

INTRODUCTION

The ST-100 *Argos* is a third generation autonomous tourist submarine built by Consub Equipamentos E Serviços Ltda. of Rio de Janeiro, Brazil. The submarine is classified +A1 *Sub III* by Det Norske Veritas (DNV) having received its class certificate on October 7, 1994. The submarine is capable of transporting 16 passengers and two crew members to depths of 100 meters. The official DNV identification number is 17906.

PRESSURE HULL & EXTERNAL FRAME

The pressure hull resists the hydrostatic forces imposed by seawater and isolates the occupants from the external environment. The pressure hull is a steel cylindrical section mated to a forward steel hemisphere with integrated spherical sector viewport, and also joined to an aft hemispherical steel section. The pressure hull is composed of fine grained, medium tensile steel with an internal diameter of 2100 mm and a shell thickness of 19.05 mm. Ring frames are placed internally and serve to stiffen the hull, while lateral viewports are sealed with o-rings and a retaining ring into forged steel inserts between the frames.

The *Argos*' rated design depth is 100 meters with a critical depth of 263 meters. The forward hemispherical sector viewport for the pilot is composed of transparent polymethyl methacrylate (acrylic plastic) and is 1500 mm in diameter. There are eight spherical sector side viewports, one for every two passengers, that are 800 mm in diameter. In the majority of tourist submarines the side windows are generally flat, but spherical sectors are more load resistant and provide better downward viewing. Two entrance trunk and hatch combinations, one forward and one aft, are 900 mm in diameter.

The *Argos* has a metallic framework attached to the pressure hull that provides support for the fiberglass deck and superstructure as well as attachment points for high pressure air and oxygen bottles, main ballast tanks, etc. A steel skid assembly provides a base that protects the bottom of the pressure hull and is used for securing hard ballast tanks, the drop weight assembly, thrusters and other components. A pipework frame provides collision protection for the forward viewport.

INTERNAL ARRANGEMENT

The *Argos* was designed to provide passengers with a comfortable environment from which to view the subsea world, and the degree of comfort and the quality of the view are obviously critical to passenger acceptance of the vehicle and the experience as a whole. The *Argos*, with a 2100 mm passenger compartment diameter is considerably more spacious than any comparably sized tourist submarine. In addition, the side viewports are the largest in the industry. The overall effect is one of spacious comfort.

The main design compromise is in finding sufficient battery storage space within the pressure hull while still prioritizing passenger comfort. Battery capacity is a key issue directly related to vehicle speed, range and endurance. The *Argos* has two battery boxes that form the basis for the molded passenger seats. This design is characterized by center aisle and a seating arrangement that has the passengers situated back to back, with two passengers facing each viewport. The advantage of this

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Argos Technical Specifications:

<i>Classification:</i>	<i>DNV +IA1</i>
<i>Maximum Depth:</i>	<i>100 meters</i>
<i>Passengers:</i>	<i>16</i>
<i>Crew:</i>	<i>2</i>
<i>Length:</i>	<i>10.7 meters</i>
<i>Height:</i>	<i>5.0 meters</i>
<i>Width:</i>	<i>3.5 meters</i>
<i>Pressure hull diameter:</i>	<i>2.1 meters</i>
<i>Draft:</i>	<i>3.1 meters</i>
<i>Weight in air:</i>	<i>40.6 tons</i>
<i>Autonomy:</i>	<i>80 hours</i>
<i>Mission time:</i>	<i>8 hours</i>
<i>Maximum speed:</i>	<i>3 knots</i>
<i>Electrical power:</i>	<i>120VDC/24VDC</i>
<i>Forward/reverse thrust:</i>	<i>4 x 5 HP</i>
<i>Lateral thrust:</i>	<i>1 x 5 HP</i>
<i>Vertical thrust:</i>	<i>2 x 5 HP</i>

approach is that it provides considerable space for batteries and still allows for easy passenger access and egress down the center aisle.

Aft of the passenger space is a non-structural bulkhead divider with two hinged doors that provide access to the machinery compartment.

Forward of the passenger space is the pilot's compartment situated behind a large spherical sector acrylic viewport located in the forward portion of the pressure hull. All control and navigation functions are carried out from this area.

BALLAST & TRIM SYSTEMS

The *Argos* has a main ballast tank (MBT) system composed of eight, 880 liter capacity rectangular ballast tanks, four per side, attached to the upper sides of the vehicle and which are open to seawater at the base. The system includes a set of air injection and vent valves connected to main and reserve high pressure air tanks located within the framework outside the pressure hull. The purpose of the main ballast tanks is to provide the vehicle with the necessary freeboard, stability and buoyancy while in the surfaced condition. Main ballast tanks can also be blown at depth in an emergency, resulting in a rapid, uncontrolled ascent.

The variable water ballast tank (VBT) system, sometimes referred to as hard ballast, is designed to allow the vehicle to be neutrally buoyant regardless of passenger load. The VBT capacity is equivalent to the weight of the rated maximum number of passengers. In the case of the *Argos* there are four cylindrical tanks, two per side, and each tank has a capacity of 450 liters for a total of 1800 liters. This will allow the submarine to operate with a total of only two crew on board, in which case the variable ballast tanks would be full, or with a full load of passengers and empty VBTs.

The VBTs are one-atmosphere, pressure resistant tanks, affixed to the skid assembly outside the pressure hull. Water free-floods into the tanks when the requisite valves are actuated, and the tanks are emptied by the introduction of air at 200 psi over ambient. Differential longitudinal trim is effected by filling or venting either the bow tanks or the stern tanks to compensate for passenger movement within the pressure hull.

The high pressure air system for the MBTs and VBTs is composed of six cylinders each of 100 liter capacity at 3000 psi. The cylinders are divided into independent main and reserve systems of three cylinders each. Pressure reducing valves allow for a reduction in pressure to 200 psi.

The *Argos* also has a provision for lead ballast that can be varied to compensate for differences in water salinity or additions or deletions of equipment.

An emergency lead drop weight of 2200

kilograms is located between the skids. The weight is released by the actuation of two hydraulic cylinders powered by a manual pump mounted in the pilot's compartment. Releasing the drop weight will allow the submarine to surface with a full load of passengers and crew in the event of a subsea entanglement or other emergency.

ELECTRICAL POWER & DISTRIBUTION

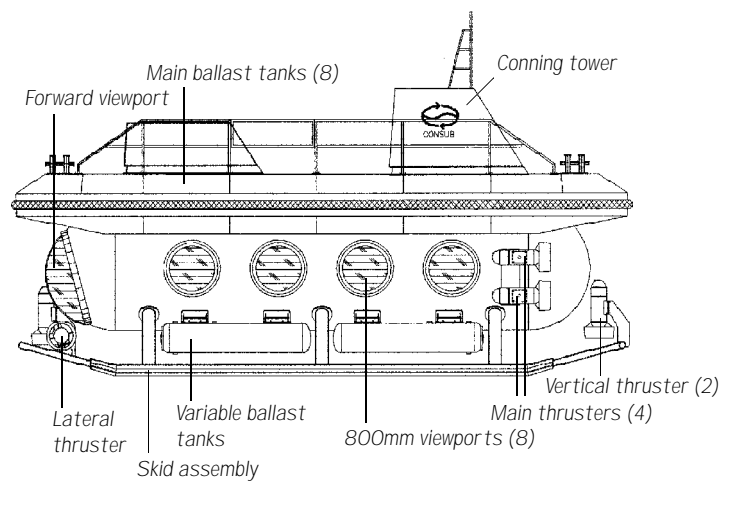
The *Argos* derives power from lead acid storage batteries. The primary consumers, the thrusters, are operated from 120VDC current. Life support, navigation, control and communication systems use 24VDC or 12VDC current.

Battery selection and systems design is critical to a safe and successful vehicle. The batteries chosen are an advanced lead acid traction type battery with automatic distilled water top-off capability from Saturna, a Varta subsidiary. The batteries were selected to last a minimum of 1500 deep cycle charges or five years.

The main battery is composed of two 120 VDC banks of 756 Ah each connected in parallel for a total of 1512 Ah at a C-8 rate. The main battery provides power for the seven thruster motors. An auxiliary battery of 24VDC and 756Ah provides power for all of the remaining electrical consumers. An emergency battery of 24VDC and 175 Ah provides power to the life support and communications systems in the event of an auxiliary power failure.

The batteries are located inside the pressure hull beneath the passenger seats in air-tight enclosures. Monitors are installed to detect the presence of hydrogen. A palladium catalyzer recombines any hydrogen with oxygen, generating water vapor

Fig. 1. The *Argos* in profile



which is collected in a filter in the circuit.

The *Argos* has well designed electrical systems with extensive circuit protection and ground fault detection capability.

PROPULSION & MANEUVERING CONTROL

Tourist submarines generally have considerable parasitic drag as a result of the externally mounted components, including thrusters, main and variable ballast tanks, exostructure, high pressure air and oxygen bottles, external frames and other equipment. Speeds are quite low, with a typical maximum of 3.0 knots. Actual operating speeds are in the region of 0.5 – 1.0 knot, as faster speeds tend to be the enemy of observation.

Forward and reverse thrust on the *Argos* is provided by four, sealed, fixed electrical thrusters operating at 120V and generating 5 HP each at 800 rpm. Lateral thrust and directional control is effected by a single transverse bow thruster of identical power, while vertical maneuvering is accomplished by two additional vertical thrusters, one each on the bow and stern portions of the submarine. The propeller for each thruster is contained in a Kort nozzle which is screened to prevent accidental ingestion of foreign objects. All the thrusters are identical and interchangeable.

Maneuvering is intuitively accomplished through a single proportional joystick control. Course changes to port and starboard are caused by moving the joystick to the left or right which activates the bow thruster. Forward or reverse thrust is caused by pushing the joystick forward or pulling it aft. The joystick is also used to actuate the vertical thrusters.

LIFE SUPPORT & SAFETY SYSTEMS

In a tourist submarine the cabin pressure is always maintained at very close to one atmosphere, regardless of the depth of the vessel. Life support is effected by injecting pure oxygen into the cabin to maintain 19%-22% by volume, while the carbon dioxide is absorbed by a chemical compound in a scrubber system.

High pressure oxygen is stored in six individual bottles located outside the pressure hull. The main oxygen system consists of two 15 liter bottles at 2465 psi and provides sufficient oxygen for 18 people for an entire day of operation. A second, independent emergency oxygen system consists of four 50 liter bottles at 2465 psi and provides a minimum of 72 hours of life support for a full complement of passengers and crew.

The oxygen supply, reduced in pressure to 36 psi by a regulator, is injected into the cabin and is controlled manually by the pilot.

The carbon dioxide component of the air in

the passenger cabin is removed through adsorption by circulation through a porous bed of soda-lime. A high volume blower forces the air through the scrubber canisters. Carbon dioxide levels are thus maintained at levels below 0.5% by volume. Aboard *Argos* there are four electrically powered scrubbers, two on the port side of the passenger cabin, and two on the starboard. Each scrubber is capable of absorbing the CO₂ produced by 18 people over a two hour period.

Emergency scrubber compound weighing 250 kg is stored in accessible sealed containers within the pressure hull. In the event of emergency the scrubber compound can be replaced periodically. Carbon dioxide is monitored by the atmospheric monitor system and a manual gas monitor is also included in the emergency supplies.

The *Argos* also has an air conditioning system to cool and dehumidify the cabin air. The total flow rate of the scrubbers and the air conditioner is 570 m³ hr⁻¹.

Fire protection includes both active and passive fire systems. Passive systems include flame retardant materials, while the active systems include high temperature alarms and two portable 6 kg Halon 1301 fire suppression extinguishers. Individual closed circuit emergency breathing systems with two hour capability are provided for each passenger for use in the event of atmospheric contamination by fire.

Emergency food and water rations, inflatable life preservers and first aid kits are included in the submarine emergency equipment.

COMMUNICATIONS, NAVIGATION & MONITORING

During tourist submarine operations a Surface Officer aboard a tender vessel tracks the submarine and remains in constant contact with the submarine pilot through an underwater telephone (UWT). It is the responsibility of the Surface Officer to make sure there are no vessel traffic conflicts when the submarine surfaces.

The UWT for the *Argos* operates on two frequencies (8.8 kHz and 27 kHz), the appropriate frequency being condition dependent. A 37 kHz emergency pinger locator is also integrated into the UWT system. In addition to the UWT there is a pilot controlled VHF radio for surface communications, and an internal intercom system and an AM-FM radio and tape deck as well.

Navigation is typically accomplished by reference to submerged objects and dead reckoning. Virtually all tourist submarines are constrained to one or two dive sites, and the pilots quickly become familiar with the subsea route which is usually less than one nautical mile in length. A fluxgate elec-

tronic compass provides heading information on a digital display located on the pilot's console. A Bourdon tube style depth gauge provides depth information while a color depth sounder provides altitude data, the bottom profile and also has an adjustable proximity alarm. In addition, a front facing depth sounder will provide a profile of any obstacles ahead along with distance information.

A gyroscope provides an inertial attitude reference to the horizontal plane and course information with a maximum drift of one degree per hour.

A color video camera mounted above the sail provides external viewing to the pilot through a monitor located on the pilot's console. Passengers are equipped with monitors as well, and a video cassette deck is also available.

Other instrumentation includes an alarm system for water egress, atmospheric monitors for O₂, CO₂ and H₂, motor over-temperatures, etc. In addition there are electrical voltage and amperage meters, oxygen and high pressure air pressure gauges, battery amp-hour meter, as well as a wide variety of control valves, electrical switches and circuit breakers. The result is an impressive array of switches and instrumentation in the pilot area.

IN SUMMARY

The *Argos* represents a state-of-the-art autonomous tourist submarine built to the highest possible safety standards by a leading subsea technology company noted for its exceptional technical competence.

Submarine & Submersible Design, Engineering, Refit & Construction
Tourist Submarines • Semi-submersibles • SeaRoom Habitats
Marine Leisure Business Plans • Turnkey Operations
Comprehensive Site Survey • T-Sub Site Selection
Feasibility Studies • Personnel Recruitment
Submersible Operations • Training



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