



THERMAL ELECTRIC ELEMENTS
AUSTRALIA



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Technical

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18.1

Calculation for Superheated Steam

Example:

340kg per hour of steam with 90% quality, having an inlet gauge pressure of 700kPa is to be superheated to a temperature of 230°C. How many kilowatts of power is required?

From the reference guide:

1. Plot a point equalling 700kPa on the centre reference line of "P"
2. From that point, mark a line through 90% on the quality scale to the watt hour/weight scale. The answer is 82.5 Watts/kilogram.
3. Note that the saturated temperature of steam at 700kPa is 170°C. A temperature of 230°C is required, therefore a 60°C temperature rise is required.
4. From the point of 700kPa plotted on the centre reference line of "P" mark a line through 60°C on the S scale to the watt hour/weight scale. The answer is approximately 200 Watts/kilogram.
5. Subtract 82.5 from 200 = 117.5
6. Power required = Weight x Watt hour/kilogram
= 340kg x 117.5
= 39,950 Watts
Always add 20% for loss + 7,990 Watts
Total power = 47,940 Watts
Answer = 48kW

Definitions

Saturated Temperature: is the temperature at which water boils at a given pressure. At zero gauge pressure the temperature is 100°C (212°F), as steam pressure increases the saturated temperature increases - refer to "P" reference scale.

Quality of Steam: is the amount of moisture present in the steam, which is measured as the percentage of the total weight. Quality of steam 100% minus the percentage of moisture content, therefore dry steam has 100% quality.

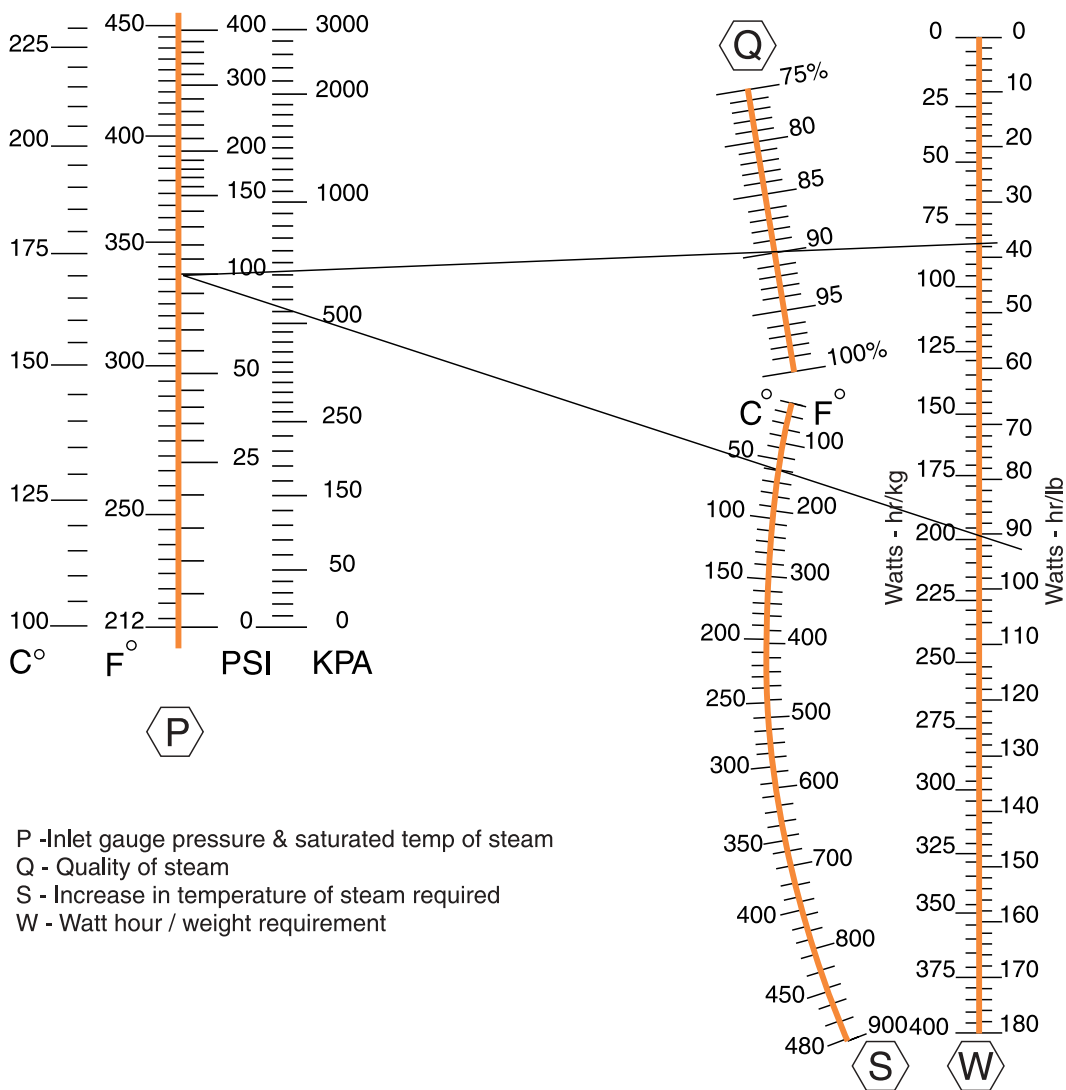
Degrees of Superheat: is the increase of steam temperature above the inlet saturated temperature.

Watt hour per Weight: is the power required to superheat the steam to above the saturated temperature. This is known as Watts per hour per kilogram (pound) required.

Weight of Steam per hour: is the flow rate of steam which will be passing through the electric heating unit per hour. This information is vital for the most efficient design of the heater.

18.2

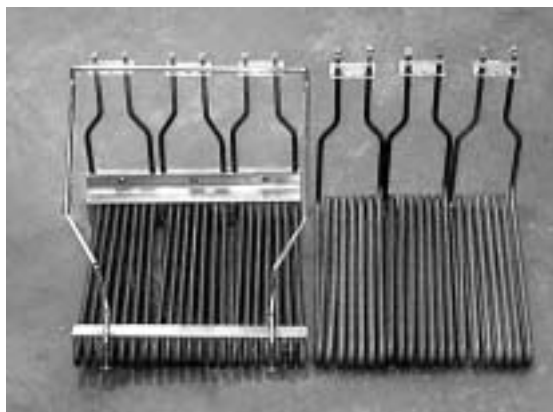
Quick Reference Guide for Electrically Heated Steam



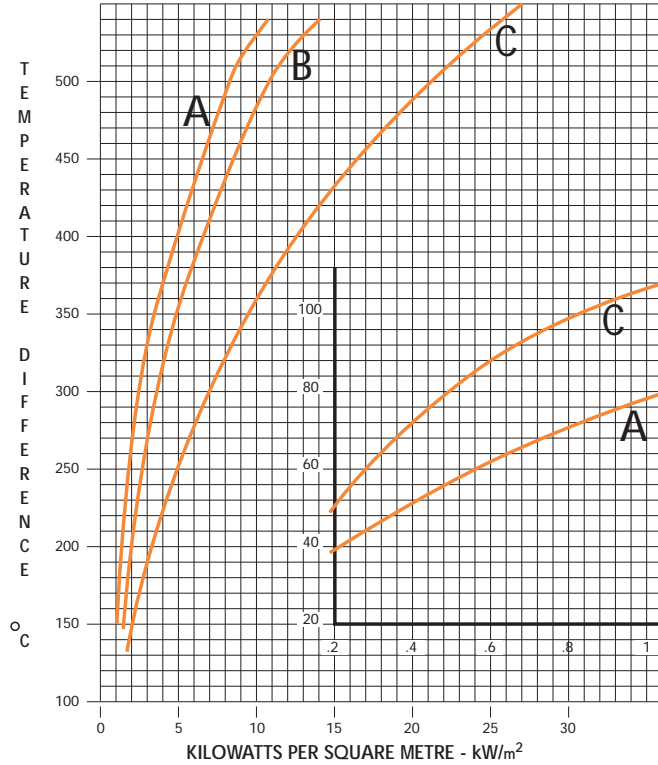
18.3

Watt Density to Element Sheath Temperature at 20°C ambient (70°F)

WATT DENSITY			SHEATH TEMPERATURE	
kW/m ²	Watt/cm ²	Watt/in ²	°C	°F
1.55	0.16	1	90	195
3.1	0.3	2	135	275
4.0	0.38	2.5	155	310
4.6	0.46	3	175	350
6.2	0.62	4	215	420
7.75	0.78	5	260	500
9.3	0.93	6	290	555
12.4	1.24	8	360	680
15.5	1.55	10	400	750
18.6	1.86	12	450	840
23.25	2.32	15	485	905
31.0	3.10	20	530	985
38.75	3.88	25	580	1075
46.5	4.65	30	650	1200
54.25	5.42	35	685	1265
62.0	6.20	40	710	1310
70.0	7.0	45	750	1380
77.5	7.75	50	800	1470
93.0	9.3	60	860	1580
108.0	10.8	70	930	1705
124.0	12.4	80	950	1740

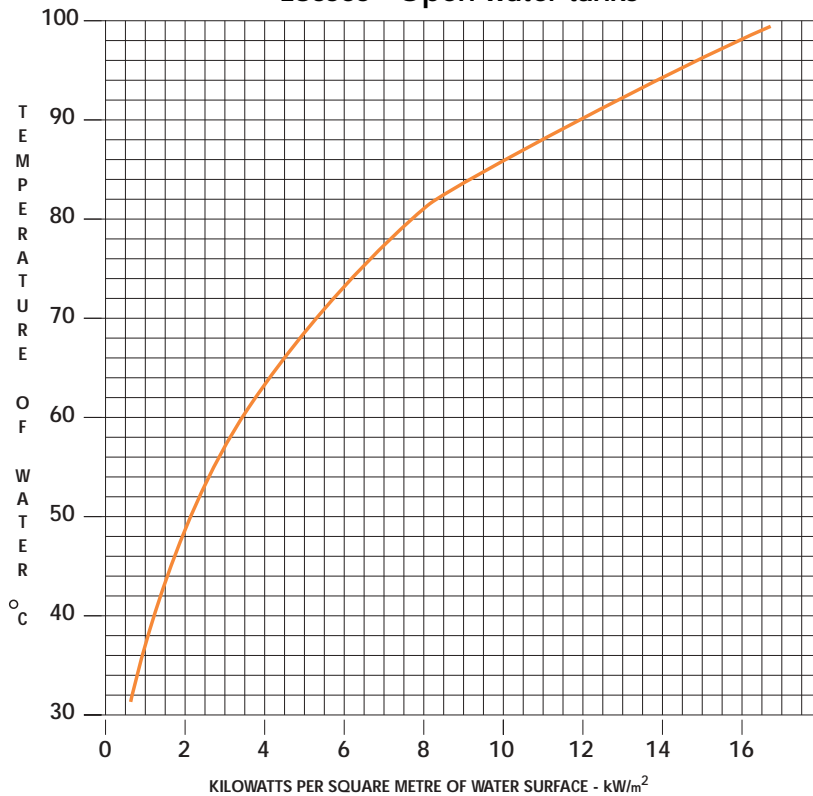


Losses - Uninsulated metal surfaces



- A. Oxidised aluminium vertical surfaces
- B. Oxidised steel bottom & horizontal surfaces
- C. Oxidised steel vertical surface losses from tanks, pipes etc

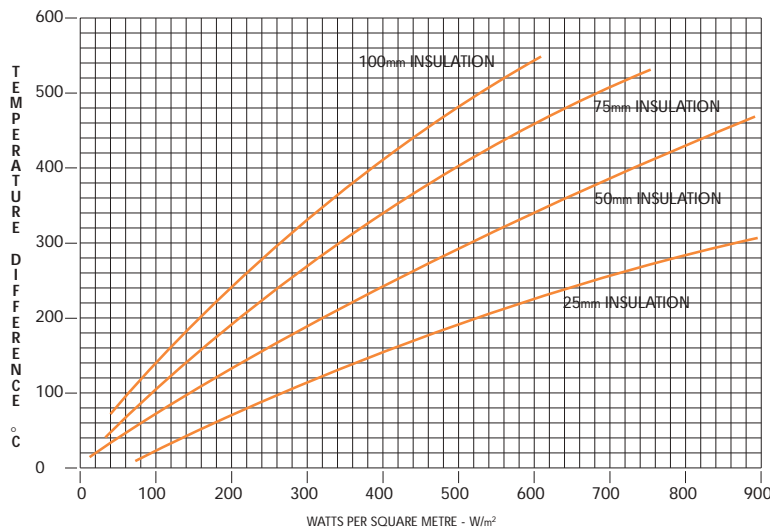
Losses - Open water tanks



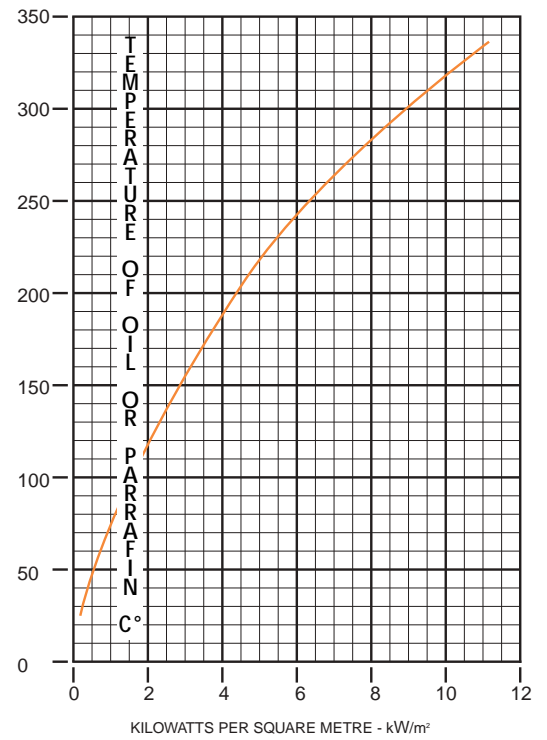
18.5

Heat Loss

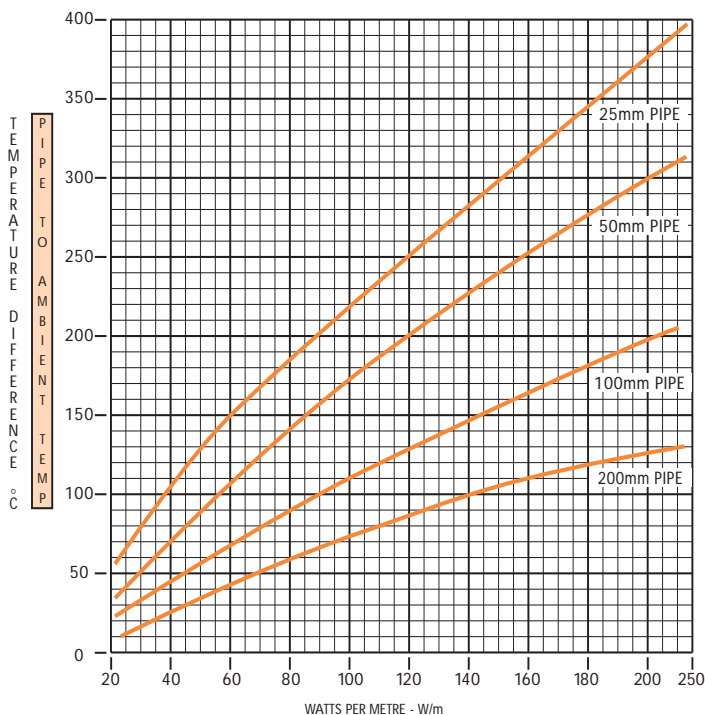
Losses - Insulated wall for ovens, tanks, pipes, etc



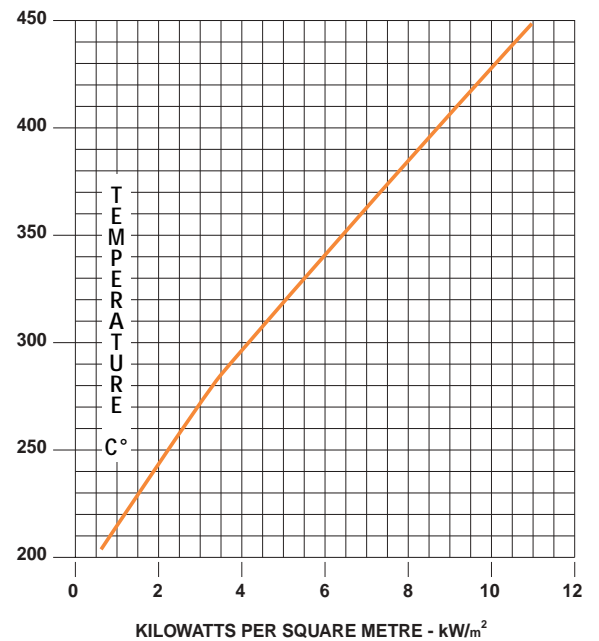
Losses - Surfaces of oil baths



Losses - For pipe lines

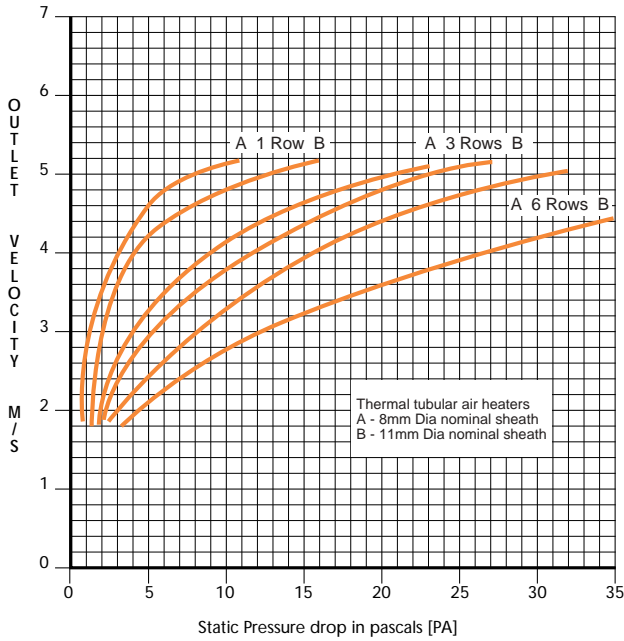


Losses - Molten metal surfaces

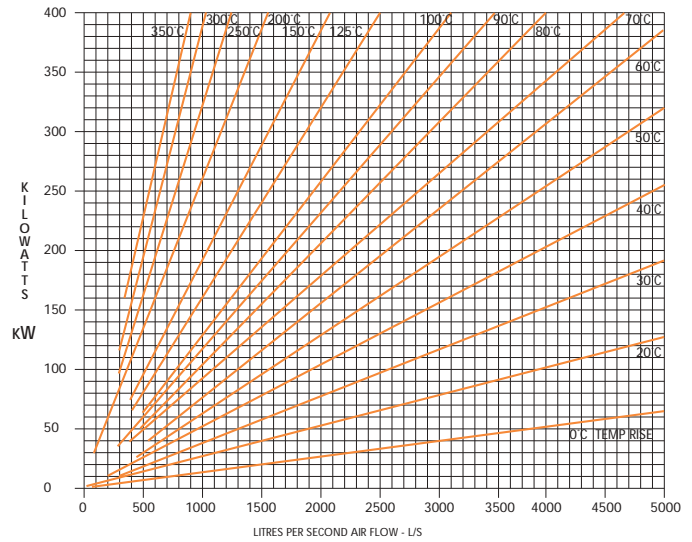


Pressure Drop & Air Heating

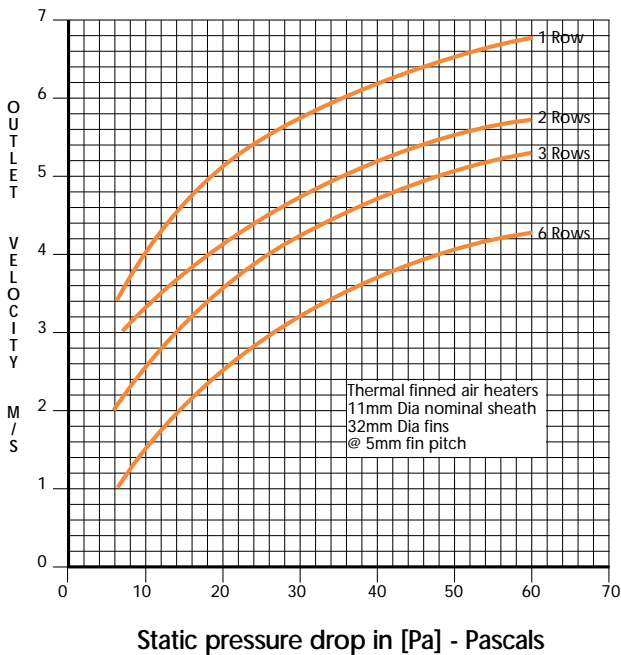
Static pressure drop for Thermal tubular air heaters



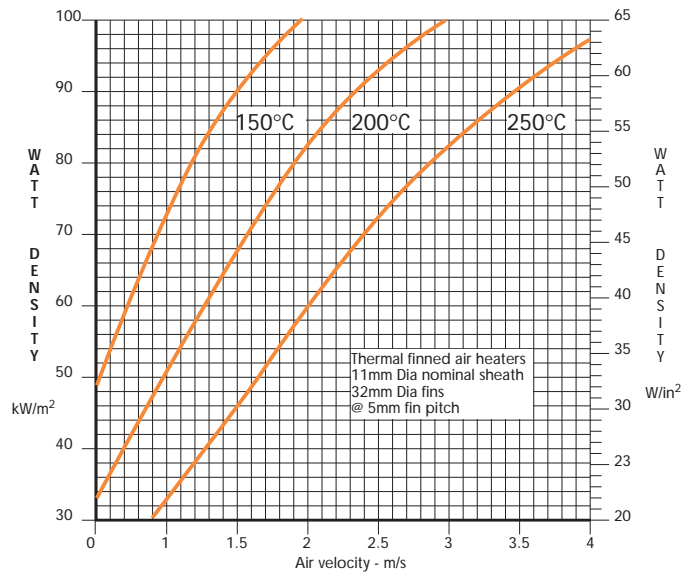
Kilowatts required for air heating



Static pressure drop for Thermal finned tubular air heaters



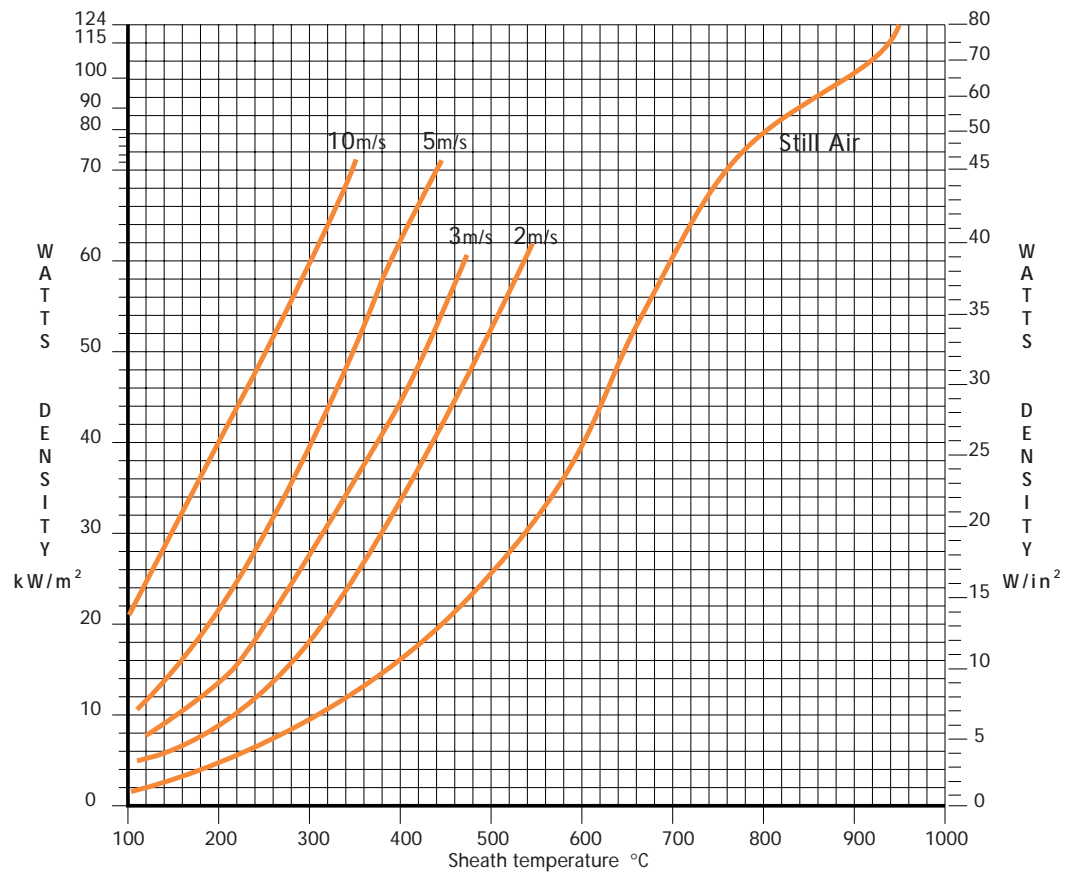
Recirculated air heating with Thermal finned tubular heaters



18.7

Sheath Temperature

Thermal tubular heating elements sheath temperature in still & moving air



Formulae and Conversion Tables

To calculate kW required to raise temperature of product the following formula may be used. This formula provides net kW to raise temperature by a desired degree in a desired time. It does not allow for inefficiencies due to heat losses through insulation etc. or changes of state.

$$\frac{V \times \rho \times C_p \times \Delta T}{t} = \text{kW required}$$

V = Volume required

ρ = Density

C_p = Specific heat capacity (kJ/kg.K)

ΔT = Required temperature change ($^{\circ}\text{C}$)

t = Required heating time in seconds

Note:

- (1) (V x ρ) can be substituted by kg in this formula where heating solids such as metals is to be carried out.
- (2) 1000 litres = 1m^3

For flow line heating use m^3 per hr flow rate to achieve kW and/or ΔT .

For more accurate check use the following formula:

$$\frac{\text{kW} \times 3600}{4.187 \times \Delta T} = \text{m}^3/\text{h} \text{ (For water only)}$$

Forced air heating formula

Example:

Air is circulated through a heater duct by a 1000CFM blower. The air enters the duct at 35°C and is heated to 120°C

Select one of two formulae:

1. $\text{kW} = \text{m}^3/\text{s} \times \Delta T \times 1.278$
2. Convert 1000 CFM to L/S (refer to table)
 $= 1000 \times 0.472$
 $= 472 \text{ litres/sec}$

$$\text{kW} = \frac{\text{L/S} \times \Delta T}{783} = \frac{472 \times 85}{783}$$

$$\text{kW} = 51.25$$

$$20\% \text{ safety factor} = 10.25$$

$$\text{kW} = 61.50$$

The heaters required will total 62 kW.

18.9

Gases and Vapours

SUBSTANCE	Average specific heat capacity		Density	
	Metric kJ/kg.K	Imperial Btu/lb.F	Metric kJ/kg.K	Imperial Btu/lb.F
Acetylene	1.465	0.35	1.169	0.073
Air	1.005	0.240	1.281	0.080
Ammonia	2.177	0.520	0.769	0.048
Carbon Dioxide	0.850	0.203	1.970	0.123
Chlorine	0.523	0.125	3.203	0.20
Ethane	1.800	0.43	1.74	0.109
Ethylene	1.675	0.40	1.66	0.073
Flourine	0.749	0.179	2.18	0.136
Hydrochloric Acid	0.816	0.195	1.634	0.102
Hydrogen	14.277	3.41	0.090	0.0056
Methane	2.512	0.60	0.716	0.045
Nitrogen	1.025	0.245	1.249	0.078
Oxygen	0.913	0.218	1.442	0.09
Water Vapour(100°C) Steam	1.926	0.460	0.80	0.050
Sulphur Dioxide	0.649	0.155	2.867	0.179

Plastics

SUBSTANCE	Average specific heat capacity		Specific Gravity	Density	
	Metric kJ/kg.K	Imperial Btu/lb.F	H ₂ O=1 at 4°C	Metric °C	Imperial °F
ABS	1.46-	0.4	1.04-	66	150
	0.35-		1.06		
	1.67				
	1.46	0.35	1.17-	60-	140-
Acrylic	1.09-	0.26-	1.19	71	160
			1.3-	149	300
	0.26-				
Polyester	2.30	0.55	1.45		
	2.30	0.55	0.91-	120	250
Polyethylene	1.34-	0.32-	0.93	60-	140-
			1.04-		
	0.32-				
Polystyrene	1.46	0.35	1.07	71	160
	1.26	0.3-	1.2-	65-	150-
PVC	2.09	0.5	1.55	75	170

18.10

Liquids

SUBSTANCE	Average specific heat capacity		Latent heat of fusion or evaporation		Boiling point		Density	
	Metric kJ/kg.K	Imperial Btu/lb.F	Metric kJ/kg	Imperial Btu/lb	Metric °C	Imperial °F	Metric kg/m ³	Imperial lb/ft ³
Acetic Acid (100%)	1.968	0.47av	404.7	174	118	244	1049	65.5
Acetone	2.152	0.514					790	49.3
- Amyl	2.977	0.711	504.8	217			816	50.9
- Ethyl	2.294	0.548	856.07	368	78	172	789	49.3
Bromine	0.448	0.107	200.06	86	58	136	3184	198.7
Glycerine	2.428	0.58	711.03	76.1	200	554	1271.4	79.38
Honey	1.465	0.35	62.34	26.8			1420	88.6
Hydrochloric acid (10%)	3.098	0.74			85	185	1259	78.6
Kerosene	2.094	0.5	244.3 -255.9	105 -110			819	51.1
Methylated Spirits	2.554	0.610					791	49.4
Milk	3.894	0.93					1029	64.2
Oil - Caster	1.817	0.434					959	59.9
- Linseed	1.842	0.44					933	58.2
- Lubricating	1.675	0.40					909	56.7
- Olive or Palm	1.972	0.471			300	572	917	57.2
- Paraffin	2.177-	0.52-			300	750	799	49.9
- Transformer	2.973	0.71						
- Transformer	1.926	0.46					869	54.2
Petroleum	2.140	0.511	309.39 -337.31	133- 145	38- 204	100- 399	877	54.7
Sea Water	3.936-	0.94-			101	214	1023	63.9
	4.103	0.98						
Sodium Hydroxide (100%)	3.496	0.835					2128	132.8
Sulphuric Acid (100%)	1.440	0.344	511.78	220	310	590	1829	114.2
Tallow	2.094	0.50	188.43	81	mp32.2	90	939	58.6
Toluene	1.842	0.440	362.9	156	111	232	881	55.0
Turpentine	1.976	0.472	309.4	133	149	300	866	54.1
Vinegar					118	244	1049	65.5
Water	4.187	1.00	2256.5	970	100	212	999	62.4

18.11

Metals & Alloys

SUBSTANCE	Average specific heat capacity		Latent heat of fusion or evaporation		Melting point		Density	
	Metric kJ/kg.K	Imperial Btu/lb.F	Metric kJ/kg	Imperial Btu/lb	Metric °C	Imperial °F	Metric kg/m ³	Imperial lb/ft ³
Aluminium cast	0.942	0.255	321.03- 395.47	138.17	660	1220	2697	168.4
Antimony	0.209- 0.218	0.050- 0.052	58.16- 102.36	25- 44	630	1166	6613	412.8
Arsenic	0.343	0.082			819	1500	5714	356.7
Brass	0.377- 0.419	0.09- 0.10	196.34	84.4	1249	2280	8451	527.5
Bronze (Comm)	0.435 0.498-	0.104 0.119-			1177	2150	8661 7102	540.6 443.3
Cast Iron (Grey)	0.544	0.13						
Copper	0.384- - 0.527	0.092 0.126	181.45	78	1083	1981	8930	557.5
Gold	0.132	0.0316	66.79	28.7	860- 1060	1580- 1940	19279 1023.5	
Gunmetal	0.448	0.107	197.87	84.2			8691	542.5
Iron (99.9%)	0.461- 0.544	0.110- 0.130	93.05	40	1535	2795	7852	490.1
-Wrought	0.477- 0.502	0.114- 0.12					7392- 461.4- 7981	492.6
Lead - Melted	0.167	0.04						
- Solid	0.130	0.031	25.59	11	327.5	621	11388	710.8
Magnesium	1.047	0.25	372.2	160	651	1204	1738	108.5
Mercury	0.138	0.033	272.18	75.16	117	243	13855	848
Nickel	0.461	0.11			1450	2642	8810	550
Silver	0.239	0.057	88.39	38	961	1761	10492	655
Solder	0.167	0.04	39.54	17	213	415	9291	580
Steel	0.502	0.12			1399	2550	7849	490
Tin - Solid	0.234	0.056	58.15	25.0	232	450	7288	455
- Melted	0.268	0.064						
Type Metal (85%) Lead (15%) Antimony	1.674	0.040			260	500	10732	670
Zinc	0.398	0.095	118.63	51	419	787	7128	445

18.12

Quick reference: Kilowatts to heat steel

Kg's in Steel	Temperature Rise in °C									
	10	25	50	100	150	200	250	300	350	400
10	.017	.042	.085	.17	.25	.34	.42	.5	.6	.68
25	.042	.1	.21	.42	.64	.85	1	1.27	1.5	1.7
50	.085	.21	.42	.85	1.3	1.7	2	2.6	3	3.4
100	.17	.42	.85	1.7	2.5	3.4	4.2	5	6	7
150	.26	.63	1.27	2.5	3.8	5	6.3	7.5	9	10
200	.34	.84	1.7	3.4	5	6.8	8.5	10.2	12	13.6
250	.42	1	2.1	4.2	6.3	8.5	10.5	12.6	15	16.8
300	.51	1.26	2.5	5	7.5	10.2	12.6	15.3	18	20.5
350	.6	1.5	3	6	9	12	15	18	21	24
400	.68	1.7	3.5	7	10.2	13.6	17	20.4	24	27.2
500	.84	2.1	4.2	8.4	12.6	16.8	21	25.2	30	33.6
1000	1.7	4.2	8.4	16.8	25.2	34	42	50.5	60	67.5

** Includes +20% tolerance to allow for high heat loss situations or low power voltage.

$$\frac{V \times p \times C_p \times \Delta T}{t} \quad \text{or} \quad \frac{\text{kg} \times .502 \times \Delta T}{t}$$

Example: To heat 10kg of Steel from 10°C to 20°C in 5 minutes

From table: .017 kW to heat in 1 hr, therefore
to heat in 5 minutes

$$.017 \times 12 = .204\text{kW Required}$$

Example: To heat 500 kg of Steel from 100°C to 200°C in 4 hrs

From table: 8.4 kW to heat in 1 Hr, therefore
to heat in 4 hrs

$$8.4\text{kW} \div 4 = 2.1\text{kW Required}$$

18.13

Quick reference: Kilowatts to heat water in 1 hour

Litres	Temperature Rise in °C									
	10	20	30	40	50	60	70	80	90	100
5	.07	.14	.21	.28	.35	.42	.49	.56	.63	.7
10	.14	.28	.42	.56	.7	.84	.98	1.12	1.26	1.4
20	.28	.56	.84	1.12	1.4	1.7	2	2.25	2.5	2.8
50	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7
100	1.4	2.8	4.2	5.6	7	8.4	9.8	11.2	12.6	14
200	2.8	5.6	8.4	11.2	14	16.8	19.6	22.4	25.2	28
300	4.2	8.4	12.6	16.8	21	25.2	29.4	33.6	37.8	42
400	5.6	11.2	16.8	22.4	28	33.6	39.2	44.8	50.4	56
500	7	14	21	28	35	42	49	56	63	70
750	10.5	21	31.5	42	52.5	63	73.5	84	94.5	105
1000	14	28	42	56	70	84	98	112	126	140
1500	21	42	63	84	105	126	147	168	189	210
2000	28	56	84	112	140	168	196	224	252	280
2500	35	70	105	140	175	210	245	280	315	350
3000	42	84	126	168	210	252	294	336	378	420
5000	70	140	210	280	350	420	490	560	630	700
10000	140	280	420	560	700	840	980	1120	1260	1400

** Includes +20% tolerance to allow for high heat loss situations or low power voltage.

$$kW = \frac{V \times P \times Cp \times \Delta T}{t}$$

Example: To heat 2000L of Water by 70°C in 4 Hours

From table: = 196 kW/h, therefore
= 186 ÷ 4

= 49 kW required

Example: To heat 10L of Water to 100°C from ambient temperature of 20°C in 10 minutes

From table: = 1.12 kW x 6

= 6.72 kW required

18.14

Quick reference: Kilowatts to heat oil in 1 hour

Litres	Temperature Rise in °C								
	10	25	50	75	100	150	200	250	300
5	.03	.075	.15	.23	.3	.45	.6	.75	.9
10	.06	.15	.3	.46	.6	.9	1.2	1.5	1.8
20	.12	.3	.6	.92	1.2	1.8	2.4	3	3.6
50	.3	.75	1.5	2.3	3	4.5	6	7.5	9
100	.6	1.5	3	4.6	6	9	12	15	18
200	1.2	3	6	9.2	12	18	24	30	36
300	1.8	4.5	9	13.8	18	27	36	45	54
400	2.4	6	12	18.4	24	36	48	60	72
500	3	7.5	15	23	30	45	60	75	90
750	4.5	11.25	21.6	33.8	45	67.5	90	112.5	135
1000	6	15	30	46	60	90	120	150	180
1500	9	22.5	43.2	67.6	90	135	180	225	270
2000	12	30	60	92	120	180	240	300	360
2500	15	37.5	73.2	113.6	150	225	300	375	450
3000	18	45	86.4	138	180	270	360	450	540
5000	30	75	146.4	227	300	450	600	750	900
10000	60	150	293	454	600	900	1200	1500	1800

** Includes +20% tolerance to allow for high heat loss situations or low power voltage.

** For lubricating oils decrease values by 17%.

$$\text{kW} = \frac{V \times P \times C_p \times \Delta T}{t}$$

Example: To heat 1500L of Oil to a temperature of 100°C in 15 Hours

From table: = 90 ÷ 15 Hrs

= 6 kW required

Example: To heat 10L of Oil from 100°C - 200°C in 20 minutes

From table: = .6kW x 3

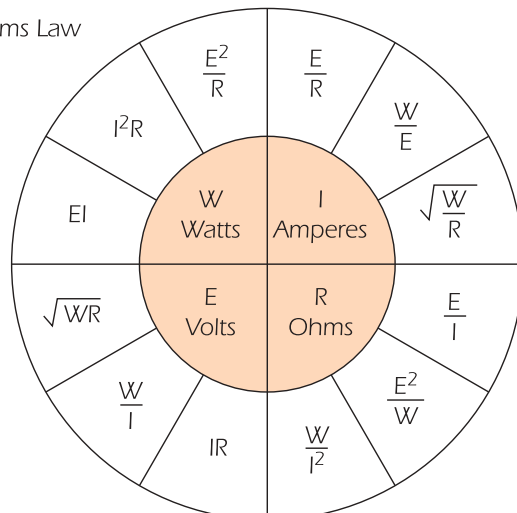
= 1.8 kW required

18.15

Ohms law quick reference

Watts	Values at 240V		Values at 110V		Values at 415V	
	OHMS	AMPS	OHMS	AMPS	OHMS	AMPS
100	576	0.4	121	0.9	1722	0.25
200	288	0.83	60.5	1.8	861	0.48
300	192	1.25	40.3	2.7	574	0.72
400	144	1.66	30.25	3.6	430	0.96
500	115	2.08	24.2	4.5	344	1.2
750	76	3.1	16.1	6.8	229	1.8
1000	57	4.16	12.1	9	172	2.4
1250	46	5.2	9.7	11.3	137	3
1500	38	6.25	8	13.6	114	3.6
1750	33	7.3	6.9	15.9	98	4.2
2000	28	8.3	6	18.1	86	4.8
2250	25	9.3	5.3	20.4	76.5	5.4
2500	23	10.4	4.85	22.75	69	6
2750	21	11.4	4.4	25	62	6.6
3000	19	12.5	4	27.2	57	7.2
3250	17.7	13.5	3.72	29.5	53	7.8
3500	16.4	14.6	3.45	31.8	49	8.4
3750	15.3	15.6	3.22	34	45.9	9
4000	14.4	16.6	3	36.3	43	9.6
4500	12.8	18.75	2.7	41	38	10.8
5000	11.5	20.8	2.42	45.5	34.4	12
5500	10.5	23	2.2	50	31	13.2
6000	9.6	25	2	54.5	28.7	14.4

Ohms Law



18.16

Density

Kilogram per cubic metre (kg/m ³)	Pound per cubic inch (lb/in ³)	Pound per cubic foot (lb/ft ³)
1	0.036×10^{-3}	0.0624
27.68×10^3	1	1728
16.02	0.578×10^{-3}	1

Length

Millimetres (mm)	Metres (m)	Inches (in)	Feet (ft)
1	10^{-3}	0.03937	0.00328
10^3	1	39.37	3.28
25.4	0.0254	1	0.0833
304.8	0.3048	12	1

Area

Square Millimetres (mm ²)	Square Metres (m ²)	Square Inches (in ²)	Square Feet (ft ²)
1	10^{-6}	1.55×10^{-3}	0.01076×10^{-3}
10^6	1	1550	10.764
645.16	0.645×10^{-3}	1	6.949×10^{-3}
92.903×10^{-3}	0.0929	144	1

Mass

Kilogram (kg)	Metric Ton (Tonne = 1000kg)	Pound (lb)	UK Ton (Ton)
1	10^{-3}	2.205	0.984×10^{-3}
10^3	1	2205	0.984
0.454	0.454×10^{-3}	1	0.461×10^{-3}
92.903×10^{-3}	0.0929	144	1

18.17

Energy

British Thermal Unit (Btu)	Kilojoule (kj)
1	1.06
0.948	1

Power

British Thermal Unit (Btu)	Kilowatt (kW)
3412	1
1	0.293×10^{-3}

Watt Density

Watt per Square Inch (Watt/in ²)	Kilowatts per Square Metre (kW/m ²)
1	1.55
0.645	1

Specific Heat Capacity

Btu/lb. °F	J/kg.K	kJ/kg.K
1	4.187×10^{-3}	4.187
238.8	1	10^{-3}
0.2388	10^3	1

Force

Kilogram Force (kgf)	Newton (N)	Pound Force (lbf)
1	9.807	2.205
0.102	1	0.225
0.454	4.448	1

18.18

Velocity

Feet per Second (ft/s)	Feet per Minute (ft/min)	Metres per Second (m/s)	Metres per Minute (m/min)
1	60	0.305	18.29
0.0167	1	0.005	0.305
3.28	196.85	1	60
0.055	3.28	0.0167	1

Pressure

Inch Water (inH ₂ O)	Millimetre Mercury (mmHg)	Pound Force Square In (lbf/in ²)	Kilopascal (kPa)
1	25.4	39.09×10^{-3}	0.2486
13.161	1	0.4912	3.386
27.70	2.036	1	6.895
4.02	0.2953	0.145	1

Volume

Cubic Millimetres (mm ³)	Cubic Metres (m ³)	Litre (litre)	Cubic Inches (in ³)	Cubic Feet (ft ³)	Imperial Gallon (gal)
1	10^{-9}	39.09×10^{-3}	61.023×10^{-6}	0.353×10^{-9}	0.220×10^{-6}
10^9	1	0.4912	61.023×10^3	35.315	219.9
10^6	10^{-3}	1	61.023	0.035	0.0220
16.4×10^3	1.64×10^{-3}	0.145	1	0.578×10^{-3}	3.6×10^{-3}
28.32×10^3	0.0283	0.145	1728	1	6.229
4546×10^3	0.0045	0.145	277.46	0.1605	1

Volume rate of flow

Cubic Foot per Second (ft ³ /s)	Cubic Foot per Minute (ft ³ /min)	Litres per Second (litres/s)	Gallons per Minute (gal/min)	Cubic Metres per Second (m ³ /s)	Cubic Metres per Minute (m ³ /min)
1	25.4	28.316	373.2	0.028	1.68
0.016	1	0.472	6.229	0.47×10^{-3}	0.0283
0.035	2.2.119	1	13.2	1×10^{-3}	60×10^3
0.003	0.1605	0.076	1	0.076×10^{-3}	4.56×10^3
35.315	2119	1×10^3	13.19×10^3	1	60
0.588	35.315	16.6	219.9	0.016	1

18.19

Temperature conversion table

°C	°F	°C	°F	°C	°F
0	32	700	1292	1400	2552
50	122	750	1382	1450	2642
100	212	800	1472	1500	2732
150	302	850	1562	1550	2822
200	392	900	1652	1600	2912
250	482	950	1742	1650	3002
300	572	1000	1832	1700	3092
350	662	1050	1922	1750	3182
400	752	1100	2012	1800	3272
450	842	1150	2102	1850	3362
500	932	1200	2192	1900	3452
550	1022	1250	2282	1950	3542
600	1112	1300	2372	2000	3632
650	1202	1350	2462	2050	3722

The tables provided are a guide to assist you in calculating your heating requirements.

For advice on your individual needs, contact our design department for further technical information.

