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Application of Boiler Feed Pumps in Combined Cycle, Thermosolar, & Biomass

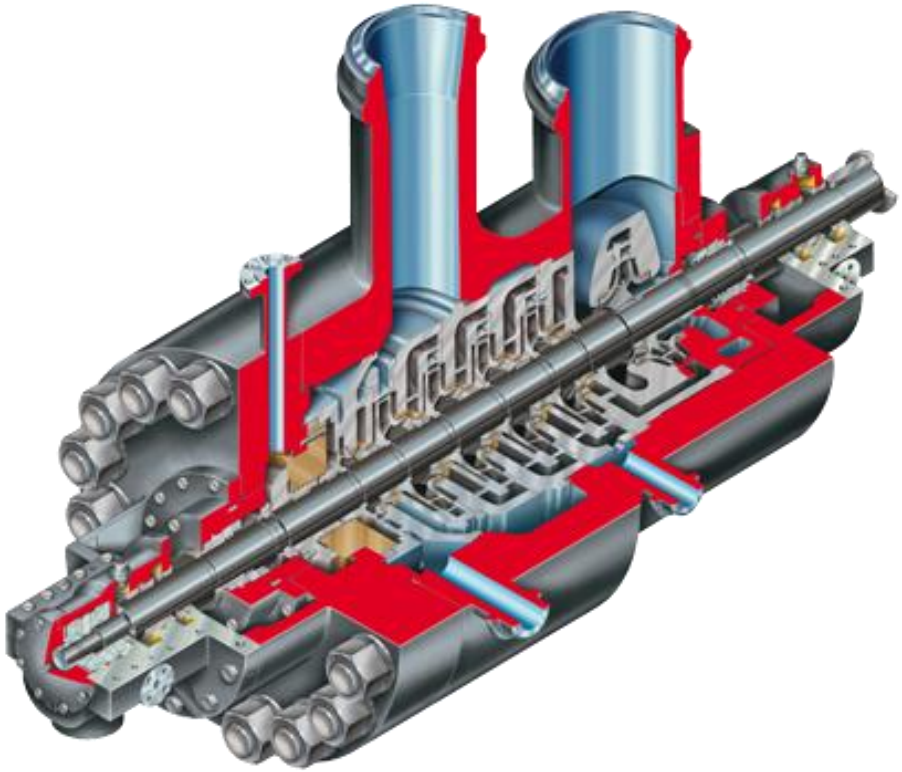
Experience In Motion

Historical Perspective

In the days of coal-fired power plants…

- **Feed Pumps were Barrel Pumps**
- **Turbine Drive or Geared FC Drive**
  - **High Speed 4500 to 6000 RPM**
  - **4-6 Stages**
- **Booster Pumps Common**
- **Base Loaded, Steady State Operation**
- **For a 500 MW Plant:**
  - **Two 50% Pumps, ~4500 GPM Each**
  - **7500 Feet TDH Subcritical**
  - **11,500 Feet TDH Supercritical**

Barrel (Diffuser)



To 21,000 GPM, 12,000 Feet, 7000 PSIG, 6000 RPM

Current Market

Natural gas is dominant…

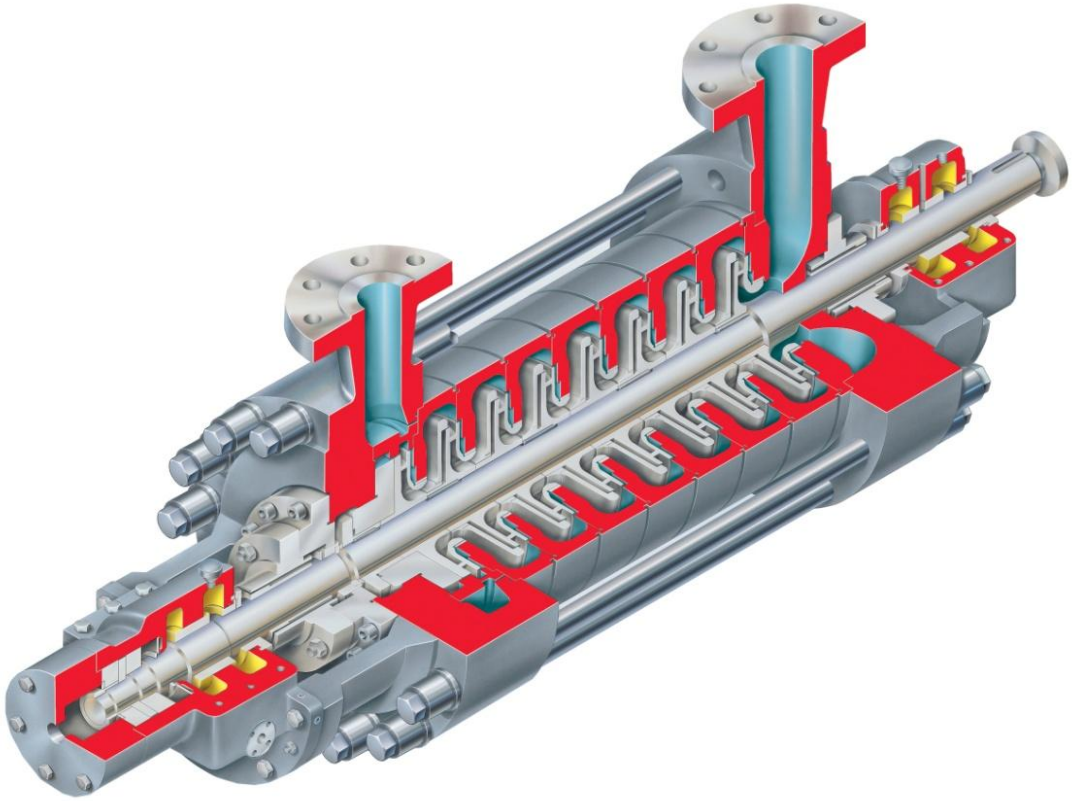
- Combined Cycle (GT + HRSG)
- Primarily Ring Sectional Pumps, Some Horizontally Split
- Motor Drive, Direct or via Fluid Coupling
  - Two-Pole Speed Nominal 3580 RPM for 60 HZ
  - 7-13 Stages
- Booster Pumps are Rare
- Daily Cycling
- For a 500 MW Plant:
  - Four 100% Pumps per HRSG, ~1500 GPM Each
  - 5000 to 6000 Feet TDH

Current Market

Thermosolar & Biomass

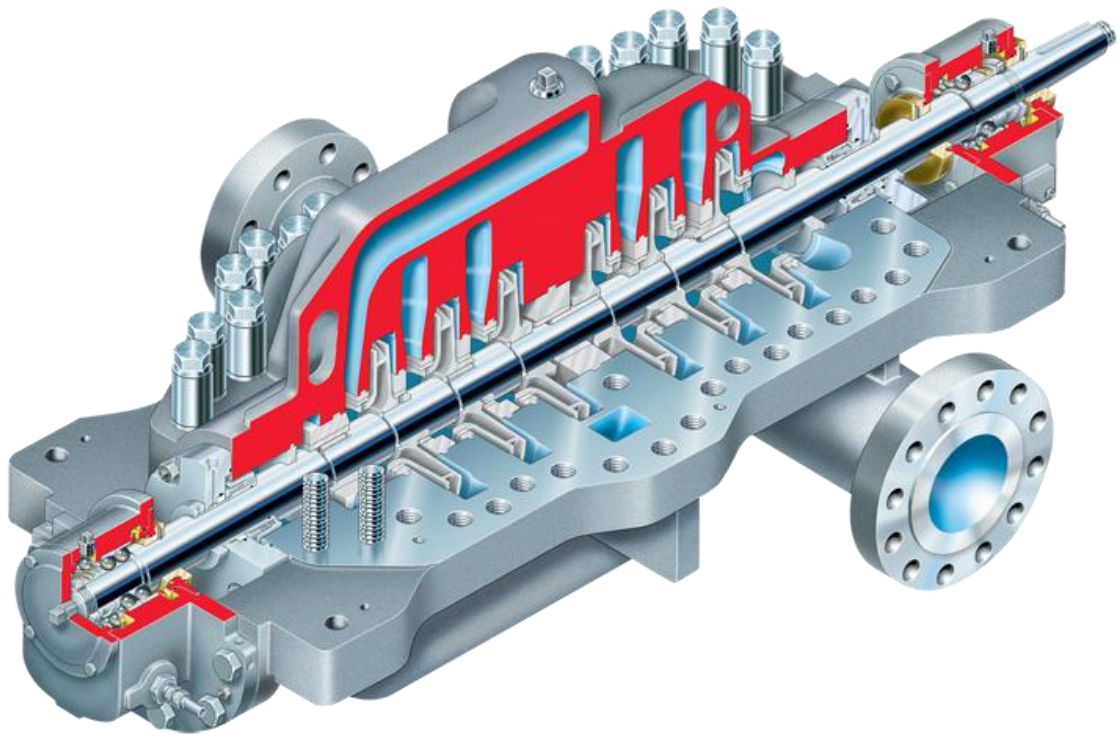
- **Pumps are Similar to CC for Largest Thermosolar & Biomass Plants**
- **Plant Size, and thus Pump Size, Varies Significantly**
- **Smallest Biomass Plants Approaching "Industrial" Size Boilers & Pumps**
- **Pump Manufacturers Need Wide Range of Products**

Ring Section



To 5000 GPM, 8000 Feet, 4000 PSIG, 5000 RPM

Horizontally Split



To 5000 GPM, 7500 Feet, 4000 PSIG, 6000 RPM

Requirements & Features

- Rapid Start-Up & Daily Cycling
  - No Warming
- Thermal Transients
  - Axisymmetric Design
  - Uniform Wall Thickness
- High Interstage Takeoffs (25% of Suction Flow)
  - Ability to “Mix” Hydraulics within Pump
  - Thrust Balance Important

Other Considerations

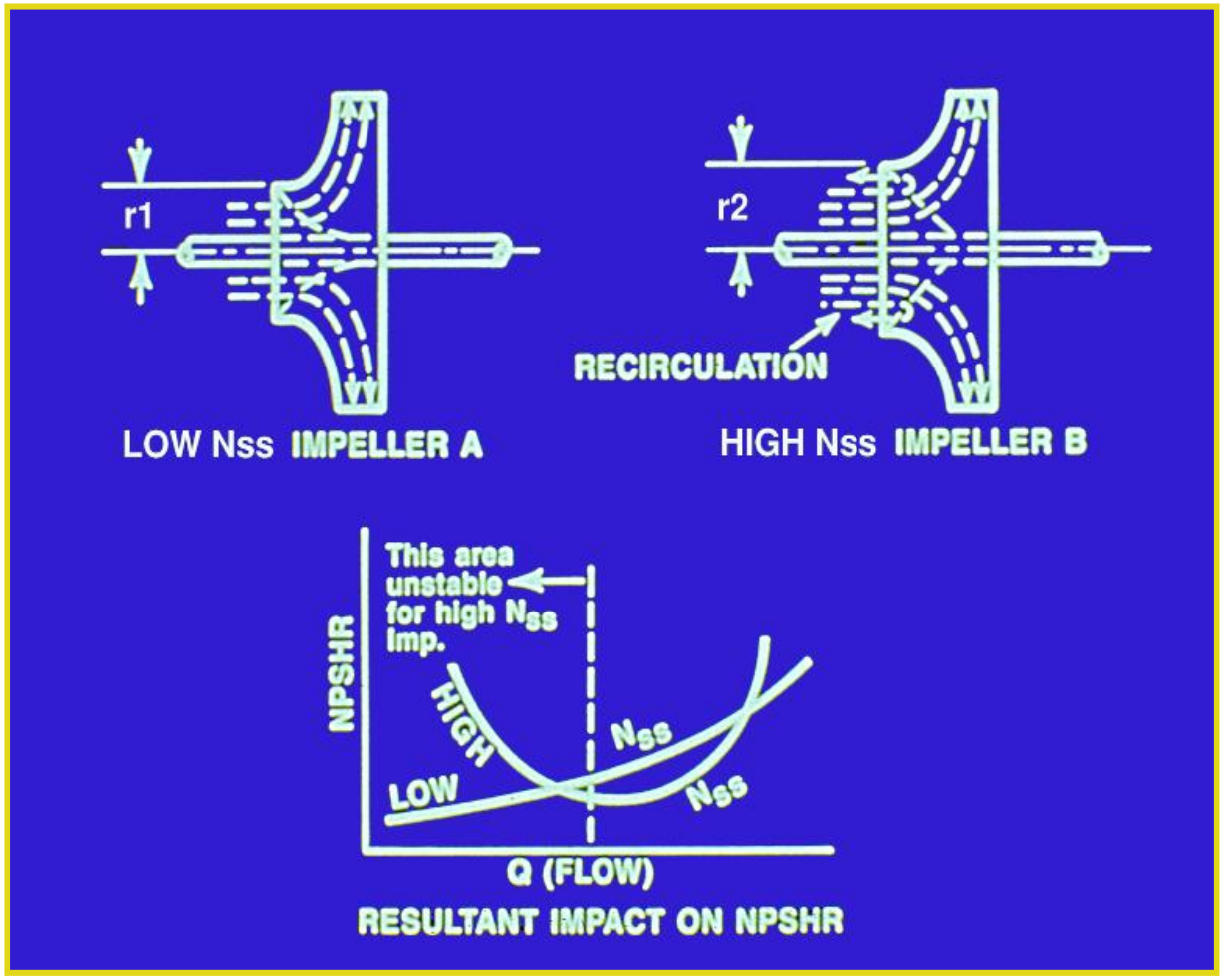
- Combined Cycle focused on Low Initial Cost
- Thermosolar focused on Power Consumption
  - Virtually all are Variable Speed (VFD or FC)
- Low NPSHa for Thermosolar & Biomass
- Plants run with Minimal Staff
  - Instrumentation for Remote Operation
  - Trust to OEM for Guidance

Low NPSHa

Impact of NPSHa

- Nss = (N x Qeye^.5)/NPSHr^.75
- Reasonable Value ~ 10,500
- Reasonable NPSHa/NPSHr Margin ~ 1.8
- Double Suction Available
- Booster Pumps Available but Not Common

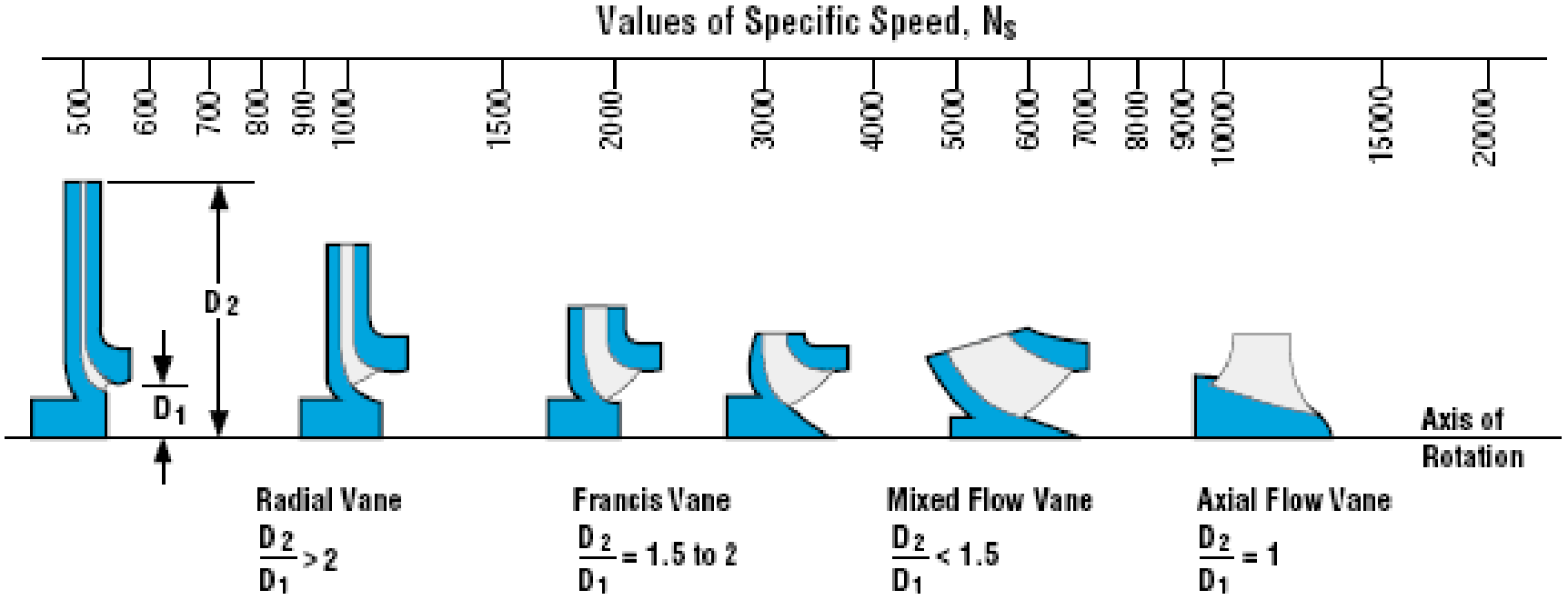
Suction Performance



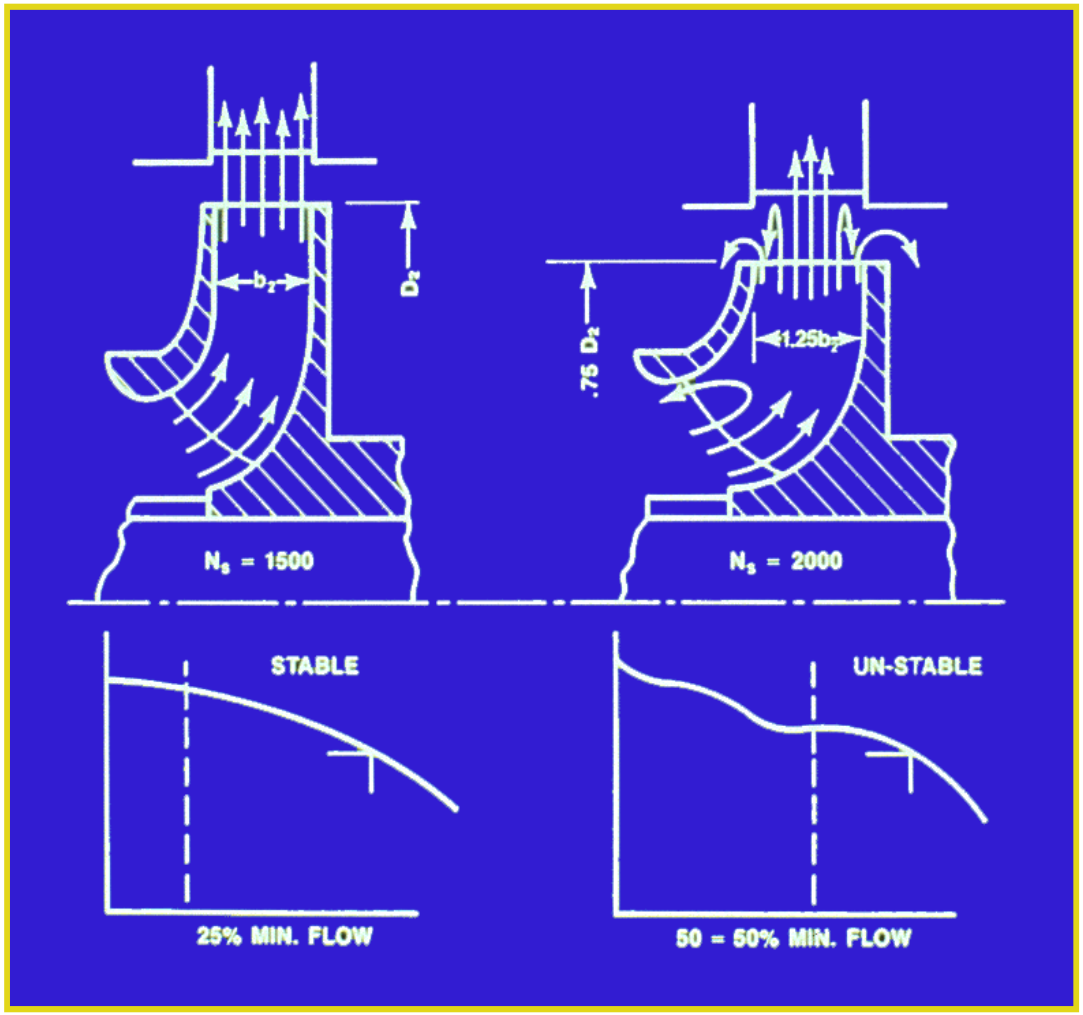
Efficiency vs. Stage Count

Impact of Specific Speed

- Ns = (N x Q^.5)/Hstg^.75
- Too Low >>> Low Efficiency
- Too High >>> Unstable Curve Shape



Specific Speed



Impact of Variable Speed

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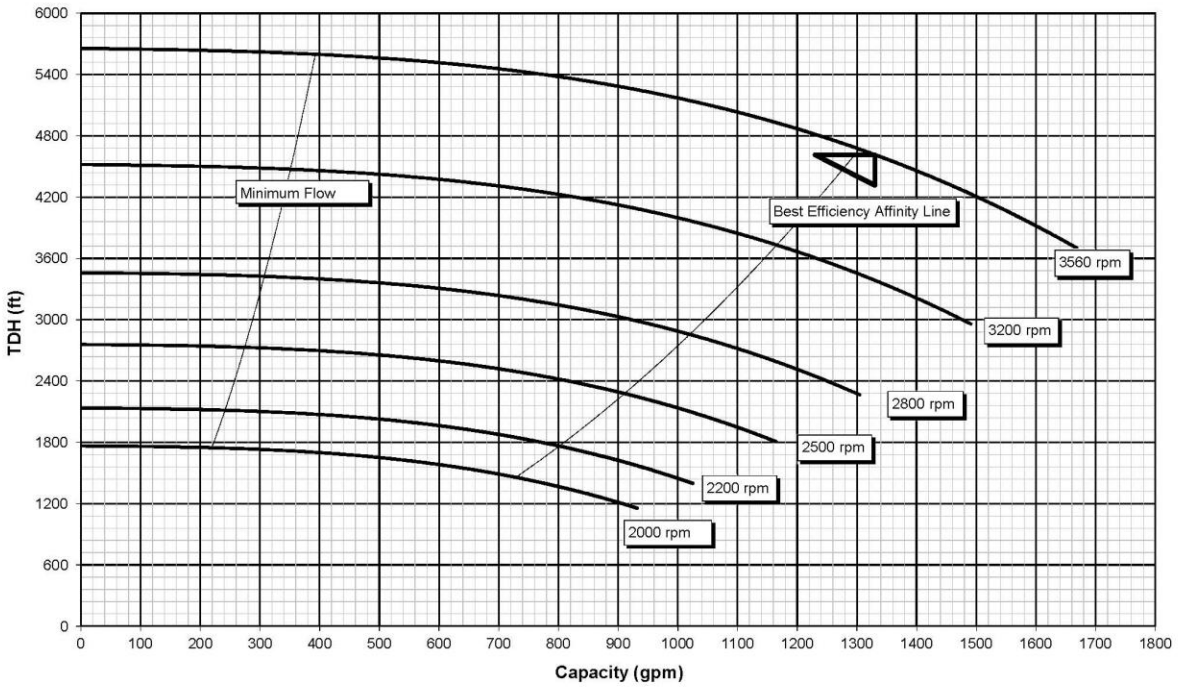
Proposed Performance

Liquid	Boiler Water	**Speed (RPM)**	3560	**Capacity (gpm)**	1330
Temperature (°F)	335	**Pump type**	4x11 DMX	**TDH (ft)**	4615
Viscosity (cSt)	0.2	**First Stage Design**	Single Suction	**Efficiency**	82.1%
Specific Gravity	0.90	**Stage Count**	11	**NPSHR (ft)**	32.3

Rev. A

Curves are approximate. Pump is guaranteed for one set of conditions. Capacity, head, and efficiency guarantees are based on shop test and when handling clear, cold, fresh water at a temperature of not over 85 degrees.



Experience

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Questions?