Pressure Hulls and Canisters 2
Cornerstone Electronics Technology and Robotics III
(Notes primarily from "Underwater Robotics – Science Design and Fabrication", an excellent book for the design, fabrication, and operation of Remotely Operated Vehicles ROVs)

- **Administration:**
  - Prayer
- **Calculating Pressure Related Forces on Spheres and Cylinders:**
  - One intrinsic property of pressure is that the net force it exerts on a surface at any point is always perpendicular to the surface at that point.

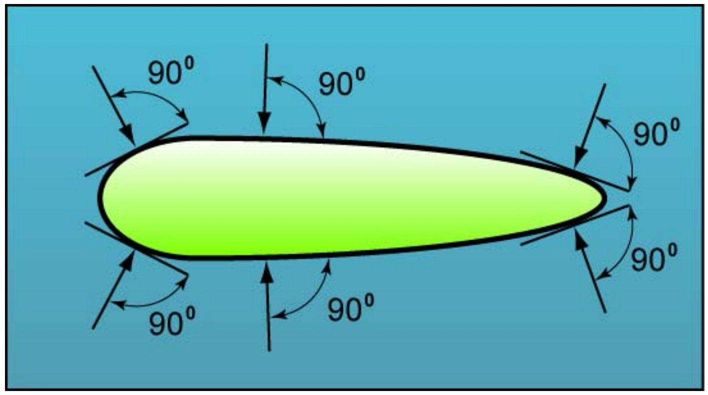

Figure 1: Hydrostatic Pressure Forces Are Perpendicular to the Surface

  - Pressure force acting on a sphere: If you sum all of the pressure forces pushing against a hemisphere, the net force is equal in magnitude and direction to the net force pressing on a circular area with the same diameter. See Figure 2.

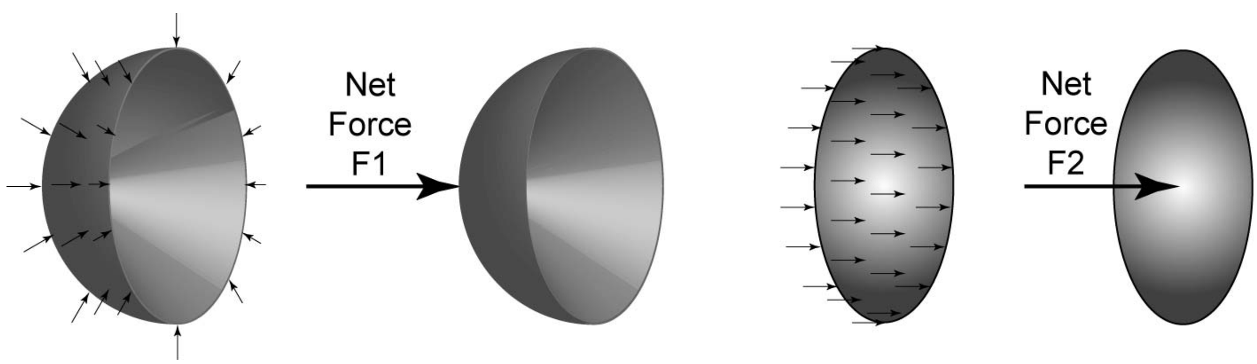

Figure 2: Net Force F1 Acting on a Hemisphere Equals the Net Force F2 Acting on a Circle (With the Same Diameter)

Example: Determine the force (in pounds) acting on a hemisphere end cap for a canister with a diameter of 6 inches at a freshwater depth of 15 feet.

First, calculate the hydrostatic pressure at 15 feet in freshwater.

Set up the proportion:

Ratio with Knowns = Ratio with Unknown Pressure x

$$\frac{14.7 \text{ psi}}{34 \text{ ft}} = \frac{x \text{ psi}}{15 \text{ ft}}$$

Solving for x,

$$x = \frac{14.7 \text{ psi x } 15 \text{ ft}}{34 \text{ ft}}$$

$$x = 6.5 \text{ psi}$$

Now find the area of a circle with the same diameter as the hemisphere:

$A = \Pi r^2$
$A = 3.14 \text{ x } (3 \text{ in})^2$
$A = 28.3 \text{ in}^2$

Finally, determine the total force pressing on the hemisphere:

Force = Pressure x Area
$F = 6.5 \text{ lb/in}^2 \text{ x } 28.3 \text{ in}^2$
F = 184 pounds

- Pressure force acting on a cylinder: Similarly, if you sum all of the pressure forces pushing against a half a cylinder, the net force is equal in magnitude and direction to the net force pressing on a rectangular area with the same length and width. See Figure 3.

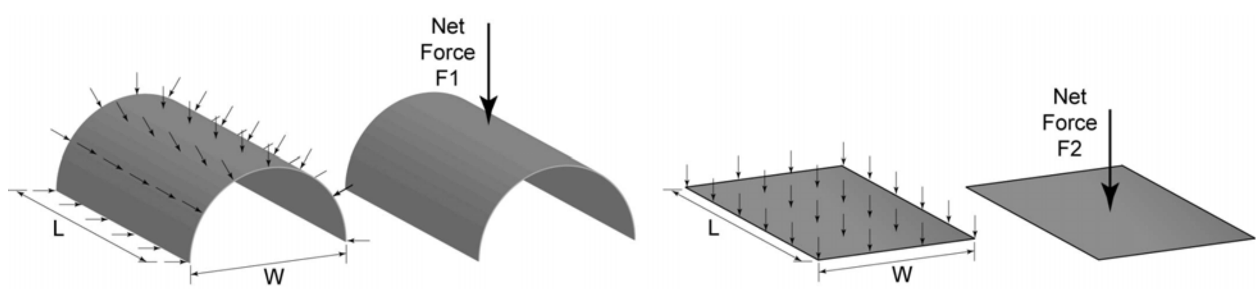

Figure 3: Net Force F1 Acting on a Half of a Cylinder Equals the Net Force F2 Acting on a Rectangle with the Same Length and Width

- **Constructing Leak-Proof Openings:**
  - Waterproofing a resealable canister with penetrations is one of the difficult challenges that can prove very frustrating. As stated in Lesson 1, "hydrostatic pressure also has an intrinsic ability to penetrate any gaps in waterproofing measures, leaving evidence of the leak."
  - O-rings – a circle of material with round cross section which create a seal through squeeze and pressure.
    - O-Ring seal – the combination of a gland and an O-ring providing a fluid-tight closure.
      - Moving (dynamic) – O-ring seal in which there is relative motion between some gland parts and the O-ring – oscillating, reciprocating, or rotary motion. Made of harder material. Typically there are better options than O-rings in dynamic settings.
      - Non-moving (static) – O-ring seal in which there is no relative motion between any part of the gland and the O-ring. Requires a softer material.
    - Gland – cavity into which O-ring is installed. Includes the groove and mating surface of second part which together confine the O-ring.

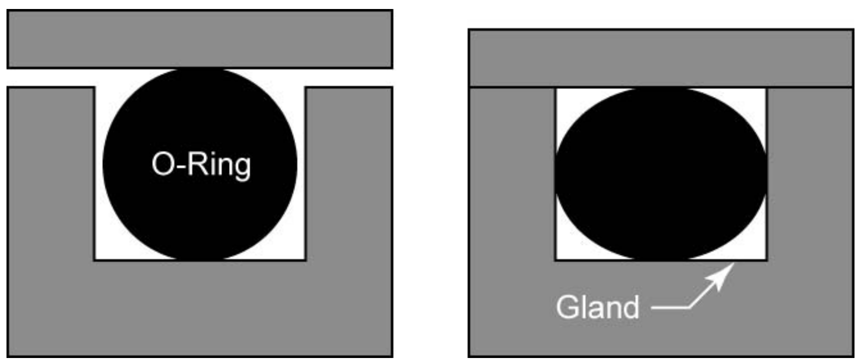

Figure 4: O-Ring and Gland in a Static Seal

    - O-rings account for over 90% of all watertight seals in underwater equipment.
    - A general guideline is that an O-ring should compress to about 90% of its initial diameter.
    - O-rings should be lubricated with a thin layer of silicone grease to facilitate slight movements.
    - Advantages:
      - Low cost
      - Replaceable
      - Requires a relatively simple machined groove for seal
      - As the pressure differential increases, the effectiveness of the O-ring seal increases.

- Musts that must be met for O-rings to function properly:
  - O-ring groove must be the correct dimension.
  - Sealing surfaces must be machined to within 1/1000th of an inch tolerance.
  - Surfaces must be smooth
  - Groove corners must be rounded

- U-cup seals:
  - U-cups derive their name from their shape and are self-sealing on both the inside diameter and outside diameter.
  - The lips of the U-cup should always be toward the pressure force.
  - Works well at shallow depths. However at greater depths, the seal presses against the shaft increasing the friction and slowing the motor rotation. At greater depths, the C-cup seal can fail by being pushed into the bilge pump housing.

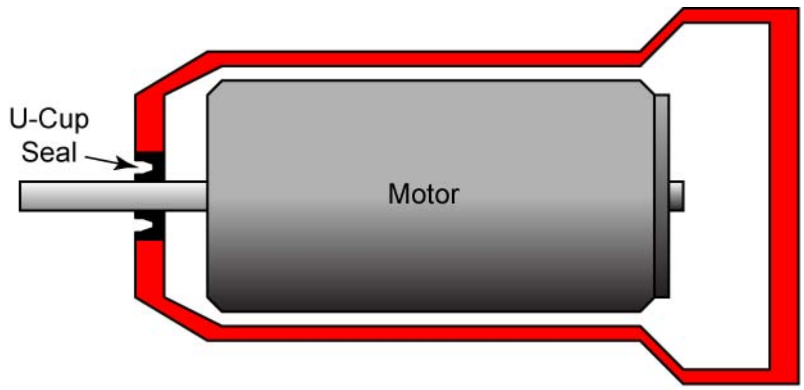

Figure 5a: U- Cup Seal **Figure 5b: U- Cup Seal in a Bilge Pump**

- **Pressure Hull Penetrators:**
  - A pressure hull penetrator is used to bring liquids, gasses, or circuits (electric or optic) from outside a vehicle pressure hull to the inside, while maintaining a leak proof path to the inside of the vehicle.

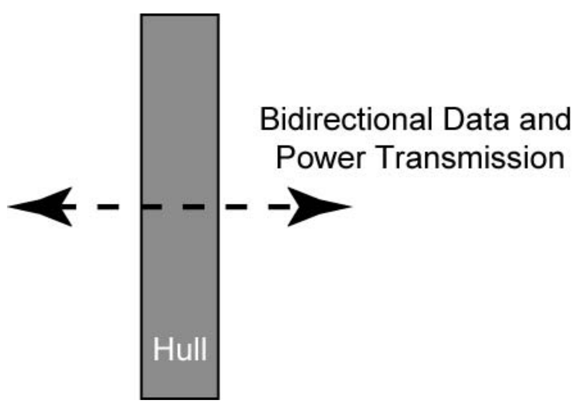

Figure 6: Penetrators Provide for Watertight Data and Power Transmission through a Hull

- Making a hole for the penetrator to enter the hull weakens the hull. The area around the penetrations may need reinforcement. In smaller pressure canisters, the end cap is usually thicker when penetrated.
- Canister end caps must provide easy access, yet maintain watertightness.
- Electrical connectors:
    - Electrical connectors must be selected for the correct number of conductors and those conductors must be sized correctly to manage the voltage and current load.
    - To extend the life and increase the reliability of connectors, apply silicone grease to the entire surface of each male pin. Grease should also be applied at the entrance of each socket.
    - Most subsea connectors are not “wet mateable”, that is, all connections and disconnections must be made in dry conditions.
    - A ROV designer should become familiar with the wide variety of connectors available by browsing websites of several manufacturers. Several websites are listed below:
        - http://subconn.com/
        - http://www.impulse-ent.com/
        - http://www.underwatersystems.com/welcome.html
        - http://seaconworldwide.com/
        - http://www.ak-ind.com/index.html
        - http://www.birns.com/index.php?section=product&category_id=11
        - http://www.gisma-connectors.de/
- Pressure Can Access:
    - Pressure canisters are normally smaller in size than a pressure hull and they usually house electrical and electronic components.
    - The canister wall thickness is determined by what depth the canister will be submerged.
    - Three common sealing methods for pressure canisters:
        - Piston seal: A portion of the end cap is inserted into the pressure canister, as a piston is inserted into a cylinder. The O-rings are compressed between the “piston” and the inner surface of the canister, forming the waterproof seal. Under pressure, the canister is wall is compressed against the O-rings.

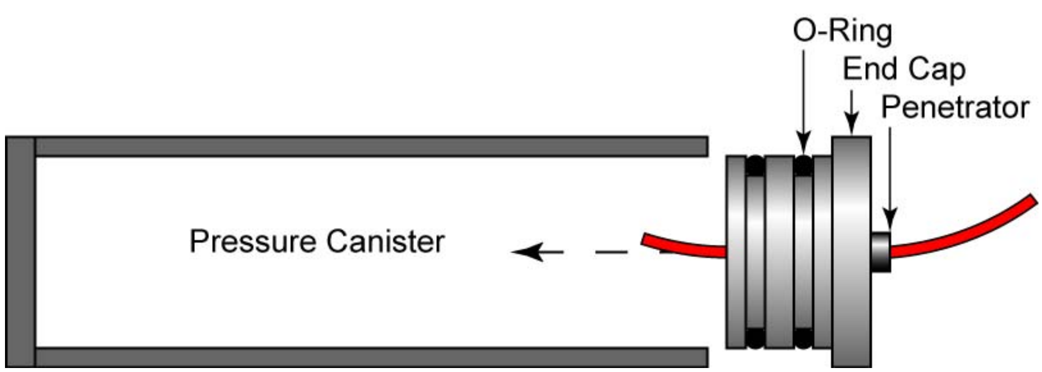

Figure 7: Piston Seal End Cap Inserted into the Pressure Canister

- Flange or face seal: A flange is glued or welded to the canister cylinder and the end cap is bolted to the flange. The O-ring or rubber gasket is pressed against the flange which forms the watertight seal.

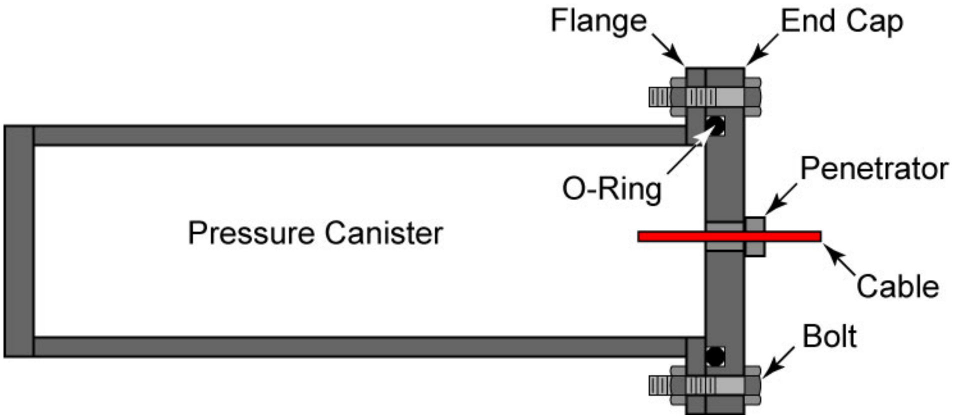

Figure 8: End Cap Bolted to Pressure Canister Flange

- Jam jar seal: The term "jam jar" relates to the type of mason canning jar that uses a gasket and screw down lid to form a seal. See Figure 9 and 10.

Figure 9: Common Mason Glass Jar Used in Home-Canning
(From: http://www.sallypasleyvargas.com/2010/08/peach-orange-preserves-theyre-jam-good.html)

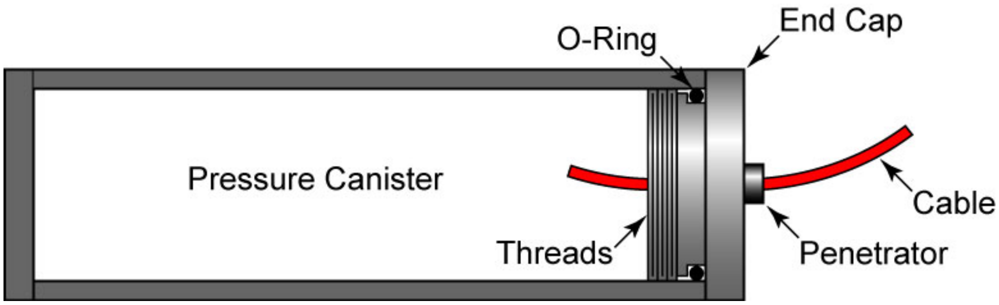

Figure 10: Canister with a Threaded "Jam Jar" Seal

- Safely relieving pressure build-up inside a pressure canister:
  - The air inside a pressure canister can be compressed into a smaller volume when water leaks into the canister under pressure. This air pressure must be relieved before removing the end cap or the cap can burst off when loosened.

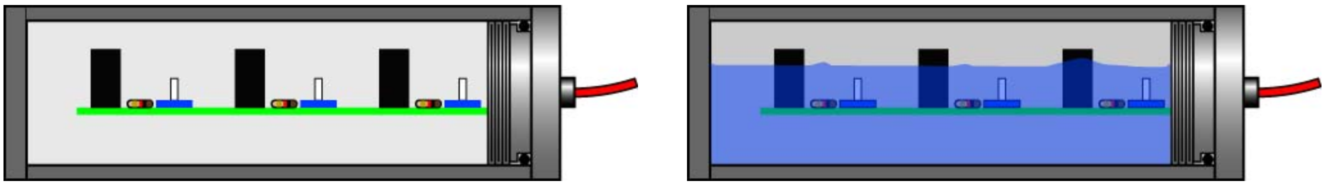

Figure 11: Air in Pressure Canister Compressed by Water Leak

  - Pressure can also be increased when the air inside a canister is heated (and expanded) by the electronic components inside the canister.

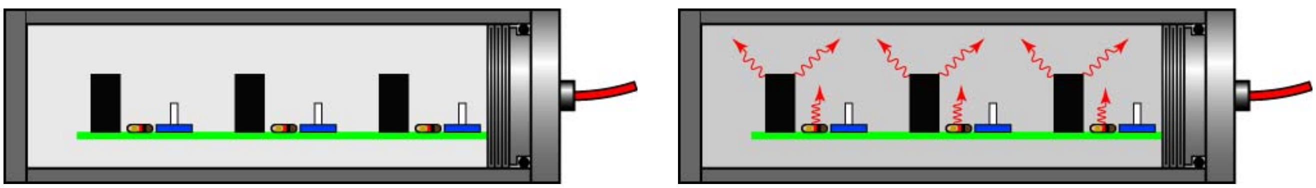

Figure 12: Air Pressure Increased from Electronic Component Heating

  - If batteries are enclosed in a canister, they may emit hydrogen gas which can pressurize a canister.

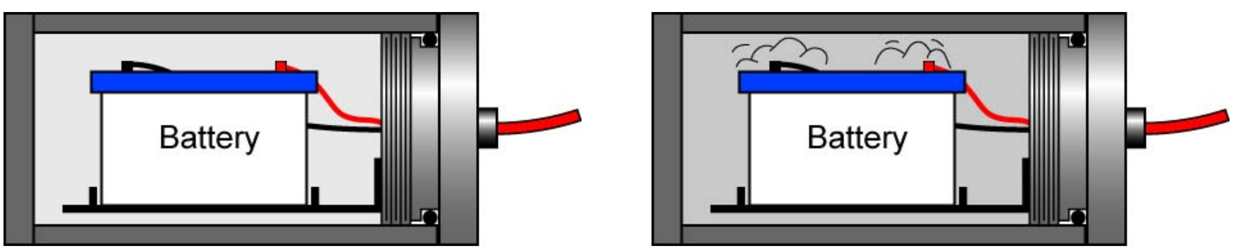

Figure 13: Increase in Pressure from Battery Hydrogen Gas Leak

  - The potentially dangerous pressurized air can be relieved by a seal screw or pressure relief valve mounted in the end cap or the canister housing. See the textbook page 238 for details.

        - Removing condensation inside a canister:
            - When submerging an air-filled canister into cold water, condensation can form on the inner walls of the canister.
            - Three methods to prevent condensation build-up in a canister:
                - Minimize the amount of air space inside the canister.
                - Insert a desiccant product to absorb the moisture. Desiccant is a substance, such as calcium oxide or silica gel that has a high affinity for water and is used as a drying agent. Several desiccant products may be found at: http://www.uline.com/Grp_21/Desiccants?pricode=WE449&gclid=CP6Pv__TnKsCFcteTAodfXo8kw

Figure 14: Common Silica Gel Desiccant Bag

                - Replace the air and the water vapor with a dry, inert gas, like nitrogen.

- **Pressure-Compensation Techniques:**
    - If the chamber inside the pressure canister does not have to be air at 1 atm, non-conductive liquid or gas can be introduced into the chamber to compensate for the outside pressure.
    - Oil compensation:
        - Some electronics, motors, and batteries are able to work in a pressurized oil-filled canister. The incompressible oil resists the outside pressure on the canister housing.
        - Conveys the outside pressure to the each component that must be able to withstand the pressure applied.
        - A bladder-compensation chamber must be attached to the canister to equalize the inside and outside pressures.
        - With pressures equalized inside and outside the canister, pressure-resistant shapes such as cylinders do not have to be used.
    - Gas compensation:
        - Canister is filled with compressed gas, such as dry nitrogen or air, to compensate for the ambient water pressure.
        - Sensors and valves control the internal pressure equal to or slightly above the external pressure.
        - Air-compensated systems should be designed, built, and operated under watchful direction of a qualified adult trained in compressed gas physics and scuba equipment.

- **Encapsulation or Potting:**
    - Encapsulation eliminates the need for housing by encapsulating the component in a solid or rubbery substance.
    - Encapsulation traps the heat generated by the embedded component.
    - If epoxy is used to encapsulate, the component is permanently embedded – it cannot be repaired or changed.