

DIRECT OIL COOLING...PART 1



Learn a lesson from a rusty reel!

Keep your car's engine clean and free-running to **UNLOCK HORSEPOWER**

Few men will let a reel rust or corrode to where it causes backlash. Yet many let the same thing happen to their car engines. For, like rust on a reel, engine deposits cause friction that binds vital parts—steals power, wastes gasoline, promotes costly wear.

Pennzoil with Z-7 disperses these harmful contaminants, lets *the Tough Film*® lubricate completely—unlocking horsepower for instant response, better gasoline mileage.

For summer, change to Pennzoil with Z-7 and *feel* the difference!

Sound your **Z** for the **LONG QUART**

NOW with Z-7 the POWER INGREDIENT

PENNZOIL
the Tough Film
MOTOR OIL

Switch now at this sign . . .

BETTER DEALERS IN EVERY STATE FEATURE PENNZOIL® PRODUCTS

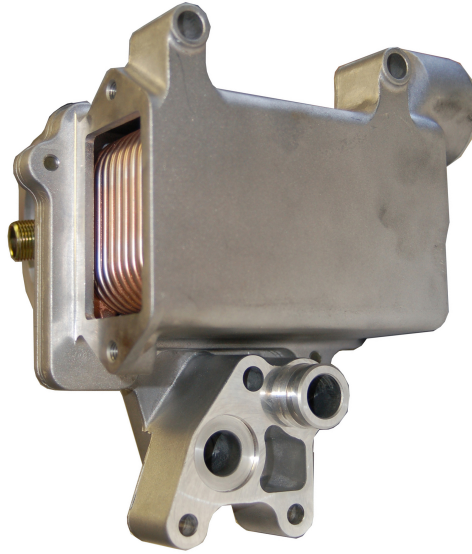
© 1955, The Pennzoil Co., Oil City, Pa., Member Penn. Grade Grade Oil Assn., Permit No. 2



SUMMER is over, the fish are in the freezer, and with that, it is time for my annual reel cleaning and vehicle servicing regimen; an oil change is always part of it. I am reminded of what that oil went through on all those fishing trips. It all started with a realization that my thermo viscous fan should not be such a common occurrence. I would be flying seemingly effortlessly up steep mountain grades with my big camper load, on a 103 degree Arizona day, in air conditioned comfort, and in complete complacent silence, dreaming of bass boils. Then I awoke eyes wide and startled, to the sound of a 747 landing on top of me...THAT FAN!

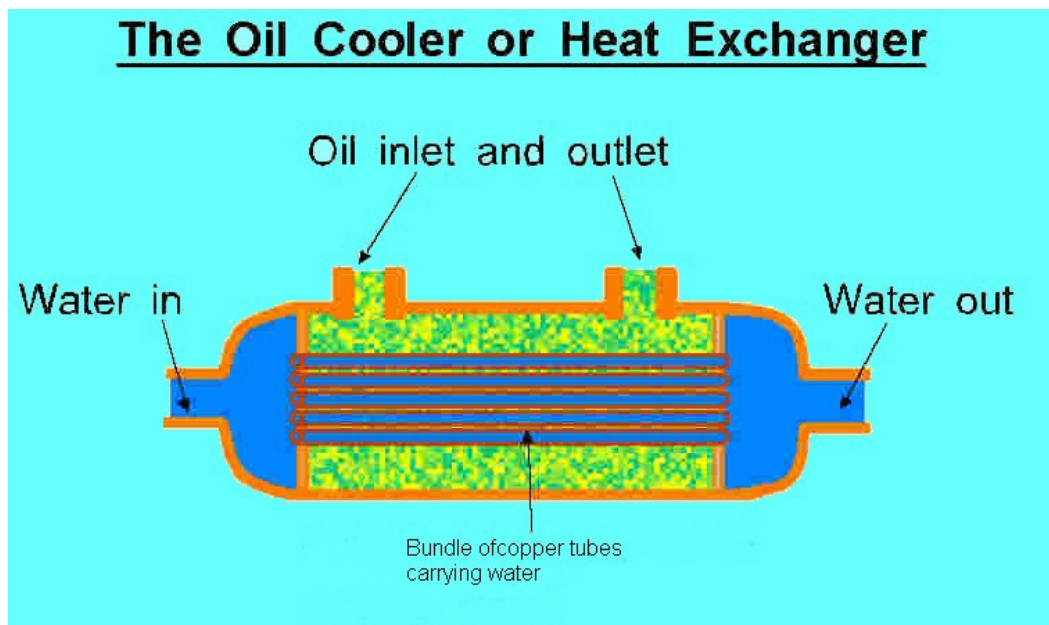
I just wanted to silence that fan, and all heat issues it was the aural signature of. I remember the first time I heard it, going 70 mph on slight rising terrain with NO load. On a 114 degree sunny day, it doesn't seem to shut off. Adding insult to injury I know I am losing 2-3 mpg whenever it is in full spin. I have heard the statement "that fan is normal, be glad you have it" a hundred times. I am glad. Glad I don't have to believe that any more. What if I said that you are an oil overheater, and you have never seen it? Crazy am I? Do you have an oil temperature gauge? If you knew what your oil temp was when you towed through my back yard, you would own one. The oil overheats on every summer camping trip. Presently, oil is cooled indirectly at the stock engine mounted oil-water cooler. Oil heat must be

conveyed to the coolant, then to the radiator, then to the atmosphere, making it *in*-directly cooled.

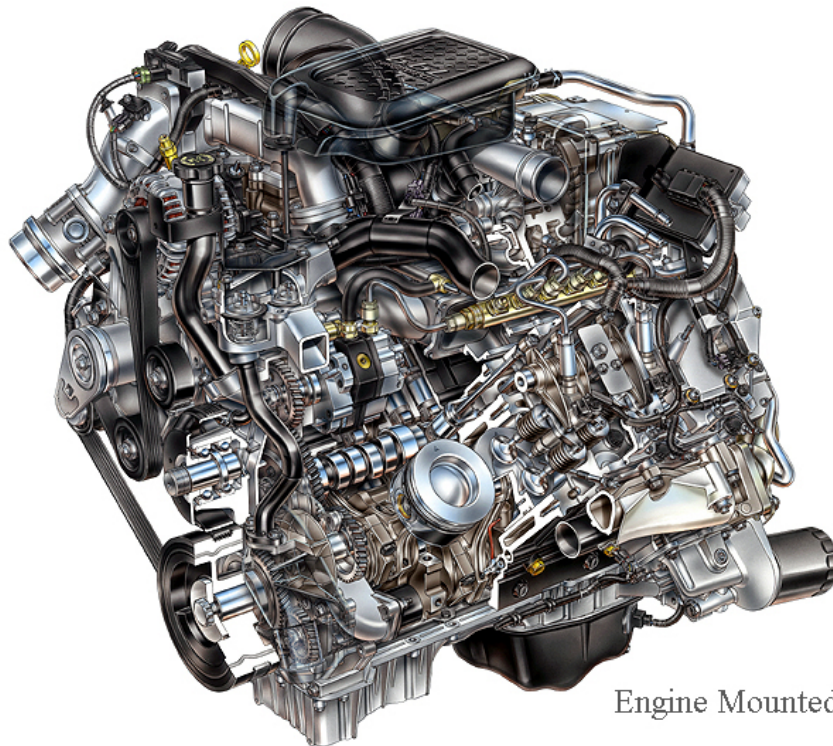


Stacked Plate Duramax Coolant-to-Oil Heat Exchanger

If it looks unfamiliar, you are looking at the side that fastens to the motor. The coolant passes over a series of plates which contain the flowing hot motor oil. On the far side (left), the filter thread is visible. This heat exchanger mounts to the driver's side motor and houses the filter element. The oil inlet and outlet are the parallel ports on the bottom. The coolant comes straight from the water pump and enters on the upper right, and emerges at the large plate opening at the left. Simplified, it looks like this:



On the cutaway below, it is bolted on to the lower right, filter attached.



Engine Mounted Cooler

HEAT TRANSFER FOR DUMMIES

We should look at what is expected of the oil. But before we do, it will be helpful to understand the cooling system first, since oil interfaces with the coolant in that heat exchanger. The cooling system either rejects the heat the motor produces or it doesn't. If coolant rises 15 degrees in the motor, it must be cooled 15 degrees in the radiator. When it doesn't, engine coolant temperature, ECT, rises over time in direct correlation with the cooling shortage, until, once again, the heat offloaded equals the cooling system heat generated. To demonstrate, consider the motor as a single mass of 1000 lbs, with an average heat capacity of .20 BTU/lb/F. If ECT rises at a rate of 5 degrees per minute to the overheat stage, then the shortage can be easily calculated. The simple formula is:

$$Qdot = Mdot * Cp * \Delta T.$$

Q is the heat in BTU's per hour

M is the flow rate of the coolant or oil, usually pounds per hour.

Cp is the fluids capacity for holding heat energy, specific heat.

DeltaT is the temperature change of the coolant or oil.

$$1000 \text{ lb} * .20 \text{ (BTU/lb/F)} * 5 \text{ (F/min)} * 60 \text{ (min/hr)} = 60,000 \text{ BTU/hr}$$

If ECT rises doubly 10 degrees per minute, instead of 5, then the radiator heat rejection deficit is also double, 120,000 BTU/hr.

Because of limited airflow, an aerodynamic reality, the rejection ability for the OEM radiator on a hot day is around 400,000 BTU/HR (Qdot); add 30,000 if the AC is off. But at times of extended high loads we need more like 500,000. Just take 80 gpm of coolant that weighs 8.3 lb/gal, and a heat capacity of 0.8 BTU/lb/F, and some quick math, solve for deltaT in the formula above and we get 16 degrees. All the radiator has to do is cool the coolant 16 degrees. *“Can that be so challenging?”* Perhaps considering that a drop of coolant spends exactly 0.75 seconds in the radiator, sure, that is a challenge. Even worse, that uphill bound 60 mph air parcel is slowed down 82%. A 65 mph vehicle speed produces, at best, 11-12 mph kinetic airflow over the radiator. And this reduced quantity of cooling air is heated up significantly, before ever reaching the radiator, in cascade fashion, by:

1. transmission cooler (4 F), then
2. the AC condenser, (12 F), and finally
3. The Charge Air Cooler (48 F with stock boost, 95 F with augmented boost).

On a 100 degree day, the little air that even makes it to the radiator is at a nicely pre-heated 164 degrees! (Ref 1.) Does this make the challenge more clear? **Item 3 is such a variable, I have dedicated an entire article to it. You can see that [HERE](#).**

Yet the only difference between the vehicle that overheats, and the one that does not, is often only 2 degrees coolant temp exiting the radiator. Yes, 2 degrees is 60,000 BTU/hr, and that’s all we have to come up with to make a noticeable difference.

THE RESEARCH

As a simplified model, this is easy to understand. Since it is not likely that we can get the radiator to do much better, we are left with adding capacity to the shortage, right? Well, yes, but how shall we do this? Which coolant shall we build capacity upon?

(“yes he has been drinking anti-freeze again, there is only one ‘coolant’, albeit green, yellow, Orange-red... not amber!”)

Actually, in today’s high performance motors there are 2 coolants, both equally important in the transport of combustion heat away from the motor. Water **and** oil. The water half is fairly well understood already. Oil on the other hand, is underrepresented, relegated to simple lubrication duties, yet it is now much more.

Note: I am using the term “water” here, since a 50/50 coolant mixture takes on most of water’s thermal properties. Also, the term “coolant” will now apply to BOTH water AND oil in this article.

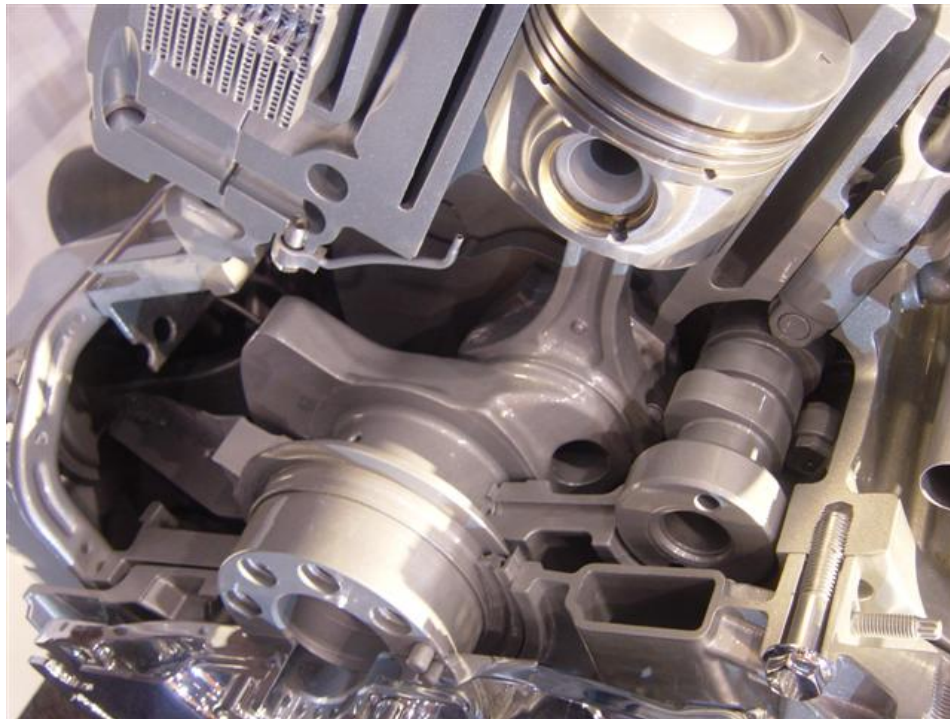
From SAE Study 2001-01-1073 Engine Lubrication System Model for Sump Oil Temperature Prediction, Steve Zoz, and Steve Strepak et al:

“The typical approach to engine design has been that very little thought is given to oil temperature and oil cooling until engine dynamometer or vehicle testing has uncovered a *problem*”

“Energy into the oil-The two primary energy transfers to the oil are from combustion and from friction, though energy also enters the oil through contact with blow-by gases...the combustion contribution arrives in the oil through two paths: 1) convection to the piston, conduction through the piston, and then convection to the oil at the rings, under crown and skirt, and 2) convection to the bore wall, conduction down the bore wall, and convection to the oil at the lower portion of the bore.”

“The addition of oil squirters was modeled by increasing both the oil flow rate to the under crown and the under crown convective heat transfer coefficients. “

Under piston flooding has indeed changed the role of oil as a coolant, doubling and tripling piston heat removal through oil transport on many vehicles. You can see one just under the piston. What you can't see is the internal piston design. Oil shoots up and disperses internally, saturating a large area in its conduction and convection role.



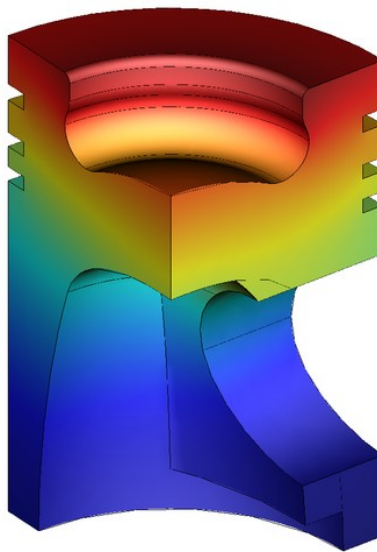
Piston oil squirter shown

Internal Combustion Engine Handbook p. 283

“For engines with high specific output, piston cooling is now indispensable. Lubricating oil is diverted from the main flow and injected through injection nozzles against the underside of the piston or into piston cooling channels for the piston cooling. *Pressure controlled valves prevent heat being unnecessarily drawn from the piston when the engine, and hence oil, is cold...* “

Unfortunately, this pressure gated strategy of regulating under piston flow is flawed. As stated, a threshold minimum pressure enables under piston cooling. With a given viscosity, this pressure will be strictly rpm dependent, as pressure increases with flow rate. Low pressure at low rpm, and vice versa. In design phase, the assumption was made that low RPM is equivalent to low load and low thermal stress. Good enough. But as we know, viscosity (and oil pressure) drops quickly as oil rises above this design temperature. **This drop in pressure has the detrimental effect of reducing or closing off cooling oil flow to the squirters when it is needed most, an odd design paradox.** See our problem now: a bit of a self destruct mechanism. Oil temperature control resolves it, bringing pressure back to its design point by restoring the intended viscosity to the oil. This is extremely important to piston life.

Thermograph images of a typical TD piston, show that the piston underside is approximately 250-400 F lower than top surface temperatures. With a 1200 F EGT run, this places oil in direct exposure to 500+ degree surfaces in high load conditions. Now you can tell anybody who disputes it, oil is indeed a coolant, which MUST, in turn, be cooled.



Diesel Piston Temperature Distribution

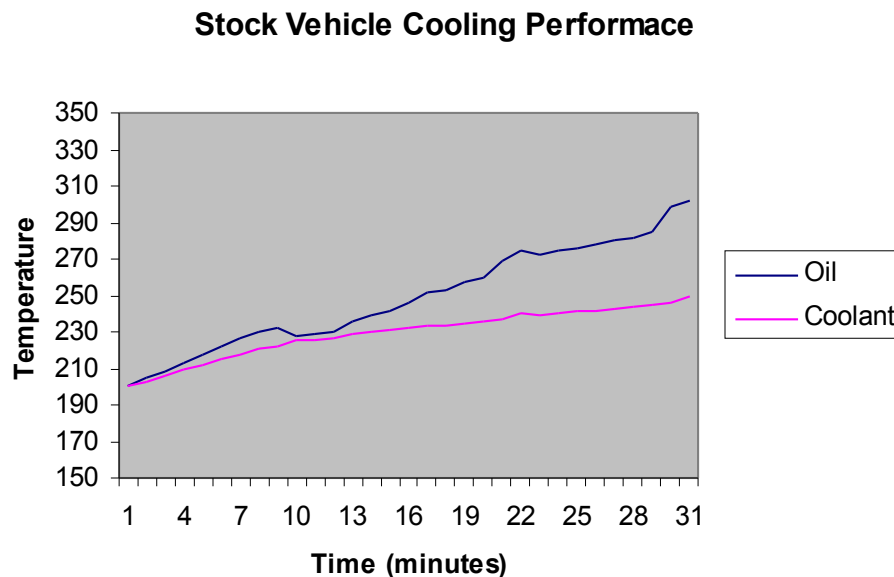
The most notable test result was the effect of RPM on oil temperatures. The effect of doubling RPM, **with no additional workload**, raised oil sump temperatures 54 degrees! This is explained with a couple of phenomena. There's more friction, obviously. But also, oil flow rate (and thus heat transfer) rises almost linearly with RPM. In contrast, the lossy nature of centrifugal water pumps does not afford the same capability. In point of fact, most water pumps realize reduced flow rate at redline rpm, due to low pressure suction and partial cavitation anomaly. This is also the case with the Duramax water pump.

So while oil flow increases sharply with rpm, water flow stays flat or even reduces moderately. This increase in oil flow increases the oil's heat transfer coefficient (a fancy way to describe less resistance to conduction) significantly, while the water's heat transfer coefficient declines, if anything, after peak pump rpm is reached. Plainly stated, at higher rpm, the proportionate role of oil as a coolant increases significantly.

"So what? All the oil's thermal energy is dumped into the water, at the OEM cooler, correct?"

No. The best standard industry-wide efficiency for this heat exchange device is 80%. That means at least 20% of the energy picked up by the oil in the motor does **not** transfer to the water, leaving the oil warmer than the water on each cycle.

"what does this mean?"



The oil continues to rise in temperature with high RPM's and workload, until it becomes such a thermal burden at 80% heat exchange, that water cannot contain it at the 210 degree regulated water temperature. Under load, oil temps heads north of 280 F before there is any sign of trouble on the ECT gauge. 280 degrees. It gets much worse, up to 380 degrees at coolant purge stage. 380 degree oil, after all, will do a job on the

temperature of anything at 210 degrees, and it can't stay that way for long. This is the downfall to indirectly air cooling the oil with water, regardless of radiator capacity.

But back up a bit. This is NOT a liquid cooled vehicle. Boats are liquid cooled. Cars are **air-cooled**. ALL CARS! No I haven't been sniffing VW exhaust. True we use coolant, but the coolant only *transports* all the heat to the radiator for release to the air. Coolant is just the transport component. Liquid-to-**air** heat exchange is the only way this vehicle stays cool, (aside from a small radiation factor). Only 30% of the fuel we burn performs work. The rest is wasted as heat. Of the 70% of waste combustion heat that does not perform wheel work, 30% must find its way to the atmosphere via the radiator. Offloading oil heat into the coolant does not help this cause, nor does it effectively cool the oil, if expectation is oil at 205 F, the optimum oil temperature hydrodynamic lubrication and oxidation resistance. 275 F is the max spec. For conventional oil, this is at a point where lubrication is still significant, though quite degraded. The cooling media (water) itself is at 200 F. We know the engine mounted cooler can not get close to 100% efficiency, so, with the exception of warm-up, the oil will always leave the cooler at a higher temperature than the coolant. (And, by-the-way, water will always be heated by the oil also, let's not forget what we are seeing past our white knuckles on that ECT gauge.)

Back to our 60,000 BTU/HR need. We have to make a choice. Cool the oil or the water?

The water, under the best hi-altitude circumstances, boils at 260 F under pressure. But just as bad, when it gets to 244 F (248 F on some vehicles), it commands the motor to start killing power through a phased in PCM (ECU) defuel schedule. That's only 20-30 degrees past where the thermostats are regulating the water.

On the other hand the PCM could care less what my oil temperature is. (A little secret: GM doesn't either, as long as there is oil, if they cared, they would give us an oil temp gauge). The D-max oil is seen at 350-400 degree local oil temps in some cases, well above the spec maximum, and certainly in the "worthless lubrication" category.

So on to answer the question: Which option will give me a better temperature differential for heat exchange with 100 degree air? The 350 degree (oil), or the 240 degree (water)? You may know the answer by now. It is oil. Tip: get a gauge that goes to at least 280 F, 320 F is even better.



Next time, I plan to explore the lube system capabilities a little more; we'll look at more oil limitations and I will make specific recommendations to fix the issue of oil overheating, including a well respected oil cooling system. I will also explain how this can be done, while decreasing the performance robbing fan activity, by finding another air source that does not depend on the fan, nor requires the addition of electric fans.

PART 2

Last time, the role of engine oil, as a coolant, was studied. Cooling was broken down to direct and indirect methodologies. Ultimately all vehicles are air cooled, using oil and water media to transport heat to the atmosphere. It was shown that indirect cooling, using water as the interim heat transfer medium, suffers efficiency limitations that permit oil temperature to rise unrestrained at high combined work loads and rpm. Direct cooling, by contrast, is necessary to control oil temperature, viscosity, and flow rate to design spec limits in these same conditions. Under piston oil squirting has shifted more of the Turbo Diesel total cooling burden to the oil, up to 50%. It has become necessary to introduce alternative oil cooling methods to compensate for the added heat load carried by oil, an issue that the manufacturer has not been very attentive to.

With the observation of worst case oil temperatures exceeding 360 degrees, and resultant curb level oil pressure, what are the symptoms and pitfalls of running oil temperature this high? How does this all correlate to excessive fan operation, and other heat related problems, and how can we fix it?

A MYTH PUT TO REST

In the cooling system world of heat exchange, it is common knowledge that a pound of water holds more heat than a pound of oil, 40% more. There has been plenty of emphasis on this point by advocates of indirect oil cooling. These versed “experts” want you to think that because water has higher heat carrying capacity, then it must always be the best heat transfer medium. The same knucklehead will quickly follow-up, quoting typical flow rate differences between oil and water. Here is a new concept.

E.N.E.R.G.Y. B.A.L.A.N.C.E.

Seen in Part 1, this familiar simple formula applies to every radiator, TOC, oil cooler, fuel cooler...basically all heat exchange systems in steady state equilibrium. It describes the heat energy exchange, Q,

$$Q\dot{=}M\dot{C}_p\Delta T$$

Q is heat which is transferred between the applicable mediums, water to air, or oil to air.

M is the quantity of the cooling media,

C_p is the heat capacity, a constant for each medium.

Delta T is simply the change in temperature of the medium during the heat exchange.

“dot” notation just represents that this is a rate equation, happening over time, in a closed loop system.

With most of these equation variables fixed by design, heat (Q or Qdot) exchange is reduced to deltaT, or ITD, the Inlet Temperature Difference between **air** and the selected coolant. With respect to heat transfer, ITD is the *driving force* behind heat exchange, analogous to pressure, in your garden hose, or voltage in your house circuits. Want brighter light, just turn up the voltage. Want more heat rejection, increase deltaT. If deltaT is zero, of course heat exchange is zero.

In the case of our energy balance, the maximum theoretical delta T is ITD. On a 100 degree day, ambient air passes over the AC condenser and the intercooler first, and heated to 164 F before it sees the radiator. So for the purpose of heat exchange, the air effectiveness is somewhat reduced because of its increased heat state, before it ever reaches the radiator. This reduces the all-important ITD driving force, reducing it by 64 degrees, a review of Part 1. Simply put, the radiator is at a disadvantage with its placement downstream of the CAC and condenser.

ITD

OIL: The ITD between 164 degree air and hot 320 F oil is..... **156 F**.

WATER: For the air and 220 degree water, it is..... **56 F**.

156 F (oil) ITD vs. 56 F (water) ITD, or a 3 fold difference in heat exchange driving force.

Adhering to the governing tenant that energy is neither lost nor gained, but conserved, the First Law of Thermodynamics. ***All heat, Q, shed by the water (or oil), is picked up by the air.*** Stated another way, the Q lost by the oil or water, must equal the Q gained by the **air**, our energy balance,

$$Q_{\text{coolant}} = Q_{\text{air}},$$

and since $Q = M \cdot C_p \cdot \Delta T$, then

$$(M \cdot C_p \cdot \Delta T)_{\text{coolant}} = (M \cdot C_p \cdot \Delta T)_{\text{air}}$$

Remember “coolant” in the equation refers to either water OR oil. Each transports heat in it’s own closed loop. This equation has **2 sides**, meaning either side, if limited, will limit heat exchange of the other side, since they are equal. If all this geek math scares you, we’re done with it. It is safe to breath. The underlined section is important to take away.

So, if the **air** is limited in either quantity or thermal heat carrying capacity, the ability to cool the coolant, is LIMITED. 50/50 can carry 0.8 Btu/lb-F, Oil can only carry 0.5 Btu/lb-F. So a pound of oil can transport only about 2/3rds the thermal energy of 50/50 coolant. This is what Mr. Argumentative was trying to say. And there is no disputing it. The problem is, it doesn’t matter, and it is vitually irrelevant. Why? Because the **air side**, as stated, is used in each case to carry the heat away. Air has only 0.25 BTU/lb-F for heat capacity, and a pound of air is a LOT of air. **Quantify** You need a house size parcel of **air** to equal the heat carrying capacity of a few gallons of hot dense liquid.

Airflow through the fins is always limiting and is always the biggest challenge and always comes up short, on heat removal, of what the liquid side can supply. The more air you can move, the more effective heat removal becomes. This is why we have a fan. Without it, the radiator would have to be a much larger monstrosity than it already is.

The air exiting the cooler/radiator can only approach that of the water/oil. IOW, the **air** can/will get warmer with oil that is 320 degrees, vs. water at 220 F, hence will carry more heat away, higher Q. Specific heat carrying capacity (Cp) differences between oil and coolant really **do not** factor in here, because we don't have unlimited **air** flow, which is saturated with heat in either case. In the case of water coolant, the theoretical highest we will see air get is 220 F, because that is the highest temp coolant we can allow. With oil that could be 320 F, air can get to 320 F. And if the same limited size air parcel must do the job in each case, then 320 F air is carrying away more heat (driving force). All that matters is the right hand side of the equation, the **air** side of the "energy balance". It limits the left side. That "deltaT" difference alone governs all **AIR** cooled heat exchangers. I don't care how much ranting and raving you can do, or how good you are at selling used flip-flops. As long as air is in this shortage condition, all other properties are mute.

Beware of fantastic sounding claims of doubling cooling system rejection ability. Bull salsas! That requires a minimum doubling in airflow. Also, beware that you would ever have to add multiple fans, to eliminate the noise of one. It's a cover up for poor design considerations, to the detriment of the electrical system. Stressed alternators fail prematurely in today's high heat environments due to electrical overload conditions. Just 2500 cfm from an electric fan requires 50 amps in this atypical resistive cooling stack, a multifunction cooling fin sandwich that is 8" thick. A 50 amp accessory, in a system with just 100 amps to run the entire vehicle, will overtax the electrical system. This should not be overlooked, if even only used on an intermittent basis. An "improvement", like a remotely mounted fanned radiator, is not a well thought out solution to a relatively simple science problem. Airflow is the only shortage, and a fan is a poor approach when you have a moving vehicle with all kinds of 70 mph kinetic energy to tap. The next time you stick your head out the window running 70 mph, and inflate your lungs, remember the fans you have seen and what they do.

Note: You are never told by the electric fan manufacturer that the flow rates they have quoted are measured in zero resistance test platforms. If you have a fan that is suppose to pull 3000 cfm with 18 amps, trust me, when integrated and shrouded in front of the heat exchanger, you will be lucky to get 1200 cfm with a 20 amp draw. This reality in fluid flow is the single biggest reason that designers using electric fans, fail to meet intended targets.

When should you consider an electrical fan? ...never. We already have the highest flowing fan in the industry. It moves twice the air volume of the highest powered electrical fan available. In fact, it is virtually impossible to formulate an electrical fan

that even comes close, because the motor would need to be as large as...a Duramax. Go figure, it's true, we have a 300 HP motor that drives our fan...any rebuttals?

MORE REASONS DIRECT OIL COOLING IS IMPORTANT

“Don't I want both oil AND water temperature under control?”

Yes. Water is cooled directly, heat conveyed directly to the atmosphere via the radiator. Presently, oil is cooled indirectly, with efficiency loss. Heat must be conveyed to the coolant, then to the radiator, then to the atmosphere. The only way to change that is to thermostatically control oil temperature with its own system of **air-oil** heat exchange, thermostatic temperature and flow controls.



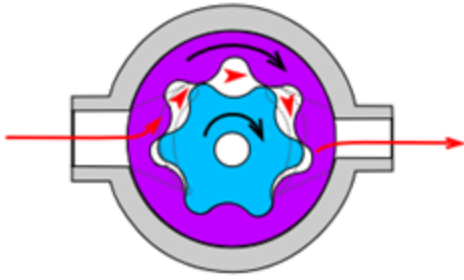
Oil, in this motor and some others, can transport 30-50% of the motors heat load. Also, your motor is much happier if it and the oil are at 200 F, not 300 F. Oil is no longer much of a lubricant at 350 degrees, (though it evaporates very well at this temperature) with only slightly more viscosity than water. So regulating it to 200 has the unique benefit of a motor that is creating, in fact, less friction heat.

In short, here is what I come up with, experimentally using a flow meter designed for this task, and an oil interface plate, shown here.█

At idle oil flows at 20% of its high rpm flow rate, 3.5 gpm and 16 gpm respectively. Water flows at 40% of its high rpm flow rate, 25 gpm and 65 gpm respectively. The explanation is found in plumbing system design. The water pump is a centrifugal design, referred to by designers as a constant pressure pump. A 120 GPM pump with no plumbing resistance, but suffers due to the plumbing limited constant head design, flowing only 60 gpm at 2000 rpm.



With its associated plumbing, it has little ability to overcome inherent plumbing resistance. If you block a water hose, the pump will just keep on spinning like nothing happened. It will not care. The pressure at the blockage will only be as high as the pump vane design, which is designed low for system protection. It “pushes” with a *constant* force and that force (*head*) has little to do with water flow rate if you dead-head it, by blocking the output. Hence the term ‘*constant head*’ pump.



The oil pump, conversely, is known as a “constant displacement” or constant volume type gear pump. It moves oil, with great force, and lower volume than the water pump. The mini-Sherman of the pump world, it is capable of several hundred psi system pressures if left unprotected. The plumbing design of the lube system is protected by a number of bypasses because of its ability to overpressurize. Without them (bypasses), the pump could easily bust a gasket or seal.

It also appears that on the GM turbo diesel vehicle, that the oil pump cycles one revolution for every 2 engine rpms, or a gear reduction thereabouts. With this arrangement, it cycles oil in a wide range of flow rate that is highly rpm dependent, from 3 to 16 gpm, up to 5 times its idle rate of flow. Water will only see 2.5 times its idle flow.

MOURNING LOSSES

Even a constant displacement pump can suffer flow reduction. Ours will flow 16 gpm just fine, but only 14 if the oil gets overheated, a 15% flow reduction. Here’s why.

When the oil pump was designed, it was optimized for a specific viscosity, in conjunction with oil film thickness and lubrication needs; hence the mfr recommended viscosity rating on oil. Below or above this viscosity, the oil flow rate is less than optimum. When cold, oil is so thick that plumbing resistance runs skyward, and oil is dumped back into the sump to keep pressure reasonable. After warmup, as the workload increases and oil gets hotter, and thinner, more of the oil leaks by the intended gear path, recirculating internally, resulting in reduced oil flow to the motor.

Not only is the lower flow of overheated inhibiting cooling, but the lower viscosity is allowing metal/metal surfaces to get closer together, as the oils hydrodynamic film layer gets thinner. It means that abrasive contaminants in the oil will wear motor parts more, as more and more of these particles, while under the filter’s micron radar, are larger than the film thickness. The result is accelerated wear according to the science of lubrication.

Note that 210 F is the optimized oil temperature for a typical oil pump. It is not a coincidence that this aligns with peak water temperature allowances. That is the typical low-load oil temperature of this truck on a 90 degree day, and the temperature that most motor builders spec for peak lubricity. The high limit is normally spec’d at approximately 260 F. I digress like a 1st grader. Back to the gear oil pump, and resistance to flow.

That oil pressure gauge reading displays resistance to flow, typically 45-90 psi at 2000 rpm, depending on temperature.

“Yeah so what, oil at WOT can still only flow half that of water at idle.”

Sure, but I'm not done. We now see that oil heat transfer becomes proportionately more effective at higher rpm compared to water, its flow rate of change rising at 200% that of water. However, it still does NOT flow more volume than the water pump, and it never will. The difference is that the oil travels to areas that corrosive water is not allowed to go; it bathes every square inch of the motors moving parts, hot by virtue of conduction. Oil's paler flow rate allows it more residence time for heat exchange. Oil temperature rise in the motor can be as much as 45 degrees before it emerges to be cooled, compared to water's 15 degree typical rise.

What does all this say? At overload workloads; oil can carry 30-50% of the motor's conduction heat product, leaving water responsible for the remainder.

“Where does this heat normally go?”

Into the water! At the OEM cooler.

“Is the oil thermostatically controlled?”

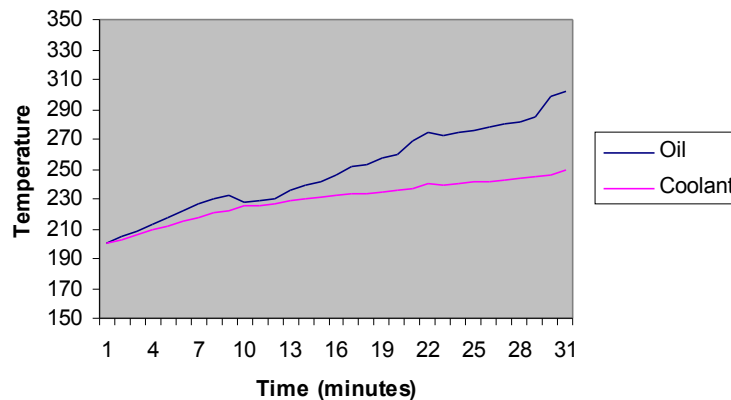
No. It is at the whim of the water temperature to control its rise, oil-water ITD actually. But as we learned, the heat exchange is only 80% effective, and only 80% of the energy picked up by the oil can be offloaded to the water.

“Where does the rest go?”

Nowhere, it is **conserved** in first law thermo fashion. It manifests in constantly rising oil temperature, accumulating stored thermal energy each cycle, until the workload is removed. If you mount an oil temperature gauge; it will change the way you look at cooling. Mash the pedal up a hill with a heavy load, and oil rises at the rate of 30 degrees per minute, see chart below.

So if you were to plot oil temp and water temperature on the same chart, you would see that oil stays warmer than water, as they rise together. Its temperature always leads that of the radiator coolant by 30-50 degrees or more when under big load. As can be seen here, oil is pulling up coolant, in the stock oil-coolant heat exchanger, located inside the oil filter housing.

Stock Vehicle Cooling Performance



Efficiency problem of indirect oil cooling
Shows a constant 175 HP engine load

“And what does this do to the water?”

Heats it up, as demonstrated in Part 1. Considering that the radiator typically is only good for about a 15 degree drop in water temp (mainly because of limited airflow and restricted ITD), you can see that oil is adding to the radiators workload, in a sense, diminishing “headroom” needed to maintain a steady-state 210 F ECT. If the radiator didn’t have to reject the oils heat load, it would be more effective.

“Can’t I just expand the water capacity? Maybe replace the radiator with a larger one, or add an aux radiator, won’t that control oil temperatures?”

If it is an objective to control oil temperatures, then most definitely NO. You can bring oil temperatures down a bit this way, but all the water capacity in the world won’t change the reality of 80% efficiency in the water-oil cooler. The remaining 20% has no choice but to manifest in higher oil temperatures shown in the above chart. It cannot be eliminated. ...do you really want another radiator that is regulated to 200 degrees to cool oil to that temperature?

SAE Tech paper 970939: Thermal Balance Between the Engine Oil and the Engine Coolant of Turbo Diesel Engines, by Valeo Thermal Systems:

“...we have known for more than 20 years, that there is a relationship between the oil sump and engine coolant temperature. The relationship: when the coolant temperature decreases the oil sump decreases almost by the **same value**.”

This, however, is little consolation to 360 degree oil, if only improved by the 20 or 30 degrees that water temperature is lowered.

A bigger problem for oil temperature is that the water, charged is controlled to a temperature that serves the the oil. Oil, in the stock thermal controls. The 180-220 degrees for the efficiency. The water or care what the oil the problem and it is not making a better radiator. Harp Seal fillets to odds.



water cooling system, not configuration has no water is controlled to purpose of motor thermostats do not know temperature is. **THAT** is going to change by Your chances of selling Greenpeace carry better

ANOTHER MYTH ON ICE

Since the radiator is served by a restriction sensitive centrifugal pump, adding to the plumbing slows down water flow. Here is a little known secret. Practically, the only way to make the radiator more effective is to increase water flow rate. With our new understanding of heat transfer, it should be clear that a higher flowing water pump (or lower plumbing resistance) will have the net effect of increasing the average ΔT between water and air, thereby increasing Q . That is how you make motor water cooling more effective. If you have ever subscribed to the much maligned myth “if you decrease the flow rate, then water spends more time getting cooled in the radiator, yada yada...”, consider, for every minute the lower flow pump circulates in a slower flowing system, the water molecule spends exactly the same amount of time in the radiator, because the slower moving molecule makes less frequent trips through it. The average ΔT is lower, decreasing Q . Snuffed! Hopefully I have forever squelched this foolishness about how “less equals more”!

OEM ANTICS

A separate control for oil temperature comes with a cost generally considered unacceptable for the manufacturer. It’s all about money. Consider the 2nd generation Corvette for example. For a few years GM chose to factory fill the known 280 degree lubrication system with synthetic oil. Not because they were selling to enthusiasts (a great marketing ploy) but because they were too frugal to add proper oil cooling, when a \$5 expenditure in more tolerant oil was more economically feasible. Fact. They even managed to spin this decision as a high performance, no-compromise, *benefit* of buying this car. Ouch!

“Bottom line, are you saying that controlling oil temperature, is the only way to accomplish both things at once, oil temperature control AND cooling system expansion?”

Yes, correct. ☺ Check out this paper, good read.

Ref 1, [SAE 2004-01-1257, 2005 Ford GT-Maintaining Your Cool at 200 MPH, Curtis M Hill, Glenn D. Miller, Michael R Evans, and David M Pollock](#)

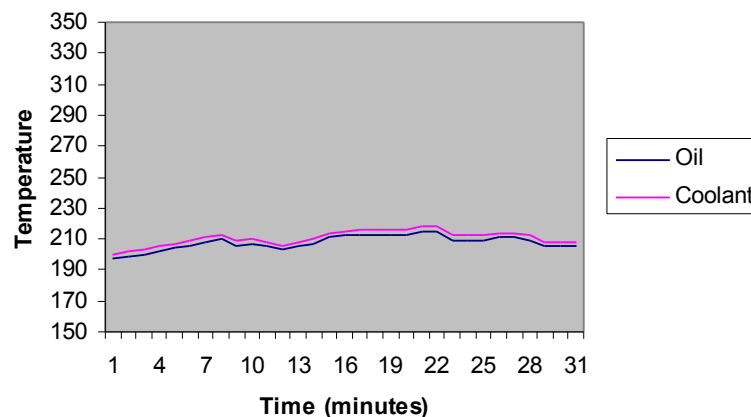


Introducing the fully air dammed Turbo-Diesel Engine Oil Cooler, TD-EOC. Here is an example of a thermostatically regulated oil cooling system larger than any commercially available EOC. It is necessarily large due to the shear increase in oil cooling needs of modern turbo-diesels. It sheds all oil heat BEFORE it goes on to heat the water. It adds up to 121,000 BTU/HR to the cooling system when coupled with the air dam, nicely preventing overheating conditions, and helps prevent fan engagement, another photo of it appears at the end of the article. The beauty of its effectiveness rests on the fact that, under load, oil always heats up before coolant, and those warmer temperatures lead to superior heat exchange.

ROLE REVERSAL

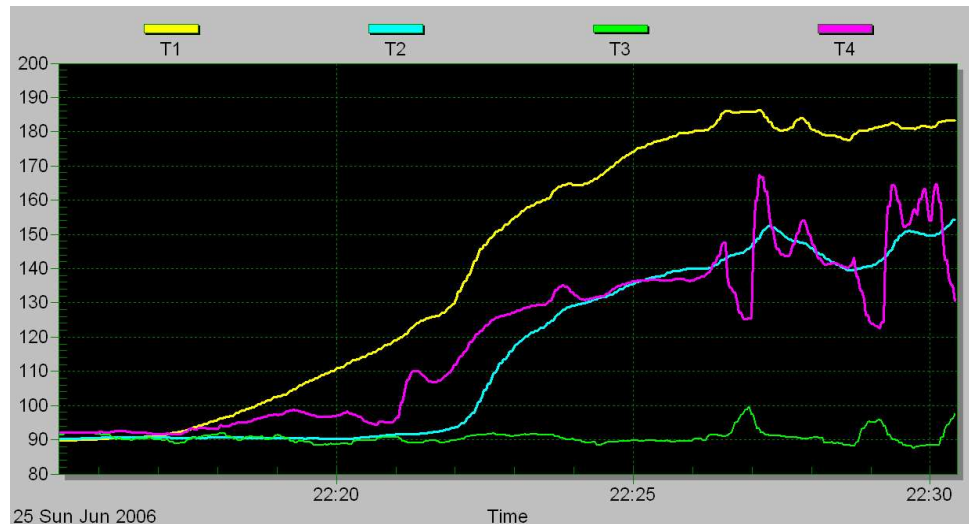
Unlike the chart above, the direct cooled oil stays controlled. If you add enough direct oil-to-air cooling, you can even reverse the OEM cooler heat exchange, using oil to actually cool the water, the radiators normal task. The TD-EOC does this effectively 90% of the time, taking heat away from the fan and motor bay area.

Direct Oil Cooling



If you add enough **primary** oil-to-air cooling, you can even reverse the oem cooler heat exchange, using oil to actually cool the water, the radiators former task. The TD-EOC does this effectively 90% of the time, taking heat away from the fan and motor bay area.

Test data of the TD-EOC, at 12 gpm, on a 90 degree day. Thermostatic protection was set to 180 F for this test. **Yellow** is the bulk oil temperature coming out of the motor. **Blue** represent the oil temperature after the cooler, single pass (less than 2 seconds residence time). At 70 mph, this is a 40 degree reduction, or around 60,000 BTU/HR. **Red** and **green** represent the ambient air temp increase, front to back, across the width of the EOC.



This EOC is located in it's own air parcel, beneath the radiator stack. It is clear that the energy that is removed from the oil, to make it cooler, is transferred to the air, making it hotter, as we have learned.

$$Q_{\text{coolant}} = Q_{\text{air}}$$

This is no-load (empty). As the workload goes up, oil also heats up beyond 180, up to 260 (down from 360) in a truly abusive extended cycle and heat rejection will increase further to 121,000 BTU/hr on a hot 100 degree day, 140,000 BTU/hr on an 80 degree day. Do you see the benefit of having hot oil when it comes to getting rid of heat? All done without a single electrical part!!!

There are a whole host of other benefits seen here.

- Lower oil temperatures, load dependent, as much as 100 degrees lower.
- Prevents viscosity induced, oil pressure decay.
- Improved under piston squirter performance- increased piston life.
- Reduction/Elimination of fan occurrence-increases mpg.
- Increases duty cycle of vehicles, allows heavier workloads.
- Overheat Protection *guarantee**, 100,000 BTU/hr cooling system expansion

- 15 degree transmission temp reduction (with dam option).
- Improved AC performance, estimated at 30% capacity (with dam option)
- Restored hydrodynamic lubrication at the lower, design oil temperatures
- Elimination of oil foaming and pump cavitation
- Longer life for all lubricated components, turbo longevity.
- Reduced oil consumption and evaporation thickening.
- Engineered simple, and reliable, no moving parts, fans or relays. Can be removed to stock condition in 10 minutes, with one tool.
- Lowest cost "per BTU" option available for cooling, less than 1 cent per BTU.
- Free flowing design, oil flow to the motor is not reduced.
- 20% System Capacity Expansion, 2 quarts. More additive protection. Compare to typical coolers with less than 0.5 quart capacity
- Thermostatic control of oil temperature-will not run cold or overcool the motor.
- Temp control permits use of less expensive non-synthetic oils if desired.
- Longer oil change intervals, temperature sensitive additives last longer.
- Uses stock filtration location and filter-warranty friendly
- Reduced shutdown time (turbo) after heavy work with reduced coking
- Designed with Fumoto drain plug- optional
- Protected location with fresh air stream
- No special tools required.
- Compatible with by-pass filtration.

Note, the reduction of fan remarks. No electric fans are added to accomplish this, the essence of a solid engineering approach, minimalism. The electrical system will not be burdened with unnecessary loads. An alternator failure will leave you stranded much longer than an overheat.



Pricing for TD-EOC is \$599 with complete kits at only \$799, found [HERE](#)
 More information can be found on our support site, [HERE](#)

Bio: Michael Patton, a degreed Chemical Engineer and SAE member, www.sae.org, specializing in solutions to energy related problems. My interest is servicing difficult challenges that require innovative solutions involving heat transfer, fluid mechanics, and thermodynamics. Optimization and iteration are common methods employed, Please contact Michael at Beekiller@cox.net



Copyright @ 2006, All rights reserved, Reproduction, storage in a retrieval system or transmission of this article, in any form, or by any means, mechanical, electronic, photocopying or facsimile or otherwise, is strictly forbidden without the written consent of the author..