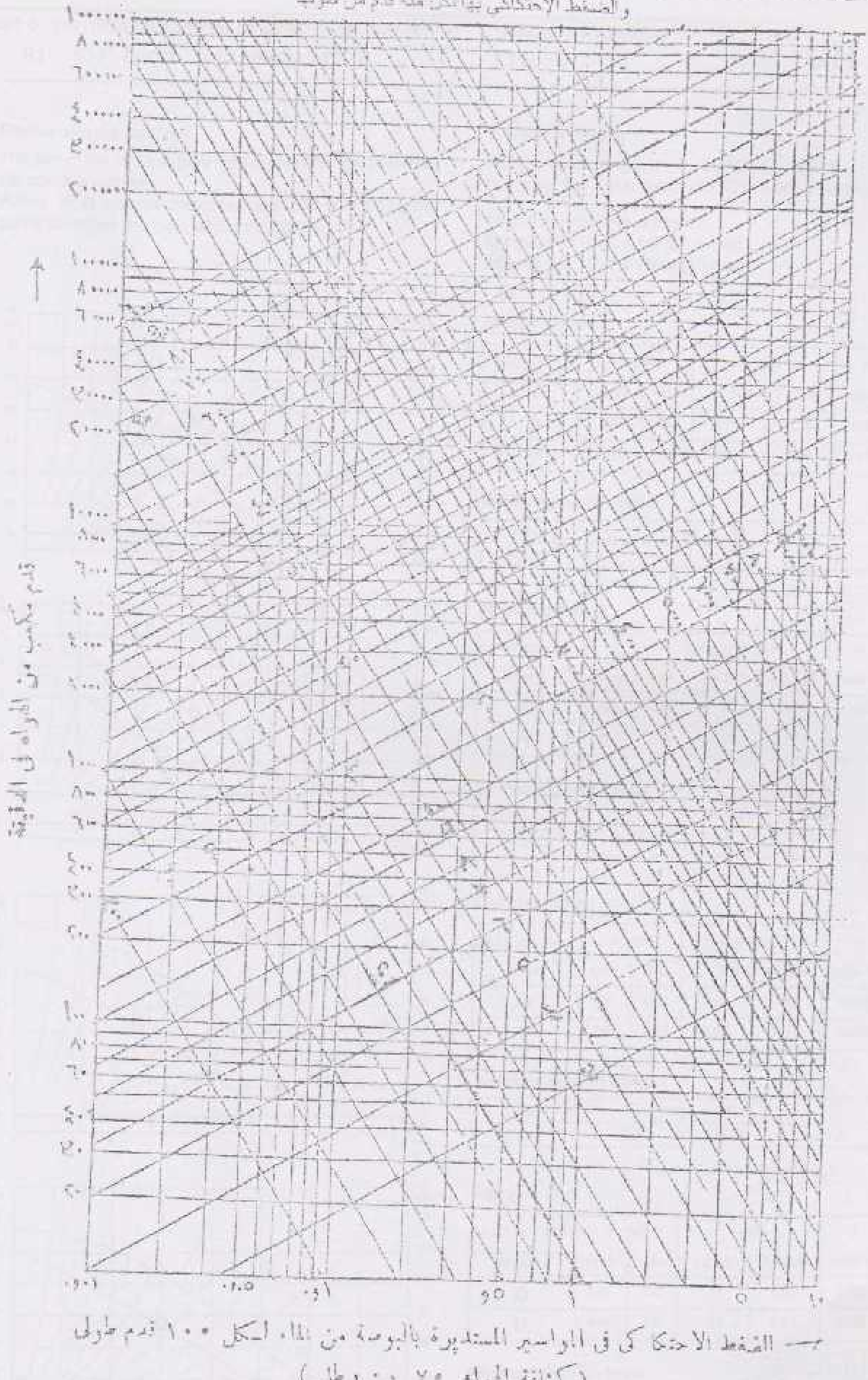


Chart 5b: اللوحة البيانية لأقطار المواسير وسرعة الهواء فيها وكمية الهواء المنقولة
والضغط الاحتكاكي بها لكل مئة قدم من طولها



رسم ٢٠ : اللوحة البيانية لأقطار المواسير وسرعة الهواء فيها وكمية الهواء المنقولة
والضغط الاحتكاكي بها لكل مائة قدم من طولها

Chart 6: performance curve of DN 50 circular pump

R2C 50 / R2CD 50 - 2 poles / 50 Hz

Circulator pumps
3 Phase

DN 50

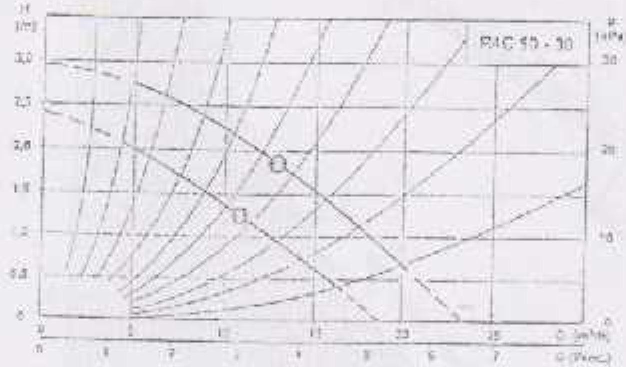
Performance curves

The part of the curve in bold type represents the preferential operative zone.
Points ⊖ ⊙ indicate the speed and their position on the curve identifies the best efficiency point.

Working fields

Temperature range: from - 20 °C to + 130 °C
Domestic hot water: from +15 °C to + 60 °C (bronze vers.)

Maximum working pressure
flanges PN 6: 0,6 MPa (6 bar)
flanges PN 10: 1,0 MPa (10 bar)

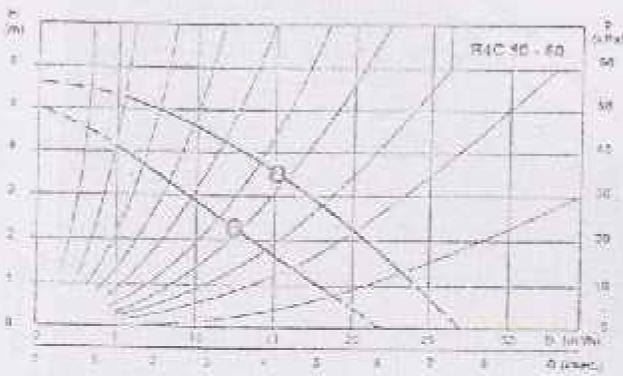


Electrical data

R4C 50 - 30	P_1 (W)		In (A)		n
speed	max	min.	3 x 380	3 x 220	(min⁻¹)
⊖	230	160	0,74	1,28	1390
⊙	132	93	0,33	0,56	1170

Minimum suction head

t (°C)	75	90	120
h_1 (m)	0,5	1,0	13,5

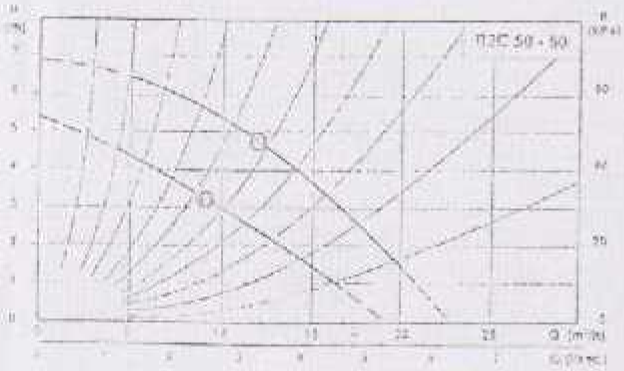


Electrical data

R4C 50 - 60	P_1 (W)		In (A)		n
speed	max	min.	3 x 380	3 x 220	(min⁻¹)
⊖	425	220	1,10	1,91	1390
⊙	290	140	0,60	1,04	1170

Minimum suction head

t (°C)	75	90	120
h_1 (m)	0,5	4,0	16,5

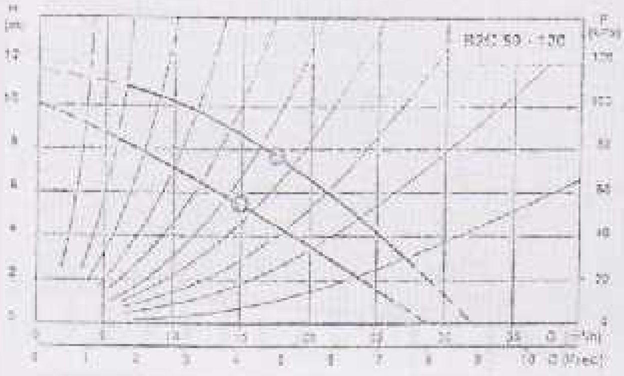


Electrical data

R2C 50 - 50	P_1 (W)		In (A)		n
speed	max	min.	3 x 380	3 x 220	(min⁻¹)
⊖	390	240	0,95	1,65	2800
⊙	243	145	0,43	0,75	2280

Minimum suction head

t (°C)	75	90	120
h_1 (m)	0,5	2,0	14,5



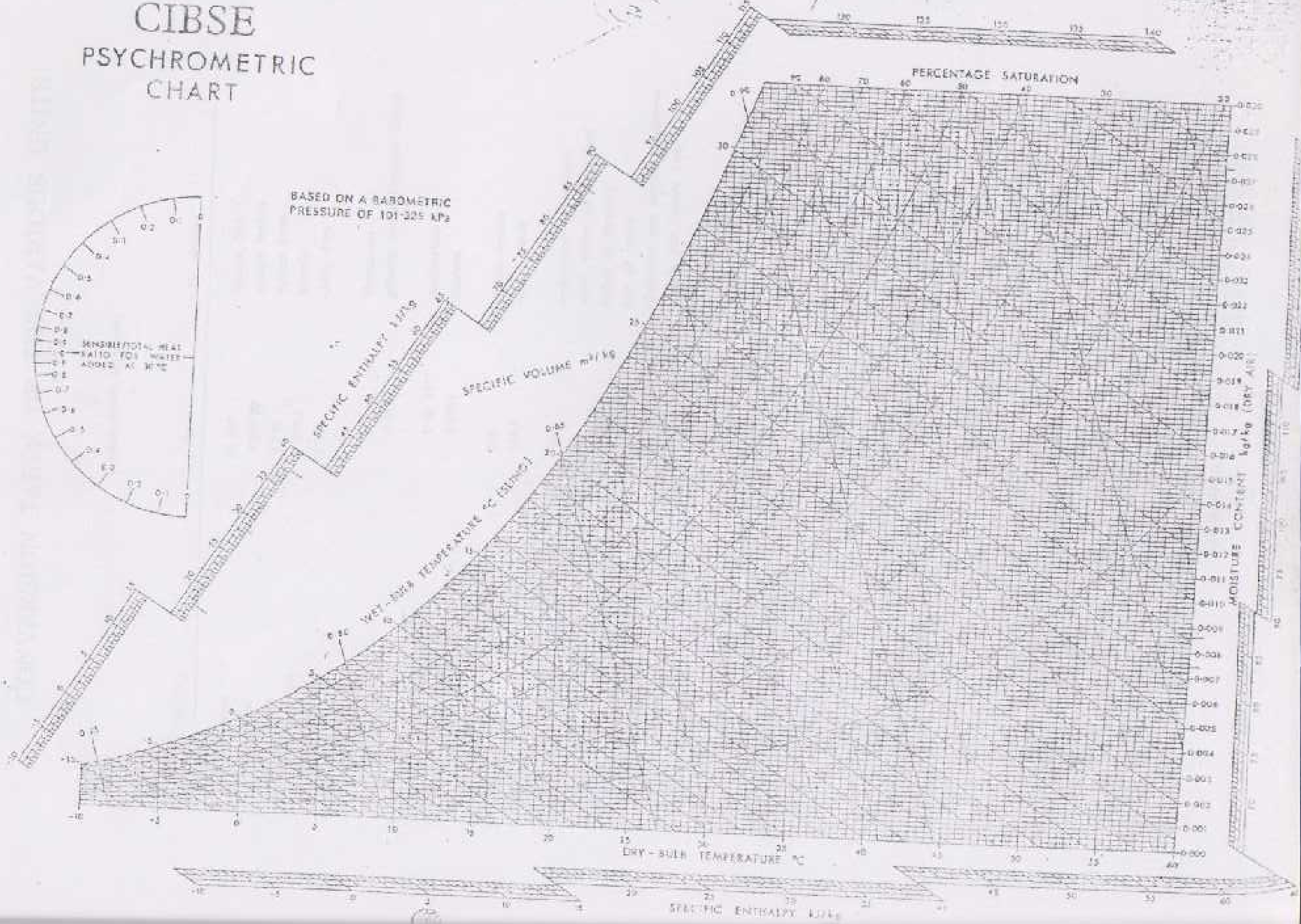
Electrical Data

R2C 50 - 120	P_1 (W)		In (A)		n
speed	max	min.	3 x 380	3 x 220	(min⁻¹)
⊖	885	480	1,75	3,02	2700
⊙	650	370	1,18	2,04	2050

Minimum suction head

t (°C)	75	90	120
h_1 (m)	3,5	7,0	19,5

CIBSE PSYCHROMETRIC CHART



CONVERSION TABLE OF THE VARIOUS UNITS

(alphabetically arranged)

Multiply	*By*	*To obtain*
acres	43 560	square feet
acres	4 046.85	square metres
acres	4 840	square yards
acre feet	7 758.4	barrels
acre feet	43 560	cubic feet
amperes	0.1	abamperes
ampere turns	1.2566	gilberts (magnetomotive force)
Ångstroms	1×10^{-8}	centimetres
Ångstroms	0.0001	microns
are	100	square metres
are	119.6	square yards
atmospheres	76	centimetres of mercury
atmospheres	760	torrs (mms of mercury)
atmospheres	29.921	inches of mercury
atmospheres	33.8985	feet of water
atmospheres	1.0332	Kilograms per square centimetre
atmospheres	14.696	pounds per square inch
atmospheres	1.0133	bars
atomic mass units (amu)	1.66×10^{-24}	grams
atomic mass units (amu)	1.49×10^{-3}	ergs
atomic mass units (amu)	931	mev (million electron volts)
barrels	5.6146	cubic feet
barrels	34.97	Imperial gallons
barrels	42	U.S. gallons
barrels	158.987	litres
barrels per hour	0.1589	cubic metres per hour
barrels per day (oil)	50	tons per year (depending on the density of the oil)
bars	1.01972	kilograms per square centimetre
British thermal units (Btu)	778.2	foot-pounds
British thermal units	1 055.06	joules
British thermal units	0.000293	kilowatt-hours (Kwh)
British thermal units	0.252	kilocalories
British thermal units per second	1.416	horsepower

CONVERSION TABLE (contd.)

Multiply	*By*	*To obtain*
British thermal units per pound	2.326	joules per gram
bushels (Imperial)	4	pecks
bushels (Imperial)	0.036	cubic metres
bushels (U.S. dry measure)	0.0352	cubic metres
cable lengths (U.S.)	720	feet
cable lengths (British)	608	feet
calories	4.187	joules
carats	200	milligrams
centares	1	square metres
centares	10.76	square feet
centilitres	0.01	litres
centimetres	0.3937	inches
centimetres	0.0328083	feet
centimetres	0.01094	yards
centimetres	10	millimetres
centimetres of mercury	5.352391	inches of water
centimetres of mercury	0.193368	pounds per square inch
centimetres of mercury	27.84507	pounds per square foot
centimetres of mercury	135.951	kilograms per square metre
centimetres per second	1.9685	feet per minute
centimetres per second	0.036	kilometres per hour
centimetres per second	0.02237	miles per hour
chains (Gunther)	4	rods
chains (Gunther)	66	feet
chains (Engineers')	100	feet
coulombs	3×10^9	electrostatic units of charge (esu)
cubic centimetres	0.00099973	litres
cubic centimetres	0.06102338	cubic inches
cubic centimetres	0.00003532	cubic feet
cubic feet	1 728	cubic inches
cubic feet	7.480519	U.S. gallons
cubic feet	6.288	Imperial gallons
cubic feet	28 317.017	cubic centimetres
cubic feet	28.31625	litres
cubic feet of water	62.42833	pounds
cubic feet per minute	0.1247	U.S. gallons per second
cubic feet per minute	0.471704	litres per second

Multiply	*By*	*To obtain*
cubic inches	16.387162	cubic centimetres
cubic inches	0.0163876	litres
cubic metres (steres)	61,023.375	cubic inches
cubic metres	35.314455	cubic feet
cubic metres	264.17	U.S. gallons
cubic metres	219.97	imperial gallons
cubic metres	6.2989	barrels (bbl)
cubic metres	999.98	litres
cubic metres	1.308	cubic yards
cubic metres per hour	151	barrels per day
cubic yards	27	cubic feet
cubic yards	0.7646	cubic metres
decagrams	10	grams
decagrams	0.353	ounces
decalitres	10	litres
decalitres	2.64	U.S. gallons
decalitres	0.35	cubic feet
decametres	10	metres
decametres	32.81	feet
decigrams	0.1	grams
decigrams	1.543	grains
decilitres	0.1	litres
decimetres	0.1	metres
decimetres	3.94	inches
degrees arc	0.01745329	radians
drams	27.343	grains
drams	1.771	grams
dynes	10^{-5}	newtons
dynes	2.247×10^{-6}	pounds
electron volts (ev.)	1.602×10^{-19}	joules
electrostatic units of potential	300	volts
ells	1.25	yards
farads (coulombs/volt)	9×10^{11}	electrostatic units of capacitance

CONVERSION TABLE (contd.)

Multiply	*By*	*To obtain*
fathoms	6	feet
feet	30.48006	centimetres
feet	12	inches
feet	0.3048	metres
feet	0.3333	yards
feet of water	0.88	inches of mercury
feet of water	0.295	atmospheres
feet of water	0.43353	pounds per square inch
feet per minute	0.0113636	miles per hour
feet per minute	0.508	centimetres per second
feet per second	0.5920858	knots
feet per second	0.681818	miles per hour
fluidounces (U.S. liquid measure)	29.573	cubic centimetres
fluidounces (U.S. liquid measure)	8	fluidrams (U.S.)
fluidounces (Imperial)	28.416	cubic centimetres
fluidounces (Imperial)	8	fluidrams (British)
fluidrams (U.S. liquid measure)	60	minims (U.S.)
fluidrams (U.S. liquid measure)	3.696	cubic centimetres
fluidrams (Imperial)	60	minims (British)
fluidrams (Imperial)	3.5516	cubic centimetres
foot-poundals	0.04213	joules
foot-pounds (ft. lb)	1.3554	joules (watt-seconds)
foot-pounds	0.138255	metre-kilograms
foot-pounds per second	0.00136	kilowatts
foot-pounds per second	0.00182	horsepower
furlongs	10	chains
furlongs	660	feet
gallons (U.S. gallons)	0.83268	Imperial gallons
gallons (U.S.)	0.13368	cubic feet
gallons (Imperial)	0.1605	cubic feet
gallons (U.S.)	3.785332	litres
gallons (U.S.)	4	quarts
gallons (Imperial)	0.0285	barrels
gallons (Imperial)	4.545	litres
gallons (U.S.)	0.023809	barrels
gallons (U.S.) per mile	2.8247	litres per kilometre
gills (U.S. liquid measure)	4	fluidounces
gills (U.S. liquid measure)	118.3	cubic centimetres
gills (Imperial)	5	fluidounces
gills (Imperial)	142.1	cubic centimetres

CONVERSION TABLE (contd.)

Multiply	*By*	*To obtain*
grains	0.0648	grams
grains per cubic foot	0.0299	grams per cubic metre
grains per U.S. gallon	0.01712	grams per litre
grams	15.43236	grains
grams	0.035274	ounces
grams	0.00224623	pounds
grams	6.85×10^{-5}	slugs
grams	1 000	milligrams
grams	0.001	kilograms
grams	980.665	dynes
grams per cubic centimetre	62.42833	pounds per cubic foot
grams per cubic centimetre	0.0361	pounds per square inch (psi)
grams per cubic centimetre	8.345	pounds per (U.S.) gallon
hands	4	inches
hectares	2.471	acres
hectograms	100	grams
hectograms	3.527	ounces
hectolitres	100	litres
hectolitres	3.53	cubic feet
hectolitres	2.84	bushels (dry)
hectometres	100	metres
hectometres	109.36	yards
henry (volt.sec/amp.)	10^9	electromagnetic units (of inductance)
horsepower	0.7457	kilowatts
horsepower	0.7068	British thermal units per second
horsepower	33 000	foot-pounds per minute
horsepower	550	foot-pounds per second
horsepower	745.7	watts
horsepower	0.1781	kilocalories per second
horsepower	1.013872	metric horsepower
horsepower (metric)	75	kilogram meters per second
horsepower (metric)	735.498	watts
horsepower hour	2 545.06	British thermal units (Btu)
hundredweights (short)	100	pounds
hundredweights (short)	45.36	kilograms
hundredweights (long)	112	pounds
hundredweights (long)	50.802	kilograms

CONVERSION TABLE (contd.)

Multiply	*By*	*To obtain*
inches	2.54000508	centimetres
inches	1 000	mils
inches of mercury	0.033421	atmospheres
inches of mercury	33.8639	millibars
inches of mercury	13.5951	inches of water
inches of mercury	0.491157	pounds per square inch
inches of mercury	0.03453	kilograms per square centimetre
inches of water	0.073556	inches of mercury
inches of water	0.1868324	centimetres of mercury
inches of water	0.0361275	pounds per square inch
inches of water	0.00246	atmospheres
joules (watt-seconds)	0.2388	calories
joules	10^7	ergs
joules	0.7376	foot pounds
kilocalories	3.96707	British thermal units
kilograms	2.204622	pounds (avoirdupois)
kilograms	2.679	pounds (troy)
kilograms	70.931	poundals
kilograms	1 000	grams
kilogram-metres	7.233	foot-pounds
kilogram-metres	9.8066×10^7	ergs
kilogram-metres per second	9.8066	watts
kilograms per square centimetre	0.9678	atmospheres
kilogram per square centimetre	28.958	inches of mercury
kilogram per square centimetre	14.2234	pounds per square inch (psi)
kilolitres	1 000	litres
kilolitres	1.31	cubic yards
kilometres	0.62137	miles
kilometres	0.53955	nautical miles
kilometres per hour	0.9113426	feet per second
kilometres per hour	54.68	feet per minute
kilometres per hour	0.9113	feet per second
kilometres per hour	0.539	knots
kilowatts	0.9478	British thermal units per second
kilowatts	737.6	foot-pounds per second
kilowatts	1.341	horsepower
kilowatt hour	3 415	British thermal units
kilowatt hour	3.6×10^6	joules
knots	1	nautical miles per hour
knots	1.15155	miles per hour
knots	1.852	kilometres per hour

Multiply	*By*	*To obtain*
leagues	3	miles
light years	9.4605×10^{15}	metres
links	20.1168	centimetres
links	0.22	yards
links	7.92	inches
litres	1 000.027	cubic centimetres
litres	61.02503	cubic inches
litres	0.0351	cubic feet
litres	0.006289	barrels
litres	0.2199	Imperial gallons
litres	0.2643	U.S. gallons
litres	0.908	quarts (dry measure)
litres	1.057	quarts (liquid measure)
metres	39.37	inches
metres	3.280833	feet
metres	1.093611	yards
metres	4.97	links
metres	0.199	rods
metres	100	centimetres
metres	1 000	millimetres
metres per second	2.237	miles per hour
metres per second	3.6	kilometres per hour
metres per second	196.85	feet per minute
microns	10^{-6}	metres
microns	10 000	Ångstroms
miles (statute)	5 280	feet
miles (statute)	1 760	yards
miles (statute)	1.609347	kilometres
miles (statute)	0.8683925	nautical miles
miles (nautical)	1.852	kilometres
miles per hour	1.4667	feet per second
miles per hour	0.8683925	knots (nautical miles per hour)
miles per hour	0.447	metres per second
miles per hour	88	feet per minute
millilitres	1	cubic centimetres
millimetres	0.03937	inches
millimetres	1 000	microns
millimetres	0.001	metres
millimetres	0.04	inches

CONVERSION TABLE (contd.)

Multiply	*By*	*To obtain*
mils	0.001	inches
minims (U.S. liquid measure)	0.0616	cubic centimetres
minims (imperial)	0.0592	cubic centimetres
myriametres	10 000	metres
myriametres	6.2	miles
nails	2.25	inches
newtons	10^5	dynes
newton-metres	10^7	ergs
ounces (avoirdupois)	28.3495	grams
ounces (avoirdupois)	437.5	grains
ounces (troy)	31.103	grams
parsecs	3.26	light years
pecks	2	imperial gallons
pennyweights	1.555	grams
pints (U.S. liquid measure)	0.473	litres
pints (U.S. dry measure)	0.55	litres
pints (imperial)	0.5683	litres
poundals	0.13825	newtons
pounds (avoirdupois)	1.215	pounds troy
pounds (avoirdupois)	0.45359	kilograms
pounds (or pounds avoirdupois)	16	ounces
pounds	7 000	grains
pounds per cubic foot	0.1337	pounds per U.S. gallon
pounds per cubic foot	16.01837	kilograms per cubic metre
pounds per cubic foot	0.01602	grams per cubic centimetre
pounds per cubic inch (psi)	27.68	grams per cubic centimetre
pounds per square inch	2.036	inches of mercury
pounds per square inch	2.309	feet of water at 16C
pounds per square inch	0.06805	atmospheres
pounds troy	240	pennyweights
pounds troy	5 760	grains
pounds troy	0.3732	kilograms
quarts	2	pints
quarts (U.S. liquid measure)	0.946	litres

Multiply	*By*	*To obtain*
quarts (U.S. dry measure)	1.101	litres
quarts (British or Imperial)	1.36	litres
quintals	100	kilograms
radians	57.29578	degrees arc
radians per second	0.159155	revolutions per second
radians per second	9.5493	revolutions per minute
revolutions	6.283185	radians
rods	5.0292	metres
rods	5.5	yards
roods	40	square rods
scruples	1.295	grams
slugs	32.175	pounds
slugs	14.59	kilograms
square centimetres	0.0001	square metres
square centimetres	0.155	square inches
square centimetres	0.001076	square feet
square feet	929	square centimetres
square feet	144	square inches
square feet	0.0929	square metres
square feet	0.111	square yards
square inches	6.451626	square centimetres
square inches	0.0069	square feet
square kilometres	0.3861	square miles
square kilometres	10^6	square metres
square kilometres	247.1	acres
square links	62.726	square inches
square metres	10.76	square feet
square metres	1.195983	square yards
square metres	1550	square inches
square miles	640	acres
square miles	258.9	hectares
square yards	0.836	square metres

CONVERSION TABLE (contd.)

Multiply	By	To obtain
steres (cubic metres)	1.31	cubic yards
stones	14	pounds
stones	6.348	kilograms
therms	10^5	British thermal units
thermies	10^6	calories
thermies	3,967.09	British thermal units
tons	20	hundredweights
tons (long)	2 240	pounds (avoirdupois)
tons (long)	1.016	metric tons
tons (short)	2 000	pounds (avoirdupois)
tons (short)	0.9072	kilograms
tons (metric)	0.9842	long tons
tons (metric)	1.102	short tons
torrs	1 333.22	dynes per square centimetre
volt (joule/coulomb)	0.00333	electrostatic units of potential
watts (joules per second)	10^7	ergs per second
watt seconds	10^7	ergs
weber (volt-sec)	10^8	maxwells (of magnetic flux)
yards	0.9144	metres

VAPOUR PRESSURE OF WATER BETWEEN 0° & 200°C

(in mm. of mercury)

Temp.	0	1	2	3	4	5	6	7	8	9
0	4·581	4·924	5·290	5·679	6·094	6·536	7·006	7·503	8·036	8·599
10	9·198	9·831	10·504	11·217	11·972	12·771	13·617	14·511	15·457	16·456
20	17·512	18·626	19·802	21·043	22·351	23·729	25·181	26·709	28·316	30·012
30	31·792	33·663	35·630	37·695	39·864	42·139	44·537	47·051	49·656	52·407
	0	2	4	6	8	10	12	14	16	18
40	55·29	61·46	68·23	75·62	83·69	92·40	102·1	112·5	123·8	136·1
60	149·2	163·8	179·3	196·1	214·2	233·7	254·7	277·2	301·4	327·4
80	355·2	385·6	416·8	450·8	487·2	525·9	567·1	611·0	657·7	707·3
100	760·0	815·9	875·1	937·9	1004·3	1074·6	1148·3	1227·2	1309·0	1397·2
120	1 489	1 586	1 688	1 795	1 908	2 026	2 150	2 281	2 417	2 560
140	2 710	2 867	3 032	3 203	3 383	3 570	3 766	3 970	4 183	4 405
160	4 636	4 875	5 127	5 388	5 650	5 941	6 234	6 538	6 853	7 181
180	7 521	7 874	8 238	8 617	9 009	9 413	9 835	10 270	10 719	11 183
200	11 664	12 160	12 672	13 201	13 748	14 311	14 892	15 492	16 110	16 747