Advanced Propulsion System
GEM 423E

Week15 :Waterjet Propulsion

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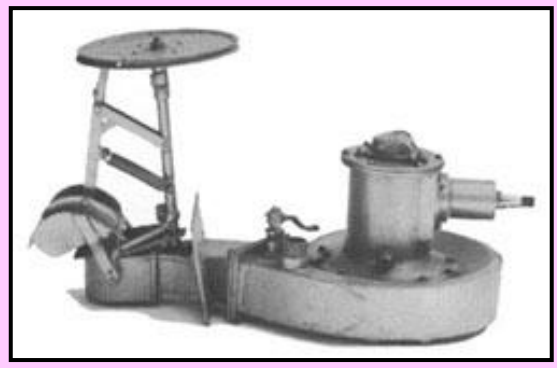
Waterjet History

Waterjet History

- In the early 1950s, when Sir William Hamilton began experimenting with marine jets, he followed the lead of the most successful invention to date, the American Hanley Hydrojet.
- Using a round centrifugal waterpump that drew in the water and expelled it through a steerable nozzle under the boat, he was able to achieve an encouraging but unspectacular speed of 11 mile per hour.

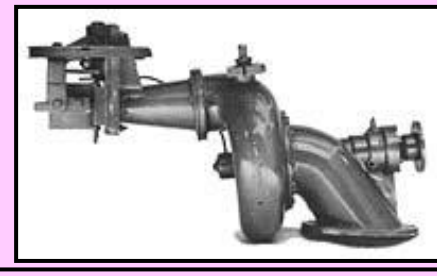
- **1954**
- A slight modification to expel the jet stream above the waterline proved the turning point in marine jet propulsion, increasing speed to 17mph and eliminating all underwater appendages.
- Waterjet propulsion was at last truly successful and the Hamilton Waterjet was born.

- This first type of unit was named "Quinnat" and consisted of a vertical shaft centrifugal unit, driven through a right angle gearbox.



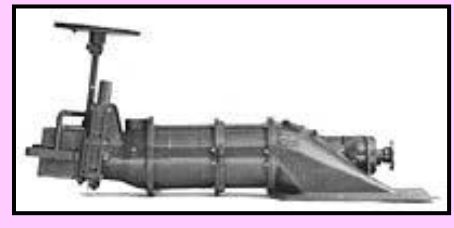
• 1956

- The first batch of "Rainbow" jet units were produced.
- A small direct drive centrifugal type of unit, the Rainbow gave a good performance in a suitable light craft, without the noise of a gearbox.
- About 125 were manufactured and marketed in New Zealand.



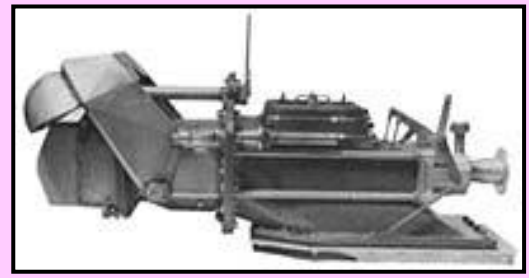
• 1957

- This year saw the birth of the "Chinook" unit.
- A twin impeller axial-flow turbine, the Chinook was far more efficient with its straight-through flow and two-stage pressure build up.
- Following this came the three-stage Chinook unit which increased performance further.

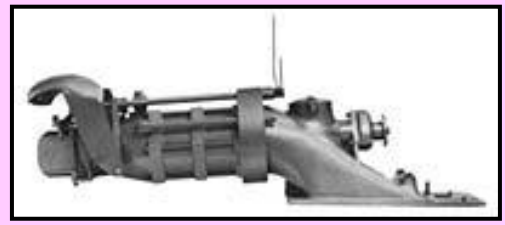


- **1963**
- The "Colorado" series of jet units was a completely new, greatly simplified design which halved the cost of the unit.
- This series was developed into a full range of one, two and three stage units driving a wide range of boats from river-runabouts to off-shore racing craft.

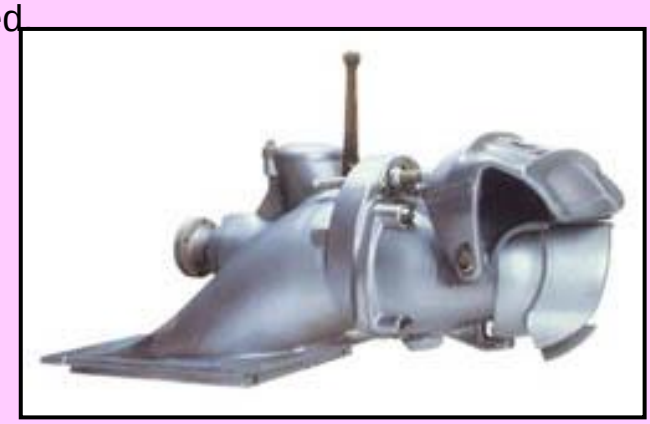
- **1970**
- This year saw the introduction of the "Work Jets" - larger, heavy duty units designed for diesel commercial vessels, large launches etc.
- The Work Jets were the forerunners to today's Hamilton HM Series of larger waterjets.



- **1973**
- The 750 series of jet units evolved a standardised method of installation in hulls, regardless of the number of stages.
- This gave more cockpit space in the boat and employed modern controls and engines.

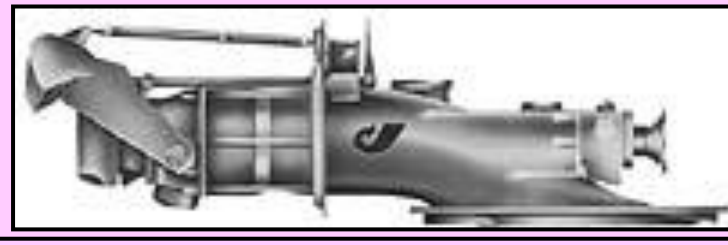


- **1975**
- First 'commercial' waterjet, Model 1031, introduced



- **1980**
- 400 Series waterjets are introduced.
- These are for craft up to 30 metres long.
- **1984 - 1990**
- Split duct deflector developed for 1031 jets and then introduced on all Hamilton Waterjets.
- The split duct design increases astern thrust by directing the jet stream down and to the sides of the boat transom to avoid recycling and increase steering responsiveness.
- HM Series waterjets, for craft up to 60 meters, is introduced.

- **1991**
- HS Series waterjets, for 50-65 knot craft, is introduced.
- These were multi-stage waterjet units designed for high-speed light commercial craft with power inputs up to 1600kW.



- **1992**
  Total Quality Management programme, FOCUS, implemented to ensure the highest level of quality in all aspects of waterjet production.
- **1993-98**
- **New jet models introduced to fill holes in Hamilton's waterjet range - HJ241, HJ321, HM461.**
  Existing models further developed with more efficient intake and screen designs, 0 and 5 degree intake block options, and improved anti-fouling/anti-corrosion protection.
- **Largest Hamilton Jet model waterjets developed HM651, HM721, HM811.**

- **1994**
  Turbo impeller developed along with HJ212 model to replace the multi-stage 773 unit in trailerable boats. The Turbo impeller improves jet performance in aerated water conditions.
- **1996**
  Control Monitoring Unit (CMU) developed as a fully electronic jet and engine control system for larger waterjets.
- **1998**
  Patented JT Steering system introduced. Nozzle design minimises thrust loss when steering to improve steering control and course-keeping efficiency.

- **2000**
- **MECS (Modular Electronic Control System) supersedes CMU for electronic control.**

What is Waterjet Propulsion System

What is Waterjet Propulsion System

- Once waterjets were used exclusively for small, high-speed boats.
- They, in fact, are more efficient than conventional propellers when speeds are over 25 knots.
- Waterjets now are being built for work boats that need to go slow.
- Like the conventional fixed-pitch propeller, they lack very-low-speed thrust modulation.

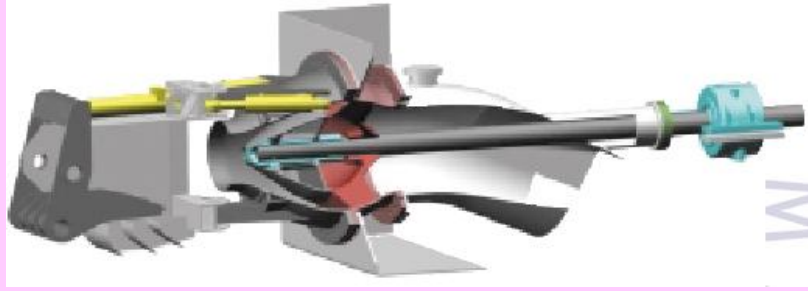
- Unlike the propeller though, they can moderate their thrust by partially engaging reversing buckets so that they do have the ability to go very slow.
- Depending upon the configuration, the waterjet drive usually includes a clutch but often does not require a reduction gear.
- Occasionally a reversing reduction gear is installed to allow back flushing of the waterjet.

How a Waterjet works

How a Waterjet works

- A water jet is used as a propulsion system for high-speed vessels and is modelled with STAR-CD. The main component of a water jet installation is a mixed-flow pump, which includes a stator bowl and a nozzle.
- The water is supplied through an inlet duct. An example of a water jet assembly is shown in figure 1. The flow through the inlet duct can be characterised by the Inlet Velocity Ratio (IVR), defined as ratio of the ship speed and the average axial velocity across the pump's inlet.

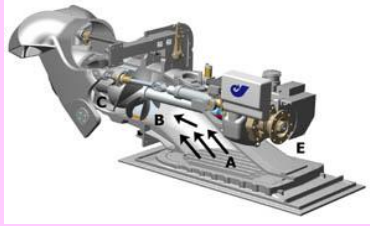
- It should be obvious that the latter is a function of the mass flow, and therefore related to the applied power of a water jet.



- A waterjet generates propulsive thrust from the reaction created when water is forced in a rearward direction.
- It works in relation to Newton's Third Law of Motion - "every action has an equal and opposite reaction".
- A good example of this is the recoil felt on the shoulder when firing a rifle, or the thrust felt when holding a powerful fire hose.

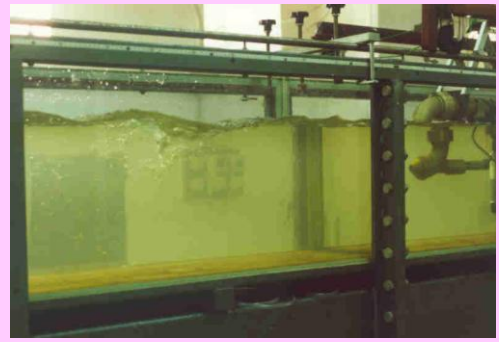
- Put simply, the discharge of a high velocity jet stream generates a reaction force in the opposite direction, which is transferred through the body of the jet unit to the craft's hull, propelling it forward (see diagram below).
- In a boat hull the jet unit is mounted inboard in the aft section. Water enters the jet unit intake on the bottom of the boat, at boat speed, and is accelerated through the jet unit and discharged through the transom at a high velocity.

- The picture opposite shows where water enters the jet unit via the Intake (A). The pumping unit, which includes the Impeller (B) and Stator (C), increases the pressure, or "head", of the flow. This high pressure flow is discharged at the nozzle (D) as a high velocity jet stream. The driveshaft attaches at the coupling (E) to turn the impeller.



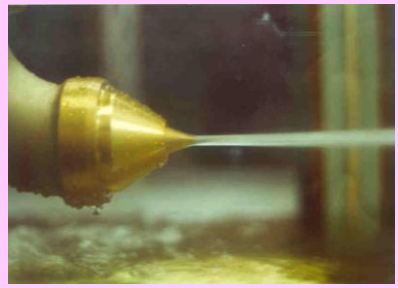
- Steering is achieved by changing the direction of the stream of water as it leaves the jet unit. Pointing the jet stream one way forces the stern of the boat in the opposite direction which puts the vessel into a turn.
- Reverse is achieved by lowering an astern deflector into the jetstream after it leaves the nozzle. This reverses the direction of the force generated by the jet stream, forward and down, to keep the boat stationary or propel it in the astern direction.

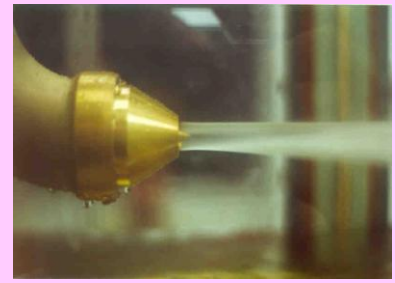
- The first prototype (here under trial in the water channel) has a 2-nozzle configuration, where the final version will use 7 nozzles to allow the control of all the 6-DOF of an underwater vehicle.



- To produce and control the required thrust, the system uses specially-designed variable-area nozzles.
- The area of the nozzle is controlled by a spear valve

- To allow very high-speed control of the jet intensity, the spear valve is actuated by a directly-coupled linear electric motor.





Advantages of Waterjet

- Waterjet propulsion has many advantages over other forms of marine propulsion, such as stern drives, outboard motors, shafted propellers and surface drives. These advantages include...

- **Excellent Manoeuvrability**
- **High efficiency**
- **Low drag and shallow draft**
- **Low maintenance**
- **Smooth and quiet**
- **Total safety**
- **Maximum engine life**
- **Simplicity**
- **Easy installation**

Excellent Manoeuvrability

- Precise steering control at all speeds
- "Zero Speed" steering effect provides 360° thrusting ability for docking and holding stationary.
- Sideways movement possible with multiple jet installations.
- High efficiency astern thrust with "power-braking" ability at speed

High efficiency

- Propulsive coefficients as good or higher than the best propeller systems achievable at medium to high planing speeds

Low drag and shallow draft

- Absence of underwater appendages reduces hull resistance shallow draught - Jet intake is flush with hull bottom to afford minimum draught

Low maintenance

- No protruding propulsion gear eliminates impact damage or snags
- Minimum downtime and simple maintenance routines

Smooth and quiet

- No hull vibration, no torque effect and no high speed cavitation gives maximum comfort levels on board
- Low underwater acoustic signature

Total safety

- No exposed propeller for complete safety around people in the water

Maximum engine life

- Jet unit impeller is finely matched to engine power
- Power absorption is the same regardless of boat speed
- No possibility of engine overload under any conditions

Simplicity

- Single packaged module
- No heavy and expensive gearbox required for many installations. Simple driveline from engine to jet coupling

Easy installation

- Complete factory tested package, ready to bolt in
- No difficult engine alignment problems