NATIONAL INSTITUTE OF OCEANOGRAPHY

WORMLEY, GODALMING, SURREY

SURV TRIALS

APRIL—MAY 1968

Report on preliminary trials

by

N. C. FLEMMING

N.I.O. Internal Report No. A.31

MAY 1968

NATIONAL INSTITUTE OF OCEANOGRAPHY

WORMLEY, GODALMING, SURREY

SURV* TRIALS

APRIL - MAY 1968

Report on preliminary trials

by

N. C. FLEMMING

* Standard Underwater Research Vessel

N.I.O. INTERNAL REPORT No. A.31

MAY 1968

INTRODUCTION

SURV is a 6·2 ton two-man submersible designed and built by Lintott Engineering Limited of Horsham Sussex. The craft was tested in Portland Harbour in August --September 1967. During these trials the life-support was shown to be adequate, frequent dives were made to 20 - 50 ft. and the motors were run for periods of up to fifteen to twenty minutes per dive. The two major problems revealed were tilting instability on the surface, when the conning tower was out of the water, and frequent breakdowns of the logic circuitry in the solid-state DC-AC inverters. The stability was improved promptly be alterations of the ballast and the trim tank arrangements, but the inverters had to be redesigned back at the factory over the winter 67-68.

In November 1967 the National Institute of Oceanography proposed to Lintott Engineering Limited that SURV should be chartered in April/May 1968 for the combined trial of the craft and geological survey of sand ribbons in the Plymouth area. This would establish the usefulness and practicability of such a craft in British waters, and form a logical next step in the progressively more detailed survey of sand ribbon carried out by Stride (1959), and Flemming and Stride (1967). Although some forty submersibles have been built abroad (Abel, 1965; Terry, 1966; Flemming, 1968.) they have generally been employed in good water conditions, low sea state, weak currents, and good visibility, and no submersible has ever been used in British waters. To ensure that useful results could be obtained, N.I.O. advised Lintott on the installation of navigational equipment, a manipulator, and photographic equipment. These items are discussed separately below. N.I.O. also undertook to provide a suitable mother craft and the diving and handling team to ensure that adequate seamanship was applied to the raising and lowering of the craft, handling on the surface, and general safety.

British Petroleum Limited and Total Oil Marine contributed to the cost of the project.

The "James No. 95", a 400 ton dredging hopper barge, was chartered from the James Contracting & Shipping Company Limited, of Southampton, and suitable derrick and controls installed as described below. All equipment was transported to Millbay Docks and assembled over the 29th April to 1st May. The equipment was stored in the Research Vessel Unit store, and every assistance was given by RVU and Willoughby's Dock yard. The Royal Naval Diving School at H.M.S. Drake generously loaned two dry diving suits for the surface swimmers.

PERSONNEL

N.C. Flemming	Planning, safety and experimental results.
N.M.G. Flemming	Diver and Photographer.
R.L. Jack	Diver and Engineer.
J. Ward	Diver and Engineer.
A. Collier	Lintott Project Engineer.
M. Humphrey	Pilot of SURV.
P. Walker	Electrical Fitter.
P. Shoulders	Electronic Fitter
Cptn. Swinstead	Captain of "James No. 95."
Crew of seven	Crew of "James No. 95."
R.I. Walker	Sponsor on behalf of British Petroleum Limited.
D. Woods	Sponsor on behalf of Total Oil Limited.
M. Gerbaud	Observer on behalf of Compagnie Francaise des Petroles.

PERSONNEL cont:

A.J.O. Thompson	Director of James Contracting & Shipping Limited.
O. Imray	Observer and recorder for British Petroleum Limited.

CHRONOLOGY

1st May; raised and lowered SURV on the derrick of "James No. 95" and motored SURV on both engines on the surface in Millbay Docks for ten minutes. Ward, Jack, and N.M.G.F., placed transponders at the work site in one hundred and eighty five feet of water and dived to check the tautness of the bottom line and the height of the transponders from the sea floor.

2nd May: Steamed to a point inside the breakwater in Plymouth Sound with a water depth of eight fathoms. On first trial the radio communication between the mother ship and SURV broke down, and SURV had to be towed back to the site before a dive was made. Subsequent motoring on the surface resulted in the failure of the port inverter. Three tethered dives were made to eight fathoms each lasting ten to twenty minutes. All communication systems on the surface and underwater performed excellently, and the manipulator was tested and performed well. Photographs were taken successfully through the portholes by available light. SURV was returned to dock and electrical repairs were made to the port inverter. The fuse was replaced and oscilloscope tests made of the pulse shapes at various points in the logic circuitry, and output from the thyristors.

3rd May: Anchored at same point in eight fathoms. Humphrey piloted SURV for five minutes on both motors, testing manoeuvrability and speed control. Then calibrated gyro-compass on the surface for five minutes. On resuming motor controls port motor was again found to be dead and the inverter had failed. The N.I.O. camera was then mounted on the forward frame and SURV made a series of tethered dives. The camera was operated successfully and flash photographs taken from inside SURV at the depth of eight fathoms.

"James No. 95" then steamed to the work site eight miles out from Rame Head, and hove to near the northern transponder marking buoy. There was a light swell from the south west, about two to three foot wave height and five second period. There was a northerly light breeze ruffling the water surface. Stern on to the swell, SURV was lifted and lowered into the water rapidly and with no difficulty. Pilot and observer entered SURV while it was suspended at deck height over the side, and were lowered into the water. An attempt was made to lower SURV on the derrick to a depth of twenty to thirty feet to test the response of the navigation system to the transponders on the sea floor. Owing to the drift of the "James No. 95" in the wind SURV dragged at an angle to the derrick and it was not possible to lower her safely. SURV was lifted back on deck with the crew inside and was returned to dock and work resumed on the inverters.

4th May: "James No. 95" anchored in shallow water near Drake Island for the sole purpose of putting SURV in the water on the surface to test motors and inverters. The starboard system worked reliably, but the port inverter fuse blew after three minutes. SURV was hoisted inboard, and a barrel of water arranged under the propellers so that the motors and inverters could be tested running. The starboard inverter drove the starboard propeller repeatedly ahead and astern at all speeds. The port inverter fuse was repaired, and the port inverter coupled to the starboard motor. After four minutes the inverter blew. Beacuse of the complexity of the inverter switching system, a simple transfer of all the starboard inverter leads to the port motor would not establish beyond doubt that the inverter was reliable and that it was the port motor which was at fault. The leads were successively transferred and tested, and the starboard inverter finally drove the port motor successfully ahead and astern through most of the speed range with no trouble. The port motor made a rough running sound, and it was thought that there might be a loose bearing or winding. Nevertheless it was clear that the starboard inverter was capable of driving the port motor without blowing, while the port inverter could not. (It should be noted that a spare inverter was carried, but the port inverter referred to here was the more reliable of the two which could be fitted in that position.)

5th May: The port motor was stripped, and although the rotor was found to be slightly loose on the shaft, it was not considered that this could have caused the failure of the inverter. The port inverter was stripped and tested extensively, and it was concluded that the thyristors had been damaged or over-loaded by the repeated trials. It was decided that a new set of higher-rated thyristors should be installed.

6th May: Westinghouse were unable to supply larger thyristors from stock, and so a set of the same size as originally used was ordered and delivered by train at 5.p.m. The new thyristors were soldered into the circuit, and tested on the oscilloscope. The inverter was coupled to the port motor which was run in a barrel of water as before. After three and a half minutes the inverter fuse blew again. At this point it was decided to abandon the trial.

7th May: The 45ft. fishing launch "Westward" was hired for the day to locate and recover the transponders. Although both dan buoys had been carried away, probably by drift nets (they were both recovered), the trawl floats remained on the surface, and were found by horizontal sextant fixes. To test the efficiency of the underwater navigation system developed for SURV the transmitter and receiver from SURV were mounted on a pole and held below "Westward" while we motored around the transponders. In spite of the steep angle and consequent strong bottom echo, and the clouds of bubbles produced by "Westward's" forward motion and the rough sea, a signal was obtained, and the distance from the transponder could be measured.

Both transponders were then cut from their sinkers by divers and lifted to the surface.

SURFACE SHIP

The surface support ship was the "James No. 95", 400 tons. The James was originally a hopper barge, but half of the hopper had previously been decked in to support a variety of winches, pumps, and auxiliary motors, for dredging and gravel sampling. For the present project the remainder of the hopper well was bridged with a sheet of 1" mild steel just above the water line. The sheet was fitted with lugs so that SURV could be held down with cables. It was an advantage to have SURV so low in the ship where motion was at a minimum.

The lifting gear was as follows. A 14" diameter steel mast supported a 12" diameter 30ft. boom. A $2\frac{3}{4}$" circumference wire was employed to support the boom, and the main lift was by a similar wire, working through a gun-tackle purchase. Ten-ton blocks were used throughout, and the whole system tested to 6·25 tons and certified by Lloyds. The boom was swung by $1\frac{1}{2}$" guys powered by a double drum Denison-Deri hydraulic winch. The main lifting power was a Henry Sykes ten-ton winch, driven from a 40 horse power Lister diesel through a hydraulic torque converter and a 20:1 reduction gear. The torque converter provided a neutral position, and gear ratios from 1:1 to 2·26:1 in both directions. Control for both the torque converter and the diesel was hydraulic.

The speed and accuracy with which this winch could be operated resulted in all lifting operations being absolutely trouble free, even when the ship was rolling.

When SURV was tight up against the top block on the derrick the power guides on the boom effectively prevented swaying, but just after lifting from the deck, and when SURV was just out of the water, the length of wire between SURV and the block permitted considerable swinging. Three 1" spunstron guys were attached to the lifting points on SURV and a turn taken in each rope on a suitable strong point on deck. It was possible to prevent swinging by paying out these lines slowly, and taking the strain up whenever necessary. When SURV was suspended outboard two lines were kept taut to prevent spinning, but there was no sure way of preventing her bumping the sides of "James No. 95". The reach of the boom was such that there was a 4ft. gap between SURV and the rubbing strakes, and the side of "James No. 95" had been smoothed by inserting a large panel of wood between the rubbing strakes. Rubber fenders were also used. In practice the only times that SURV bumped were when she turned bow to stern on to the side of the ship. Provided that she was prevented from spinning, the gap provided by the reach of the boom was adequate to ensure safety. SURV was handled in this way with cameras and transducers mounted on the forward frame, and none of this equipment ever bumped against the ship.

SAFETY AND COMMUNICATIONS

Preliminary instructions were issued as to the division of responsibilities between the Captain of "James No. 95", and the Project Engineer for Lintott, and myself. These instructions also listed safety procedures and the circumstances under which the pilot of SURV could be instructed to alter course or surface, or the dive terminated. A large part of the safety of the operation and the efficiency of any work carried out would depend on effective communication between the surface units and the submerged craft. Because of the experimental nature of the trials, SURV towed a float on the surface, and this was tracked by a 12ft. zodiac inflatable dinghy with a 20 horsepower Johnson engine. Thus the "James No. 95", the dinghy, and the submersible must be kept in continuous contact. As soon as the hatch of SURV is closed, and the dinghy, the ship, and the submersible are more than 50ft. apart, a breakdown of communications could immediately lead to chaos.

After the first dip this was quickly appreciated, and strict communications procedure observed from then on. The communication system cannot be regarded as a luxury trimming to the operation, or simply one of a number of safety precautions. The communications are absolutely essential to the work, and the people with responsiblity and authority must be on the communication sets, or have immediate access to them.

Three ex-army 88 sets were used for communications between "James No. 95" and the dinghy, and with SURV when she was on the surface. An acoustic communication set produced by N.B.A. Controls, Limited, was used between the dinghy and SURV when she was submerged. There was also a plug-in telephone for contacting SURV on the surface, but the radio and acoustic communications were so reliable that this was superfluous. The acoustic communicator was tested between the dinghy and SURV at a depth of eight fathoms over a range of $\frac{1}{4}$ of a mile, and found completely intelligable. The radios were testing over $\frac{1}{2}$ a mile range from the deck of James to the dinghy, and from the dinghy to SURV when she was out of the water. Maximum range from the dinghy to SURV in the water might be less than this, and from the dinghy to to deck of James probably more.

While heavy loads are frequently handled from vessels without the aid of swimmers or divers, there is a great deal to be said for having people present who accept getting wet, rather than hesitate momentarily before acting at a vital moment. It is the practice in all American and French operations to have swimmers in attendance of submersibles, spacecraft, and so on, and it adds greatly to speed and safety, even if the same operation could usually be carried out with elaborate equipment handled by personnel keeping their feet dry.

During the SURV trials one swimmer was always fully suited up and ready to go in the water, while a second was available with standby diving equipment, though diving equipment was not actually worn at any time except when inspecting and lifting the transponders. It is possible to stand on the deck of SURV in wellington boots, and to unhook the lifting shackles. However a man on the deck tends to tilt the craft when there are two crew members inside, and the operation would be doubly difficult in a rough sea. Tasks routinely carried out by the surface swimmer consisted of moving and attaching lifting hooks, attaching and removing the towing bridle, altering ballast weights for trim, checking motors for freedom from fouling or other damage during lowering, adjustment of photographic target suspended from the frame, observation of SURV to check stability during ascent and descent. The swimmer could also change the claw on the manipulator, remove geological samples from the sample bag, and replace empty corers in the storage frame.

Since the proposed maximum working depth of the trial was 180 to 200ft., which is within the safe range of aqualung diving, the presence of divers on the project was an added safety precaution, both because they could attach a cable to the outside of SURV if it proved necessary to lift her from the surface, and because they have been trained to make free ascent from this depth and could therefore escape from the craft if it were permanently damaged on the bottom.

This insistence on having trained divers on the project was purely because of the experimental nature of the trial. As soon as any submersible has demonstrated some tens of hours of trouble free operation at sea it would be perfectly safe to take anybody diving in it, provided that they were not liable to suffer from claustrophobia.

MANIPULATOR AND ACCESSORIES

For this trial a simple manipulator arm was installed by Lintott. It consisted of a rigid rod which could be extended or pulled back into the hull of the submersible through a sealed ball joint. The movement was compensated by springs for the hydrostatic pressure of the water tending to force the rod back into the hull. A pistol grip operates a rod through the main shaft so that a claw on the outer end can be opened and closed. The pistol grip can be locked in position so that an object can be picked up and held automatically while other tasks are carried out.

The manipulator head could also be fitted with a fixed shovel. In this form the manipulator was tested at a depth of eight fathoms. With SURV resting on the bottom I used the shovel to dig a pit in cohesive silt and sand to a depth of 1ft. The working area of the shovel could be clearly viewed from the porthole, and samples lifted and brought closer to the porthole for examination.

The system for taking and preserving samples was not tested at sea. A rack was mounted in the front of the frame and was in range of the manipulator floor. A sheet of $\frac{1}{4}$" rubber was fixed on an aluminium sheet drilled with 4" diameter holes. The rubber across the holes was cut with two perpendicular slots so that any object pushed through the hole would be firmly held. Sediment samplers were made by wiring 10" linen sample bags onto 4" diameter 6" long polythene tubes with bevelled edges. The samplers were stored on the frame by pulling the bag ends through the slotted rubber sheets. Six samplers could be stored on the rack at one time. To take a sample the manipulator claw was secured and locked on to one of the tubes, and the sample bag withdrawn from the rack. The tube could be scooped into the sea floor and a disturbed sample taken and then the sample bag dropped into a storage sack. As it fell into the sack the weight of the tube tended to make the sample bag bend and close. This system was tested on land but not underwater. Although it sounds primitive, it would enable six numbered samples to be taken on each dive, and for their position to be recorded. This is an advance over the usual method used on submersibles where samples are dumped loose into a sack, and therefore become mixed up.

Although the manipulator is easy to use, and is sufficiently simple for it to be free of technical troubles, the presence of such a sliding ball joint in the hull, however strong, is a weak point. With an extensive rack of experimental equipment in front, the manipulator would not be the first thing to strike in a collision. But in the absence of such a rack, the submersible could drive into an obstacle and break the manipulator shaft, which could result in a steady leak. Nevertheless, in its present form the manipulator is a very useful tool for work done to about 200ft, and provided that SURV does not have to be manoeuvred in an area of uncharted obstacles.

PHOTOGRAPHY

An available light photograph through the floor porthole when the submersible is resting on the bottom covers an area of about 1ft. in diameter. In Plymouth Sound the visibility underwater was 6 to 8ft., but in the open sea, where the visibility was 30ft., it would have been possible to take pictures through the porthole at a range of 10 to 15ft. and consequently obtain a picture of about 6ft. in diameter.

An N.I.O. deep sea camera with shutter was mounted on SURV. One of the firing leads was earthed to the outside of the hull, and the other passed through a seal to the interior. A simple switch enabled the camera to be triggered. The camera was mounted almost vertically to photograph a point directly in front of the porthole, and the flash at about 45° to illuminate the same spot. The focussing range to the sea floor when SURV is resting on the bottom is 5·5 ft., but if SURV hovered off the bottom a picture of about 10ft. in diameter could be taken. As mounted for this trial the exterior camera photographed a sea floor area within which the manipulator could take samples.

NAVIGATION SYSTEM

Two N.I.O. transponders were modified by Mr. M.J. Tucker to give different pulse lengths. These transponders were moored 15ft. off the bottom from 300 lb. sinkers, and buoyed by three trawl floats secured close to them. A 2mm wire was attached to three trawl floats on the surface and a yellow fibreglass dan, supporting a 20ft. aluminium scaffolding pole, radar reflector, and flashing light. It was essential for accurate navigation that the distance between the transponders on the sea floor be known exactly, and so they were connected by 400 yards of 2mm wire on the bottom. The first transponder was dropped, then the bottom line payed out on a north-south axis, the second dan towed out by the dinghy, then the second transponder dropped. To check that the transponders were clear of the bottom and the bottom line really taut, a dive was made on one transponder immediately after placing it in position.

The recorder system was a modified echosounder, prepared by N.B.A. Controls Limited, the transmitter and receiver were mounted on a flexible mast above SURV, and the returning signal plotted by the pen recorder. From the range of the two transponders it would be possible to plot the position of SURV on pre-drawn circle-range charts. (The mounting of the radio aerial and acoustic transducers on a flexible polythene mast was an excellent bit of design, as it protected them completely from damage by knocking on fouling by ropes). Since SURV never dived on the deep water work site the system was not properly tested, but the transmitter, receiver, and recorder were later mounted on the launch "Westward", and signal obtained from the transponders, so that there is little doubt that the system would work.

MAINTENANCE

The batteries require charging at 15 amps for ten hours, and then some time for gassing. A spare set of batteries is carried on board, but changing the batteries requires a 3 cwt. plumb vertical lift, which is a bit difficult to arrange at sea, but can be accomplished rapidly in harbour. Air cylinders for ballast also have to be changed, but this is not such a sensitive operation. Daily recharging of the CO2 absorbent in the life support system is simple. The inverters were extremely unreliable throughout the trial, and it was this unreliability which caused the trial to be stopped.

CONCLUSIONS

The weather conditions and tidal current in the Plymouth area from the 29th April to the 6th May inclusive were such that SURV could have been handled on the surface and underwater every day, provided the motors had been functioning reliably.

Underwater visibility was excellent, and since all the ancillary equipment was demonstrated to work reliably, there is little doubt that the original work programme of mapping and sampling at 200ft. could have been completed, In view of the extreme unreliability of the SURV inverters, it is obviously impossible to recommend that this craft is suitable for oceanographic work in its present form, or in fact even to say that it has been tested properly. Nevertheless, failure to achieve the main goal can be attributed to one identifiable technical fault, and the successful testing of the other equipment, and the general ease of handling of SURV from the mother ship, shows beyond doubt that a small submersible can be used in British waters to obtain scientific results.