Table 1: Keel-Cooler External Surface Area per Installed Power
Up to 85°F (29.4°C) Seawater Temperature

Steel, painted, ¼"–5⁄16" (6.3mm–8mm) thick	Surface Area		
	sq ft/bhp	m²/bhp	m²/kW
Generators and stationary vessels (dredges, etc.)	1.00	0.093	0.125
Slow-moving vessels (towboats, etc.)	0.50	0.046	0.062
Free-running vessels, under 8 knots	0.40	0.037	0.050
Fast free-running vessels, over 8 knots	0.34	0.032	0.042
Aluminum, painted ¼"–5⁄16" (6.3mm–8mm) thick	**Surface Area**		
	sq ft/bhp	m²/bhp	m²/kW
Generators and stationary vessels (dredges, etc.)	0.60	0.056	0.075
Slow-moving vessels (towboats, etc.)	0.30	0.028	0.037
Free-running vessels, under 8 knots	0.24	0.022	0.030
Fast free-running vessels, over 8 knots	0.20	0.019	0.025
Copper or Copper-Nickel Tube, unpainted	**Surface Area**		
	sq ft/bhp	m²/bhp	m²/kW
Generators and stationary vessels (dredges, etc.)	0.21	0.020	0.0262
Slow-moving vessels (towboats, etc.)	0.15	0.014	0.0183
Free-running vessels, under 8 knots	0.12	0.011	0.0147
Fast free-running vessels, over 8 knots	0.10	0.009	0.0125

Table 2: Ke
Copper or Cop
Up to 85°F (29
Round Tube Ap

Tube OD, in	
1⅛	1.13
1	1.00
⅞	0.88
¾	0.75
⅝	0.63
½	0.50
⅜	0.38
5⁄16	0.31
¼	0.25

Notes: (a) Tub
flows freely ar
(b) Square tub
of round tube.

Required Cooling Surface Area

Regardless of configuration, keel cooling is a heat-transfer process, and the surface area required for adequate cooling—heat transfer—will vary depending on: the thermal conductivity of the material (steel, aluminum, copper); the material's wall thickness; the flow rate of water passing over the outside of the cooler and through the inside of the cooler; and the outside seawater temperature. Paint reduces effective heat transfer, as does fouling from marine growth. On steel, rust and mill scale further reduce efficient heat transfer.

Accordingly, painted steel requires more area than painted aluminum (including allowance for some fouling), while unpainted copper or copper-nickel tube requires less area than either steel or aluminum. Not only is the copper-nickel tube wall generally thinner than steel or aluminum hull plate or standard structural shapes, and not only does copper have the highest thermal conductivity, but both copper and copper-nickel are non-

Table 3: Keel-Cooler Tube Length: cm/bhp a
Copper or Copper-Nickel Tube up to 29.4°C (85°F) Seawa
Round Tube Approx. 1.5mm–2.5mm Wall

	Generators and Stationary		Slow-Moving		
Tube OD, mm	cm/bhp	cm/kW	cm/bhp	cm/kW	cm
28	10.6	22.2	29.7	15.5	
27	11.0	23.0	30.8	16.1	
26	11.4	23.9	32.0	16.7	
25	11.8	24.8	33.3	17.4	
24	12.3	25.9	34.7	18.1	
23	12.9	27.0	36.2	18.9	
22	13.4	28.2	37.9	19.8	
21	14.1	29.6	39.7	20.7	
20	14.8	31.0	41.6	21.7	
19	15.6	32.7	43.8	22.9	
18	16.4	34.5	46.3	24.1	
17	17.4	36.5	49.0	25.6	
16	18.5	38.8	52.0	27.2	
15	19.7	41.4	55.5	29.0	
14	21.1	44.4	59.5	31.0	
13	22.7	47.8	64.1	33.4	
12	24.6	51.7	69.4	36.2	
11	26.9	56.5	75.7	39.5	
10	29.6	62.1	83.3	43.5	
9	32.9	69.0	92.5	48.3	
8	37.0	77.6	104.1	54.3	
7	42.2	88.7	119.0	62.1	
6	49.3	103.5	138.8	72.4	
5	59.1	124.2	166.6	86.9	

Notes: (a) Tubes should be mounted so seawater flows f
(b) Square tube can be 78% of the length of roun

fouling and therefore require no paint.

Table 1 gives recommended external surface areas for keel coolers of various materials and at different boat speeds.

Length of Tubing for Required Surface Area

Integral tank keel coolers are not installed on wood or fiberglass boats; instead, what is specified for those boats is external tubing (which is most common on metal hulls as well). The length of round tubing or pipe required can be sized from the charts above using the standard formula for the circumference of a circle:

Circumference = π x dia.

Where:
π = 3.14
dia. = tube's outside diameter in inches

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