

## **Introduction**

The SPT-16 was designed by Jacques Piccard, and manufactured by Sulzer Brothers Limited (Sulzer Thermtec AG) located in Wintertur, Switzerland. The SPT-16 is a moderately sized tourist submersible. It is a departure from the large 'Greyhound buses' which are common to this industry today. The SPT-16 is capable of diving to 100 meters (330 feet) with a daily endurance equivalent to eight, one hour dives. Remarkably large and uniquely configured spherical sector side viewports provide spectacular viewing for the occupants.

Submarines have a history far older than that of the airplane. Originally, they were developed for military purposes and their manufacture became a routine process during the first world war. The search for oil and gas on our continental shelves during the 1960's and 1970's in particular, made civilian submarine manufacture and operation a commonplace activity.

The idea of using submarines purely for recreation was first introduced at the Swiss world exposition in 1963 where the 'Auguste Piccard' was launched. This submarine carried 35,000 delighted passengers on 1,011 dives during that year.. The idea rapidly gained in popularity and a new business has since emerged. Today, more than 40 tourist submarines are in operation and collectively they will carry over two million passengers this year on dives as deep as 800 feet (240 meters). In addition to this industry's unprecedented growth, it also enjoys a good safety record.

All of us have been introduced to the wonders of the undersea world through the magnificent productions of the Cousteau and National Geographic Societies, many of which have used small submarines. Numerous documentaries are made each year which highlight the delicate, fragile but incredibly beautiful ecosystems of the ocean using data acquired by submarines. Until recently however, these adventures, discoveries and experiences were limited to organizations with enormous budgets staffed predominately by marine scientists. The advent of submarines for recreation has changed all of this and it is now possible to experience the splendor of the underwater world in the comfort and safety of a submarine.

## **The SPT-16 Submarine**

The SPT-16 was assembled in Switzerland, the process aimed towards satisfying guidelines established by the American Bureau of Shipping (ABS). ABS is involved in the process of certification of manned submersibles since 1968. As part of this process, ABS witnessed the test of every material system and component on the SPT-16.

The process began back in 1989 when samples of materials to be used in the sub were destructively tested. In addition, welding on the vessel was subjected to 100% X-Ray examination, followed by a closely controlled pressure test of the completed hull (including viewports and major systems). Once the SPT-16 was completed, a manned dive was performed (August 21, 1994) with a local surveyor aboard to the certification depth of 100 meters (330 feet). During this dive, major systems were demonstrated to function properly and to the surveyors satisfaction. Finally, maintenance and operating manuals were submitted for review and the submarine was declared certified by ABS. In order to retain this classification, the submarine will undergo an intensive survey after its annual refit as well as a special survey every four years.

The main pressure hull, a cylinder of 1.8 meters (6 feet) inside diameter, is formed from medium tensile steel plates. Forged viewport and hatch rings are inserted and the whole of the exterior is stiffened with closely spaced T section frames. Along the sides of the deck and directly aft of the entrance hatch are the six main ballast tanks. These tanks are fitted with vent valves in the top and openings to the sea at the bottom. To bring the submarine to the surface, these tanks are blown dry with compressed air and to dive the air is released through the hydraulically opened and fail-safe spring closed vent valves.

Located amidships are the two 1 kW electric vertical thrusters, used for powering the submarine up and down in the water column. These thrusters are complemented by comparably sized, independently controlled, bow and stem thrusters mounted in the submarines skid framework to allow the pilot to rotate or crab the vessel. The 15 kW main propulsion motor, located internally, drives a large propeller housed in a steerable, unidirectional Kort nozzle providing excellent surfaced or submerged control of the vessel.

At the aft end of the deck is the submarines sail. Passengers embark and disembark from a main entrance hatch located within the sail which is equipped with a 80 cm (31.5 inch) diameter spherical sector viewport. Once submerged, passengers can enjoy a view overhead from either this viewport or through an identically sized forward hatch viewport. Normally, the forward overhead hatch viewport, is used by the copilot during surfacing or surfaced navigation allowing the pilot to remain in his seat. A secondary helm station is located in this forward entrance hatch trunking so the submarine can be operated safely on the surface with the hatches secured as well.

Once below, passengers are seated in a gray leather interior bathed in ample lighting. A Blaupunkt audio and public address system fills the cabin with either peaceful music or interesting commentary while the air conditioned cabin atmosphere is maintained, with no increase in pressure to the occupants. The submarine is equipped with a metabolic makeup style life support system and the pilot carefully monitors cabin pressure, carbon dioxide, oxygen and hydrogen levels at all times throughout a dive. The submarine is equipped with three days of emergency life support for a full crew of 18 people. In addition, there are individual re-breathers for each occupant in the event of a contaminated cabin atmosphere, which provide a further 4-6 hours of self contained life support.

A full height central aisle makes best use of the 1.8 meter (6 feet) diameter pressure hull and stretches from the pilots compartment to the sound-proofed machinery space bulkhead. The seating is arranged in four groups of four with each pair of passengers sharing an 80 cm (31.5 inch) diameter spherical sector viewport. This seating arrangement promotes conversation and interaction between the customers in a way which is significantly easier than standard bench style, back to back seating of all other tourist submarines. Quartz halogen external lights illuminate the subsea vista, intensifying the abundant natural coloring both during deep daytime dives or at night. The photographic opportunities for passengers through these optically correct windows are at present.

The batteries on the SPT-16 are arranged in eight separate cases which form the back of the passengers seats. The capacity of the electrical system has been generously sized to allow for up to eight, one hour dives during a day. These tubular lead-add batteries are equipped with an automated watering system to simplify battery maintenance and an elaborate hydrogen monitoring system for safety. Recharge time for these particular cells is approximately eight hours. The electrical system is split into three independent systems, a 120 Volt main, and two 24 Volt banks.

The pressure hull is closed at the forward end by a spectacular 1.8 meter diameter hemispherical viewport. With the center of curvature near to the pilots eye it provides a commanding and unobstructed view forward. The pilots control and instrumentation panels have been deliberately positioned away from the viewport allowing passengers, particularly in the forward compartment, to enjoy this view as well. Grouped directly in front of and around the pilot are all of the controls necessary for operating the submarine. At the aft most end of the passenger compartment is the machinery space which is separated by a fire and sound proofed bulkhead.

The overall weight of the loaded submarine is controlled by the variable ballast system which consists of six external tanks located in the skid section. Water is admitted to or blown out of these tanks to compensate for various passenger loads. In addition to this a trim system filled with fresh drinking water (part of the submarines emergency life support requirement) and consisting of two external and two internal tanks located at the extreme end of the submarine allows the pilot to vary the pitch angle of the submarine.

Communication is maintained both while surfaced and submerged. A VHF marine transceiver fitted with an antenna mounted on the sail provides communication with either the support ship or main operations and ticketing office. An underwater telephone or UWT equipped with dual frequencies, two sets of transducers and output power of up to 100 Watts allows the submarine to communicate with a support ship up to 3 kilometers (2 miles) away while submerged.

## Technical Highlights of the SPT-16

- The SPT-16 was designed and manufactured by the qualified manufacturing firm (Sulzer ThermoTec AG) in Switzerland using contemporary components and assembly techniques.
- Conceptual design was supplied by Jacques Piccard, a world famous Swiss oceanographer and explorer who has over forty years experience in manned submersibles.
- Suitability of the design for operation in either fresh or salt water in cold or warm climates.
- Certification by ABS, an endorsement which allows the SPT-16 to join the growing list of ABS classed manned submersibles and the unblemished safety record this group currently enjoys.
- Quality assurance - The highest standards were exercised during the manufacturing process of the SPT-16 by Sulzer, a company which also builds complete nuclear power plants, diesel engines and other heavy equipment.
- Portability - This 33 metric ton submersible can be quickly and easily transported by road, rail, air or sea. This may prove useful for an operator engaged in seasonal activities or interested in using more than one location.
- High levels of comfort - an industry first! Sulzer designers have successfully arranged seating in the SPT-16 in such a way as to enhance a feeling of camaraderie amongst the crew. Passengers are seated in four sections resembling small railway compartments. In each section, the four occupants sit fore and aft facing one another thus promoting conversation. In addition, due to the limited seating capacity, customers enjoy a more intimate, and personalized experience. The interior of the submersible has been covered in a high quality top-grain gray leather complimented by a Pirelli style floor.
- Excellent viewing - The SPT-16 has set new standards for viewing in the industry and is fitted with large viewports currently found in few, if any, manned tourist submersibles. A total of 11 viewports are found in the SPT-16 including a 1.8 meter (6 feet) inside diameter hemispherical forward viewing port for the pilot, the view from which can be enjoyed by the passengers also due to the thoughtfully compact and carefully placed pilots control and instrumentation panels. Passengers enter the submersible from the aft hatch which is one of two (2) 800 mm diameter (31.5 inch) hemispherical acrylic hatches, and enjoy the breathtaking scenery from one of eight (8) equally sized, spherical sector viewports, which run along the side of the submersible.

## Technical Highlights (continued)

- A one atmosphere pressure cabin environment with full climate control of temperature, humidity and air purification ensures customers will enjoy a comfortable and pleasant experience in either tropical or northern climates at any depth.
- A high performance, ultra efficient main propeller and Kort nozzle design combined with a streamlined exterior helps the vehicle slip through the water with a minimum amount of drag, thereby enhancing the submersibles efficiency and endurance both on the surface and submerged. In addition, four (4) positioning thrusters ensure the submersible has good maneuverability.
- High freeboard (now exceeds current ABS requirements) and good surfaced stability will allow for the safe surface transfer of passengers while at sea.
- All systems are sized for a capacity of up to eight (8) one hour tours per day. In addition, by using advanced tubular lead-acid batteries equipped with a patented autofill system, recharge time has been reduced to a maximum of eight (8) hours and maintenance greatly simplified.
- Excellent interior and deck lighting system to improve passenger confidence and increase surfaced visibility at night, even though night dives are not advisable.
- Atmospheric monitoring systems are fitted to notify the pilot of precise oxygen, carbon dioxide and hydrogen levels at all times and are equipped with both audible and visual alarms.
- Emergency equipment - The submersible is fitted with emergency equipment to support a full crew for a full 72 hours (ABS requirement). The SPT-16 has three (3) separate power sources but none of the essential life support systems require electricity. Other emergency equipment includes an advanced fire detection and extinguishing system and individual, self-contained, oxygen producing re-breathers for survival in a smoke filled cabin. Further, the SPT-16 has an independent manually operated and hydraulically released emergency buoy equipped with 1 kilometer (approximately 3280 feet) of kevlar line to clearly indicate to a surface vessel its position on the seabed. In addition, there are three (3) separate de-ballasting systems, two (2) of which require no electrical power and one (1) of which requires no electrical power or high pressure air to bring the submersible safely back to the surface. The manually released, lead filled drop weights are separated into ten individual releases as a further safety precaution.

Environmentally friendly - The submersible has been designed to reduce any adverse negative environmental impact. No fossil fuels are used in the operation of the vessel. In addition, careful training of the pilots is intended to reduce contact with coral reefs and other delicate marine organisms.

# SPT-16 Technical Specifications

## Dimensions

Total dry weight	33 metric tons (67,000 lbs)
Internal hull diameter	1.8 meters (6 feet)
External hull diameter (including rings)	2.1 meters (6.9 feet)
Overall length	13.2 meters (43 feet)
Overall height	4.76 meters (15.6 feet)
Overall width	2.7 meters (8.9 feet)
Transport height	3.6 meters (11.8 feet)
Draught loaded	2.3 meters (7.6 feet)

## Performance Characteristics

Operating depth (max.)	100 meters (328 feet)
Speed (approximately)	5 km/hr (3.5 knots)
Crew size	1 Pilot, 1 Co-Pilot
Passenger capacity	16
Main propulsion	15 kW (22.5 hp)
Lateral thrusters	2 x 1 kW (1.5 hp) nominal in tubes
Vertical thrusters	2 x 1 kW (1.5 hp) nominal in tubes
Battery capacity	120 Volt - 71 kWh, 24 Volt - 42 kWh
Autonomy per day	8 dives @ 1 hour
Compressed air	40 x 50 l / 200 bar (3000 psi)
Oxygen	40 x 50 l / 200 bar (3000 psi)
Life support CO2 absorption	regulated at less than 0.5 %
Life support oxygen	regulated at 21.5 %
Air conditioning	4.5 kW (16,000 Btu/hr)
Payload	1440 kg (3,200 lbs)
Buoyancy (soft ballast)	3500 kg (7,700 lbs)
Freeboard	0.8 meters (31.5 in)

## Instrumentation

Gyro compass	Anschutz
Echo sounder	Apelco
Pinger	Mesotech
Pressure gauges	Digital and analog
VHF radio	Sailor RT
Underwater telephone	Mesotech 703 A
Atmospheric monitors (H2, O2, CO2)	Zeiger, MSA
Pinger locating device	Mesotech

## **SPT-16 Technical Specifications (continued)**

### **Viewing**

Front viewport (hemispherical)	1.8 meters (5.9 ft)
Entrance hatches (hemispherical)	800 mm x 2 (31.5 in)
Lateral viewports (spherical)	800 mm x 8 (31.5 in)
Underwater lights in casing, sail, front & sides	20

### **Safety**

Test depth	125 meters (410 ft)
Emergency position indicators	Buoy and pinger
Emergency dropweights	1600 kg (3,500 lbs)
Life support	12 hrs. for 18 people
Emergency life support	72 hrs. for 18 people
Emergency rebreathers (one per person)	MSA 4-6 hr. capacity
Atmospheric sampling system	Drager and Gastech
Fire extinguishing system	Halon 1301
Life jackets (one per person + childrens sizes)	
Three independent power sources and three independent methods of surfacing	

### **Support Equipment**

120 Volt and 72 Volt microprocessor controlled battery chargers  
Bauer K14 compressor with breathing quality filtration system  
Extensive spare parts inventory, tools and consumables

### **Certification**

American Bureau of Shipping (ABS) +A1 Manned Submersible

### **Designer(s) and Manufacturer**

Dr. Jacques Piccard and Sulzer Brothers Limited, Winterthur, Switzerland

