Approaches to Prevent Outboard Motors From Flipping Into Boats After Striking Floating or Submerged Objects

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PropellerSafety.com

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Note: A Supplement to This Volume Has Been Issued

Supplement #1 is now available.

This paper is for informational purposes only. It is not professional advice for those considering modifying any boat(s) or marine drive(s) with any devices.

Forward

Welcome to the third edition of our inventory of ways to prevent outboard motors from breaking off and flipping into boats when striking submerged objects or in rough water. The list includes old school approaches, modern approaches, high-tech approaches, and a few futuristic approaches.

When we published the first edition back in late 2013 few boaters were even aware this could happen. Since then our efforts to have these accidents recognized as an accident scenario vs. one of a kind accidents have had considerable success.

Our efforts to increase awareness took a turn when we recognized larger outboard motors and especially bass boats were increasingly showing up on our lists. The ability to target our message increased awareness.

We are happy to see The Leash being patented and entering the marketplace. We are happy to see numerous patents issued to major marine manufacturers for devices that could be used to prevent outboard flipped in accidents. At least two more marine drive manufacturers (Yamaha and Suzuki) were forced to recognize this accident scenario exists in court. All of this has happened since the first edition of this paper.

Notable events include:

1. One approach we promoted was patented and entered the marketplace (The Leash).
2. Brunswick patent an approach we first revealed here, (Active Tilt).
3. Showa patented a two stroke tilt cylinder.
4. Yamaha launched a new approach when they patented a motor clamp preloaded in compression, allowing it to accept higher tension loads before failing.
5. Multiple Brunswick patents teach anticipating imminent collisions and preparing the system to best deal with them.
6. Continued developments in breakaway drives from those designing through hull drives.
7. Brunswick / Mercury patented a breakaway skeg.
8. Caterpillar patented a breakaway skeg.
9. FLIR patented a system to anticipate impacts and prepare outboard motors for that impact.
10. Yamaha patented a system for consumer outboards that records collision information.
11. Yamaha was forced to recognize outboard motors can break off and flip into boats in the Clippard case.
12. Suzuki was forced to recognize outboard motors can break off and flip into boats in the Barhanovich case.
13. USCG Captain Tom Boross recognizing the accident scenario at a National Boating Safety Advisory Council (NBSAC) meeting. (see next page for details)

Captain Tom Boross of the U.S. Coast Guard spoke at the 95th National Boating Safety Advisory Council (NBSAC) in April 2016. He spoke regarding a study that reviewed 21,000 USCG Boating Accident Report Database (BARD) accidents and identified 888 propeller accidents. His comments below come from the official NBSAC95 minutes.

> *"Some of these incidents occurred when a propeller of an underway vessel struck a submerged object and the propeller recoiled and the engine launched and came up out of the water and came inside the boat which amazed him and members of his staff, as there were hundreds of those events."*

Captain Boross's comments above marked a significant event in boating industry recognition of the issue.

We personally clarified how these accidents happen to Captain Boross and to NBSAC in March 2017, and again called NBSAC's attention to these accidents.

Our third edition includes several new approaches. We hope some of them will be picked up by the industry as well.

The January 2016 entry of The Leash into the marketplace was a watershed moment. It brought a highly visible product specifically designed to prevent this accident scenario to bass tournament anglers. The conversation began in earnest and is still going on. The existence of The Leash has done a great deal to elevate the issue.

Recommended Reading

If you lack a full understanding of how outboard motors can break off and enter boats when submerged objects are struck, or in rough water, we suggest you review the following articles before proceeding.

1. Log Strike Testing: Part 1

2. Log Strike Testing: Part 2

3. Design Chart for Preventing Outboard Motors From Entering Boats

4. Outboard Motor Log Strike Mode by Speed and Resistance to Impact Chart (see **Figure 73)**

5. Bass Boat Outboard Motors Should be Fail-Safe Impact Tested

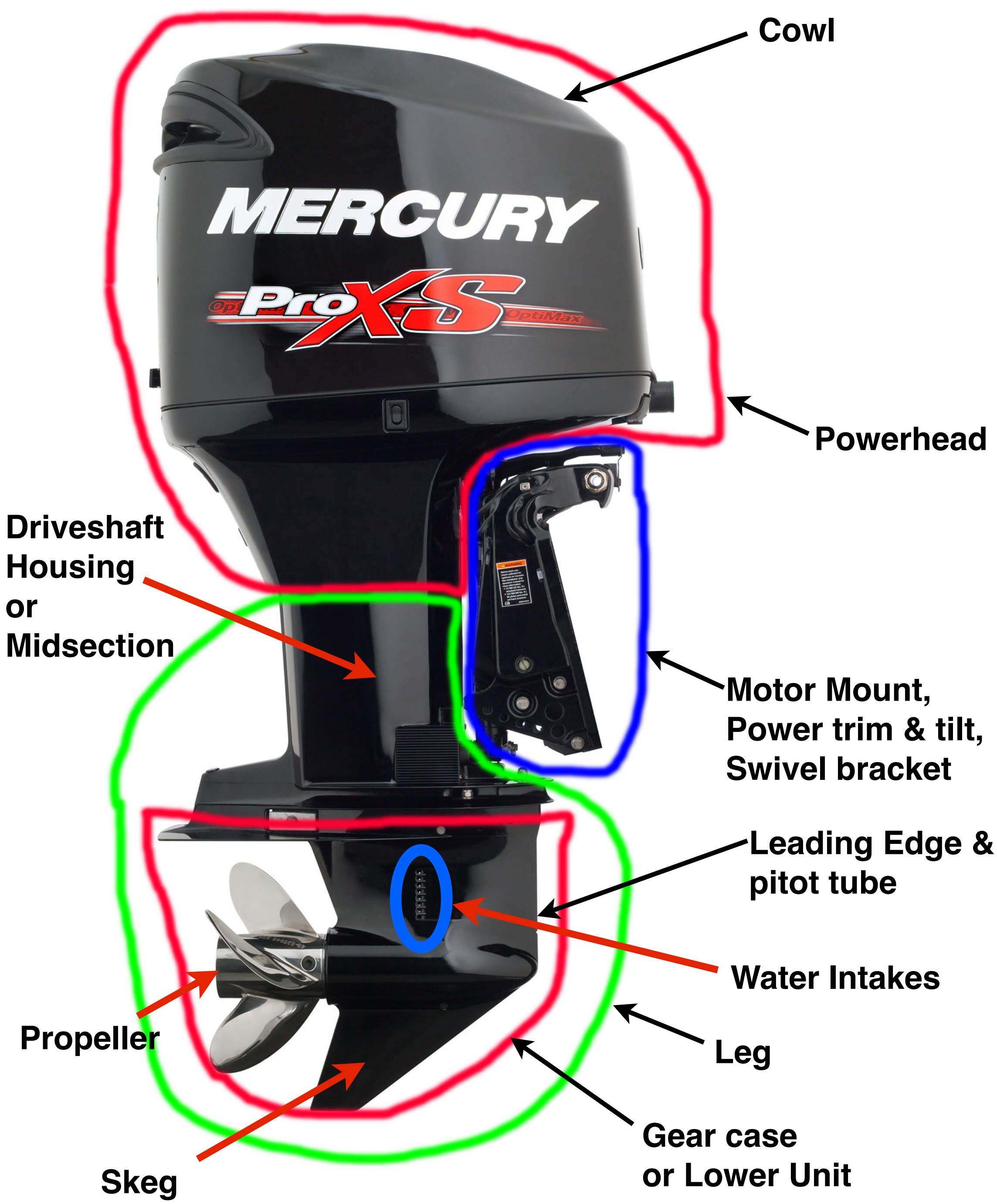

Figure 0. Mercury Marine 175 Pro XS outboard segments labeled labeled on a current Mercury promotional image

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Introduction

What Happens When an Outboard Motor Flips into a Boat?

Over time, several media reports and state boat accident reports of large horsepower outboard motor flipping into the boat accidents were reviewed and archived at PropellerSafety.com. As time passed, two scenarios generally consistent with accident reports, photographs, and observations of several of these accidents developed. See the peach and violet colored areas in the upper right corner of **Figure 73**.

Scenario #1 (breaks off at the top):

The outboard motor strikes a submerged object, a combination of slower vessel speed and/or a softer, more moveable object allows the leg of the outboard to clear the object without being ripped off. The outboard continues to swing upward and reaches the top of its swing with considerable energy remaining. The outboard then slams over crashing its cowl into the the rear deck, breaking partially free, or breaking free and rotating on into the vessel. This scenario represents the peach colored area in **Figure 73**.

Scenario #2 (breaks off at the bottom):

When a large outboard motor strikes a large floating or fixed submerged object at speed, it breaks off near the bottom of its upward swing. The log strike system does not allow the outboard to clear the object fast enough. Kinetic energy of the boat creates forces too great for mounting components, and one or more components fail (clamp brackets, mounting brackets, swivel bracket, PPT tilt cylinder, jack plate, transom).

As the outboard swings upward and the prop breaks the surface of the water, propulsion force diminishes to near zero, as the prop leaves the water the boat looses its bow up trim and may be knocked into a bow down trim from the collision, the boat instantly begins to slow down from the collision and drag. Engine RPM almost instantly increases as the propeller hits air (less resistance to propeller rotation in air than in water). Eyewitnesses talk about hearing the “propeller out of water”.

As the outboard motor continues to rotate over itself and the boat begins to slow down with respect to the outboard motor, cables and lines along the starboard side of the boat to the outboard motor begin to pull tight. The lines begin to rip free from where they are normally covered over in the stern.

These lines and cables restrict forward movement of the starboard side of the power head relative to the boat. The leg (where the propeller is attached) continues to rotate over the powerhead and begins to lay over toward the passenger area of bass boats due to resistance from all the lines and cables pulling the starboard side of the powerhead to starboard stern. In bass boats, the remaining energy of the collision continues to swing the propeller forward into the area of the neck support at the top of the passenger seat. (see **Figure 63**) This scenario represents the violet colored area in the upper right corner of **Figure 73**.

Often outboards thrash around on board as the propeller strikes some combination of people, seats, the gunnel, and the deck, then goes overboard still running and sinks. The cowl is sometimes found floating nearby. The engine stops when it runs out of air, the propeller cuts certain lines / cables to the outboard, someone yanks the kill switch lanyard, or someone turns the engine off.

Accident scene photos often show lines and cables running over the back of the boat to a submerged outboard motor dangling from them. (see **Figure 49**)

Those in the passenger seat of bass boats or operators of center console boats are more likely to be struck by the propeller than bass boat operators. The propeller generally comes down in the passenger area (see **Figure 63**) or middle of boat, not on the starboard side.

These collisions are very violent and happen very fast. Individual accidents will not always precisely follow the descriptions presented.

How Often Does it Happen?

See our list of outboard motors striking submerged objects and flipping into boats.

What Types of Things Are Struck?

Floating and submerged objects struck by outboard motors include:

1. Wood (submerged stands of trees, floating trees, submerged stumps, floating logs, railroad ties, human made wooden structures)
2. Rocks, underwater outcroppings, very small islands
3. Concrete pilings / piers, dykes, low water dams, retaining walls, sea walls, old salt water barriers
4. Submerged bridges, sunken vessels, submerged cars
5. Dredge pipes
6. Flood debris (floating and submerged)
7. Reefs
8. Objects displaced by hurricanes
9. Sand bars
10. Unknown objects

Can the Problem be Designed Out?

To help prevent similar accidents in the future, we encourage marine drive manufacturers, boat builders, boat dealers, and entrepreneurs to view our Bass Boat & Motor Design Flow Chart, consider the solutions proposed here, and employ them and others as they see fit.

We are not claiming all these approaches work, or are practical. We list them to stimulate discussion, increase awareness of the problem, inspire more solutions, and to encourage action.

Log Strike Systems

When impacted at speed, high density fixed objects (resting on the bottom) and large floating objects of a density near that of wood (floating) are particularly dangerous. Marine drive manufactures use log strike systems to allow the drive to swing up and over objects and settle back down to the original depth / trim after the collision. Large outboards typically use hydraulic relief valves to limit flow from the rod end of the tilt cylinder during a strike to retard the upward swing of the drive. We previously covered log strike systems and their testing in a two part post.

We refer to testing of these systems as log strike testing, others may refer to these tests as driftwood testing, or dry land impact testing.

It is Time for Change

It is time to reevaluate use of traditional log strike systems on some vessels. Outboard motors are increasing in horsepower, becoming heavier, and faster. Recreational boats are becoming bigger, heavier, and faster. Use of twin, triple, and even quad outboards is on the increase. High horsepower fishing boats powered by large outboards compete in fishing tournaments where speed is of the essence. These trends result in higher impact energies. Large outboards are flipping into boats under power (propeller turning at several thousand RPM due to being in the air) causing serious injuries and death.

Boating has become more widespread and human presence has resulted in more items in and under the water (more debris, more submerged piers, more lakes formed with stumps or trees left standing, more dredging resulting in more dredge pipes, and intense storms washing more debris into reservoirs).

Extreme swings in lake levels due to drought or allowing more water downstream for other uses are bringing previously unknown hazards near the surface.

Several solutions to help prevent outboard motors from breaking off and flipping into boats during collisions with floating and submerged objects have been proposed. The proposed solutions are grouped and enumerated in the **Table of Contents**.

Definitions

Definitions

Back in a 1992 a U.S. Coast Guard report on Recreational Boat Collision Research, the Coast Guard identified and defined two types of collisions relative to our report.

CWFLO - Collision with a **Floating Object**

CWFXO - Collision with a **Fixed Object**

The same paper recognized “**Submerged Objects**” (logs, rocks, swimmer, diver, etc.) as a hazard to be avoided.

This paper tends to recognize:

Floating object - as an object that floats in the water

Submerged object - as an object that rests on the bottom or floats beneath the surface.

This paper tends to use **Floating object** and **Submerged object** interchangeably to represent both types of objects. However, we encourage you to remember there are times and places outside of this report where the 1992 Coast Guard definitions apply.

Clamp Bracket - refers to the 2 vertical brackets on larger outboards that bolt to the transom. Clamp Brackets actually clamp to the transom on older and smaller outboards. We sometimes refer to Clamp Brackets as a **Motor Brackets**. See **Figure 15**.

Proposed Solution:

1. Increase Minimum Speed at Which Outboard Motor Breaks Off

1. Increase Minimum Speed at Which Outboard Can Enter the Boat

Several approaches to prevent outboard motors from entering boats do so by increasing the minimum speed at which an outboard motor can break off.

If the outboard motor does not break off, it cannot fully enter the boat.

Some of these approaches are enumerated below.

- **1A. Reduce Peak Loads**
  - **1A1. Increase Time of Contact to Reduce Peak Loads**
  - **1A2. Tilt Cylinder Provides Two Stage Damping**
  - **1A3. Minimize overshoot of log strike system relief valves**
  - **1A4. Active Control of Tilt Cylinder**
  - **1A5. Share the Load**
  - **1A6. Stops at Top of Swing**
  - **1A7. Reduce Weight of Outboard Motor(s)**
  - **1A8. Reduce Boat Mass**
  - **1A9. Drastically Reduce Boat and/or Outboard Motor Drag**
  - **1A10. Reduce Maximum Boat Speeds**

- **1B. Increase Strength of Existing Structural Components**
  - **1B1. Use High Performance, Offshore, Commercial, or Racing Parts**
  - **1B2. Increase Physical Dimensions of Parts**
  - **1B3. Use Stronger Materials**
  - **1B4. Use High Impact resistant Alloys**
  - **1B5. Increase Capacity of Hydraulic System to Absorb Energy**
  - **1B6. Use Smart Materials**
  - **1B7. Preloading Structural Components**
  - **1B8. Use Stronger Processes to Form the Parts**
  - **1B9. Optimize Current Designs for Strength (CAE)**

- **1C. Drive Designed to Fail in a Manner by Which it Cannot Enter the Boat**
  - **1C1. Frangible / Break Away Drives**
  - **1C2. Break Away Skeg**

- **1D. Alternative Swivel Bracket Designs**

- **1E. Propulsion Configurations More Resistant to Flipping Into Boats**
  - **1E1. Outboard Brackets**
  - **1E2. Outboard Shallow Drives, Mud Drives and Surface Drives**
  - **1E3. Replace Some Outboard Motors With Alternative Drives**

These approaches will now be individually addressed.

1A. Reduce Peak Loads

Reducing peak loads is a means of increasing the minimum speed at which an outboard motor will break off. Ways to reduce peak loads will now be discussed.

1A1. Increase Time of Contact to Reduce Peak Loads

Several inventors have proposed increasing the time of contact with submerged or floating objects to reduce peak loads felt by the drive and its supporting structure. For example see **Figure 1**, **Figure 2**, and **Figure 3**.

When a large, non-fracturable submerged rock is struck at high speed, the drive has to respond immediately. It must swing up over the object against resistance supplied by the log strike system and against its own rotational inertia (resistance of the mass of the drive to kicking up) in a small fraction of a second. Tremendous forces are applied to the log strike system and its support structure.

Drive manufacturers and inventors have searched for ways to lengthen time of contact to allow the drive to initially rotate upwards at a slower speed and to allow the log strike system time to begin to respond.

1A1a. Elastomeric contact

Back in 1962 Outboard Marine Corporation (OMC) filed a patent for an elastomeric (rubber) nose cone to reduce damage to the drive. Some drawings from the resulting **US Patent 3,151,597** are shown in **Figure 1**. OMC says, the bumper made from resilient material is:

"... for extending the time interval during which impact occurs, thereby reducing the magnitude of the resultant impact force, and thereby also protecting the unitary assembly."

OMC also notes that bending or rupturing of the bumper absorbs energy and reduces the amount of energy passed on to the shock absorbing system (log strike system).

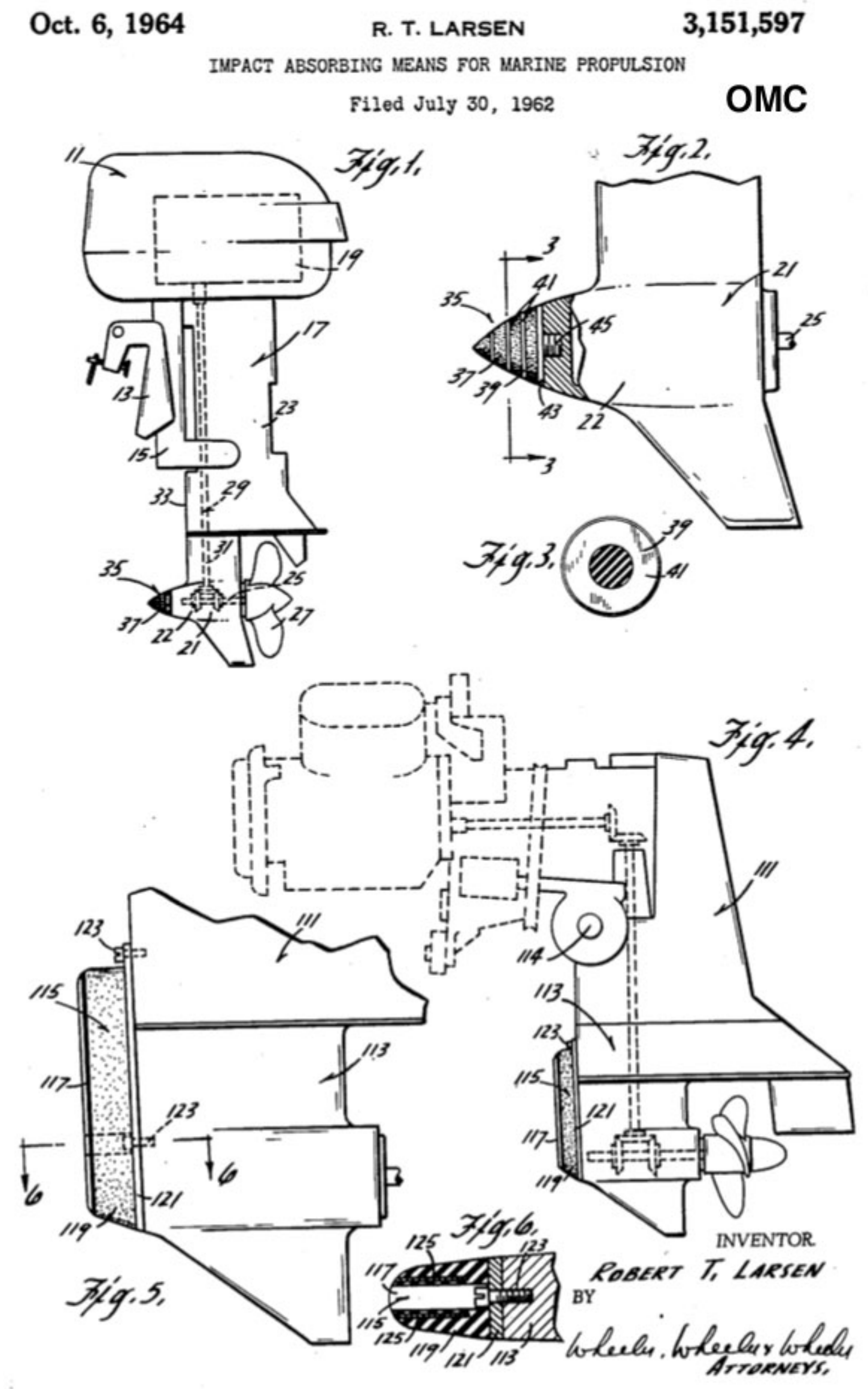

Figure1: US Patent 3,151,597 OMC elastomeric bumper

Douglas Builders applied for **US Patent 5,399,113** in 1994, see **Figure 2**. The patent abstract states:

> *"The cylinder and piston arrangement provides some cushion enabling damage-reducing backwards and upwards limited rocking on impact at low to moderate speeds. Impact sensing mechanisms conventionally also release the pressure in the cylinder and piston arrangement at low and low-moderate speeds but are generally ineffective at moderate and high speeds to limit damage."*

Douglas Builders propose the use of a rubber "boot" over the lower part of the drive. The boot narrows to a knife edge out in front of the leading edge of the drive. The patent states:

> *"On striking a submerged object, not only does the rubber of the boot itself yield to cushion the impact, but the time spent in further travel of the drive lower portion after initial contact gives the impact sensing mechanism more time to release the hydraulic positioning mechanism so that the drive can timely swing backwards and upwards over the struck submerged obstacle if the motor boat was proceeding at moderate speeds."*

#24 in the patent drawing is a grill to allow water through the boot to the water intakes.

Douglas Builder notes the boot could be factory or aftermarket installed.

For higher speed impacts, Douglas Builder proposes several ways in which the clevis / coupling on the end of the trim cylinder rod could be released. While this aspect of Douglas Builder's invention is a frangible approach, we put the invention in this category due to the rubber boot being a cushioning approach.

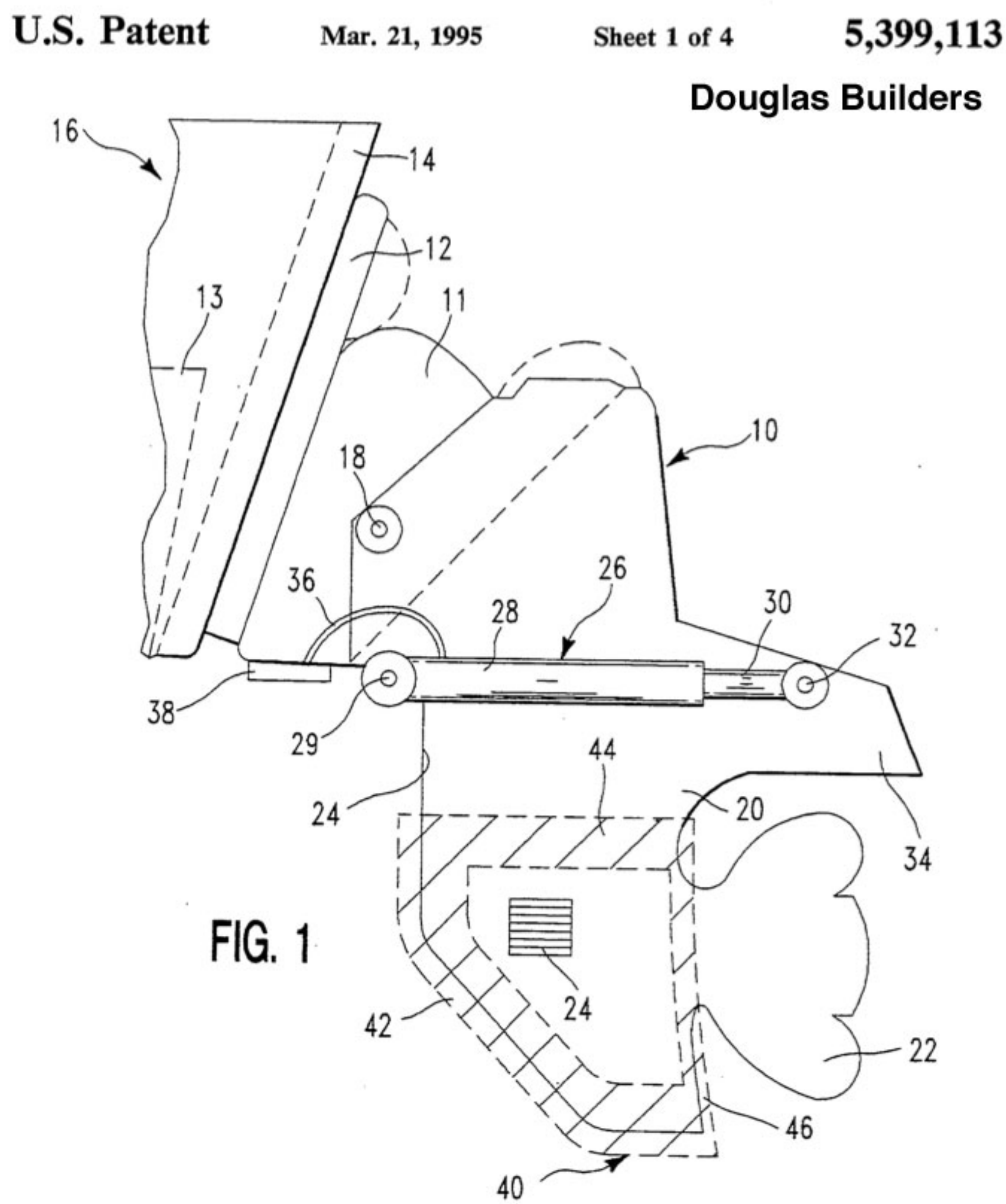

Figure 2: US Patent 5,399,113 Douglas Builders boot

1A1b. Crushable metal contact

In **US Patent 6,966,806**, Brunswick proposes a combination of a crushable nose cone and crushable leading edge for the lower portion of the drive, #12 in **Figure 3**. Brunswick notes the crushable portion can be made from a weaker material, or by providing crush boxes (#81, #82) within the structure. Brunswick also notes that by proper material selection, crushable nose cones and leading edges can resiliently return to their shape after impact in some instances.

The crushable nose cone portion includes a water intake (#70) to supply water for cooling the engine.

Brunswick says the purpose of their crushable nose cone and leading edge is to protect the main body of the drive.

Brunswick built upon this approach later in **US Patent 8,062,082** (see **Figure 20** in our Frangible section) with their 2-stage crushable and frangible design for the Zeus drive.

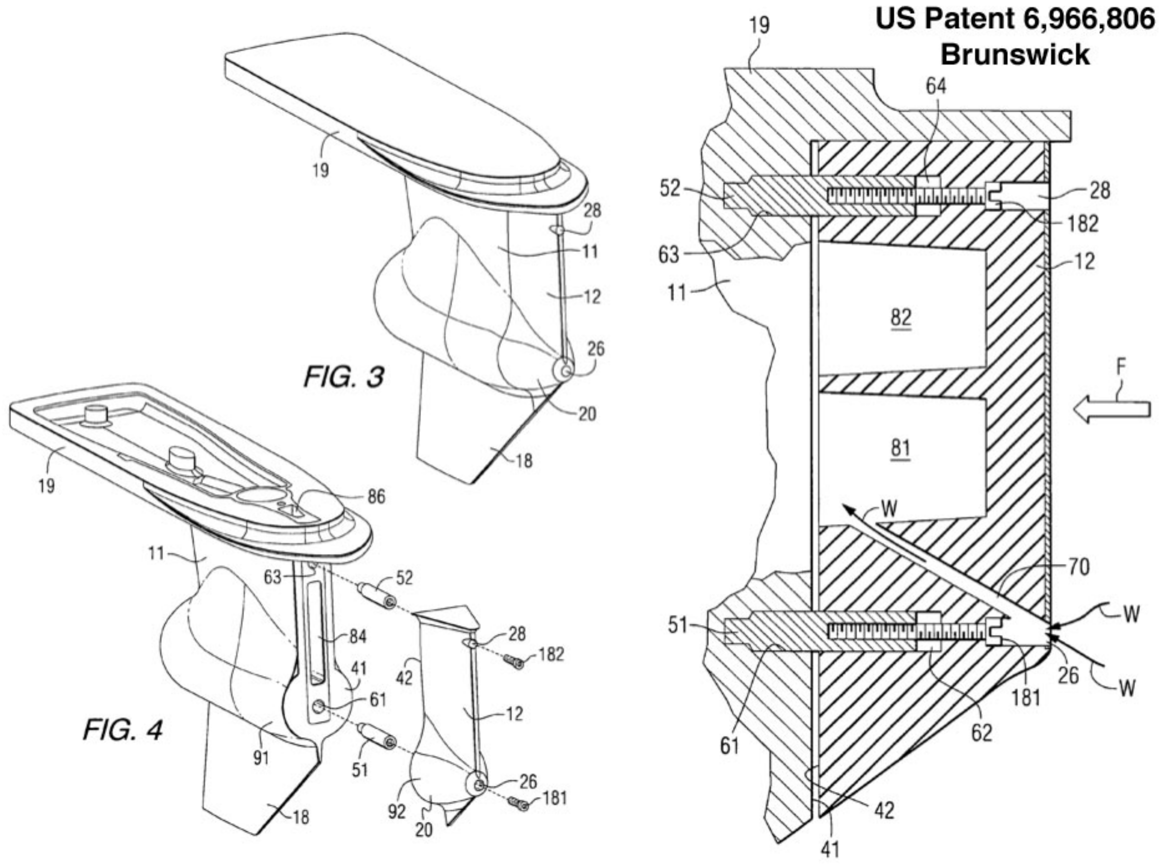

Figure 3: US Patent 6,966,806 Brunswick crushable nose & leading edge

Brunswick's **US Patent 6,966,806** teaches making the crushable part (item #12 in **Figure 3**) from a resilient material such as synthetic rubber. They teach the synthetic rubber could be coated by a harder polymer material, allowing the part to resiliently return to its prior shape following some impacts.

Brunswick's patent teaches that alternatively, item #12 in **Figure 3** could be made from an impact deadening compliant material that might not spring back into shape.

Brunswick's later patent, **US Patent 8,062,082**, for a crushable nose cone for the Zeus drive shown in **Figure 20**, teaches use of aerogels or other energy absorbing foams in the empty cavity of the nose cone.

We suggest both designs now consider the use of aluminum Metal Foam as a possible alternative crushable material for use in open cavities such as #81 and #82 in **Figure 3**.

1A1c. Motor mounts

The industry uses rubber motor mounts to mount the motor to the vertical steering tube that passes through the swivel bracket as seen in **Figure 4**.

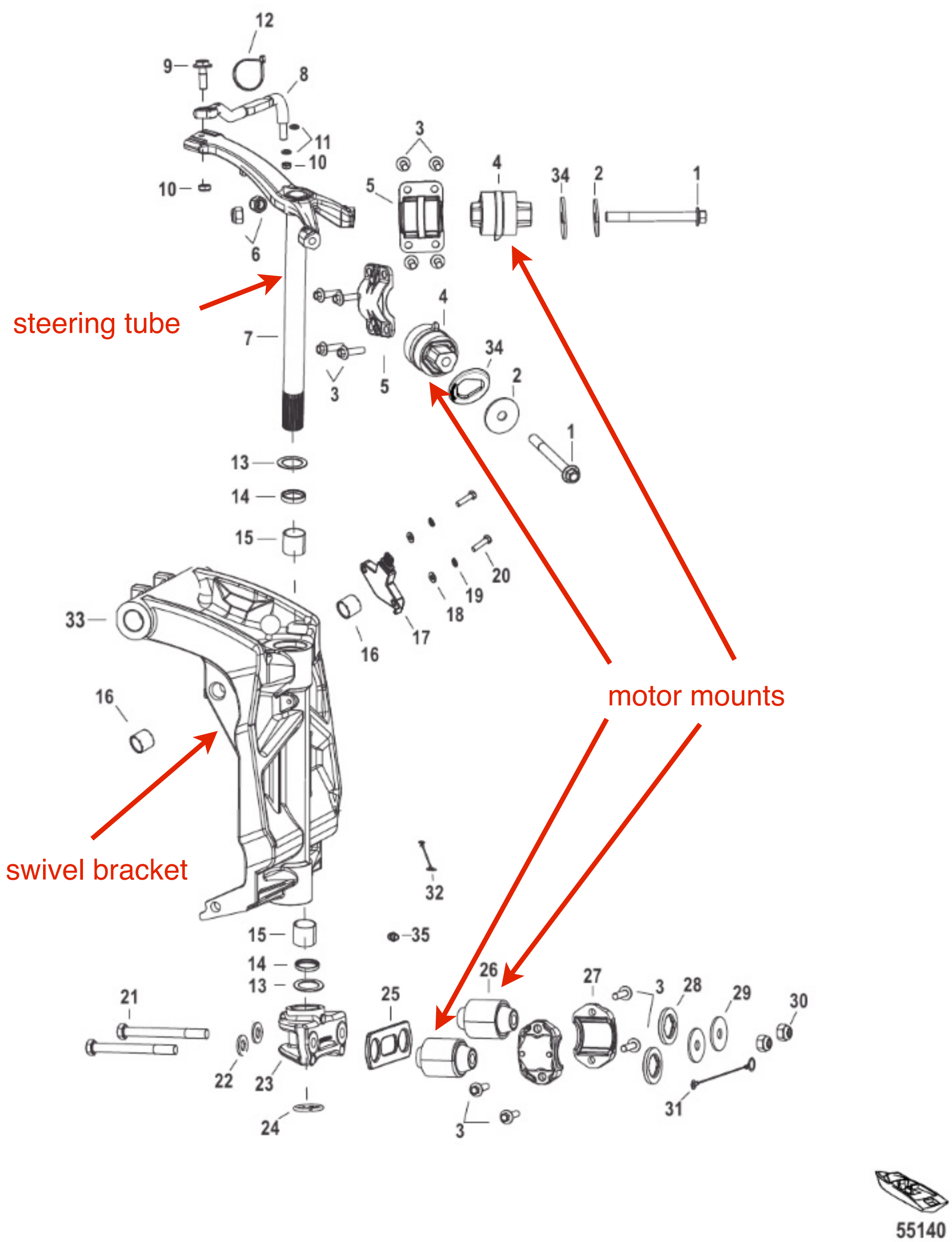

Figure 4: Motor Mounts, Swivel Bracket and Steering Tube
Example from Mercury Electronic Parts Catalog

Motor mounts, as seen in **Figure 4**, are critical in reducing vibration and in allowing the outboard to begin to swing up before the relief valves have time to open. Manufacturers can be observed improving motor mount designs from time to time in the patent literature.

Optimizing motor mounts for maximum energy absorption during early stages of a collision with a submerged object is one way to reduce peak loads.

1A1d. Transom breakage / rigidity / flexibility

Occasionally, during impacts with submerged objects pieces of older transoms break off along with the outboard motor still attached to them.

When modern transoms fail during impact with submerged objects, it tends to be by cracking vs. breaking off large pieces. While cracking of the transom does absorb considerable energy, there are better ways to address the hazard of outboard motors flipping into boats.

The transom needs to be solid, and able to withstand loads encountered during collisions with submerged objects though out its lifetime.

Two characteristics need to be balanced in a transom.

1. The transom needs to be rigid and not break during impacts, including not allowing mounting bolts to pull through the transom.

2. The transom needs to flex during impacts to increase collision time, allowing the relief valves time to open before the outboard is pulled off or broken off the transom.

We briefly address each characteristic.

Rigidity (plates and braces)

Attention has been focused on increasing rigidity of transoms. Several firms offer small or large transom plates providing support on the inside of the transom. Outboard motor mounting bolts typically pass through these plates and are less likely to pull through the transom during collision with a submerged object.

Transom braces can be seen on some used boats. Braces or struts are typically affixed from the motor mounting plates mentioned above to the stringers. Stringers are the support structure bonded to a boat hull. Stringers typically run parallel to the length of the boat. Transom braces can add considerably more stiffness to the transom than transom plates alone.

Flexibility

When dry land impacts tests are captured by high speed photography, it is very apparent that transoms absorb energy during impacts with submerged objects. The top of the transom is observed tilting/bowing excessively backwards during initial impact. Once the outboard swings up a ways and certainly by the time the outboard clears the object, the top of the transom begins to swing back toward its normal position, then the outboard continues its upward rotation.

This effect can also be observed in rod end pressure measurement of the tilt cylinder during dry land impacts and in rod end force measurements. Rod end pressure peaks, then significantly drops (after the object is cleared and the transom begins pulls back in), then rod end pressure significantly rises again. Rod forces mirror rod end pressure measurements.

Some videos actually show the angle of the drive (tilt) appearing to decrease during this phase (drive is swinging down instead of swinging up when top of transom is bowing out), then the drive begins to swing upward again.

Summary

The transom is a very important component of the log strike system. It must flex /bend/ twist, but not crack or break, or allow motor mounting bolts to pull through.

By flexing, the transom extends collision time, reducing maximum forces.

Little attention has been drawn to the role of transoms during impacts with floating or submerged objects. Thus, we suspect the opportunity still exists to optimize transoms to absorb more energy during initial impact while maintaining the rigidity needed to prevent breakage.

Research needs to be done to better understand the dynamics of transoms during on water impact testing.

1A2. Tilt Cylinder Provides Two Stage Damping (at top or at bottom)

If the boat is on plane, the outboard strikes a submerged object, and the outboard cannot swing up fast enough to clear the object, the outboard can be pulled off / ripped off the boat before the the outboard clears the object.

Rotational inertia of the outboard is the resistance of the outboard to angular acceleration (being relatively vertical behind the boat when underway, then rapidly swinging up during a log strike). If dampening provided by the hydraulic log strike system plus the rotational inertia of the outboard adds up to too much resistance before the outboard clears the object, components may fail.

To reduce initial resistance supplied by the log strike system, some outboard manufacturers patented tilt cylinders with two stage damping at the bottom.

Note, there are 2 basic types of two stage damping designs for outboard tilt cylinders.

1. Two stage damping tilt cylinders designed to allow the outboard to swing upward, clearing the log or obstacle with minimal or a low amount of resistance to its upward swing, then a heavier force is applied to resist the momentum of the outboard as it continues to swing upward. These two stage cylinders help prevent the outboard from breaking off at the bottom (breaking off before it clears the object).

2. Two stage damping tilt cylinders designed to provide additional cushioning at the very end of their stroke (top of the outboard's tilt range). This type is designed to prevent metal to metal contact within the tilt cylinder. Such metal to metal contact can result in a considerable shock load if the outboard rotates all the way up and still has rotational energy after reaching the top. Cylinders of this design (end of stroke cushioning) can help prevent outboards from over rotating, crushing their cowl on the back deck, breaking off, then rotating on into the boat.

As seen on the following pages, designs for two stage damping of tilt cylinders have long been known. Several major outboard manufacturers have patented or licensed them at some time.

It remains to be known why they are not in use at this time. We suspect it has to do with complexity and cost.

Brunswick (Kiekhaefer Corporation and Mercury Marine)

Kiekhaefer Corporation

Kiekhaefer Corporation, which later became Mercury, did some early work in this area.

Carl Kiekhaefer, himself, patented an early two stage cylinder for tilting outboards. **US Patent 2,953,335**, Outboard Propulsion Unit for Boats. The patent was issued 20 September 1960. The patents read almost like he was speaking about today's time:

> *"With the relatively large and high powered outboard motors capable of high speed, common today, impact with a submerged or floating object imparts a considerable angular momentum to the motor about its pivotal axis in an upward direction causing a considerable impact between the motor and its mounting bracket at the top of the pivot."*

Mr. Kiekhaefer knew it was important to allow the outboard to clear obstacles before strongly damping its upward swing. His patent reads:

> *"The arrangement and construction of the damping mechanism provides that there be little or no damping of the pivoting propulsion unit in the upward direction until the leading edge of the skeg is substantially on a horizontal plane with the bottom of the boat or substantially free of the water surface so that the propulsion unit can clear the obstacle which caused the unit to pivot. Thereafter progressively heavier damping is applied to prevent a violent impact at the top of the pivot."*

Charles Alexander filed a patent application in 1963 resulting in **US Patent 3,246,915** Outboard Propulsion Unit for Boats which issued on 19 April 1966. The patent for a two stage tilt cylinder was assigned to Kiekhaefer Corporation (Mercury).

Charlie Alexander's patent explained the problem, and proposed a two stage damper as a solution:

> *"However, in order to provide the propulsion unit relief from obstructions in the water, it is extremely desirable that any such shock absorber be constructed to provide only a minimum amount of resistance to the initial portion of the upward tilting movement of the unit." ...*
>
> *"The damper assembly is operative following the initial tilting of the unit in either direction and damps and dissipates the angular momentum of the unit as the latter approaches the limit positions of tilting movement to enable the unit to come to a safe controlled stop thereat."*

Carl Kiekhaefer's **US Patent 2,953,335**, Charles Alexander's **US Patent 3,246,915**, and several other patents following in this section taught the need to allow the outboard to slip up and over submerged objects before applying large forces to retard its upward swing. That knowledge appears to have been forgotten over the passage of time by today's outboard manufacturers.

Brunswick / Mercury Marine

Active Tilt - in 2015 Brunswick filed a patent for a log strike system using Magneto-Rheological (MR) fluid in which the “blow off” pressure of the cylinder can be actively controlled during a log strike. In effect, creating an infinite stage cylinder.

See our coverage of these cylinders and Brunswick’s **US Patent 9,290,252** in section **1A4. Active Control of Tilt Cylinder.**

Outboard Marine Corporation

Outboard Marine Corporation (OMC) patented a two stage outboard tilt cylinder in 1993. In **US Patent 5,195,914**, OMC said:

> *"It is generally believed that the loads reach a maximum when the outboard motor begins to rotate up from the impact, while still in contact with the underwater object. At this point, the rotating part of the outboard is subjected to high loading from the shock absorber as well as impact loads caused by the object."*

As a result, OMC proposes a tilt cylinder that provides a smaller initial counterforce during maximal loading (when the object is first struck), and a higher counterforce as the outboard continues to swing upward after clearing the object.

OMC says functionality of a two stage device reduces potential for damage to the motor, motor mounts, transom, and swivel bracket assembly.

OMC achieves two stage cushioning by allowing the traditional piston that would normally house relief valves to slide within a piston they call a slider piston (#54 in **Figure 5**).

OMC's two-stage cushioning patent does not place relief valves in the traditional piston (#50 in **Figure 5**). Instead, it uses three check valves that allow fluid trapped between the piston and the slider piston to exit toward the barrel end of the cylinder as the rod extends after striking submerged object.

During collision with a submerged object, the piston rod continues to extend and the piston reaches the upper end of the slider piston. The upper end of the slider piston has four holes that align and communicate with the check valve holes and with the open through hole in piston (#50 in **Figure 5**). OMC says this communication could be accomplished by adding groves to the top of the traditional piston. The holes (#72) in the slider piston are smaller than the holes in the traditional piston (#50), increasing the resistance to upward movement.

The piston also has a small hole bored through it to allow the piston to settle back down to the other end of the slider piston after the collision.

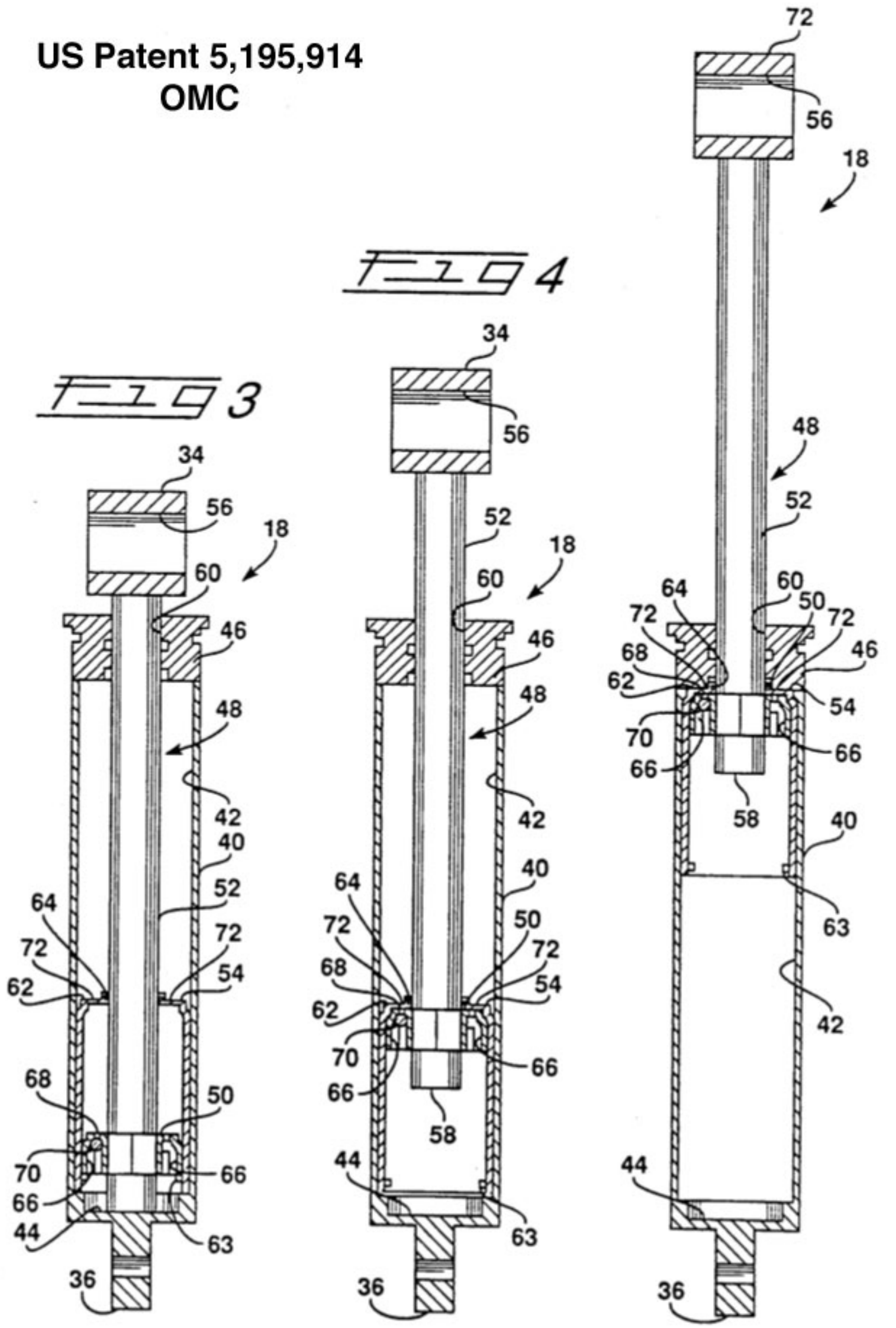

Figure 5: US Patent 5,195,914 OMC 2 stage shock piston

Volvo Penta

Four Swedish inventors filed a patent application resulting in **US Patent 5,584,225** Hydraulic Cylinder, Especially for Trim and Tip Cylinder for Outboard Type Boat Propeller Drive Units that issued on 17 December 1996. The patent was assigned to Volvo Penta.

The inventors of this two-stage cylinder say their device makes "*it possible to vary the resistance to piston movement caused by an external force, depending on the position of the piston in the cylinder.*"

Yamaha (Sanshin)

Sanshin (renamed Yamaha Marine in February 2003) was issued a two stage shock absorber patent in Japan in 1989.

Japan Patent JPH01282088. Shock Absorber for Leaping up of Marine Propulsion Machine. Saito Hideki and Onoe Akihiro. Assigned to Sanshin.

The patent covers throttling the area of a passage to increase hydraulic resistance (dampening) when the lower part of the outboard clears the water. Typically when the outboard remains attached and clears the water (the obstruction) its rotation begins to slow. As cylinder rod speed decreases, resistance generated by relief valve shock absorbers begins to decrease with decreasing flow rates.

This patent lowers the initial resistance until the lower part of the propulsion unit clears the water. At that point, a fluid passage is further throttled increasing dampening. The result is a two humped dampening chart as seen in **Figure 6** that has a lower peak “A” than conventional systems.

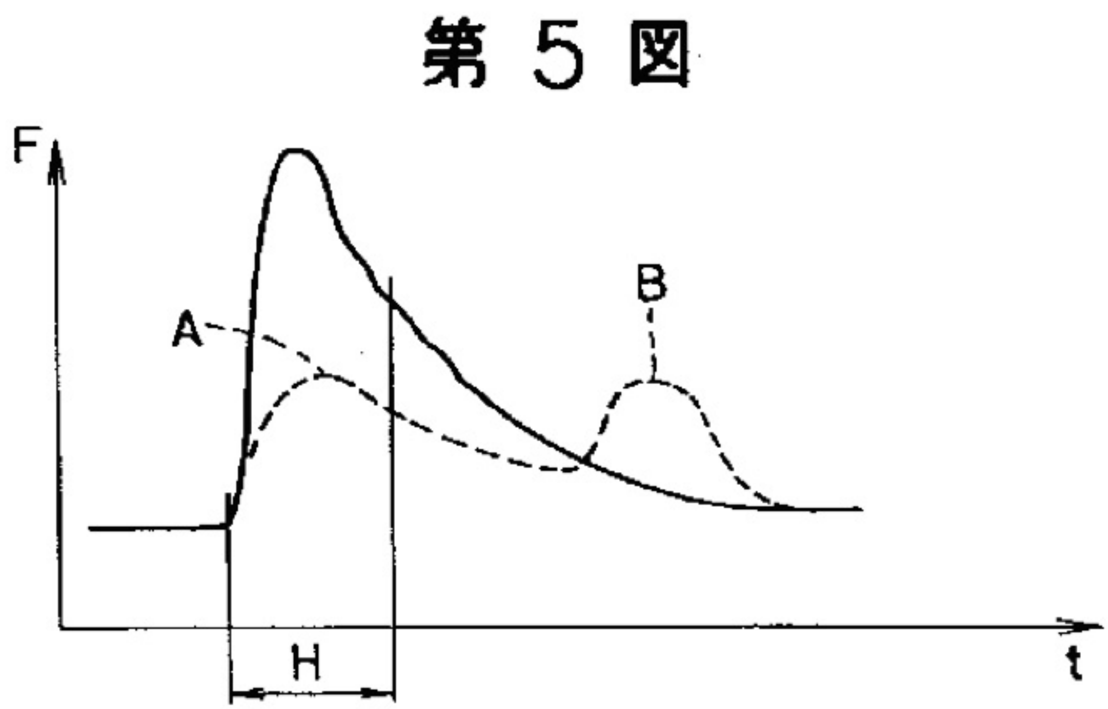

Figure 6: Figure 5 from Sanshin Japan Patent JPH01282088
Solid line represents piston rod speed after strike
Dotted line represents damping force

Per a machine translation of the patent, Sanshin says traditional methods create high dampening forces before the lower part of the propulsion unit clears the water resulting in unnecessary stress to the propulsion unit. (see section #5 on page 790 of the patent).

Yamaha US Patent 6,309,264

The patent application resulting in **US Patent 6,309,264** Cylinder Assembly for Marine Propulsion Unit listing Hideaki Saito as inventor was filed on 30 August 1999. The patent was originally assigned to Sanshin (early name for Yamaha Marine) and issued on 31 October 2001.

On 15 October 2001, the above patent was assigned to Soqi Kabushiki Kaisha with an effective date of 20 September 2001.

On 30 December 2007 the above patent was assigned to Yamaha Motorpowered Products Co. Ltd. Japan with an effective date of 4 January 2006.

The combined trim and tilt cylinder patent includes two levels of relief valves. One for normal impacts and another for when “a massive obstacle is struck”.

Speaking about traditional tilt cylinders in columns 3 and 4 of the patent, the inventor says;

> *“As has been noted above, when an underwater obstacle is struck the outboard drive, the popping up action is caused by this hydraulic mechanism and destruction of the outboard drive is prevented from occurring effectively. However in the event that a massive obstacle is struck and huge force is abruptly exerted upon the outboard drive, tremendous pressure is produced in the tilt cylinder bore 21. If this pressure is beyond the ability of the shock absorber valve 31, the piston rod 22 will be greatly restricted in its rapid upward motion As a result the outboard drive may not clear the obstacle smoothly.* ***This gives rise to deterioration of durability of the outboard drive****.”*
> Bolding added by us.

We interpret “***This gives rise to deterioration of durability of the outboard drive****.”* to include events like the outboard motor breaking off and flipping into the boat.

The invention has a second shock absorber mechanism to handle these extreme strikes. The design as illustrated used eight relief valves for the second stage of protection.

Yamaha US Patent 7,128,625

The patent application resulting in **US Patent 7,128,625** Tilt and Trim System of Outboard Drive of Propulsion Unit listing Saito as inventor was filed on 12 September 2004. The patent was originally assigned to Soqi Kabushiki Kaisha and issued on 31 October 2006.

On 30 December 2007, the above patent was assigned to Yamaha Motorpowered Products Co. Ltd. Japan with an effective date of 4 January 2006.

This patent allows the drive to “popup” when striking underwater obstacles, but the entire range of movement is limited to reduce shocks at the end of the drive’s upward swing. A spring loaded “oil lock piston” is used to prevent metal on metal contact between the cylinder piston and the cylinder end cap at maximum extension of the cylinder rod.

Yamaha Acquired Rights to Two Patents

Yamaha acquired or acquired rights to **US Patent 6,309,264** and **US Patent 7,128,625** in December 2007. The patents teach how to design an outboard to:

1. Survive striking a “massive obstacle” and the resulting “huge force” by allowing the outboard to rapidly clear the obstacle.

2. Prevent metal on metal contact at the top of the swing of the outboard after striking such an obstacle.

Several Two Stage Damping Patents for Tilt Cylinders Have Been Issued

Among patents covering two stage damping of hydraulic tilt cylinders are:

1. **Japan Patent JPH01282088** Shock Absorber for Leaping up of Marine Propulsion Machine. Saito Hideki and Onoe Akihiro. Assigned to Sanshin.

2. **US Patent 2,953,335** Outboard Propulsion Unit for Boats. Invented by E.C. (Carl) Kiekhaefer.

3. **US Patent 3,246,915** Outboard Propulsion Units for Boats. Assigned to Kiekhaefer Corporation (Mercury).

4. **US Patent 5,195,914** Two Stage Tilt Cylinder Mechanism. Assigned to Outboard Marine Corporation (OMC).

5. **US Patent 5,584,225** Hydraulic Cylinder Especially a Trim and Tip Cylinder for Outboard Type Boat Propeller Drive Units (two stage damper). Assigned to Volvo Penta.

6. **US Patent 6,309,264** Cylinder Assembly for Marine Propulsion Unit. Invented by Hideki Saito. Patent issued 30 October 2001. Patent rights assigned to Yamaha Motorpowered Products Co. Ltd. Japan on 30 December 2007 with an effective date of 4 January 2006.

7. **US Patent 7,128,625** Tilt and Trim of Outboard Drive of Propulsion Unit (damped without positive stops). Assigned to Soqi Kabushiki Kaisha. Assignment of Assignors Interest: Assignor Saito Hidaeki on 12 September 2004 with an effective date of 1 September 2004. Ownership of patent assigned to Yamaha Motorpowered Products Co. Ltd. Japan on 30 December 2007 with an effective date of 4 January 2006.

8. **US Patent 7,513,809** Outboard Motor Tilt Actuator with Shock Damping Feature (two stage damping). Assigned to Parker-Hannifin.

9. **US Patent 9,290,252** Systems and Methods for Controlling Trim Position on a Marine Propulsion Device on a Marine Vessel. Assigned to Brunswick. (active tilt).

10. **US Patent 9,932,997** Trim and Tilt Apparatus for Marine Vessel Propulsion Machine and Marine Vessel Propulsion Machine. Assigned to Showa. Issued 3 April 2018. (basically a cylinder inside of a cylinder).

Use more though piston relief valves

The goal of two stage damping is to allow the outboard to kickup and clear the obstruction with minimal resistance to its upward swing. Traditional non-two stage designs use relief valves in the tilt cylinder piston.

An alternative design related to two-stage damping is for the non-two stage designs to use more though piston relief valves of the same size and setting. At the initial strike, there is a very high flow rate though the through piston relief valves, raising the pressure beyond their set point. More valves could share the flow rate, bring down the overshoot, and allow the outboard to kickup quicker at a lower maximum pressure.

For example, Yamaha’s VMX SHO 200/225/250 service manual shows four through piston relief valves in use. If more were added, overshoot would likely be reduced at higher boat velocities. The additional relief valves would allow the drive to kickup easier at first than the current design, but still not as easy as true two-stage damping tilt cylinders.

1A3. Minimize overshoot of log strike system relief valves

Hydraulic relief valves are used inside tilt cylinders allowing the outboard to tilt up when it strikes something, and to absorb the energy of the impact.

Theoretically when the pressure of a system protected by a relief valve increases to the pressure setting of the relief valve, the relief valve opens and prevents the pressure from further increasing.

In real life, if the pressure in the system protected by the relief valve suddenly spikes, many systems will temporarily overshoot (exceed) the setting of the relief valve. System pressure can overshoot because:

A. The relief valve cannot act fast enough
B. Some relief valves begin to open at one pressure (crack), but not fully open until a higher pressure (hysteresis)
C. Size of the relief valve
D. The path for fluid to and/or past the relief valve restricts very high flow rates
E. The path for fluid exiting the relief valve restricts very high flow rates

When an outboard motor strikes a submerged object, the relief valves must open very quickly and almost instantly bypass high flow rates though small passages.

The spring and ball relief valves typically used inside tilt cylinder pistons for relief valves overshoot their set pressure when the outboard motor strikes submerged objects at speed.

The system of relief valves can be redesigned to absorb larger amounts of energy (larger relief valves set to higher pressures), however that may increase forces on other structural components, including the transom.

Another approach is to get all you can from the existing design. Among ways to accomplish this are to determine the profile (pressure in the rod end of the cylinder vs. time, cylinder rod force vs. time, and rod extension vs. time) needed to stop maximum loads without overloading the structure. Then maintain that profile through the upward swinging of the drive.

To accomplish this task we need relief valves that can provide the needed pressure vs. time curve as the rod extends when fixed objects are struck.

In 2010, Teleflex patented a trim / tilt cylinder log strike system design in which the traditional relief valve springs are heavier, but the preload is less. See **US Patent 7,722,418** drawings in **Figure 7**. Preload is the amount of force generated by the spring when hydraulic pressure is zero, which relates to how far the spring is compressed when hydraulic pressure is zero.

Teleflex says springs typically used in trim / tilt system relief valves have a spring constant of approximately 200 to 400 pounds per inch, meaning it takes 200 to 400 pounds to compress them one inch. Teleflex proposes a heavier spring constant in the range of 875 pounds per inch. Teleflex claims that by using this higher spring constant and by controlling the maximum size of the orifice when the spring guide contacts its upper stop, there is much less sensitivity to spring preload.

Conventional trim / tilt cylinders often use six relief valves (spring loaded balls). The high spring constant design only requires four.

A byproduct of heavier springs, is lower preloads allowing relief valves to open at relatively low pressures and dissipate energy from low energy impacts.

We suggest, high spring rate designs also allow the relief valves to open faster in really high impacts (they crack open at lower pressures) which would reduce peak loads at impact OMC discussed in their 5,195,914 patent (**Figure 5**).

In addition, if Teleflex were to install all 6 relief valves, instead of four, pressures would be more controlled under higher speed impacts of fixed or almost fixed objects.

Figure 8 shows forces generated in the trim / tilt cylinder rod during an impact, and variability of those forces based on light springs or heavy springs with changes in preload. For example, heavy springs with preloads ranging from plus 25 percent to minus 25 percent of the target preload create less variance in pressures than light springs with preloads ranging from only plus 8 percent to minus 8 percent of the target preload. Heavy springs also result in a lower peak impact force.

Similarly, **Figure 9** shows cylinder stroke (travel) vs. time for the same impact is much more consistent with heavier springs and controlled orifice size than for lighter springs and a less controlled orifice size.

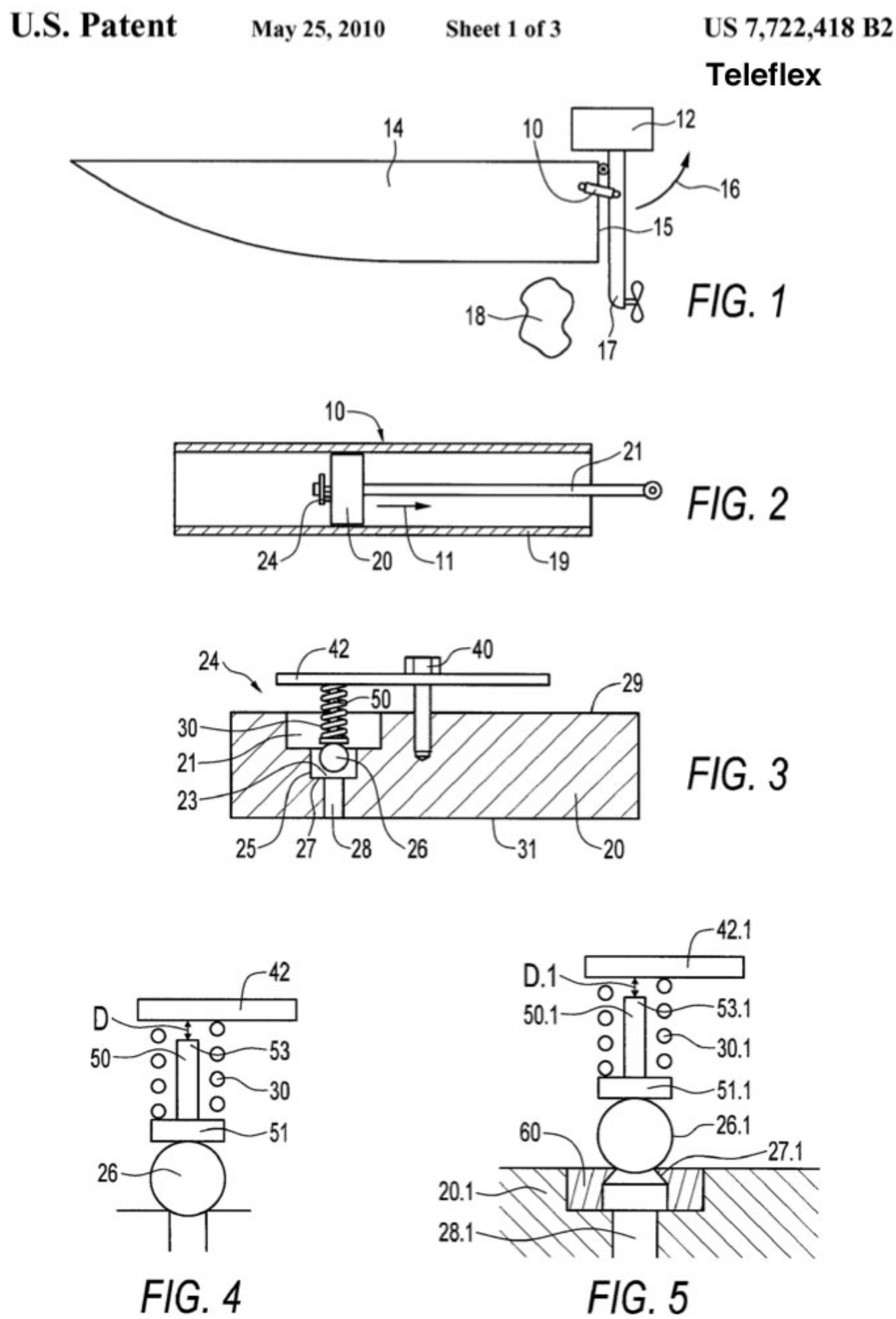

Figure 7: US Patent 7,722,418 Teleflex shock piston relief valve

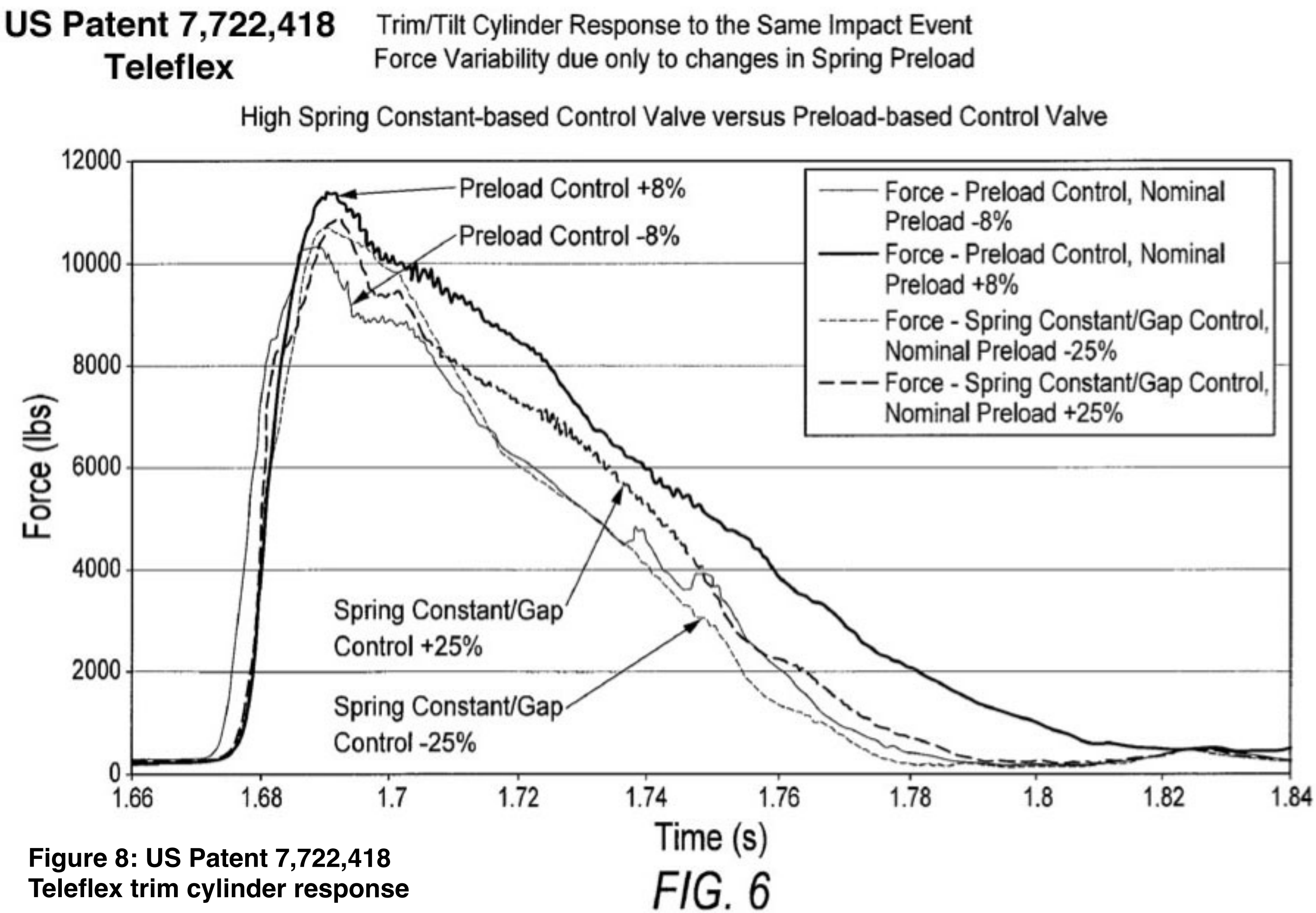

Figure 8: US Patent 7,722,418
Teleflex trim cylinder response

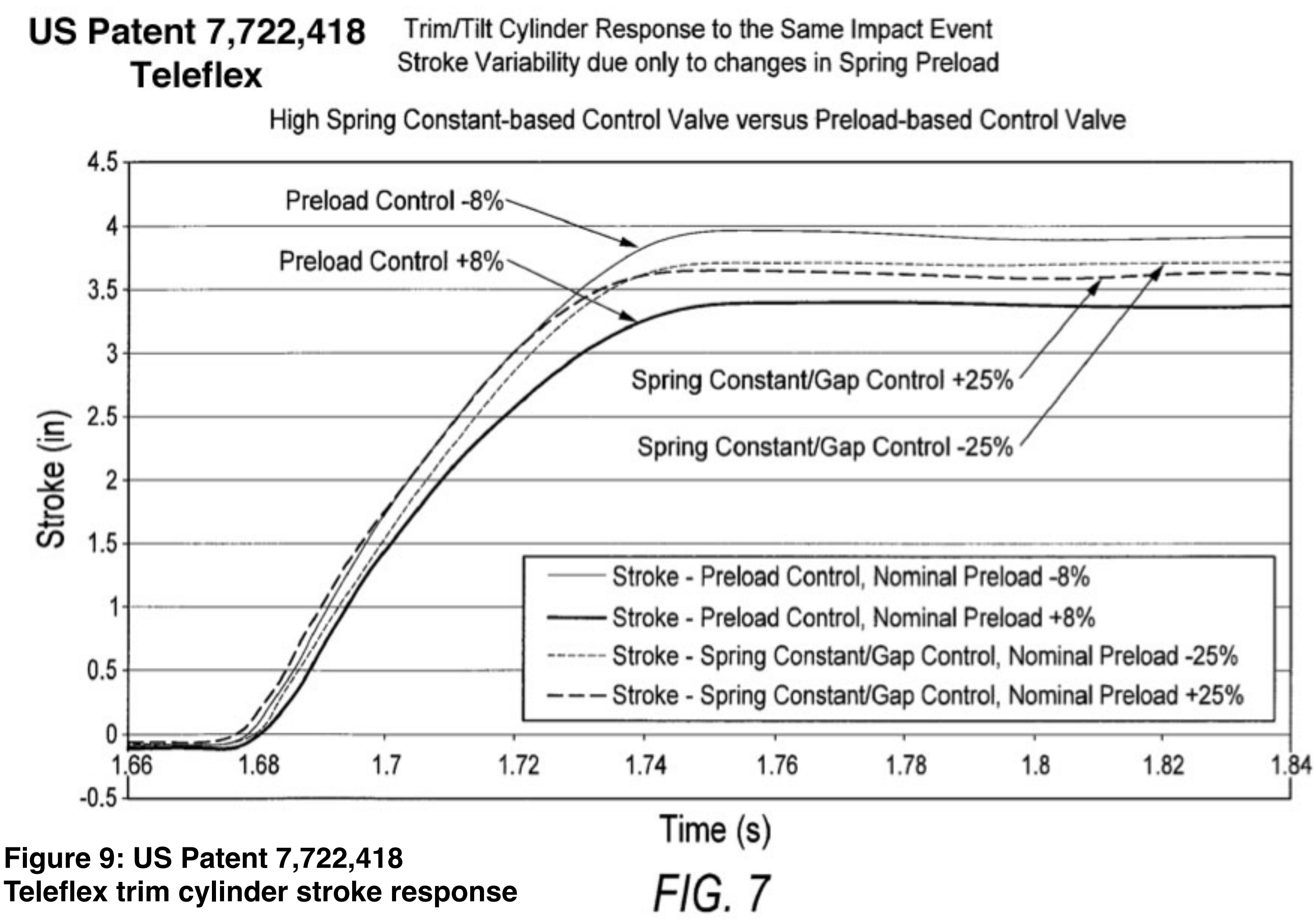

Figure 9: US Patent 7,722,418
Teleflex trim cylinder stroke response

Showa patented an outboard tilt cylinder based on the use of a “flexing disk blow-off assembly”. They claim the valve can open a large flow path at lower pressures and quickly seats after the event. The relief valve is composed of a flexible disk / washer (item 112 in **Figure 10**) that covers up ports from the rod side. When rod side pressure spikes, the periphery of the disk bends away from its seat to allow fluid to exit. Showa says the design can be used as one large flexible disk or as several smaller ones.

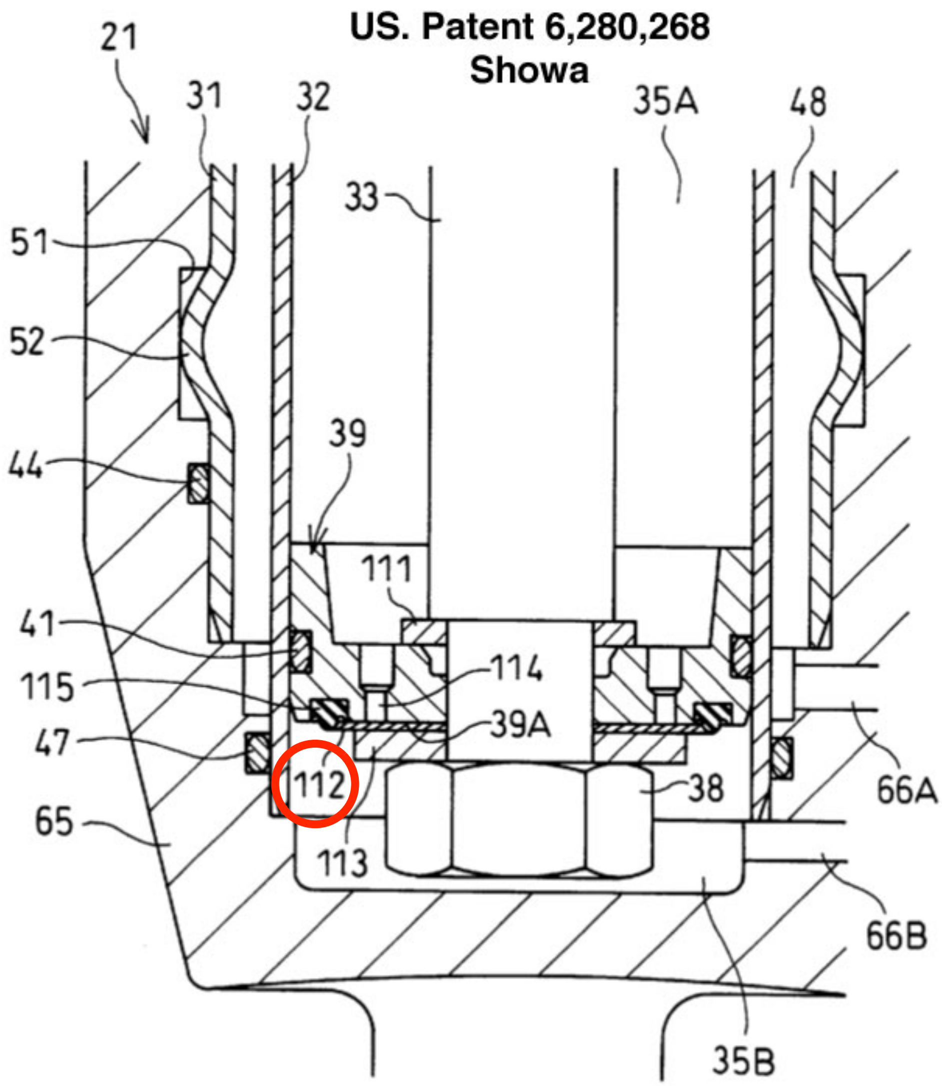

Figure 10: US Patent 6,280,268 Showa flexible disk blow off valve

1A4. Active Control of Tilt Cylinder

This section builds on the discussion of trying to achieve maximum performance from the existing system in the previous section. Taking active control of tilt cylinder rod forces, tilt system pressures, and/or stresses in the swivel bracket is the ultimate way to get the most out of the existing system.

Note - the industry now has some systems that automatically trim the boat some refer to as active trim. That is not the function we are speaking of here.

Magneto-Rheological (MR) fluids make this active tilt possible. The apparent viscosity of smart fluids can be controlled with an electromagnet. MagneRide MR shock absorbers have been OEM installed on several production luxury automobile models for over a decade.

A cutaway of a Delphi MagneRide is shown in **Figure 11**. In 2009, Bejing West Industries (BWI) acquired the Chassis Division of Delphi that builds MagneRide.

MR shocks have been used in marine applications. For example, in 2013, Shockwave Marine Suspension Seating supplied Magneto Rheological Active Damping seats (MRAD) for vessels in rough water marine applications.

MR shocks could also be very useful in tuning todays relief valve design to stop the upward swing of the drive without overloading other components. Just install an MR shock in place of the tilt cylinder during log strike testing and experiment to find the best damping profile. Then design the trim cylinder cushioning system to approximate that profile.

As to the ability of an MR system to respond fast enough and to handle the loads, we cite the automotive bumper reference and a Navy seat reference below:

“Frontal Crash Mitigation using MR Impact Damper for Controllable Bumper.” David Woo, Seung-Bok Choi, Young Tae Choi, and Norman M. Wereley. Journal of Intelligent Material Systems and Structures. A Sage journal. Vol.18. Pgs.1211-1215. (December 2007).

Adaptive Magnetorheological (MR) Shock Absorbers for High Speed Watercraft Seats. Presented by Gregory Hiemenz. Multi-Agency Craft Conference. 14 June 2011. Little Creek - Fort Story, VA.

Figure 11: Delphi MagneRide

Brunswick Active Tilt Control Patent

Since we posted the section on Active Tilt Control, Brunswick Corporation filed a patent application leading to **US Patent 9,290,252**.

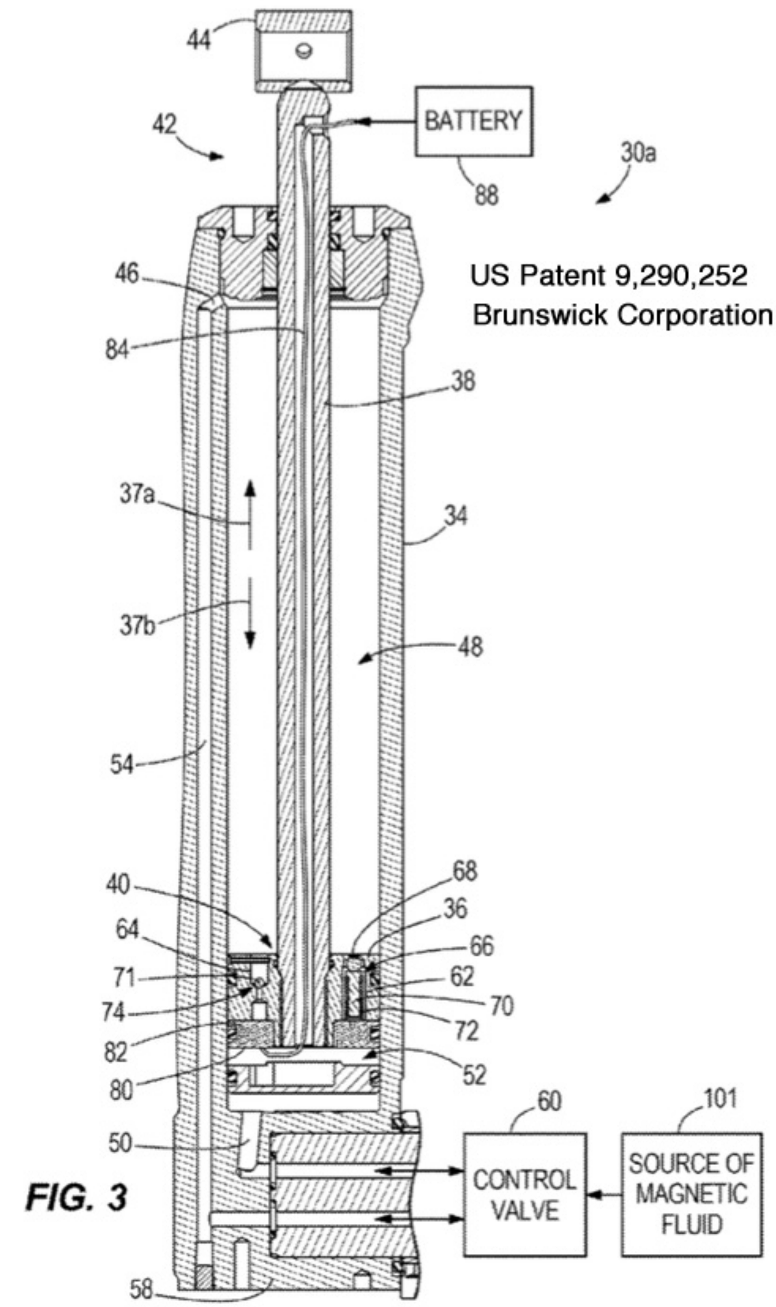

Figure 12: Figure 3 from Brunswick Active Tilt Cylinder US Patent 9,290,252

As seen in **Figure 12**, externally, Brunswick's active tilt cylinder looks like a normal tilt cylinder. It uses Magneto-Rheological (MR) fluid instead of oil. The system also includes a magnet and some electrical wires. By changing voltages, Brunswick controls viscosity of the magnetic fluid, thereby restricting movement of the tilt cylinder piston.

In order to take full advantage of the cylinder's capabilities, Brunswick's Active Tilt Cylinder system includes sensors and uses the Engine Control Unit (ECU) for access to more variables and computing power.

By knowing how far the tilt cylinder rod is extended, engine RPM, what gear the drive is in, engine load, boat speed, rod end pressure of the tilt cylinder, the system can make decisions on how best to respond to events like log strikes in real time.

The ECU and potentially other computers, in combination with previously computed response maps (what to do based on status of certain inputs and outputs) can optimize tilt cylinder response during collisions with submerged objects and in rough water conditions.

Brunswick's patent states in column 10:

> *"the system can include the above noted engine speed sensor and the engine control unit can be programmed with a calibration map that is developed for engine speed (e.g. rotations per minute) and a corresponding "blow-off" pressure profile for the trim actuator."*

This approach basically creates an infinite stage cylinder in which "blow off" pressure can be actively adjusted by a computer during impact.

Brunswick's CANBUS system allows active tilt systems access to many variables such as boat speed, boat acceleration, outboard RPM, if the system is in gear or not, direction of travel, tilt angle, rate of change of tilt, steering angle, etc. In addition certain physical variables could be input during setup, such characteristics of the boat.

Brunswick's patent goes on to teach how the system can be used in combination with sensors detecting imminent impacts to improve tilt cylinder response.

Continued

PLEASE NOTE - we refer to the invention on the previous two pages as Brunswick's / Mercury's Active Tilt patent. During this same time frame Brunswick / Mercury introduced a feature they call Active Trim (Active Trim, not Active Tilt). Brunswick's Active Trim system integrates with onboard GPS and other sensors to actively trim the boat during normal operation. In June 2018, Brunswick's Active Trim system received The Sustainable Product of the Year award from the Wisconsin Sustainable Business Council. See **Figure 13**.

Figure 13: Brunswick Active Trim Control
image courtesy of Mercury Marine

While Brunswick's current Active Trim feature currently makes no use of their Active Tilt cylinder patent, we can envision Active Tilt being included at some future date.

It is interesting Brunswick integrated GPS speed sensing into their Active Trim system. Historically, they would have gone with engine RPM and gear position (in neutral, forward, or reverse) to get some feel of forward speed for establishing an optimal trim. Now, by directly accessing GPS speed data, Brunswick is better able to optimize trim.

The same GPS speed data now used by Brunswick's Active Trim system could be very useful for making split second decisions during impact with a submerged object.

1A5. Share the Load

Structural components of outboard motors can be overloaded and break during impacts with submerged objects.

Some outboard structural components are already used in multiples to share the load, such as two motor mounting brackets, four outboard mounting bolts, four jack plate mounting bolts, and four outboard motor mounts.

Duplicity of components increases strength and provides backup in the event one of them fails.

The swivel bracket is noticeably missing from the list of duplicate components. it is frequently broken in instances in which the outboard motor enters the boat.

A tether known as The Leash will be discussed in depth later in this report. However, it will be introduced now. See **Figure 14**.

The Leash consists of two high tech straps with loops on both ends. The straps link together and the two ends with washers in them go under the outboard motor mounting bolts. See **Figure 14**.

The Leash is sized per your particular outboard and jack plate to allow the outboard to reach maximum tilt without resistance, then quickly become tight if the outboard continues to rotate up. Some have estimated during a collision with a submerged object, an outboard can rotate an additional 5 degrees after it reaches maximum tilt.[1] This occurs due to everything stretching, including metal parts. If additional energy remains after the outboard rotates this additional 5 degrees, the outboard may break off and rotate into the boat.

The Leash “Shares the Load” by providing another path to carry the load around the swivel bracket. The outboard is pushing up against The Leash as it swings up after striking a submerged object and The Leash is pulling on the top outboard mounting bolts.

By creating this additional path, some outboards will not break off and rotate into the boat.

The Leash basically acts as a harness or exoskeleton for the swivel bracket and shares its load.

Note - The Leash does not share the load in instances in which the outboard motor breaks off before it clears the object.

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[1] Affidavit of Edward V. Fritsch II. Barhanovich vs. Bean & Suzuki. U.S. District Court. Southern District of Mississippi. Southern Division. Filed 30 July 2015. Page 11 of 33. PACER Document #360-1.

When we study The Leash more fully later in this report, we will learn The Leash can restrain the outboard in the event the outboard motor breaks off.

Figure 14: The Leash
Jamie Hartman Fishing image 25 April 2018 Grand Lake, OK. Facebook

1A6. Stops at Top of Swing

A crushable stop placed to stop the tilt cylinder after it reaches reaches maximum normal extension could absorb some of the remaining energy and prevent the outboard from breaking off in some situations. The crushable stop could be placed external to the log strike system or, it could be placed inside the tilt cylinder.

If the tilt cylinder and its attachment points were strong enough, a crushable block could be placed inside the tilt cylinder at the rod end. The piston would only strike the crushable block when the cylinder exceeded its normal stroke. The crushable block could be built with hollow areas similar to those seen in Brunswick's crushable nose cone and leading edge seen in **Figure 3**, or as a crush tube. As the cylinder rod continues to extend, the crushable block would absorb the remaining energy of the upwardly rotating outboard motor.

Hitting the crushable stop would likely result in a failure of the tilt cylinder, however, a failed tilt cylinder is preferable to the outboard breaking off and flying into the boat or falling into the lake.

1A7. Reduce Weight of Outboard Motor(s)

Outboard motors flip into the boat after striking submerged objects in part because of their mass. When the lower leg strikes something, the leg begins to rotate backwards and upwards. Modern, large, higher horsepower outboard motors are heavy. All that weight begins to rotate. If the mass and rate of rotation is too great for the log strike system to handle, the swivel bracket, jack plate, or other parts may fail, the outboard flips over itself and enters the boat.

Techniques for making outboard motors lighter include:

1. Modern, large outboards are generally lighter than their predecessors.

2. Use twin outboards. Reports of both twin outboards striking an obstruction are rare. Even if they did, the individual outboards would each be considerably lighter than the single outboard they replaced.

3. Apply an improved version of Volvo Penta's XDP Ocean Series composite stern drive technology (composite gear case) to outboards to reduce weight

4. Historically, two stroke outboards have been lighter than four stroke outboards.

5. Use a lower horsepower outboard motor. Cleaning the hull and removing excess weight and accessories can regain some of the lost speed, as can changing to a smaller, lighter boat, and to a stainless steel propeller.

Stainless steel propellers improve performance (thinner prop blades turn at higher RPMs) with less horsepower, but add weight to the outboard themselves.

1A8. Reduce Boat Mass

Kinetic energy of a boat during a collision with a submerged object is proportional to mass of the boat plus the outboard motor times the velocity squared. Many opportunities exist to decrease boat mass (weight).

Among them are:

1. Switch to a lighter outboard motor as described in the previous section.

2. Consider using an aluminum hull (they are much lighter than corresponding fiberglass hulls)
.
3. Do not purchase a larger boat than you really need.

4. If you only need a really large boat once a year and fish the rest of the year with a buddy or two, consider buying a smaller boat and renting a larger boat for those few times you need it.

5. Only go out with the gear you need.

6. If you have not used something all year and it is not a tool or a piece of safety equipment, you likely do not need it onboard.

7. If you carry a spare stainless steel propeller, consider carrying an Aluminum or plastic backup propeller to decrease weight.

8. Do not run with more fuel than you need plus a reasonable reserve.

9. Do not fill live wells unless you need them.

10. Limit the amount of gear guests carry on board your boat.

11. Take the ice coolers you need onboard. Do not carry multiple large coolers unless you need them.

When calculating impact forces from the standpoint of the boat, the mass that matters is the objects solidly attached to the boat that will not fly around or slosh around during impact.

Note - if the outboard log strike system responds fast enough, and has enough capacity, the mass influencing collision forces can be limited to the mass of the portion of the outboard motor that swings upward.

1A9. Drastically Reduce Boat and/or Outboard Motor Drag

This approach is generally not yet ready for additional recreational boat applications.

Researchers have long worked on ways to significantly reduce drag in water. I myself worked on one in college long ago (use of long string polymer to reduce drag in pipes). That method and long string polymer injection is still around.

The Soviets began using marine drag reduction technologies long ago with Wing in Ground Effect (WIG) vessels and the VA-111 Shkval supercavitating torpedo, both of which only became broadly known in the west in recent years.

The U.S. military pursued several marine drag reduction approaches including SWATH and air cushioned vessels.

Other approaches include films (ribblets), coatings, injecting air bubbles, heated surfaces, and vibration. To date in the marine industry, these efforts have focused on larger vessels and ships, not traditional recreational boats.

Major reductions in drag could allow lower horsepower outboard motors to achieve similar acceleration and speed performance. Being able to downsize your outboard motor one frame size and still power your boat at the same speeds reduces the mass of your outboard motor. Reducing the mass of your outboard motor reduces the loads generated when an object is struck (lighter motor struck at same speed). This could reduce the probability the outboard will flip into the boat when it strikes a submerged object.

Marine drag reduction methods are often separated into Active and Passive approaches. Active approaches are those when the the vessel or object is doing something such as vibrating. In passive approaches the vessel or object is passive, such as the boat or drive has a special coating or surface.

More recent drag reduction efforts have focused on making objects smoother / slicker, and allowing air in the barrier between the object and the water.

Superhydrophobic surfaces show some promise. They stay dry by trapping a layer of air near the surface. Traveling waves (waves created by the object) are also receiving attention. Bionics (the science of applying methods in nature to man's problems) continues to make progress, for example the Olympic swim suits.

In some instances multiple approaches may be used at the same time.

Drag reduction technologies have influenced recreational boat hull designs (planing hulls, stepped hulls, tunnel drives, catamarans) and drives (Arneson) in years past. They will likely again do so in the future.

1A10. Reduce Maximum Boat Speeds

A common thread in many “flipped in” accidents and proposed solutions is speed. Impact energy is proportional to the square of boat speed. Speed is a critical variable. While most proposed solutions try to deal with the energy created by speed, one obvious solution is to reduce maximum boat speeds.

Speed reduction can be accomplished several ways. Most of them fall into three categories:

1. Limiting maximum RPM
   a. Use the Engine Control Unit (ECU) to limit maximum engine RPM
   b. Use an overspeed governor to limit maximum RPM
   c. Use a rev limiter

2. Reducing maximum horsepower

   A. Detune the outboard
   B. Limit maximum RPM (note this approach was listed separately as item #1)
   C. Switch to a smaller outboard motor
   D. Use of a fob like Mercury uses on their 1550 dual calibration stern drive[2]
   E. Lower maximum horsepower rating on boat capacity plates
   F. Bass tournament organizations reduce the maximum horsepower limit

3. Limiting maximum boat speeds

   A. Input boat speed or an estimated boat speed into the Engine Control Unit (ECU) which controls throttle position, air intake and other variables to reduce power to not exceed a programmed maximum speed
   B. Input boat speed or an estimated boat speed into a control unit which increases resistance such as trim tabs to limit boat speed to the desired maximum speed
   C. Limit maximum RPM (note this approach was listed separately as item #1)
   D. Use of a valet key

A number of speed limiting systems are already on the market for boats. Most are used to limit engine power in certain situations such as when the engine detects overheating or some other fault, when a certain key is not present, or when there is desire to switch from a high performance mode to a recreational mode. For example, Mercury’s Guardian system essentially speed limits the boat in certain situations to protect the outboard motor. The same system could be used to protect people in certain situations.

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[2] Mercury Racing 1550 Sterndrive. Press Release. 12 February 2015. (dual calibration stern drive)

PWC manufacturers have been speed limiting consumer model PWCs built for sale in the U.S. to a maximum speed of 67mph for over fifteen years.

Bass anglers want to jump up on plane fast, access to full power in blast offs, and access to maximum horsepower at times other than at maximum speed. Thus, the limiting or partial limiting of maximum boat speeds is more attractive than simply limiting maximum horsepower or limiting maximum RPM.

Limiting maximum speeds is not without precedence. Automobiles, boats, personal watercraft (PWC), all terrain vehicles (ATV), snowmobiles, and automobiles have all been speed limited.

Automobiles

Several luxury and performance production cars are speed limited. Japan speed limited its cars,[3] Germany speed limits some of its cars,[4] Ford allows owners to speed limit their cars for younger drivers and others via their MyKey system,[5,6] and Ford is known for speed limiting the 2011 V6 Mustang.

Boats

A number of speed limiting systems are already on the market for boats. Most are used to limit engine power in certain situations such as when the engine detects overheating or some other fault, when a certain key is not present, or when there is desire to switch from a high performance mode to a recreational mode.

Tournament bass boats are currently speed limited by tournament organizations limiting engines to a maximum of 250 horsepower.[7, 8]

PWC, ATV, Snowmobiles

Many personal watercraft (PWC), all terrain vehicles (ATV), and snowmobiles come with adjustable speed limiters for renters/ novices beginners learning how to ride. Some PWC rentals are speed limited in addition to the normal speed limiting (meaning a rental operation may choose to limit their PWCs to something below 67 mph.)

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[3] Why Japan Finally Got its Foot off the Brake. The Japan Times. 13 April 2008.

[4] Gentleman’s Agreement: Not So Fast, Sir! Autoevolution. 28 July 2012.

[5] Ford MyKey System Explained. Autoevolution. 19 November 2009.

[6] Use Ford MyKey to Help Encourage Responsible Driving. Ford web site. 4 April 2016.

[7] Official Rules. B.A.S.S. Nation. Effective January 1, 2016. (3 pages of the rules)

[8] 2016 FLW Tour Rules. FLW FIshing League Worldwide. partial screen capture marked. captured 27 April 2016.

PWC top speed limit

Power is a major part of the thrill of riding many Personal Watercraft. The ability to take off quickly, maintain speed in turns, accelerate at speed, carry multiple riders, and deliver snappy performance are desired features. Similar to bass boats, maximum horsepower has increased dramatically through the years. PWC cruise controls and speed limiters address water jet issues of being airborne at times as bass boats can be temporarily airborne as well.

As a result of increasing horsepower, modern PWC are capable of going much faster than those of years ago. However, In 1999, the Personal Watercraft (PWC / jetski) industry came to a "handshake" agreement with the U.S. Coast Guard to limit maximum PWC speeds to 65 mph plus a 2 mph leeway.

The following quote comes from the October 1999 meeting of the U.S. Coast Guard's National Boating Safety Advisory Council minutes:

> *"**Captain Holmes** said ... He said that he was pleased to announce that a consensus was reached with PWC industry on a manufacturers' speed cap of 67 mph, i.e., 65 plus 2 for any production variances. "*

The Wave Runner has made Yamaha a prominent manufacturer in the PWC industry. WaveRunner performance models and those of their competitors are capable of going faster, sometimes much faster than 68 mph. However PWC manufacturers have been speed limiting consumer model PWCs built for sale in the U.S. to a maximum speed of 67mph for about fifteen years.

In addition to speed limiting PWC on the top end and providing adjustable speed limiter for beginners, Yamaha also has an exclusive No Wake mode for maintaining an optimum speed (engine RPM) in no wake zones.

Outboard rev limiters

Yamaha has a rev limiter on their VMAX SHO 200-225-250 horsepower outboards.[9] Several online references say the VMAX SHO outboard rev limiter is set at 6100 RPM.

Several marine firms have horsepower, RPM, or speed limiting patents. Among those patented by Yamaha are:

1. **US Patent 6,695,657**. Engine Control for Watercraft. Assigned to Yamaha. See near bottom of column 13 where multiple lanyards can be used to restrict engine horsepower or RPM.

2. **US Patent 6,895,286**. Control System Optimizing the Function of Machine Assembly Using GA-Fuzzy Inference. Assigned to Yamaha. Illustrates Yamaha's capabilities to use Fuzzy Logic and Genetic Algorithms to control outboard motors and Personal Watercraft (PWC). While not specifically discussing limiting engine horsepower, RPM or boat speed, technologies and approaches could lend themselves to this task.

3. **US Patent 7,549,900**. Operational Control Apparatus for Planning Boat. PWC cruise control that includes the ability to limit maximum speed when not in cruise control mode.

4. **US Patent 8,033,878**. Vessel Speed Control System For Small Planing Boat and Small Planing Boat Utilizing the Same. Assigned to Yamaha. Limits maximum speed.

5. **US Patent Application 2013/0252490**. Watercraft. Assigned to Yamaha. Limits maximum speed. Can determine speed from time "filtering" engine RPM, watercraft speed sensor, watercraft speed sensor based on water flow, or GPS speed input. Speed can be limited by modifying engine variables or by increasing vessel resistance (like trim tabs).

Speed limiters are an alternative available to outboard manufacturers trying to prevent outboard motors from flipping into boats after striking submerged objects.

Geofencing could be used to restrict access to full power with no time limit to certain lakes or certain areas of those lakes.

Geofencing could be supplemented with the calendar (more runoff debris in the spring), lake levels, depth finders, water conditions, use of fobs, lanyards or other techniques to further expand the use of full power if desired. Yamaha's Fuzzy Logic / Genetic Algorithms patent could lend itself to considering inputs like these, then selecting an appropriate maximum speed.

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[9] The V MAX SHO Yamaha Marine Hot Sheet effective 1 November 2009. page 3.

In its simplest mode, speed limiting could limit boats to a maximum speed equal to the minimum speed at which their log strike system begins to fail. Outboards installed with fail-safe designs (fails in a mode not allowing the outboard to enter the boat) would not need to be speed limited.

Optional enhancements could include the ability to run full speed for a few minutes at a time, and the ability to run full speed within geofenced areas known to be free of submerged hazards.

If large boats could accept a maximum speed fob, bass tournaments could distribute fobs based on lake conditions (risk level). This feature might also be of interest to those trying to prevent boat to boat collisions on weekends with several bass tournaments in operation of the same lake.

1B. Increase Strength of Existing Structural Components (swivel brackets, motor brackets)

A common suggestion toward preventing these accidents is to make stronger structural components. While it is a good idea, one must use caution to not just chase point of failure to the next link in the chain. One must also make sure other issues are not created by the changes (sometimes called unintended consequences). Integrity of the transom must also be considered.

Outboard manufacturers place certain requirements upon installation of their outboards by boat builders in order for their warranty to be in effect. For example, field engineers check to make sure sufficient cooling water is pulled in to cool the engine, and to make sure controls (throttle, shift, steering) work properly. Some outboard manufacturers already place some requirements on transoms for certain sizes of outboard motors. Those requirements could include some basic strength requirements or performance requirements on how transoms responds to impacts.

In typical industrial equipment situations, a common approach to failure is to add more steel. However, boats being used in a marine environment creates a range of issues not seen in most industrial applications. Recreational boats are fraught with corrosion issues, vibration issues, and a never ending quest to minimize size and weight of larger outboard motors.

Several approaches to increasing strength of existing structural components follow. They must be considered alongside issues raised above.

1B1. Use High Performance, Offshore, Commercial, or Racing Parts

Most major outboard manufacturers already have clamp brackets and swivel brackets for 300 horsepower and above outboard motors. Mercury and some other outboard manufacturers build specific models of outboards for high performance, commercial, offshore, and racing applications.

Larger, stronger clamp brackets and swivel brackets for those applications could be adapted to recreational outboard applications, or at least the engineering expertise, materials, and manufacturing processes used to produce them could be used to increase recreational outboard motor durability.

1B2. Increase Physical Dimensions of Parts

As per the industrial equipment approach mentioned earlier, add more steel, or in this instance add more aluminum.

By increasing physical dimensions of structural components one can increase their strength. For example by increasing thickness of clamp brackets and overall dimensions of swivel brackets one can make them stronger.

While doing so, one must remember they are increasing mass of the outboard motor and boat which work against you during impacts. Plus increasing physical size and weight of the outboard goes against the industry's efforts to make outboard motors smaller and lighter.

Thus, increasing physical dimensions of parts must be done selectively, sparingly, and with targeted precision. See (**Section 1B8**)

1B3. Use Stronger Materials

Many looking at the problem suggest use of stronger materials, particularly steel for outboard motor structural components.

While steel can add considerable strength within the same frame size of existing components, steel significantly increases weight of the boat and outboard motor which work against you in impacts with submerged objects, and in its everyday operation.

Steel brings corrosion issues to the marine environment. Steel cannot be easily formed into the same parts using existing processes at outboard motor manufacturers.

While the future may bring carbon fiber or other stronger alternative materials to the table, for now aluminum appears to be the practical material for some outboard motor structural components.

1B4. Use High Impact Resistant Alloys

Previous sections (**Section 1B2**, **Section 1B3**) noted some challenges with just beefing up parts or changing them to steel. This section explores aluminum alloys.

When metal parts are impacted at high strain rates (metal is stretching at a high rate), such as in an automobile crash, some alloys can absorb more energy than others.

For example, Mercury Marine explored this subject during development of their impact resistant M-367 aluminum alloy.

This quote comes from our website coverage of Mercury's developments:

> *"The very basics of what happened is Mercury found that small quantities of Strontium could make certain aluminum alloys more durable, allowing parts made from them to stretch more before incurring a permanent set which allowed their structural parts (like swivel brackets) to absorb more energy during a collision with a submerged object before failing. These alloys were not just more durable, they were more durable at high strain rates (when a load was applied very quickly such as during a crash). Thus Mercury was able to raise the speed at which their components would fail in some collisions."*

Brunswick / Mercury made the following statement in **US Patent 7,347,905** and **US Patent 7,666,353**.

> *"An outboard assembly consists of (from top to bottom, vertically) an engine, a drive shaft housing, a lower unit also called the gear case housing, and a horizontal propeller shaft, on which a propeller is mounted. This outboard assembly is attached to a boat transom of a boat by means of a swivel bracket. When the boat is traveling at high speeds, a safety concern is present if the lower unit collides with an underwater object. In this case, the swivel bracket and/or drive shaft housing may fail and allow the outboard assembly with its spinning propeller to enter the boat and cause serious injury to the boat's operator. Thus, it is a common safety requirement in the industry that an outboard assembly must pass two consecutive collisions with an underwater object at 40 mph and still be operational. Further, as the outboard assembly becomes more massive, this requirement becomes more difficult to meet. As a result, it is generally accepted that outboards having more than 225 HP have problems meeting industry requirements particularly if the drive shaft housings are die cast because of the low ductility and impact strengths associated with conventional die cast AlSi alloys. Accordingly, it would be highly advantageous to be able to die cast drive shaft housings with sufficient impact strength so that the drive shaft housings could be produced at a lower cost. Similarly, it would be advantageous to manufacture gear case housings and stern drive Gimbel rings for these same reasons."*

Beyond not breaking, high impact resistant alloys bring another useful element to the table. They absorb more energy than traditional alloys. All the energy from the impact must go somewhere, the more that goes into the metal without it breaking, the better.

1B5. Increase Capacity of Hydraulic System to Absorb Energy

Increasing the amount of energy dissipated by the hydraulic system reduces the amount of energy remaining in impacts in which the outboard reaches the top of its swing.

Ways to increase the amount of energy dissipated by the hydraulic system include:

A. Increasing diameter of the hydraulic cylinder (more surface area at same pressure equals more force)

B. Increasing relief valve pressure (more pressure on same area equals more force).

Either of these changes could create additional forces requiring design changes throughout the log strike system, including the cylinder and the transom.

Engineers may need to increase cross sectional area of the cylinder and/or relief valve pressure settings if a two stage damping cylinder approach is selected. See **Section 1A2**. By allowing the outboard to quickly clear the object with minimal resistance, greater forces may need to be applied once the outboard clears the object. Otherwise less energy will be absorbed than would have been over the entire upward swing of the outboard.

1B6. Use Smart Materials

Smart materials react to changes in their environment. The changes are reversible and can occur many times.

The magnetic fluid used in Active Tilt Cylinders (see **Section 1A4**) is an example of a smart material.

The field of smart materials bears watching/monitoring to see if rapid advancements in this field create other materials useful in preventing outboard motors from entering boats.

1B7. Preloading Structural Components

During impacts with submerged objects, outboard motor clamp brackets can experience high stresses in the region the clamp bracket bends around the top of the transom.

Clamp brackets can be preloaded in compression using bolts to allow them to survive the tension in this area created by a considerably larger or faster log strike.

For example, see Brunswick's **US Patent 8,833,725** Apparatus for Supporting Marine Engines, teaches how to preload clamp brackets in compression. See **Figure 15**.

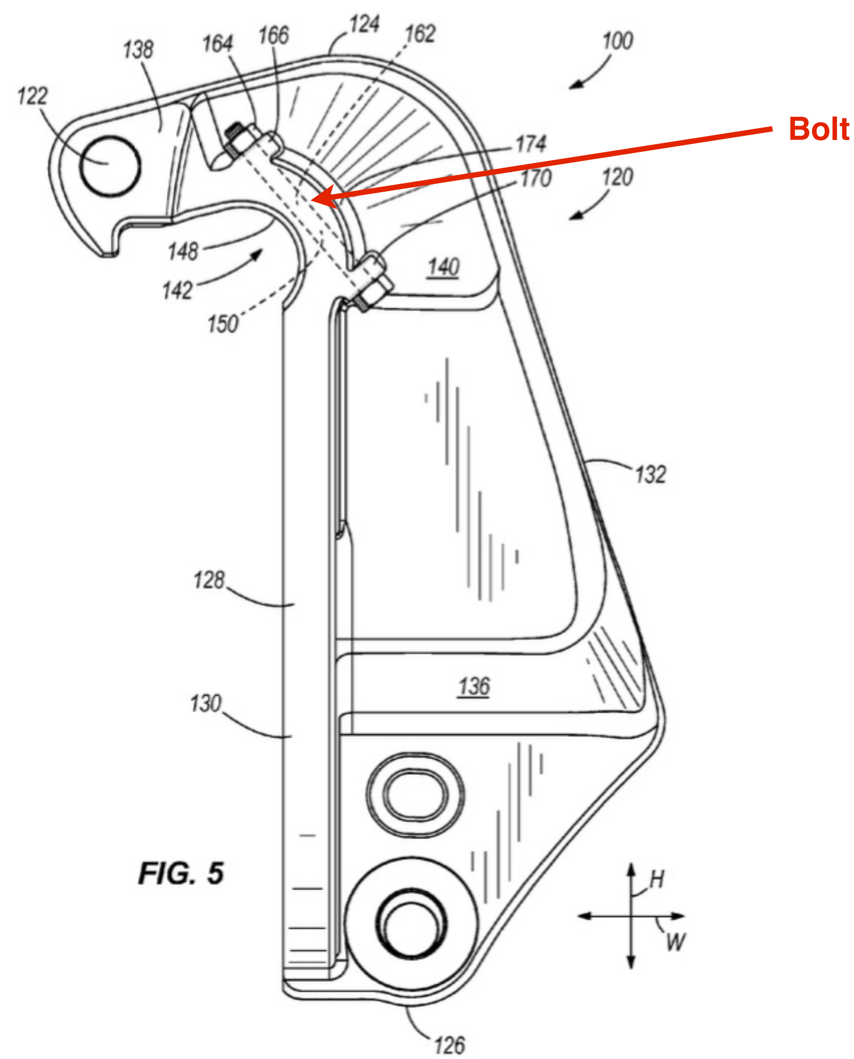

Figure 15: Figure 5 From Brunswick US Patent 8,833,725
bolt places mounting bracket in compression

Similar techniques could be used to shore up swivel brackets in areas they frequently fail. For example, some swivel bracket fail after the L shaped bend in near the area the tilt cylinder attaches to the swivel bracket as seen in **Figure 16** and **Figure 17**.

Figure 16: Failed swivel bracket
150 horsepower Mercury Marine

Flanges could be formed on the underside of the upper and lower portion of the swivel bracket (lower portion is the area that broke off) in the area of the generally horizontal break shown in **Figure 16** and **Figure 17**. Bolts could be used to preload this vertical area in compression, similar to the motor bracket in **Figure 15**. Thus it would take a greater impact load to fail the swivel bracket.

Figure 17: Failed swivel bracket
150 horsepower Mercury Marine closeup

1B8. Use Stronger Processes to Form the Parts

Use of manufacturing processes resulting in stronger parts has previously been suggested as a way to prevent outboard motors from flipping into boats.

For example the use of forged aluminum or forged steel swivel brackets have been suggested.

Swivel brackets are large highly complex parts. While an aluminum forging may be possible, cost of such a forging would be substantial.

Mercury Marine currently uses a heat treating process known as T6 to increase strength of their cast aluminum swivel brackets.

Future advancements in heat treating techniques may provide stronger parts.

Mercury is using pressurized lost foam casting techniques to form swivel brackets. Other manufacturers are likely using pressurized die casting and sand casting methods.

We anticipate swivel brackets will continue to be cast from aluminum.

Advances in casting technologies and casting methods may continue to bring higher strength levels to outboard motor structural components (swivel brackets, mounting brackets, jack plates)

1B9. Optimize Current Designs for Strength (CAE)

Instrumenting land based and on water based impact testing can help identify critical areas, along with parts sales, warranty data, field testing, and accident reports.

As mentioned earlier, increasing physical dimensions of parts must be done selectively, sparingly, and with targeted precision.

Modern Computer Aided Engineering (CAE) and Finite Element Modeling (FEM) programs can aid in this endeavor.

1C. Drive Designed to Fail in a Manner by Which it Cannot Enter the Boat

Equipment is often designed to fail in a manner that causes minimal damage to itself or human life. One common approach is a breakaway design. A portion of the device breaks off to “save” the more valuable parts of the equipment. Sometimes, the “breakaway” can be quickly reconnected with minimal loss in downtime or value. Shear pins are often used in breakaway designs.

Breakaway concepts have long been used in agricultural equipment when an implement being pulled through soil may strike an obstacle or a rock. For example, **US Patent 2,612,827**[10] in **Figure 18**. shows a releasable implement connection for a combination plowshare and fertilizer injector striking a rock.

The image of an agricultural plow striking a rock is uncannily similar to an outboard motor striking a rock or a floating log.

[10] US Patent 2,612,827. Releasable Implement Connection. Assigned to Sperry Corporation.

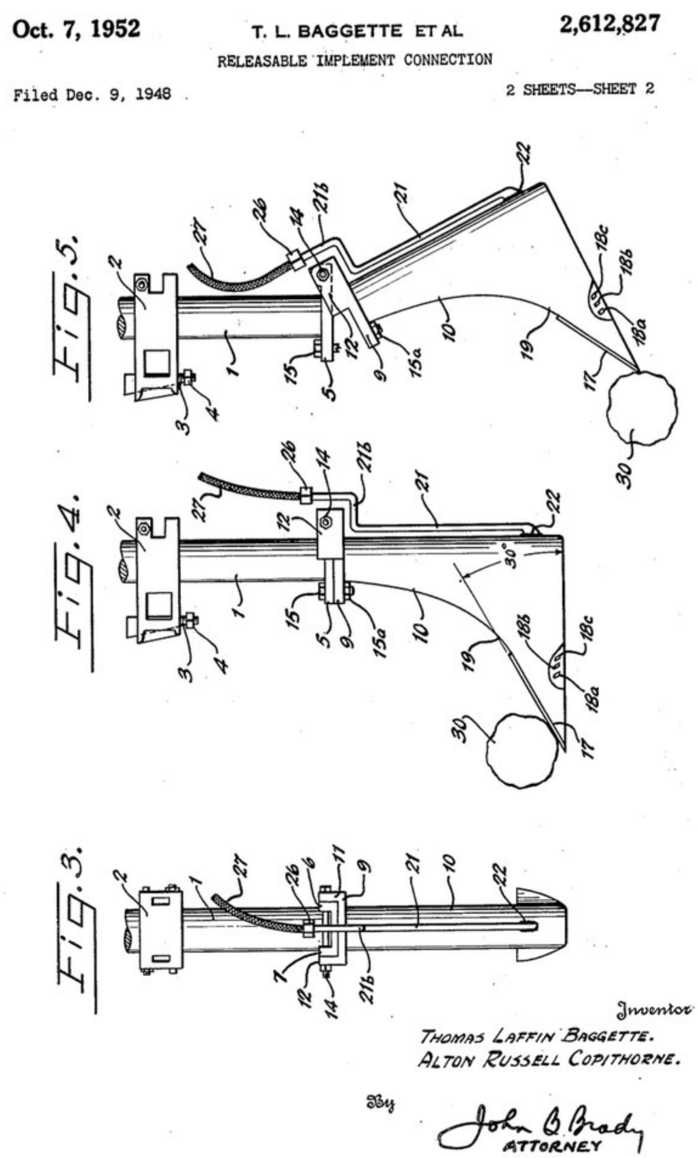

Figure 18: US Patent 2,612,827
Breakaway agricultural implement resembling an outboard leg striking a rock

The patent above resembles **US Patent 2,917,019**,[11] a 1950s breakaway outboard design shown in **Figure 26**.

[11] US Patent 2,917,019. Propeller Housing Attachments. Fred C. Krueger.

Yamaha **US Patent 4,936,240** shown in **Figure 19** addresses how to prevent catastrophic damage to hydrofoil vessels when striking floating logs. The foil support breaks at a predetermined load (such as when striking a log) and the projection (leg) is allowed to pivot on a hinge to prevent damage. In the patent, Yamaha says existing log strike systems are too large, complex, and expensive. Yamaha says being large, complex, and expensive is due to the need to hold the leg against great forces and to perform the shock absorber function only when even greater forces act on the leg. The breakaway design is said to be more economical, less complex, and require less structure.

Yamaha's patent drawing show in our **Figure 19** has a very strong resemblance to the leg of an outboard motor.

United States Patent [19]

Yokoyama et al.

[11] **Patent Number: 4,936,240**

[45] **Date of Patent: Jun. 26, 1990**

[54] **STRUCTURE FOR HOLDING UNDERWATER PROJECTIONS**

[75] Inventors: **Fumitaka Yokoyama; Masayuki Hattori; Tsukasa Okuzaki,** all of Shizuoka, Japan

[73] Assignee: **Yamaha Hatsudoki Kabushiki Kaisha,** Shizuoka, Japan

[21] Appl. No.: **305,253**

[22] Filed: **Feb. 1, 1989**

[30] **Foreign Application Priority Data**

Feb. 9, 1988 [JP] Japan 63-29970

[51] **Int. Cl.**[5] **B63B 1/30**
[52] **U.S. Cl.** **114/282**
[58] **Field of Search** 114/274, 278, 279, 280, 114/281, 282; 440/56, 64; 403/2

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289495	12/1987	Japan .
13896	1/1988	Japan .

Primary Examiner—Joseph F. Peters, Jr.
Assistant Examiner—Jesüs D. Sotelo
Attorney, Agent, or Firm—Jordan and Hamburg

[57] **ABSTRACT**

A structure for holding an underwater projection projecting downward from the bottom of hull of a hydrofoil craft or the like. The projection is connected at its rear end base portion to the hull by a hinge pivotally movably rearward and held at its front end base portion in a predetermined downwardly projecting state by a breakable holder. The projection is held in this state during usual navigation. The holder breaks when a predetermined force acts rearward on the projection, permitting the projection to move about the hinge, whereby the projection is prevented from damage.

6 Claims, 5 Drawing Sheets

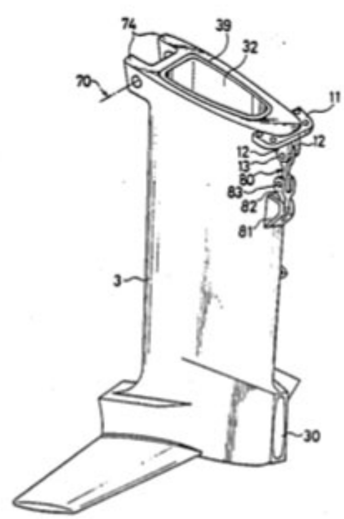

Figure 19: US Patent 4,936,240 Yamaha hydrofoil frangible leg

1C1. Frangible / Break Away Drives

Designing the gear case of an outboard motor to breakaway during severe collisions prevents it and the rest of the outboard from entering the boat. Several approaches allowing gearcases to break off came to light during development of Brunswick's through hull drive (Zeus), ZF's pod drive, Volvo Penta's forward facing through hull drive (IPS), and Caterpillar's through hull drive. These through hull drives for larger vessels must breakaway during impacts with larger submerged objects at speed. If the drive were torn off, a gaping hole in the hull could sink the vessel. **See Figure20**.

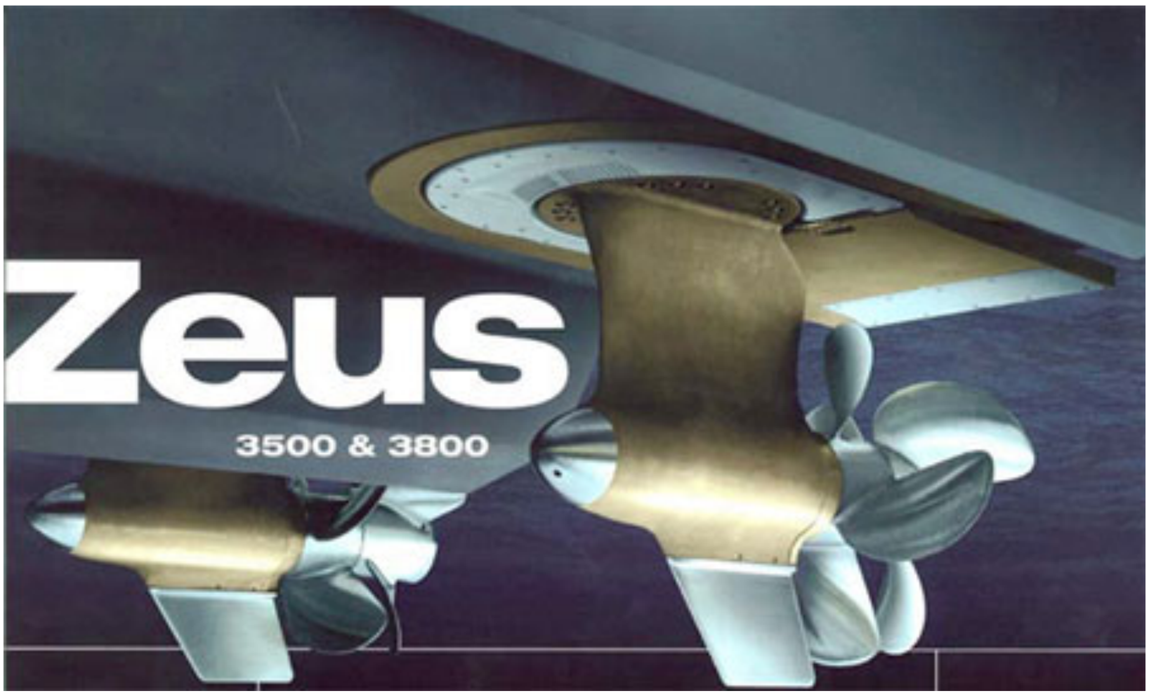

Figure 20: Brunswick's Zeus drive

Among Brunswick, Volvo, ZF, and Caterpillar patents in this field are:

US Patent 6,315,623 Volvo Penta controlled separation
US Patent 7,435,147 Brunswick break away skeg for a marine propulsion device
US Patent 7,867,046 Brunswick break away mount for a marine drive
US Patent 8,011,983 Brunswick break away mount for a marine drive

US Patent 8,062,082 Brunswick marine drive with staged energy absorption capability
US Patent 8,267,731 Volvo Penta breakaway safety system
US Patent 8,506,338 ZF connecting piece that can be inserted into a boats hull
US Patent 8,579,669 Volvo Penta breakaway safety system for an aquatic vessel
US Patent 9,187,164 Caterpillar marine pod breakaway connection

The patents listed on the previous page predominantly focus on break away drives, crushable drives, and staging energy absorption based upon the load (crushing in low energy collisions, breaking away in higher speed collisions).

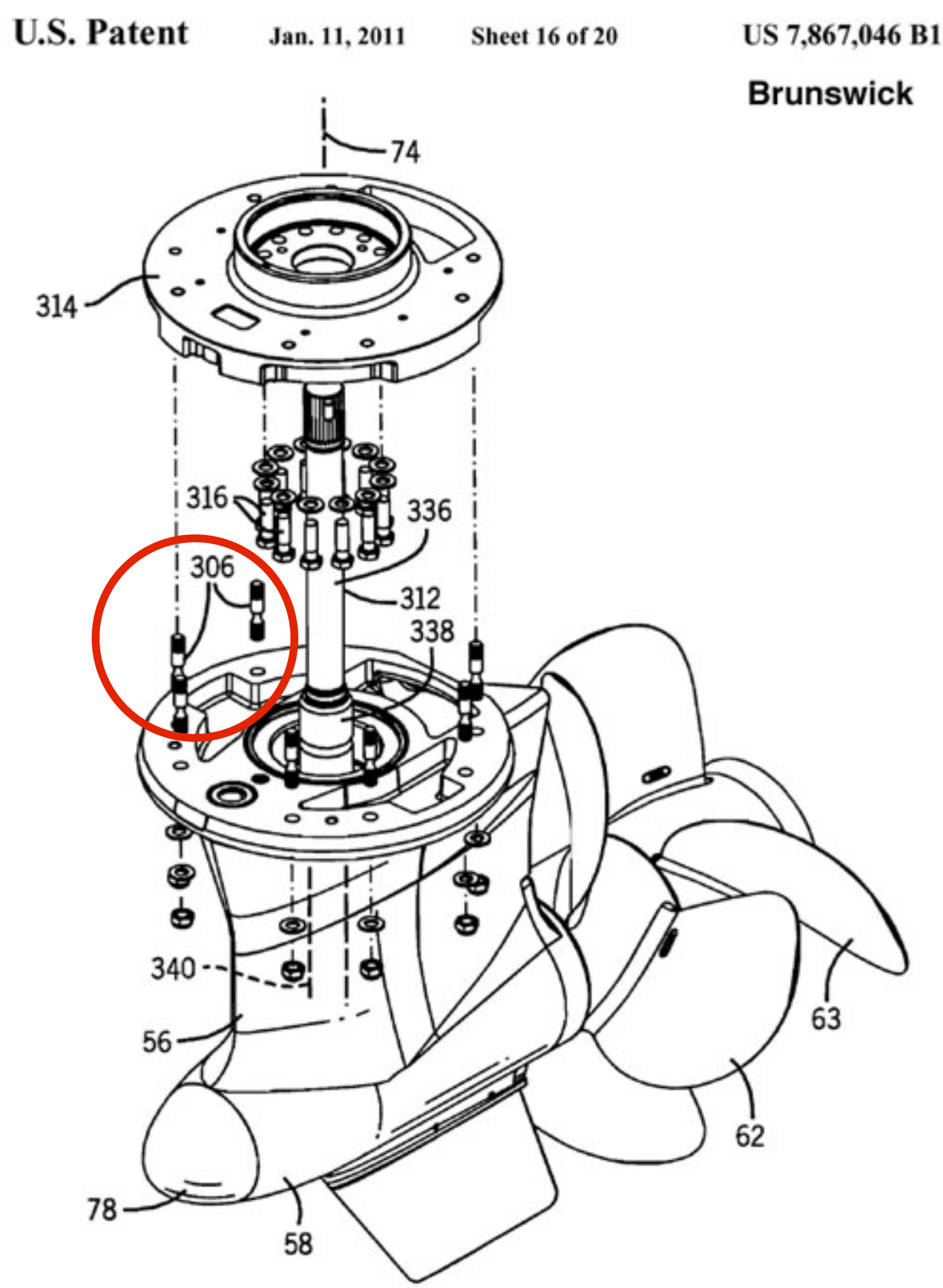

Figure 21: US Patent 7,867,046 Brunswick Zeus drive

Brunswick's 7,867,046 patent sketch (**Figure 21**) shows a break away mount using frangible bolts (item #306 in **Figure 21** and **Figure 22**)

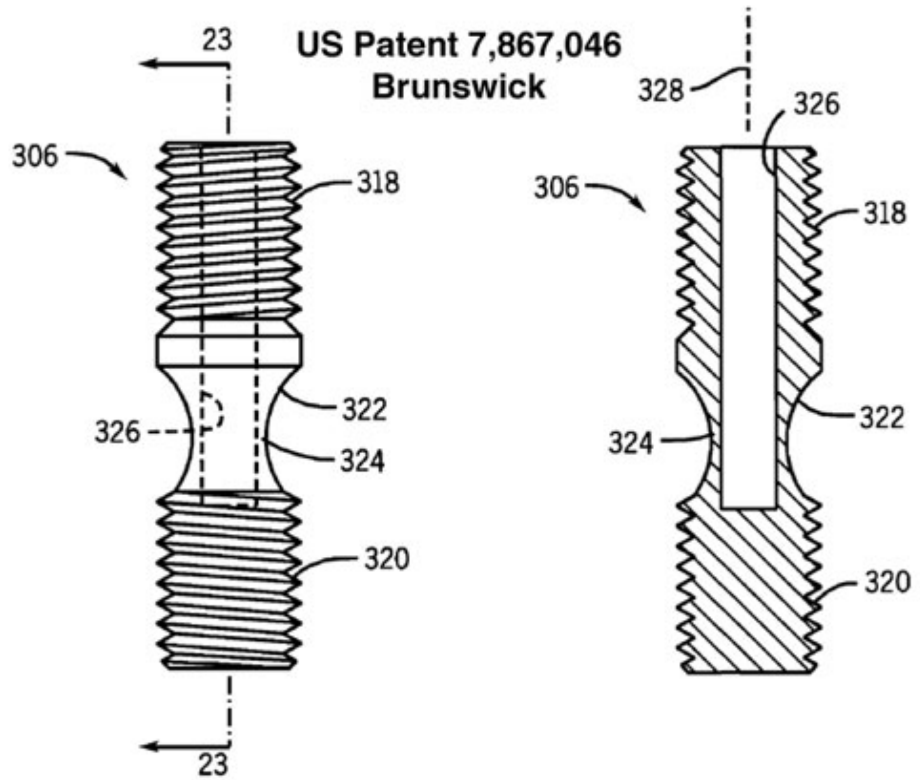

FIG. 22 FIG. 23

Figure 22: US Patent 7,867,046 frangible bolts

The necked down, hollowed out #306 bolts are designed to fail before the bolts numbered #316 in **Figure 18**. Their design allows Brunswick to control their failure strength and the failure location. In addition, it allows bolts to be made from stronger materials and have a larger diameter at the threads so they can be torqued sufficiently tight.

The #306 bolts are designed to break first and allow the drive to separate from the vessel. If they fail to break (probably due to being replaced by higher strength fasteners), the #316 bolts will break and the drive can still separate from the vessel.

A video of the Zeus drive breaking away[12] can be seen on our website page hosting this report.

Brunswick's 8,062,082 patent (**Figure 23**) shows a two stage design. The nose cone crushes to absorb the energy in collisions below about 4 miles per hour, while a number of shear bolts (#306 in **Figure 21**) fail in higher speed collisions allowing the drive to partially or completely breakaway. The combination (crush, then breakaway) allows a faster breakaway speed than would have been possible without the crushing phase.

Brunswick notes vessel mass and speed determine the vessel's kinetic energy. When a through hull drive on a heavy vessel impacts a submerged object at speed, the vessel can suffer significant damage. In addition, sudden deceleration can cause passengers to be thrown forward. The device described in Brunswick's patent is designed to:

1. Absorb some of the energy from the collision
2. Reduce sudden deceleration during impacts with submerged objects at slower speeds
3. Prevent catastrophic damages and injuries from impacts with submerged objects at higher speeds

Brunswick's 8,062,082 patent includes three hypothetical / example graphs (their Figures 12 through 14) charting the force of a larger vessel impacting 2 inch, 6 inch, 12 inch, 24 inch, and 36 inch nose cones at different velocities, resulting decelerations, and impact velocity versus time to stop.

Much longer nose cones than traditionally used can be observed on ZF's larger versions of the Zeus drive.

[12] Zeus Product Video. YouTube. CumminsMerCruiser. Uploaded 15 August 2011. http://www.youtube.com/watch?v=3ld4fJJHhRo 12 minutes 32 seconds. (about 3:30 on the video) (fixed object impact about 4:00) mp4

U.S. Patent Nov. 22, 2011 Sheet 4 of 8 US 8,062,082 B1

Brunswick

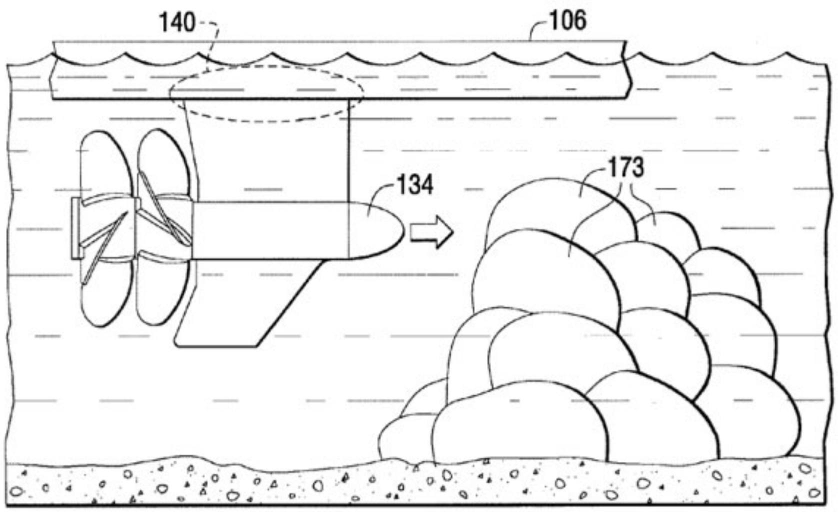

FIG. 10

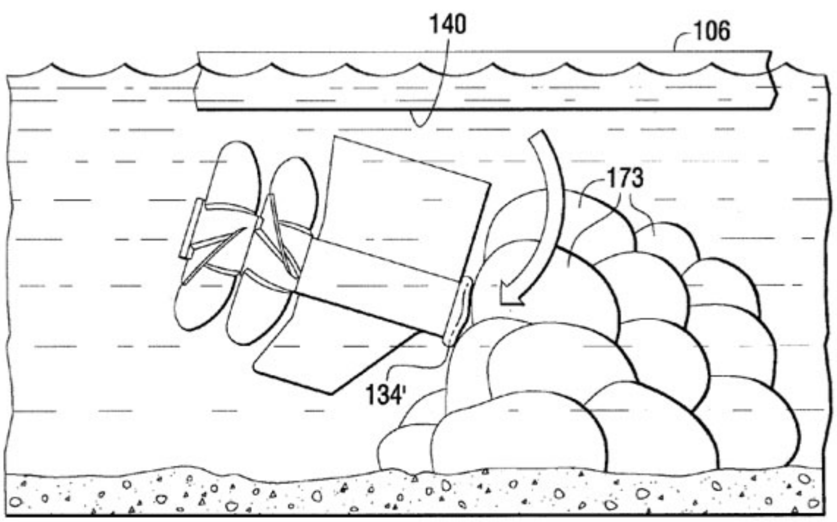

FIG. 11

Figure 23: US Patent 8,062,082 Brunswick two stage design

Volvo Penta faced similar problems with their IPS drive and its forward facing propellers.

Figure 24, US Patent 8,267,731, shows Volvo IPS propellers barely clearing a rock which strikes the bottom of the drive. Volvo's fracture initiating device (#200) is activated by the control unit (#250) based on the signal received from one or more sensors (#260). The fracture initiating device (#200) can be powered by explosives, by a spring, or by other means. The patent suggests sensors could include:

1. Strain gages on the fracture region of the drive
2. Gyroscopes to measure sudden changes in angular orientation of the drive leg or vessel
3. Engine RPM tachometers
4. Accelerometers detecting sudden acceleration or deceleration of the hull
5. Vessel speed indicators
6. A sonar system for detecting submerged objects

An algorithm can determine when to blow the drive based on sensor inputs.

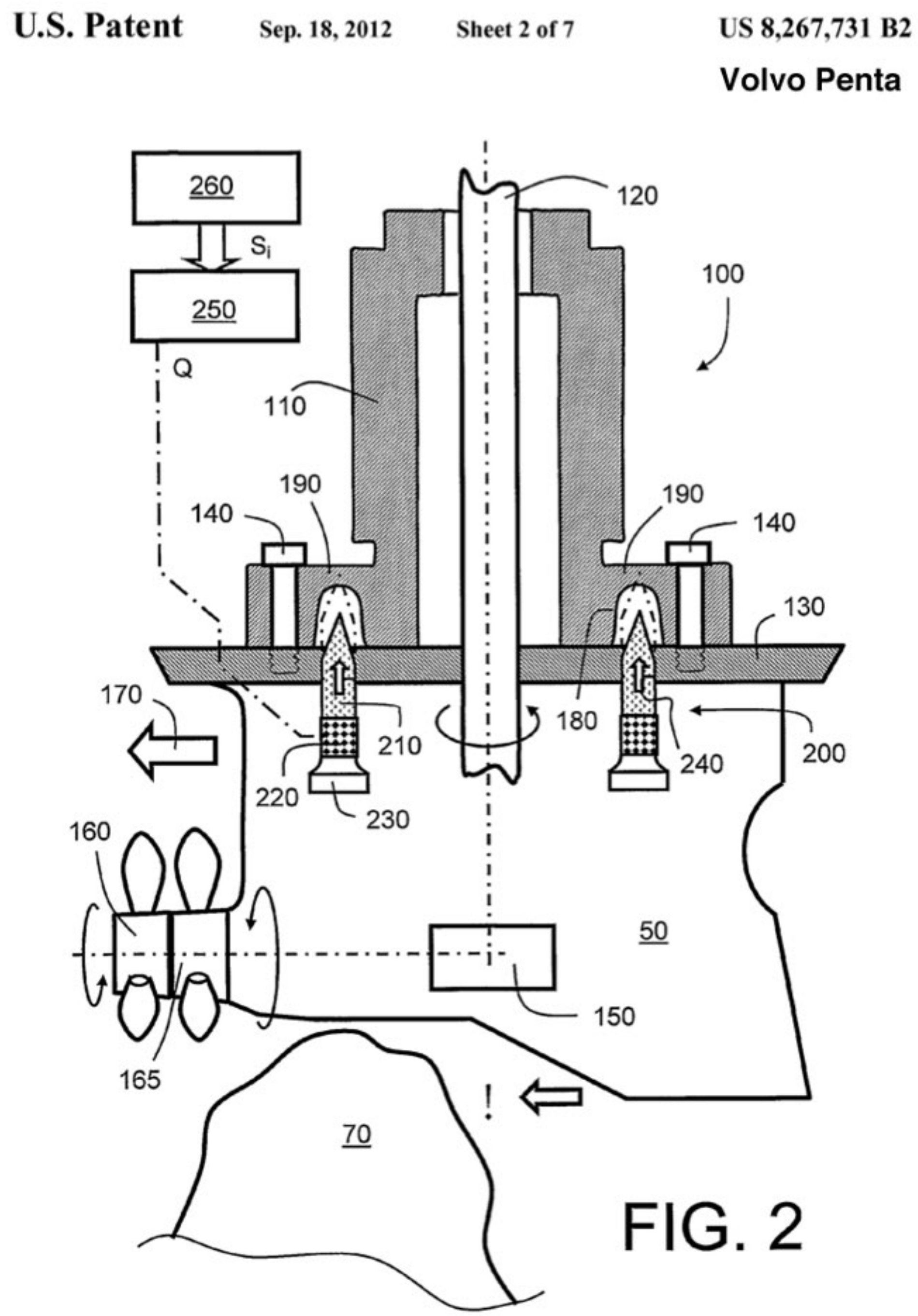

Figure 24: US Patent 8,267,731 Volvo Penta sensor based approach

Volvo Penta followed up with **US Patent 8,579,669** (see **Figure 25)** for an IPS drive with a more mechanical approach to separation. They proposed an intentionally weakened region (#18) designed to yield on impact in combination with a fracturable member (#14) attaching the gear housing to the vessel. The fracturable member allows the drive to shear off during an impact when the weakened region yields.

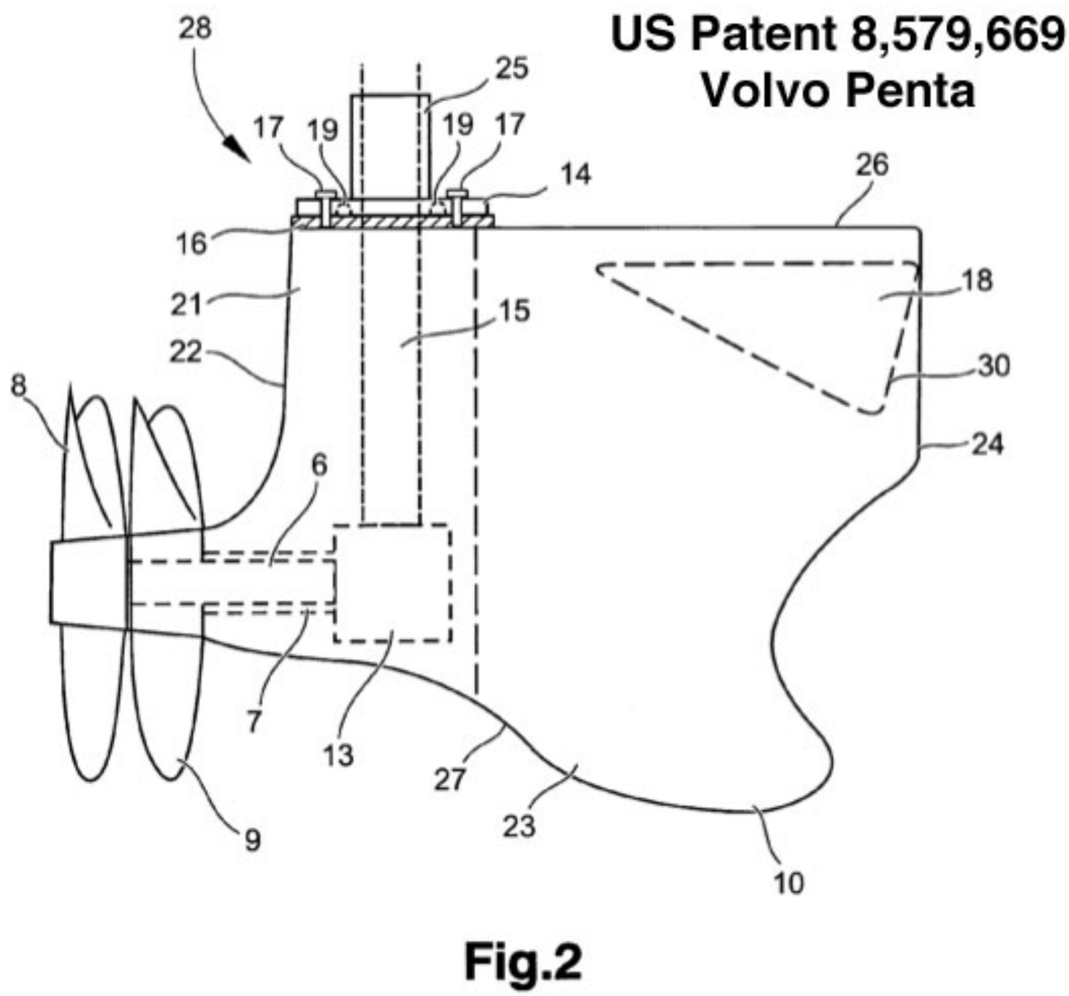

Figure 25: US Patent 8,579,669 Volvo Penta fracturable member approach

Fred C. Krueger filed what became **US Patent 2,917,019** way back in 1955 with a simpler approach, see **Figure 26**. He used a faux leading edge (#79) that squeezes handles (#75) together when the leading edge is struck, allowing the lower half of the drive to swing back and up from a pivot pin (#74).

Krueger also recognized the hazard of the engine turning at a high RPM during impacts and used a spring (#62) to shutoff the engine with a push rod when the drive hinge opens.

After the impact, the drive either swings back into place or can be pulled or pushed into place, the engine restarted, and the voyage continued.

Calculations by an expert in the Barhanovich case found that if an outboard motor was going 12 miles per hour or faster, and broke off, it had enough energy to rotate into the boat.[13]

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[13] Letter from Edward V. Fritsch of ATA Associates, Inc.. to Andrew Wilson of Simon, Peragine, Smith & Redfearn. 4 December 2017. Barhanovich vs. Bean & Suzuki. U.S. District Court. Southern District of Mississippi. Southern Division. Filed 13 December 2017. Page 7 of 8. PACER Document #526-4.

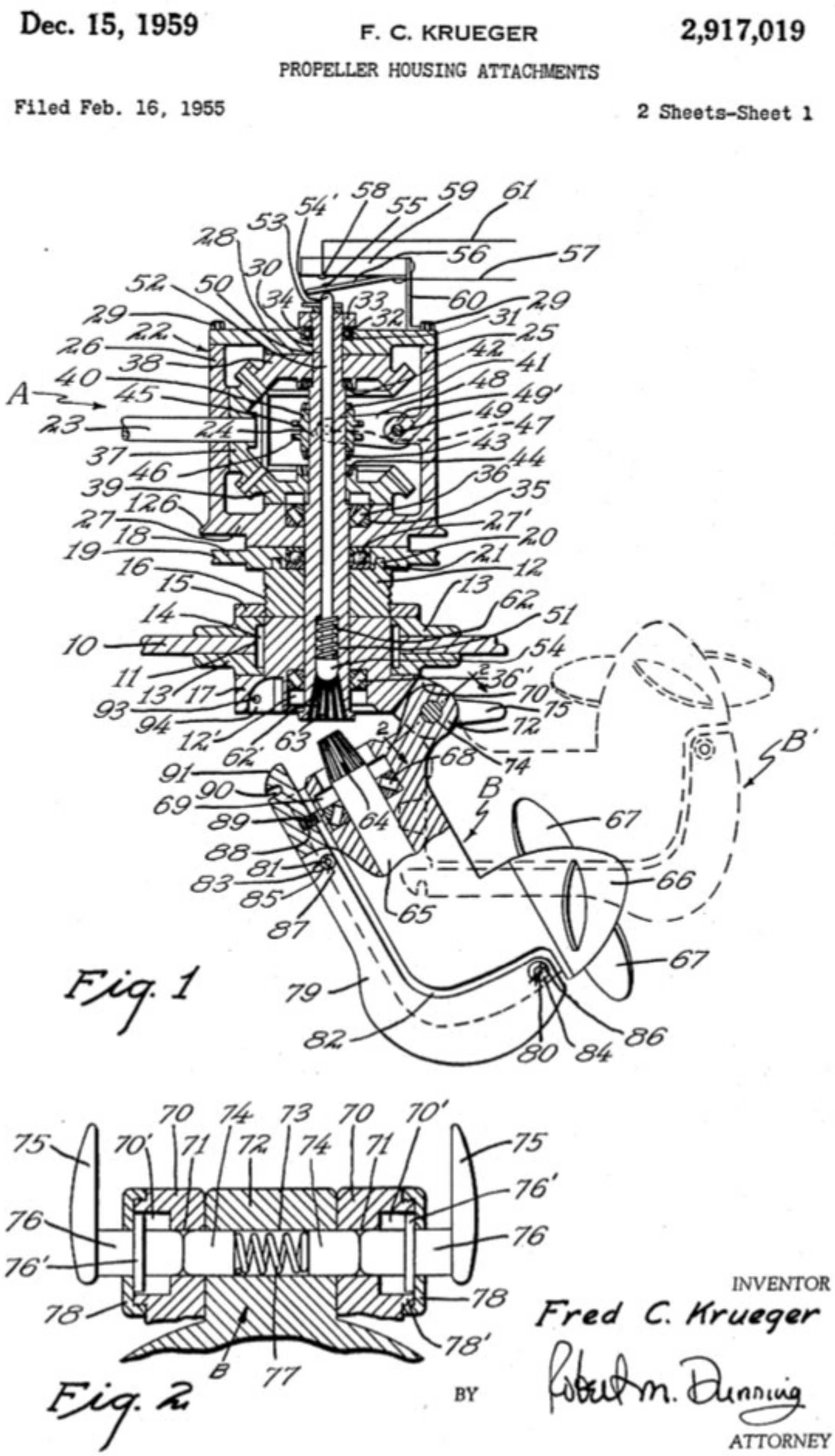

Figure 26: US Patent 2,917,019 Krueger

1C2. Break Away Skeg

Breakaway skegs

Designing the skeg, the vertical fin at the very bottom of the outboard (see **Figure 0**), to breakaway in collisions with submerged objects can prevent the entire outboard motor from breaking off. If the skeg is the contact point with submerged objects and the skeg breaks off before the outboard breaks off, the outboard is prevented from entering the boat.

Being the lowest part of the outboard motor the skeg is particularly exposed to striking submerged objects. There is a small industry surrounding replacement skegs, skeg protectors, and repairing skegs.

Bass boat outboard skegs are especially exposed to striking submerged objects because bass boats spend considerable time on plane without much of the outboard in the water AND because they frequent shallow water.

Brunswick / Mercury Marine **US Patent 7,435,147** for a breakaway skeg (**Figure 27**) explains the importance of the skeg being able to breakaway before the drive is broken away from the boat.

(12) **United States Patent**
Eichinger

(10) **Patent No.:** **US 7,435,147 B1**
(45) **Date of Patent:** **Oct. 14, 2008**

(54) **BREAKAWAY SKEG FOR A MARINE PROPULSION DEVICE**

(75) Inventor: **Charles H. Eichinger**, Oshkosh, WI (US)

(73) Assignee: **Brunswick Corporation**, Lake Forest, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/811,030**

(22) Filed: **Jun. 8, 2007**

(51) **Int. Cl.**
B63H 20/34 (2006.01)

(52) **U.S. Cl.** **440/78**; 114/127; 114/140; 441/79

(58) **Field of Classification Search** 114/127, 114/140; 440/78; 441/79
See application file for complete search history.

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Primary Examiner—Sherman Basinger
(74) *Attorney, Agent, or Firm*—Wiilam D. Lanyi

(57) **ABSTRACT**

A marine propulsion device is provided with a breakaway skeg having first and second attachment points. The first and second attachment points are configured to result in the second attachment points disengaging from a gear case or housing structure prior to the first attachment point. The attachment points can comprise open or closed slots and, when an open slot is used for the first attachment point, it can be provided with a first edge along which a first pin can exert a force along a preselected angle in response to an impact force on the skeg. The arrangement of attachment points allows a reaction force at the second pin to be predetermined in a way that assures the detachment of the skeg from the housing structure prior to the detachment of the housing structure from another structure, such as the boat hull, or transom.

12 Claims, 5 Drawing Sheets

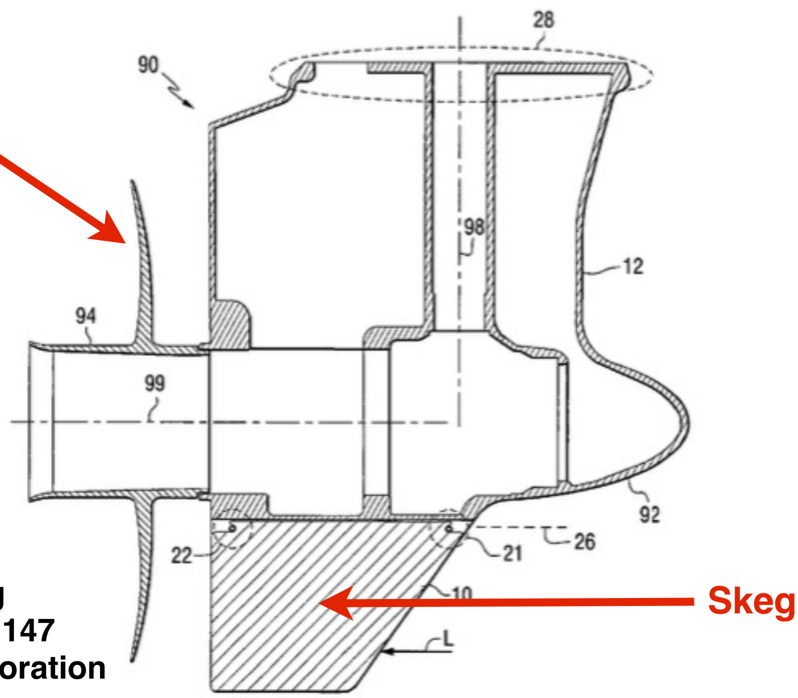


Figure 27:
Breakaway Skeg
US Patent 7,435,147
Brunswick Corporation

The patent abstract from **US Patent 7,435,147** (**Figure 27**) is enlarged and marked up in **Figure 28**.

US Patent 7,435,147
Breakaway Skeg for a Marine Propulsion Device

(57) **ABSTRACT**

A marine propulsion device is provided with a breakaway skeg having first and second attachment points. The first and second attachment points are configured to result in the second attachment points disengaging from a gear case or housing structure prior to the first attachment point. The attachment points can comprise open or closed slots and, when an open slot is used for the first attachment point, it can be provided with a first edge along which a first pin can exert a force along a preselected angle in response to an impact force on the skeg. The arrangement of attachment points allows a reaction force at the second pin to be predetermined in a way that assures the detachment of the skeg from the housing structure prior to the detachment of the housing structure from another structure, such as the boat hull, or transom.

Figure 28: US Patent 7,435,147 abstract
Breakaway Skeg assigned to Brunswick

Brunswick / Mercury's patent abstract in **Figure 28** above specifically teaches how to assure the skeg breaks off before it causes the outboard motor to break off the transom.

In 2017, Caterpillar was issued **US Patent 9,701,381** for a breakaway skeg.

Caterpillar's breakaway skeg uses a series of shear tabs with pins through them. Caterpillar's patent specifically shows their breakaway skeg in use on an outboard motor, a stern drive, and a through hull drive.

Caterpillar's patent states:

> *"The attachment features of the breakaway skeg may therefore be designed to provide a strong enough attachment to to the lower portion of the gear case to stay intact during navigation but must fracture or breakaway above a predetermined stress in order to prevent damage to the lower portion of the gear case."*

Caterpillar says they are able to maintain a Factor of Safety (FOS) of about 1.5 to 2 based on yield strength of the material. Meaning the skeg can survive about 1.5 to 2 times normal navigation and steering loads. It breaks away above those loads.

Both Brunswick's/Mercury's and Caterpillar's efforts were likely born from the challenges of Pod (though hull) Drives.

1D. Alternative Swivel Bracket Designs

Outboard swivel brackets allow modern outboards to steer, tilt, and trim. When floating or submerged objects are struck by the outboard motor, the swivel bracket allow the outboard to swing up and over the obstruction, then settle back down, all while being positively retained to the transom.

As modern outboard motors grow in horsepower, size, and weight, they propel boats faster and faster. More mass (boat plus outboard plus contents of the boat and fuel) at higher speeds results in more stress being placed on outboard swivel brackets during impacts with floating or submerged objects.

Outboard motors, especially larger outboard motors, breaking loose and flipping into boats after striking floating or submerged objects often result from a broken swivel bracket.

A typical swivel bracket from Mercury Marine is shown in **Figure 29** with the two axis of rotation identified. The feet of the bracket, labeled lower trim limit, settle down against a rod to establish the limit of trim under (negative trim, rotating the lower leg up under the boat).

The highly complex shape of Mercury's swivel bracket in **Figure 29**, along with the thinness of the material, two upper arms from the trim & tilt axis of rotation, and the thin shell around the steering tube (axis of rotation) provide multiple sites for potential failures / breakage.

We are not saying all swivel brackets are under designed, we are merely saying striking floating or submerged objects at speed can cause some of them to fail.

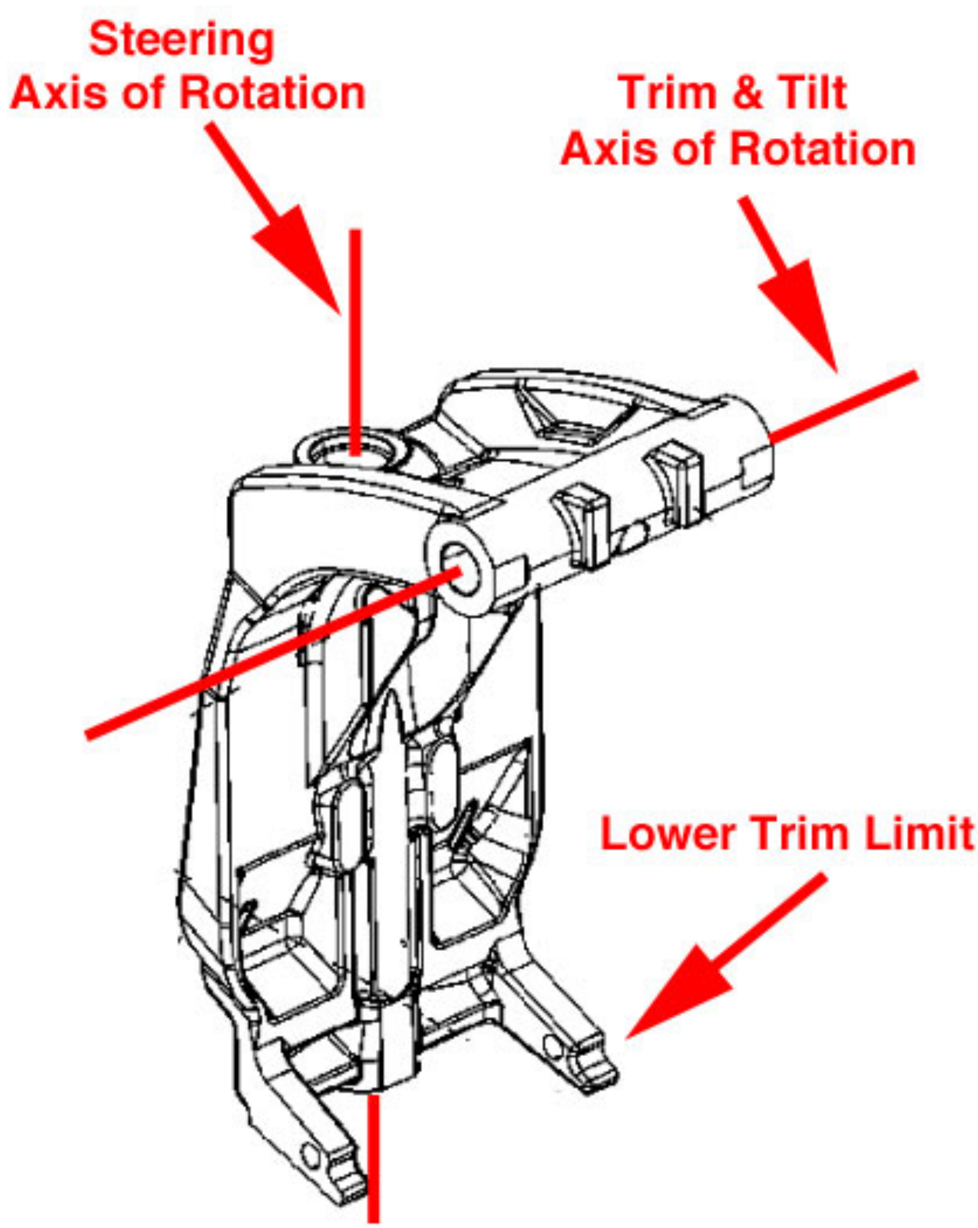


Figure 29: Typical Outboard Swivel Bracket, Mercury Marine

An example of a failed Mercury Marine 150 horsepower outboard swivel bracket is shown in **Figure 16** and **Figure 17**. It fractured near the top viewed from the stern. The steering tube broke out of the swivel bracket, allowing the outboard to break free. Several alternative designs have been proposed for swivel brackets, especially for those used in special / niche applications.

One problem with large outboards is the space required for the powerhead to turn when steering the boat. Larger engines/powerheads require considerable space to rotate when steered. These larger outboards are typically:

1. Set back some from the boat or
2. Hang over the transom or
3. Poke through a transom cutout

A Sanshin (predecessor to Yamaha Marine) swivel bracket, **US Patent 5,224,888** shown in **Figure 30** addresses this problem.

The Sanshin bracket allows the outboard powerhead to be dropped in place similar to the L-drive. Its lower leg can be rotated below the swivel bracket for steering. While other proposed drives move both trim and steering functions below the powerhead, Sanshin only moved steering to the lower leg. Trim and tilt remain conventional, except for interacting with the alternative swivel bracket.

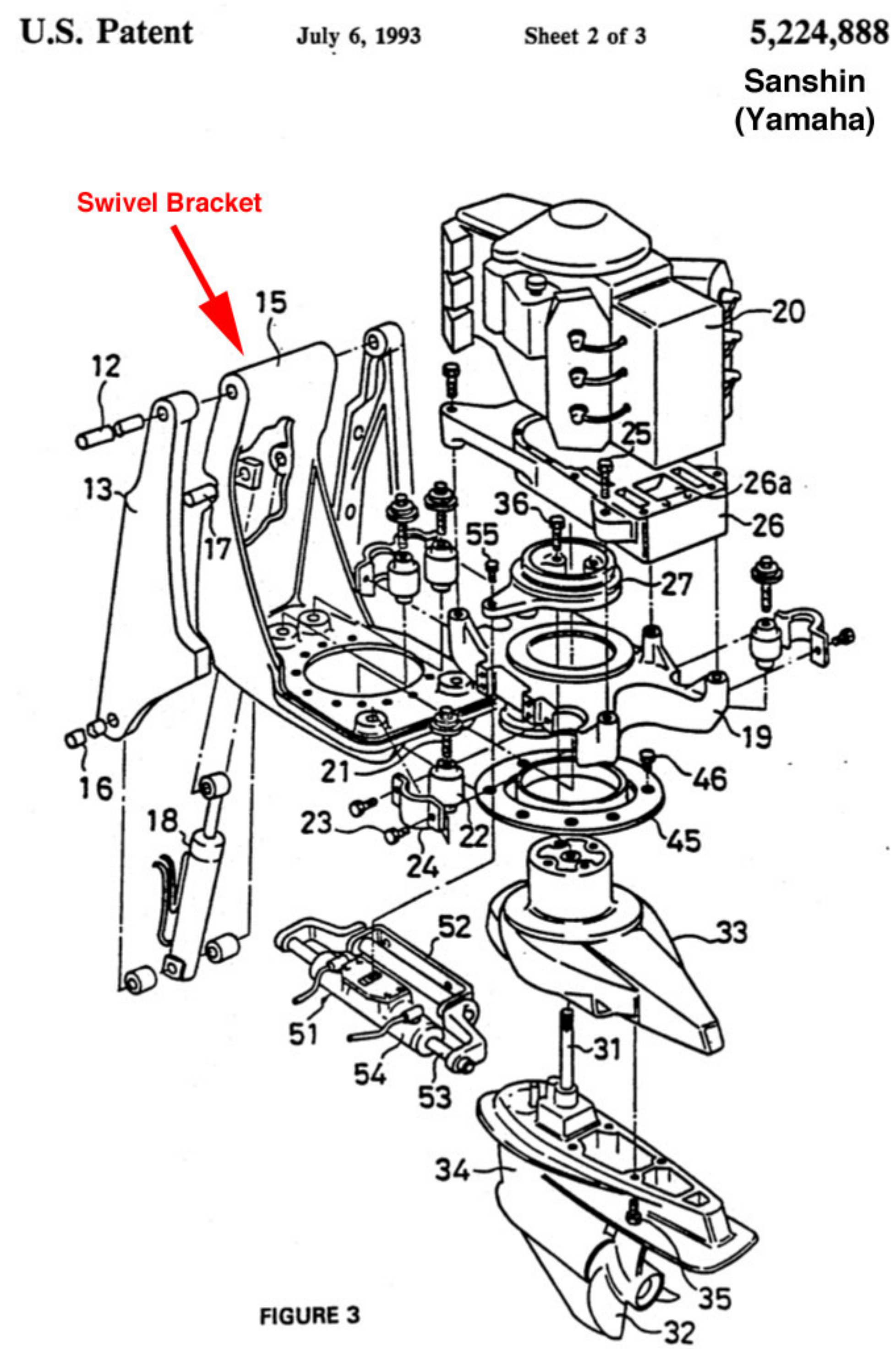


Figure 30: US Patent 5,224,888 Sanshin Swivel Bracket

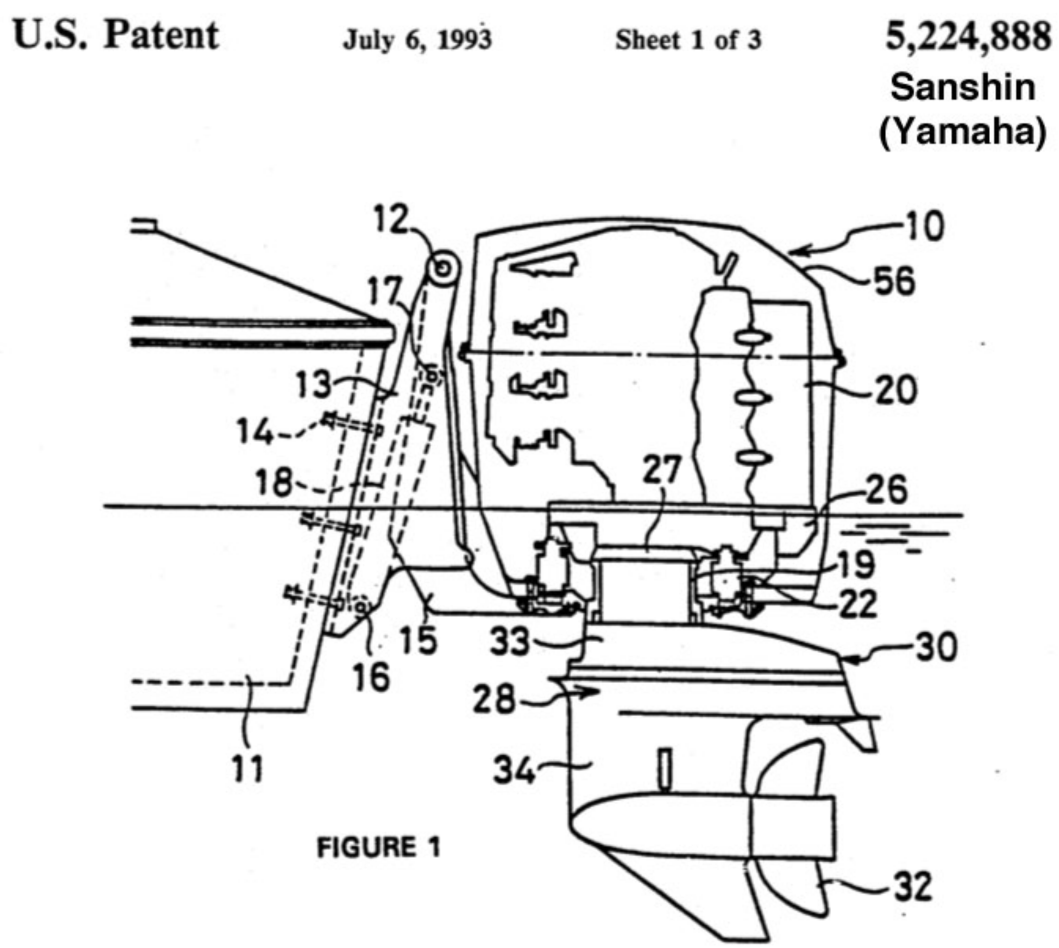


Figure 31: US Patent 5,224,888 Sanshin Swivel Bracket Installed

Sanshin's swivel bracket is shown installed above. While Sanshin set out to provide a more compact installation for outboards, their proposed swivel plate design as seen in **Figure 30** and **Figure 31** offers opportunities to be much stronger than a traditional bracket. Its shape is far less complex, plus it offers opportunities to be made thicker, to have a full width connection to a solid tilt tube / through tube, and for the use of gussets to further strengthen the design.

Existing swivel bracket failures often involve the vertical pole (steering tube) conventional outboards rotate around, breaking away from the swivel bracket. The vertical pole is no longer present in Sanshin's design. While stress calculations, computer modeling and testing would be required to confirm our suppositions, it appears Sanshin's proposed bracket could easily be made considerably stronger than a conventional swivel bracket for the same application. Additionally, rotating the lower unit for steering provides an opportunity to allow the lower unit to break away in an impact similar to other break away designs discussed earlier.

In addition, the outboard powerhead is mounted lower in **Figure 31**, giving the outboard a lower center of mass, making it more challenging for the outboard to enter the boat. Plus the transom extends across in front of the outboard as a physical barrier. Bass boats currently tend to have the powerhead up over the transom and at least partially in the vessel.

2018 TRACKER® Pro Team™ 195 TXW

Figure 32: 2018 Tracker Pro Team 195 TXW
Tracker promotional image

Figure 32 above, a Tracker promotional image, shows how outboards are currently mounted to bass boats with the powerhead way up and over the transom.

One can see how much easier it would be for a traditional bass boat outboard motor to flip into the boat as shown in **Figure 32** than for an outboard on the swivel bracket shown in **Figure 31**.

However, Sanshin's design would require much more freeboard at the transom (at least right in front of the outboard).

1E. Propulsion Configurations More Resistant to Flipping Into Boats

Traditional outboard motors are sometimes installed in less than traditional ways. In addition, outboard motors have been proposed in a number of configurations. Some of these less that normal outboards or less than normal installations are more resistant to flipping into boats.

In this section we will consider the use of:

1E1. Outboard brackets
1E2. Outboard shallow drives, mud drives and surface drives
1E3. Replacing some outboards with alternative drives

1E1. Outboard Brackets

Sometimes called transom brackets, Gill brackets, motor brackets, or outboard brackets, they allow the outboard to run a couple feet further back behind the boat in cleaner water. Bracket manufacturers say they improve efficiency, reduce fuel consumption, provide additional floatation and stability, and provide a more economical alternative when re-powering an older stern drive boat.

Some are constructed as flat pads like the example from Armstrong Nautical Products shown in **Figure 33**. Others look more like fiberglass additions to extend the hull, and some are just mechanical brackets.

Figure 33: Armstrong Nautical Products Outboard Bracket

Outboard brackets lower the center of gravity of the outboard, allow use of shorter drive legs as their propellers typically run higher in the water, and the transom could provide a physical barrier to drives entering the boat. In addition, outboard brackets could be designed to extend during impacts to lengthen time of contact and reduce peak loads.

1E2. Outboard Shallow Drives, Mud Drives and Surface Drives

Several specialty outboard manufacturers produce outboard motors under 40 horsepower for running in very shallow water, muddy conditions, and stumpy waters.

Their products tend to fall into three camps:

1. Long shaft outboards, such as the 35 horsepower Vanguard Go Devil.
2. Outboard surface drives such as the 35 horsepower Beavertail Vanguard.
3. Slightly conventional looking outboards like the 36 horsepower Pro-Drive outboard.

Examples of these three types of specialty outboards are shown in **Figure 34**.

By running so high in the water they are mostly protected from debris by the boat. By designing what corresponds to their nose cone up to the engine, and by avoiding leading vertical edges, these outboards significantly reduce their propensity to flip into the boat when striking submerged objects.

Not as extreme, several outboard manufacturers, including Mercury Marine and Yamaha, offer a “Shallow Water Drive” feature, option, or kit for their conventional outboard motors. “Shallow Water Drive” provides one or more trim positions beyond normal trim range for use in very shallow water at off-plane speeds. The result is “some” forward thrust for navigating and steering in conditions outboards would normally hit bottom.

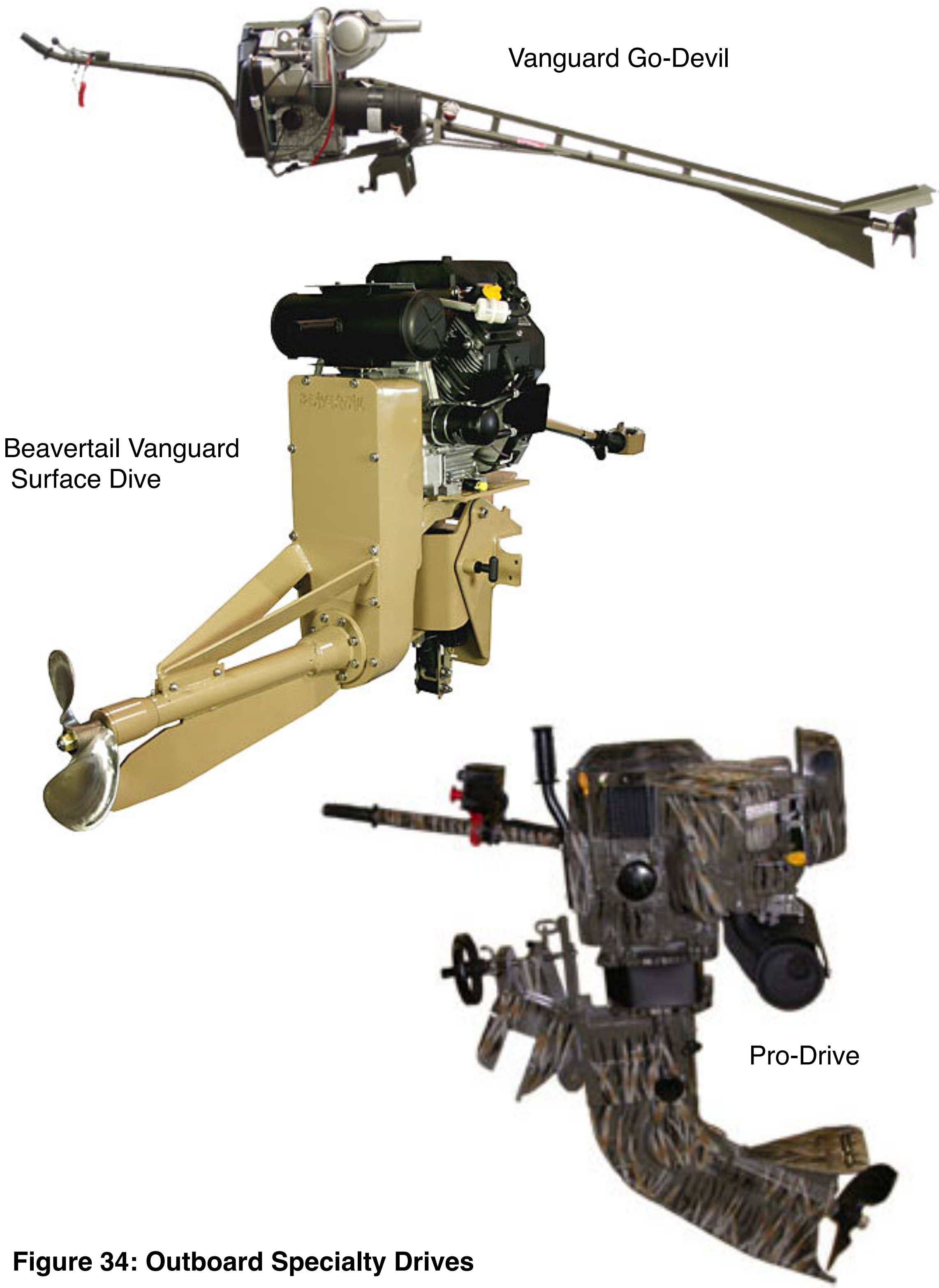


Figure 34: Outboard Specialty Drives

1E3. Replace Some Outboard Motors With Alternative Drives

Some types of marine drives utilize reconfigured outboard motors (outboard powerheads with alternative versions of lower units) and are less likely to flip into the boat.

Among these drive types and proposed drive types are:

1. Tunnel drives
2. Pod drives / through hull drives (Brunswick Zeus and Volvo Penta IPS)
3. Jet drives (intake in bottom of hull)
4. Outboard well drives / inboard outboards / hidden outboards (see list below)

Major marine manufacturers have proposed and/or launched several outboard drives in which the outboard is either down in a well (in a hole) or is hidden, typically by fiberglass panels. Some of these drives have been called inboard outboards (because the outboard motor is ahead of the transom and not visible). This whole group of drives provides opportunities to prevent the drive from entering occupied areas of the boat when the boat is underway. Several of these outboard drives and applications are listed below:

1E3a. L-drive (Chrysler, Force, U.S. Marine / Bayliner, Mercury Marine)
1E3b. OMC Quiet Rider
1E3c. Mercury Marine **US Patent 5,108,325** (for a Mercury L-drive)

1E3d. Sanshin **US Patent 5,088,945** (Nose Over Drive)
1E3e. Bombardier **US Patent 6,609,939**
1E3f. Sea Ray Venture 370

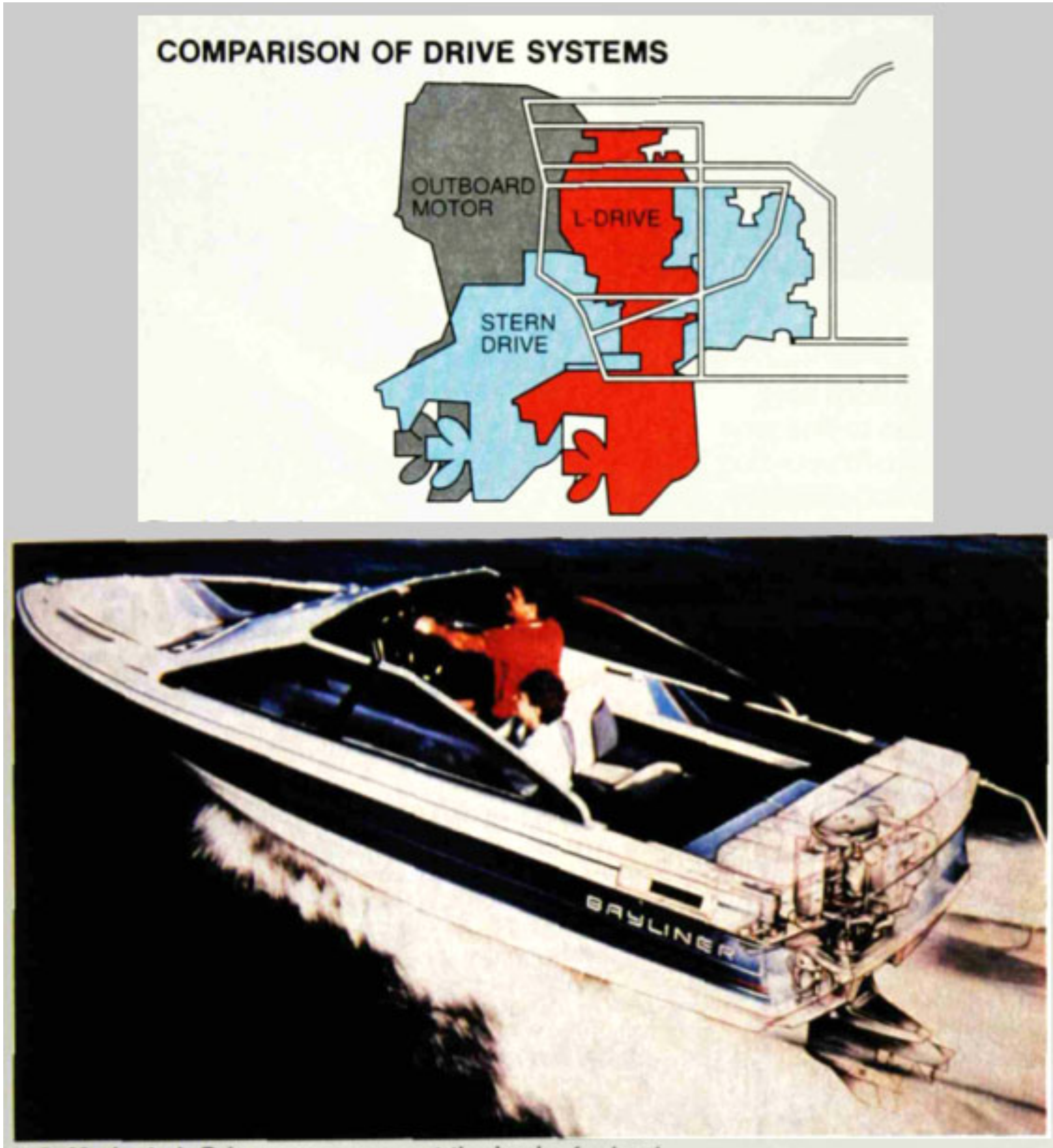
1E3g. Pursuit SC 365i
1E3h. Houseboat swim platform application (see **Figure 62**)
1E3i. Corsiva 590 tender and Corsiva 690 tender (new in the UK in 2012)

1E2j. Chris Craft 17 foot Lancer outboard (about 1971)
1E3k. De Antonio Yachts D23 motor boat (new in Spain in 2012)
1E3l. Sailboats have used hidden outboards for decades

We will now briefly illustrate approaches **1E3a** through **1E3g**. We do so in order for our readers to visualize how these approaches could help prevent outboard motors from flipping into the boat. More can be learned about the remaining entries with a Google search. These designs could especially prevent outboards from entering occupied areas of boats if extra attention was devoted to the hazard during design.

1E3a. **L-drive (Chrysler, Force, U.S. Marine / Bayliner, Mercury Marine)**

The L-drive shown in **Figure 35** was known by many company names as it passed though several companies during its production. Basically, they took an outboard motor, turned the engine to one side, and stuck the leg through the bottom of the hull. The L-drive steers, trims, and tilts the lower leg while the powerhead section remains stationary. U.S. Marine won a *Design News Excellence in Design Award* for the L-drive in 1989.



U.S. Marine's L-Drive saves space at the back of a boat.

Figure 35: U.S. Marine L-drive
images from Design News March 27, 1989

1E3b. OMC Quiet Rider

Outboard Marine Corporation's Quiet Rider shown in **Figure 36** was their response to the L-drive. OMC mounted an outboard through a fiberglass swim platform, covered it with a fiberglass shell, and supplied intake air to the outboard via a snorkel. This gave OMC and their boat lines access to an L-drive type product with an invisible outboard.

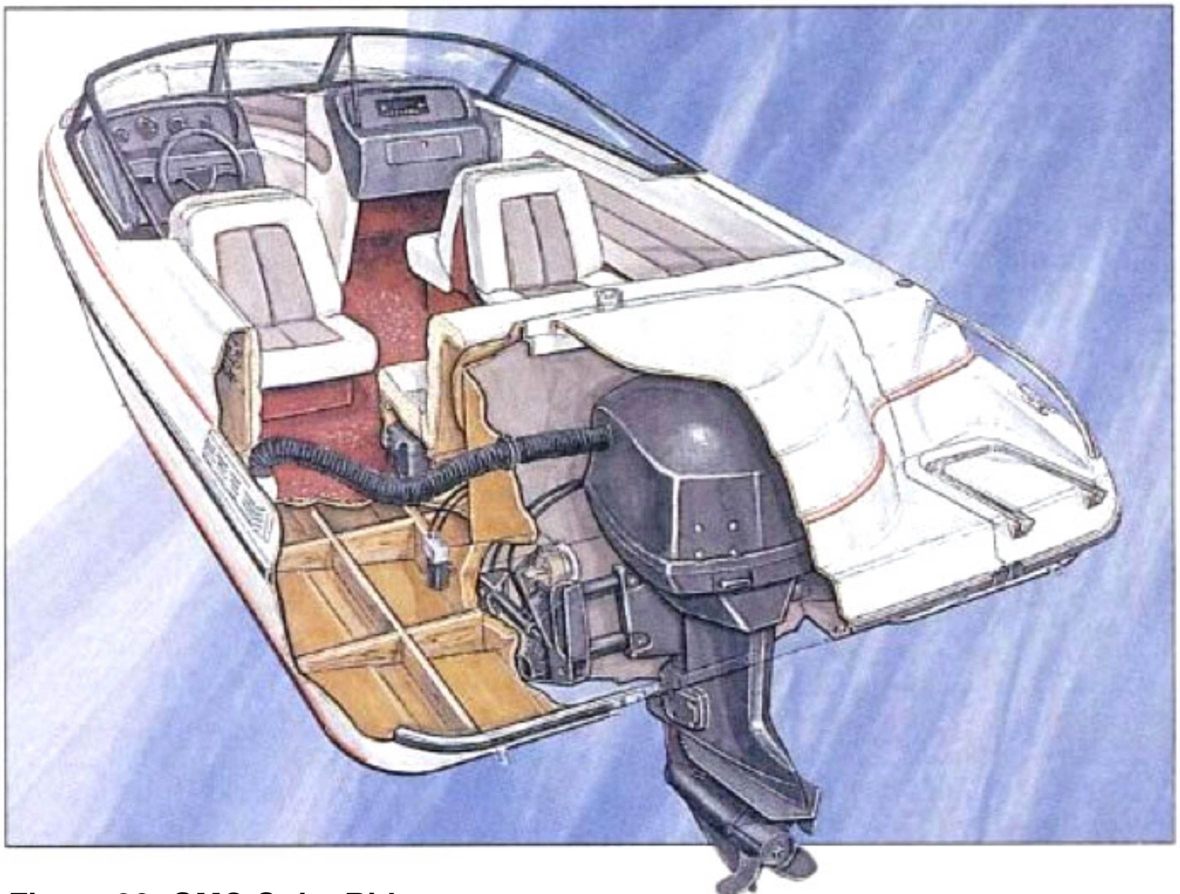


Figure 36: OMC Quiet Rider
image from Popular Mechanics February 1992 page 75

1E3c. Mercury Marine US Patent 5,108,325 (L-drive patent)

Later Brunswick patents refer to **US Patent 5,108,325** seen in **Figure 37** as Mercury Marine's L-drive patent. It is a through hull drive with a u-joint in the lower section to allow steer, trim, and tilt. This may represent a drive Mercury called the Mirage that did not make it to production.

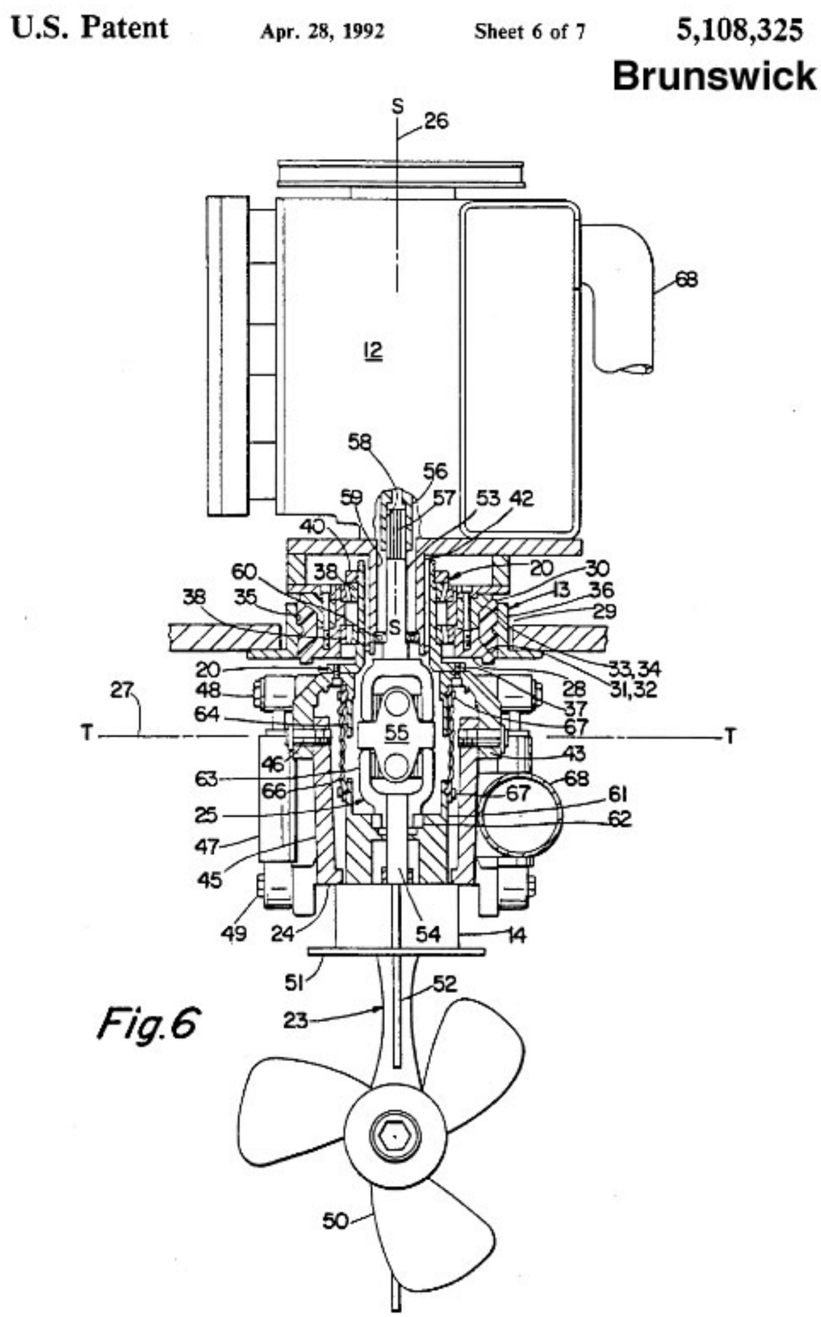


Figure 37: US Patent 5,108,325 Mercury Marine L-drive

1E3d. Sanshin US Patent 5,088,945 (Nose Over Drive)

In 1992, Sanshin (now Yamaha Marine), in the spirit of the L-Drive, patented an outboard (**US Patent 5,088,945**) with the engine turned 90 degrees forward into the boat as seen in **Figure 38**. They went on to file at least two more patents on this design. This approach provides an easy opportunity to tie the drive down with a band up and over the nose of the the outboard. The strap would tie the nose down to the transom, only allowing it to swing upward through the normal tilt range.

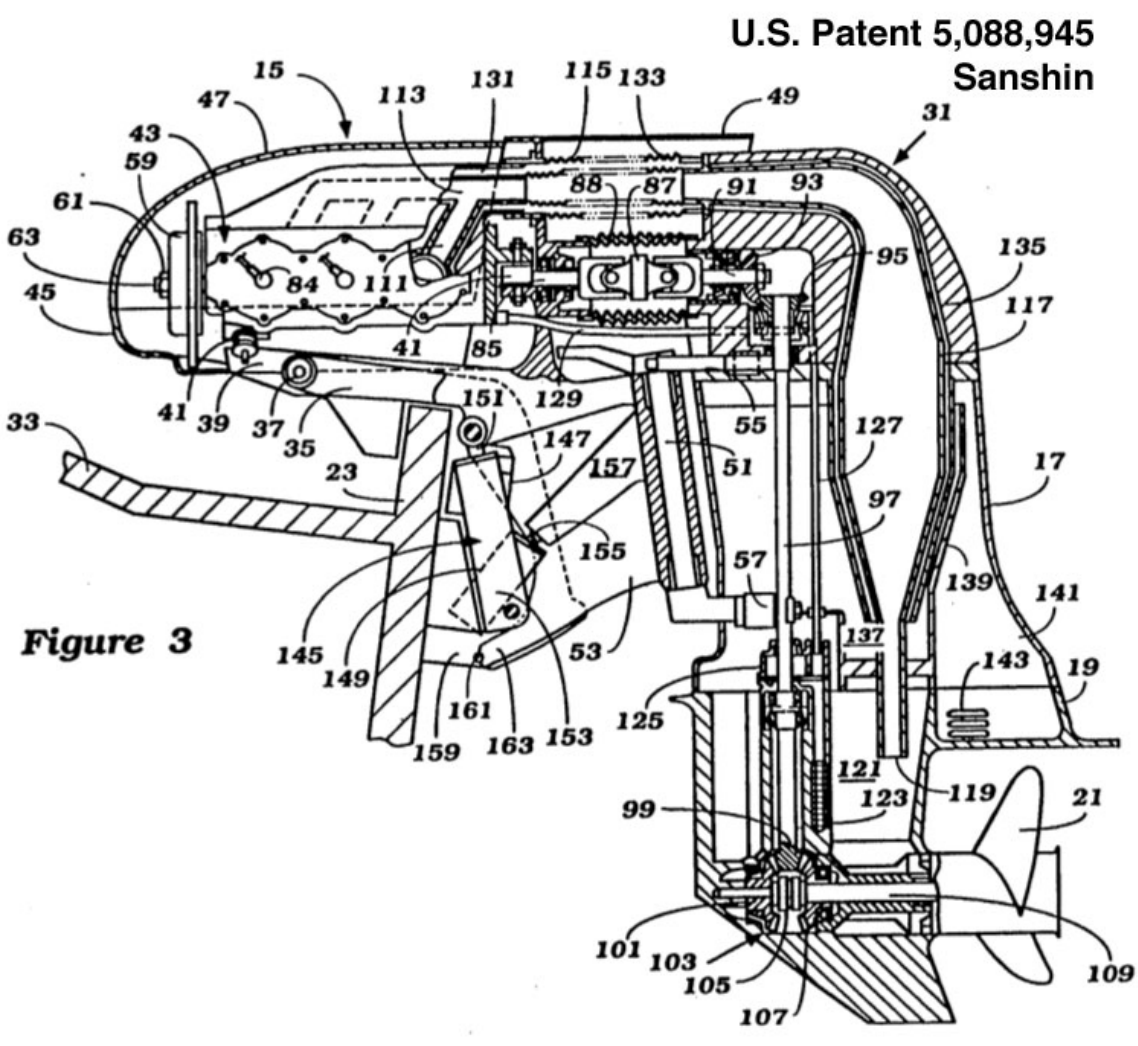


Figure 38: US Patent 5,088,945 Sanshin Nose Over Drive

1E3e. Bombardier US Patent 6,609,939

Bombardier Recreational Products laid claim to a “hidden” outboard drive with their **US Patent 6,609,939** seen in **Figure 39**. Bombardier refers to it as a drop down installation, referring to how the outboard powerhead can be dropped down and affixed to the hull.

The lower unit bolts up from the bottom. Once installed, it is hidden from view by a cover.

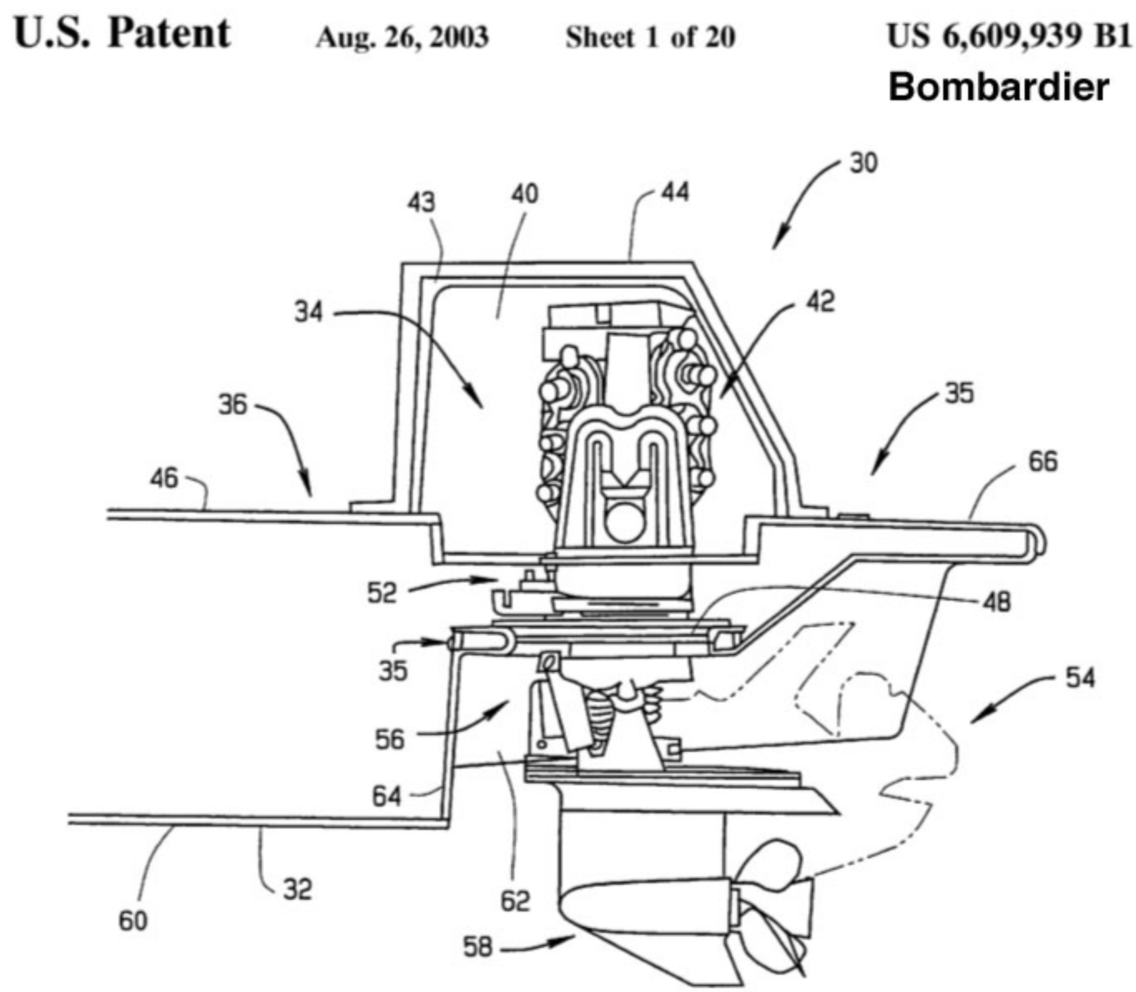


FIG. 1

Figure 39: US Patent 6,609,939 Bombardier drop down installation

1E3f. Sea Ray 370 Venture

In model year 2013, Sea Ray launched “hidden” outboards in a large 37 foot boat known as the Sea Ray 370 Venture. Most previous “hidden”, “well”, inboard outboard attempts were confined to boats at least 10 feet shorter in length. Seen in **Figure 40**, the design places large twin Mercury Verado outboards in wells at the stern with snorkels to the side for intake air. By spreading the two outboard wells, and allowing a walk through between them, the vessel is able to have a flat, full width, full size swim platform.

Sea Ray 370 Venture was named 2012 boat of the year by the editors of Boating Magazine.

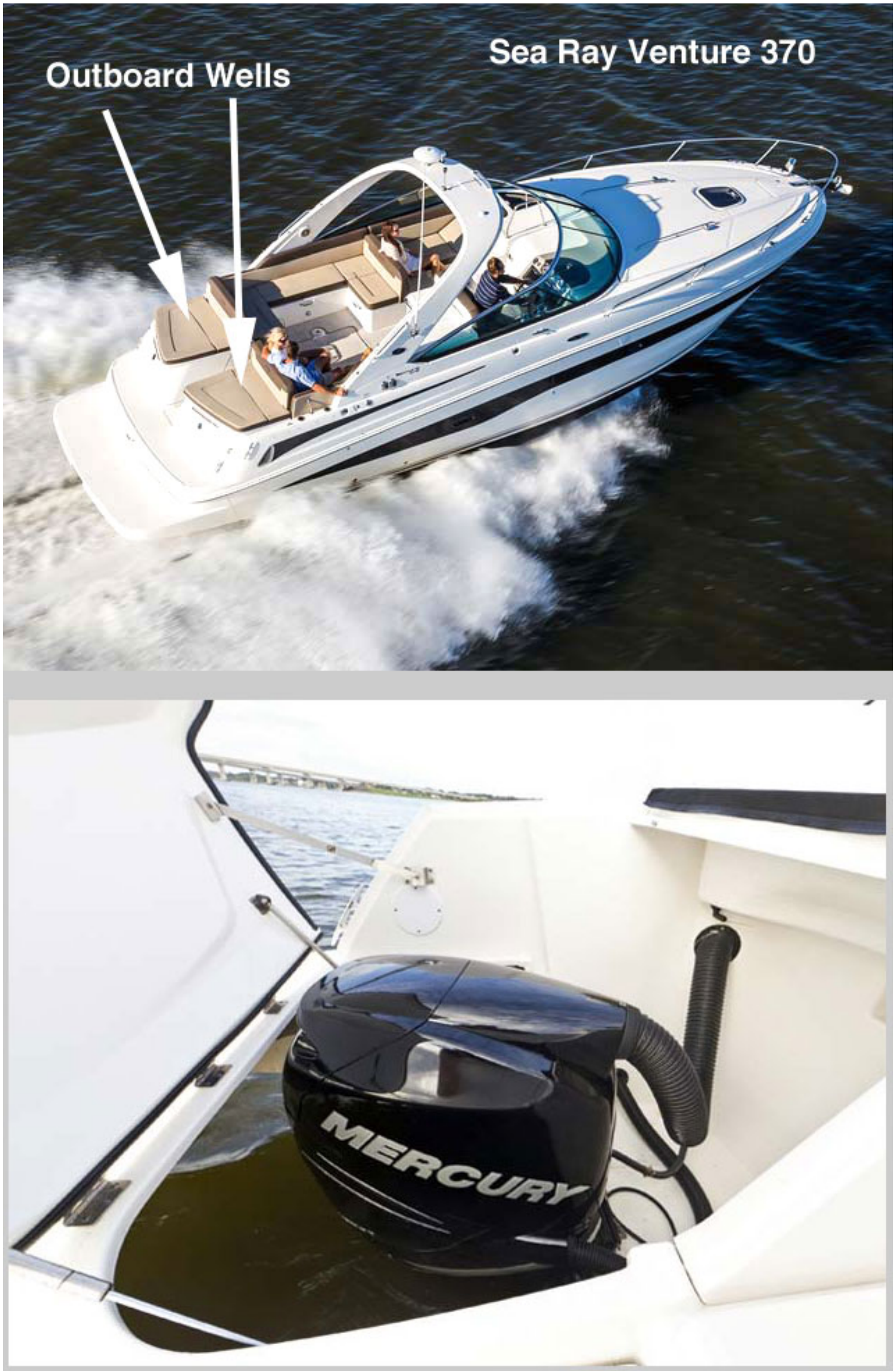


Figure 40: Sea Ray 370 Venture, photos by Sea Ray

1E3g. Pursuit SC 365i

Pursuit introduced the SC 365i sports yacht in late 2012. In the same class as Sea Ray's 370 Venture, both these vessels extend the use of outboard wells beyond their previous targets. Pursuit mounts large twin Yamaha outboards, and mounts them closer together than Sea Ray did. Pursuit offers a walk though path along one side of the outboard enclosure to a flat, full width swim platform as seen in **Figure 41**.

Figure 41: Pursuit SC 365i, images from Pursuit brochure

Proposed Solution:

2. Restrain Outboard if it Breaks Off

2. Restrain Outboard if it Breaks Off

Modern large outboard motors running at speed striking fixed or nearly fixed submerged objects can break off. Some that break off will flip into the boat. Some that flip into the boat will severely injure or kill those on board.

There are several approaches for restraining the outboard motor and preventing it from entering the boat, or limit its entry to unoccupied areas. Among them are:

2A. The Leash
2B. Use a Strap, Chain, or Cable to Limit Maxim Tilt
2C. Use Existing Lines as Tethers
2D. Use a Cable Similar to Those Used on Portable Outboards
2E. Mercury Marine Tether
2F. Restrain the Jack Plate Slide

Each of these methods will be briefly discussed.

2A. The Leash

Previous versions of this section talked about NASCAR using Vectran tethers on race car tires to prevent them from flying into other cars or the crowd. We suggested an outboard tether based on the same technology. In early 2016, The Leash came on the market.

Online forum discussions on the problem have turned from ropes, chains, and straps, to the Leash, its cost, and the current lack of test data.

The Leash is composed of two Vectran "ropes". The shorter rope has braided loops on both ends. The longer rope has what looks like heavy duty washers or flat spools on both ends. The attachment process is described here, but is much more easily understood by viewing **Figure 14 or Figure 42**.

The shorter rope wraps around the back of the upper leg of the outboard motor with the loops facing forward.

The "washer" on one end of the longer rope goes under one of the bolts mounting the outboard motor to the transom, or if you have a jack plate it goes under one of the bolts mounting the jack plate to the transom. The loose end of the longer rope now threads through one loop of the shorter rope, passes behind the swivel bracket, then threads through the other loop of the shorter rope, and is then similarly attached to the transom on the opposite side.

In September 2017, **US Patent 9,771,136** was awarded to The Leash, LLC.

Figure 42: The Leash as seen in two images on their Facebook page

During impact with a submerged object, the outboard hopefully clears the object and begins to rotate upwards. The momentum of the impact continues to rotate the outboard upward. If the outboard reaches maximum tilt, it does so with no or minimal resistance from The Leash. If the outboard then continues to rotate upwards as all the components stretch, The Leash begins to share the load with the swivel bracket. If the outboard does break off, The Leash will restrain it.

Similarly, if the outboard was unable to clear the object fast enough and was ripped off the boat, The Leash will restrain it from entering occupied areas of the boat.

In early 2015 we noticed some jack plates (like Slidemaster) including U-bolts on the sides for use as attachment points for trailer tie downs as seen in **Figure 43** and **Figure 44**. In April 2016 we noticed Atlas jack plates had them too.

The recently integrated jack plate trailer tie downs could be designed for dual use. They could also be an attachment point for tethers preventing outboard motors from entering boats. For example, a product like The Leash could be attached to the sides of the jack plate vs. the motor mounting bolts. The ability for The Leash to connect to the jack plate might only require one “rope” resulting in a more economical, easier installation.

Figure 43: Yamaha 250 VMAX SHO on Slidemaster Jack Plate with U-bolt tie down behind a Skeeter boat

Polson 7 February 2015 Tulsa Boat Show image DSCN3540

U-bolts on the side of the jack plate in **Figure 43** and **Figure 44**, are currently used as trailer tie downs. With proper design, they could also be used as an attachment point for tethers preventing outboard motors from entering boats. Attachment points on the jack plate might allow The Leash to reduce to one tether loop, reducing cost and complexity.

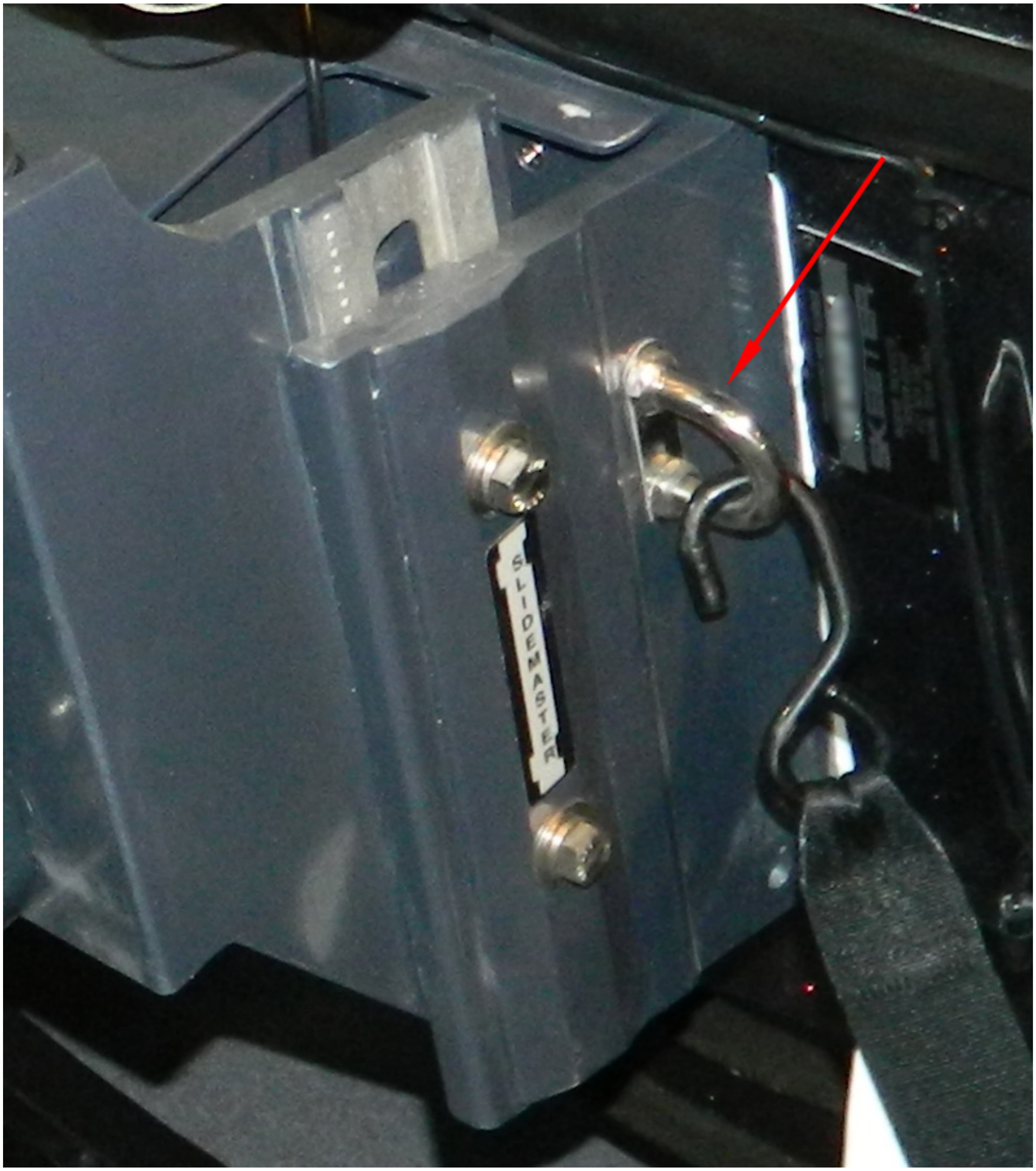


Figure 44: Slidemaster Jack Plate U-bolt (enlargement of Figure 43)

Since then we have observed some Leash installations utilizing an upper forward bolt hole on the side of the jackplate instead of a motor mounting bolt. The installation looks much smoother with the Leash laying flat against the jackplate (see **Figure 45**), but it is one step removed from the motor mounting bolt if something goes wrong.

Figure 45: Installing The Leash on a Jack Plate

2B. Use a Strap, Chain, or Cable to Limit Maxim Tilt

Run a strap, chain, or cable across the drive, then secure it to the transom in a manner to sustain the impact loads. The strap, chain, or cable can be covered with a sheath, hose, or similar covering to prevent the cable or chain from scratching the outboard motor.

This method has been used by South Carolina Department of Natural Resources (DNR) for several years. Two through transom eyes are installed, one on each side of the motor. A hose covered, stainless steel cable is affixed around the outboard motor and attached to each of the through transom eyes. (see **Figure 46** and **Figure 47**).

Figure 46: South Carolina Department of Natural Resources instructional image on Aquatic Invasive Species. The cable is clearly visible.

Figure 47: South Carolina Department of Natural Resources (DNR) patrol boat

Figure 47 above was cropped, Photoshopped to reduce shadows, and labeled from an image in a 7 February 2014 South Carolina DNR Facebook post.[14] SC DNR uses a clevis between the end of the cable and the eyebolt to allow the cable to quickly disconnected.

Tethering the outboard to the transom has been around a long time. A July 1972 Coast Guard boating tips article[15] encouraged bass boaters to install and use a chain covered with a thick hose following an outboard motor flipping into one of the Coast Guard's own boating safety vessels. A portion of Mr. Cipra's article is reproduced in **Figure 48.**

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[14] South Carolina DNR Facebook image captured 7 February 2014.

[15] The Bass Boat. Coast Guard Boat Tips. Dave Cipra, USCG Boarding Officer. Weekender. Panama City News - Herald's recreation Guide. Friday 2 June 1972. Pgs.2-3.

The Bass Boat.
Coast Guard Boating Tips.
by Dave Cipra. Boarding Officer. USCG.
The Weekender.
Panama City News - Herald's
Recreation Guide
Supplement to the News-Herald.
Panama City Florida 2 June 1972.
Pages 2-3.

COAST GUARD boat tips

by dave cipra
boarding officer, uscg

With drill in hand, you may give some thought to bolting down the engine. The addition of a safety chain, with a release, is not so much for the motor's benefit as your own.

Most outboards naturally skip over submerged objects but have no safety catch to stop the upward swing. Coast Guard safety personnel have found — from experience, unfortunately — that an outboard can flip all the way into a boat if it hits a solid object at high speed.

This problem is not unique to bass boats but it may be more common, since they are used in waters with submerged stumps and such. The motor usually tears heck out of the steering cables and throttle connections and comes to rest with a spinning propeller midway between a passenger's left and right ears.

A safety chain, covered with a thick rubber hose (radiator hose is good) to protect from scratches, can be fitted around the shank of the motor and bolted to the transom. Most outboard motormen already use a similar chain as insurance against the motor's falling off due to vibrations. A safety chain can serve both purposes.

The chain should be slack enough to allow the motor to rise above the bottom of the hull and a strong snap-type release will allow quick removal. Don't use cheap dime-store chain or snaps. Use something you would stake your life on.

The Coast Guard boating safety team that discovered this potential hazard luckily did not have its third crewman on board. He would have been sitting in a centered rear seat — the final resting place of the berserk motor. All boats will eventually be fitted with safety chain.

Figure 48: Safety Chain. The Bass Boat. Coast Guard Boating Tips. Dave Cipra.

2C. Use Existing Lines as Tethers

It is common for outboard motors that enter the boat, to bounce around a while on the rotating propeller, exit the boat, and sink.

Numerous lines and cables run from the boat to large outboard motors: steering, throttle, and shift cables, fuel lines, electrical power lines, sensor lines, CAN buss lines. At least some of these lines typically remain connected after the accident. They are typically observed still connected with the motor on the deck OR the motor is dangling from them in the water behind the boat. See **Figure 49**.

Figure 49: Outboard motor dangling from lines

Lines and cables attached to large outboard motors already partially control the outboard's trajectory (and the propeller's trajectory) when the outboard breaks off and flips into the boat. See the **What Happens?** section in the **Introduction.**

It may be possible to redesign the existing cables and lines, and their attachment points or their restraints to restrain the drive from entering the boat far enough to strike those on board. Alternatively, it may be possible to use existing cables and lines to direct the outboard to a safer area when it breaks off, perhaps even overboard. If not, an additional cable could be added to the bundle and properly restrained for these purposes.

A 2015 American Society of Mechanical Engineers (ASME) technical paper describes the process of redirecting a projectile with a tether.[16] The paper has application to the current design (how the cables are currently redirecting the outboard) AND how they could be used to direct the outboard motor somewhere else.

[16] Impulse Redirection of a Tethered Projectile. Faraji, Veile, Hemleben, Zaytsev, Wright, Luchsinger, and Hatton. Proceedings of ASME 2015 Dynamic Systems and Control Conference. DSCC2015-9708.

2D. Use a Cable Similar to Those Used on Portable Outboards

Similar methods have long been used on portable, “clamp on” outboards to prevent them from sinking if they fall off the transom. For example, Yamaha’s 70 horsepower outboard motor owners manual[17] includes the warning seen in **Figure 50**. Note, the warning was clipped from two pages and reassembled as one continuous document.

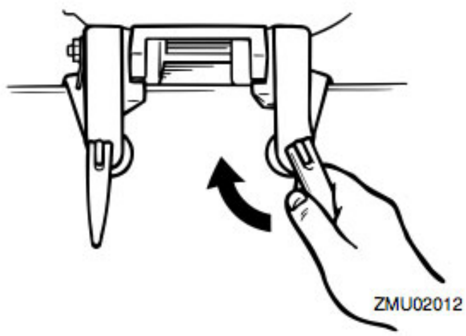
Small outboards use inexpensive restraint cables. Several can be found online for $10 to $20. Attwood’s version is shown in **Figure 51**. Larger outboards would require larger, stronger cables and secure attachment points.

[17] Yamaha 70 Owners Manual. LIT-18626-06-95 6H3-28199-1T. (digital version). Pgs.24-25.

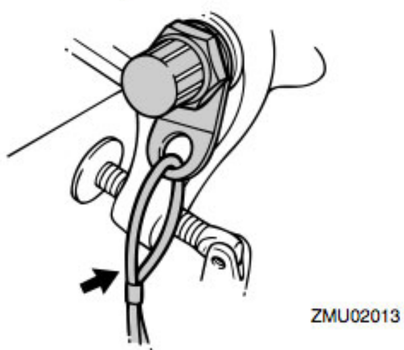
EWM00640

⚠ WARNING

Loose clamp screws could allow the outboard motor to fall off or move on the transom. This could cause loss of control and serious injury. Make sure the transom screws are tightened securely. Occasionally check the screws for tightness during operation.



2. If the engine restraint cable attachment is equipped on your engine, an engine restraint cable or chain should be used. Attach one end to the engine restraint cable attachment and the other to a secure mounting point on the boat. Otherwise the engine could be completely lost if it accidentally falls off the transom.



3. Secure the clamp bracket to the transom using the bolts provided with the outboard (if packed). For details, consult your Yamaha dealer.

Figure 50: Restraint cable warning on Yamaha 70 horsepower outboard 70 horsepower outboard owners manual 2006 or later

Figure 51: Attwood restraint cable / outboard motor safety cable for small outboard motors #11664-3

2E. Mercury Tether

Brunswick / Mercury Marine patented a tether for large outboard motors back in 1969.

1. **US Patent 3,434,44**8 Combined Impact Damping and Power Lift Mechanism for an Outboard Propulsion Unit. See **Figure 52**.

2. **US Patent 3,434,450** Mounting Arrangement for Hydraulic Impact Damping and Power Lift Means for an Outboard Propulsion Unit.

United States Patent Office — 3,434,448 — Patented Mar. 25, 1969

1

3,434,448
COMBINED IMPACT DAMPING AND POWER LIFT MECHANISM FOR AN OUTBOARD PROPULSION UNIT ASSEMBLY
William L. Woodfill, Oshkosh, Wis., assignor to Brunswick Corporation, Chicago, Ill., a corporation of Delaware
Filed Jan. 12, 1967, Ser. No. 608,903
Int. Cl. B63h *21/26;* F15b *13/04*
U.S. Cl. 115—41 — 11 Claims

ABSTRACT OF THE DISCLOSURE

The hydraulic system includes a cylinder piston assembly which extends between adjacent members pivoted relative to each other and which bridges the tilt axis of the outboard propulsion unit. The system includes means for holding forward and reverse thrust of the unit and provides for power and manual lifting of the unit, power trimming of the unit even while underway, and damping of the angular momentum imparted to the drive member upon impact with a submerged or floating object.

In the maximum tilt position, movement of the power unit 4 is checked by the nylon restraining strap 21 the respective ends of which are anchored on the transverse rod 22 carried by the swivel bracket 8 and which is looped over the transverse rod 23 of the transom bracket 7. The restraining strap 21 is pulled taut over the rod 23 when power unit 4 reaches the maximum tilt position.

Patent Claim #11

11. The invention as set forth in claim 10 wherein the means to check the upward tilt movement of the drive member comprises a flexible strap which bridges the tilt axis and is pulled taut when said drive member reaches the maximum tilt position.

Figure 52: US Patent 3,434,448 Outboard Tether
assigned to Brunswick Corporation

Mercury's tether which was used in thousands of outboard motors, some of which are still in service today, was a heavy nylon strap about 1.75 inches wide and about one to two feet long depending on the application.

Mercury's tether had a loop at both ends as seen in **Figure 53**.

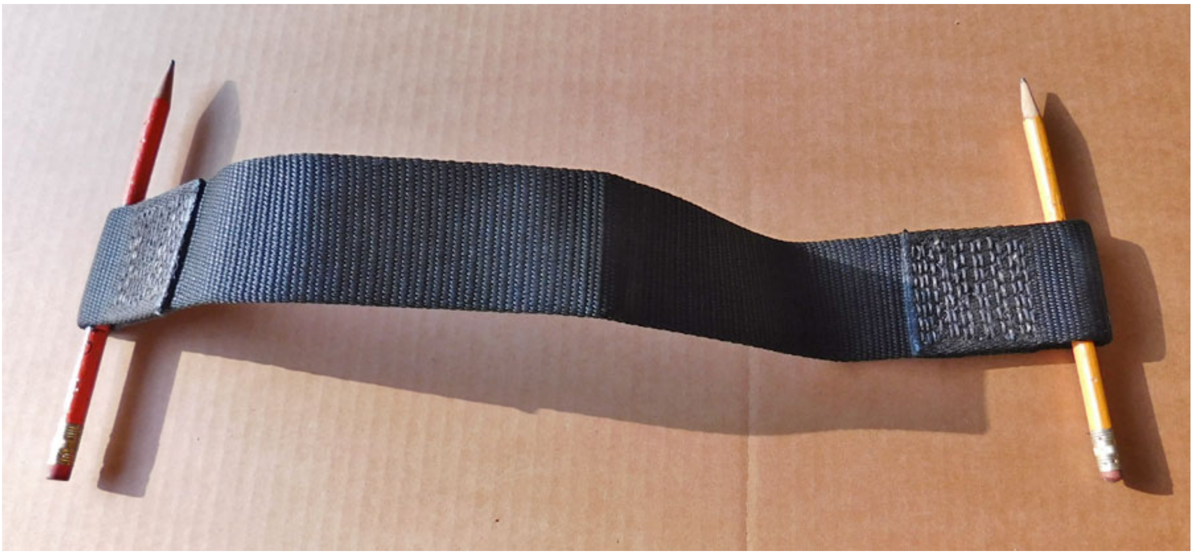


Figure 53: Mercury's Tether

One loop was slipped over a rod tied to the swivel bracket, the other end passed over a rod that was part of the transom bracket, then the remaining end was looped over the same rod as the first loop as seen in **Figure 54**.

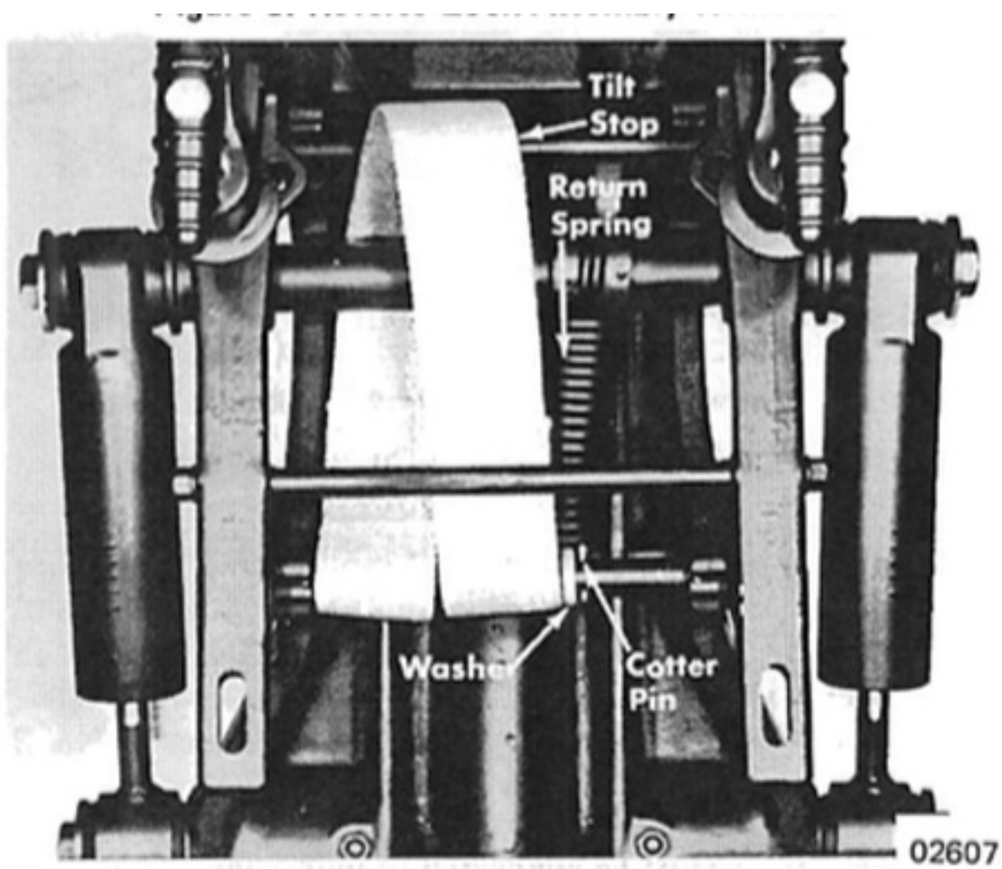


Figure 6. Tilt Stop Installed

Figure 54: Mercury's Tether Installed

More information about Mercury's tether is available from our website.

2F. Restrain the Jack Plate Slide

Some jack plate manufacturers such as Atlas are known for securing the slide with a cable or otherwise preventing the slide from exiting the top of the jack plate and entering the vessel while underway. See **Figure 55**.

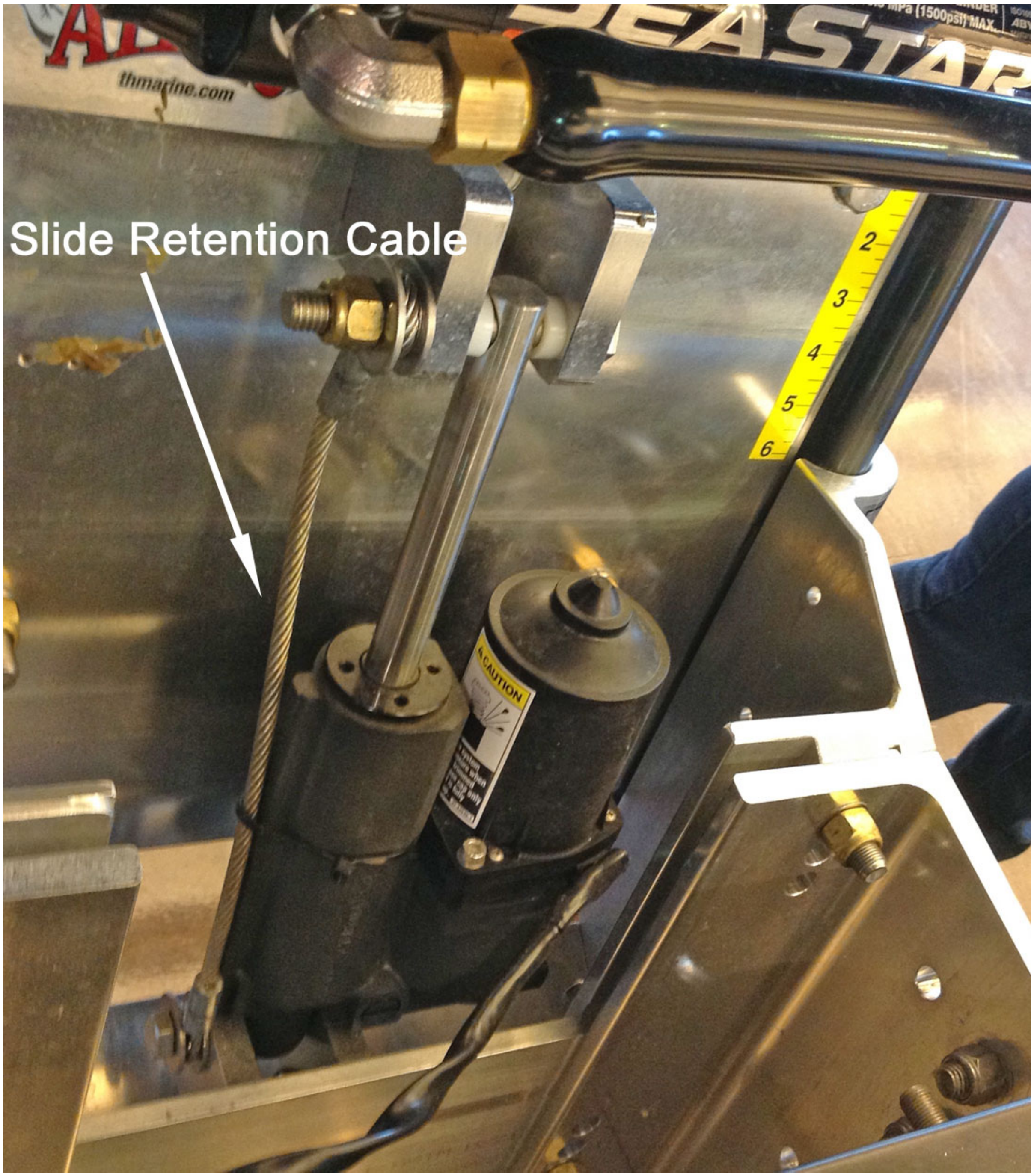


Figure 55: Atlas jack plate with slide retention cable

Proposed Solution:

3. Physical Barriers Prevent Outboard From Entering Boat

3. Physical Barriers Prevent Outboard From Entering Boat

Physical barriers can be used to prevent outboard motors from flipping into boats.

This section will discuss three categories of these devices.

3A. Mechanical Fences, Engine Crash Bars, Tow Bars, Roll Over Bars, & Poling Platforms
3B. Swim Platforms
3C. Bass Boat Rear Platform Seat

3A. Mechanical Fences, Engine Crash Bars, Tow Bars, Roll Over Bars, & Poling Platforms

When Mercury Marine was conducting open water log testing, they used mechanical screen fences at the transom to prevent drives and parts of drives from flipping into the boat as seen in the stern drive log strike photo, **Figure 56**. We used a filter on the photo to prevent copyright theft of the original image.

The drive is clearly visible at the stern. It has flipped vertically 180 degrees and is trying to enter the boat, propeller first, at the screen.

Figure 56: Mercury Marine on water log strike testing

Transom fence prevents stern drive from entering boat

Figure 57 shows an early Mercury outboard on water log strike test. The fence to prevent the outboard from entering the boat is clearly visible.

Figure 57: Early Mercury log strike test cage / fence

Several government and commercial outboard boats have engine crash rails extending from the stern and going around the outboards. Crash rails call attention to the engine's location and prevent inadvertent backing of engines into above water objects or structures. They also prevent towed boats, approaching boats, or Personal Watercraft (PWC) from striking the engines.

If a crash rail were strong enough, properly placed, and if the transom to which it is mounted is strong enough to absorb the load, it could stop the upward swing of an outboard after it struck a submerged object. **Figure 58** shows commercial vessel versions of these bars from Boston Whaler and from Munson. The engine crash bar on Munson's aluminum boat looks very sturdy.

Some commercial boats have tow bars mounted across the width of the vessel near the stern. These bars, properly designed, could also be of use in preventing an outboard from entering the boat. For example, see the tow bars on the Boston Whalers in **Figure 58** and **Figure 59**.

Figure 58: Outboard Motor crash bars

Top: Boston Whaler commercial boat w/engine crash bars & torsional tow bar

Bottom: Munson aluminum commercial boat w/engine crash bars

Some small commercial boats used in rough water have roll bars (see **Figure 59**) that, properly designed, could prevent an outboard from further entering the boat.

Figure 59: Boston Whaler with engine crash bars, torsional tow bar, and roll over bar

I took the photo in **Figure 59** through a chain link fence at Kaw Lake near Ponca City Oklahoma in May 2012. This U.S. Army Corps of Engineers lake patrol boat has outboard motor crash rails, a torsional tow bar, and a roll over bar with some lights and a radio antennae mounted to it.

One or more of these bar systems (crash rails, torsional tow bars, or roll over bar), properly designed, could prevent an outboard motor from further entering the boat after striking a submerged object.

TurboSwing manufacturers a towed sports tow bar, TurboSwing (**Figure 60**). They also manufacture a heavy duty version, TowRescue, for commercial towing and workboat applications. Similar in design to engine crash rails, both products offer design opportunities to restrict outboards from flipping into boats.

Figure 60: TurboSwing

Some poling platforms (ladders to a flat platform flat to stand above the outboard motor area and push the boat along in shallow water with a long pole) might be redesigned to stop outboard motors from entering the boat. A poling platform by Custom Marine of Jacksonville, Florida is shown in **Figure 61**.

Figure 61: Custom Marine Poling Platform

3B. Swim Platforms

Many recreational boats have swim platforms. They provide easy access to the water and are great for water skiing or tubing. Outboard boat swim platforms typically consist of two pads, one on either side of the outboard motor. A few outboard swim platforms encircle the outboard motor and could provide some resistance against the outboard flipping up into the boat.

Some houseboat swim platforms / swim decks extend out over outboard motors and provide considerable resistance to outboards flipping into the boat, but most houseboats go so slow it is not an issue for them. **Figure 62** shows a houseboat swim platform with an outboard engine cover that doubles as a seating area. The engine cover is shown rotated up to the open position.

Figure 62: Houseboat Swim Platform Outboard Engine Cover

3C. Bass Boat Rear Pedestal Seat

Some bass anglers leave their bass boat's rear pedestal seat in the upright position when underway in hopes it will help keep the outboard motor from "coming in on them". While we have seen some instances in which the rear pedestal seat helped protect those onboard, we have seen at least one fatal accident in which the outboard came through over the rear pedestal seat. See **Figure 63**.

Outboard motors can go pretty high before they come back down. We have seen one partially land on top of a t-top, some flip all the way over the boat, and one almost land in another boat. Look at **Figure 63** a moment and image being the passenger.

For those relying on the rear pedestal seat, some design work could make that approach more effective. For example, the base the post is stuck in, the post, and the seat could be designed to be stronger, to absorb energy, and / or to deflect the outboard.

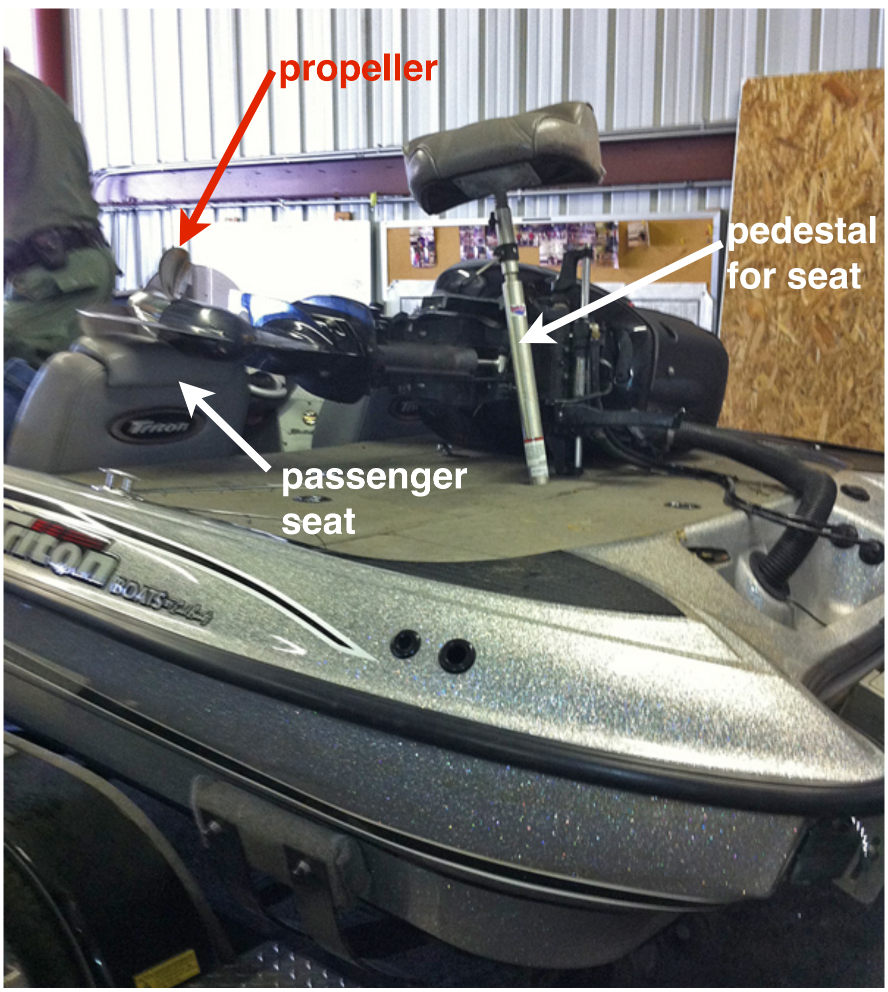


Figure 63: Outboard Came in Over the Rear Pedestal Seat

Proposed Solution:

4. Warn of the Hazard

4. Warn of the Hazard

This section will cover traditional warnings for the hazard of outboard motors breaking off and flipping into boats. It will also cover one area responsible for several outboard motors breaking off and flipping into boats, the lack of adequate warnings on dredge pipes. We conclude by calling for marking known long term submerged hazards.

4A. Warning in Operators Manual, On Boat, On Outboard

Some outboard manufacturer's operators manuals warn of the hazard of parts of or entire outboard motors entering the boat during impacts with submerged objects. We know of no "on boat" warnings or "on product" warnings currently being used for this hazard.

Our example warnings for this hazard shown in **Figure 64** have not been tested.

We suggest such warnings as a means of raising awareness of the hazard, especially for passengers who cannot be expected to read the outboard operator's manual. Note - passengers are struck more frequently than boat operators.

We suggest such warnings be considered for placement in:

1. The outboard motor's owners manual
2. On the outboard motor
3. The boat where the passenger and operator can both see it
4. The boat operator's manual.

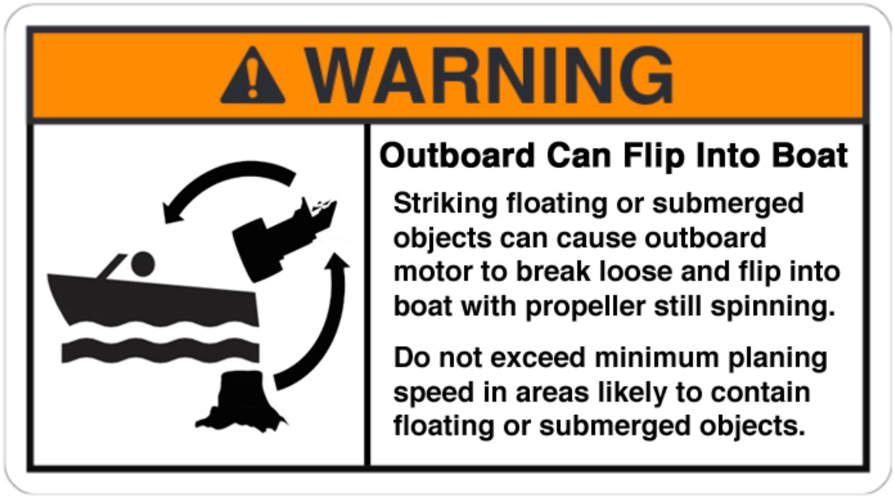
The Warning Label Group for the Boating Industry Risk Management Council (BIRMC) developed Label Placement Criteria including 4 independent tenants for placing the label on the product. Two tenants are: (1) Has been the subject of boating safety concerns and/or liability claims in the marine industry, (2) Deals with a safety issue that cannot be engineered out nor guarded against.

BIRMC Criteria #1 has been met as numerous lawsuits have been filed on this issue. As to BIRMC Criteria #2, the industry repeatedly makes that statement in court, "the hazard cannot be engineered out nor guarded against". Thus a warning should be placed on the product per BIRMC guidelines.

The same BIRMC Label Placement Criteria state that topics warned of "on product" should be expounded upon in collateral literature (the manual).

One might consider integrating "rough water" into the warnings in the manual as a similar hazard. Swivel brackets and other structural components have been known to break in rough water.

#1



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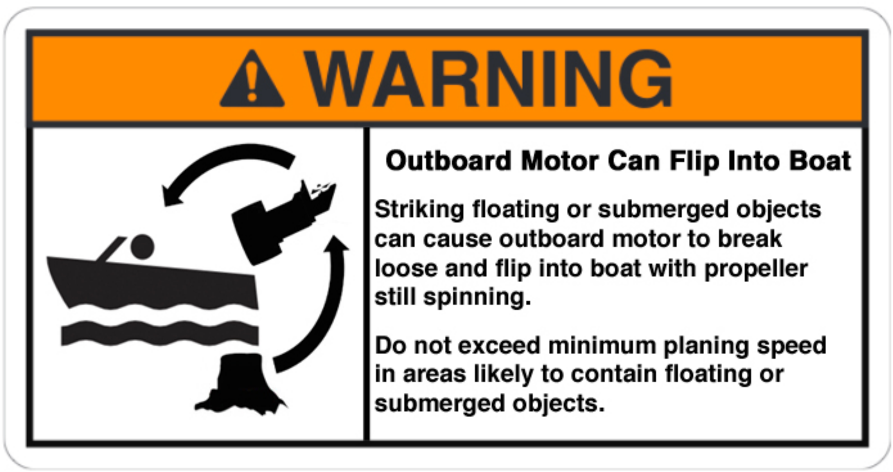

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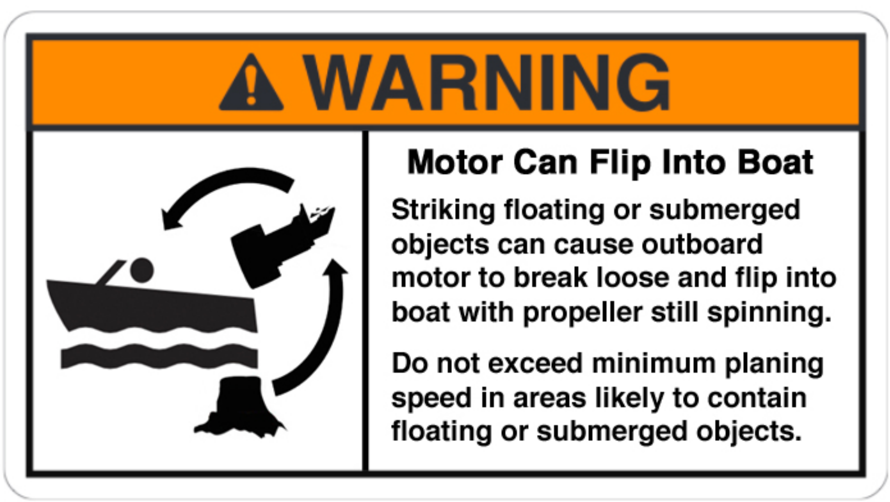

Figure 64: Polson Enterprises Warnings
Three examples of “outboard flipped in” warnings

4B. Marking of Dredge Pipes

Several outboard motors strike dredge pipes, break off, and flip into boats. Plus many more dredge pipes are struck than just those resulting in outboards flipping into boats.

Dredging operations have a history of not properly marking dredge pipes. In addition, long sections of dredge pipes sometimes get away from them and drift aimlessly in open water. Existing markings or buoys can breakaway or drift away in a storm or hurricane.

Dredge pipes can be a foot and a half in diameter and a few thousand feet long. Sometimes they are used to dredge areas deeper, sometimes they are used to deposit dirt dredged from somewhere else onshore or to build up an island.

One popular version of dredging floats the pipe to the general area it needs to be in, the pipe is likely curled in multiple “S” shapes as it snakes back and forth. When a slurry of dirt and water is pumped through the pipe, the pipe sinks. When they need to move it, they pump only water through it and the pipe floats to the surface. The top edge of the pipe is just at the surface, most of the pipe is submerged. Floating dredge pipes are very difficult to see, even in smooth water.

When one dredge pipe strike involving a serious injury or fatality is reported, several other reports of recent strikes tend to follow. It is as if dredging firms just live with the non-fatal accidents, then when someone is killed all of a sudden they become concerned.

At times, dredging operations have elected to “float the pipe” to move it on very busy boating season holidays greatly increasing the chance of the pipe being struck.

We are aware there are some conscientious dredging firms out there doing their best to mark dredge pipes in both daylight and dark conditions. However, as a whole, the industry has a reputation for not properly marking dredge pipes.

One method of marking dredge pipes is the use of buoys. Problems with buoys include they may be spaced a few hundred feet apart along the pipe, and they can drift a considerable distance from the pipe. Thus when thousands of feet of pipe are snaked in multiple “S” curves it is impossible for a boater to ascertain the general path of the pipe. The boater just sees the buoys, if the pipe is marked at all, and begins to envision a safe path through the area that does not really exist.

4C. Mark Existing Submerged Hazards

Some areas have permanent submerged hazards known to the locals but they appear on no maps and catch novices or visitors to the area off guard. With bass tournaments bringing speed and large outboard motors to new areas, the potential for disaster has been increased.

For example, a sunken barge or old salt water barrier was said to be in the Neches River in Limestone Texas, North of Four Oaks Ranch Road near the city of Beaumont. (Reference U.S. Coast Guard Boating Accident Report Database #2012-TX-0004). There are many such hazards around the country. A move to properly mark them or move them would prevent some of these accidents.

Proposed Solution:

5. Minimize the Hazard Once Outboard Enters the Boat

5. Minimize the Hazard Once the Outboard Enters Boat

Methods suggested in this section reduce the hazard once the outboard enters the boat.

5A. Kill Engine to Stop Propeller From Rotating

The time between the outboard motor breaking off the boat and the outboard entering occupied areas of the vessel presents an opportunity to mitigate injuries and fatalities.

An outboard motor flying into the boat is a significant safety hazard, especially a large outboard. However, the same outboard with a propeller still rotating under power is far more dangerous. See **Figure 63**. Several people have been critically injured or killed by outboard motor propellers still rotating under power in occupied areas of the vessel. Steering cables and fuel lines tend to remain attached and the propeller turns at very high RPMs due to air being much less dense than water.

Log strike systems are designed to allow the outboard motor to flip up and over the obstruction. When the outboard motor's propeller begins to clear the water, it begins to rotate much faster in air. The log strike system dissipates impact energy, and the outboard motor settles back down to its previous trim position. Some designs throttle back or kill the engine during impacts for various purposes.

Among early attempts were F.C. Krueger's **US Patent 2,917,019** filed in 1955 shown earlier as **Figure 26**. Krueger used a push rod to kill the engine as the lower part of this drive was allowed to swing backwards and upwards from a hinge during a collision.

Krueger was not the only early inventor to recognize the need to slow or kill the engine when the drive or part of the drive swings up. Edwin B. Nolt of Sperry Rand filed a similar claim in 1960 which eventually issued as **US Patent 3,036,543**.

At that time, large outboards were reaching 80 to 100 horsepower. When an object is struck and the drive swings up clear of the water, the propeller rotates much faster.

When the now very rapidly rotating propeller swings back down and reenters the water, it can cause a sudden jolt. This jolt may cause those on board to fall, to be tossed into the structure of the boat, or to fall overboard. In addition, the engine may be damaged from the ultra high RPMs reached while the propeller was out of the water, and the transom may be damaged from the shock of the high speed propeller reentering the water. Lastly, propeller damage can be minimized by stopping its rotation as soon as something is struck.

Nolt proposed a means of automatically protecting the boat by reducing the speed of the engine or by killing the engine when the propeller swings up. He used a push rod activated by the drive when it swings up to reduce a throttle. Nolt similarly used the upward swinging drive to make and break contacts to kill the engine.

Kiekhaefer Corporation (Mercury) patented a system to kill stern drive engines before the propeller re-entered the water, then restart them once the drive returned to its original position:

US Patent 3,136,287. Inboard-Outboard Drive for Watercraft. Assigned to Kiekhaefer Corporation. The Kiekhaefer patent issued in 1964.

As early as 1959, Mercury was already touting their Safety Tilt Switch on their larger outboard motors.[18]

A "breakaway" kill switch similar in function to the one used by the boat operator can be used to kill a large outboard motor when it breaks free of the boat. When the outboard breaks off and begins to leave the transom, it pulls out the "lanyard", and the engine is killed.

Designs for killing the engine or slowing its RPM when a marine drive strikes a submerged object and flips up that made it to production include:

A. Mercury (Kiekhaefer Corporation) used a Safety-Tilt Switch to automatically cut ignition (stop providing an ignition spark to the engine cylinders) until the outboard motor's propeller returned to the water after striking a submerged object as early as 1960.[19,20]

B. By 1962 a Kiekhaefer MerCruiser stern drive momentarily slowed the engine when propellers kicked up from striking submerged objects.[21]

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[18] Kiekhaefer is Leader in Outboard Progress. Oshkosh Northwestern IL. Friday January 9, 1959.

[19] Mercury is the World's No.1 Outboard in Reliability. Popular Boating. March 1960. Third Cover. via Google Books.

[20] Mercury: The Most Powerful Name in Outboards. Advertisement. Motor Boating. March 1961. Pgs.12-13. via Google Books.

[21] Astern for '62. Motor Boating. October 1962. Pg. 30.

Sanshin (became Yamaha Marine) was awarded **US Patent 4,734,065** System for Stable Running of Marine Propulsions in 1988. The patent reveals a collection of methods to detect the outboard motor has struck something and the propeller is rotating in the air. The patent covers their detection methods and their techniques for throttling back the engine. The first page of Sanshin's patent is shown in **Figure 65**. The same concept could be used to kill the engine if it leaves the transom. Stopping power to the propeller could reduce some of the mayhem and chaos after the outboard enters the boat. We recognize the engine may fly from transom to occupied areas in a fraction of a second. However, if the engine is killed in gear and the fuel is shut off, there is substantial resistance to continued rotation of the propeller. In addition, it might be possible to change firing rotation of the cylinders to more quickly brake the engine as it is shut down.

According to Sanshin:

> *"Although permitting popping up of the outboard drive when an underwater obstacle is struck protects the outboard drive, when the outboard drive returns to its normal running position, there can be certain unsatisfactory conditions arise in the resulting watercraft. For example, the rapid change of trim can produce a surging in the condition in the watercraft that can upset the passengers, it can cause a rolling operation of the watercraft or it could result in an abrupt and unexpected turn in the watercraft's direction. Although these conditions are less objectionable that those which would result it popping up were not permitted, it would be desirable if they could be voided."*

Sanshin enumerates methods they propose achieve stability of the vessel after the outboard motor pops up by slowing the speed of the outboard engine for a time period after it returns to its previous trim position. Sanshin lists four ways of detecting impact with a submerged object:

1. Pressure sensor on rod end of trim / tilt cylinder
2. Change rate of trim angle as measured from the trim position indicator (how fast the trim position is changing)
3. Trim position moved to outside normal trim positions
4. Impact sensor mounted to front lower end of outboard drive

Sanshin says they can slow the engine at least three ways:

1. Misfiring cylinders
2. Reduce fuel flow
3. Throttle intake air

Sanshin's patent also teaches using a throttle position sensor and a comparator circuit to prevent slowing the engine if it is already at a low throttle position and killing the engine.

United States Patent [19]

Nakahama et al.

[11] **Patent Number: 4,734,065**

[45] **Date of Patent: Mar. 29, 1988**

[54] **SYSTEM FOR STABLE RUNNING OF MARINE PROPULSIONS**

[75] Inventors: **Ryoji Nakahama; Katsuji Hirade; Takashi Koike,** all of Hamamatsu, Japan

[73] Assignee: **Sanshin Kogyo Kabushiki Kaisha,** Japan

[21] Appl. No.: **870,458**

[22] Filed: **Jun. 4, 1986**

[30] **Foreign Application Priority Data**

Jun. 5, 1985 [JP] Japan 60-121700

[51] **Int. Cl.**[4] **B63H 21/26**

[52] **U.S. Cl.** **440/1**; 440/61; 440/56

[58] **Field of Search** 440/1, 55, 56, 61, 65, 440/900, 84, 88; 114/275, 276, 279, 280; 180/277, 279

[56] **References Cited**

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4,554,892	11/1985	Amenori et al.	440/900

Primary Examiner—Joseph F. Peters, Jr.
Assistant Examiner—Edwin L. Swinehart
Attorney, Agent, or Firm—Ernest A. Beutler

[57] **ABSTRACT**

A number of embodiments of arrangements for stabilizing the running of a marine propulsion unit by slowing the speed of the propulsion unit when an underwater obstacle is struck. In some embodiments, the slowing is accomplished by misfiring of the engine and in other embodiments, the speed is reduced by throttling the fuel supply to the engine. The embodiments illustrate the application of the principle to an outboard drive of an inboard/outboard drive arrangement or for an outboard motor. The striking of the underwater obstacle is sensed by either an impact sensor, by sensing the angular position of the outboard drive, or by sensing the rise in pressure in a shock absorber that resists the popping up action.

16 Claims, 11 Drawing Figures

Sanshin (Yamaha)

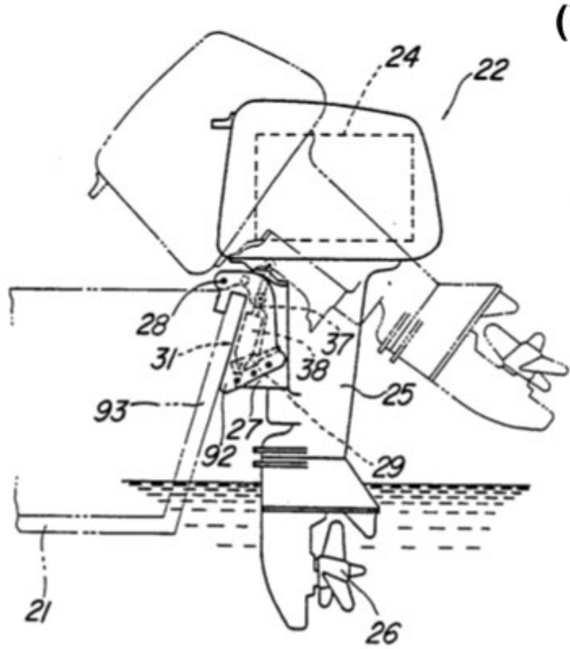

Figure 65: US Patent 4,734,065

We suggest similar techniques could be used to detect breakaway of the outboard motor, and to kill the engine in those conditions. Additional indicators the outboard has broken free and may enter the boat include:

1. Steering cable tension
2. Engine RPM spike for more time than a normal strike and settle back down
3. Outboard is upside down (rotates over itself)
4. Loud noise (swivel bracket broke)
5. Sudden deceleration of the vessel
6. Tilt angle acceleration (rate of change of tilt)
7. Shock load to the boat when drive lands in boat
8. Drive is gone from the transom
9. Propeller torque (impacting things other than water)
10. Swivel bracket is no longer in one piece
11. Jackplate slide vertically exited its track
11. Sudden change in forward stress of major hull components (drive no longer pushing boat) that lasts longer than a normal log strike and settling back down, or than hopping a wave or wake.
12. Monitoring the ground (continuity) wires on components likely to break free

Two or more indicators could be used together to help reduce false alarms (false positives).

Now, with CAN-BUS, SmartCraft (Brunswick / Mercury Marine), Electronic Vessel Control / EVC (Volvo Penta), I-Command (Bombardier Recreational Products / BRP), Command Link (Yamaha), K-Line (Honda), NMEA 2000, and other similar network bus systems along with engine control modules (ECMs), it is easier to detect the engine over revving following impact with a floating or submerged object, quick changes in boat velocity, and other variables indicative of a impact or the outboard propeller rising above the water. For example, see **Figure 66**, Brunswick's 2001 **US Patent 6,273,771**, Control System for a Marine Vessel. Brunswick's and similar bus systems from Brunswick's competitors, could be used to throttle the engine back, and to kill the engine in instances in which the drive is detected to have broken free.

Mercury's Engine Guardian system already offers several modes the engines default to in order to protect themselves if they overheat or have other issues. The same system could be used to protect people as well as the engine.

(12) **United States Patent**
Buckley et al.

(10) **Patent No.: US 6,273,771 B1**
(45) **Date of Patent: Aug. 14, 2001**

(54) **CONTROL SYSTEM FOR A MARINE VESSEL**

(75) Inventors: **George W. Buckley**; **Vojislav V. Divljakovic**; **Phillip K. Gaynor**, all of Fond du Lac; **Jeffery C. Ehlers**, Neenah, all of WI (US); **Daniel E. Clarkson**, Stillwater, OK (US)

(73) Assignee: **Brunswick Corporation**, Lake Forest, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/528,144**

(22) Filed: **Mar. 17, 2000**

(51) **Int. Cl.**[7] **B60K 41/00**
(52) **U.S. Cl.** .... **440/84**; 114/144 RE
(58) **Field of Search** .... 114/144 R, 144 E, 114/146; 440/84; 74/480 B; 701/206, 213

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Primary Examiner—Jesus D. Sotelo
(74) *Attorney, Agent, or Firm*—William D. Lanyi

(57) **ABSTRACT**

A control system for a marine vessel incorporates a marine propulsion system that can be attached to a marine vessel and connected in signal communication with a serial communication bus and a controller. A plurality of input devices and output devices are also connected in signal communication with the communication bus and a bus access manager, such as a CAN Kingdom network, is connected in signal communication with the controller to regulate the incorporation of additional devices to the plurality of devices in signal communication with the bus whereby the controller is connected in signal communication with each of the plurality of devices on the communication bus. The input and output devices can each transmit messages to the serial communication bus for receipt by other devices.

51 Claims, 11 Drawing Sheets

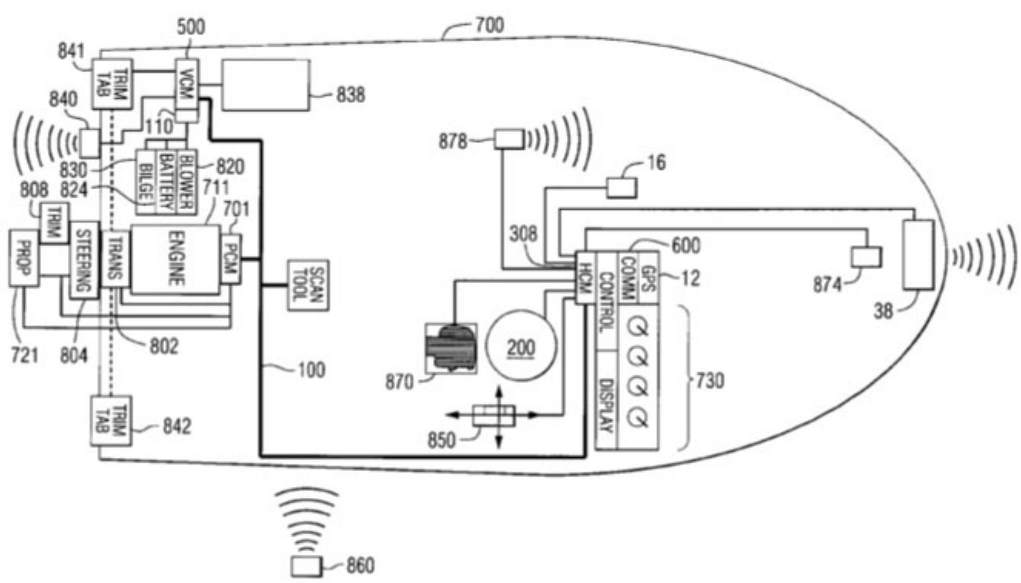

Figure 66: US Patent 6,273,771 Brunswick Control System

5B. Propeller Guard to Prevent Contact With the Propeller

About any type of propeller guard is useful out in the air, because moving water is not trying to pull you into the guard. A propeller guard could keep the propeller from contacting those onboard, and reduce the propensity of outboards to dance and skip around the boat after they break off.

Being struck by a guard on an outboard motor falling from the sky could severely injure you, but the option seems much more favorable that being struck by an open propeller running a few thousand RPM.

Note - Outboard motors breaking off and flipping into boats tend to be associated with speed. Some propeller guards have issues (boat handling, drag, fuel consumption, maximum speed) at speed.

5C. Safety Propellers

In recent years a few Safety Propellers have emerged that may provide some protection at low RPM out of the water. For example, RingProp, the Turning Point Aegis Safety Prop (see **Figure 67**), and the MagBlade.

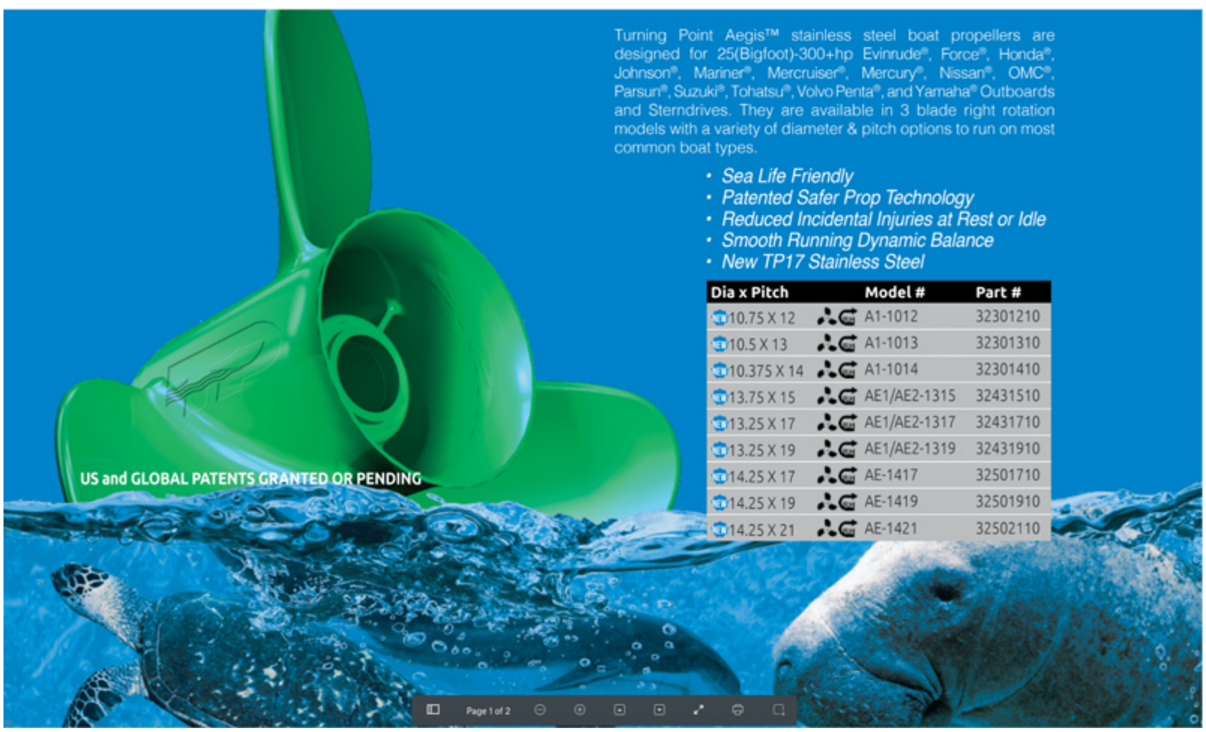

Figure 67: Turning Point Aegis Safety Prop flyer (2017)

5C. Restrain the Outboard From Entering Occupied Areas of the Boat

Several previously proposed solutions focused on preventing the outboard from entering the boat. While that is wonderful, it is possible to yield a little ground. What we really want to do is to prevent the outboard from entering occupied areas of the vessel.

Some boats, such as bass boats, have a large rear deck with no seating in that area. if the outboard landed on the deck and did not bounce on into occupied areas, that would be much more favorable than landing in the seating area.

See **Section 2 Restrain the Outboard if it Breaks Off** and the previously mentioned paper on using a tether to control the trajectory of an object.[22]

[22] Impulse Redirection of a Tethered Projectile. Faraji, Veile, Hemleben, Zaytsev, Wright, Luchsinger, and Hatton. Proceedings of ASME 2015 Dynamic Systems and Control Conference. DSCC2015-9708.

Proposed Solution:

6. Advanced Detection of Imminent Impact

6. Advance Detection of Imminent Impact

While trying to detect objects before the outboard motor strikes them may sound a bit like rocket science, there have been many developments in this field in recent decades.

Hydrofoils, often used as fast ferries, are at risk of striking submerged objects including floating logs and deadheads (vertically floating logs). Hydrofoils have been developing debris collision avoidance systems since the 1970s.

Irwin Kaplan was among early inventors deploying these techniques to recreational boating. His 1981 patent, **US Patent 4,290,043** transmitted a beam of light toward the waterline in front of the vessel. A receiver detected reflected light and sounded alarm when an object was detected. His approach could also detect objects floating at or just below the surface.

Kaplan's patent above was later cited by a U.S. Navy's patent, **US Patent 5,646,907** Method and System for Detecting Objects at or Below the Water's Surface. Navy's patent used a pulsed laser beam to detect objects at or near the surface, Navy's patent noted the importance of avoidance of objects at or just below the water's surface to pleasure boat operators.

Later, Kaplan filed another patent application, **US 2002-0126024** for an enhanced version of his previous device.

Brunswick and Volvo Penta have both been issued multiple patents for systems designed to detect swimmers in the water near the propeller. Some of these methods could lend themselves to detecting floating and submerged obstacles in the vessel's path.

Brunswick was recently issued patents in which systems to detect objects before being struck by outboard motors were discussed.

In **US Patent 9,927,520** Method and System for Close Proximity Collision Detection, Brunswick teaches using distance sensors to determine if an object is within a predefined distance from the vessel and if any portion of the vessel is moving toward the object. While the application may target joysticks being used in tight quarters, the concepts can be extended to hazardous objects in the water.

In **US Patent 9,290,252** Systems and Methods for Controlling Trim Position of Marine Propulsion Device on a Marine Vessel, Brunswick teaches use of magnetic fluid in a tilt cylinder for Active Tilt control to dynamically control rod end pressures during impact. Brunswick teaches a version of this patent in which they use lasers or other sensors to detect imminent impact. When an imminent impact is detected Brunswick presets the system for impact. See **Figure 68**.

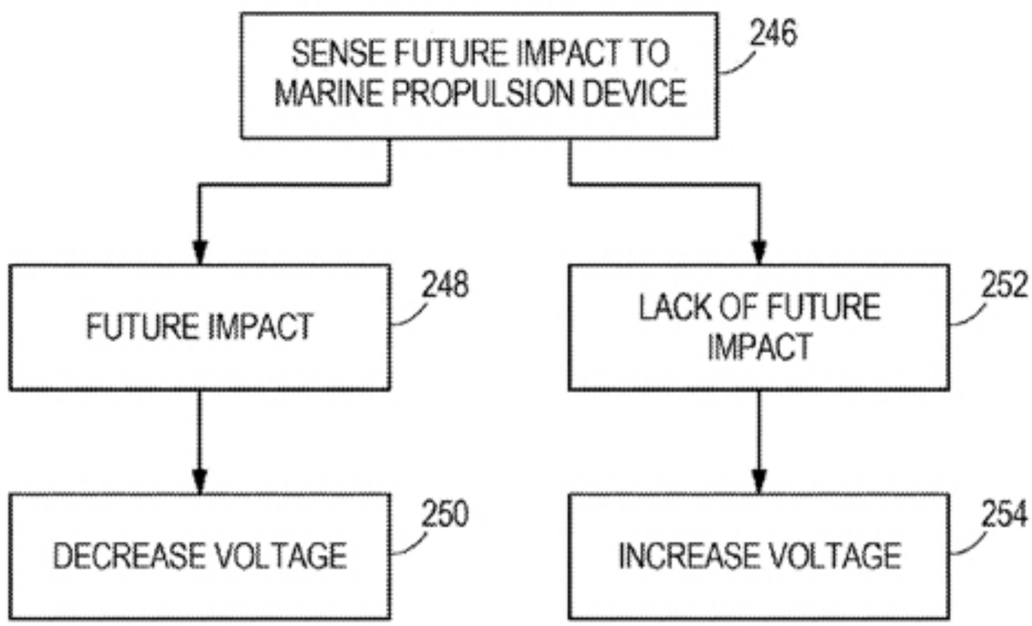

FIG. 11

Figure 68: Figure 11 in US Patent 9,994,375 assigned to Brunswick

In **US Patent 9,944,375** Systems and Methods for Controlling Trim Position of Marine Propulsion Device on a Marine Vessel, Brunswick teaches use of conventional hydraulic fluid to achieve active control of a tilt cylinder. A parallel external cylinder rod/strap can be braked / arrested during collision with a submerged object. Just like the magnetic fluid system above, the traditional hydraulic fluid system can be used with hazard detection sensors and preset the system for impact. See **Figure 69**.

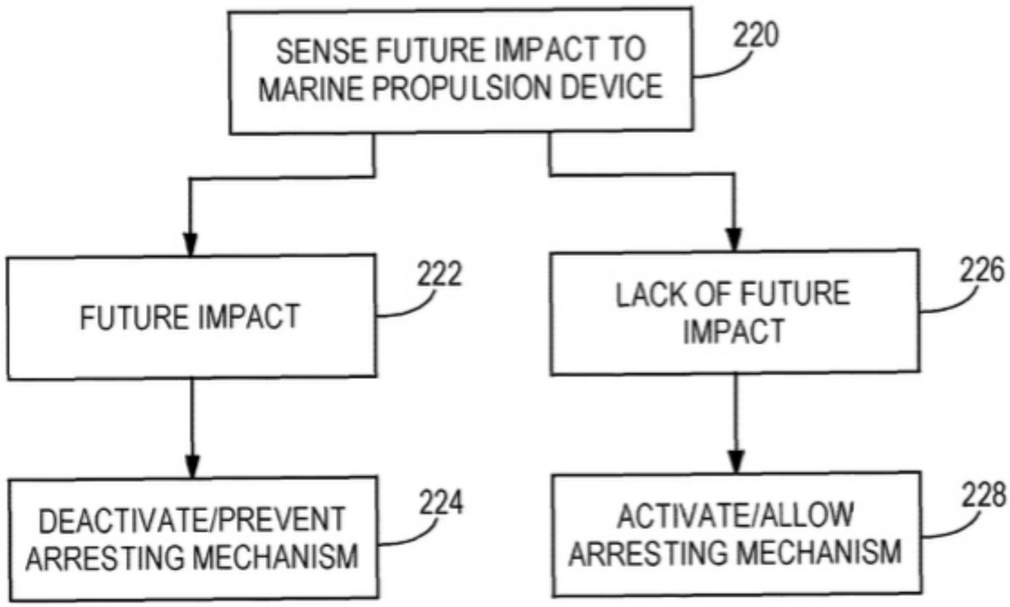

FIG. 12

Figure 69: Figure 12 of US Patent 9,944,375 assigned to Brunswick

In 2017, FLIR Systems, whose Raymarine brand is well known in the recreational boating industry, filed **US Patent Application, US 2017/0158297** Watercraft Protection Systems and Methods. FLIR's patent application teaches using sensors on vessels powered by outboard motors, inboards, or stern drives to detect depth and objects in the water. These inputs plus boat speed data can be used to anticipate impacts with floating objects, submerged objects, or groundings. The system then adjusts the depth of the marine drive to prevent impacts and displays information about the event.

A 2009 US Patent from France also lays some groundwork in this field, **US Patent 7,483,336** Device For Avoiding Obstacles for High-Speed Multi-Hulled Watercraft assigned to Thales.

Proposed Solution:

7. Standards

7. Standards

American Boat and Yacht Council (ABYC) sets voluntary standards for the boating industry. Currently no ABYC standards exist for:

7A. Testing outboard motor log strike systems
7B. Verifying outboard motors fail in a safe manner when they break from the boat after striking a submerged object
7C. Jack plates
7D. Breakaway mounts
7E. Tethers
7F. Dredge Pipe Marking Regulations

NOTE - ABYC recently announced a new component certification program that might be used to accomplish some of the tasks mentioned above.

We suggest standards could help drive compliance resulting in safer boats and informed customers.

In addition, regulations for marking dredge pipes need updated in light of today's dredging techniques, recreational vessels, technologies, and boaters.

7A. Testing Outboard Motor Log Strike Systems

Most major outboard manufacturers have their own log strike testing procedure. Some have on water log strike testing, some test on dry land, some do both.

Standards would allow comparison of performance between outboard lines within one manufacturer and across lines between manufacturers as to their basic performance at log strike test speeds.

Increasing transparency of these test procedures would increase their quality.

7B. Verifying Outboard Motors Fail in a Safe Manner

Standards could provide a consistent method to test outboards to verify they fail in a safe manner when striking submerged objects at speed.

Basically outboards need to:

1. Break apart in a manner in which the entire outboard cannot enter the boat, or
2. Be installed in a configuration that prevents them from entering the boat (like in a well), or
3. Be tethered to prevent entry to the boat or to occupied areas of the boat, or
4. Be designed in a manner to prevent them from entering the boat, or
5. Not be able to achieve enough speed to break free from the boat, or
6. Be installed on a boat with a mechanical barrier preventing the outboard from entering occupied areas, or
7. Be able to absorb the load without failing.

7C. Jack Plates and Lift Plates

Some outboard motors flipping into the boat have been attributed to jack plates / lift plates not securely retaining the drive. Jack plates are an accessory. They attach to the transom (back) of the boat while the outboard motor attaches to a plate that slides up and down inside the rails of the jack plate structure bolted to the transom. This allows the propeller to be vertically raised or lowered in the water. Operators seeking higher speeds or running in shallow water want to raise the propeller as high as practically possible when underway. This reduces drag, increases boat speed, and reduces the likelihood of striking bottom. Jack plates also allow the propeller to run a little further back in less disturbed water which can increase efficiency and reduce fuel consumption.

Some jack plates / lift plates are manual (you set the height and tighten some bolts). Others are hydraulic powered. Their height to be adjusted while underway.

Some jackplates have been blamed for allowing the drive to slip up and out of their grip when underway, or for allowing them to slip up and out when striking submerged objects. Other jackplates have been blamed for shearing bolts in impacts with submerged objects and allowing the outboard motor to break free from the boat.

Larger outboards are often used on bass boats which often use jack plates and run at higher speeds than most boats. This contributes to bass boats striking submerged objects at higher speeds. As a result, jack plate and lift plate designers need to especially consider the forces involved in these collisions and make sure their plates will retain control of the outboard in all situations.

Chains and plastic covered cables have been proposed as a method of tying the slide to the base unit on the transom. See **Section 2F**. Some jack plates have stops at the top.

ABYC voluntary performance standards for jack plates specifying they must resist certain loads, retain the plate against certain loads, and prevent the plate from exiting out the top could prevent some of these accidents.

7D. Breakaway Mounts

Break away mounts are somewhat similar to jack plates and lift plates in construction and use. Designed for small outboards without hydraulic log strike systems, they mount between the transom and the outboard. Break away mounts allow small outboards to swing up and over stumps at very slow speeds, such as in duck hunting applications. CMC's BA-130 Break Away Mount (**Figure 70**) is one of these devices. Some break away mount users are concerned the outboard may swing up so fast it breaks away and lands in the boat. Online forums have discussed the use of DIY (Do It Yourself) chains to retain the outboard. Chains were seen in use on a CMC Break Away Mount at the SeeLite booth at the 2013 Arkansas Outdoor Expo in July 2013, see **Figure 71**.

Figure 70: CMC BA-130 Break Away Mount

Figure 71 CMC w/chain

Breakaway mounts could similarly benefit from ABYC voluntary standards providing certain loads they must pass and requiring chains where appropriate.

7E. Tether Standards

No standards currently exist for outboard motor tethers, such as The Leash or Mercury Marine's tether. Performance standards or standard tests could help establish this product line, build confidence in the products, and save lives.

7F. Dredge Pipe Marking Regulations

The existing dredge pipe marking and lighting regulations such as:

1. CFR Title 33 Section 88.15 Lights on Dredge Pipelines
2. Reclamation Safety and Health Standards (RSHS) Section 28 Watercraft and Dredging
3. CFR Part 64, Subpart B Sunken Vessels and Other Obstructions

need revisited in terms of proper marking of dredge pipe locations. We suggest investigating dredge pipe strikes such as those listed on our page of dredge pipe strikes to better understand the problem.

Of particular concern are requirements for daylight marking of dredge pipes when they are floated during installation, for moving, or during removal. Among concerns are how far apart the markers should be, how visible the markers should be, how close the markers should be to the actual location of the pipe (buoys on chains drift in the wind from over the pipe), and the way pipes are snaked (thousands of feet of pipe folded into "S" shapes) making it practically impossible to determine the "run" of the pipe (what path the pipe really takes). See **Section 4B Marking of Dredge Pipes**.

Plus anything that could be done to increase visibility of the pipe itself (color, sound, vertical spurts of water, rotation, float it higher, etc).

Basically they need to take modern boaters in modern boats out on the water and observe how well they can see and understand dredge pipe markers / warnings, and how well they understand / comprehend what the safe path through the area is. New regulations and guidelines need to make dredging safer for today's boats and boaters.

Proposed Solution:

8. Jack Plate Consensus Development

8. Jack Plate Consensus Development

Beyond standards, Outboard manufacturers have several options at their disposal to control or at least influence which jack plates are used with their drives:

1. Boat builders could be required to use jack plates meeting certain requirements or standards before outboard installations would be approved.

2. In the field, use of a non approved jack plate could void outboard warranties.

3. Outboard manufacturers could encourage ABYC to develop jack plate standards including log strike requirements for jack plates.

4. Outboard manufacturers could educate builders, dealers, and the public on the role of jack plates in log strike safety and how to select a safe one.

5. Outboard manufacturers could work with jack plate manufacturers in assisting them to develop safer jack plates and assist them in testing them.

No evidence of this happening has been observed in the industry media or literature.

Proposed Solution:

9. Increase Awareness of the Hazard

9. Increase Awareness of the Hazard

At least one boating industry expert reports being aware of the hazard of outboard motors flipping into boats since the 1950s. However, in recent years two major outboard manufactures denied awareness of the problem prior to the accident in litigation at that time.

The industry expert has a long history of knowledge of the problem. He thinks those working in the propulsion side of the boating industry are generally aware of the problem, but boaters are not.

Increasing awareness of the problem could:

1. Stimulate new solutions
2. Encourage safer behavior
3. Reduce injuries and fatalities

9A. Public Service Announcements

Public Service Announcements, PSAs, are the classic approach to raising awareness. The U.S. Coast Guard annually issues grants to non-profits to promote various boating safety topics in the media (wear a life jacket, attach your kill switch lanyard, etc.) A small fraction of those funds could go toward developing some materials, PSAs, and a web page devoted to this topic. A slogan and a spokesperson, such as Rex Chambers who recently spoke out in a Leash video would be one approach.

The book, Nudge, by Richard H. Thaler and Cass R. Sunstein provides many examples and ideas for those trying to “nudge” behavior.

9B. Bass Tournaments Increase Awareness

Bass tournaments have done wonders for increasing life jacket wear and kill switch use among bass tournament anglers.

Tournaments could feature a speaker on occasion on this topic to raise awareness of the problem and some of the proposed solutions, including The Leash.

Bass tournament organizations could visit with locals about hidden/submerged dangers in the tournament area and make sure all anglers are aware of them. Water level changes can expose new hazards. For example, a bridge may create a submerged hazard like what happened during a tournament on Kentucky Lake[23].

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[23] Clippard fatality. 9 May 2013. U.S. Anglers Choice Region #3 Team Championship.

Proposed Solution:

10. Utilize the Fracture Mechanics of Wood

10. Utilize the Fracture Mechanics of Wood

Today's log strike systems are designed around the premise of allowing the drive to flip up and over the log, then settle back down to its original depth.

Wood exhibits elasticity and plasticity when being crushed at speed. At some speed, the wood begins to break/split in font of the leading edge of the drive and the force actually goes down.

In some circumstances, impact forces can be greater when allowing the drive to swing up, than if the drive were locked down (when the boat had enough speed, mass, and the drive was rigid enough to cut through the log after the log began to fail plastically).

Wood (floating logs, stumps, driftwood, sunken trees, wooden structures, etc.) is among the most common materials stuck by outboard motors. We encourage further study of how wood fractures in this situation. Then applying that knowledge to build better log strike systems.

We suggest some search terms and references below. Wood and impact journals cited below contain many other references that may also be of interest.

Search Terms:

1. Linear-Elastic Fracture Mechanics (LEFM) of wood
2. Elasto-Plastic Fracture Mechanics (EPFM) of wood using the J-Integral Method
3. Added Mass (to accelerate a submerged object you must also accelerate some water out of the way)
4. Anistropic (many properties of wood are direction dependent)

References:

1. Drift-wood Collision Load on Bow Structure of High-speed Vessels. Yasumi Toyama. Marine Structures. Vol.22. Pgs.24-41. (2009).
2. Effect of Impact Velocity on the Fracture of Wood as Related to the Pulping Process. J.E. Berg. Wood Science and Technology. Vol.35. Pgs.343-351. (2001).
3. Impact of Water Storage on Mechanical Properties of Spruce as Detected by Ultrasonics. F. Efransjah, G. Kilbertus, and V. Bucur. Wood Science Technology. Vol.23. Pgs.35-42. (1989).
4. Historical and Present-Day References Concerning Impact on Wood. W. Johnson. International Journal of Impact Engineering. Vol.4. No.3. Pgs.161-174. (1986).

Proposed Solution:

11. Record Impact Data

11. Record Impact Data

One way to improve the performance of log strike systems is to record data in normal impacts just like lots of other data is recorded by the Engine Control Unit (ECU) and use this data to improve log strike system designs.

Impact data such as date, time, and even location if GPS data is available, engine RPM, boat speed if it is directly available, tilt angle vs. time, tilt angle acceleration vs. time, tilt angle acceleration vs tilt angle, and maximum tilt angle could be recorded.

The basic data plus the number of impacts recorded could be fed back to designers to develop a better understanding of the problem.

Yamaha patented such a device back in 2015, **JP5810881B2** Device, Method and Program for Controlling Collision of Outboard Motor. See **Figure 72**.

JP2013123954 (A) → JP5810881 (B2)

Bibliographic data: JP5810881 (B2) — 2015-11-11

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DEVICE, METHOD AND PROGRAM FOR CONTROLLING COLLISION OF OUTBOARD MOTOR

Page bookmark	JP5810881 (B2) - DEVICE, METHOD AND PROGRAM FOR CONTROLLING COLLISION OF OUTBOARD MOTOR
Inventor(s):	SHOMURA NOBUYUKI, ; KATAOKA TATSUNORI, ; 庄村 伸行, ; 片岡 辰徳
Applicant(s):	SUZUKI MOTOR CORP, ; スズキ株式会社
Classification:	**- international:** ***B63B43/18; B63H20/00; B63H20/10; B63H21/21***
	- cooperative: **B63H20/10**
Application number:	JP20110272552 20111213 Global Dossier
Priority number(s):	JP20110272552 20111213
Also published as:	→ JP2013123954 (A)

Abstract of JP2013123954 (A)

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PROBLEM TO BE SOLVED: To enhance the accuracy of determining collision of an outboard motor, and to maintain the history of the collision.SOLUTION: An outboard motor 3 can be operated to vertically tilt around a tilt shaft 34. The outboard motor 3 is protected by permitting the upward tilt of the outboard motor 3 when the outboard motor 3 is collided with an obstacle such as driftwood during cruising. A calculation part calculates the rate of change in the tilt of the outboard motor 3 which is expressed by the rate of change in the output signal of a tilt angle detector 48. When the state exceeding the set value is continued for the predetermined time or longer, the calculation part calculates the change in the tilt of the outboard motor 3 to be expressed by the variation in the output signal of the tilt angle detector 48. When the set value is exceeded, it is determined that the outboard motor 3 is collided with an obstacle. When a collision is determined, the collision history including the information at the collision including the rate of change in the tilt of the outboard motor 3, and the variation in the tilt of the outboard motor 3 is recorded in a memory.

Figure 72: Japan Patent JP5810881B2 Collision Recorder for Outboard Motors assigned to Yamaha image via ESPACEnet

Note - this same patent was also published as **JP2013123954A**.

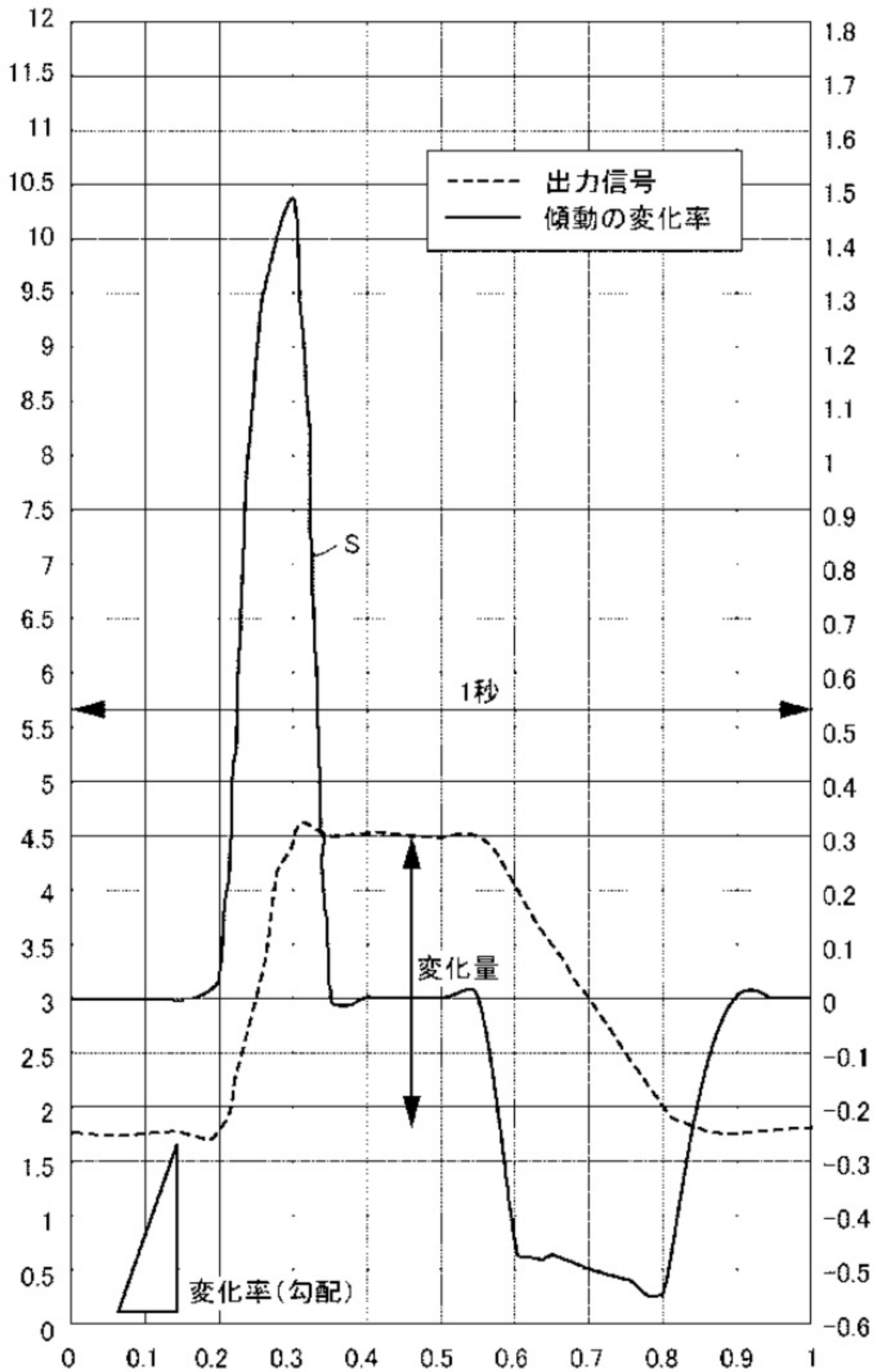

Figure73: Tilt (dotted line, reads to left) vs change rate of tilt (solid line, reads to right) recorded during a collision. Patent JP201312954A. Time scale range is 0 to 1 second.

Figure 73 taken from Yamaha's patent plots tilt vs. rate of change of tilt during an impact as it would be recorded using methods taught in their patent.

A collection of data of normal impacts, impacts severe enough to separate the outboard from the boat, and impacts in which an outboard motor enters the boat would lead to a better understanding of impacts, and of the forces generated. That knowledge would lead to a better understanding of how to absorb and / or dissipate the energy of these impacts.

Closing Thoughts & Comments

Closing Thoughts

Large outboard motors are flipping into boats and injuring or killing those on board. They come into the boat with their engine running and the propeller rotating at thousands of RPM. Over half a century ago, Krueger[24] and Nolt[25] both showed how the engine could be killed during impacts events. Nowadays, many alternatives exist to detect when the outboard leaves the water, leaves the transom, and kill the engine.

By the 1960s major manufacturers had learned the importance of allowing the outboard to clear the submerged object before applying heavy resistance to its upward rotation.

These findings (ability to kill the outboard when it leaves the water, and allowing the outboard to clear the object before applying heavy resistance) both seem to have been lost through the passage of time.

Over that time, recreational boating has matured to a broad range of boaters, activities, vessels, and waters. Outboard motors have grown drastically in size and weight, boat speeds have significantly increased, outboards are powering a larger percentage of all new boats vs a decade ago. Bass tournaments have been extremely successful in energizing tens of thousands to purchase high horsepower bass boats.

The combination of events described above plus the knowledge lost over time discussed above has created a problem. We suggest marine drive manufacturers, boat builders, and boat dealers consider the risk level of their products and use measures to reduce those risks as appropriate.

One place to begin, bass fishing boats powered by large outboards are disproportionately represented on our large outboards flipped in accidents list (Triton, Ranger, Phoenix, Bass Cat, Champion, and others).

We also direct your attention to our Preventing & Mitigating Injuries & Fatalities from Outboard Motors Flipping into Boats page which includes a large spreadsheet that identifies many other opportunities to prevent or mitigate these accidents.

We could not complete this work without including a copy of our Log Strike Mode by Speed and Resistance Chart. **Figure 74** shows the various modes in which bass boat outboards respond to a range of objects being struck at a range of velocities.

Thank you for your attention to this topic. Please pass this paper along to others who may find it useful.

---

[24] US Patent 2,917,019. Fred C. Krueger. Filed in1955.

[25] US Patent 3,036,543. Edwin B. Nolt of Sperry Rand. Filed in 1960.

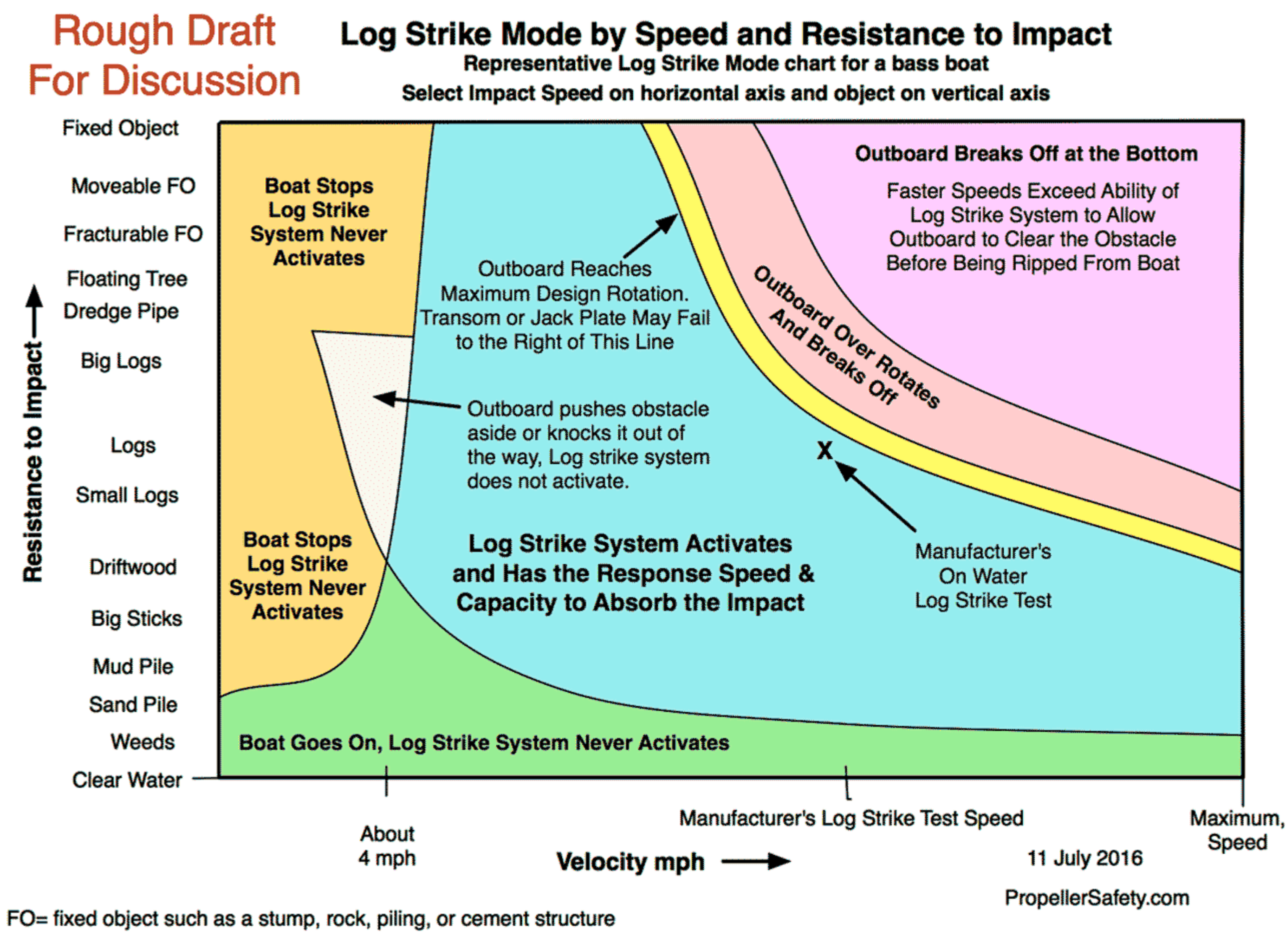

Figure 74: Log Strike Mode Chart

Comments

We welcome your comments, corrections, and suggestions regarding this report. Please visit PropellerSafety.com, click on the contact us tab on the top menu, and share your thoughts with us.

THE END