

A REVIEW OF EXHAUST ELBOW EVOLUTION and RESONANCE REVERSION

Jane Christen, SAMS-AMS®

Modern wet exhaust engines are suffering damage from resonance reversion water ingestion with startling frequency. Many engines are catastrophically damaged within just a few hours of operation. In an effort to determine the cause of these failures we have been called to attend, I have consulted with a master mechanic and performed a variety of tests. To understand the conditions that are causing the damage, a brief review of the descriptive terms is in order.

Resonance: a vibration of large amplitude in a mechanical system caused by a relatively small periodic stimulus. This describes the vibration or hum that occurs when the engine cylinders are firing. Each cylinder emits a sound when the fuel and air ignite concussively (explosively) to drive the piston down. The sequential firing of six or eight cylinders at 1,800 to 4,500 rpm creates a vibration resonance – although the weight of the engine and the balance of the drive train is set up to minimize the vibration as much as possible.

Vibration breaks the surface tension of water and allows it to move in an upward direction, almost like a capillary action. The ***Resonance*** of the running engine will allow the exhaust cooling water to “walk” up the tailpipe – back towards the engine.

Reversion: the act of returning or of turning the opposite way. This describes the exhaust water returning back towards the engine instead of discharging out the tailpipe. When each cylinder in the engine fires, there is a push out and a suction in. In four-stroke engines the intake and exhaust valves meter the suction and discharge in the cylinder. With aggressive valve overlap timing of modern electronically controlled engines (essentially post 1998), an opportunity occurs for suction of exhaust gases - and exhaust cooling water - back into the engine.

If exhaust cooling water has walked up the tailpipe into the mixing elbow because of ***Resonance***, the suction of ***Reversion*** can bring the water into the engine through the exhaust valve.

Resonance Reversion is the correct term to use to describe the ingestion of exhaust water by an engine while it is running.

During conversations with a very experienced master mechanic regarding yet another boat engine that was damaged by exhaust water, we were advised that he had discovered the form of the exhaust elbow casting had changed at some undetermined point in time. The mechanic reported for many years there was a lip or hook cast into the elbow on the discharge side – called a vacuum-break. This lip would redirect water that was walking up the tailpipe from resonance reversion, back into the exhaust stream and away from the engine.

The mechanic explained that he had been consulted by Flagship engines in the 1960s, because those engines were suffering from resonance reversion water contamination. Upon opening the exhaust elbow, the mechanic found the vacuum-break had been omitted. Re-design of the Flagship exhaust elbow resolved the problems. He advised that in the 1970s, Volvo engines suffered from resonance reversion, and that was also corrected by redesign of the exhaust elbow.


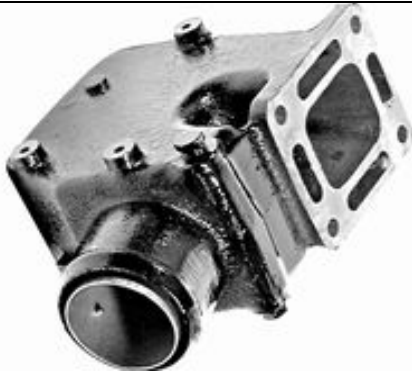

In an effort to identify what may have been changed recently to lead to the current crop of failures, I researched the MerCruiser exhaust elbow part number history and purchased several exhaust elbows for testing.

RESEARCH: Utilizing the resources available on the internet, we looked up MerCruiser exhaust elbow part numbers for all the V-8 I/O, V-8 IB, V-6, and Ski boat engines with parts currently available. We excluded the engines that use a Gil style exhaust, and those with high performance headers and tailpipes. We then collated this data and discovered the following patterns.



End Emitters: Starting with the oldest engines on which MerCruiser continues to offer OEM exhaust elbows as maintenance parts, we find four elbows listed for the 1960's through 1970's model engines that have the exhaust at the end of the manifold. All four of these elbows are apparently revised editions of the original elbow, as the current part numbers have superceded earlier numbers. Engines of this vintage are not as frequently encountered, so were not a focus of our review at this time. The form of all four of these elbows appears to include an effective vacuum-break.

Center Emitters: In approximately 1981, MerCruiser changed the exhaust manifold design to a center discharge model. The center emitting exhaust elbows began with the same general design as the ones from the 1960s (p/n 72963A9, 76351A2, 76668A3, 76771A2).

MerCruiser exhaust elbows p/n 98502A2 (0 degree down angle) and p/n 98504A3 (15 degree down angle), both with 3 inch O.D. outlet dimensions, are used on the small V-8 engines 1981 through 1995. These are the original (non-superceded) part numbers.

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|  <p>Photo 1.</p> | <p>P/N 98502A2 Fits MIE GM V-8 with center rise outlet exhaust manifold.</p> |
|  <p>Photo 2.</p> | <p>P/N 98504A3 Fits MCM/MIE GM V-6 & V-8 engines with center rise outlet exhaust manifold.</p> |
|  <p>Photo 3</p> | <p>Upon slicing open p/n 98504A3 elbow, we found there is a very slight hook towards the exhaust discharge.</p> <p>This appears to be an effective design to prevent resonance reversion.</p> |

Next Generation: MerCruiser V-6, V-8 and Ski boat engines (excluding those using Gil style pipes, or high performance header and tailpipe) for the years of **1987 through 2002** are now using p/n 807988A2. This exhaust elbow appears from the superceded list to have been designed and put into use about 1998 with the 0L002000 and up serial number engines. P/n 807988A2 is also engineered for the earlier engines, and supercedes four (4) original part numbers on the 1987 through 1998 engines. The Bravo engines of this era originally offered stainless steel elbows (p/n 816900A5, 816900A7, 816900A9) which have all been discontinued. The stainless elbows and the cast iron elbows p/n 807988A2 were all designed to fit the same exhaust manifold, so the cast iron p/n 807988A2 is universal. **The design of this elbow is a major change, in that there is no apparent impediment for resonance reversion.**

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|  <p>Photo 4</p> | <p>P/N 807988A2 Fits MCM/MIE GM V-6 & V-8 engines with center rise outlet exhaust manifold</p> |
|  <p>Photo 5</p> | <p>Upon slicing open a p/n 807988A2 elbow, it is immediately apparent how smooth a path is present for resonance reversion.</p> |

Our research, experience and anecdotal information indicates the introduction of exhaust elbow model p/n 807988A2 around 1998, occurred at about the same time as the electronically controlled engines with more aggressive valve overlap were introduced. The p/n 807988A2 elbow is a 4 inch O.D. with 7 degree down angle casting. This larger size was reportedly introduced for the higher horsepower engines, as everything prior was 3 inch O.D. with either 0 degree, 15 degree or 90 degree down angle.

We do not know if the four earlier superseded elbows for 1987 to 1998 engines were designed with a vacuum break, as we have been unable to locate any of these units. While searching for the earlier elbows, we considered it was possible one of the aftermarket suppliers would have the earlier configuration design. We ordered an Osco elbow that is sold under the Boat/US brand for testing.



Photo 6

This is the elbow built by Osco for Boat/US. It is an “aftermarket” replacement for MerCruiser p/n 807988A2. It is Osco p/n 4354 and/or Boat/US p/n 274009

Note that this casting has a kink in the top line of the discharge that is not present in the MerCruiser model. Because the kink is in the top line, it appears this would be inadequate to prevent resonance reversion, although it will disturb the exhaust flow and possibly provide some help.

Because we were unable to locate any exhaust elbows of this generation with a vacuum-break, we prepared the following drawing to indicate the approximate casting detail that is reported by the master mechanic as having been present previously.



Photo 7. Example of "Vacuum-Break" hook drawn on photo.

The mechanic advised that it was his presumption this casting detail had been lost during redesign by a new crop of engineers that did not know the reason for the lip. He also advised that previously one of the standard diagnostic procedures when inspecting an engine that had suffered water damage was to reach into the back of the elbow and check on the status of the vacuum-break. He explained that this casting detail would eventually erode away from impingement, leaving the engine vulnerable to reversion.

Next Generation – Phase B: As nearly as we can determine, within the first few months of 2003, MerCruiser began fitting new engines with a new exhaust elbow, p/n 864309T01 or 864591T02 (down angle is difference). The new elbows were reported to **once again** have a “vacuum-break” of some sort included in the casting. The 864309T01 unit is used on V-6 and V-8 I/O and *inline* (non V-drive) Ski boat engines. The 864591T02 elbow is listed on the V-8 IB and Ski Boats with V-drive. We ordered elbow p/n 864309T01 for testing.



Photo 8

The p/n 864309T01 elbow is a “dry joint” elbow. Note the water passages buttressed around the exhaust joint where the elbow mounts on the manifold.

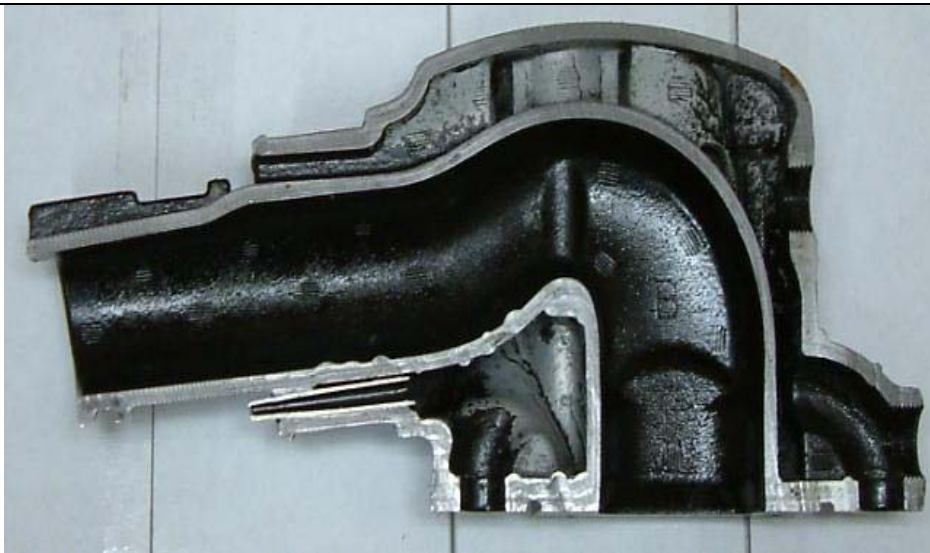


Photo 9

This elbow is essentially the same as p/n 807988A2 with the water loop added for the dry joint. There is a slightly irregular hump in the upper line of the discharge pipe. **No indication of an effective vacuum-break is observed.**

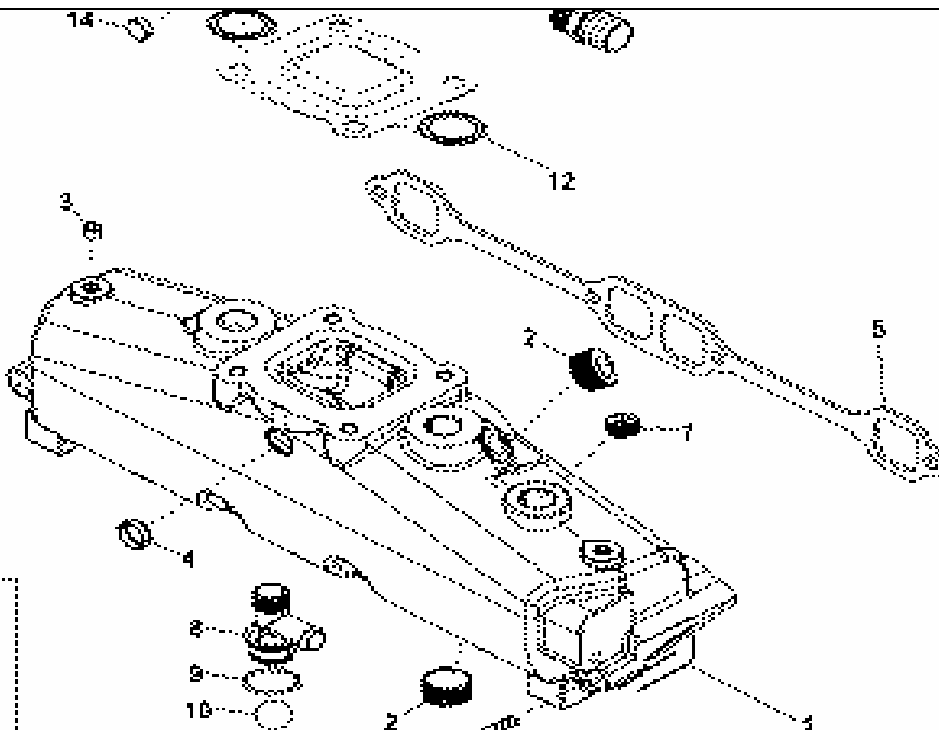
MerCruiser has introduced an exhaust elbow that includes a vacuum break. This is p/n 864591T02 and is listed for use on for MIE GM V-8 (350 & 377 cid) *inboard and ski boat* engines with dry joint exhaust manifold (2002 and newer) The specifications are 4 inch (102 mm) O.D., 14 degree down angle, Ceramic coated. It is unknown if the exhaust manifold p/n 865049T01 that is used with the “T01 and T02” elbows can be retrofitted to earlier model engines.



Photo 10

This is p/n 864591T02. The vacuum break casting detail is highlighted in the photo.

Dry joint elbow requires exhaust manifold p/n 865029T01.



This is exhaust manifold p/n 865029T01. This manifold has the water connections for the dry joint exhaust elbows.

The other issue of possible note is relative to the evolution of angle and size of the exhaust elbow. The one size fits all aspect of the universal p/n 807988A2 elbow, allows very little margin of adjustment for installation of the various engines into a wide variety of boat models.

| P/N | Eng. Model Era | Outlet dimension | Manifold to Discharge |
|------------------|----------------------|--------------------|-----------------------------|
| | | | <i>End emitting</i> |
| 72963A9 | 1968-1981 | | 0 degree down angle |
| 76351A2 | 1966-1982 | | 90 degree down angle |
| 76668A3 | 1970-1982 | | 90 degree down angle |
| 76771A2 | 1977-1980 | | Drop 0 degree down angle |
| | | | <i>Center emitting</i> |
| 98503A2 | 1981-1992 | 3 inch O.D. | 0 degree down angle |
| 98504A3 | 1981-1992 | 3 inch O.D. | 15 degree down angle |
| 807988A2 | 1982-2002 | 4 inch O.D. | 7 degree down angle |
| 274009 | Boat/US, Osco | 4 inch O.D. | 7 degree down angle |
| | | | |
| 864309T01 | 2003 | 4 inch O.D. | 7 degree down angle |
| 864591T02 | 2003 | 4 inch O.D. | 14 degree down angle |

The parts marked in red are the units that do not appear to have any casting detail to avoid resonance reversion. The part marked in green does have a vacuum break detail in the casting.

SUMMARY: Engines ingest exhaust water for a variety of reasons and under a variety of conditions. A vacuum-break cast into the exhaust elbow will not prevent all water damage, but will reduce the incidence of resonance reversion water damage.

While a re-designed exhaust elbow with an effective vacuum-break would be of significant help on new engines, the p/n 807988A2 elbow - which is almost universal for the last 15 years of engine production, is worthy of scrutiny. Attention to the complete system on engines of this vintage is prudent. Installation of a Resonator Kit may be beneficial. Maintenance of the internal shutters is also strongly suggested.

Surveyor Field Inspection: How do we determine if a water damaged engine has suffered from resonance reversion? If the boat owner reports the engine hydrolocked while it was running, it is reasonable to suspect resonance reversion as the cause. An engine that is damaged by resonance reversion of the exhaust water will show evidence of water in the cylinders – that is, an absence of carbon on the pistons and spark plugs.

If the engine reportedly failed to start after the last “normal” shut-down, consider other factors including gulp from an abrupt and/or high speed shut-down before presuming resonance reversion. If the exhaust valves show corrosion but there is no appreciable amount of water in the cylinder, consider “constant mist” which can be from poor discharge down angle, engine angle and other factors.

The primary key to remember is that resonance reversion only occurs in an operating engine. It can induce sufficient water to cause hydrolock.

Jane Christen, SAMS-AMS[®] is a marine surveyor specializing in loss and damage inspections. She is a past Regional Director for SAMS, and currently serves as chair of the Insurance Committee and the e-Committee. She is also a member of SNAME, IAMI, and ABYC. Jane holds a Level I Thermography certificate from ITC, and performs Infrared inspections. Jane and her partner Rex Michel, are Michel & Christen Marine Loss/Damage Surveyors (800-794-0089) with offices in southern California and western Washington.