Keith Eickert
Offshore Performance Products
11 Industry Drive Palm Coast, FL 32137
386-446-0660 www.keitheickert.com

TECH TIPS FROM THE CHIEF

WATER REVERSION
what is it and how can I avoid it?

In our discussions with customers regarding exhaust systems, the topic of water reversion is raised frequently. I have noticed there is a fair amount confusion or misinformation in regards to this subject so I would like to take this opportunity to try to dispel the myths.

During my research for this article the first thing that struck me was the terms “Water Reversion” and “Water Ingestion” are being used interchangeably when in fact they are two distinctly different problems in the world of power boating. So let us start first with some definitions and explanations.

Straight from the Merriam Webster Dictionary here are the general definitions and then we will describe examples of each of these terms and how they apply to marine engines:

Reversion
Pronunciation: ri-'v&r-zh&n, -sh&n
Function: noun
Etymology: Middle English, from Middle French, from Latin reversion-, reversio act of returning, from revertere
1 a : the part of a simple estate remaining in the control of its owner after the owner has granted there from a lesser particular estate b : a future interest in property left in the control of a grantor or the grantor's successor
2 : the right of succession or future possession or enjoyment
3 a : an act or the process of returning (as to a former condition) b : a return toward an ancestral type or condition : reappearance of an ancestral character
4 : an act or instance of turning the opposite way : the state of being so turned
5 : a product of reversion; specifically : an organism with an atavistic character : THROWBACK

Example: Your idling through the harbor at minimum speed, the engine is idling at 750 RPM, upon safely securing the boat to your dock you shut down the engine. You immediately decide to do a quick inspection so you remove the four bolts securing your exhaust riser to your exhaust manifold and pop it off to take a quick look inside. When you shine your flashlight down into the exhaust manifold, you notice it is wet with a small puddle of water accumulation in the bottom of the runners. The most likely cause is water reversion due to your camshafts overlap.

Ingestion
Pronunciation: in-'jest

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Function: transitive verb
Etymology: Latin ingestus, past participle of ingerere **to carry in, from in**- + gerere to bear
: to take in for or as if for digestion
- in·gest·ible /-'jes-t&-b&l/ adjective
- in·ges·tion /-'jes-ch&n, -'jesh-/ noun
- in·ges·tive /-'jes-tiv/ adjective

Example: You are up on plane and running along about 100 yards off the beach at your normal cruise speed showing 3500 RPM on your tachometer enjoying a beautiful day of boating. Suddenly a Jet Ski rider cuts across your bow, so close that you can no longer see him. You instinctively grab your throttles and pull them back to neutral. The boat quickly comes off plane and settles back into the water while your wake rushes up to meet the stern of the boat. As the wake hits the transom the water rushes up your exhaust ports (transom tips) and into your exhaust system filling your manifolds with water and causing the engine to stall. This is water ingestion.

While the effects and damage these two events can create is very similar, the cause and solution to prevent them are quite different.

During my research, I came across a number of manufacturers literature describing their exhaust tips or mufflers as being equipped with anti-reversion devices when in fact they are referring to anti-ingestion devices. To prevent water ingestion from occurring be sure your exhaust tips have an anti-surge valve of some type installed. These are commonly referred to as “Flappers” and can be made of rubber, neoprene, plastic or stainless steel and mounted inside of the exhaust tip. Some models are external and clamp onto the outside of the exhaust tip. Your boat should be equipped with one or both of these styles. The anti-surge valve with stop the flow of water from rushing up your exhaust pipes when you suddenly come off plane or when you beach your boat while wave action laps against your transom.

Now let us dig into the subject of reversion and its causes.

Current gasoline engines are designed in such a manner that the intake and exhaust valves overlap in their opening and closing times. The overlap allows for a more through evacuation of exhaust gases from the cylinder. Such overlap creates a negative pressure within the exhaust system at idle. When the engines is shut down, or at idle, negative pressures pull residual water from the exhaust hose back into the engine cylinder.

Reversion is simply the exhaust pulse flowing backwards momentarily during the overlap phase of the camshaft at low cycling rates (low RPM/Idle speeds). During the overlap phase, the piston is pushing out the last of the exhaust gases and prior to reaching top dead center (T.D.C) the intake valves and the exhaust valves are still partially open. At high cycling rates, the inertia of the incoming intake charge and the outgoing exhaust

pulses keep the exhaust flowing in the proper direction. However, at low cycling rates, as the piston is pushing out the last of the exhaust gases the intake valve opens and some of the spent exhaust charge is pushed into the intake manifold. As the piston reaches top dead center and begins the intake stroke the exhaust valve is still not completely closed. As a result, the piston pulls from the intake and exhaust valves simultaneously causing the exhaust gases to flow in a reverse direction. This is normally not a problem until you add water into the exhaust stream.

In addition to the engines cooling water being discharged into the exhaust stream in "Wet Style", exhaust system we also have to contend with condensation. Because we have the hot exhaust gases surrounded by a cool water jacket droplets of water form within your exhaust system as the result of condensation. If you were able to insert a camera into your exhaust pipe, you see these droplets "walking" backwards towards your exhaust valves at idle speeds.

Reversion can be severe enough to seize or stall the engine, add water to the oil, rust the exhaust seats, etc. This effect only happens at idle speeds, but remember that during shut down the engine encounters the greatest chance of reversion.

For these reasons, we have set a guideline for camshaft selection. Our guidelines are based on 454 c.i. with a 285 degree camshaft (230 degree exhaust duration at .050), on a 112 degree lobe center. Cams that are more aggressive may cause reversion. These figures are just guidelines. Cubic inches, valve size, exhaust valve timing, etc., will all have an effect on reversion. The only true test is to run the engine with the headers attached, shut it down, remove the headers and check for water residue in the header and exhaust ports. Should your engine exhibit signs of reversion there are many exhaust and tailpipe configurations that can eliminate water reversion.

ANTI REVERSION TIPS:

- Header selection - Choose a design that will introduce water into the exhaust stream as late as possible. "Dry style" exhaust systems where the cooling water is not mixed into the exhaust stream and discharged through a separate overboard discharge can eliminate the possibility of reversion; however, dry exhaust is very loud and may cause problems if you are boating in an area with noise ordinances.

- Cubic inch displacement - The tip here is simple, the bigger they are the harder they suck back. Either reduce the duration of the cam or start adding some anti reversion options such as dry exhaust.

- Camshaft selection - With regards to headers the only thing your concerned about is how much piston movement in volume takes place while the exhaust valve is open on the intake stroke. A wide lobe separation angle actually advances the exhaust valve-timing event, which will close the exhaust valve

sooner, but the down side is it also moves the horsepower and torque curve up the RPM range.

- Connecting rods - Marine engine builders rarely think of connecting rod ratios effecting reversion, but it does. A longer than stock connecting rod will make the piston dwell at the top during the overlap cycle thus less piston movement with regards to crank rotation.

Measuring Exhaust Elbow Height

The height of the exhaust elbows (tail pipes or risers) and the slope or down angle must be within specified dimensions to prevent water intrusion problems. Measurements must be taken with the boat in the water with a load distribution similar to that which will be experienced during normal operation.

IMPORTANT: Any load distribution conditions that will affect the exhaust system height and slope must be accounted for to obtain proper measurements.

1. Fill fuel, water, waste water, and heater tanks to maximum capacity. People or weights can be used to simulate these loads if desired.
2. Add maximum allowable cargo weight to the boat in the areas where it will be stowed, including refrigerators and lockers.
3. Add average passenger weight in all locations where each passenger will sit during normal operation.

There are two methods for determining exhaust elbow height, use whichever method is easiest for you to accomplish.

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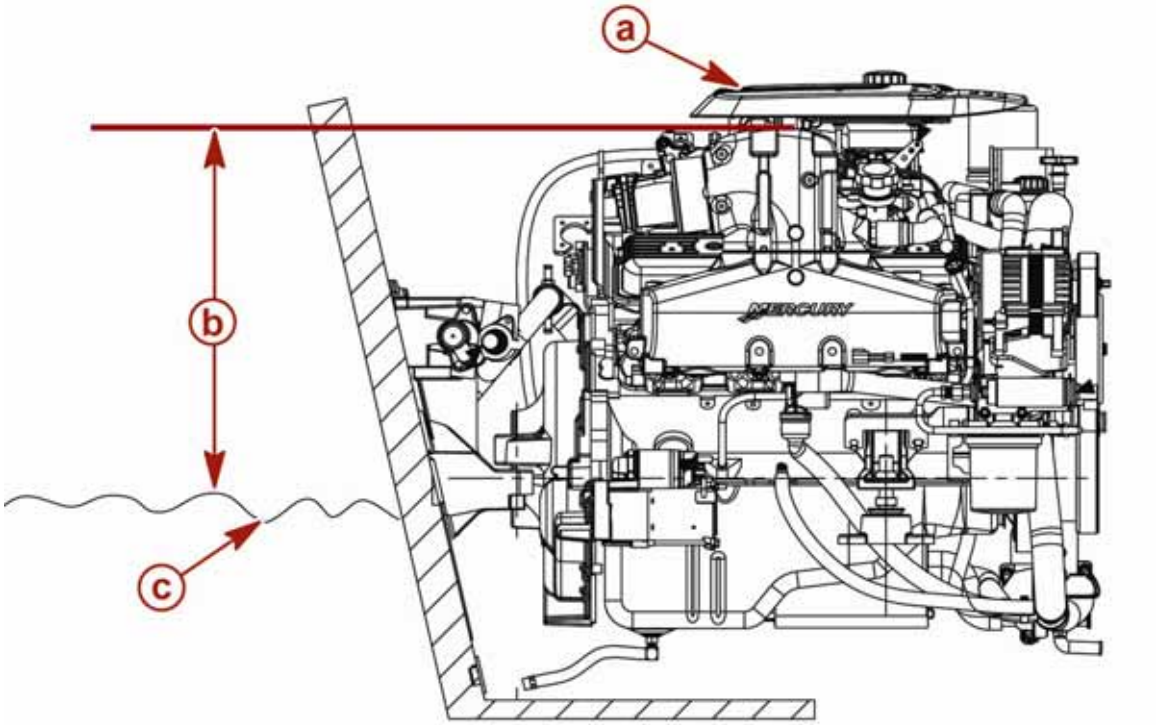
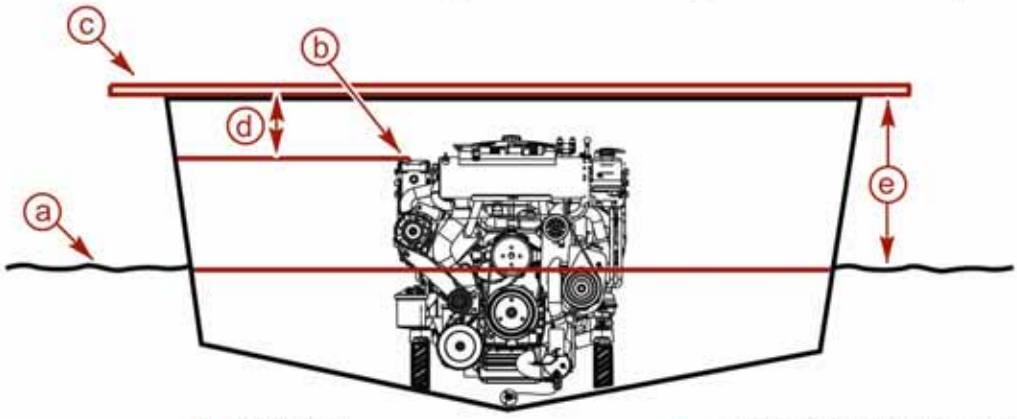


a - Highest point on exhaust elbow
b - Measurement
c - Waterline



a - Waterline
b - Top of exhaust elbow
c - Straight edge
d - Measurement between straight edge and top of exhaust elbow
e - Measurement between straight edge and waterline

Straight Edge Method

1. Place a straight edge across the boat.

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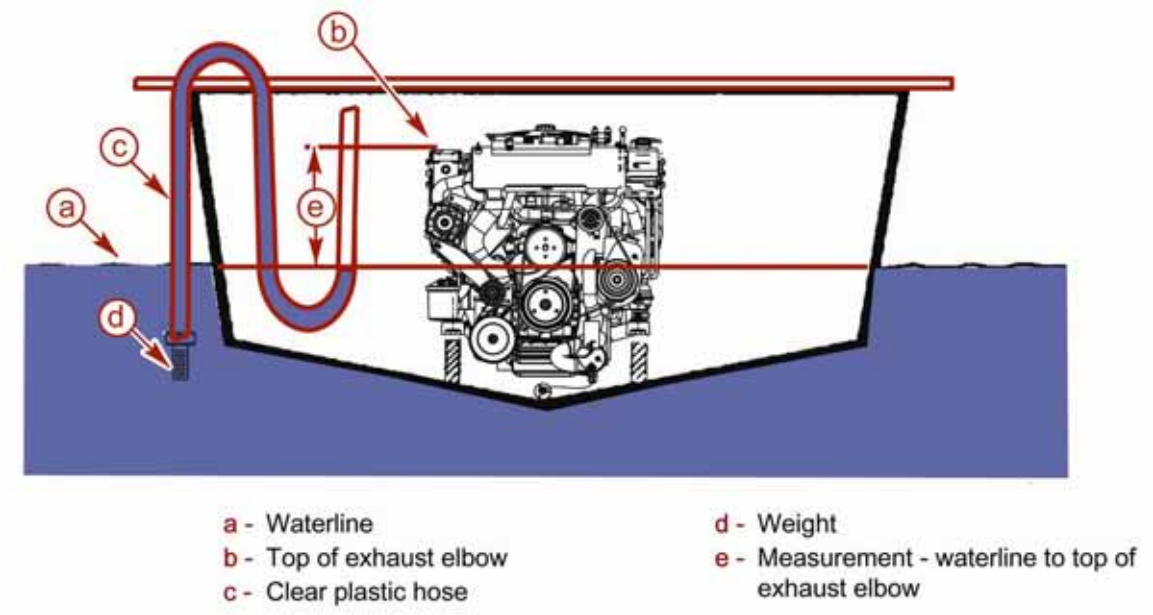
2. With the straight edge above the engine as shown above, measure the distance between the straight edge and the top of the exhaust elbow.
3. Ensure that the boat is level from side-to-side, using a level or inclinometer. Then, measure the distance between the straight edge and the outside waterline.
4. The difference between these two measurements is the exhaust elbow height above the waterline. A minimum of 13 inches is required.
5. Using an inclinometer measure the downward slope between the exhaust riser and the transom tip (exhaust port). A slope of 12 degrees or greater is desirable, 9 degrees would be an absolute minimum.



Clear Hose Method for Measuring Exhaust Elbow Height

1. Obtain a 5/16” – 3/8” diameter clear hose approximately 15 feet long. Put a metal fitting or weight on one end of the hose to keep that end of the hose submerged below the waterline.
2. Put the weighted end of the hose over the port or starboard side of the boat, keeping it in line with the engine’s exhaust elbow.
3. Coil excess hose in the bilge of the boat, keeping it below the waterline.
4. Lower the open end of the hose and siphon water until it starts to come out of the hose. Put a finger over the hose and lift the open end until it is at the tip of the exhaust elbow.
5. Slowly take your finger off the end of the hose to let the water level stabilize. The water will seek the level of the water outside of the boat. Keep the hose close to the exhaust elbow and as vertical as possible.
6. Make sure that the boat is level (side-to-side) using a level or inclinometer.

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7. The measurement between the water in the hose and the top of the exhaust elbow is the exhaust elbow height. A minimum of 13” is required.
8. Using an inclinometer measure the downward slope between the exhaust riser and the transom tip (exhaust port). A slope of 12 degrees or greater is desirable, 9 degrees would be an absolute minimum.