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70. That following commissioning, THRESHER conducted operations in the Eastern Atlantic area, for the purposes of shakedown, training and evaluation.
71. That this was a much longer operating period than is normal before a post shakedown availability, and was provided because of the need to test the many new developments and equipments incorporated into THRESHER.
72. That THRESHER conducted about 40 dives to test depth (B1) feet) during this period. (CONF)
73. That from 16 April 1961 to 21 May 1962 THRESHER visited the Electric Boat Division of General Dynamics Corporation, Groton, Connecticut, for instrumentation and shock hardening in preparation for scheduled shock tests.
74. That during this availability, 115 silver brazed joints in her hydraulic systems were tested by ultrasonic means. Of these, eight did not meet all requirements of then existing bonding standards. Two of these joints were replaced. The remaining six were accepted after decision by the Bureau of Ships that the existing deficiencies were not such as to warrant replacement. (CONF)
75. That these six joints all satisfactorily withstood the shock tests which followed. (CONF)
76. That during a visit to Cape Canaveral in early June, THRESHER was struck by a tug and suffered damage to the exterior plating of one of the main ballast tanks.
77. That THRESHER returned to the Electric Boat Division, where all damage was repaired.
78. That a thorough inspection revealed no damage to the pressure hull nor any damage which affected the safety of the ship.
79. That shock tests of THRESHER were conducted in the Key West area during the period 17 - 29 July 1962. (CONF)
80. That the shock tests involved detonation of B1 (SECRET)
81. That the maximum shock factor was B1 (SECRET)
82. That similar shock tests have been conducted against other submarines, including nuclear submarines. (CONF)
83. That the shock factor (relationship between the weight of the charge, and the slant range) was (CONF)

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84. That during THRESHER's shock tests, there was no loss of main power, and no hull rupture was suffered. (CONF) ✓
85. That a number of derangements occurred to joints, fittings, bolts, rivets, straps and some machinery foundation elements. (CONF) ✓
86. That although an inspection was made and damaged items were scheduled for repair during the post shakedown availability, additional items continued to become evident, even in the late stages of the availability. (CONF) ✓
87. That several days after the shock tests, THRESHER made a dive to B<sub>1</sub> or B<sub>2</sub> feet, during which a minor leak was discovered in the #2 PUFFS hydrophone weld. (CONF) ✓
88. That depth was limited to less than 200 feet until the post shakedown availability when the nature of the damage could be determined. (CONF) ✓
89. That full power trials were conducted en route to Portsmouth, New Hampshire, for post shakedown availability.
90. That THRESHER arrived at Portsmouth 11 July 1962.
91. That the commanding officer's evaluation of the first year of operations is contained in his letter, serial 086 of 16 November 1962.(Ex. 111). (CONF) ✓
- a. He called THRESHER "the best ASW submarine afloat today."
  - b. He pointed out THRESHER's deficiencies, highlighting the following:
    - (1) Overly complex in many areas.
    - (2) Difficult to handle on surface or near surface.
    - (3) Vulnerability of auxiliary sea water system.
  - c. He stated, "In my opinion the most dangerous condition that exists in THRESHER is the danger of salt water flooding while at or near test depth."
92. That post shakedown availability commenced on 16 July 1962, with an estimate of approximately 35,000 man-days and a scheduled duration of six months.
93. That major jobs originally scheduled for post shakedown availability included hard tank stiffening, conversion of hydraulic systems from cellulube to petroleum based oil, items based on findings of the Board of Inspection and Survey, and repairs found necessary as a result of inspections to be made for shock trial damage. (CONF) ✓
94. That the post shakedown availability grew by addition of new work, including a large job involving the PUFFS (Passive ranging sonar) equipment, extensive items pertaining to additional noise reduction, and other modifications. (CONF) ✓

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95. That THRESHER's post shakedown availability completion date was successively extended from 18 January to 15 February, to 28 February, to 30 March, to 2 April, and finally to 11 April, because of work added and the under-estimation of the effects of new and old work. The total of man-days expended was over 100,000.

96. That damage to THRESHER caused by shock tests was intensively investigated by ship's force, Bureau of Ships, and Shipyard personnel after the tests, during sound trials and transits, and on return to Portsmouth Naval Shipyard. Despite such efforts, shock damage continued to be found during the entire post shakedown availability. Of significance was the discovery of loose condenser foundation bolts in January, 1963, and a misaligned torpedo ejection pump in March, 1963. This pattern of continuing discovery of shock damage during post shakedown availability parallels that found in SKIPJACK and SKATE in similar extended availabilities after shock trials.

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(CONF)

97. That at THRESHER's arrival conference, a visual and ultrasonic surveillance of sil-braze joints 2 inches and larger in sea water systems which were unlagged and accessible was placed on a not-to-delay vessel basis.

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(CONF)

98. That by letter to the Commander, Portsmouth Naval Shipyard dated 28 August 1962, the Bureau of Ships (Exhibit 115):

- a. Called attention to the fact that gross failures of sil-brazed joints in vital submarine systems made it a matter of urgency to develop an inspection program for them.
- b. Directed Portsmouth Naval Shipyard to "employ a minimum of at least one ultrasonic test team throughout the entire assigned post shakedown availability to examine, insofar as possible, the maximum number of sil-braze joints."
- c. Requested Portsmouth Naval Shipyard to forward comments, suggestions and recommendations based on results of the tests.

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(CONF)

99. That job orders issued for the surveillance inspection called for use of one ultrasonic test team, to test first those joints not lagged, and provided that if time permitted thereafter, lagging would be removed to permit tests of additional joints.

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(CONF)

100. That the job orders called for periodic reports of results of tests to the Planning and Estimating and Design Divisions.

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101. That the periodic reports of sil-braze inspections were not forwarded as requested. Condition sheets of individual defects were forwarded. (CONF) ✓
102. That by 29 November 1962, 145 old joints had been ultrasonically tested in the surveillance program, with a rejection rate of 13.8 per cent. (CONF) ✓
103. That the standard prescribed by the Bureau of Ships for acceptance of a sil-braze joint by ultrasonic test was 40 per cent bond, 25 per cent minimum, either land. (CONF) ✓
104. That on 29 November 1962, the Quality Assurance Division reported the results of the survey of old joints to Planning and Estimating Division and requested decision as to whether lagged joints should be unlagged for testing. (CONF) ✓
105. That decision was made on 4 December 1962 not to unlag and ultrasonically test additional old joints in THRESHER. This decision was known to the management personnel of the Shipyard, including the Production Officer and the Commander, who were apprised of the results of the survey. (CONF) ✓
106. That a copy of this decision was furnished the Commanding Officer of THRESHER. (CONF) ✓
107. That no further ultrasonic testing of old sil-braze joints was conducted pursuant to this program after 29 November 1962. (CONF) ✓
108. That neither the results of the surveillance nor the decision not to proceed further with ultrasonic tests of old joints was made known to the Bureau of Ships or to anyone in the operational command line higher than the Commanding Officer of THRESHER. (CONF) ✓
109. That Portsmouth Naval Shipyard management and workers exhibited a high degree of confidence in sil-braze joints in THRESHER's piping systems.

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110. That the results of ultrasonic tests on sil-braze joints in SCULPIN and SKIPJACK during shipyard availabilities were as follows:

<u>Ship</u>	<u>Shipyard</u>	<u>Approximate Date</u>	<u>Joints Tested</u>	<u>Rejected Joints</u>
SCULPIN	Mare Island	April 1962	387	22.2%
SKIPJACK	Portsmouth	August 1962	322	22.5%

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(CONF)

111. That prior to THRESHER's post shakedown availability, there had been reports of serious failures of sil-braze joints in BARBEL, SKATE, SNOOK, SCULPIN, ETHAN ALLEN and THRESHER. *Bi*

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(CONF)

112. That the approximate number of sil-braze joints in an S5W reactor equipped ship is *L Bi* and above in hazardous systems.

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(CONF)

113. That results of the ultrasonic tests of sil-braze joints in SKIPJACK were not reported by Portsmouth Naval Shipyard to the Bureau of Ships, Deputy Commander Submarine Force, U. S. Atlantic Fleet, or higher authority.

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(CONF)

114. That flexible hoses were replaced during THRESHER's availability in accordance with process instructions existing in the Shipyard.

115. That the process instructions did not fully define specifications for allowable twist.

116. That a training program existed for making up flexible hoses.

117. That no formal training program existed for installing flexible hoses.

118. That some flexible hoses were twisted in initial installation, but were corrected.

119. That an inspection program for flexible hose installations existed and was carried out.

120. That a comprehensive flexible hose listing was prepared for THRESHER. This was used for quality assurance planning and inspection.

121. That some valves in THRESHER's hydraulic, auxiliary sea water and other systems were installed backwards during the post shakedown availability to permit testing of systems, some due to inadvertence and one due to an error in the ship's plans; however, all were corrected and properly installed prior to departure of the ship for sea trials.

122. That the Ship Information Book and working plans for THRESHER's auxiliary sea water system call for cross-connection of the system as the normal operating mode. Installation of new check valves in the constant vent portion of this system during the post shakedown availability made possible complete separation of the auxiliary sea water system into two loops.

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123. That high pressure air and hydraulic systems require a high order of small particulate matter rejection during fabrication, installation and repair.
124. That difficulties were experienced in operating the high pressure air system, and in leakage from the reducing valves. These difficulties, which began early in the life of the ship and extended throughout the post shakedown availability, appeared to stem from the presence of minute particles in the system.
125. That the difficulties with the high pressure air valves, particularly leakage and venting, were reported as having been corrected prior to sea trials.
126. That the hull repairs, access patches and hull stiffening work was done in accordance with existing Bureau of Ships instructions and was checked by non-destructive test means as being satisfactory.
127. That the hull surveillance inspection scheduled during the post shakedown availability was completed.
128. That after the final system test of the auxiliary sea water system aft, Reserve Feed Tank No. 2 was over-pressurized on 8 March 1963. (CONF) U
129. That the Reserve Feed Tank top was displaced one to two inches by over-pressurization and the ship's B1 gallon-per-day distiller was also displaced. (CONF) U
130. That the drain line and other lines mounted on the reserve feed tank top were affected by the displacement of the top. (CONF) U
131. That the distiller was restored to its proper position and checked by visual, hydrostatic and short operational test. (CONF) U
132. That the reserve feed tank was repaired and tested by pressure and other non-destructive tests. (CONF) U
133. That based on a decision that no overstress problem was involved, drain and other lines on the tank top were not tested, nor were stress calculations made prior to sea trials. (CONF) U
134. That stresses calculated after the loss of THRESHER by two separate activities indicated that stress levels on the drain and other lines mounted on the tank top were not excessive. (CONF) U
135. That the auxiliary sea water system aft was not retested following the casualty to the reserve feed tank. (CONF) U
136. That documentation of ship's systems, components and normal operating modes was not delivered to THRESHER by the end of her construction period. It was never made complete and accurate in all respects. (CONF) U

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137. That detailed damage control studies of flooding casualties, consequences, and recommended actions were not required by the building specifications for THRESHER.

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(CONF)

138. That the first dockside simulated operational cruise for purposes of crew training (fast cruise) was held 23-26 March 1963, and was terminated because of the large number of material deficiencies noted; the second and last "fast cruise" was begun on 31 March and satisfactorily completed on 1 April 1963.

139. That Atlantic Fleet Submarine Force Instructions did not require and THRESHER's sea trial agenda for deep dives on 10 April 1963 did not provide for, operation of sea valves at various depths prior to proceeding to test depth for the first time after her post shakedown availability.

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(CONF)

140. In the second "fast cruise"; during one of the drills involving a simulated flooding casualty in the after auxiliary sea water system, it required twenty minutes to isolate a leak. This was one of the early drills. Changes had been made in the system involved during the post shakedown availability.

141. B1

There was no evidence to indicate that THRESHER planned to test the operation of sea valves at various intermediate depths en route to test depth on her first deep dive. There is evidence that it was planned to do this on a second scheduled dive to deep depth.

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(CONF)

142. That THRESHER was at the Sound Pier for sound trials during the period 1 April to 4 April, and in drydock from 4 April to 8 April 1963, to make repairs to torpedo door shutters and main circulating water valve MSW5. During this period liberty was granted to the crew.

143. That testing of systems was in accordance with Portsmouth Naval Shipyard Instruction 4855.2 and the substance of Portsmouth Naval Shipyard Instruction 4730.8 (of March 1963), and other applicable instructions. A comprehensive test program was conducted.

144. That the number of people in the quality assurance program in the Portsmouth Naval Shipyard has increased from 152 to 243, and the direct expenditures for the program from approximately \$1,200,000 to approximately \$2,800,000 in the past two years.

145. That all work undertaken by the Shipyard during THRESHER's post shakedown availability was reported as having been completed satisfactorily, and the Commanding Officer expressed his concurrence that the work was complete.

146. That Portsmouth Naval Shipyard has had an extensive training program over the past two years, expending about \$1,300,000 in the Shipyard, of which the Pipe Shop (56) portion was about \$400,000.

147. That during THRESHER's post shakedown availability, the total work effort performed at Portsmouth Naval Shipyard also included construction of five submarines, one submarine conversion and the overhaul and repair of five submarines; other minor ship repair work and some manufacturing

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148. That starting in 1962 there was a joint identification plant prepared by shipyards for new construction submarines.

149. That at the Portsmouth Naval Shipyard there is no standard method for maintaining in one place, on or near a ship, a documented status of ship's systems as regards operational status, components removed, components unusable, restrictions, etc; such a procedure is often called a "rip out" procedure. It involves authorization documents, instructions for tagging of removed components, assignment of component responsibilities, etc.

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150. That Portsmouth Naval Shipyard has authority to deviate from building specifications in certain areas, and is using the specifications as goals rather than requirements in certain cases.

151. That workers and management at Portsmouth Naval Shipyard are not in all cases adhering to the process and procedure documents to insure the benefits which derive from such documents.

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152. That Portsmouth Naval Shipyard considers the state of cleanliness of Shop 56 (Piping Shop) not adequate to permit work of requisite quality. This was confirmed by a view of the premises taken by the Court. The Shipyard is constructing "clean room" facilities for manufacture and assembly of air and hydraulic piping systems.

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153. That during the course of proceedings, a test demonstration for the Court of Inquiry was held in Drydock No. 2 at the Portsmouth Naval Shipyard. A stream of water was released to atmosphere at THRESHER's test depth pressure against a piece of electronic equipment. The stream produced tremendous force, spray, fog and noise.

154. B1

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155. That the complexity of modern submarines has increased at a rapid rate. The advent of nuclear propulsion, ballistic missiles, and greatly increased speeds and operating depths has made it essential that all information affecting their safe operation be analyzed and promptly disseminated.
156. That Commander Submarine Force, U. S. Atlantic Fleet, has a system of disseminating information which affects submarine operational safety.
157. That there is at present no organization at any level within the Navy with the sole responsibility for submarine safety.
158. That submarine diving trainer equipment does not have the capability to simulate the attendant effects of large flooding and associated damage control situations for training. (CONF)
159. That all submarines are now restricted to a maximum depth of BI feet. (CONF)
160. That during the past four years, the Navy's annual shipbuilding program has increased from approximately \$2,500,000,000 to \$4,500,000,000.
161. That during the past four years, the civilian personnel ceiling of the Bureau of Ships in Washington, D. C. has been reduced from 3800 to 3100.
162. That during the period from 1959 to 1963, the number of naval officers designated for Engineering Duty (ED) has declined from 1057 to about 840.
163. That the number of naval officers serving as technical and management officers in the Portsmouth Naval Shipyard has been reduced over the past few years. This is particularly serious in the Design Division where, in 1956, five Assistant Design Superintendents were assigned - none is so assigned today; and in the Shipbuilding and Repair Division, where the loss of ten qualified officers (mainly ED) in 1961 and 1962 has reduced capabilities.

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164. That during recent years, the advent of the nuclear submarine has resulted in a major increase in the complexity and difficulty of submarine design, construction and maintenance.

165. That the increase in complexity of nuclear submarines has resulted in an appreciable increase in the responsibilities imposed upon their commanding officers during the construction and post shakedown availability periods.

166. That the following changes of key personnel were effected during THRESHER's post shakedown availability:

- a. There was a change of THRESHER's Commanding Officer in January, 1963.
- b. There was a change of THRESHER's Executive Officer in January, 1963.
- c. There was a change of THRESHER's Ship Superintendent in December, 1962.
- d. There was a change of THRESHER's Assistant Ship Superintendent in November, 1962.

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OPINIONS

1. That the loss of the U.S.S. THRESHER was in all probability due to:
  - a. An initial flooding casualty from an orifice between 2" and 5" in size in the engine room, which continued, compounded by
  - b. Loss of reactor power due to an electrically-induced automatic shutdown,
  - c. Inadequate operating procedures with respect to minimizing the effects of a flooding casualty and the loss of reactor power, and *Bi* (CONF)
  - d. A deficient air system, susceptible to freeze-up, with low capacity and low blow rate.
2. That there is a danger that, in melding together fact and conjecture, conjecture may be stretched too far and become accepted as fact, thus narrowing the field of search for possible causes of the casualty.
3. That the fact that the court has singled out certain cases for study should not deter others, particularly members of the crews of similar ships, from continuing to study the many questions raised by the THRESHER's loss.
4. That it would be prudent to retain the current interim depth limitation now imposed upon all submarines until each individual submarine's readiness has been reassessed in regard to the factors listed in Opinion 1 above. (CONF)
5. That a flooding casualty in THRESHER could have resulted from:
  - a. A faulty sil-braze joint.
  - b. Undiscovered shock damage. (CONF)
  - c. A flexible hose failure.
  - d. A casting or piping failure.
  - e. A minor hull failure.
  - f. Unknowns, including component failure.
6. That loss of reactor power in THRESHER could have resulted from:
  - a. Inadequate protection of electrical switchboards from salt water, particularly from below.
  - b. Location of vital equipments and back-up equipments where a single casualty could inactivate both. (CONF)
  - c. Other causes.

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7. That submarine operating procedures at the time of the loss of THRESHER were inadequate, in that:

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- a. Cross-connecting of sea water systems was excessively used, particularly at deep submergence.
- b. The concept of securing salt water systems on a flooding casualty and the resulting operating limitations and capabilities had not been appropriately investigated.
- c. The concept of Bi with the attendant advantages was not generally appreciated and was not followed on the deep dive of THRESHER.
- d. Bi
- e. Pre-planned damage control actions and system isolations in order to reduce flooding control reaction time had not been fully explored.
- f. Submarine Force, Atlantic Fleet Instructions did not require and THRESHER agenda for deep dives on 10 April 1963, did not provide for operation of sea valves at various depths to insure proper operation prior to proceeding to test depth for the first time after a protracted overhaul.

8. That THRESHER Class main ballast tank blow system deficiencies were found to be as follows:

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- a. An inadequate blow rate.
- b. An inadequate capacity.
- c. A tendency to freeze up at line restriction points; for example, at the conical strainers in the reducing valves, and
- d. A designed closing of the on-line air bank valves when electric power was lost, followed by a 10-50 second air equalizing delay time before the reserve bank is available on the line.

9. That to provide maximum safety at deep depths Bi feet and greater), all large sea water system hull and stop valves should be hydraulically operable. To provide maximum assurance of operability, sea valves should be operated from a primary station in or near a normally manned area, while hull valves should be operated from a different station, so located that a leak would not prevent access to at least one station.

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10. That a low pressure auxiliary sea water system (low pressure fresh or salt water) would greatly reduce the possibility of flooding at deep depths and should be provided in new construction at an early date. (The great reduction in the length of piping and hoses exposed to sea pressure would

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eliminate the need for considering many of the solutions proposed hereafter for the currently installed systems. Their consideration is desirable for submarines already built and under construction. A heat exchanger installation is probably the quickest way to provide a low pressure auxiliary sea water system, but other methods should be investigated.)

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(CONF)

11. That the basic auxiliary sea water loop system concept and design for the THRESHER Class is good, and is an improvement over the single header "Christmas tree" systems installed in other nuclear submarines.

12. That operation of the current auxiliary sea water system in the <sup>Bi</sup> with remote control from a single operating station, preferably the maneuvering area, would improve overall system reliability and safety, particularly from a system isolation viewpoint; therefore, the Ship's Instruction Book and working plans for the THRESHER Class auxiliary sea water system which call <sup>Bi</sup> should be modified at the earliest to require split plant operation as normal mode.

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(CONF)

13. That the constant vent system in the THRESHER Class is a safety hazard.

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(CONF)

14. That constant vents in submarine auxiliary sea water systems need to be closed at deep submergence to increase the safety of the ship; design of components must take this into account.

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(CONF)

15. That there were many reasons for the Bureau of Ships and Portsmouth Naval Shipyard continuing the use of sil-braze joints in piping systems of submarines. These included: years of shipbuilding practice and service, extensive test, improvement in processes and non-destructive test techniques, the lack of weldable fittings, and the high welded-joint rejection rates in all shipyards.

16. That prior to THRESHER's post shakedown availability, there had been a sufficient number of serious failures of sil-braze piping joints in submarines to require thorough investigation by all responsible for THRESHER's safety. (Fact 111)

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(CONF)

17. That there were indications of high rejection rates of sil-braze joints made in the period 1958-1961 in shipyards other than the Portsmouth Naval Shipyard (Fact 110)

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(CONF)

18. That Portsmouth Naval Shipyard did not aggressively pursue the ultrasonic inspection of sil-braze joints in THRESHER as required by the Bureau of Ships letter of 28 August 1962 (Exhibit 115). Deputy Commander Submarine Force, U.S. Atlantic Fleet did not aggressively pursue the ultrasonic inspection, nor did the Commanding Officer, THRESHER.

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19. That the rejection rate of 13.8% on original sil-braze joints in THRESHER was a clear indicator that additional action was required.

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20. That the confidence of the Portsmouth Naval Shipyard personnel in sil-braze joints was not fully warranted in the case of the auxiliary sea water, trim and drain, or air conditioning systems in THRESHER because:

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- a. Several submarines had suffered casualties which nearly resulted in their loss. Of these, the most pertinent was the U.S.S. Barbel, which suffered a failure of a 5-inch sil-braze joint on 30 November 1960 at an approximate depth of 31 feet.
- b. BARBEL investigation showed inadequate quality assurance in Portsmouth Naval Shipyard sil-brazing process prior to 1961.
- c. There had been no extensive retrofit of high quality sil-braze joints under the improved quality developed by Portsmouth Naval Shipyard after THRESHER's initial criticality.
- d. Portsmouth Naval Shipyard had conducted ultrasonic tests on sil-brazed systems in SKIPJACK, finding about 22.5 per cent of joints not meeting the Bureau of Ships prescribed standards. In this case the Shipyard did not report the results to the Bureau of Ships or to Deputy Commander Submarine Force, U.S. Atlantic Fleet.
- e. No ultrasonic tests of original sil-braze joints in the auxiliary sea water or trim and drain systems in THRESHER had been conducted prior to the post shakedown availability.

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21. That the management of the Portsmouth Naval Shipyard did not exercise good judgment in determining not to unlag pipes in order to continue the directed ultrasonic test surveillance of original sil-braze joints in THRESHER after November 1962.

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22. That the Bureau of Ships improvement and corrective actions regarding the sil-braze problem were not applied at the Bureau level, or in the field, with sufficient vigor in that:

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- a. The continuing flow of information from the operating forces indicated that poor workmanship or design had resulted in inferior and unsatisfactory applications of the silver braze process; this should have resulted in more detailed investigation of the adequacy of sil-braze in hazardous systems;
- b. There was insufficient inspection and audit by the Bureau of the shipbuilding and repair activities to insure that specifications were being met; and
- c. The best tool for determining adequacy of sil-braze, i.e., ultrasonic inspection, was not sufficiently exploited from a coverage or timeliness basis.

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23. That it appears that insofar as submarine shock tests are concerned: <sup>U</sup> ~~(SECRET)~~

- a. The instrumentation and inspection techniques and levels of effort utilized to date have not insured that all damage is found in the early intensive investigations of damage.
- b. That more effort and instrumentation is required to insure that all damage has been found.
- c. <sup>BI</sup>
- d. That until the matters mentioned briefly in a, b. and c. above are more fully explored and necessary actions are taken, it would be prudent to:
  - (1) Limit the shock factors used in shock tests to or less.
  - (2) Increase considerably the level of action in arranging shock tests to provide intensive planning, calculation of effects, instrumentation and inspection before and after such tests.

24. That in view of the many potential sources of casualties and their serious consequences in high performance submarines, such as THRESHER, there is a need to re-emphasize and improve, where indicated, the quality assurance program in shipbuilding and repair yards.

25. That the quality assurance program of the Portsmouth Naval Shipyard would be improved by appropriate consideration of the following:

- a. Quality Assurance Division should report directly to the Shipyard Commander.
- b. Quality assurance should be engineered and planned, utilizing the statistical approach and should de-emphasize the "inspector" approach.
- c. Quality assurance audits should be forwarded to management on a regular basis.
- d. Quality assurance should record all defects, not just remaining defects (for example, brazers and inspectors reject joints and do not report defects found which are readily correctable. This method does not reveal to management all process deficiencies).
- e. Quality assurance ultrasonic test and welding radiographic test requirements should not depend on initiation of inspection requests by pipefitters and welders, but should be separately initiated by the job order preparing authority to facilitate cross-checking.

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- f. A quality assurance program should be developed for flexible hose installation and checkout.
  - g. The Quality Assurance Division does not currently have power to disqualify workers observed to be violating procedures, process controls and normal operating instructions, but must so recommend to the shop supervision involved. It might be advisable to permit quality assurance personnel to temporarily remove qualifications (brazers' cards, etc.) under such circumstances to insure that defective work is not built into submarines during the normal administrative handling time for disqualification action.
  - h. Welding quality is under the Welding Engineer and is not completely integrated with the quality assurance program in the same manner as other processes are. It is believed desirable to integrate this effort.
  - i. Condition sheets (for defects discovered) should be reviewed, analyzed and summarized by the Quality Assurance Division for presentation to management to insure that process deficiencies are brought to management's attention.
26. That the Portsmouth Naval Shipyard attitude towards, and facilities for, minute particulate matter rejection, in general, are not conducive to delivery of high performance systems of the requisite super-cleanliness. Processes of fabrication, installation and repair of such piping systems require engineering revision and facility preparation and, more importantly, personnel training to provide an adequate basis for super-cleanliness. (This is most important for high pressure air and hydraulic systems, but is applicable for other systems.) (CONF)
27. That dummy valves used as spacers and valves installed backwards for tests should be so marked (tagged) and should be designated in the ship's system status or "rip out" procedure.
28. That the quality of work performed by Shop 56 (Pipe Shop) at Portsmouth Naval Shipyard has improved since the BARBEL incident, particularly in the sil-braze area and in material identification and control, workmanship and quality assurance.
29. That type commanders should be provided with the capability to evaluate hull surveillance information for each individual submarine. (CONF)

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30. That an identification and listing program for flexible hoses, as provided by Portsmouth Naval Shipyard for THRESHER, was excellent and should be provided for all submarines. (CONF)

31. That the pipe joint identification program developed in 1962 by submarine new construction shipyards should be applied to earlier submarines to provide a sound basis for checking joint quality verification (CONF)

32. That those responsible for Submarine Ship Information Books should insure that they are completed and delivered with the ship. (CONF)

33. That there is a need at Portsmouth Naval Shipyard for additional detailed written repair procedures, inspection routines and quality assurance audit programs, to: (CONF)

- a. Insure that repairs to submarines are, in fact, accomplished in accordance with the sound engineering judgment available.
- b. Insure that management's policy is fully carried out.
- c. Permit planned audit procedures for quality assurance to provide the high assurance of quality and safety necessary.
- d. Provide the basis for management information for problem-solving.

34. That a "Ship's System Status" or "rip out" procedure is needed to maintain information on the status of the complicated systems of nuclear submarines and the division of responsibility between the submarine and the Portsmouth Naval Shipyard. (CONF)

35. That contract designs of submarines determine the basic operational and safety procedures; therefore, it is important that the Bureau of Ships should: (CONF)

- a. Insure that design personnel are familiar with operational procedures, B1
- b. Insure that there is adequate feedback of information on earlier systems from shipbuilding yards and submarine operating personnel.
- c. Insure that damage control under various casualty conditions is thoroughly considered before the final system parameters are rigidly defined, and B1
- d. Insure that design personnel become familiar with each other's problems and goals; in effect, break down the walls which apparently compartment such personnel into small areas of expertise.

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36. That the basic design of THRESHER Class submarines is good, and its implementation resulted in the development of a high performance submarine. There are certain improvements desirable to increase the safety margin, as set forth in the recommendations.
37. That since high performance submarines require full quality assurance and a high degree of uniformity, the Bureau of Ships should require adherence to specifications.
38. That all submarine air system design criteria need to be reviewed for adequacy and safety. Of particular importance are the following: (CONF)
- a. Air blow rate for main ballast tanks.
  - b. Air bank capacity.
  - c. Effect of depth.
  - d. Air condition as regards:
    - (1) Particulate matter rejection
    - (2) Moisture
  - e. Air system mechanical design for inclusion of and positioning filters, strainers and dehydrators.
  - f. Emergency blow capability.
  - g. Number of allowed pressure reductions in air system.
  - h. Allowable mechanical pressure reduction devices in main ballast tank normal and emergency blows.
  - i. Provision of internal drainage of water from air banks into the pressure hull.
  - j. Emergency de-ballasting by chemical gas generation or other means.
  - k. The fail-closed concept for the three air banks now normally carried on the line in the THRESHER Class is not desirable for safety of the ship at test depth and should be modified to provide fail-on-the-line; i.e., air bank valves open.
39. That the high pressure blow of submarine main ballast tanks needs to be tested under conditions simulating a full blow at test depth. (CONF)
40. That equipment locations in the THRESHER Class submarines are not so selected as to maximize resistance to damage and to facilitate control after damage; for example:

a. B1

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- b. That protection from water streams and spray of the <sup>Bi</sup> KW ship's service motor generator sets and their electrical connections in the auxiliary machinery space in the THRESHER Class submarines needs improvement.

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(CONF)

41. That electrical switchboards in the auxiliary machinery space and engine room of submarines are not sufficiently protected from water streams or spray, especially from below.

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(CONF)

42. That the deficiencies which probably caused THRESHER's loss (Opinion 1) could have been reduced by thorough and imaginative analysis and timely dissemination of all information to be had from the BARBEL and other casualties.

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(CONF)

43. That submarine diving trainers do not have sufficient capability for simulation of flooding casualties and resulting damage control action. These trainers are important, both for training of personnel and for development of operating procedures for recovery from many casualty situations.

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(CONF)

44. That there is a lack of information regarding operating procedures for submarines under varying casualty situations.

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(CONF)

45. That the following is a reasonable rationalization of probable events in THRESHER between 0909-0918.1R on 10 April 1963:

It is recognized that the specific nature of the THRESHER loss cannot be determined by assumptions and computer solutions based on those assumptions. The following analysis is made in an effort to determine the parameters of the unknown factors, such as size of leak, by utilizing known factors and the most probable variants of their interpretation as the inputs for computer solutions. It is impossible, with the information now available, to obtain a more precise determination of what actually happened.

Analysis of all of the facts available led to the conclusion that the location of a flooding casualty which might have initiated the loss of THRESHER was in the engine room.

From the many computer solutions there emerge three which bracket the probable actual situation.

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It is known with reasonable certainty that at 0909R the THRESHER was at test depth. At about 0910R a message from THRESHER announced a course change to 090 T from 000°T and gave no indication of any difficulty.

It is known, without much doubt, that at 0911R the main coolant pumps of THRESHER, which had been running <sup>Bi</sup> since the start of the dive, either stopped or were slowed. <sub>Bi</sub>

If the main coolant pumps stopped, there would have been an automatic reactor shutdown (SCRAM). This would have meant no normal main propulsion power available until after the 7.1 minutes between 0911R and time of collapse depth. There is an Emergency Propulsion Motor which could be run from the battery, but it must be unclutched from main turbine drive and the power available from this source is only sufficient for about 5 knots.

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If, instead of stopping, the main coolant pumps had B1 and main propulsion therefore kept available, there could have been power for about B1 knots.

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In Case I of the three computer solutions the assumptions were:

1. At test depth.
2. On main propulsion at about 8 knots, B1
3. Power lost at 0911R when pumps stop.
4. Emergency propulsion motor placed on propulsion at 0913R.
5. Blow of main ballast tanks from 0913.6 to 0914.1R.
6. Collapse at 0918.1R.

The ship trajectory curve developed by computer solution of this case showed it to be not highly probable, mainly due to the fact that the ship would have decreased depth only about 100 feet by the time the message was transmitted saying, "Experiencing minor difficulties . . ." etc.

In this case, assuming a reasonably good trim, the size of orifice through which flooding could have occurred (with .8 coefficient of discharge) would have been greater than 2" and nearer 2" than 3".

In Case II the assumptions are:

1. At test depth.
2. On main propulsion at about 8 knots, B1
3. On a turn with 20° right rudder and 5° down angle on the boat.
4. At 0910.5R flooding occurs and pumps B1
5. Full speed and 15° up angle ordered at 0911R.
6. Main propulsion power remained available at least until 0912.5R, at which time a speed of about B1 knots would have been reached.
7. Main ballast tank blow initiated at 0909.8R and terminated at 0911.3R.
8. Second main ballast blow began at 0913.6R and ceased at 0914.1R.
9. Collapse at 0918.1R.

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Had the main turbines remained on propulsion much longer than 0912.5R with the main coolant pumps <sup>Bi</sup> THRESHER could have surfaced with a flooding casualty due to any pipe rupture in the ship except <sup>Bi</sup>. The next smaller pipe size in THRESHER is <sup>Bi</sup>. Even a <sup>Bi</sup> size line rupture would produce excessive trim angle prior to the time of the message which indicated "minor difficulty." Main circulating water line rupture or hull rupture are dismissed as remote possibilities, since the actual hull collapse occurred at 0918.1R and would have occurred much earlier had either of these two casualties occurred, causing the change in power at 0911R.

In Case III the assumptions are:

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The same as in Case II, except that both flooding and full speed with a 15° up angle occur 1.5 minutes earlier.

This is the most probable approximation of the sequence of events. The ship trajectory curve developed from a computer run with these assumptions indicates that, just prior to the sending of the "Minor difficulties ..." message at 0913R, depth would have been reduced to about <sup>Bi</sup> feet, and no trouble would yet have developed in maintaining the ordered 15° up angle.

The air blows postulated in both this case and in Case II are predicated on indications on <sup>Bi</sup> and on the demonstrated tendency for the strainers in the air reducing valves to ice up and fail in approximately the times indicated in the assumption. Furthermore, the phrase "Am attempting to blow ..." in the 0913R message would not be inconsistent with a 90 second blow which had been interrupted by a frozen reducer at 0911.3R or an electrical failure which would have imposed a denial of main ballast tank blow capability for at least ten to fifty seconds.

Case III indicates a hole of a little more than <sup>Bi</sup>.

From all of these studies, it would appear that the flooding which occurred was through a hull orifice (with coefficient of discharge of .8) <sup>Bi</sup> but not much larger than <sup>Bi</sup>. The corresponding pipe sizes in THRESHER's piping systems would have been between <sup>Bi</sup>.

46. That manpower loading by the Shipyard in the last two weeks of THRESHER's post shakedown availability was not excessive.
47. That THRESHER's crew had adequate time for rest immediately prior to departure for sea trials.
48. That the Commanding Officer, SKYLARK, failed fully to inform higher authority of all the information available to him pertinent to the circumstances attending the last transmission received by SKYLARK from THRESHER on 10 April 1963, as it was his duty to do, for an unreasonable length of time; but that this could not conceivably have contributed in any way to the loss of THRESHER and was not materially connected therewith.

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49. That although we may never learn the exact cause of the tragic loss of THRESHER, we do know enough to make it necessary for us to explore in depth the many possible causes, to the end that their correction may reduce the probability of a future submarine loss from the same cause.

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(CONF)

Some of the possible causes are in the material and operational fields and have been separately treated. Less tangible and more difficult are the possible causes that fall in the personnel field.

THRESHER was well manned by experienced officers and men. They enjoyed the respect of their contemporaries and had earned it.

Portsmouth Naval Shipyard Management and workers looked upon THRESHER as their finest creation. They were proud of her.

Yet, in conscience, the court must report that there are causes in the personnel field which may well have contributed to the loss of THRESHER, and which deserve earliest attention at the highest level.

During a period of expanding volume of work and greatly increasing technical complication in submarine construction and repair, the court finds that the numbers of specially trained, technically competent officers, in both the Bureau of Ships and in the Portsmouth Naval Shipyard, have been seriously reduced. Some of these have been replaced by civilian engineers, but the workload on the officers remaining continues to increase. This situation is seriously impairing the submarine building and repair programs.

At the Portsmouth Naval Shipyard it is resulting in a reduced level of attention to vital submarine design and operational matters which could affect safety. If the situation continues, Portsmouth Naval Shipyard could well become an unreliable and unsafe activity just at the time when the overhaul of Polaris Fleet Ballistic Missile submarines must begin.

50. That the nuclear submarine program is placing upon the Navy and the nation demands for highly qualified and trained manpower in great numbers.

✓  
(CONF)

The Navy has established training programs to provide the officers and men to man and operate our highly complex and advanced new submarines, but urgent steps are required to attract into the submarine program and to hold the high caliber young men necessary for safe operation of our submarine force.

51. That during the overhaul and post shakedown availability periods, the responsibilities of the commanding officers of these increasingly complex submarines have become so extensive as to require a high order of technical backup from the operational chain of command. This backup is presently limited by the lack of adequate numbers of officers experienced in the operation of high speed submarines.

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52. That the evidence does not establish that the deaths of those embarked in THRESHER were caused by the intent, fault, negligence or inefficiency of any person or persons in the naval service or connected therewith.

53. That the substantially contemporaneous transfer of THRESHER's Commanding Officer, Executive Officer, Ship's Superintendent and Assistant Ship's Superintendent in the final portion of her post shakedown availability was not conducive to optimum completion of the work undertaken.

54. That the lessons learned from the inquiry into the loss of THRESHER are of such moment as to require wide dissemination within the Navy.

55. That the findings and opinions of this court point out numerous practices, conditions and standards which were short of those required to insure the thorough overhaul and safe operation of the U.S.S. Thresher. These same shortcomings militate against the safe construction and overhaul of all submarines at the Portsmouth Naval Shipyard and are, in varying degrees, applicable to other submarine construction and repair yards. Vigorous steps should be taken to correct them.

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(CONF)

These shortcomings have developed incident to the rapid changes in materials, workmanship and operating conditions of submarines during the last decade and to the accelerated pace of the submarine program. They can be blamed on no individual or individuals, and many would not have come to notice had THRESHER not been lost.

The responsibility for the loss of THRESHER cannot be charged to neglect or dereliction on the part of any individual or group of individuals.

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#### RECOMMENDATIONS

1. That the interim depth restrictions now imposed upon all submarines should remain effective until careful consideration, for each individual submarine, is given to the probable factors contributing to the loss of THRESHER, as listed in Opinion 1.
2. That the design of submarine sea water systems be reviewed and new construction be modified as follows:
  - a. Provide a low pressure system for auxiliary sea water service.
  - b. Provide remote hydraulic operation for all sea water system sea and hull valves, with the sea valves operated from a primary station in or near a normally manned area and the hull valves operated from a different station so located that a leak will not prevent access to at least one of the two stations.
  - c. That a loop system be provided wherever practicable, with split loop operation provided as the normal mode of operation.
  - d. That the constant vent sub-system be eliminated.
3. That for THRESHER Class submarines the following be provided:
  - a. Elimination of the constant vent sub-system, with substitution of internal venting by manual means.
  - b. Hydraulic remote operation for hull and stop valves.
  - c. Modifications to the auxiliary sea water system plans and Ship's Information Book to show split loop operation as the normal mode.
  - d. Instructions in the Ship's Information Book for safe operation of the trim and drain system at deep depths, with information on valve opening and closure times.
4. That additional inspection, repair and certification of sil-braze joints for operating submarines be performed to attain an acceptable level of reliability.
5. That in new submarine construction all sil-braze joints in hazardous systems above one inch in inside diameter be ultrasonically tested, certified and documented.
6. That in hazardous piping systems of submarines designed to operate below 300 feet, sil-braze joints of more than two inches in inside diameter be replaced by welded joints when replacement is required.

(SECRET)

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7. That for new construction submarines, welded piping joints be specified for joints of more than two inches in inside diameter in hazardous systems.

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(CONF)

8. That shock tests of nuclear submarines be deferred until such time as the Bureau of Ships has reassessed the following:

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(CONF)

- a. The adequacy of instrumentation coverage and capability to insure that all damage is found shortly after the shock tests.
- b. The shock resistance and mass interaction of system components and their associated piping and foundations as compared to hull resistance.

9. That shock factors not exceed approximately B1 when tests are resumed unless the action taken pursuant to Recommendation 8 above indicates it is safe to proceed further.

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10. That the quality assurance program at Portsmouth Naval Shipyard be further emphasized and improved in scope along the lines indicated in this court's opinions.

11. That the Bureau of Ships require submarine shipbuilding activities to:

- a. Adhere to specifications, and
- b. Obtain approval of the Bureau of Ships for all waivers where this is not practicable.

12. That the Bureau of Ships increase its audit activity to insure adherence to specifications for submarine building, overhaul and repair.

13. That submarine air system design criteria be reviewed for adequacy and safety and, subsequent to such review, that the air systems be modified. (See Opinion 38)

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(CONF)

14. That in THRESHER Class submarines, the air system modifications and tests include:

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~~(CONF)~~

- a. Elimination of the conical strainers in the Marotta reducing valves.
- b. Test of the air systems for a full air bank blow through the main ballast tanks to insure full blowing.
- c. Tests of the main ballast tank structure to determine its adequacy on a direct 4500 psi blow.
- d. Elimination of the B1 psi reducers as soon as the air system and ballast tanks have been proven or altered to be capable of accepting 4500 psi.
- e. Provision of 4500 psi blow of main ballast tanks.

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15. That increased emphasis be given to damage control considerations in the selection of locations for vital submarine equipment, and that primary and secondary sources not be located in close proximity to each other. (CONF) ✓

16. That electrical switchboards of submarines be better protected from salt water. (CONF) ✓

17. That submarine diving trainers be provided the capability of simulating ship reaction to flooding casualties at deep depth. (CONF) ✓

18. That studies be undertaken on a high priority basis to develop submarine operating procedures which will maximize recovery possibilities under various damage control situations. The following are merely a few examples of the many circumstances which might obtain and which should be explored: (CONF) ✓

B1

19. That separate and distinct submarine operating procedures be established to govern operations under various situations of depth and speed, to include the following: (SECRET) ✓

B1

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