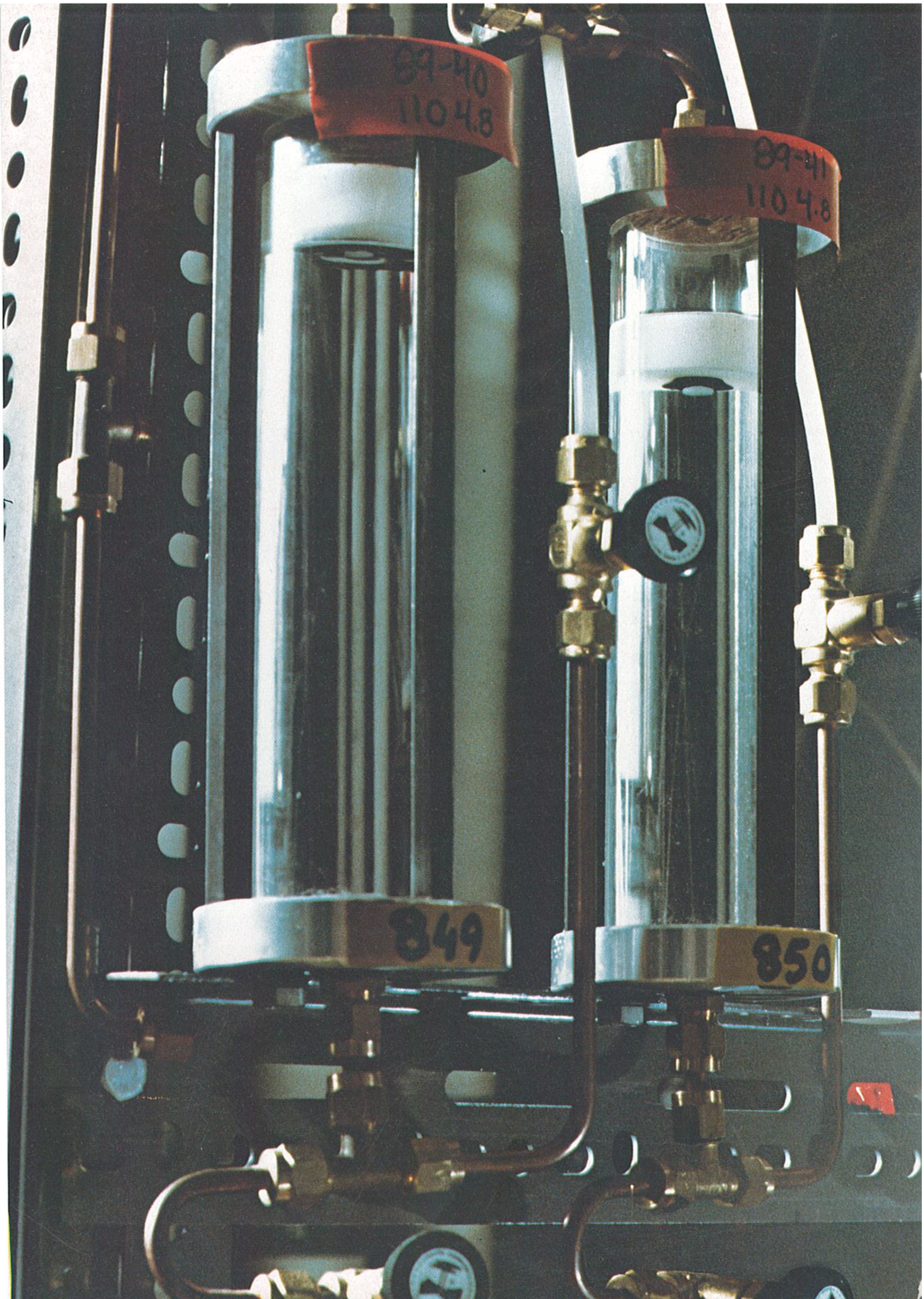

89-40
1104.8
89-41
1104.8
849
850

Testing Boards

INTERNATIONALLY RECOGNIZED TESTING BOARDS (SELECTION BY COUNTRY)

AUSTRIA
Österreichisches Kunststoffinstitut
Franz-Grill-Straße 5, A-1030 Wien

BELGIUM
Institut du Génie Civil
6, Quai Banning, B-4000 Liège

CANADA
Canadian Standards Association,
Certification Division
178, Rexdale Blvd, Rexdale, Ontario

SWITZERLAND
Eidgenössische Materialprüfungs-
und Versuchsanstalt
Überlandstraße,
CH-8600 Dübendorf

WEST GERMANY
Staatliche Materialprüfungsanstalt
Darmstadt
Postfach 11 09 49, D-6100 Darmstadt

DENMARK
Jydsk Teknologisk Institut
Marselis Bolevard 135,
DK-8000 Århus C

SPAIN
Instituto de Plastico y Caucho
Juan de la Cierva 3, Madrid 6

FRANCE
Centre Scientifique & Technique du
Bâtiment; 4 Avenue du Recteur–
Poincarie, F-75782 Paris Cedex 16

GREAT BRITAIN
The National Water Council, Fitting
Testing Station The Causeway,
Staines Middlesex, TW 18 3DR

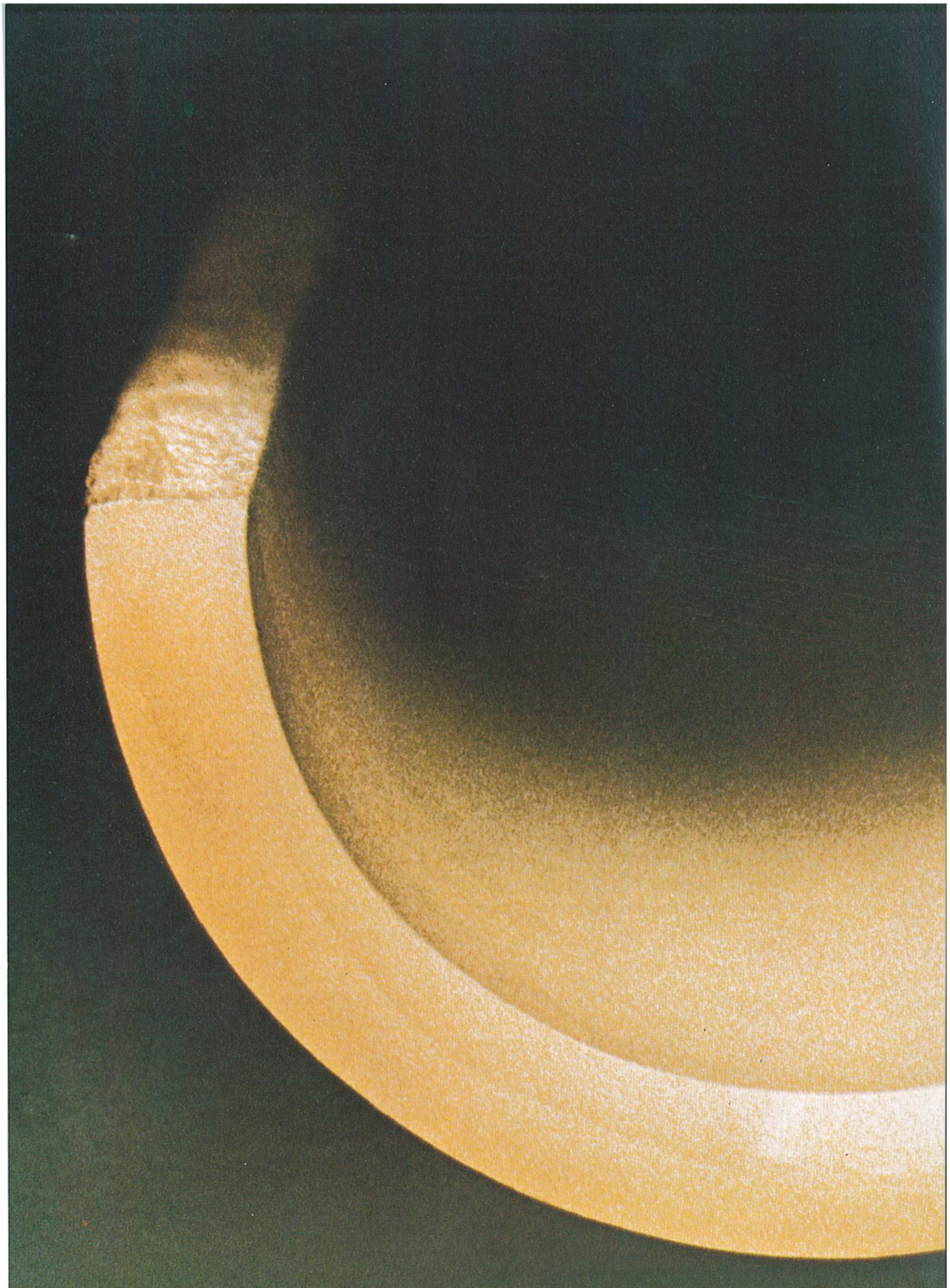
ITALY
Istituto Italiano dei Plastici
Via C. I. Petitti 16. 20149 Milano

NETHERLANDS
Keuringsinstituut voor Waterlei-
dingsartikelen KIWA NV
Postbus 70, NL-2280 AB Rijswijk

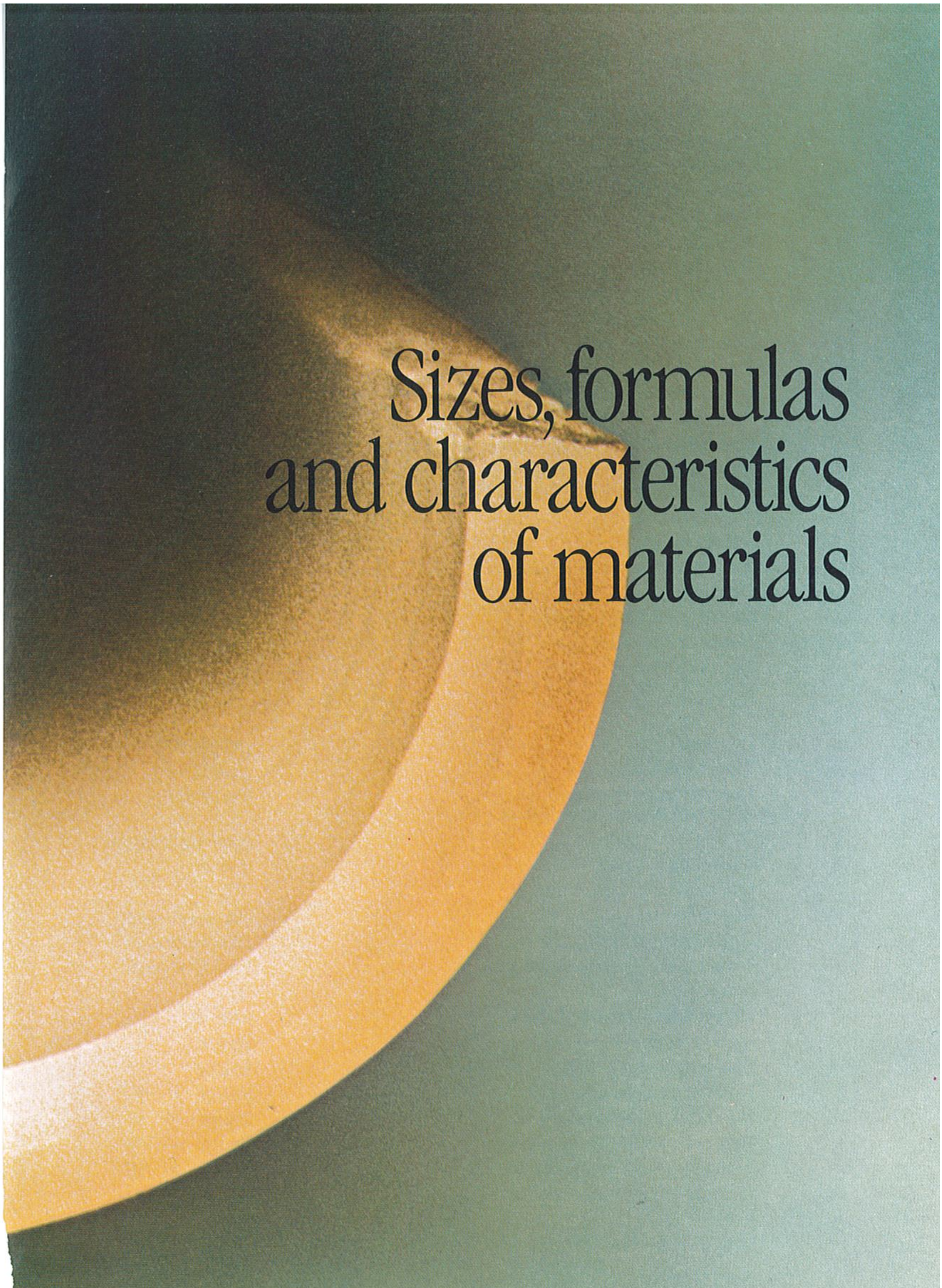
SWEDEN
Studsvik Energiteknik AB
S-611 82 Nyköping

FINLAND
VTT VVS-Tekniska Laboratoriet
Värmemansgränden 3,
SF-02150 Esbo

UNITED STATES
National Sanitation Foundation,
P.O. Box 1468,
Ann Arbor, Michigan 48106



Sizes, formulas and characteristics of materials



Symbol	Quantity	Unit
l	Length (Pipe length)	ft
d	Diameter (general)	in
d_o	Outside diameter	in
d_i	Inside diameter	in
r	Tubing radius	in
r_a	Average tubing radius	in
s	Wall thickness (of tubing)	in
δ	Thickness, layer thickness	in
A	Surface, cross section	ft^2
V	Volume	ft^3
h	Height	ft
Δh	Difference in height	ft
v	Velocity	ft/sec
g	Gravitational acceleration (local) ($\approx$ 32.17)	ft/sec
R	Ratio of diameter to wall thickness (D/s) (Standard Dimension Ratio, SDR)	Dimensionless
m	Mass (weight)	lb_m
m_T	Tubing weight	lb_m
m_M	Weight of medium in tubing	lb_m
ρ	Density	lb_m/ft^3
ρ_T	Density of tubing material	lb_m/ft^3
ρ_M	Density of medium	lb_m/ft^3
ρ_W	Density of water	lb_m/ft^3
F	Force	
lb_F		
p	Pressure	psi (lb_F/in^2)
Δp	Difference in pressure	psi (lb_F/in^2)
σ	Normal stress (tension) Also: Wall stress, hoop stress	psi (lb/in)
$\dot{V}$	Throughput volume	gpm (gallons/min.)
υ	Kinematic viscosity	ft^2/sec
υ_w	Kinematic viscosity of water	ft^2/sec
Re	Reynolds number	Dimensionless
c	Pipe friction index*	Dimensionless
T	Temperature (thermodynamic)	R (= °F + 460)
t	Temperature	°F
a	Linear-expansion coefficient	ft/ft · R
Q	Amount of heat	Btu/hr
Q_l	Heat loss	Btu/hr
λ	Thermal conductivity	Btu/hr · ft · °F
α	Thermal-transfer coefficient	Btu/hr · ft^2 · °F
k	Thermal-penetration coefficient	Btu/hr · ft^2 · °F
Λ	Thermal-conductance coefficient	Btu/hr · ft^2 · °F
R_t	Thermal-penetration resistance	ft^2 · hr · °F/Btu
π	3.1416	
ln	Natural logarithm	

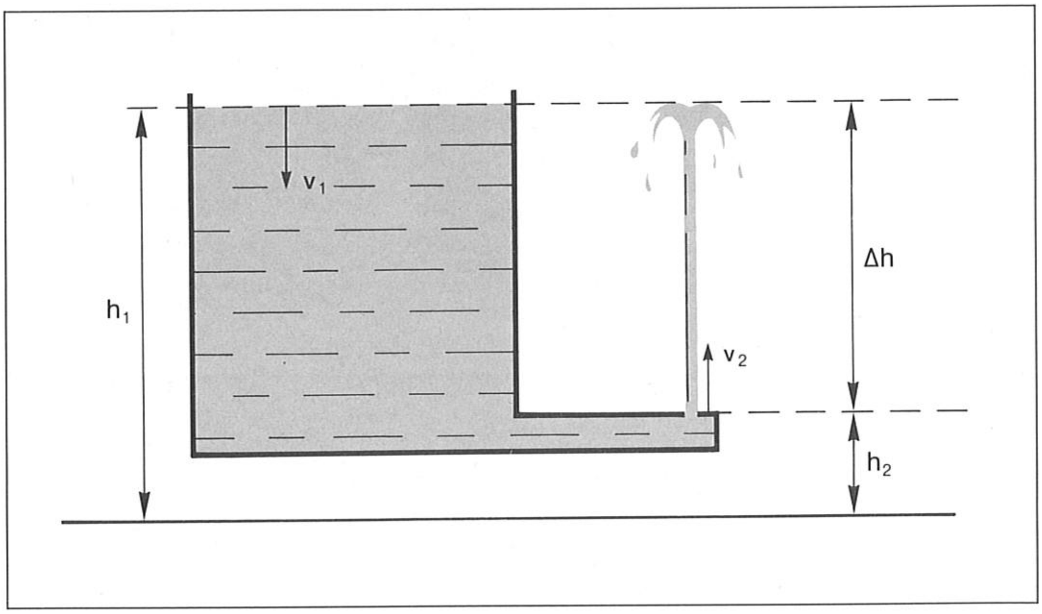
* In technical literature λ is often used.

Formulas used for pipeline calculations

1. Piping weight based upon a length of 1 foot
   $m_T = \pi/144 \cdot (d_o - s) \cdot s \cdot l \cdot \rho_T$ (lb_m) $l = 1$ ft
2. Piping capacity based upon a length of 1 foot
   $V = \pi/576 \cdot d_i^2 \cdot l$ (ft^3) $l = 1$ ft
3. Weight of the medium in the pipe based on a length of 1 foot
   $m_M = \pi/576 \cdot d_i^2 \cdot \rho_M \cdot l$ (lb_m) $l = 1$ ft
4. Density of water as a function of temperature (empirical, numerical-value equation that is valid for the range of 50 to 200°F)
   $\rho_W \approx 62.2685 + .0077761 \cdot t - .0001252 \cdot t^2 + .000000157 \cdot t^3$ (lb_m/ft^3)
5. Kinematic viscosity of water as a function of temperature (empirical, numerical-value equation that is valid for the range of 50 to 200°F)
   $\upsilon_W \approx 10^{-6} (28.001587 - .371028 \cdot t + .0020269 \cdot t^2 - .00000384 \cdot t^3$ (ft^2/sec)
6. Pressure drop per foot of pipe
   $\Delta p = c \cdot \rho \cdot v^2 \cdot l/24 \cdot d_i^2 \cdot g$ (psi)

6.1 c is the pipe friction index. The following equation is sufficiently precise for flowing water in any of the various Wirsbo-PEX tubings (Nikuradse's formula)
   $c = .0032 + .221 \cdot Re^{-.237}$ (good for $10^4 < Re < 10^8$)

7. This isolates and illustrates the water head $v^2/2$ g from the Bernoullian equation

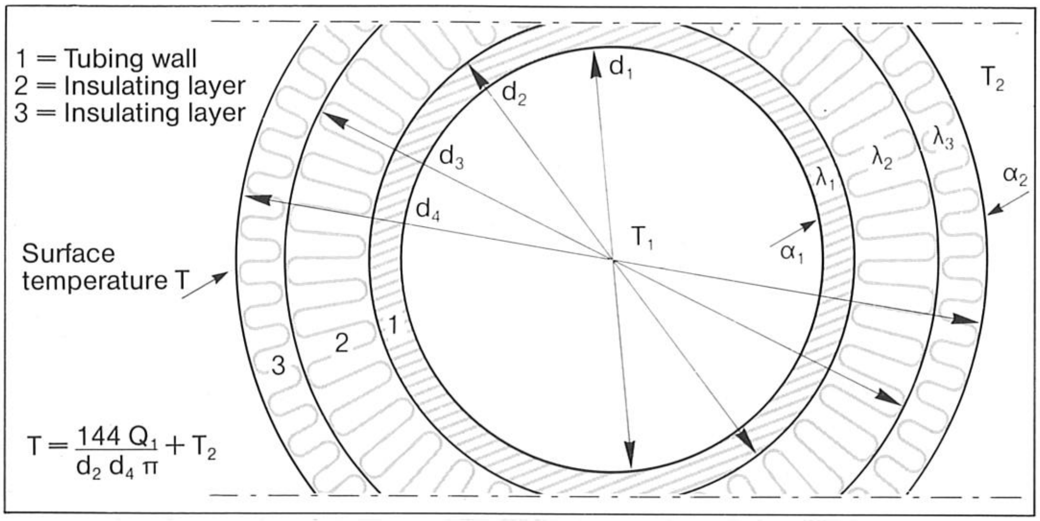


Ignoring the effect of fluid friction and assuming a large volume of liquid (with a velocity v_1 approaching zero), the exit velocity v_2 is arrived at from the following two equations:

7.1 $\Delta h = h_1 - h_2 = v_2^2/2 \cdot g$ (static head) (ft)

7.2 $v_2 = \sqrt{2 \cdot g \cdot \Delta h}$ (exit velocity) (ft/sec)

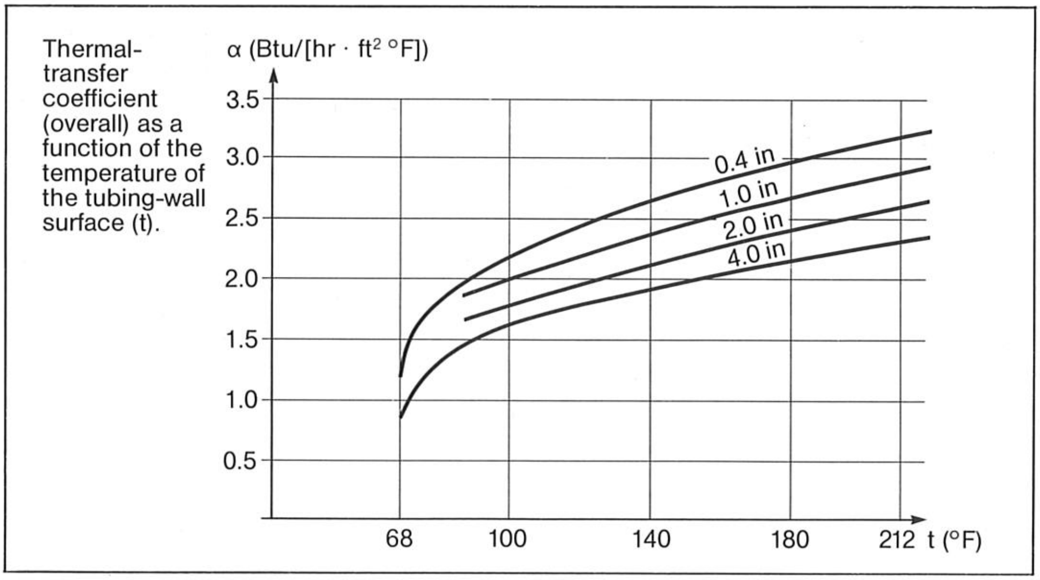
8. Heat loss in pipelines based upon a length of 1 foot as illustrated on an exposed cross-section of tubing that contains two layers of insulation.



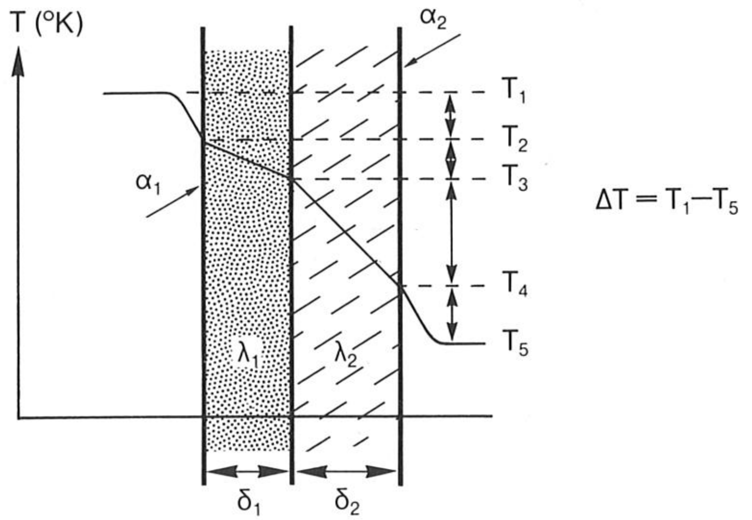
$$Q_L = \frac{\pi \cdot l \cdot (T_1 - T_2)}{12/(\alpha_1 \cdot d_1) + 12/(\alpha_2 \cdot d_4) + \ln (d_2/d_1) \cdot 1/(2 \cdot \lambda_1) + \ln (d_3/d_2) \cdot 1/(2 \cdot \lambda_2) \ldots \ldots + \ln (d_4/d_3) \cdot 1/(2 \cdot \lambda_3)} \quad \text{(Btu/hr)} \quad l = 1 \text{ ft}$$

In cases where the liquid to be carried in the pipeline is warm, the term that contains the thermal-transfer coefficient α_1 is low enough to ignore when compared to the other terms of the equation. If the tubing has no insulating layers, then $d_2 = d_3 = d_4$. The natural logarithm of the fractions d_3/d_2 or d_4/d_3 (which at that point would each take on the value of 1) would be zero. The corresponding terms of the equation would be dropped.

8.1 The thermal transfer coefficient takes into account the transfer of heat due to convection and due to radiation. The following graph shows, with adequate precision, the thermal-transfer coefficients of insulated and noninsulated tubing under free-flow conditions with a surrounding air temperature of 68°F.



9. Heat loss through uniform layers (walls) based upon a 1 square foot surface.



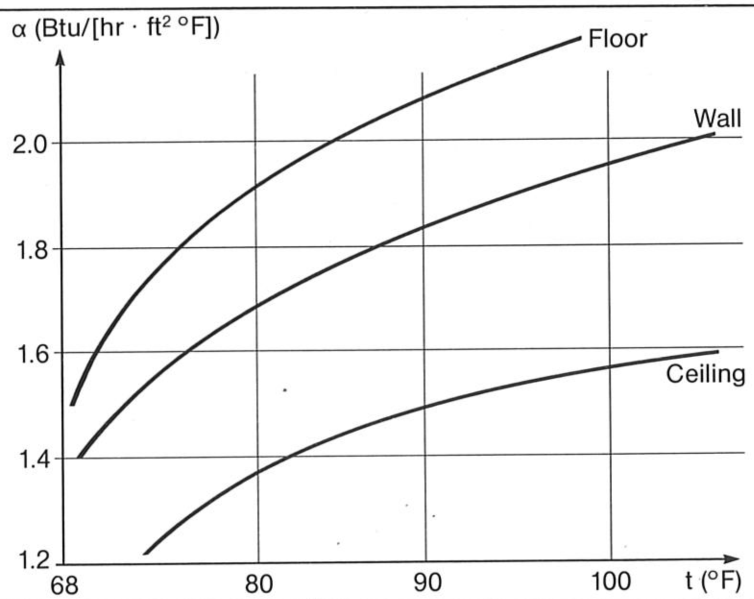
$$Q = \frac{A \cdot \Delta T}{1/\alpha_1 + \delta_1/(12 \cdot \lambda_1) + \delta_2/(12 \cdot \lambda_2) + 1/\alpha_2} = K \cdot A \cdot \Delta T \qquad \text{(Btu/hr)} \quad A = 1\ ft^2$$

9.1 k is the thermal-penetration coefficient. Its reciprocal value 1/k is the thermal-penetration resistance.

$$1/k = 1/\alpha_1 + \delta_1/(12 \cdot \lambda_1) + \delta_2/(12 \cdot \lambda_2) + 1/\alpha_2 \qquad (hr \cdot ft^2 \cdot {}^\circ F/Btu)$$

9.2 The thermal-transfer coefficient takes into account the transfer of heat due to convection and due to radiation. The following graph illustrates with adequate precision the sum of the thermal-transfer coefficients on smooth surfaces without any forced air movement and at a surrounding temperature of 68°F.

Thermal-transfer coefficient of buildings with surface heating as a function of the surface temperature t.



10.2 The relationship between the dimensions of a pipe, the internal pressure and the pressure on the piping wall (circumferential stress, hoop stress σ). According to international agreement the following equation is valid:

10.1 $p = 2 \cdot \sigma \cdot s/(d - s)$ (psi)

or transposed

10.2 $\sigma = p \cdot (d_o - s)/2\ s = p \cdot r_a/s$ (psi)

or transposed

10.3 $s = p \cdot d_o/(2 \cdot \sigma + p)$ (in)

or transposed from 10.2

10.4 $2\ \sigma/p = d_o/s - 1 = R\ - 1$ (dimensionless)

For the relationship between the outside diameter and the wall thickness, we have introduced here the value $R = d_o/s$. In English speaking countries and especially in United States, it is also referred to as the SDR or Standard Dimension Ratio.

10.5 Another relationship between the diameter and the wall thickness is shown in the equation $P = d_I/s$. This is also sometimes referred to as the SDR but that is incorrect. If we add the equation in 10.2 the result is the following equation:

$2\ \sigma/p = d_i/s + 1 = P + 1$ (dimensionless)

11. The following are various ways of expressing the throughput volume of pipelines. They are all derived from formula 2 without taking length into account.

11.1 $\dot{V} = 1/77.01 \cdot \pi \cdot d_i^2 \cdot v$ (gallons/sec)

11.2 $\dot{V} = 1/576 \cdot \pi \cdot d_i^2 \cdot v$ (ft/sec)

11.3 $\dot{V} = 6.25 \cdot \pi \cdot d_i^2 \cdot v$ (ft/hr)

11.4 $\dot{V} = .7791 \cdot \pi \cdot d_i^2 \cdot v$ (gpm)(gallons/min)

11.5 $\dot{V} = 46.75 \cdot \pi \cdot d_i^2 \cdot v$ (gallons/hour)

In the preceding formulas it is possible to insert $d_i = d_o - 2\ s$ as an alternative.

12. Heat loss for water as a function of the throughput volume and the difference in temperature.

12.1 $Q_l = 8.324\ \dot{V} \cdot \Delta T$ (Btu/hr)

when V is expressed in gallons/hour and ΔT equals the drop in temperature along the line.

12.2 $Q_l = 1222 \cdot d_i^2 \cdot v \cdot \Delta T$ (Btu/hr)

CONVERSION FACTORS

Metric and nonmetric (English and American) equivalents

1. Length (l)

meter m	inch in	foot ft	yard yd	mile ml	nautical mile
1	39,370	3,280 8	1,093 6	$0,621\,37 \cdot 10^{-3}$	$0,539\,96 \cdot 10^{-3}$
$25,4 \cdot 10^{-3}$	1	$83,333 \cdot 10^{-3}$	$27,778 \cdot 10^{-3}$	$15,783 \cdot 10^{-6}$	$13,715 \cdot 10^{-6}$
0,304 8	12	1	0,333 33	$0,189\,39 \cdot 10^{-3}$	$0,164\,58 \cdot 10^{-3}$
0,914 4	36	3	1	$0,568\,18 \cdot 10^{-3}$	$0,493\,74 \cdot 10^{-3}$
$1,609\,3 \cdot 10^{3}$	$63,36 \cdot 10^{3}$	$5,28 \cdot 10^{3}$	$1,76 \cdot 10^{3}$	1	0,868 98
$1,852 \cdot 10^{3}$	$72,913 \cdot 10^{3}$	$6.076\,1 \cdot 10^{3}$	$2,025\,4 \cdot 10^{3}$	1,150 8	1

1 micron (μ) = 10^{-6} meters, 1 ångström (Å) = 10^{-10} meters

2. Surface (A)

m^2	in^2	ft^2	yd^2	acre	$mile^2$
1	$1,550\,0 \cdot 10^{3}$	10,764	1,196 0	$0,247\,10 \cdot 10^{-3}$	$0,386\,10 \cdot 10^{-6}$
$0,645\,16 \cdot 10^{-3}$	1	$6,944\,4 \cdot 10^{-3}$	$0,771\,61 \cdot 10^{-3}$	$0,159\,42 \cdot 10^{-6}$	$0,249\,10 \cdot 10^{-9}$
$92,903 \cdot 10^{-3}$	144	1	0,111 11	$22,957 \cdot 10^{-6}$	$35,870 \cdot 10^{-9}$
0,836 13	$1,296 \cdot 10^{3}$	9	1	$0,206\,61 \cdot 10^{-3}$	$0,322\,83 \cdot 10^{-6}$
$4,046\,9 \cdot 10^{3}$	$6,272\,6 \cdot 10^{6}$	$43,56 \cdot 10^{3}$	$4,84 \cdot 10^{3}$	1	$1,562\,5 \cdot 10^{-3}$
$2,590\,0 \cdot 10^{6}$	$4.014\,5 \cdot 10^{9}$	$27,878 \cdot 10^{6}$	$3,097\,6 \cdot 10^{6}$	640	1

1 hectare (ha) = 10^4 m^2

3. Volume (V)

m^3	in^3	ft^3	yd^3	imp. gallon	US gallon
1	$61,024 \cdot 10^{3}$	35,315	1,308 0	219,97	264,17
$16,387 \cdot 10^{-6}$	1	$0,578\,70 \cdot 10^{-3}$	$21,434 \cdot 10^{-6}$	$3,604\,6 \cdot 10^{-3}$	$4,329\,0 \cdot 10^{-3}$
$28,317 \cdot 10^{-3}$	$1,728 \cdot 10^{3}$	1	$37,037 \cdot 10^{-3}$	6,228 8	7,480 5
0,764 56	$46,656 \cdot 10^{3}$	27	1	168,18	201,97
$4,546\,1 \cdot 10^{-3}$	277,42	0,160 54	$5,946\,1 \cdot 10^{-3}$	1	1,201 0
$3,785\,4 \cdot 10^{-3}$	231	0,133 68	$4,951\,1 \cdot 10^{-3}$	0,832 68	1

1 liter (l) = 10^{-3} m^3

4. Mass (m), weight

kg	pound lb	slug	ounce oz	brit. hundred-weight cwt	brit. ton	US cwt sh cwt	US ton sh tn
1	2,204 6	$68,522 \cdot 10^{-3}$	35,274	$19,684 \cdot 10^{-3}$	$0,984\,21 \cdot 10^{-3}$	$22,046 \cdot 10^{-3}$	$1,102\,3 \cdot 10^{-3}$
0,453 59	1	$31,081 \cdot 10^{-3}$	16	$8,928\,6 \cdot 10^{-3}$	$0,446\,43 \cdot 10^{-3}$	$10 \cdot 10^{-3}$	$0,5 \cdot 10^{-3}$
14,594	32,174	1	514,79	0,287 27	$14,363 \cdot 10^{-3}$	0,321 74	$16,087 \cdot 10^{-3}$
$28,350 \cdot 10^{-3}$	$62,5 \cdot 10^{-3}$	$1,942\,6 \cdot 10^{-3}$	1	$0,558\,04 \cdot 10^{-3}$	$27,902 \cdot 10^{-6}$	$0,625 \cdot 10^{-3}$	$31,25 \cdot 10^{-6}$
50,802	112	3,481 1	$1,792 \cdot 10^{3}$	1	$50 \cdot 10^{-3}$	1,12	$56 \cdot 10^{-3}$
$1,016\,1 \cdot 10^{3}$	$2,24 \cdot 10^{3}$	69,621	$35,84 \cdot 10^{3}$	20	1	22,4	1,12
45,359	100	3,108 1	$1,6 \cdot 10^{3}$	0,892 86	$44,643 \cdot 10^{-3}$	1	$50 \cdot 10^{-3}$
907,19	$2 \cdot 10^{3}$	62,162	$32 \cdot 10^{3}$	17,857	0,892 86	20	1

1 slug = 1 lbf · s^2/ft
Measurements used in the USA:
US cwt: short hundredweight; british cwt: long hundredweight
US ton: short ton; british ton: long ton

5. Velocity (v)

m/s	km/h	ft/s	mile/h	Knots kn/h
1	3,6	3,280 8	2,236 9	1,943 8
0,277 78	1	0,911 34	0,621 37	0,539 96
0,304 8	1,097 3	1	0,681 82	0,592 48
0,447 04	1,609 3	1,466 7	1	0,868 98
0,514 44	1,852	1,687 8	1,150 8	1

6. Density (ρ)

kg/m^3	lb/in^3	lb/ft^3
1	$36,127 \cdot 10^{-6}$	$62,428 \cdot 10^{-3}$
10^3	$36,127 \cdot 10^{-3}$	62,428
$27,680 \cdot 10^{3}$	1	$1,728 \cdot 10^{3}$
16,019	$0,578\,70 \cdot 10^{-3}$	1

7. Force (F), Gravity (G)

Newton N	dyne	kilopound kp	pound-force lbf
1	0,1 · 10^{6}	0,101 97	0,224 81
10 · 10^{-6}	1	1,019 7 · 10^{-6}	2,248 1 · 10^{-6}
9,806 6	0,980 66 · 10^{6}	1	2,204 6
4,448 2	0,444 82 · 10^{6}	0,453 59	1

8. Momentum (M)

Nm	kpm	lbf – in	lbf – ft
1	0,101 97	8,850 8	0,737 56
9,806 6	1	86,796	7,233 0
0,112 99	11,521 · 10^{-3}	1	83,333 · 10^{-3}
1,355 8	0,138 26	12	1

9. Pressure (p), normal stress (σ)

Pascal Pa	bar	Technical atmospheres	kp/mm^{2}	Torr (mm HG)	Physical atmospheres	lbf/in^{2}
1	10 · 10^{-6}	10,197 · 10^{-6}	0,101 97 · 10^{-6}	7,500 6 · 10^{-3}	9,869 2 · 10^{-6}	0,145 04 · 10^{-3}
100 · 10^{3}	1	1,019 7	10,197 · 10^{-3}	750,06	0,986 92	14,504
98,066 · 10^{3}	0,980 66	1	10 · 10^{-3}	735,56	0,967 84	14,223
9,806 6 · 10^{6}	98,066	100	1	73,556 · 10^{3}	96,784	1,422 3 · 10^{3}
133,32	1,333 2 · 10^{-3}	1,359 5 · 10^{-3}	13,595 · 10^{-6}	1	1,315 8 · 10^{-3}	19,337 · 10^{-3}
101,32 · 10^{3}	1,013 2	1,033 2	10,332 · 10^{-3}	760	1	14,696
6,894 8 · 10^{3}	68,948 · 10^{-3}	70,307 · 10^{-3}	0,703 07 · 10^{-3}	51,715	68,046 · 10^{-3}	1

1 mWs = 9,81 · 10^{3} Pa

10. Energy (E), Work (W)

Joule J	Kilowatt hours kWh	kpm	Kilocalories kcal	Horsepower hours hp/h	ft · lbf	Brit. thermal unit Btu
1	0,277 78 · 10^{-6}	0,101 97	0,238 85 · 10^{-3}	0,377 67 · 10^{-6}	0,737 56	0,947 82 · 10^{-3}
3,6 · 10^{6}	1	0,367 10 · 10^{6}	859,85	1,359 6	2,655 2 · 10^{6}	3,412 1 · 10^{3}
9,806 6	2,724 1 · 10^{-6}	1	2,342 3 · 10^{-3}	3,703 7 · 10^{-6}	7,233 0	9,294 9 · 10^{-3}
4,186 8 · 10^{3}	1,163 · 10^{-3}	426,94	1	1,581 2 · 10^{-3}	3,088 0 · 10^{3}	3,968 3
2,647 8 · 10^{6}	0,735 50	0,27 · 10^{6}	632,42	1	1,952 9 · 10^{6}	2,509 6 · 10^{3}
1,355 8	0,376 62 · 10^{-6}	0,138 26	0,323 83 · 10^{-3}	0,512 06 · 10^{-6}	1	1,285 1 · 10^{-3}
1,055 1 · 10^{3}	0,293 07 · 10^{-3}	107,59	0,252 00	0,398 47 · 10^{-3}	778,17	1

1 erg = 0,1 10^{-6} J

11. Power (P)

Watt W	kp/s	kcal/s	kcal/h	Horsepower (metric)	Horsepower – HP	ft · lbf/s	Btu/h
1	0,101 97	0,238 85 · 10^{-3}	0,859 85	1,359 6 · 10^{-3}	1,341 0 · 10^{-3}	0,737 56	3,412 1
9,806 6	1	2,342 3 · 10^{-3}	8,432 2	13,333 · 10^{-3}	13,151 · 10^{-3}	7,233 0	33,462
4,186 8 · 10^{3}	426,94	1	3,6 · 10^{3}	5,692 5	5,614 6	3,088 0 · 10^{3}	14,286 · 10^{3}
1,163	0,118 59	0,277 78 · 10^{-3}	1	1,581 2 · 10^{-3}	1,559 6 · 10^{-3}	0,857 79	3,968 3
735,50	75	0,175 67	632,42	1	0,986 32	542,48	2,509 6 · 10^{3}
745,70	76,040	0,178 11	641,19	1,013 9	1	550	2,544 4 · 10^{3}
1,355 8	0,138 26	0,323 83 · 10^{-3}	1,165 8	1,843 4 · 10^{-3}	1,818 2 · 10^{-3}	1	4,626 2
0,293 07	29,885 · 10^{-3}	69,999 · 10^{-6}	0,252 00	0,398 47 · 10^{-3}	0,393 02 · 10^{-3}	0,216 16	1

12. Temperature, thermodynamic (T), other temperature scales

	Kelvin scale (T_K) K	Celsius Scale (t_c) °C	Rankine scale (T_R) °R	Fahrenheit scale (t_F) °F	Physical state
Correlating temperature	0 K	–273,15°C	0°R	–459,67°F	Absolute zero
	255,372 K	–17,778°C	459,67°R	0°F	
	273,15 K	0°C	491,67°R	32°F	Melting point of ice
	273,16 K	0,01°C	491,688°R	32,018°F	Triple point T_{tr} of water
	373,15 K	100°C	671,67°R	212°F	Boiling point of water
Correlating temperature differential	1 K	1°C	1,8°R	1,8°F	
	0,4555 56 K	0,4555 56°C	1°R	1°F	

$t_c = 5/9\ (t_F - 32)$

PHYSICAL AND TECHNICAL RATINGS OF SOME SPECIFIC MATERIALS

Tensile strength and elasiticity modulus of Wirsbo-PEX tubing

The tensile-strength and E-modulus ratings were supplied by the Technological University of Stockholm, Institute for Light Construction. The tests were based essentially upon DIN 53455 and DIN 53457. The samples were pieces of tubing.

1. Tensile strength at the highest force σ_B (N/mm^2)

t (°C) / $\dot{\varepsilon}$ (%/min)	23	60	80	100
1	13,7	10,4	8,4	6,6
10	16,8	11,5	9,2	7,2
100	20,2	14,7	10,0	8,0

2. Elasticity modulus E (N/mm^2)

	Secant modulus E_s N/mm^2			Tangent modulus E_t N/mm^2		
t (°C) / ε (%)	23	60	80	23	60	80
1	630	250	150	350	155	105
2	470	195	125	215	115	90
5	275	130	95	90	60	50
10	160	85	60	30	22	17
50	–	20	15	–	5	3

Elongation speed $\dot{\varepsilon}$ = 10 %/min

3. Secant modulus E_s (N/mm^2)

t (°C)	23°C			60°C			80°C		
$\dot{\varepsilon}$ (%/min) / ε(%)	1	10	100	1	10	100	1	10	100
1	505	630	855	190	250	320	130	150	185
2	380	470	635	165	195	250	110	125	155
5	225	275	370	110	130	165	80	95	110
10	130	160	195	70	85	100	50	60	70

4. Tangent modulus E_t (N/mm^2)

t (°C)	23°C			60°C			80°C		
$\dot{\varepsilon}$ (%/min) / ε (%)	1	10	100	1	10	100	1	10	100
1	285	350	585	125	155	240	90	105	140
2	190	215	285	100	115	165	75	90	100
5	80	90	115	50	60	85	40	50	55
10	20	30	50	18	22	30	15	17	20

5. Density and thermal conductivity of various materials

Piping, shaped pieces	ρ lb/ft³	Btu/h°F
Metals		
Steel	,48	48,5
Copper	,556	170,
Copper		210,
Stainless stell	,556	9,2
Brass	,531	69,
Bronze	,543	35,
"Esmatur" (dezincification-free brass)	,512	58,
XLPE (PEX)	,059	0,22
Building materials		
Dry concrete	,14	0,81
Light concrete, dry	,031	0,069
Wood-fiber tiles*	,038	0,075
Mineral/glass wool	,0012 –,0025	0,029
Polyurethane (PUR), foamed*	,0025	0,021
Polystyrol (PS), foamed*	,0012	0,023
Cross-linked polyethylene (PEX), foamed*	,0019	0,023
Linoleum	,069	0,110
PVC coating, poured**	,087	0,046
Other		
Ice	,057	1,39
Water	,062	0,35
Air	,0008	0,014

* Varies according to density

** In the case of plastic coatings, the manufacturer's specifications should be consulted.

6. Characteristics of plastics in comparison to steel

Material	Linear thermal-expansion coefficient	Density lb/ft³	Heat conductivity Btu/h°F
LDPE	83	.057	0,18
HDPE	72	.060	0,24
XLPE (PEX)	78	.059	0,22
PP-C	56	.056	0,081
PB	72	,057	0,13
PVC	44	,087	0,104
Steel	6	,487	33,5

7. Air/water-vapor mixture

Temperature, saturation pressure and amount of water for each spatial unit of saturated air.

°C	Vapor pressure mm Hg	Vapor pressure millibar	g/m³	°C	Vapor pressure mm Hg	Vapor pressure millibar	g/m³	°C	Vapor pressure mm Hg	Vapor pressure millibar	g/m³
−30	0,280	0,373	0,333	18	15,48	20,63	15,41	86	450,9	601,0	366,7
−25	0,47	0,626	0,550	19	16,48	21,97	16,36	88	487,1	649,2	394,3
−20	0,77	1,03	0,88	20	17,54	23,38	17,34	90	525,8	700,8	423,5
−15	1,24	1,65	1,38	21	18,65	24,86	18,38	91	546,1	727,9	Rise in pressure: 98–99°C: 25,97 mm Hg/34,62 mb; 99–100°C: 26,76 mm Hg/35,67 mb; 100–101°C: 27,6 mm Hg/36,8 mb
−12	1,63	2,17	1,80	22	19,83	26,43	19,47	92	567,0	755,8	
−11	1,78	2,37	1,96	23	21,07	28,08	20,62	93	588,6	784,5	
−10	1,95	2,60	2,14	24	22,38	29,83	21,82	94	610,9	814,3	
− 9	2,13	2,84	2,33	25	23,76	31,67	23,09	95	633,9	844,9	
− 8	2,32	3,09	2,54	26	25,21	33,60	24,42	96	657,6	876,5	
− 7	2,53	3,37	2,76	27	26,74	35,64	25,81	97	682,1	909,2	
− 6	2,76	3,68	2,99	28	28,35	37,79	27,28	98	707,3	942,8	
− 5	3,01	4,01	3,24	29	30,04	40,04	28,81	99	733,2	977,3	
− 4	3,28	4,37	3,51	30	31,83	42,43	30,37	100	760	1013,0	
− 3	3,57	4,76	3,81	32	35,7	47,5	33,8	101	787,6	1049,8	
− 2	3,88	5,17	4,13	34	39,9	53,2	37,6	102	815,9	1087,5	
− 1	4,22	5,62	4,47	36	44,6	59,4	41,8	104	875,1	1166	Vapor pressure kp/cm²
± 0	4,58	6,10	4,84	38	49,7	66,2	46,1	106	937,9	1250	
+ 1	4,93	6,57	5,18	40	55,3	73,7	51,2	108	1004,4	1339	
+ 2	5,29	7,05	5,55	45	71,9	95,8	65,4	110	1074,6	1432,3	1,460
+ 3	5,69	7,58	5,94	50	92,5	123,3	83,0	112	1148,7	1531,1	1,561
+ 4	6,10	8,13	6,35	55	118,0	157,3	104,1	114	1227,3	1635,9	1,668
+ 5	6,54	8,72	6,76	60	149,4	199,1	130,1	116	1309,9	1746,0	1,780
+ 6	7,01	9,34	7,35	62	163,8	218,3	141,8	118	1397,2	1862,3	1,899
+ 7	7,51	10,01	7,72	64	179,3	239,0	153,5	120	1489,1	1984,8	2,024
+ 8	8,05	10,73	8,26	66	196,1	261,4	168,0	130	2026	2700	2,754
+ 9	8,61	11,48	8,80	68	214,2	285,5	182,5	140	2710	3612	3,68
+10	9,21	12,28	9,39	70	233,7	311,5	198,0	150	3570	4758	4,85
+11	9,84	13,12	10,00	72	254,6	339,4	214,6	160	4636	6179	6,30
+12	10,52	14,02	10,66	74	277,2	369,5	232,4	180	7520	10023	10,22
+13	11,23	14,97	11,30	76	301,4	401,8	251,4	200	11659	15540	15,85
+14	11,99	15,98	12,03	78	327,3	436,3	271,7	250	29818	39744	40,53
+15	12,79	17,05	12,79	80	355,1	473,3	293,3	300	64433	85882	87,6
+16	13,63	18,17	13,60	82	384,9	513,0	316,2	374	165467	220551	224,9
+17	14,53	19,37	14,52	84	416,8	555,5	340,7				

Absorption Method

The relative humidity φ can be arrived at from the relationship between the amount of water by weight in a specific amount of air when compared with the amount of water by weight in the same amount of air at its saturation point. See the table above (under the heading (g/m³). Changes in the pressure and temperature of the mixture in the measuring equipment are to be taken into account if they occur.

Psychrometer method

The partial pressure p_D of the water vapor is arrived at from the semi-empirical Sprung psychrometer formula.

$p_D = p_f - 0.49\ (t - t_f)$ (mm Hg)

$p_D = p_f - 0.66\ (t - t_f)$ (millibars)

Where: t – is the temperature on dry thermometer

t_f – is the temperature on the wet thermometer

p_f – is the saturation pressure at t_f

The formula is valid for the temperature range from −20°C. to +30°C. Its preciseness should correspond to that of the temperature readings. The factor preceding the terms in parentheses (the psychrometrical difference in temperature) is proportional to the barometric pressure which here is assumed to be 760 mm Hg = 1013 millibars. In case the current value is quite different, that factor can be corrected to reflect the acutal barometric pressure.

The formula for the relative humidity would then be: $\varphi = p_D/p'$ where p' = the saturation pressure at the current temperature.

Conversion tables

Metric and nonmetric (English and American) units

1. Length – Inches (fractions) into millimeters

in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
1/32	0.794	5/32	3.969	9/32	7.144	13/32	10.319	17/32	13.494	21/32	16.669	25/32	19.844	29/32	23.019
1/16	1.588	3/16	4.762	5/16	7.938	7/16	11.112	9/16	14.288	11/16	17.462	13/16	20.638	15/16	23.812
3/32	2.381	7/32	5.556	11/32	8.731	15/32	11.906	19/32	15.081	23/32	18.256	27/32	21.431	31/32	24.606
1/8	3.175	1/4	6.350	3/8	9.525	1/2	12.700	5/8	15.875	3/4	19.050	7/8	22.225	1	25.400

2. Length – Inches (decimal fractions) into millimeters and vice versa

in		mm	in		mm	in		mm	in		mm
0·03937	1	25·4	0·62992	16	406·4	1·22047	31	787·4	2·20472	56	1422·4
0·07874	2	50·8	0·66929	17	431·8	1·25984	32	812·8	2·28346	58	1473·2
0·11811	3	76·2	0·70866	18	457·2	1·29921	33	838·2	2·36220	60	1524·0
0·15748	4	101·6	0·74803	19	482·6	1·33858	34	863·6	2·55905	65	1651·0
0·19685	5	127·0	0·78407	20	508·0	1·37795	35	889·0	2·75590	70	1778·0
0·23622	6	152·4	0·82677	21	533·4	1·41732	36	914·4	2·95275	75	1905·0
0·27559	7	177·8	0·86614	22	558·8	1·49606	38	965·2	3·14960	80	2032·0
0·31496	8	203·2	0·90551	23	584·2	1·57480	40	1016·0	3·34645	85	2159·0
0·35433	9	228·6	0·94488	24	609·6	1·65354	42	1066·8	3·54330	90	2286·0
0·39370	10	254·0	0·98425	25	635·2	1·73228	44	1117·6	3·74015	95	2413·0
0·43307	11	279·4	1·02362	26	660·4	1·82202	46	1168·4	3·93700	100	2540·0
0·47244	12	304·8	1·06299	27	685·8	1·88976	48	1219·2			
0·51181	13	330·2	1·10236	28	711·2	1·96850	50	1270·0			
0·55118	14	355·6	1·14173	29	736·6	2·04724	52	1320·8			
0·59055	15	381·0	1·18110	30	762·0	2·12598	54	1371·6			

Example: 20 inches equals 508 millimeters and 20 millimeters equals 0.78407 inches.

3. Length – Feet into meters and vice versa

ft		m	ft		m	ft		m
3.2808	1	0.3048	78.740	24	7.3152	177.17	54	16.459
6.5617	2	0.6096	82.021	25	7.6200	183.73	56	17.069
9.8425	3	0.9144	85.302	26	7.9248	190.29	58	17.678
13.123	4	1.2192	88.583	27	8.2296	196.85	60	18.288
16.404	5	1.5240	91.86	28	8.5344	203.41	62	18.898
19.685	6	1.8288	95.14	29	8.8392	216.97	64	19.507
22.966	7	2.1336	98.42	30	9.1440	216.54	66	20.117
26.247	8	2.4384	101.71	31	9.4488	223.10	68	20.726
29.528	9	2.7432	104.99	32	9.7536	229.66	70	21.336
32.808	10	3.0480	108.27	33	10.058	236.22	72	21.946
36.089	11	3.3528	111.55	34	10.363	242.78	74	22.555
39.370	12	3.6576	114.83	35	10.668	249.34	76	23.165
42.651	13	3.9624	118.11	36	10.973	255.91	78	23.774
45.932	14	4.2672	121.39	37	11.278	262.47	80	24.384
49.213	15	4.5720	124.67	38	11.582	269.03	82	24.994
52.493	16	4.8768	127.95	39	11.887	275.59	84	25.603
55.774	17	5.18163	131.23	40	12.192	282.15	86	26.213
59.055	18	5.48644	137.80	42	12.802	288.71	88	26.822
62.336	19	5.79125	144.36	44	13.411	295.28	90	27.432
65.617	20	6.0960	150.92	46	14.021	301.84	92	28.042
68.898	21	6.4008	157.48	48	14.630	308.40	94	28.651
72.178	22	6.7056	164.04	50	15.240	314.96	96	29.261
75.459	23	7.0104	170.60	52	15.850	321.52	98	29.870

Example: 10 feet equals 3.0480 meters and 10 meters equals 32.808 feet.

4. Surface – Square feet into square meters and vice versa

f^2		m^2	f^2		m^2	f^2		m^2
10·764	1	0·0929	279·86	26	2·4155	559·72	52	4·8310
21·528	2	0·1858	290·63	27	2·5084	581·25	54	5·0168
32·292	3	0·2787	301·39	28	2·6013	602·78	56	5·2026
43·056	4	0·3716	312·15	29	2·6942	624·31	58	5·3884
53·820	5	0·4645	322·92	30	2·7871	645·83	60	5·5742
64·583	6	0·5574	333·68	31	2·8800	667·36	62	5·7600
75·347	7	0·6503	344·45	32	2·9729	688·89	64	5·9458
86·111	8	0·7432	355·21	33	3·0658	710·42	66	6·1316
96·875	9	0·8361	365·97	34	3·1587	731·95	68	6·3174
107·64	10	0·9290	376·74	35	3·2516	753·47	70	6·5032
118·40	11	1·0219	387·50	36	3·3445	775·00	72	6·6890
129·17	12	1·1148	398·27	37	3·4374	796·53	74	6·8748
139·93	13	1·2077	409·03	38	3·5303	818·06	76	7·0606
150·70	14	1·3006	419·79	39	3·6232	839·58	78	7·2464
161·46	15	1·3936	430·56	40	3·7161	861·11	80	7·4322
172·22	16	1·4865	441·32	41	3·8090	882·64	82	7·6180
182·99	17	1·5794	452·08	42	3·9019	904·17	84	7·8039
193·75	18	1·6723	462·85	43	3·9948	925·70	86	7·9897
204·51	19	1·7652	473·61	44	4·0877	947·22	88	8·1755
215·28	20	1·8581	484·38	45	4·1806	968·74	90	8·3613
226·04	21	1·9510	495·14	46	4·2735	990·28	92	8·5471
236·81	22	2·0439	505·90	47	4·3664	1011·8	94	8·7329
247·57	23	2·1368	516·67	48	4·4594	1033·3	96	8·9187
258·33	24	2·2297	527·43	49	4·5523	1054·9	98	9·1045
269·10	25	2·3226	538·20	50	4·6452	1076·4	100	9·2903

Example: 10 square meters equals 107.64 square feet and 10 square feet equals 0.9290 square meters.

5. Volume – Cubic feet into cubic meters and vice versa

ft^3		m^3	ft^3		m^3	ft^3		m^3
35·315	1	0·0283	918·18	26	0·7362	1836·4	52	1·4725
70·629	2	0·0566	953·50	27	0·7646	1907·0	54	1·5291
105·94	3	0·0850	988·81	28	0·7929	1977·6	56	1·5857
141·26	4	0·1133	1024·1	29	0·8212	2048·3	58	1·6424
176·57	5	0·1416	1059·4	30	0·8495	2118·9	60	1·6990
211·89	6	0·1699	1094·8	31	0·8778	2189·5	62	1·7557
247·20	7	0·1982	1130·1	32	0·9061	2260·1	64	1·8123
282·52	8	0·2265	1165·4	33	0·9345	2330·8	66	1·8689
317·83	9	0·2549	1200·7	34	0·9628	2401·4	68	1·9256
353·15	10	0·2832	1236·0	35	0·9911	2472·0	70	1·9822
388·46	11	0·3115	1271·3	36	1·0194	2542·7	72	2·0388
423·78	12	0·3398	1306·6	37	1·0477	2613·3	74	2·0955
459·09	13	0·3681	1342·0	38	1·0760	2683·9	76	2·1521
494·41	14	0·3964	1377·3	39	1·1043	2754·5	78	2·2087
529·72	15	0·4248	1412·6	40	1·1327	2825·2	80	2·2654
563·03	16	0·4531	1447·9	41	1·1610	2895·8	82	2·3220
600·35	17	0·4814	1483·2	42	1·1893	2966·4	84	2·3786
635·66	18	0·5097	1518·5	43	1·2176	3037·1	86	2·4353
670·98	19	0·5380	1553·8	44	1·2459	3107·7	88	2·4919
706·29	20	0·5663	1589·2	45	1·2743	3178·3	90	2·5485
741·61	21	0·5947	1624·5	46	1·3026	3249·0	92	2·6052
776·92	22	0·6230	1659·8	47	1·3309	3319·6	94	2·6618
812·24	23	0·6513	1695·1	48	1·3592	3390·2	96	2·7184
847·55	24	0·6796	1730·4	49	1·3875	3460·8	98	2·7751
882·87	25	0·7079	1765·7	50	1·4158	3531·5	100	2·8317

Example: 10 cubic meters equals 353.15 cubic feet and 10 cubic feet equals 0.2832 cubic meters.

6. Volume – US gallons into liters and vice versa

gallons		l	gallons		l	gallons		l	gallons		l
0·246	1	3·785	2·906	11	41·639	5·812	22	83·279	11·888	45	170·343
0·528	2	7·571	2·642	12	37·854	6·340	24	90·850	13·209	50	189·270
0·793	3	113568	3·434	13	49·210	6·868	26	98·420	14·530	55	208·197
1·057	4	15·142	3·698	14	52·996	7·397	28	105·991	15·850	60	227·124
1·321	5	18·927	3·963	15	56·781	7·925	30	113·562	17·171	65	246·051
1·585	6	22·712	4·227	16	60·566	8·454	32	121·133	18·492	70	264·978
1·849	7	26·498	4·491	17	64·352	8·982	34	128·704	19·813	75	283·905
2·113	8	30·283	4·755	18	68·137	9·510	36	136·274	21·134	80	302·832
2·378	9	34·069	5·019	19	71·923	10·039	38	143·845	22·455	85	321·759
2·642	10	37·854	5·283	20	75·708	10·567	40	151·416	23·776	90	340·686

Example: 5 liters equals 1.321 US gallons and 5 US gallons equals 18.927 liters.

7. Mass, weight – Pounds into Kilograms and vice versa

lb		kg	lb		kg	lb		kg
2.2046	1	0.4536	35.274	16	7.2575	68.343	31	14.061
4.4092	2	0.9072	37.479	17	7.7111	70.548	32	14.515
6.6139	3	1.3608	39.683	18	8.1647	72.753	33	14.969
8.8185	4	1.8144	41.888	19	8.6183	74.957	34	15.422
11.023	5	2.2680	44.092	20	9.0718	77.162	35	15.876
13.228	6	2.7216	46.297	21	9.5254	79.366	36	16.329
15.432	7	3.1752	48.502	22	9.9790	81.571	37	16.763
17.637	8	3.6287	50.706	23	10.433	83.776	38	17.287
19.842	9	4.0823	52.911	24	10.886	85.980	39	17.690
22.046	10	4.5359	55.116	25	11.340	88.185	40	18.144
24.251	11	4.9895	57.320	26	11.793	92.594	42	19.051
26.456	12	5.4431	59.525	27	12.247	97.003	44	19.958
28.660	13	5.8967	61.729	28	12.701	101.41	46	20.865
30.865	14	6.3503	63.934	29	13.154	105.82	48	21.772
33.069	15	6.8039	66.139	30	13.608	110.23	50	22.680

Example: 10 kilograms equals 22.046 pounds and 10 pounds equals 4.5359 kilograms.

8. Density – Pounds per cubic foot into kilograms per cubic meter and vice versa

lb/ft^3		kg/m^3	lb/ft^3		kg/m^3	lb/ft^3		kg/m^3
0.062428	1	16.019	1.2486	20	320.37	2.9965	48	768.89
0.12486	2	32.037	1.3734	22	352.41	3.1214	50	800.93
0.18728	3	48.056	1.4983	24	384.44	3.4335	55	881.02
0.24971	4	64.074	1.6231	26	416.48	3.7457	60	961.11
0.31214	5	80.093	1.7480	28	448.52	4.0578	65	1041.2
0.37457	6	96.111	1.8728	30	480.56	4.3699	70	1121.3
0.43699	7	112.13	1.9977	32	512.59	4.6821	75	1201.4
0.49942	8	128.15	2.1225	34	544.63	4.9942	80	1281.5
0.56185	9	144.17	2.2474	36	576.67	5.3064	85	1361.6
0.62428	10	160.19	2.3723	38	608.70	5.6185	90	1441.7
0.74913	12	192.22	2.4971	40	640.74	5.9306	95	1521.8
0.87399	14	224.26	2.6220	42	672.78	6.2428	100	1601.9
0.99884	16	256.30	2.7468	44	704.81	6.5549	105	1681.9
1.1237	18	288.33	2.8717	46	736.85	6.8671	110	1762.0

Example: 10 kilograms per cubic meter equals 0.62428 pounds per cubic foot. 10 pounds per cubic foot equals 160.19 kilograms per cubic meter.

9. Temperature – Degrees Fahrenheit into degrees Celsius and vice versa

°F		°C	°F		°C	°F		°C
−148	−100	−73.3	53.6	12	−11.1	203.0	95	35.0
−130	−90	−76.8	57.2	14	−9.9	212.0	100	37.7
−112	−80	−62.2	60.8	16	−8.8	248.0	120	48.9
−94	−70	−56.7	64.4	18	−7.7	284.0	140	60.0
−76.0	−60	−51.2	68.0	20	−6.6	320.0	160	71.1
−58.0	−50	−45.6	71.6	22	−5.5	356.0	180	82.2
−40.0	−40	−40.0	75.2	24	−4.4	392.0	200	93.3
−22.0	−30	−34.4	78.8	26	−3.3	413.6	212	100.0
−4.0	−20	−28.9	82.4	28	−2.2	482.0	250	121.1
14.0	−10	−23.3	86.0	30	−1.1	572.0	300	148.8
23.0	−5	−20.6	89.6	32	0	662.0	350	176.6
24.8	−4	−20.0	93.2	34	1.1	752.0	400	204.4
26.6	−3	−19.4	96.8	36	2.2	842.0	450	232.3
28.4	−2	−18.8	100.4	38	3.3	932.0	500	260.0
30.8	−1	−18.2	104.0	40	4.4	1112.0	600	315.6
32	0	−17.7	113.0	45	7.2	1292.0	700	371.3
33.8	1	−17.2	122.0	50	10.0	1472.0	800	426.6
35.6	2	−16.6	131.0	55	12.8	1652.0	900	482.2
37.4	3	−16.1	140.0	60	15.6	1832.0	1000	537.7
39.2	4	−15.5	149.0	65	18.4	2192.0	1200	648.9
41.0	5	−15.0	158.0	70	21.2	2552.0	1400	760.0
42.8	6	−14.4	167.0	75	23.9	2912.0	1600	871.2
44.6	7	−13.8	176.0	80	26.7	3272.0	1800	982.3
46.4	8	−13.3	185.0	85	29.5	3632.0	2000	1093.3
48.2	9	−12.7	194.0	90	32.2	4532.0	2500	1371.1
50.0	10	−12.2						

Example: 50 degrees Celsius equals 122.0 degrees Fahrenheit. 50 degrees Fahrenheit equals 10.0 degrees Celsius.

10. Thermal Conductivity – Btu · in/ft² · h · degrees F into W/K · m

Btu	0,00	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0.09
0,10	0,0144	0,0159	0,0173	0,0187	0,0202	0,0216	0,0231	0,0245	0,0260	0,0274
0,20	0,0288	0,0302	0,0317	0,0332	0,0346	0,0361	0,0375	0,0389	0,0404	0,0418
0,30	0,0433	0,0447	0,0461	0,0476	0,0490	0,0505	0,0519	0,0534	0,0548	0,0562
0,40	0,0577	0,0591	0,0606	0,0620	0,0634	0,0650	0,0663	0,0678	0,0692	0,0707
0,50	0,0721	0,0735	0,0750	0,0764	0,0779	0,0793	0,0808	0,0822	0,0836	0,0851
0,60	0,0865	0,0880	0,0894	0,0908	0,0923	0,0937	0,0952	0,0966	0,0981	0,0995
0,70	0,101	0,102	0,104	0,105	0,107	0,108	0,110	0,111	0,112	0,114
0,80	0,115	0,117	0,118	0,120	0,121	0,123	0,124	0,125	0,127	0,128
0,90	0,130	0,131	0,133	0,134	0,136	0,137	0,138	0,140	0,141	0,143
1,00	0,144	0,146	0,147	0,149	0,150	0,151	0,153	0,154	0,156	0,157
1,10	0,159	0,160	0,162	0,163	0,164	0,166	0,167	0,169	0,170	0,172
1,20	0,173	0,174	0,176	0,177	0,179	0,180	0,182	0,183	0,185	0,186
1,30	0,187	0,189	0,190	0,192	0,193	0,195	0,196	0,198	0,199	0,200
1,40	0,202	0,203	0,205	0,206	0,208	0,209	0,211	0,212	0,213	0,215
1,50	0,216	0,218	0,219	0,221	0,222	0,224	0,225	0,226	0,228	0,229
1,60	0,2307	0,2321	0,2336	0,2350	0,2364	0,2379	0,2393	0,2408	0,2422	0,2436
1,70	0,2451	0,2465	0,2480	0,2494	0,2509	0,2523	0,2537	0,2552	0,2566	0,2581
1,80	0,2595	0,2610	0,2624	0,2638	0,2653	0,2667	0,2682	0,2696	0,2710	0,2752
1,90	0,2739	0,2754	0,2768	0,2783	0,2797	0,2811	0,2826	0,2840	0,2855	0,2869
2,00	0,2884	0,2898	0,2912	0,2927	0,2941	0,2956	0,2970	0,2984	0,2999	0,3013

Example: What value does 0.23 Btu · in/ft² · h · degrees F. have in the corresponding metrical unit? Begin in the BTU column and locate the value 0.20. From there, follow the table to the left until arriving at the 0.03 column and read the value 0.0332 (W/K · m).