BETA MARINE

Keel Cooling Tank Design For Narrowboats

Introduction

Due to the nature of narrow boats and the conditions that they operate in, by far the most popular way of cooling the diesel engine is through "keel" coolers. These are usually just a double skin of steel boxed onto the side of a narrow boat. The design of these is very important, due to the amount of heat that needs to be dissipated. A typical modern diesel engine is roughly 30% efficient which means that fuel, when combusted in the engine, only uses 30% of the heat for power and the rest is not utilised, 40% goes through the exhaust and 30% into the coolant. When put into context a typical engine producing 10 kw:

10 kw of heat is taken into the cooling system, the slower the engine runs the less heat needs to be dissipated. For example a Beta 43 produces 43 bhp at full speed which equates to 32 kw therefore at full speed roughly 30 kw of heat must be lost through a steel surface that has been "insulated" with thick paint on the outside. In order to loose such a large amount of heat through what is a thick painted surface means it requires a large area.

The most important factors to consider when designing a keel cooling tank for a canal boat are:-

(a) The surface area of the tank in contact with the cold water out side the boat;

(b) The ability of the tank design to ensure that all the water passing through the tank is forced to make contact with this cold surface and cannot take a "short cut";

(c) The total volume of the system and the effect on expansion.

Based on calculations and our experience, we have concluded that the best keel cooling tank for a canal boat should be vertical and built into the swim. The tank should be slim preferably 30-40mm, with the inlet at the top one end, and the outlet at the same end but at the bottom, making sure that there is a bleed screw at the highest point. This tank has a baffle dividing it into two parts and forcing the water to flow round in a U shape. This baffle should be continuously welded to the outer plating to give good thermal conductivity and as tight a fit as possible to the inner side of the tank. A simple baffle is preferred so as to keep the restriction placed upon the engine circulating pump down to a minimum, allowing maximum flow of water across the cooling surface. **Vertical tanks are preferred** as they maintain the maximum amount of contact with the outer surface, base tanks are less efficient, due to the fact that the hot water remains at the top of the tank away from the cold base , however they can be made more efficient if they are kept to a minimum depth of 30-40 mm, utilising the same baffle system as the vertical tank, and by welding “fins” to the base before manufacture this type of tank can be even more efficient. The attached drawings show the preferred designs.

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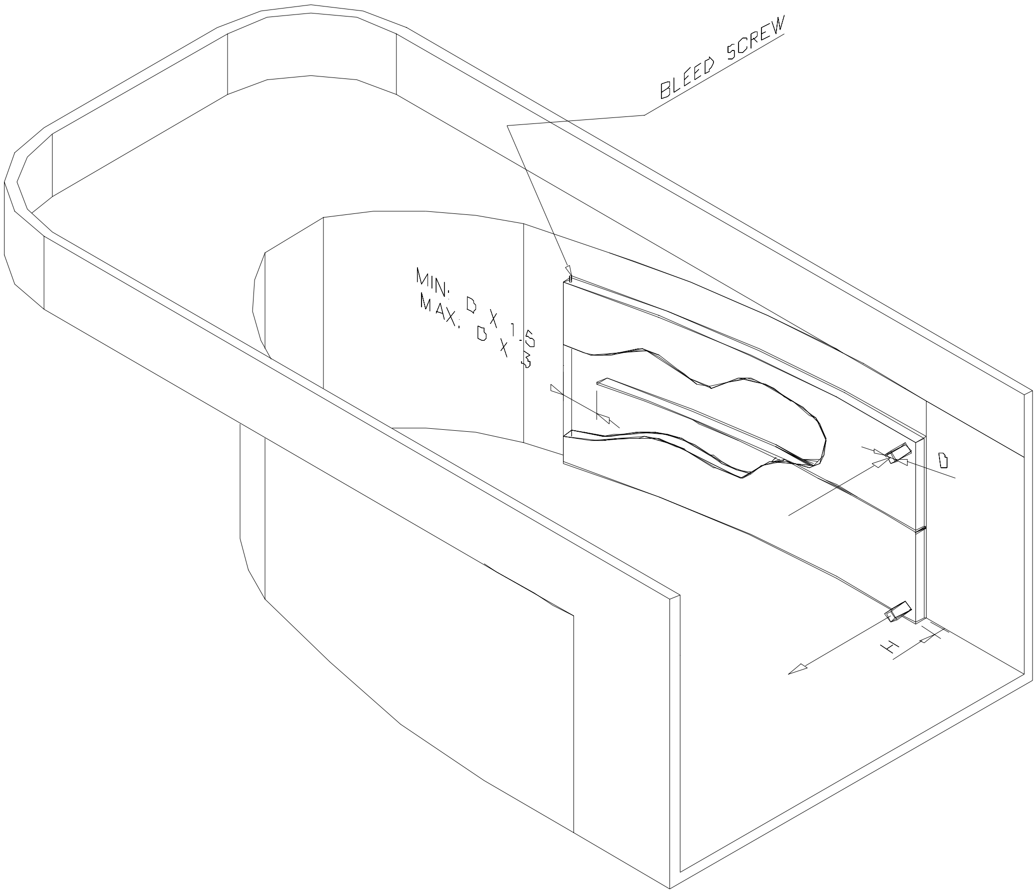
Vertical tank



Calculations

The surface area of the outer skin which forms one side of the tank should be sized as follows:

This rule is based on a ***steel hull***:

$\frac{\text{Engine bhp}}{4}$ = area in square feet (Engine kw / 32 = area square metres)

For ***aluminium boats*** we can use the following rule, because aluminium has a higher thermal conductivity, the cooler size may be smaller.

$\frac{\text{Engine bhp}}{5}$ = area in square feet (Engine kw / 40 = area square metres)

This gives us the following areas for the Beta range of engines:

Beta Engine		Steel ft²	Alumnium ft²
	BZ482	3.5	2.5
	Beta 16	4.0	3.2
	BD722	5.0	4.0
	Beta 25	6.3	5.0
Beta 28	BD1005	7.0	5.5
Beta 35	BV1305	8.8	7.0
Beta 38	BV1505	9.5	7.5
Beta 43	BV1903	10.8	8.5
Beta 50	BV2203	12.5	10.5
	BF2803	15.5	12.4
	BV3300	18.8	15.0
	BV3800	22.5	18.0
Generating Sets			
	BetaGen 7	4.0 (twin)	3.5 (twin)
	BetaGen 11	6.3 (twin)	4.5 (twin)

This area assumes that the engine is developing its maximum continuous power at full engine rpm and it is therefore what we recommend. In practice much smaller areas have been used without overheating and this is possible due to a number of factors which effect the engine. These are:-

(a) The power used by most boaters when cruising on the canal is considerably less than maximum;

(b) Many canal boat engines are over propped and are incapable of reaching their maximum rpm and therefore power even on a river.

A typical example is as follows:-

Greenline 38 in a 50 footer

Maximum attainable rpm 2500 (over propped)

HP at maximum rpm = 25 continuous

$\therefore$cooling area required = $\frac{25}{4}$ = 6.25 square feet

Cruise rpm = 1400

Using the propeller law curve the engine output will be approximately 10/11 bhp

$\therefore$area required at cruise rpm = $\frac{11}{4}$ = 2.75 square feet.

These figures show that the slower the engine runs the less area is required to cool it. Overheating problems usually occur when the owner takes his boat on the river for the first time, and these figures show the big increase in cooling area required as the power goes up.

Expansion

We favour slim tanks, as they give much better mixing as described above but just as important, less expansion. When water heats up its density drops thus increasing its volume, a typical water antifreeze mix of 30% at 10°C has a density of 1043 kg/m^3, this falls to 1005 kg/m^3 at 80°C (a typical engine running temperature). This is approximately 4% difference in volume, and so for a 10 gallon system the expansion is around 3 pints, therefore provision is required for expansion of 3 pints, if not the water is lost through the overflow, and has to be replaced each time the engine cools down.
So the larger the cooling system the larger the expansion. The objective must be to keep the volume of the total system as low as possible using a slim line tank.

Generating Sets

Generating sets can be considered by using the formula = $\frac{\text{power output (kW)}}{1.75}$ =area ft^2

It is advisable to have twin tanks when cooling a generating set as the duty of a set is generally when the boat is moored, which can be against the bank thus stopping any cooling water from getting to the outside surface.

Conclusion

(1) We recommend that all boats should be given a run on a river or tied up at maximum rpm for at least 1.5 hours to ensure that their propeller/keel cooling tank combination is OK.

(2) Use a slim tank with one baffle as described.

(3) Use twin tanks when fitting a Generating set, both tanks to be of full size.