CRYOGENICS IN SUBMARINES

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IMI Truflo Marine
Engineers and manufacturers of high integrity valves, actuators and air distribution stations.
FIRST LEVEL VALVES

SAFETY CRITICAL

FAILURE NOT ACCEPTABLE

HIGH INTEGRITY

QUALITY ASSURANCE OF ALL PARTS
<table>
<thead>
<tr>
<th>RANK</th>
<th>COUNTRY</th>
<th>TOTAL SUBMARINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>US</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td>NORTH KOREA</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>RUSSIA</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>CHINA</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>INDIA</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>JAPAN</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>TURKEY</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>SOUTH KOREA</td>
<td>13</td>
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<tr>
<td>9</td>
<td>IRAN</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>UK</td>
<td>11</td>
</tr>
</tbody>
</table>
RELATIVE SIZES
SUBMARINE TYPES

▶ Diesel Electric Hunter Killer (SSK)
  ▷ Low Cost
  ▷ Established Technology
  ▷ Low Underwater Endurance (5 days)

▶ Air Independent Propulsion Hunter Killer (SSK)
  ▷ Medium Cost
  ▷ Very Quiet Operation
  ▷ 14 Day Underwater Endurance (O2 dependent)

▶ Nuclear Hunter Killer (SSN) or Ballistic Missile Carrier (SSBN)
  ▷ Size and Speed
  ▷ 90 Day Underwater Endurance (Only Food Dependent)
  ▷ Now Fuelled for Life
Over 100 Nuclear Powered Subs Worldwide
700 Nuclear reactors since 1950
Twenty ‘Major’ Incidents
Submerged endurance of Nuclear Sub only limited by food
Standard submerged tour for nuclear sub 90 days
Cost Circa £1 to 3 Billion + Decommissioning
Fuel Cell Exceptionally Quiet
Various Technologies; Fuel Cell, Closed Cycle Diesel
AIP is Dependent on Oxygen
Oxygen Stored as LOX
Current submerged tour for AIP 14 days
Cost circa £ 100 to 500 Million
Fuel Cell Combines Pure H2 and O2

CCD Uses ‘Underwaterised’ Diesel and O2

Stirling Cycle Uses Diesel and O2

Requirement is Lots of O2 Commonly Stored In Liquid Form in Large Pressurised Cryogenic Tanks
HYDROGEN FUEL CELL

HYDROGEN CELL SYSTEM

H2

O2

N2

NITROGEN

OXYGEN

HYDROGEN

GAS HUMIDIFIER

CATALYSTS

FUEL CELL

ELECTROLYTES

POSITIVE / NEGATIVE CATHODES

WATER

ELECTRICITY

BATTERY
CRYOGENIC STORAGE OF OXYGEN

- Estimated Stored Quantity of LOX Circa 40 to 100 Tonnes
- Quick Refuelling Facility Required
- Safety System Able to Discharge -182°C into Sea, at Dive Depth
- Sea Water Corrosion Resistance
- Leak Proof at Cryogenic Temperatures
- Secondary Containment seals
- BAM Approved Seal Materials for High Pressure LOX
- Shock Proof at all Operating Conditions
EVERYTHING IS TESTED!
Questions?