SPFA-121

Spray Polyurethane Foam Estimating Guide

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ABOUT SPRAY POLYURETHANE FOAM ALLIANCE (SPFA)

Founded in 1987, the Spray Polyurethane Foam Alliance (SPFA) is the voice, and educational and technical resource, for the spray polyurethane foam industry. A 501(c)6 trade association, the alliance is composed of contractors, manufacturers, and distributors of polyurethane foam, related equipment, and protective coatings; and who provide inspections, surface preparations, and other services. The organization supports the best practices and the growth of the industry through a number of core initiatives, which include educational programs and events, the SPFA Professional Installer Certification Program, technical literature and guidelines, legislative advocacy, research, and networking opportunities. For more information, please use the contact information and links provided in this document.

DISCLAIMER

This document was developed to aid building construction and design professionals in choosing spray-applied polyurethane foam systems. The information provided herein, based on current customs and practices of the trade, is offered in good faith and believed to be true to the best of SPFA's knowledge and belief.

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DOCUMENT HISTORY

Date	Sections Modified	Description of Changes
1994		
June 2004		
August 2015	All	Administrative changes
January 2021	Front Cover and Header	New SPFA Logo

TECHNICAL OVERSIGHT COMMITTEE

Mission Statement

The mission of the Technical Committee is to provide a wide range of technical service to the SPF (spray polyurethane foam) industry such as, but not limited to:

(1) Review existing documents and serve as a clearing house to ensure the "Continuity of Value" of technical information published by SPFA and others concerning the products and services to the SPF industry;
(2) Review, research, develop, and issue documents concerning new products, systems and services; and
(3) To identify, explore, develop, and communicate an understanding of technical issues facing to the SPF industry.

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Useful Data and Physical Constants

π = 3.14159
e = base, natural logarithms = 2.718

1 calendar year	= 365 days	
	= 52.14 weeks	
	= 8,760 hours	

WATER

Weight at 20°C (68°F):	1 liter	= 1 kg
	1 gallon	= 8.33 lb
	1 cubic foot	= 62.32 lb
Heat of fusion	= 79.67 cal/g	= 143.4 Btu/lb
Heat of vaporization	= 539.6 cal/g	= 971.2 Btu/lb
Viscosity at 20 °C (68 °F)	= 1.0 mPa•s	
	= 1.0 centipoise	

AIR

Density at 0 °C (32 °F) and 1 atm (STP) = 1.293 g/l
= 0.0808 lb/ft^3

GASES

STP = Standard Temperature and Pressure
= 0 °C (32 °F) and 101 kPa (1 atm or 760 mm Hg)

Molar Volumes:	1 gm mole	= 22.41 l
	1 lb mole	= 359.05 ft^3

METRIC PREFIXES

Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hector	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Abbreviations

°C	Degrees centigrade or Celsius
°F	Degrees Fahrenheit
°K	Degrees Kelvin
°R	Degree Rankine
abs	Absolute
apoth	Apothecary's weight
atm	Atmosphere
av	Avoirdupois weight
bd ft	Board foot
Btu	British thermal unit
cal	Calorie
cm	Centimeter
dr	Dram
ft	Foot
ft H_2O	Feet of water (pressure)
g	Gram
gal	Gallon
gcal	Gramcalorie, equal to a calorie
Hg	Mercury
hp	Horsepower
hr	Hour
in	Inch
in Hg	Inches of mercury (pressure)
J	Joule
kg	Kilogram
kgcal	Kilogram calorie, equal to 1000 g-cal
km	Kilometer
kw	Kilowatt
lb	Pound
lbf	Pound force
lbm	Pound mass
L	Liter
m	Meter
mil	Mil
min	Minute (time)
mm	Millimeter
mm Hg	Millimeters of mercury (pressure)
mol	Mole
mph	Miles per hour
N	Newton
Pa	Pascal (pressure, stress)
ppm	Parts per million
psf	Pounds per square foot
psi	Pounds per square inches
rf sq	Roofing square
s	Second (time)
W	Watt
yd	Yard

Frequently Used Conversion Factors

Length

1 m = 3.28 ft
1 ft = 304.8 mm
1 in = 25.4 mm
1 mm = 0.0394 in

Area

1 m^2 = 10.76 ft^2
1 ft^2 = 0.0929 m^2

Volume / Capacity

1 L = 0.264 gal
1 gal = 3.79 L
1 gal = 0.133 ft^3
1 ft^3 = 7.48 gal
1 m^3 = 35.3 ft^3

Weight

1 kg = 2.21 lb
1 lb = 0.454 kg

Density

1 kg/m^3 = 0.0624 lb/ft^3
1 lb/ft^3 = 16.0 kg/m^3

Pressure

1 kPa = 0.145 psi
1 psi = 6.89 kPa

Temperature

°C = (°F - 32) x 0.556
°F = (1.8 x °C) + 32

Coating Coverage

1 liter covers 1 m^2 at 1 mm thickness (100% solids)
1 gallon covers 1604 ft^2 at 1 mil thickness (100% solids)

Surface Areas

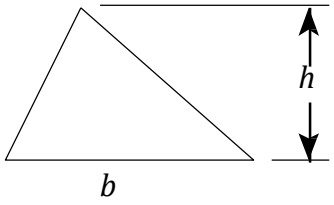
TRIANGLE

$A = \frac{bh}{2}$

where

b = length of the base

h = height of the triangle

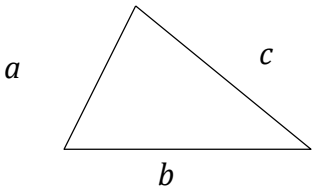


$A = \sqrt{[s(s-a)(s-b)(s-c)]}$

where

$s = a + b + c$

a,b,c = length of each side

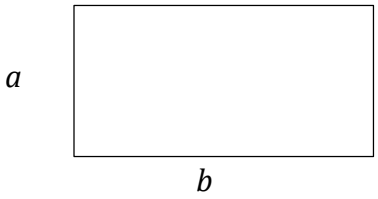


RECTANGLE

$A = ab$

where

a,b = length of adjacent sides



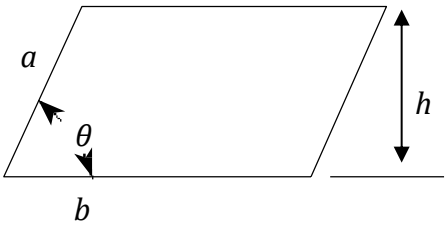
PARALLELOGRAM
(OPPOSITE SIDES PARALLEL)

$A = bh$

where

b = length of the base

h = height



$A = ab \sin\theta$

where

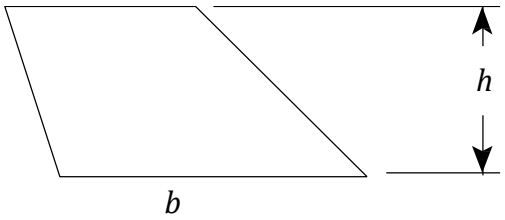
a,b = length of adjacent sides

θ = angle between the sides

TRAPEZOID (FOUR SIDES, TWO PARALLEL)

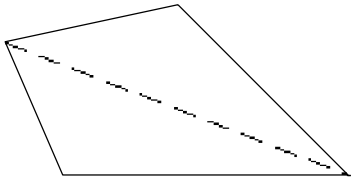
$A = \left(\frac{1}{2}\right) h\,(a + b)$

where a,b = length of the parallel sides
h = height



TRAPEZIUM
(FOUR SIDES, NO SIDES PARALLEL)

$A = sum\ of\ the\ two\ adjoining\ triangles$



REGULAR POLYGON OF "N" SIDES

$$A = \left(\frac{1}{4}\right) n a^2 \cot\left(\frac{180°}{n}\right)$$

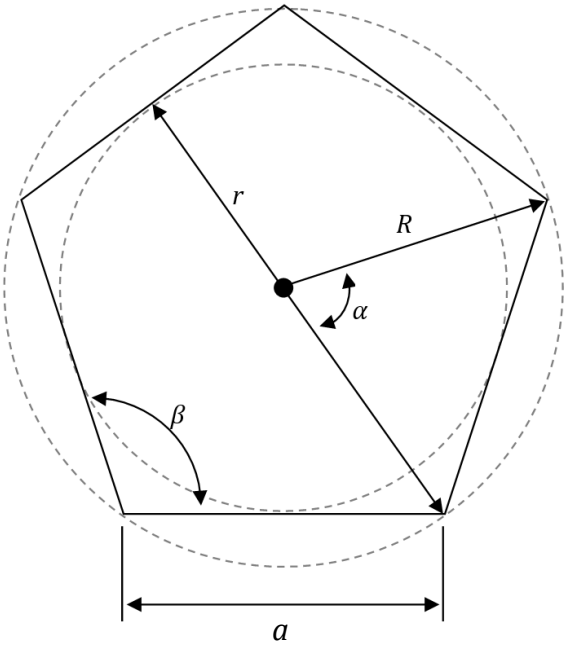
$$R = \left(\frac{a}{2}\right) \csc\left(\frac{180°}{n}\right)$$

$$r = \left(\frac{a}{2}\right) \cot\left(\frac{180°}{n}\right)$$

$$\alpha = \frac{360°}{n} = \frac{2\pi}{n}$$

$$\beta = 180° \left[\frac{(n-2)}{n}\right] = \pi\left[\frac{(n-2)}{n}\right]$$

$$a = 2r \tan\left(\frac{\alpha}{2}\right) = 2R \sin\left(\frac{\alpha}{2}\right)$$



where a = length of one side
R = radius of circumscribed circle
r = radius of inscribed circle
α, β = angles shown on diagram

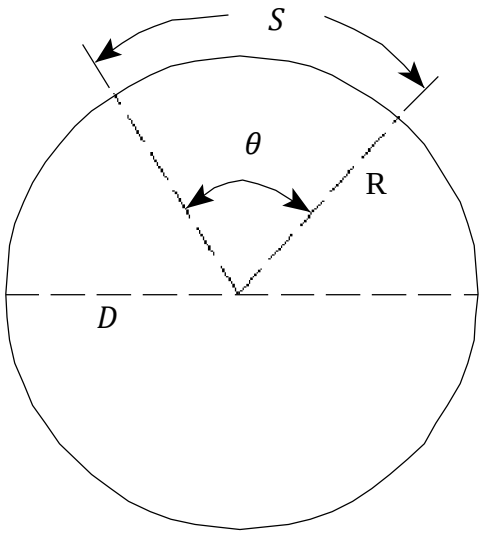
CIRCLE

$$A\ (circle) = \pi R^2 = \frac{\pi D^2}{4}$$

$$C = 2\pi R = \pi D$$

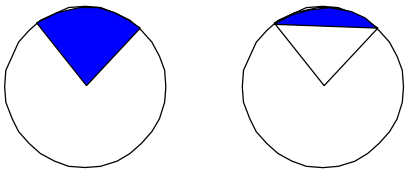
$$S = \frac{\pi R \theta}{180}$$

where R = radius
D = diameter
C = circumference
S = length of arc subtended by θ



$$A(\text{sector}) = \frac{\pi R^2 \theta}{360°}$$

where θ = sector angle in degrees

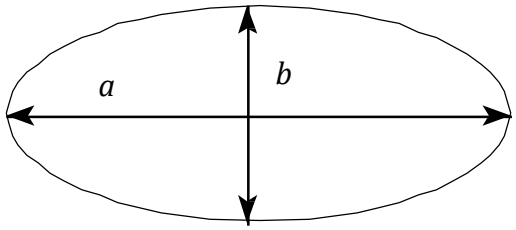


$$A(segment) = \frac{R^2}{2}\left(\frac{\pi\theta}{180} - \sin\theta\right)$$

ELLIPSE

$$A = \frac{\pi ab}{4}$$

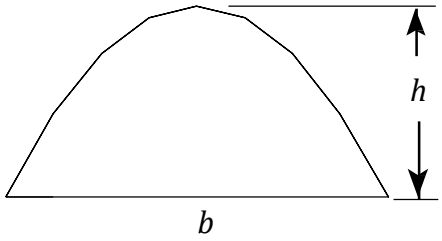
where a,b = length of the major and minor axes



PARABOLA

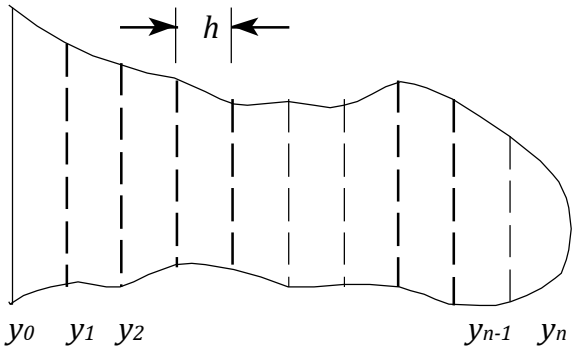
$$A = \frac{2bh}{3}$$

where b = base of parabola
h = perpendicular height

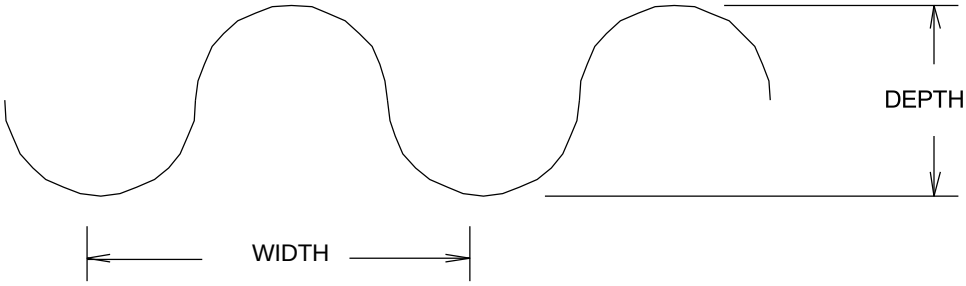


AREA BY APPROXIMATION (TRAPEZOIDAL RULE)

$$A = h\left[\frac{y_0 + y_n}{2} + y_1 + y_2 + \cdots + y_{n-1}\right]$$



Surface Areas of Standard Corrugated Materials



Multiply the overall area by the appropriate multiplier below.

Example: 100 sq. ft wall has corrugations 2-1/2 inches wide and 1/2 inch deep. What is the surface area?

The multiplier from table below is 1.09
Surface Area = 100 sq. ft x 1.09 = 109 sq ft

Width	Depth	Multiplier
1.25 in (32 mm)	1/4 in (6 mm)	1.09
2.5 in (64 mm)	1/2 in (13 mm)	1.09
2.67 in (68 mm)	1/2 in (13 mm)	1.08
	9/16 in (14mm)	1.10
	3/4 in (19 mm)	1.17
	7/8 in (22 mm)	1.23
4.2 in (110 mm)	27 mm	1.14
	1-1/2 in (38 mm)	1.26

FOR CORRUGATIONS NOT LISTED:
Divide the corrugation depth by the width. Use the multiplier from table below:

Depth / Width	Multiplier
0.16	1.06
0.18	1.08
0.20	1.09
0.22	1.11
0.24	1.13
0.26	1.15

Depth / Width	Multiplier
0.28	1.17
0.30	1.19
0.32	1.22
0.34	1.24
0.36	1.27
0.38	1.29

Volumes and Areas of Solids

CUBE

$V = a^3$

$A = 6a^2$

where a = length of side

REGULAR PARALLELOPIPED (RECTANGULAR SOLID)

$V = abc$

$A = 2(ab + ac + bc)$

where a, b, c = length of the sides

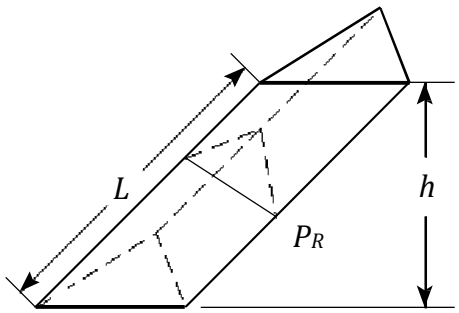
PRISM OR CYLINDER

$V = A_b h$

where A_b = area of the base
h = perpendicular height

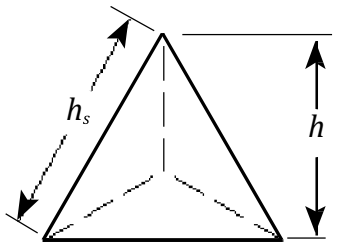
$A_L = P_R L$

where A_L = lateral area (not including base and top)
P_R = perimeter of right section
L = length of lateral edge



PYRAMID OR CONE

$$V = \frac{A_b h}{3}$$



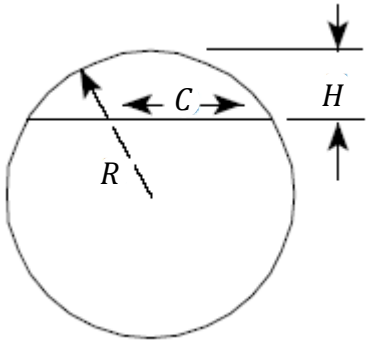
where A_b = area of the base
h = perpendicular height

$$A = \frac{P_b h_s}{2}$$

where P_b = perimeter of the base
h_s = slant height

SPHERE

$$V = \left(\frac{4}{3}\right) \pi R^3$$



A = 4 πR^2

where R = radius

DOME (SEGMENT OF A SPHERE)

$$A = 2\pi RH = \left(\frac{\pi}{4}\right)(4H^2 + C^2)$$

Circumference, Area, and Volume of Circles and Cylinders

METRIC (SI) UNITS

Diameter (mm)	Circumference (mm)	Area of Circle (m^2)	Volume of Cylinder per Meter of Height	
			(m^3)	(L)
250	785	0.0490	0.0490	49.1
500	1,570	0.200	0.200	196
750	2,360	0.440	0.440	442
1,000	3,140	0.79	0.79	785
1,250	3,930	1.23	1.23	1,230
1,500	4,710	1.77	1.77	1,770
1,750	5,500	2.41	2.41	2,410
2,000	6,280	3.14	3.14	3,140
2,250	7,070	3.98	3.98	3,980
2,500	7,850	4.91	4.91	4,910
2,750	8,640	5.94	5.94	5,940
3,000	9,420	7.07	7.07	7,070
3,250	10,200	8.30	8.30	8,300
3,500	11,000	9.6	9.6	9,620
3,750	11,800	11.0	11.0	11,000
4,000	12,600	12.6	12.6	12,600
4,250	13,400	14.2	14.2	14,200
4,500	14,100	15.9	15.9	15,900
4,750	14,900	17.7	17.7	17,700
5,000	15,700	19.6	19.6	19,600
5,250	16,500	21.6	21.6	21,600
5,500	17,300	23.8	23.8	23,800
5,750	18,100	26.0	26.0	26,000
6,000	18,800	28.3	28.3	28,300
6,250	19,600	30.7	30.7	30,700
6,500	20,400	33.2	33.2	33,200
6,750	21,200	35.8	35.8	35,800
7,000	22,000	38.5	38.5	38,500
7,250	22,800	41.3	41.3	41,300
7,500	23,600	44.2	44.2	44,200

Circumference, Area, and Volume of Circles and Cylinders

METRIC (SI) UNITS

Diameter (mm)	Circumference (mm)	Area of Circle (m^2)	Volume of Cylinder per Meter of Height	
			(m^3)	(L)
7,750	24,300	47.2	47.2	47,200
8,000	25,100	50.3	50.3	50,300
8,250	25,900	53.5	53.5	53,500
8,500	26,700	56.7	56.7	56,700
8,750	27,500	60.1	60.1	60,100
9,000	28,300	63.6	63.6	63,600
9,250	29,100	67.2	67.2	67,200
9,500	29,800	70.9	70.9	70,900
9,750	30,600	74.7	74.7	74,700
10,000	31,400	78.5	78.5	78,500
10,250	32,200	82.5	82.5	82,500
10,500	33,000	86.6	86.6	86,600
10,750	33,800	90.8	90.8	90,800
11,000	34,600	95.0	95.0	95,000
11,250	35,300	99.4	99.4	99,400
11,500	36,100	104.0	104.0	104,000
11,750	36,900	108	108	108,000
12,000	37,700	113	113	113,000
12,250	38,500	118	118	118,000
12,500	39,300	123	123	123,000
12,750	40,100	128	128	128,000
13,000	40,800	133	133	133,000
13,250	41,600	138	138	138,000
13,500	42,400	143	143	143,000
13,750	43,200	148	148	148,000
14,000	44,000	154	154	154,000
14,250	44,800	159	159	159,000
14,500	45,600	165	165	165,000
14,750	46,300	171	171	171,000
15,000	47,100	177	177	177,000
15,250	47,900	183	183	183,000
15,500	48,700	189	189	189,000
15,750	49,500	195	195	195,000
16,000	50,300	201	201	201,000
16,250	51,100	207	207	207,000

Circumference, Area, and Volume of Circles and Cylinders

METRIC (SI) UNITS

Diameter (mm)	Circumference (mm)	Area of Circle (m^2)	Volume of Cylinder per Meter of Height	
			(m^3)	(L)
16,500	51,800	214	214	214,000
16,750	52,600	220	220	220,000
17,000	53,400	227	227	227,000
17,250	54,200	234	234	234,000
17,500	55,000	241	241	241,000
17,750	55,800	247	247	247,000
18,000	56,500	254	254	254,000
18,250	57,300	262	262	262,000
18,500	58,100	269	269	269,000
18,750	58,900	276	276	276,000
19,000	59,700	284	284	284,000
19,250	60,500	291	291	291,000
19,500	61,300	299	299	299,000
19,750	62,000	306	306	306,000
20,000	62,800	314	314	314,000
20,250	63,600	322	322	322,000
20,500	64,400	330	330	330,000
20,750	65,200	338	338	338,000
21,000	66,000	346	346	346,000
21,250	66,800	355	355	355,000
21,500	67,500	363	363	363,000
21,750	68,300	372	372	372,000
22,000	69,100	380	380	380,000
22,250	69,900	389	389	389,000
22,500	70,700	398	398	398,000
22,750	71,500	406	406	406,000
23,000	72,300	415	415	415,000
23,250	73,000	425	425	425,000
23,500	73,800	434	434	434,000
23,750	74,600	443	443	443,000
24,000	75,400	452	452	452,000
24,250	76,200	462	462	462,000
24,500	77,000	471	471	471,000
24,750	77,800	481	481	481,000
25,000	78,500	491	491	491,000

Circumference, Area, and Volume of Circles and Cylinders

METRIC (SI) UNITS

Diameter (mm)	Circumference (mm)	Area of Circle (m^2)	Volume of Cylinder per Meter of Height	
			(m^3)	(L)
25,250	79,300	501	501	501,000
25,500	80,100	511	511	511,000
25,750	80,900	521	521	521,000
26,000	81,700	531	531	531,000
26,250	82,500	541	541	541,000
26,500	83,300	552	552	552,000
26,750	84,000	562	562	562,000
27,000	84,800	573	573	573,000
27,250	85,600	583	583	583,000
27,500	86,400	594	594	594,000
27,750	87,200	605	605	605,000
28,000	88,000	616	616	616,000
28,250	88,700	627	627	627,000
28,500	89,500	638	638	638,000
28,750	90,300	649	649	649,000
29,000	91,100	661	661	661,000
29,250	91,900	672	672	672,000
29,500	92,700	683	683	683,000
29,750	93,500	695	695	695,000
30,000	94,200	707	707	707,000
30,250	95,000	719	719	719,000
30,500	95,800	731	731	731,000
30,750	96,600	743	743	743,000
31,000	97,400	755	755	755,000
31,250	98,200	767	767	767,000
31,500	99,000	779	779	779,000
31,750	99,700	792	792	792,000
32,000	101,000	804	804	804,000
32,250	101,000	817	817	817,000
32,500	102,000	830	830	830,000
32,750	103,000	842	842	842,000
33,000	104,000	855	855	855,000
33,250	104,000	868	868	868,000
33,500	105,000	881	881	881,000
33,750	106,000	895	895	895,000

Circumference, Area, and Volume of Circles and Cylinders

METRIC (SI) UNITS

Diameter (mm)	Circumference (mm)	Area of Circle (m^2)	Volume of Cylinder per Meter of Height	
			(m^3)	(L)
34,000	107,000	908	908	908,000
34,250	108,000	921	921	921,000
34,500	108,000	935	935	935,000
34,750	109,000	948	948	948,000
35,000	110,000	962	962	962,000
35,250	111,000	976	976	976,000
35,500	112,000	990	990	990,000
35,750	112,000	1,000	1,000	1,000,000
36,000	113,000	1,020	1,020	1,020,000
36,250	114,000	1,030	1,030	1,030,000
36,500	115,000	1,050	1,050	1,050,000
36,750	115,000	1,060	1,060	1,060,000
37,000	116,000	1,080	1,080	1,080,000
37,250	117,000	1,090	1,090	1,090,000
37,500	118,000	1,100	1,100	1,100,000
37,750	119,000	1,120	1,120	1,120,000
38,000	119,000	1,130	1,130	1,130,000
38,250	120,000	1,150	1,150	1,150,000
38,500	121,000	1,160	1,160	1,160,000
38,750	122,000	1,180	1,180	1,180,000
39,000	123,000	1,190	1,190	1,190,000
39,250	123,000	1,210	1,210	1,210,000
39,500	124,000	1,230	1,230	1,230,000
39,750	125,000	1,240	1,240	1,240,000
40,000	126,000	1,260	1,260	1,260,000

Circumference, Area, and Volume of Circles and Cylinders

TRADITIONAL U. S. UNITS

Diameter (ft)	Circumference (ft)	Area of Circle (ft^2)	Volume of Cylinder per Foot of Height	
			(ft^3)	(gal)
1	3.14	0.79	0.79	5.88
2	6.28	3.14	3.14	23.5
3	9.42	7.07	7.07	52.9
4	12.6	12.6	12.6	94.0
5	15.7	19.6	19.6	147
6	18.8	28.3	28.3	212
7	22.0	38.5	38.5	288
8	25.1	50.3	50.3	376
9	28.3	63.6	63.6	476
10	31.4	78.5	78.5	588
11	34.6	95	95	711
12	37.7	113	113	846
13	40.8	133	133	993
14	44.0	154	154	1,150
15	47.1	177	177	1,320
16	50.3	201	201	1,500
17	53.4	227	227	1,700
18	56.5	254	254	1,900
19	59.7	284	284	2,120
20	62.8	314	314	2,350
21	66.0	346	346	2,590
22	69.1	380	380	2,840
23	72.3	415	415	3,110
24	75.4	452	452	3,380
25	78.5	491	491	3,670

Circumference, Area, and Volume of Circles and Cylinders

TRADITIONAL U. S. UNITS

Diameter (ft)	Circumference (ft)	Area of Circle (ft^2)	Volume of Cylinder per Foot of Height	
			(ft^3)	(gal)
26	81.7	531	531	3,970
27	84.8	573	573	4,280
28	88.0	616	616	4,610
29	91.1	661	661	4,940
30	94.2	707	707	5,290
31	97.4	755	755	5,650
32	101	804	804	6,020
33	104	855	855	6,400
34	107	908	908	6,790
35	110	962	962	7,200
36	113	1,020	1,020	7,610
37	116	1,080	1,080	8,040
38	119	1,130	1,130	8,480
39	123	1,190	1,190	8,940
40	126	1,260	1,260	9,400
41	129	1,320	1,320	9,880
42	132	1,390	1,390	10,400
43	135	1,450	1,450	10,900
44	138	1,520	1,520	11,400
45	141	1,590	1,590	11,900
46	145	1,660	1,660	12,400
47	148	1,730	1,730	13,000
48	151	1,810	1,810	13,500
49	154	1,890	1,890	14,100
50	157	1,960	1,960	14,700
51	160	2,040	2,040	15,300
52	163	2,120	2,120	15,900
53	167	2,210	2,210	16,500
54	170	2,290	2,290	17,100
55	173	2,380	2,380	17,800

Circumference, Area, and Volume of Circles and Cylinders

TRADITIONAL U. S. UNITS

Diameter (ft)	Circumference (ft)	Area of Circle (ft^2)	Volume of Cylinder per Foot of Height	
			(ft^3)	(gal)
56	176	2,460	2,460	18,400
57	179	2,550	2,550	19,100
58	182	2,640	2,640	19,800
59	185	2,730	2,730	20,500
60	188	2,830	2,830	21,200
61	192	2,920	2,920	21,900
62	195	3,020	3,020	22,600
63	198	3,120	3,120	23,300
64	201	3,220	3,220	24,100
65	204	3,320	3,320	24,800
66	207	3,420	3,420	25,600
67	210	3,530	3,530	26,400
68	214	3,630	3,630	27,200
69	217	3,740	3,740	28,000
70	220	3,850	3,850	28,800
71	223	3,960	3,960	29,600
72	226	4,070	4,070	30,500
73	229	4,190	4,190	31,300
74	232	4,300	4,300	32,200
75	236	4,420	4,420	33,100
76	239	4,540	4,540	33,900
77	242	4,660	4,660	34,800
78	245	4,780	4,780	35,700
79	248	4,900	4,900	36,700
80	251	5,030	5,030	37,600
81	254	5,150	5,150	38,500
82	258	5,280	5,280	39,500
83	261	5,410	5,410	40,500
84	264	5,540	5,540	41,500
85	267	5,670	5,670	42,500

Circumference, Area, and Volume of Circles and Cylinders

TRADITIONAL U. S. UNITS

Diameter (ft)	Circumference (ft)	Area of Circle (ft^2)	Volume of Cylinder per Foot of Height	
			(ft^3)	(gal)
86	270	5,810	5,810	43,500
87	273	5,940	5,940	44,500
88	276	6,080	6,080	45,500
89	280	6,220	6,220	46,500
90	283	6,360	6,360	47,600
91	286	6,500	6,500	48,700
92	289	6,650	6,650	49,700
93	292	6,790	6,790	50,800
94	295	6,940	6,940	51,900
95	298	7,090	7,090	53,000
96	302	7,240	7,240	54,100
97	305	7,390	7,390	55,300
98	308	7,540	7,540	56,400
99	311	7,700	7,700	57,600
100	314	7,850	7,850	58,800
101	317	8,010	8,010	59,900
102	320	8,170	8,170	61,100
103	324	8,330	8,330	62,300
104	327	8,490	8,490	63,600
105	330	8,660	8,660	64,800
106	333	8,820	8,820	66,000
107	336	8,990	8,990	67,300
108	339	9,160	9,160	68,500
109	342	9,330	9,330	69,800
110	346	9,500	9,500	71,100
111	349	9,680	9,680	72,400
112	352	9,850	9,850	73,700
113	355	10,000	10,000	75,000
114	358	10,200	10,200	76,400
115	361	10,400	10,400	77,700

Circumference, Area, and Volume of Circles and Cylinders

TRADITIONAL U. S. UNITS

Diameter (ft)	Circumference (ft)	Area of Circle (ft^2)	Volume of Cylinder per Foot of Height	
			(ft^3)	(gal)
116	364	10,600	10,600	79,100
117	368	10,800	10,800	80,400
118	371	10,900	10,900	81,800
119	374	11,100	11,100	83,200
120	377	11,300	11,300	84,600
121	380	11,500	11,500	86,000
122	383	11,700	11,700	87,500
123	386	11,900	11,900	88,900
124	390	12,100	12,100	90,300
125	393	12,300	12,300	91,800
126	396	12,500	12,500	93,300
127	399	12,700	12,700	94,800
128	402	12,900	12,900	96,300
129	405	13,100	13,100	97,800
130	408	13,300	13,300	99,300
131	412	13,500	13,500	101,000
132	415	13,700	13,700	102,000
133	418	13,900	13,900	104,000
134	421	14,100	14,100	106,000
135	424	14,300	14,300	107,000
136	427	14,500	14,500	109,000
137	430	14,700	14,700	110,000
138	434	15,000	15,000	112,000
139	437	15,200	15,200	114,000
140	440	15,400	15,400	115,000
141	443	15,600	15,600	117,000
142	446	15,800	15,800	118,000
143	449	16,100	16,100	120,000
144	452	16,300	16,300	122,000
145	456	16,500	16,500	124,000

Circumference, Area, and Volume of Circles and Cylinders

TRADITIONAL U. S. UNITS

Diameter (ft)	Circumference (ft)	Area of Circle (ft^2)	Volume of Cylinder per Foot of Height	
			(ft^3)	(gal)
146	459	16,700	16,700	125,000
147	462	17,000	17,000	127,000
148	465	17,200	17,200	129,000
149	468	17,400	17,400	130,000
150	471	17,700	17,700	132,000
151	474	17,900	17,900	134,000
152	478	18,100	18,100	136,000
153	481	18,400	18,400	138,000
154	484	18,600	18,600	139,000
155	487	18,900	18,900	141,000
156	490	19,100	19,100	143,000
157	493	19,400	19,400	145,000
158	496	19,600	19,600	147,000
159	500	19,900	19,900	149,000
160	503	20,100	20,100	150,000

Surface and Volume of Spheres

METRIC (SI) UNITS

Diameter (mm)	Surface of Sphere (m^2)	Volume of Sphere	
		(m^3)	(L)
250	0.200	0.00820	8.18
500	0.790	0.0650	65.4
750	1.77	0.220	221
1,000	3.14	0.520	524
1,250	4.91	1.02	1,020
1,500	7.07	1.77	1,770
1,750	9.62	2.81	2,810
2,000	12.6	4.19	4,190
2,250	15.9	5.96	5,960
2,500	19.6	8.18	8,180
2,750	23.8	10.9	10,900
3,000	28.3	14.1	14,100
3,250	33.2	18.0	18,000
3,500	38.5	22.4	22,400
3,750	44.2	27.6	27,600
4,000	50.3	33.5	33,500
4,250	56.7	40.2	40,200
4,500	63.6	47.7	47,700
4,750	70.9	56.1	56,100
5,000	78.5	65.4	65,400
5,250	86.6	75.8	75,800
5,500	95.0	87.1	87,100
5,750	104	100	99,500
6,000	113	113	113,000
6,250	123	128	128,000
6,500	133	144	144,000
6,750	143	161	161,000
7,000	154	180	180,000
7,250	165	200	200,000
7,500	177	221	221,000

Surface and Volume of Spheres

METRIC (SI) UNITS

Diameter (mm)	Surface of Sphere (m^2)	Volume of Sphere	
		(m^3)	(L)
7,750	189	244	244,000
8,000	201	268	268,000
8,250	214	294	294,000
8,500	227	322	322,000
8,750	241	351	351,000
9,000	254	382	382,000
9,250	269	414	414,000
9,500	284	449	449,000
9,750	299	485	485,000
10,000	314	524	524,000
10,250	330	564	564,000
10,500	346	606	606,000
10,750	363	650	650,000
11,000	380	697	697,000
11,250	398	746	746,000
11,500	415	796	796,000
11,750	434	849	849,000
12,000	452	905	905,000
12,250	471	963	963,000
12,500	491	1,020	1,020,000
12,750	511	1,090	1,090,000
13,000	531	1,150	1,150,000
13,250	552	1,220	1,220,000
13,500	573	1,290	1,290,000
13,750	594	1,360	1,360,000
14,000	616	1,440	1,440,000
14,250	638	1,520	1,520,000
14,500	661	1,600	1,600,000
14,750	683	1,680	1,680,000
15,000	707	1,770	1,770,000

Surface and Volume of Spheres

METRIC (SI) UNITS

Diameter (mm)	Surface of Sphere (m^2)	Volume of Sphere	
		(m^3)	(L)
15,250	731	1,860	1,860,000
15,500	755	1,950	1,950,000
15,750	779	2,050	2,050,000
16,000	804	2,140	2,140,000
16,250	830	2,250	2,250,000
16,500	855	2,350	2,350,000
16,750	881	2,460	2,460,000
17,000	908	2,570	2,570,000
17,250	935	2,690	2,690,000
17,500	962	2,810	2,810,000
17,750	990	2,930	2,930,000
18,000	1,020	3,050	3,050,000
18,250	1,050	3,180	3,180,000
18,500	1,080	3,320	3,320,000
18,750	1,100	3,450	3,450,000
19,000	1,130	3,590	3,590,000
19,250	1,160	3,740	3,740,000
19,500	1,190	3,880	3,880,000
19,750	1,230	4,030	4,030,000
20,000	1,260	4,190	4,190,000
20,250	1,290	4,350	4,350,000
20,500	1,320	4,510	4,510,000
20,750	1,350	4,680	4,680,000
21,000	1,390	4,850	4,850,000
21,250	1,420	5,020	5,020,000
21,500	1,450	5,200	5,200,000
21,750	1,490	5,390	5,390,000
22,000	1,520	5,580	5,580,000
22,250	1,560	5,770	5,770,000
22,500	1,590	5,960	5,960,000

Surface and Volume of Spheres

METRIC (SI) UNITS

Diameter (mm)	Surface of Sphere (m^2)	Volume of Sphere	
		(m^3)	(L)
22,750	1,630	6,170	6,170,000
23,000	1,660	6,370	6,370,000
23,250	1,700	6,580	6,580,000
23,500	1,730	6,800	6,800,000
23,750	1,770	7,010	7,010,000
24,000	1,810	7,240	7,240,000
24,250	1,850	7,470	7,470,000
24,500	1,890	7,700	7,700,000
24,750	1,920	7,940	7,940,000
25,000	1,960	8,180	8,180,000
25,250	2,000	8,430	8,430,000
25,500	2,040	8,680	8,680,000
25,750	2,080	8,940	8,940,000
26,000	2,120	9,200	9,200,000
26,250	2,160	9,470	9,470,000
26,500	2,210	9,740	9,740,000
26,750	2,250	10,000	10,000,000
27,000	2,290	10,300	10,300,000
27,250	2,330	10,600	10,600,000
27,500	2,380	10,900	10,900,000
27,750	2,420	11,200	11,200,000
28,000	2,460	11,500	11,500,000
28,250	2,510	11,800	11,800,000
28,500	2,550	12,100	12,100,000
28,750	2,600	12,400	12,400,000
29,000	2,640	12,800	12,800,000
29,250	2,690	13,100	13,100,000
29,500	2,730	13,400	13,400,000
29,750	2,780	13,800	13,800,000
30,000	2,830	14,100	14,100,000

Surface and Volume of Spheres

TRADITIONAL U.S. UNITS

Diameter (ft)	Surface of Sphere (ft^2)	Volume of Sphere	
		(ft^3)	(Gallons)
1	3.14	0.52	3.92
2	12.6	4.19	31.3
3	28.3	14.1	106
4	50.3	33.5	251
5	78.5	65.4	490
6	113	113	846
7	154	180	1,340
8	201	268	2,010
9	254	382	2,860
10	314	524	3,920
11	380	697	5,210
12	452	905	6,770
13	531	1,150	8,610
14	616	1,440	10,700
15	707	1,770	13,200
16	804	2,140	16,000
17	908	2,570	19,200
18	1,020	3,050	22,800
19	1,130	3,590	26,900
20	1,260	4,190	31,300
21	1,390	4,850	36,300
22	1,520	5,580	41,700
23	1,660	6,370	47,700
24	1,810	7,240	54,100
25	1,960	8,180	61,200

Surface and Volume of Spheres

TRADITIONAL U.S. UNITS

Diameter (ft)	Surface of Sphere (ft^2)	Volume of Sphere	
		(ft^3)	(Gallons)
26	2,120	9,200	68,800
27	2,290	10,300	77,100
28	2,460	11,500	86,000
29	2,640	12,800	95,500
30	2,830	14,100	106,000
31	3,020	15,600	117,000
32	3,220	17,200	128,000
33	3,420	18,800	141,000
34	3,630	20,600	154,000
35	3,850	22,400	168,000
36	4,070	24,400	183,000
37	4,300	26,500	198,000
38	4,540	28,700	215,000
39	4,780	31,100	232,000
40	5,030	33,500	251,000
41	5,280	36,100	270,000
42	5,540	38,800	290,000
43	5,810	41,600	311,000
44	6,080	44,600	334,000
45	6,360	47,700	357,000
46	6,650	51,000	381,000
47	6,940	54,400	407,000
48	7,240	57,900	433,000
49	7,540	61,600	461,000
50	7,850	65,400	490,000

Surface and Volume of Spheres

TRADITIONAL U.S. UNITS

Diameter (ft)	Surface of Sphere (ft^2)	Volume of Sphere	
		(ft^3)	(Gallons)
51	8,170	69,500	520,000
52	8,490	73,600	551,000
53	8,820	78,000	583,000
54	9,160	82,400	617,000
55	9,500	87,100	652,000
56	9,850	92,000	688,000
57	10,200	97,000	725,000
58	10,600	102,000	764,000
59	10,900	108,000	804,000
60	11,300	113,000	846,000
61	11,700	119,000	889,000
62	12,100	125,000	934,000
63	12,500	131,000	979,000
64	12,900	137,000	1,030,000
65	13,300	144,000	1,080,000
66	13,700	151,000	1,130,000
67	14,100	157,000	1,180,000
68	14,500	165,000	1,230,000
69	15,000	172,000	1,290,000
70	15,400	180,000	1,340,000
71	15,800	187,000	1,400,000
72	16,300	195,000	1,460,000
73	16,700	204,000	1,520,000
74	17,200	212,000	1,590,000
75	17,700	221,000	1,650,000

Surface and Volume of Spheres

TRADITIONAL U.S. UNITS

Diameter (ft)	Surface of Sphere (ft^2)	Volume of Sphere	
		(ft^3)	(Gallons)
76	18,100	230,000	1,720,000
77	18,600	239,000	1,790,000
78	19,100	248,000	1,860,000
79	19,600	258,000	1,930,000
80	20,100	268,000	2,010,000
81	20,600	278,000	2,080,000
82	21,100	289,000	2,160,000
83	21,600	299,000	2,240,000
84	22,200	310,000	2,320,000
85	22,700	322,000	2,410,000
86	23,200	333,000	2,490,000
87	23,800	345,000	2,580,000
88	24,300	357,000	2,670,000
89	24,900	369,000	2,760,000
90	25,400	382,000	2,860,000
91	26,000	395,000	2,950,000
92	26,600	408,000	3,050,000
93	27,200	421,000	3,150,000
94	27,800	435,000	3,250,000
95	28,400	449,000	3,360,000
96	29,000	463,000	3,470,000
97	29,600	478,000	3,570,000
98	30,200	493,000	3,690,000
99	30,800	508,000	3,800,000
100	31,400	524,000	3,920,000

Surface and Volume of Spheres

TRADITIONAL U.S. UNITS

Diameter (ft)	Surface of Sphere (ft^2)	Volume of Sphere	
		(ft^3)	(Gallons)
101	32,000	539,000	4,040,000
102	32,700	556,000	4,160,000
103	33,300	572,000	4,280,000
104	34,000	589,000	4,410,000
105	34,600	606,000	4,530,000
106	35,300	624,000	4,670,000
107	36,000	641,000	4,800,000
108	36,600	660,000	4,930,000
109	37,300	678,000	5,070,000
110	38,000	697,000	5,210,000
111	38,700	716,000	5,360,000
112	39,400	736,000	5,500,000
113	40,100	755,000	5,650,000
114	40,800	776,000	5,800,000
115	41,500	796,000	5,960,000
116	42,300	817,000	6,110,000
117	43,000	839,000	6,270,000
118	43,700	860,000	6,440,000
119	44,500	882,000	6,600,000
120	45,200	905,000	6,770,000

Pipe Insulation Estimates

TRADITIONAL U.S. UNITS

Nominal Pipe Size (in)	Outside Diameter (in)	Area per lin ft (sq ft)	Board Feet of Foam per 100 lin ft of Pipe Thickness of Polyurethane Foam to be Applied (in)							
			0.5	1	1.5	2	2.5	3	3.5	4
2	2.375	0.62	37.6	88.4	152	229	319	422	538	668
2.5	2.875	0.75	44.2	101	172	255	352	461	584	720
3	3.5	0.92	52.4	118	196	288	393	511	641	785
3.5	4	1.05	58.9	131	216	314	425	550	687	838
4	4.5	1.18	65.4	144	236	340	458	589	733	890
5	5.563	1.46	79.4	172	277	396	528	673	830	1,000
6	6.625	1.73	93.3	200	319	452	597	756	928	1,110
8	8.625	2.26	119	252	398	556	728	913	1,110	1,320
10	10.75	2.81	147	308	481	668	867	1,080	1,310	1,540
12	12.75	3.34	173	360	560	772	998	1,240	1,490	1,750
14	14	3.67	190	393	609	838	1,080	1,340	1,600	1,880
16	16	4.19	216	445	687	942	1,210	1,490	1,790	2,090
18	18	4.71	242	497	766	1,050	1,340	1,650	1,970	2,300
20	20	5.24	268	550	844	1,150	1,470	1,810	2,150	2,510
24	24	6.28	321	654	1,000	1,360	1,730	2,120	2,520	2,930
30	30	7.85	399	812	1,240	1,680	2,130	2,590	3,070	3,560

Spray-Applied Polyurethane Foam Yields

TYPICAL FOAM YIELDS			
m^3/kg material		bd ft per 1000 lb material	
Density (kg/m^3)	Cubic Meters per kg	Density (lb/ft^3)	bd ft
8	0.078	0.5	15,000
16	0.052	1.0	10,000
24	0.026	1.5	5,000
27	0.023	1.7	4,500
32	0.020	2.0	3,900
40	0.016	2.5	3,100
43	0.015	2.7	2,800
48	0.013	3.0	2,500

The above yields are considered "typical" for estimating purposes and are intended as a convenient guide only. Individual manufacturers' polyurethane foam chemical systems may vary. Many factors influence foam density and yield. Some of these factors include the following:

Factors That Reduce Yield	Factors That Increase Yield
• Applying foam in multiple lifts (e.g., applying two 12 mm (1/2 in) lifts will yield less than on 25 mm (1 in) lift) • Applying foam to a cold substrate • Applying foam in cold ambient conditions • Applying foam chemicals at temperatures lower than the chemical formulation speed • Applying foam in windy conditions • Applying foam to a rough, uneven surface • Feed chemicals not at proper temperature • Feed chemicals not at proper ratio	Note: While these factors may increase yield, density and compressive strength may be reduced. • Applying foam at a high altitude • Applying foam to hot surfaces • Spraying in high ambient temperatures

Calculating Spray-Applied Polyurethane Foam Yields

METRIC UNITS

$$Yields = \frac{Area\ (m^2) x\ Thickness\ (mm)}{1000\ x\ Total\ Material\ (kg)}$$

Example: Let's say you have spray-applied 3 sets (at 480 kg per set) of foam at 35 mm thickness over a 550 m^2 roof.

Total Material	= 1,440 kg
Area	= 550 m^2
Thickness	= 35 mm

$$Yield = \frac{500 m^2\ x\ 35\ mm}{1{,}000\ x\ (1{,}440\ kg)} = 0.013\ \frac{m^3}{kg\ of\ Material}$$

TRADITIONAL U. S. UNITS

$$Yields = \frac{Area\ (sq\ ft) x\ Thickness\ (in)}{Total\ Material\ (1{,}000\ lb)}$$

Example: Let's say you have spray-applied 3 sets (at 1,000 lb per set) of foam at 1-1/2 inches thickness over a 5,000 sq ft roof.

Total Material	= 3,000 lb
Area	= 5,000 sq ft
Thickness	= 1.5 in

$$Yield = \frac{5{,}000 ft^2\ x\ 1.5\ in}{3\ x\ (1{,}000\ lb)} = \frac{2{,}500\ bd\ ft}{1{,}000\ lb\ of\ Material} = \frac{25\ bd\ ft}{lb\ of\ Material}$$

Estimating Coating Requirements

Use this procedure to determine the theoretical quantity of coating required and adjustments to allow for material losses and increased surface area due to texture.

(1) Theoretical Coverage:

a. **METRIC (SI) UNITS:** The theoretical coverage rate of a coating is the number of square meters covered by one liter of a coating material spread over a flat smooth surface area at a thickness of 1 mm. One liter of a coating material that has 100% solids content by volume will cover 1 m^2, 1 dry mm thick (1 mm•m^2/L). This definition is used to calculate theoretical coverage rates for coatings containing less than 100% solids.

For example a coating with a 60% (0.60) SCV (solids content by volume) to be applied at 0.8 mm DFT (dry-film thickness) will be used in the formulas listed to arrive at various theoretical coverages. (NOTE: These calculations use solids content by volume, NOT solids content by weight.)

i. TO FIND THE THEORETICAL DRY FILM THICKNESS FOR 1 L OF COATING APPLIED OVER 1 M^2:

$$Theoretical\ Thickness\ per\ Liter = (\%Solids)\left(1\frac{mm\cdot m^2}{L}\right)$$
$$= 0.60\ x\ 1$$
$$= 0.60\frac{mm\cdot m^2}{L}$$

ii. TO FIND THE THEORETICAL NUMBER OF LITERS REQUIRED AT A SPECIFIED THICKNESS:

$$Theoretical\ Liters\ Required = \frac{DFT}{Theoretical\ Thickness\ per\ Liter}$$
$$= \frac{0.8mm}{0.60\frac{mm\cdot m^2}{L}}$$
$$= 1.3\frac{L}{m^2}$$

b. **TRADITIONAL U.S. UNITS:** The theoretical coverage rate of a coating is the number of roofing squares covered by one gallon of a coating material spread over a flat smooth surface area at a thickness of 1/1000 of an inch (0.001 in or 1 mil). One gallon of a coating material that has 100% solid content by volume will cover an area 16 rf. sq. (roofing squares), 1 dry mil thick (16 R•mil/gal). This definition is used to calculate theoretical coverage rates for coatings containing less than 100% solids. For example a coating with a 60% (0.60) SCV to be applied at 30 mils DFT will be used in the formulas listed to arrive at various theoretical coverages. (Note: These calculations use solids content by volume, NOT solids content by weight.)

c.

i. TO FIND THE THEORETICAL THICKNESS FOR ONE (1) GALLON OF COATING:

$$Theoretical\ Thickness\ per\ Gallon = \%\ \text{Solids} \bullet 16\ \frac{rf\ sq \cdot mil}{gal}$$

$$= 0.6\ x\ 16$$

$$= 9.6 \frac{rf\ sq \bullet mil}{gal}$$

(rf sq = roofing square = 100 sq ft)

ii. TO FIND THE THEORETICAL NUMBER OF GALLONS REQUIRED AT A SPECIFIED THICKNESS:

$$\#\ of\ Gallons\ per\ Roofing\ Square = \left(\frac{DFT}{Theoretical\ Thickness\ per\ Gallon}\right)$$

$$= \frac{30\ mil}{9.6\left(\frac{rf\ sq \bullet mil}{gal}\right)}$$

$$= 3.1\left(\frac{gal}{rf\ sq}\right)$$

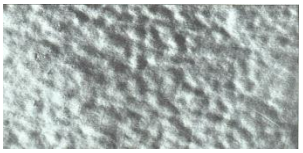
(2) Actual Coverage Requirements:

When coatings are applied over sprayed polyurethane foam, many factors, such as the polyurethane surface texture, overspray loss, container residue, equipment characteristics, applicator technique, etc., will directly affect the amount of coating material required to meet the designed in-place minimum DFT Therefore, it is very important that additional material be added to the theoretical quantities to ensure that the proper minimum coating thickness is applied. Consideration must be given to the following factors:

a. Minimum "DFT" or "DFT (dry-film thickness)": In order to perform the functions required of the elastomeric coating, the coating material should form a cured film of a prescribed thickness. The surface of sprayed polyurethane foam is somewhat uneven—never completely smooth like a sheet of glass. Therefore, peaks and valleys exist, and the film thickness over the peaks can be considerably less than in valleys. In order to overcome this potential problem, the minimum DFT of any given coating is defined as the in-place DFT at its thinnest point on the coated surface.

b. Polyurethane foam surface textures: The surface texture of sprayed polyurethane foam influences the extra material needed to achieve the minimum in-place DFT Smoother surfaces require less coating material than rougher surfaces. It is also important to note that excessively rough surface textures must not be coated due to the inability of the coating material to provide complete coverage without voids, pinholes, etc. The photographs on the following pages show various polyurethane foam textures that have been established as industry reference standards. An elastomeric coating should not be applied over a surface texture rougher than verge of popcorn.

Smooth Surface Texture

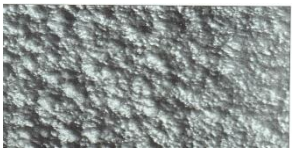


Description: The surface exhibits spray undulation and is ideal for receiving a protective coating. Even though the surface texture is classified as smooth, this surface requires at least 5% additional material than the theoretical amount.

Orange Peel Surface Texture

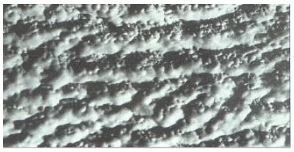
Description: The surface exhibits a fine texture and is compared to the exterior skin of an orange. This surface is considered acceptable for receiving a protective coating. This surface requires at least 10% additional material to the theoretical amount.

Coarse Orange Peel Surface Texture



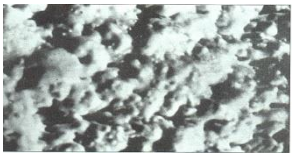
Description: The surface exhibits a texture where nodules and valleys are approximately the same size and shape. This surface is acceptable for receiving a protective coating because of the roundness of the nodules and valleys. This surface requires at least 25% additional material to the theoretical amount.

Verge of Popcorn Texture



Description: The verge of popcorn surface is the roughest texture suitable for receiving a protective coating. The surface shows a texture where nodules are larger than valleys and the valleys are relatively curved. This surface is considered undesirable because of the additional amount of coating required to protect the surface. This surface requires at least 50% additional material to the theoretical amount.

Popcorn Surface Texture or Tree bark



Description: The surface exhibits texture where valleys form sharp angles. This surface is unacceptable for coating applications.

Over-sprayed Surface Texture

Description: The surface exhibits a coarse textured pattern and/or a pebbled surface. This surface is typically found downwind from the SPF path and can vary from mild to severe. This surface requires 25%–50% additional material to the theoretical amount. Severe over-sprayed surfaces are not acceptable for coating applications.

c. Wind Loss: In spray applications, up to 30% of the coating may be lost due to wind. Consider using wind screens, and add wind loss to your coating calculations.
d. Miscellaneous Loss: A miscellaneous factor must be added to the theoretical coverage rate to cover losses due to material left in containers, equipment problems, etc. Use a percentage factor between 3% and 10%. The actual percentage will depend on the contractor's experience and efficiency.

(3) Summary: Taking into consideration minimum DFT, polyurethane foam surface textures, wind loss, and miscellaneous loss, a total percentage can be arrived at and added to theoretical coverage formulas found in the previous example. The example coating is 60% SCV to be applied at 0.8 millimeters (30 mils) DFT The AMP (additional material percentages) are as follows:

Orange Peel Texture	—	10%
Wind Loss	—	12%
Miscellaneous	—	5%
Total (AMP)		27%

Metric (SI)

Actual Coverage = Theoretical Coverage • AMP
= 1.3 L/m^2 x 1.27
= 1.7 actual L/ m^2

Traditional U.S.

Actual Coverage = Theoretical Coverage • AMP
= 3.1 gal/R x 1.27
= 3.9 actual gal/R

Theoretical Coating Requirements

NOTE: Increase these quantities for losses and surface texture.

% Solids	mm • m^2/L	Liters per Square Meter Theoretical Requirements						
		DFT (mm): 0.2	0.4	0.6	0.8	1.0	1.2	1.4
10	0.10	2.00	4.00	6.00	8.00	10.00	12.00	14.00
15	0.15	1.33	2.67	4.00	5.33	6.67	8.00	9.33
20	0.20	1.00	2.00	3.00	4.00	5.00	6.00	7.00
25	0.25	0.80	1.60	2.40	3.20	4.00	4.80	5.60
30	0.30	0.67	1.33	2.00	2.67	3.33	4.00	4.67
35	0.35	0.57	1.14	1.71	2.29	2.86	3.43	4.00
40	0.40	0.50	1.00	1.50	2.00	2.50	3.00	3.50
45	0.45	0.44	0.89	1.33	1.78	2.22	2.67	3.11
50	0.50	0.40	0.80	1.20	1.60	2.00	2.40	2.80
55	0.55	0.36	0.73	1.09	1.45	1.82	2.18	2.55
60	0.60	0.33	0.67	1.00	1.33	1.67	2.00	2.33
65	0.65	0.31	0.62	0.92	1.23	1.54	1.85	2.15
70	0.70	0.29	0.57	0.86	1.14	1.43	1.71	2.00
75	0.75	0.27	0.53	0.80	1.07	1.33	1.60	1.87
80	0.80	0.25	0.50	0.75	1.00	1.25	1.50	1.75
85	0.85	0.24	0.47	0.71	0.94	1.18	1.41	1.65
90	0.90	0.22	0.44	0.67	0.89	1.11	1.33	1.56
95	0.95	0.21	0.42	0.63	0.84	1.05	1.26	1.47
100	1.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40

% Solids	Mils • ft^2 per gal	Mils • rf sq per gal	Gallons per Square Theoretical Requirements							
			Mils: 10	20	25	30	35	40	45	50
10	160	1.6	6.23	12.5	15.6	18.7	21.8	24.9	28.1	31.2
15	241	2.41	4.16	8.31	10.4	12.5	14.5	16.6	18.7	20.8
20	321	3.21	3.12	6.23	7.79	9.35	10.9	12.5	14	15.6
25	401	4.01	2.49	4.99	6.23	7.48	8.73	9.98	11.2	12.5
30	481	4.81	2.08	4.16	5.2	6.23	7.27	8.31	9.35	10.4
35	561	5.61	1.78	3.56	4.45	5.34	6.23	7.13	8.02	8.91
40	642	6.42	1.56	3.12	3.9	4.68	5.46	6.23	7.01	7.79
45	722	7.22	1.39	2.77	3.46	4.16	4.85	5.54	6.23	6.93
50	802	8.02	1.25	2.49	3.12	3.74	4.36	4.99	5.61	6.23
55	882	8.82	1.13	2.27	2.83	3.4	3.97	4.53	5.1	5.67
60	962	9.62	1.04	2.08	2.6	3.12	3.64	4.16	4.68	5.2
65	1,040	10.4	0.96	1.92	2.4	2.88	3.36	3.84	4.32	4.8
70	1,120	11.2	0.89	1.78	2.23	2.67	3.12	3.56	4.01	4.45
75	1,200	12	0.83	1.66	2.08	2.49	2.91	3.33	3.74	4.16
80	1,280	12.8	0.78	1.56	1.95	2.34	2.73	3.12	3.51	3.9
85	1,360	13.6	0.73	1.47	1.83	2.2	2.57	2.93	3.3	3.67
90	1,440	14.4	0.69	1.39	1.73	2.08	2.42	2.77	3.12	3.46
95	1,520	15.2	0.66	1.31	1.64	1.97	2.3	2.63	2.95	3.28
100	1,600	16	0.62	1.25	1.56	1.87	2.18	2.49	2.81	3.12

Standard Size of Coarse Aggregate

PERCENT AGGREGATE THAT PASSES THROUGH INDICATED SIEVE SIZE

(Based on ASTM D 1893-93)

	Amounts Finer than Sieve Specified, Mass %		
Sieve (Specification ASTM E11)	Size No. 6 19.0 to 9.5 mm (3/4 in to 3/8 in)	Size No. 67 19.0 to 4.75 mm (3/4 in to No. 4)	Size No. 7 12.5 to 4.75 mm (1/2 in to No. 4)
1 in (25 mm)	100	100	
3/4 in (19 mm)	90 to 100	90 to 100	100
1/2 in (12.5 mm)	20 to 55	N/A	90 to 100
3/8 in (9.5 mm)	0 to 15	20 to 55	40 to 70
No. 4 [3/16 in] (4.75 mm)	0 to 5	0 to 10	0 to 15
No. 8 [3/32 in] (2.36 mm)		0 to 5	0 to 5

Typical Aggregate Weight and Coverage

Aggregate Weight (typical) = 1,400–1,900 kg/m^3
= 90–120 lb/ft^3
= 2,430–3,240 lb/yd^3
= 1.2–1.6 ton/yd^3

Aggregate Coverage (typical)

THICKNESS			
25 mm	20 mm	1 in	3/4 in
35–50 kg/m^3	25–35 kg/m^3	7.5–10 lb/ft^2	5.6–7.5 lb/ft^2
		750–1,000 lb/rf sq	560–750 lb/rf sq
		0.38–0.50 ton/rf sq	0.28–0.38 ton/rf sq

(rf sq = roofing square = 100 ft^2)Thermodynamic Definitions and Calculations

Thermodynamic Definitions and Calculations

Btu: British thermal unit is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

J: Joule is the metric (SI) unit for energy. (1 Btu = 1,055 J = 1.055 kJ)

W: Watt is the he metric (SI) unit for heat flow. (1 J/s = 1 W; 1 Btu/hr = 0.293 W)

°F: Degree Fahrenheit is the traditional U.S. unit for measuring temperature.

K or °C: Kelvin or Degree Celsius is the metric (SI) unit for temperature.

$$T_{\circ C} = \left(\frac{5}{9}\right)(T_{\circ F} - 32)$$

$$T_K = T_{\circ C} + 273$$

$$T_{\circ F} = \left(\frac{9}{5}\right)(T_{\circ C}) + 32$$

k factor: Thermal conductivity for a unit thickness of material is expressed as $\mathrm{W/m{\bullet}K}$ $(\mathrm{Btu{\bullet}in/hr{\bullet}ft^2{\bullet}{\circ}F})$.

R factor: Thermal resistance is the resistance to heat transfer of a material. Insulators have relatively high R factors. Expressed as $\mathrm{m^2{\bullet}K/W}$ $(\mathrm{{\circ}F{\bullet}ft^2{\bullet}hr/Btu})$.

Overall thermal resistance of several materials assembled in a wall or roof is calculated by adding the individual R factors:

$$R_o = R_1 + R_2 + R_3 + \cdots + R_n$$

U factor: Overall thermal conductance is equal to the inverse of the overall R factor. It is expressed as $\mathrm{W/m^2{\bullet}K}$ $(\mathrm{Btu/hr{\bullet}ft^2{\bullet}{\circ}F})$.

$$U = \frac{1}{R_o}$$

Example Thermal Insulation Calculation

Assume that a building owner needs to upgrade his roof insulation to a U factor of 0.05 Btu/h•ft²•°F. The building now has a built-up roof over 1 inch glass fiber insulation on a metal roof deck.

What thickness of SPF should be applied to the existing built-up roof to achieve the desired U factor?

TRADITIONAL U.S. UNITS

Required R-value:

$$R_{new} = \frac{1}{U} = \frac{1}{0.05} = 20\ \frac{hr \bullet ft^2 \bullet °F}{Btu}$$

Existing R-value:

Component	R-value
Outside Air Film	0.15
Built-up Membrane	0.33
1” Glass Fiber	3.2
Metal Deck	0
Inside Air Film	0.61
Overall R-value	4.29

$$R_{exist} = 4.29\ \frac{hr \bullet\ ft^2 \bullet °F}{Btu}$$

Additional insulation from SPF:

$$R_{SPF} = R_{new} - R_{exist}$$

$$= 20 - 4.29$$

$$= 16\ \frac{hr \bullet ft^2 \bullet °F}{Btu}$$

Polyurethane foam thickness to apply (use 6.0 hr•ft²•°F/Btu for the 1 inch R value for SPF):

$$Thickness = \frac{R_{SPF}}{6.0} = \frac{16}{6.0} = 2.7\ in$$

Thermal Transmission Properties of Construction Material

Material			R-Value (°F•ft²•hr/Btu)
Built-up Roof Membrane			0.33
Decks			
	Steel Deck (forgetting seams)		Negl.
	Steel Deck (considering seams)		Negl.
	Uncracked Concrete Structural Deck (6 in.)		0.5
Films, Felts & Foils			
	Aluminum Foil		Negl.
	Polyethylene	4-mil	Negl.
		6-mil	Negl.
	Polyvinyl chloride (PVC)	4-mil	Negl.
	Kraft Paper Laminate		Negl.
	Asphalt Saturated Felt No. 15		0.06
	Asphalt Saturated and Coated Felt No. 43		0.06
Construction Boards			
	Plywood	1/4 in. Exterior	0.32
		1/2 in. Exterior	0.64
	Gypsum Wall Board 3/8 in		0.32
Insulations			
	Cellular Glass 1 in.		2.9
	Polyurethane 1 in.		5.6 - 6
	Extruded Polystyrene 1 in.		5.0
	Expanded Polystyrene 1 in.		3.9 - 4
	Mineral Fiber 1 in. (unprotected)		3.2
	Cork Board 1 in.		3.9
Coatings			
	Acrylic 30 mils		Negl.
	Asphalt Mastic 60 mils		Negl.
	Butyl 30 mils		Negl.
	Chlorinated Synth. Rubber 15—30 mils		Negl.
	Silicone 20 mils		Negl.
	Polyurethane 20—35 mils		Negl.
Air Surfaces (Horizontal)			
	Still Air		
	Heat flow upward		0.61
	Heat flow downward		0.92
	Moving Air		
	15 mph wind (Winter)		0.17
	7.5 mph wind (Summer)		0.25

Note: These figures represent approximations from a variety of published sources. When determining thermal resistances for a particular system, use thermal resistance provided by the manufacturer for each specific product.

Heating Values of Fuels

Coal	13,000	Btu/lb
Electricity	3,413	Btu/kilowatt-hr
Fuel Oil #2	140,000	Btu/gal
Fuel Oil #5	151,000	Btu/gal
Fuel Oil #6	153,000	Btu/gal
Kerosene	135,000	Btu/gal
LPG	91,690	Btu/gal
Natural Gas	100,000	Btu/ccf (100 ft^3)
Steam	1,000	Btu/lb
Wood, Dry	8,600	Btu/lb

Note: Actual heating values of fuels will vary. Check with the fuel supplier for more accurate values.

Dew Point Temperatures

METRIC (SI) UNITS

Relative Humidity	Dry Bulb Temperature (°C)										
100%	-10	-5	0	5	10	15	20	25	30	35	40
90	-11	-6	-1	4	8	13	18	23	28	33	38
80	-13	-8	-3	2	7	12	17	21	26	31	36
70	-14	-9	-5	0	5	10	14	19	24	28	33
60	-16	-11	-6	-2	3	7	12	17	21	26	30
50	-18	-13	-9	-4	0	5	9	14	18	23	27
40	-20	-16	-11	-7	-2	2	6	11	15	19	23
30	-23	-19	-14	-10	-6	-2	2	6	10	14	18
20	-27	-23	-19	-15	-11	-7	-3	1	5	8	12
10	-33	-30	-26	-22	-18	-15	-11	-8	-4	-1	2
	-10	-5	0	5	10	15	20	25	30	35	40

TRADITIONAL U.S. UNITS

Relative Humidity	Dry Bulb Temperature (°F)									
100%	20	30	40	50	60	70	80	90	100	110
90	18	28	37	47	57	67	77	87	97	107
80	15	25	35	44	54	64	73	83	93	103
70	13	22	31	41	51	60	69	79	89	99
60	9	19	28	37	47	56	65	75	84	94
50	6	15	24	33	42	51	60	70	79	88
40	2	10	19	28	37	45	54	63	73	82
30	-4	5	13	21	30	38	46	56	65	73
20	-11	-3	5	13	21	29	37	45	54	62
10	-23	-15	-8	-1	7	14	21	28	36	44
	20	30	40	50	60	70	80	90	100	110

Temperature Conversion Tables

°F	Temp. in °F or °C to be converted	°C	°F	Temp. in °F or °C to be converted	°C	°F	Temp. in °F or °C to be converted	°C	°F	Temp. in °F or °C to be converted	°C
-58	-50	-45.6	14	-10	-23.3	86	30	-1.11	158	70	21.1
-56.2	-49	-45	15.8	-9	-22.8	87.8	31	-0.56	160	71	21.7
-54.4	-48	-44.4	17.6	-8	-22.2	89.6	32	0.0	162	72	22.2
-52.6	-47	-43.9	19.4	-7	-21.7	91.4	33	0.56	163	73	22.8
-50.8	-46	-43.3	21.2	-6	-21.1	93.2	34	1.11	165	74	23.3
-49	-45	-42.8	23	-5	-20.6	95	35	1.67	167	75	23.9
-47.2	-44	-42.2	24.8	-4	-20	96.8	36	2.22	169	76	24.4
-45.4	-43	-41.7	26.6	-3	-19.4	98.6	37	2.78	171	77	25
-43.6	-42	-41.1	28.4	-2	-18.9	100	38	3.33	172	78	25.6
-41.8	-41	-40.6	30.2	-1	-18.3	102	39	3.89	174	79	26.1
-40	-40	-40	32	0	-17.8	104	40	4.44	176	80	26.7
-38.2	-39	-39.4	33.8	1	-17.2	106	41	5	178	81	27.2
-36.4	-38	-38.9	35.6	2	-16.7	108	42	5.56	180	82	27.8
-34.6	-37	-38.3	37.4	3	-16.1	109	43	6.11	181	83	28.3
-32.8	-36	-37.8	39.2	4	-15.6	111	44	6.67	183	84	28.9
-31	-35	-37.2	41	5	-15	113	45	7.22	185	85	29.4
-29.2	-34	-36.7	42.8	6	-14.4	115	46	7.78	187	86	30
-27.4	-33	-36.1	44.6	7	-13.9	117	47	8.33	189	87	30.6
-25.6	-32	-35.6	46.4	8	-13.3	118	48	8.89	190	88	31.1
-23.8	-31	-35	48.2	9	-12.8	120	49	9.44	192	89	31.7
-22	-30	-34.4	50	10	-12.2	122	50	10	194	90	32.2
-20.2	-29	-33.9	51.8	11	-11.7	124	51	10.6	196	91	32.8
-18.4	-28	-33.3	53.6	12	-11.1	126	52	11.1	198	92	33.3
-16.6	-27	-32.8	55.4	13	-10.6	127	53	11.7	199	93	33.9
-14.8	-26	-32.2	57.2	14	-10	129	54	12.2	201	94	34.4
-13	-25	-31.7	59	15	-9.44	131	55	12.8	203	95	35
-11.2	-24	-31.1	60.8	16	-8.89	133	56	13.3	205	96	35.6
-9.4	-23	-30.6	62.6	17	-8.33	135	57	13.9	207	97	36.1
-7.6	-22	-30	64.4	18	-7.78	136	58	14.4	208	98	36.7
-5.8	-21	-29.4	66.2	19	-7.22	138	59	15	210	99	37.2
-4	-20	-28.9	68	20	-6.67	140	60	15.6	212	100	37.8
-2.2	-19	-28.3	69.8	21	-6.11	142	61	16.1	214	101	38.3
-0.4	-18	-27.8	71.6	22	-5.56	144	62	16.7	216	102	38.9
1.4	-17	-27.2	73.4	23	-5	145	63	17.2	217	103	39.4
3.2	-16	-26.7	75.2	24	-4.44	147	64	17.8	219	104	40
5	-15	-26.1	77	25	-3.89	149	65	18.3	221	105	40.6
6.8	-14	-25.6	78.8	26	-3.33	151	66	18.9	223	106	41.1
8.6	-13	-25	80.6	27	-2.78	153	67	19.4	225	107	41.7
10.4	-12	-24.4	82.4	28	-2.22	154	68	20	226	108	42.2
12.2	-11	-23.9	84.2	29	-1.67	156	69	20.6	228	109	42.8

Temperature Conversion Tables

°F	Temp. in °F or °C to be converted	°C	°F	Temp. in °F or °C to be converted	°C	°F	Temp. in °F or °C to be converted	°C	°F	Temp. in °F or °C to be converted	°C
230	110	43.3	302	150	65.6	374	190	87.8	446	230	110
232	111	43.9	304	151	66.1	376	191	88.3	448	231	111
234	112	44.4	306	152	66.7	378	192	88.9	450	232	111
235	113	45	307	153	67.2	379	193	89.4	451	233	112
237	114	45.6	309	154	67.8	381	194	90	453	234	112
239	115	46.1	311	155	68.3	383	195	90.6	455	235	113
241	116	46.7	313	156	68.9	385	196	91.1	457	236	113
243	117	47.2	315	157	69.4	387	197	91.7	459	237	114
244	118	47.8	316	158	70	388	198	92.2	460	238	114
246	119	48.3	318	159	70.6	390	199	92.8	462	239	115
248	120	48.9	320	160	71.1	392	200	93.3	464	240	116
250	121	49.4	322	161	71.7	394	201	93.9	466	241	116
252	122	50	324	162	72.2	396	202	94.4	468	242	117
253	123	50.6	325	163	72.8	397	203	95	469	243	117
255	124	51.1	327	164	73.3	399	204	95.6	471	244	118
257	125	51.7	329	165	73.9	401	205	96.1	473	245	118
259	126	52.2	331	166	74.4	403	206	96.7	475	246	119
261	127	52.8	333	167	75	405	207	97.2	477	247	119
262	128	53.3	334	168	75.6	406	208	97.8	478	248	120
264	129	53.9	336	169	76.1	408	209	98.3	480	249	121
266	130	54.4	338	170	76.7	410	210	98.9	482	250	121
268	131	55	340	171	77.2	412	211	99.4			
270	132	55.6	342	172	77.8	414	212	100			
271	133	56.1	343	173	78.3	415	213	101			
273	134	56.7	345	174	78.9	417	214	101			
275	135	57.2	347	175	79.4	419	215	102			
277	136	57.8	349	176	80	421	216	102			
279	137	58.3	351	177	80.6	423	217	103			
280	138	58.9	352	178	81.1	424	218	103			
282	139	59.4	354	179	81.7	426	219	104			
284	140	60	356	180	82.2	428	220	104			
286	141	60.6	358	181	82.8	430	221	105			
288	142	61.1	360	182	83.3	432	222	106			
289	143	61.7	361	183	83.9	433	223	106			
291	144	62.2	363	184	84.4	435	224	107			
293	145	62.8	365	185	85	437	225	107			
295	146	63.3	367	186	85.6	439	226	108			
297	147	63.9	369	187	86.1	441	227	108			
298	148	64.4	370	188	86.7	442	228	109			
300	149	65	372	189	87.2	444	229	109			

Temperature Conversions

°C = 5/9 (°F – 32)
°F = 9/5 (°C) + 32
°K = °C + 273.2
°R = °F + 459.7

Volume of Material in Horizontal Cylindrical Tanks

Measured % of Tank Diameter	Actual % Volume in Tank	Measured % of Tank Diameter	Actual % Volume in Tank	Measured % of Tank Diameter	Actual % Volume in Tank
100	100.0	64	67.6	30	25.2
99	99.8	63	66.4	29	24.1
98	99.5	62	65.1	28	22.9
97	99.1	61	63.9	27	21.8
96	98.7	60	62.6	26	20.7
95	98.1	59	61.4	25	19.6
94	97.6	58	60.1	24	18.5
93	96.9	57	58.9	23	17.4
92	96.3	56	57.6	22	16.3
91	95.5	55	56.4	21	15.3
90	94.8	54	55.1	20	14.2
89	94.0	53	53.8	19	13.2
88	93.2	52	52.5	18	12.2
87	92.4	51	51.3	17	11.3
86	91.5	50	50.0	16	10.3
85	90.6	49	48.7	15	9.4
84	89.7	48	47.5	14	8.5
83	88.7	47	46.2	13	7.6
82	87.8	46	44.9	12	6.8
81	86.8	45	43.6	11	6.0
80	85.8	44	42.4	10	5.2
79	84.7	43	41.1	9	4.5
78	83.7	42	39.9	8	3.7
77	82.6	41	38.6	7	3.1
76	81.5	40	37.4	6	2.4
75	80.4	39	36.1	5	1.9
74	79.3	38	34.9	4	1.3
73	78.2	37	33.6	3	0.9
72	77.1	36	32.4	2	0.5
71	75.9	35	31.2	1	0.2
70	74.8	34	30.0	0	0.0
69	73.6	33	28.8		
68	72.4	32	27.6		
67	71.2	31	26.4		
66	70.0				
65	68.8				

Unit Conversions

LENGTH

EXAMPLE: To convert a value in cm to a value in ft, multiply the value in cm by 0.03281;
(i.e., 40 cm x 0.03281 = 1.31 ft)

From \ To	mm	cm	m	km	mil	in	ft	mile
mm	1	0.1	0.001	$1x10^{-6}$	39.37	0.03937	0.00328	$6.21x10^{-7}$
cm	10	1	0.01	$1x10^{-5}$	393.7	0.3937	0.03281	$6.21x10^{-6}$
m	1,000	100	1	0.001	$3.94x10^{4}$	39.37	3.281	$6.21x10^{-4}$
km	$1x10^{6}$	$1x10^{5}$	1,000	1	$3.94x10^{7}$	$3.94x10^{4}$	3281	0.6214
mil	0.0254	0.00254	$2.54x10^{-5}$	$2.54x10^{-8}$	1	0.001	$8.33x10^{-5}$	$1.58x10^{-8}$
in	25.4	2.540	0.02540	$2.54x10^{-5}$	1,000	1	0.08333	$1.58x10^{-5}$
ft	304.8	30.48	0.3048	$3.05x10^{-4}$	12,000	12	1	$1.89x10^{-4}$
mile	$1.61x10^{6}$	$1.61x10^{5}$	1609	1.609	$6.34x10^{7}$	$6.34x10^{4}$	5,280	1

AREA

From \ To	mm^2	cm^2	m^2	km^2	in^2	ft^2	yd^2	rf sq	acre	$mile^2$
mm^2	1	0.01	$1x10^{-6}$	$1x10^{-12}$	0.00155	$1.08x10^{-5}$	$1.20x10^{-6}$	$1.08x10^{-7}$	$2.47x10^{-10}$	$3.86x10^{-13}$
cm^2	100	1	0.0001	$1x10^{-10}$	0.1550	0.00108	$1.20x10^{-4}$	$1.08x10^{-5}$	$2.47x10^{-8}$	$3.86x10^{-11}$
m^2	$1x10^{6}$	$1x10^{4}$	1	$1x10^{-6}$	1,550	10.76	1.196	0.1076	$2.47x10^{-4}$	$3.86x10^{-7}$
km^2	$1x10^{12}$	$1x10^{10}$	$1x10^{6}$	1	$1.55x10^{9}$	$1.08x10^{7}$	$1.196x10^{6}$	$1.08x10^{5}$	$2.471x10^{2}$	0.3861
in^2	645.2	6.452	$6.45x10^{-4}$	$6.45x10^{-10}$	1	0.00694	$7.72x10^{-4}$	$6.94x10^{-5}$	$1.59x10^{-7}$	$2.49x10^{-10}$
ft^2	$9.29x10^{4}$	929.0	0.09290	$9.29x10^{-8}$	144	1	0.1111	0.01	$2.30x10^{-5}$	$3.59x10^{-8}$
yd^2	$8.36x10^{5}$	8,361	0.8361	$8.36x10^{-5}$	1,296	9	1	0.09	$2.07x10^{-4}$	$3.23x10^{-7}$
rf sq	$9.29x10^{6}$	92,900	9.290	$9.29x10^{-6}$	14,400	100	11.11	1	$2.30x10^{-3}$	$3.59x10^{-6}$
acre	$4.05x10^{9}$	$4.05x10^{7}$	4,047	$4.05x10^{-3}$	$6.27x10^{6}$	43,560	4840	435.6	1	0.001562
$mile^2$	$2.59x10^{12}$	$2.59x10^{10}$	$2.59x10^{6}$	2.590	$4.01x10^{9}$	$2.79x10^{7}$	$3.098x10^{6}$	$2.79x10^{5}$	640	1

VOLUME / CAPACITY

To / From	cm^3 (ml)	L	m^3	in^3	ft^3	yd^3	fl oz	fl pt	fl qt	gal (Imp)
cm^3	1	0.001	$1x10^{-6}$	0.0610	$3.53x10^{-5}$	$1.31x10^{-6}$	0.0338	0.00211	0.00106	$2.64x10^{-4}$
L	1,000	1	0.001	61.0	0.0353	0.00131	33.8	2.11	1.06	0.264
m^3	$1x10^{6}$	1,000	1	$6.10x10^{4}$	35.3	1.31	$3.38x10^{4}$	2,110	1,060	264
in^3	16.4	0.0164	$1.64x10^{-5}$	1	$5.79x10^{-4}$	$2.14x10^{-5}$	0.554	0.0346	0.0173	0.00433
ft^3	$2.83x10^{4}$	28.3	0.0283	1,730	1	0.0370	956	59.8	29.9	7.48
yd^3	$7.65x10^{5}$	765	0.765	$4.67x10^{4}$	27.0	1	$2.59x10^{4}$	1,620	808	202
fl oz	29.6	0.0296	$2.96x10^{-5}$	1.81	0.00104	$3.87x10^{-5}$	1	0.0625	0.0313	0.00781
fl pt	473	0.473	$4.73x10^{-4}$	28.9	0.0167	$6.19x10^{-4}$	16.0	1	0.500	0.125
fl qt	946	0.946	$9.46x10^{-4}$	57.8	0.0334	0.00124	32.0	2.00	1	0.250
gal	3,790	3.79	0.00379	231	0.1334	0.00495	128	8.00	4.00	1

1 cord = 128 ft^3 = 3.625 m^3

1 bd ft = 0.00236 m^3

WEIGHT (UNDER 1 LB)

EXAMPLE: To convert a value in g to a value in lb multiply the value in g by 2.21×10^{-3}
(i.e., 400 g x 2.21×10^{-3} = 0.884 lb)

To / From	mg	grain	g	dr (apoth)	oz (av)	oz (apoth)	lb
mg	1	0.0154	0.00100	2.57×10^{-4}	3.53×10^{-5}	3.22×10^{-5}	2.21×10^{-6}
grain	64.8	1	0.0648	0.0167	2.23×10^{-3}	2.08×10^{-3}	1.43×10^{-4}
g	1,000	15.4	1	0.257	0.0353	0.0321	2.21×10^{-3}
dr (apoth)	3,890	60.0	3.89	1	0.137	0.125	8.57×10^{-3}
oz (av)	28,400	438	28.4	7.29	1	0.912	0.0625
oz (apoth)	31,100	480	31.1	8.00	1.10	1	0.0686
lb	4.54×10^{5}	7,000	454	117	16.0	14.6	1

Note: av = avoirdupois weight, the weight system of Traditional U. S. Units
apoth = apothecary's weight, a system of weights used in pharmacy

WEIGHT (1 LB AND OVER)

To / From	lb	kg	ton	metric ton
lb	1	0.454	5.00×10^{-4}	4.54×10^{-4}
kg	2.21	1	1.10×10^{-3}	0.00100
ton	2,000	907	1	0.907
metric ton	2,205	1,000	1.10	1

VISCOSITY

Dynamic Viscosity: 1 poise = 0.1 Pa•s = 0.0672 lb mass/ ft s

Kinematic Viscosity: 1 stoke = $1x10^{-4}$ m^2/s

Poise	Centipoise	Pa•s	Krebs	Ford Cup		Zahn				
			Units	3	4	1	2	3	4	5
0.1	10	0.01			5	30	16			
0.15	15	0.015			8	34	17			
0.2	20	0.02		12	10	37	18			
0.25	25	0.025		15	12	41	19			
0.3	30	0.03		19	14	44	20			
0.4	40	0.04		25	18	52	22			
0.5	50	0.05	30	29	22	60	24			
0.6	60	0.06	33	33	25	68	27			
0.7	70	0.07	35	36	28		30			
0.8	80	0.08	37	41	31		34			
0.9	90	0.09	38	45	32		37	10		
1.0	100	0.10	40	50	34		41	12	10	
1.2	120	0.12	43	58	41		49	14	11	
1.4	140	0.14	46	66	45		58	16	13	
1.6	160	0.16	48		50		66	18	14	
1.8	180	0.18	50		54		74	20	16	
2.0	200	0.20	52		58		82	23	17	10
2.2	220	0.22	54		62			25	18	11
2.4	240	0.24	56		65			28	19	12
2.6	260	0.26	58		68			30	21	13
2.8	280	0.28	59		70			32	22	14
3.0	300	0.30	60		74			34	24	15
3.2	320	0.32						36	25	16
3.4	340	0.34						39	26	17
3.6	360	0.36	62					41	28	18
3.8	380	0.38						43	29	19
4.0	400	0.40	64					46	30	20
4.2	420	0.42						48	32	21
4.4	440	0.44						50	33	22
4.6	460	0.46	66					52	34	23
4.8	480	0.48	67					54	36	24
5.0	500	0.50	68					57	37	25
5.5	550	0.55	69					63	40	27
6.0	600	0.60	71					68	44	30
7.0	700	0.70	74						51	35
8.0	800	0.80	77						58	40
9.0	900	0.90	81						64	45
10.0	1,000	1.0	85							49
11.0	1,100	1.1	88							55
12.0	1,200	1.2	92							59
13.0	1,300	1.3	95							64
14.0	1,400	1.4	96							
15.0	1,500	1.5	98							
16.0	1,600	1.6	100							

DENSITY

EXAMPLE: To convert a value in lb/ft³ to a value in kg/m³ multiply the value in lb/ft³ by 16.0 (i.e., 2.8 lb/ft³ x 16.0 = 44.8 kg/m³)

To / From	g/cm³	g/L	kg/m³	grain/ft³	lb/ft³	lb/gal
g/cm³	1	1,000	1,000	4.37×10^{5}	62.4	8.35
g/L	0.001	1	1	0.0437	0.0624	0.00835
kg/m³	0.001	1	1	0.0437	0.0624	0.00835
grain/ft³	0.00128	1.28	1.28	1	1.43×10^{-4}	1.91×10^{-5}
lb/ft³	0.0160	16.0	16.0	7,000	1	0.134
lb/gal	0.120	120	120	52,400	7.48	1

VELOCITY

To / From	cm/s	m/s	km/hr	in/s	ft/s	ft/min	mph
cm/s	1	0.01	0.0360	0.394	0.0328	1.97	0.0224
m/s	100	1	3.60	39.4	3.28	197	2.24
km/hr	27.8	0.278	1	10.9	0.911	54.7	0.621
in/s	2.54	0.0254	0.0914	1	0.0833	5.00	0.0568
ft/s	30.5	0.305	1.10	12.0	1	60.0	0.682
ft/min	0.508	0.00508	0.0183	0.200	0.0167	1	0.0114
mph	44.7	0.447	1.61	17.6	1.47	88.0	1

FLOW RATE

To / From	L/s	m³/s	gal/min	ft³/s	ft³/min
L/s	1	0.001	15.9	0.0353	2.12
m³/s	1,000	1	1.59×10^{4}	35.3	2120
gal/min	0.0631	6.31×10^{-5}	1	0.00223	0.134
ft³/s	28.3	0.0283	449	1	60.0
ft³/min	0.472	4.72×10^{-4}	7.48	0.0167	1

PRESSURE

Example: To convert a value in psi to a value in kPa multiply the value in psi by 6.89 (i.e., 15 psi x 6.89 = 103 kPa)

To / From	Pa	kPa	bar	MPa	atm	mm Hg	in Hg	ft H_2O	lb/in^2 (psi)	lb/ft^2 (psf)
Pa	1	0.001	10^{-5}	10^{-6}	$9.90x10^{-6}$	0.00750	$2.95x10^{-4}$	$3.34x10^{-4}$	$1.45x10^{-4}$	0.0209
kPa	1,000	1	0.01	0.001	0.00990	7.50	0.295	0.334	0.145	20.9
bar	10,000	100	1	0.1	0.990	750	29.5	33.4	14.5	2,090
MPa	10^6	1,000	10	1	9.90	7,500	29.5	334	145	20,090
atm	10,100	101	1.01	0.101	1	760	29.9	33.9	14.7	2,120
mm Hg	133	0.133	0.00133	$1.33x10^{-4}$	0.00132	1	0.0394	0.0446	0.0193	2.79
in Hg	3,390	3.39	0.0339	0.00339	0.0334	25.4	1	1.13	0.491	70.7
ft H_2O	2,990	2.99	0.0299	0.00299	0.0295	22.4	0.883	1	0.434	62.4
lb/in^2 (psi)	6,890	6.89	0.0689	0.00689	0.0681	51.7	2.04	2.31	1	144
lb/ft^2 (psf)	47.9	0.0479	$4.79x10^{-4}$	$4.79x10^{-5}$	$4.73x10^{-4}$	0.359	0.0141	0.0160	0.00694	1

1 Pa = N/m^2

ENERGY & WORK

To / From	Btu	g cal	kg cal	ft•lb	J	hp•hr	kw•hr
Btu	1	252	0.252	778	1,050	$3.93x10^{-4}$	$2.93x10^{-4}$
g cal	0.00396	1	0.00100	3.09	4.18	$1056x10^{-6}$	$1.16x10^{-6}$
kg cal	3.97	1,000	1	3,090	4,180	0.00156	0.00116
ft•lb	0.00129	0.324	$3.24x10^{-4}$	1	1.36	$5.05x10^{-7}$	$3.77x10^{-7}$
J	$9.49x10^{-4}$	0.239	$2.39x10^{-4}$	0.738	1	$3.73x10^{-7}$	$2.78x10^{-7}$
hp•hr	2,550	$6.41x10^{5}$	642	$1.98x10^{6}$	$2.69x10^{6}$	1	0.746
kw•hr	3,410	$8.60x10^{5}$	860	$2.66x10^{6}$	$3.60x10^{6}$	1.34	1

1 therm = 100,000 Btu

POWER

EXAMPLE: To convert a value in Btu/s to a value in kilowatt, multiply the value in Btu/sec by 0.7355 (i.e., 50 Btu/sec x 0.7355 = 36.8 kilowatt).

To / From	Btu/s	erg/s	ft•lb/s	kg cal/s	kg•m/s	hp	kW	W
Btu/s	1	1.05×10^{10}	778	0.252	108	1.41	1.05	1,050
erg/s	9.48×10^{-11}	1	7.38×10^{-8}	2.39×10^{-11}	1.02×10^{-8}	1.34×10^{-10}	1×10^{-10}	1×10^{-7}
ft•lb/s	0.00129	1.36×10^{7}	1	3.24×10^{-4}	0.138	0.00182	0.00136	1.36
kg cal/s	3.97	4.16×10^{10}	3,090	1	427	5.61	4.19	418
kg•m/s	0.00930	9.81×10^{7}	7.23	0.00234	1	0.0132	0.00981	9.81
hp	0.707	7046×10^{9}	550	0.178	76.0	1	0.746	746
kW	0.949	1×10^{10}	738	0.239	102	1.34	1	1,000
W	9.49×10^{-4}	1×10^{7}	0.738	2.39×10^{-4}	0.102	0.00134	0.00100	1

Horse-power (boiler) = 33,480 Btu/hr = 9.808 kW

THICKNESS / UNIT AREA

From \ To	ft^3	bd•ft	$mil•ft^2$	gal	m^3	$mm•m^2$	L
ft^3	1	12.0	$1.20x10^4$	7.48	0.0283	28.3	28.3
bd•ft	0.833	1	1,000	0.623	0.00236	2.36	2.36
$mil•ft^2$	$8.33x10^{-5}$	0.00100	1	$6.23x10^{-4}$	$2.36x10^{-6}$	0.00235	0.00235
gal	0.134	1.61	1,600	1	0.00379	3.79	3.79
m^3	35.3	424	$4.24x10^5$	264	1	1,000	1,000
$mm•m^2$	0.0353	0.424	424	0.264	0.00100	1	1
L	0.0353	0.424	424	0.264	0.00100	1	1

One mil = one thousandth of an inch = 0.0254 mm
Board foot = 1 ft^2 at 1 inch thickness

THERMAL CONDUCTIVITY AND INSULANCE

From \ To	Thermal Conductivity k Value $\frac{Btu \bullet in}{hr \bullet ft^2 \bullet °F}$	Thermal Conductivity k Value $\frac{W}{m \bullet K}$	Thermal Insulance R-value $\frac{°F \bullet hr \bullet ft^2}{Btu}$	Thermal Insulance R-value $\frac{K \bullet m^2}{W}$
$\frac{Btu \bullet in}{hr \bullet ft^2 \bullet °F}$	1	0.144		
$\frac{W}{m \bullet K}$	6.93	1		
$\frac{°F \bullet hr \bullet ft^2}{Btu}$			1	0.176
$\frac{K \bullet m^2}{W}$			5.68	1

PERMEANCE AND PERMEABILITY

From \ To	Permeance Perm $\frac{\text{grain}}{\text{ft}^2\bullet\text{hr}\bullet\text{in Hg}}$	Permeance $\frac{\text{ng}}{\text{s}\bullet\text{m}^2\bullet\text{Pa}}$	Permeability Perm-in $\frac{\text{grain}\bullet\text{in}}{\text{ft}^2\bullet\text{hr}\bullet\text{in Hg}}$	Permeability $\frac{\text{ng}}{\text{s}\bullet\text{m}\bullet\text{Pa}}$
$\frac{\text{grain}}{\text{ft}^2\bullet\text{hr}\bullet\text{in Hg}}$	1	57.4		
$\frac{\text{ng}}{\text{s}\bullet\text{m}^2\bullet\text{Pa}}$	0.0174	1		
$\frac{\text{grain}\bullet\text{in}}{\text{ft}^2\bullet\text{hr}\bullet\text{in Hg}}$			1	1.46
$\frac{\text{ng}}{\text{s}\bullet\text{m}\bullet\text{Pa}}$			0.685	1

Decimal Equivalents

DECIMAL EQUIVALENTS, FRACTIONS

1/64	0.01563	17/64	0.26563	33/63	0.52381	49/64	0.76563
1/32	0.03125	9/32	0.28125	17/32	0.53125	25/32	0.78125
3/64	0.04688	19/64	0.29688	35/64	0.54688	51/64	0.79688
1/16	0.06250	5/16	0.31250	9/16	0.56250	13/16	0.81250
5/64	0.07813	21/64	0.32813	37/64	0.57813	53/64	0.82813
3/32	0.09375	11/32	0.34375	19/32	0.59375	27/32	0.84375
7/64	0.10938	23/64	0.35938	39/64	0.60938	55/64	0.85938
1/8	0.12500	3/8	0.37500	5/8	0.62500	7/8	0.87500
9/64	0.14063	25/64	0.39063	41/64	0.64063	57/64	0.89063
5/32	0.15625	13/32	0.40625	21/32	0.65625	29/32	0.90625
11/64	0.17188	27/64	0.42188	43/64	0.67188	59/64	0.92188
3/16	0.18750	7/16	0.43750	11/16	0.68750	15/16	0.93750
13/64	0.20313	29/64	0.45313	45/64	0.70313	61/64	0.95313
7/32	0.21875	15/32	0.46875	23/32	0.71875	31/32	0.96875
15/64	0.23438	31/64	0.48438	47/64	0.73438	63/64	0.98438
1/4	0.25000	1/2	0.50000	3/4	0.75000	1	1.00000

DECIMAL EQUIVALENTS, INTEGERS ARE 64ths

1	0.01563	17	0.26563	33	0.51563	49	0.76563
2	0.03125	18	0.28125	34	0.53125	50	0.78125
3	0.04688	19	0.29688	35	0.54688	51	0.79688
4	0.06250	20	0.31250	36	0.56250	52	0.81250
5	0.07813	21	0.32813	37	0.57813	53	0.82813
6	0.09375	22	0.34375	38	0.59375	54	0.84375
7	0.10938	23	0.35938	39	0.60938	55	0.85938
8	0.12500	24	0.37500	40	0.62500	56	0.87500
9	0.14063	25	0.39063	41	0.64063	57	0.89063
10	0.15625	26	0.40625	42	0.65625	58	0.90625
11	0.17188	27	0.42188	43	0.67188	59	0.92188
12	0.18750	28	0.43750	44	0.68750	60	0.93750
13	0.20313	29	0.45313	45	0.70313	61	0.95313
14	0.21875	30	0.46875	46	0.71875	62	0.96875
15	0.23438	31	0.48438	47	0.73438	63	0.98438
16	0.25000	32	0.50000	48	0.75000	64	1.00000