Keel Cooling Tank Design for Narrowboats

Introduction

Keel cooling is available as an option with all our engines. Most narrowboats on English canals have keel cooling. Some estuaries and ports have fine silt and mud that blocks normal heat exchanger cooling systems, requiring a keel cooling solution; this can be also relevant for some work boats, etc.

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, 30% goes through the exhaust, 30% into the coolant and 10% radiated from the engine itself.

When put into context, a typical 50 or 60 foot narrow boat fitted with our Beta 43 engine produces 43 hp / 32 kW at full load and speed of 2,800 rev/min.

At the same time, this engine also produces 32 kW of heat into the cooling system. This heat flows to the keel cooling tanks and is transferred through the steel hull and the 'insulated' thick painted surface, into the canal or river. In order to loose such a large amount of heat through what is a thick painted surface means it requires a large area. (However, when cruising the canals and rivers the narrowboat will probably cruise at about 1,800 rev/min, creating correspondingly less heat that needs to be lost).

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 outside the boat.

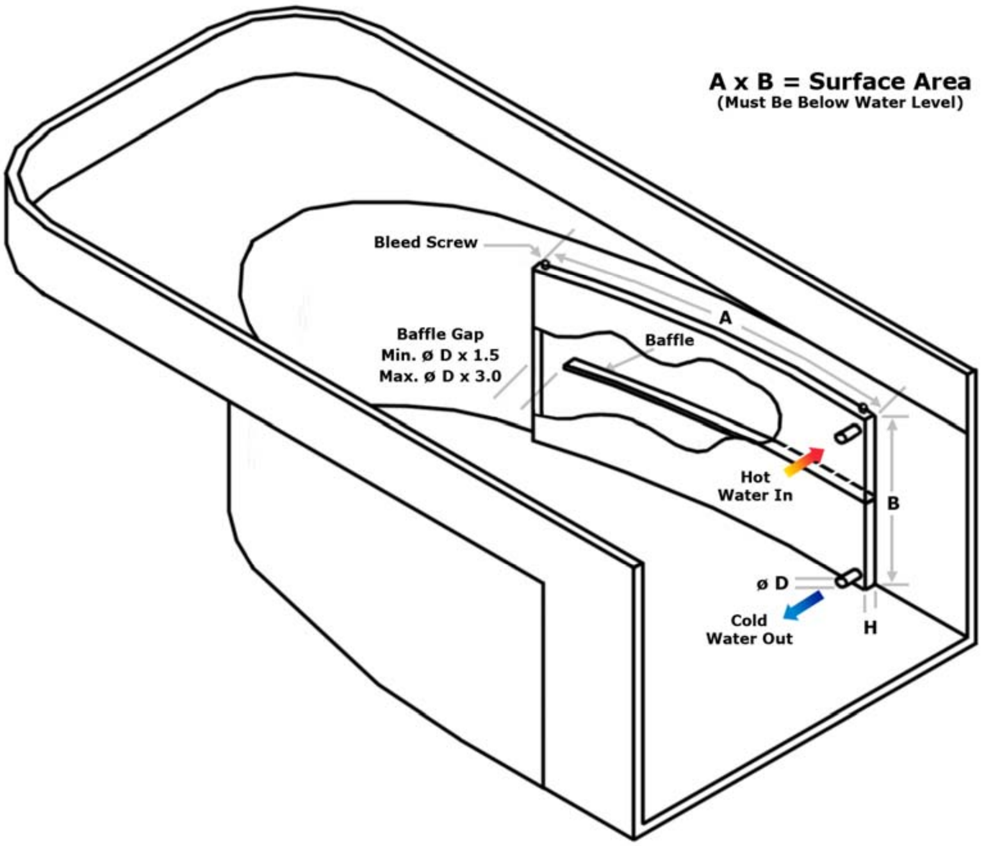
(b) The ability of the tank design to ensure that all the water passing through the tank is forced to make contact with this cold surface and cannot take a "short cut" - a baffle is normally needed.

(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. For engines up to 100 hp the tank should be slim preferably 30-40 mm, (for the Beta 120 and Beta 150 the keel cooling tank should be preferably 50-75 mm) 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 forces the water to flow round in a U shape. This baffle should be continuously welded to the outer plating of the hull 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 /outer hull, 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 drawing shows our preferred design.

Vertical tank



Calculations

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

Steel

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

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

Aluminium

\- 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 ($\frac{\text{Engine kW}}{40}$ = area square metres)

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

Beta Engine		Steel ft^2	Steel ft^2 hydraulic drive	Alumnium ft^2	Alumnium ft^2 hydraulic drive
Beta 14	BZ482	3.5	4.5	2.5	3.2
Beta 16		4.0	5.2	3.2	4.1
Beta 20	BD722	5.0	6.5	4.0	5.2
Beta 25		6.3	9.4	5.0	6.5
Beta 30	BD1105	7.0	9.1	5.5	7.1
Beta 38	BV1505	9.5	12.3	7.5	8.2
Beta 43	BV2003	10.8	14.0	8.5	9.3
Beta 50	BV2203	12.5	16.2	10.5	13.6
Beta 60	BV2403	15.5	20.1	12.4	16.1
Beta 75	BV3620	18.8	24.4	15.0	19.5
Beta 90	BV3800	22.5	29.2	18.0	23.4
Beta 105T		25.0	32.5	20.0	26.0
Beta 150		37.5	48.7	30.0	39.0
Generating Sets					
BetaGen 10	BD1105G	4.0 (twin)		3.5 (twin)	
BetaGen 12	BV1505G	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 / power, even on a river.

Main Hydraulic Drive (not just hydraulic bow thrusters)

A total hydraulic drive system has the big advantage of allowing the installation of the engine /hydraulic pump unit – anywhere in the narrow boat. However a totally hydraulic drive is a lot less efficient than a mechanical drive. We therefore recommend that you increase the ‘cooling’ surface area of the ‘Skin Tank’ by about 30 percent.

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.