THE STONE-VAPOR AUXILIARY BOILER

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Introduction

Although package auxiliary boilers have been in service in the Fleet for more than twenty years, they have not as a rule been subjected to prolonged usage at sea. Their role in ships having steam or COSAG propulsion has been to supply steam for domestic requirements in harbour when the main boilers are shut down or when shore steam is not available, i.e. 'part-time operation'. The advent of all-gas-turbine propulsion in the Royal Navy presents the auxiliary boiler with a much more demanding and vital role. How are these units going to stand up to 'full-time operation'? Those who have suffered directly (or indirectly!) from the temperamental inadequacies of some of the earlier types have a right to an answer. This article aims to cover briefly the history of the packaged auxiliary boiler and the development of the type now most likely to be successful—the Stone-Vapor boiler.

Commercial Development

The original idea, back in the 1930s, for this type of once-through boiler belongs to an Englishman, Alex Clarkson, although small flash boiler units had been used at the end of the nineteenth century to propel steam cars and buses. Clarkson's boiler consisted of a coiled tube surrounding an oil-fired burner. Water was forced through the coil and the heat from the burner evaporated it during its passage. Unfortunately, there was little control over the final steam state and the dryness varied considerably with load.

As Mr. Clarkson had no success in trying to sell his idea in this country, he went to the U.S.A. to try his fortune there. Unbeknown to him, a whole new field of steam requirement had opened with the decision of the American railways for reasons of economy to convert their stock from steam to diesel drive. As all the carriages were fitted with steam heating systems, it was decided that a small boiler should be used to provide the necessary heating rather than converting them all to some other means.

The Vapor Corporation of Chicago who manufactured a wide range of railway components were quick to see the potential of the Clarkson boiler. They developed the boiler and produced a range of sizes of the basic model to suit various requirements. Refinements soon established the present system whereby steam pressure acts on a water bypass regulator which diverts a proportion of the output of a positive displacement feed pump away from the steam generating coil back to the feed tank. The flow into the coil is then automatically metered and the correct quantities of fuel and air are delivered to the combustion chamber to provide adequate heat to evaporate the water in the coil. The output of the coil passes through a separator to give a saturated steam output of a high dryness fraction. Load changes cause alterations in the output steam pressure and thus the boiler output is adjusted by the water bypass regulator to suit the load. Safety devices are included to ensure that the boiler will automatically shut down in the event of a dangerous condition arising.

The success of this boiler meant that the Vapor Corporation were soon exporting it for installation in foreign railway systems. After the 1939–45 War, industrial and marine versions were produced; the industrial version, however, was made far less compact in order to improve accessability for maintenance.

During the middle of the 1950s, British Rail made the transition to diesel engines and were faced with the same problems as had faced the Americans twenty years earlier. As by this time the Vapor-Clarkson boiler was well established internationally, it was a logical choice. J. Stone and Co. of Deptford, who for many years had had close links with the Vapor Corporation concerning the manufacture of railway components, began producing the boiler under licence in this country. Soon Stones were looking for new outlets for their Stone-Vapor boiler (SVB) and began producing marine and industrial versions.

Up to a few years ago, the policy of the manufacturer had been to improve the existing boiler rather than to develop new models. This policy has now been changed and the effects thereof are beginning to be felt as a new range of Stone's boilers will soon be available.

Stone and Co. moved to Crawley in 1968 to a new factory site and became Stone Platt Crawley Ltd. At present all naval boilers and a proportion of commercial boilers are fully tested before release from the factory and new test facilities will soon enable every boiler to undergo test runs.

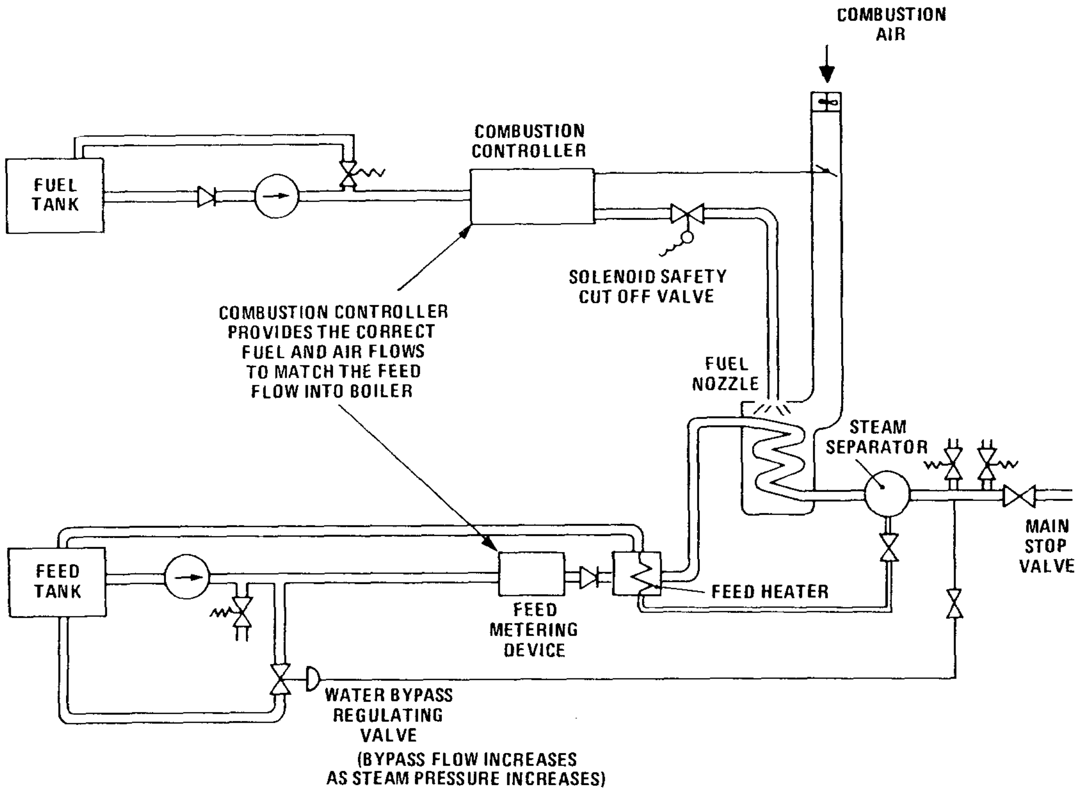

FIG. 1—BASIC FLOW DIAGRAM OF STONE-VAPOR NAVAL BOILER

Naval Developments of Auxiliary Boilers

In 1956, at the time when the Stone-Vapor boiler came to the notice of the Navy, a small output boiler was required for the 'CA' Class destroyers and J. Stone and Co. won their first naval contract with the OK4625 model. As the boilers were required urgently and as Stone's manufacturing facilities for Vapor boilers were still under development, the first four OK4625 boilers were manufactured by the Vapor Corporation in America.

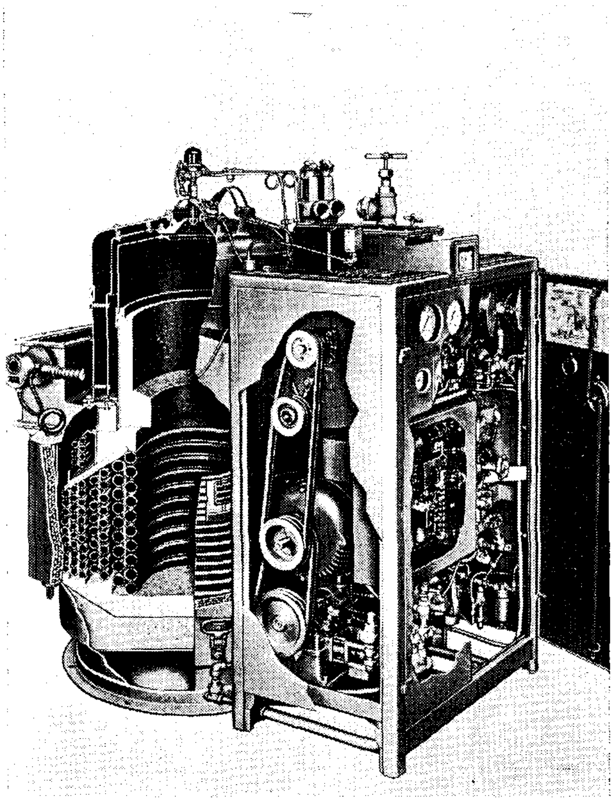

FIG. 2—MODEL OK4625 BOILER FITTED IN THE 'CA' CLASS DESTROYERS

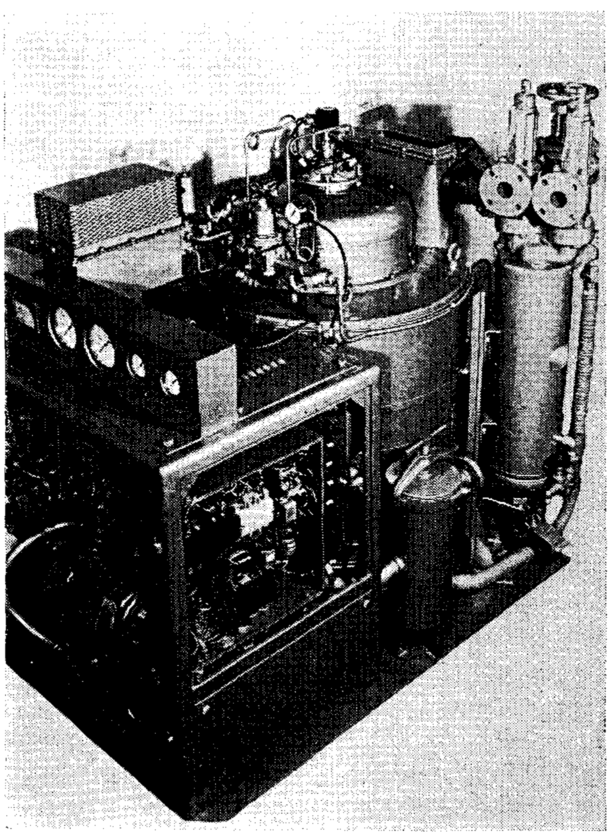

FIG. 3—MODEL OK4616, THE COMMERCIAL VERSION OF THE AD4616 INSTALLED IN THE BATTLE CLASS CONVERSIONS

The following year, a larger American-built model OK4740, was sent to the Admiralty Fuel Experimental Station (now the Admiralty Marine Engineering Establishment—AMEE) for assessment with a view to installing these units in the Y102 design. It was generally concluded that the boiler was a sound unit and, once the combustion systems were correctly tuned, would give a very satisfactory performance. The Y102 County Class destroyers were therefore fitted with OK4740 boilers. The belt drive used in the OK4625 model for the 'CA' Class destroyer conversions was changed for gear transmission in these boilers; although this created a more compact unit, it made accessibility for maintenance of certain components very poor.

The Battle Class destroyers, originally built during the war, were to be converted into radar-picket ships in 1958. The decision was made to include an auxiliary boiler in the machinery space and a survey was undertaken to establish the most suitable type. Of all the possibilities examined by the survey, the one proposed was a commercial boiler produced by Stone and Co. designated OK4616. This boiler needed some relatively minor modifications to meet the Admiralty specification. The turndown of the boiler was insufficiently large to cover the ships' requirements and accessibility of certain components had to be improved to facilitate maintenance. To increase the turndown, a dual system introducing high and low output ranges called arctic and non-arctic modes was devised. Conversion from one mode to the other was achieved by changing certain key components, the transition taking less than an hour. The boiler, modified with

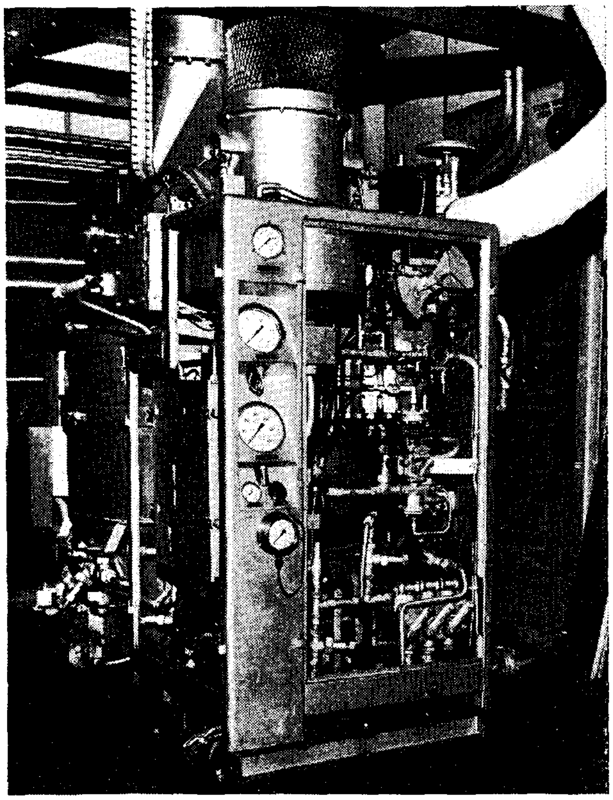

FIG. 4—MODEL AD(E)4740 WITH DOORS REMOVED

this duel turndown and with many of its components re-arranged to improve accessibility, was re-designated AD4616, the AD signifying Admiralty design.

The first ships of the *Leander* Class received AD4740 units but further electrical modifications had to be made and the models installed in the remaining *Leander* Class were designated AD(E)4740. These boilers were fitted with the dual turndown of arctic and non-arctic modes first developed for the AD4616 model. The boilers were also fitted with an extra lower diaphragm on the water by-pass regulator; this allowed the feed pump discharge pressure to act against the steam pressure on top of the regulating valve and so assist in closing it. A large steam pressure variation between powers could not be tolerated and this rearrangement helped to diminish this range.

The La Mont Boiler

By 1962, it had become obvious that the La Mont boilers fitted in the *Blackwood, Whitby* and *Rothesay* Class frigates were not a success. It had been designed to run without a watchkeeper, the control system operating automatically with various safety cut-out devices for emergencies. However, this control system was extremely complicated and caused many problems for ship's staff. For a number of reasons, spare parts were frequently unavailable for sea-going ships.

By 1962, after a number of serious failures, confidence in the boiler was very low. It was common practice for a watchkeeper to be employed; even so, the failures continued, the most common faults being in the complicated control system and the failure of safety devices to operate.

A review of the La Mont boiler was undertaken to try to solve these problems. As a short term solution, it was recommended that a watchkeeper should be used on the boiler when it was running; no increase in the ships' complement was, however, allowed for this new duty. For a long term answer, the Admiralty looked to the manufacturer to redesign the system. This was undertaken but the cost of the conversion was prohibitive; the decision was therefore taken to remove all La Mont boilers from the Fleet and to replace them with SVBs.

The Stone-Vapor Boiler

The SVB had a hard task gaining acceptance in the Fleet. In harbour, the ships' staff had become accustomed to retaining a main boiler alight to provide steam for hotel services rather than risk running the auxiliary boiler.

This boiler had its own problems often caused by infrequent use. This resulted in not only the deterioration of components but also in operators gaining insufficient experience and familiarity with the boiler. Although training courses were available for operators/maintainers, the knowledge gained needed to be consolidated by practical experience on the boiler.

Some confusion was caused by the arctic and non-arctic modes as the alternative components for the two modes superficially looked identical and the second set was often mistaken as spare gear.

The stability of the control system left much to be desired as it allowed the boiler to hunt for long periods and no method was available to damp out the oscillations. This not only caused excessive wear on all moving parts but also made the task of the evaporator watchkeeper of maintaining a clear output more difficult.

When in automatic control and a shut down occurred due to a fault, there was often no indication of the cause as the boiler was not fitted with tell-tales. Ignorance of the cause of the shut down combined with an incorrect diagnosis of the fault due to inexperience was responsible for the failure to identify isolated dangerous conditions.

Minipac

The SVB started its naval career as a rival to the John Thompson Minipac boiler fitted in the Tribal Class frigates. The Minipac was more robust and had easier access for maintenance but was a considerably larger unit. The boiler, however, proved unreliable and difficulty had been experienced in obtaining spare parts. Because of these two factors, A. and A. action has been taken to replace minipacs with SVBs.

Trials at AMEE

With the advent of the all-gas-turbine propulsion ship and the consequent more demanding role required of the boilers, an extensive analysis of the SVB was carried out.

In 1969, an AD(E)4740 SVB was sent to the AMEE so that trials sponsored by D.G.Ships could be undertaken to eliminate possible problems and to improve the reliability of the boilers.

Certain design and output criteria were checked. A 1000-hour endurance run brought to light several defects. Each failure that occurred during the test was examined carefully to try to determine remedies that could be passed on to the Fleet. As a result, the air fan and its casing were improved and other more minor modifications were introduced.

Fluids for external cleaning of the coils were tested and the best one has now become a standard maintenance item. The frequency of the clean has been reduced significantly as a result of experience gained on the test boiler.

Investigations were undertaken to determine the capability of the boiler to burn Avcat and Dieso contaminated with dirty lubricating oil.

Safety devices were tested under rigorous conditions and their correct operation determined. It was found that some safety devices did not cover all eventualities and recommendations were made to ensure that dangerous situations could not occur in future. Maintenance procedures and their frequency were examined.

The blow-down arrangement had to be modified to prevent the adverse effect on electronic equipment fitted in the machinery spaces of gas-turbine ships that would result from the large quantities of saturated steam being issued from the boiler. By putting the discharge of the blow-down through a coil submerged in the feed tank and then either into the feed tank or to the bilge, the quantity of steam eventually escaping into the machinery space was minimized.

It was realized that in the gas-turbine ships more than one boiler would be required to satisfy the steam demand. Multiple boiler installations feeding into

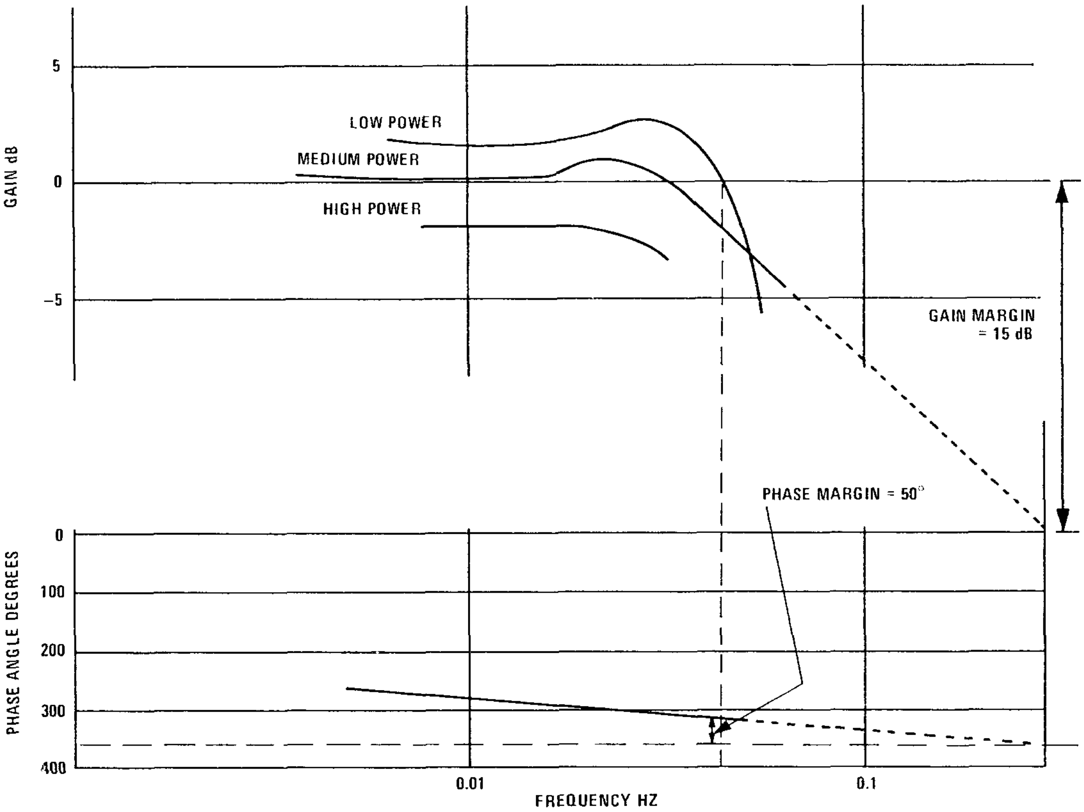

FIG. 5—FREQUENCY RESPONSE OF THE AD(E)4740 USING THE WATER BYPASS REGULATOR VALVE AS DEVELOPED AT AMEE

The smallest phase margin of 50° is well above the limiting phase margin of 30°. The smallest gain margin (extrapolated) of −15dB is also well in excess of the limit of −3dB.

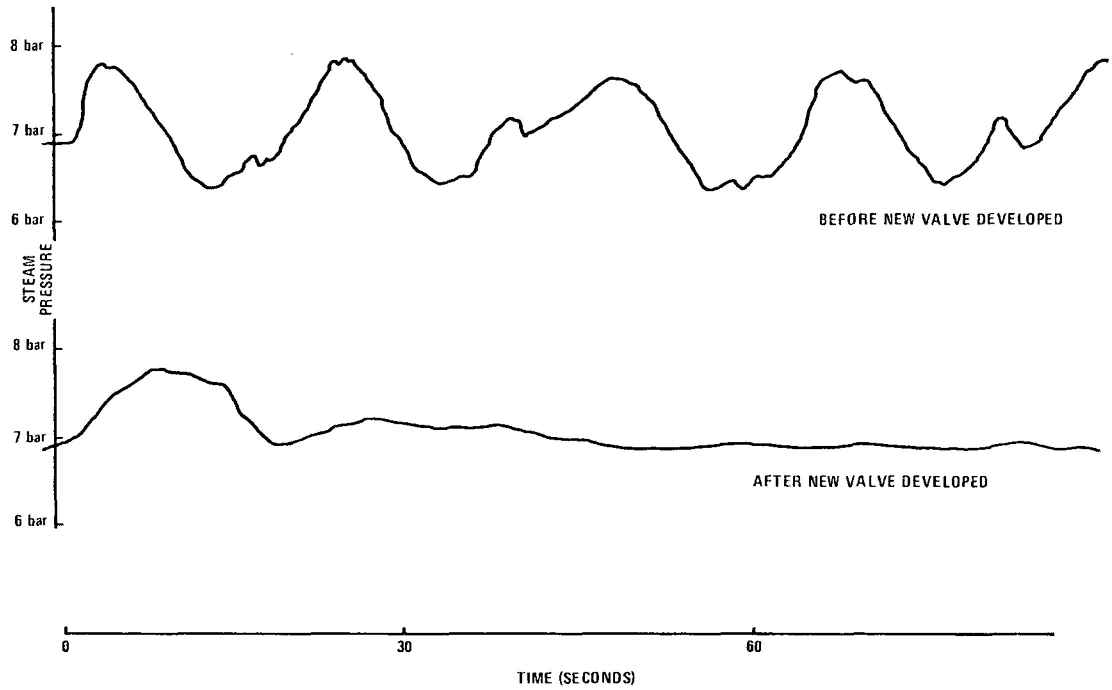

FIG. 6—TYPICAL RESPONSE OF THE STEAM PRESSURE TO A STEP LOAD CHANGE BEFORE AND AFTER THE DEVELOPMENT OF THE AMEE BYPASS REGULATOR VALVE

one manifold were favoured as these provided maximum flexibility with minimum system complication; the matching of each component, however, was a problem. The instability already experienced at certain powers in the

AD(E)4740 model could mean that with a multiple boiler installation there would be a perpetual state of hunting as one boiler could excite the others.

The poor stability of the control system was examined at the AMEE. Open-loop frequency responses and closed loop responses were taken and from the data collected a new water bypass regulator valve profile was developed. Unfortunately this increased the steam pressure differential between high and low powers considerably. To remedy this, the effective area on the underside of the regulating valve on which the feed pressure acted against the steam pressure had to be increased and a dashpot included. This succeeded in bringing the differential pressure back to an acceptable figure.

The Ship Maintenance Authority Review

In parallel with the trials at the AMEE, the Marine Engineering Liaison Panel requested the SMA to conduct a study on the AD(E)4740 SVB under the reliability, maintainability, logistic (RML) concept. They found that there were shortcomings in:

(*a*) boiler instrumentation both for monitoring performance and for initially setting up the boiler;

(*b*) diagnostic aids and instruction for fault finding;

(*c*) routines for setting up and tuning;

(*d*) safety devices from a point of view of both sufficient protection for the boiler and regulator tests to confirm correct operation;

(*e*) detection arrangements for unburnt fuel in the furnace after a flame-out.

A general point made was that the equipment often contained many detailed and, taken individually, trivial shortcomings. Sufficient of these small defects could however cause major problems in particular boilers. However, it was concluded that if the boiler was correctly set up it was quite capable of meeting its operational commitments and that it was intrinsically sound.

It was suggested that great improvements would result if ships were provided with more detailed performance figures and reference books. As a development of this, new maintenance and setting-to-work information, functional checks, fault-finding procedures and diagnostic aids are now available.

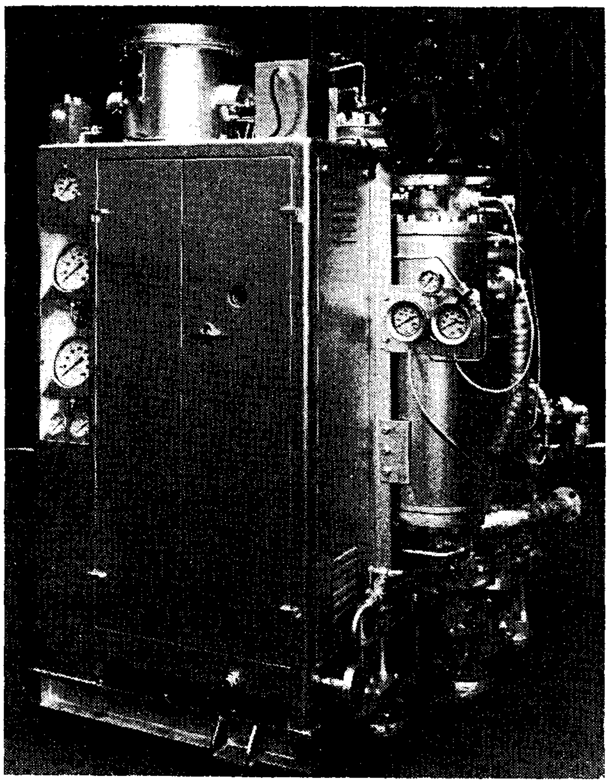

FIG. 7—MODEL AD(S)4740 BEFORE INSTALLATION IN A TYPE 21 FRIGATE

The Need for Steam

The production of water had traditionally been effected by distillation. The source of heat for the evaporators in a steam-driven ship is an obvious choice, but in ships with other forms of propulsion the source is less obvious. Diesel frigates and conventional submarines have used vapour compression distilling plants but these are heavy and complicated for their output and suffer from mechanical and scaling problems. A reverse-osmosis

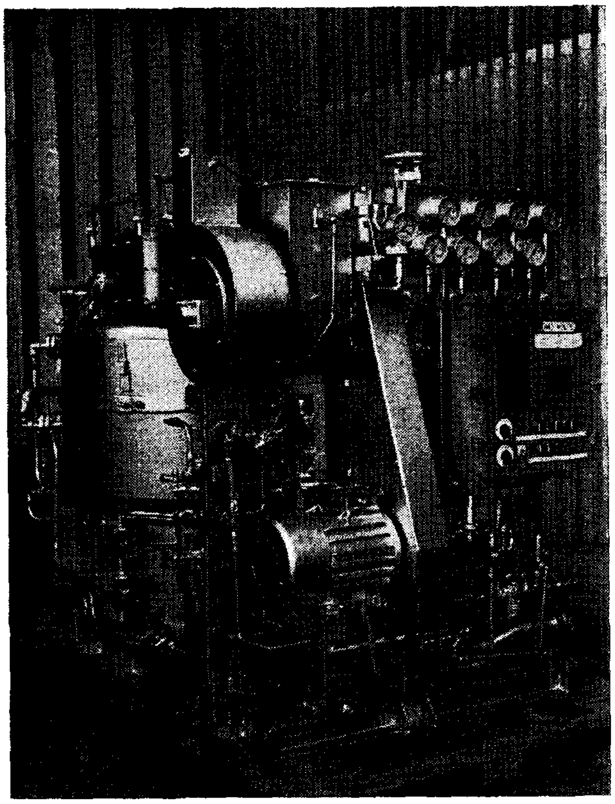

FIG. 8—MODEL AD(SE)4740 UNDERGOING TYPE-TESTING AT STONE-P5322 CRAWLEY LTD.

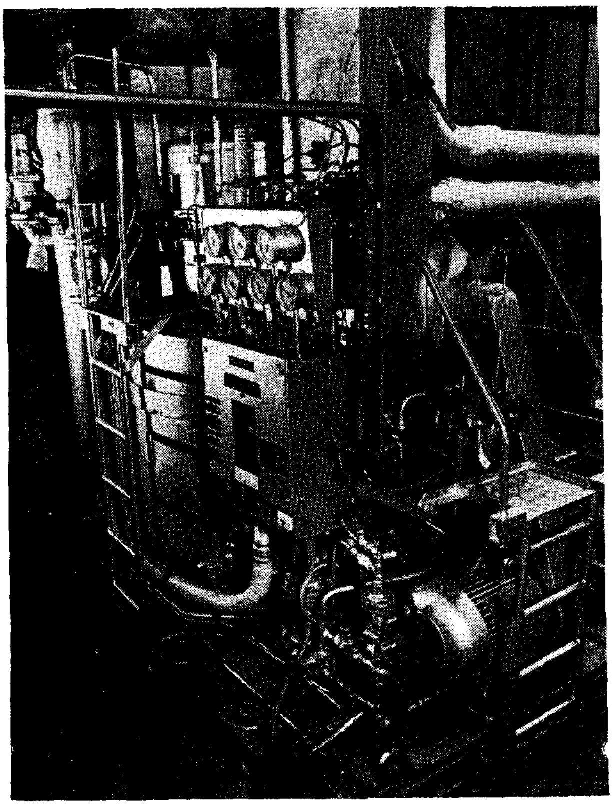

FIG. 9—MODEL AD6969—THE TYPE TO BE FITTED IN THE CAH—UNDERGOING TEST AT THE AMEE

plant being developed is not yet sufficiently advanced to be installed in the Fleet. Thus in gas-turbine ships, water production must still rely on evaporators using steam as the heating source. SVBs had been in use in the Fleet for many years and, although problems still remained, it was considered that a safe and very reliable unit could be achieved. The experience gained at sea and the tests and development carried out at the AMEE on the AD(E)4740 and at Stone Platt Crawley Ltd. paved the way for the new and improved units.

The Type 21 frigates and the Type 42 destroyers are being fitted with a development of the AD(E)4740; this is the AD(S)4740 model which superficially looks like its predecessor and has been selected initially as the Symes range unit. Two boilers will run in parallel in these ships. Major electrical modifications were needed to allow the units to comply with the new electrical standards and strengthening was required to enable the boiler to comply with NSS II shock standards.

The Future

Future developments will revert to belt and pulley drives to power the fuel pump and air fan. The gearing used in the boilers at present in service—designed originally for railway use because it gave a very compact unit—makes accessibility difficult and causes the boiler to be noisier. A new layout of components in the AD6969 model for the CAH through-deck cruiser and in the AD(SE)4740 (which will supersede the AD(S)4740 as the Symes range unit) which will be installed in the Type 22 frigate combines compactness with the improved accessibility allowed by belt drive. Instrumentation is far more comprehensive on these boilers enabling a visiting watchkeeper to see at a glance if the boiler is operating correctly.

There has been an increase in the number of safety devices fitted and test facilities are to be included to enable the correct working of these devices to be checked. Alarm indicators are to be fitted on the control panel to show:

(*a*) flame failure;
(*b*) insufficiency or failure of atomizing air;
(*c*) excessive uptake temperature;
(*d*) excessive superheat of the steam;
(*e*) motor overload.

Other boilers were considered for the CAH cruiser. The steam requirement for this ship is considerable and five AD6969 boilers are needed to fulfil it. Its competitors were much larger in output and so had the advantage of fewer units with a possible reduction in maintenance load as a consequence. However, none had service experience and, for this and for logistic reasons, a decision was made to opt for the SVBs.

Repair Policy

The boilers fitted to the all gas-turbine propelled ships, namely: the Types 21 and 22 frigates, the Type 42 destroyers and the CAH, will have an upkeep-by-exchange repair policy, the boilers being exchanged at each normal refit (aproximately every four years). Line overhaul facilities are being set up at Devenport for the AD(S)4740, AD(SE)4740 and AD6969 boilers.

Future Research and Development

The prototype AD6969 has been undergoing extensive evaluation trials at the AMEE and, to date, a redesigned burner assembly, modifications to the water-pump piston assembly and to the new control panel have been recommended. The first production boilers, due for delivery to CAH 01 in February 1975, have had the above alterations included in the design. Trials are still continuing on this boiler.

The prototype AD(SE)4740 boiler has just successfully completed type testing at Stone Platt Crawley Ltd. This boiler is now going to the AMEE to carry out extensive evaluation trials.

An AD(S)4740 boiler, ex-shock test, is also being fitted to the AMEE test facility to undergo extensive trials to check that new modifications function correctly and to iron out new problems which have arisen in the Fleet.

Training

Requirements for training personnel in the operation and maintenance of auxiliary boilers are at present under review at H.M.S. *Sultan*. Future courses are expected to include detailed training on setting to work, functional checks, and fault finding.

Conclusion

With years of development behind it and the support of extensive shore test facilities, the SVB should provide safe and reliable service to the Fleet. Confidence in this boiler will gradually grow as the hours of running are accumulated both at sea and on shore.

Messrs Stone Platt Crawley Ltd have now sold about 2500 boilers since 1956, mainly to British Rail (1000 units), hospitals, factories, schools and, of course, marine services. The satisfactory operation in all the above applications, many of which require continuous running, says much for the SVB.

Acknowledgements

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