STEAM ATOMIZATION

INTRODUCTION INTO SERVICE

BY

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Introduction

Over the next five years, the main boiler combustion equipment of all twenty-six *Leander* Class frigates will be changed to 'Steam Atomization' under Alteration and Addition 633. This change goes far beyond the substitution of steam-atomized burners for the present simplex type, involving major changes to the boiler front design and a completely new type of fuel system.

The development of the steam atomization combustion system at the Admiralty Marine Engineering Establishment is described in the reference. The purpose of this article is to describe the equipment changes which will be incorporated in the *Leanders*, and to outline the reasons for this major project.

What is Steam Atomization?

The term 'steam atomization' is currently used to cover a package of changes in two completely separate areas:

Combustion System

The present registers (five main and one half-size) are replaced by three large registers of A.M.E.E. design, and the furnace refractories are altered to suit.

The simplex pressure jet atomizer is replaced by an A.M.E.E. design with sixteen skewed jets. Steam is used for atomization of the fuel, and gives efficient atomization even where fuel pressure is a small percentage of that at full output.

The improvements over the present arrangement are:

(*a*) High turn-down (10 : 1). Boiler power can therefore be varied over the normal full operating range at sea without altering the number of registers in use, thus reducing the number of boiler watchkeepers required and eliminating the archaic task of 'sprayer punching'.

(*b*) Under no circumstances will excessive air extinguish the flame or blow it off the swirler.

(*c*) Ignition is easy; a properly stabilized flame is always established.

(*d*) Progressive flashing of burners is easy and safe.

(*e*) Reduced tendency to pulsation.

(*f*) Elimination of flame impingement at furnace boundaries.

(*g*) Elimination of swirler fouling.

Fuel System

The latest *Leanders*, with Y.160 machinery, were designed for remote control of boilers. The lack of a proper pilot register with independent fuel supply as fitted in ships with automatic combustion control was always recognized as a short-coming. This was one factor which led to a decision, made shortly after the first ship entered service, that remote boiler operation of these ships with the 'On-Off' design of register was not sufficiently safe. It is difficult to design an entirely satisfactory pilot register for all operating conditions and, therefore, in the steam atomization design the same safety function has been achieved by 'cross-linking' the fuel supply systems to the two boilers. The centre register of each boiler can be supplied from the pump supplying fuel to the outer registers on the other boiler. With both boilers and both fuel pumps in use on independent suctions, failure of one pump or contamination of one suction will not result in total flame-out of a boiler. Such protection is, of course, only given in this operating configuration, which must be a pre-requisite for remote operation in Y.160 *Leanders* in particular. It must be possible to alter boiler powers independently, particularly for manoeuvring, and therefore a novel method of fuel control has been used to allow 'cross-linking'. Fuel pump discharge pressure is kept constant at 350 p.s.i. by controlling pump steam supply in a diaphragm-operated valve sensing discharge pressure. In the fuel supply to each burner is a characterized valve (metering valve) giving very accurate control of burner supply pressure, and hence output. The three metering valves for each boiler are ganged together into one assembly. A large part of the work involved in modifying ships for steam atomization arises from these changes to the fuel supply system.

Why Fit Steam Atomization?

A very large number of ships have used the Y.100 type of combustion systems over many years with reasonable success. The work and cost of fitting steam atomization, and associated support provision and documentation, is very considerable; why fit steam atomization in the *Leanders* at this stage in their life?

Safety

The safety of burning Dieso fuel is considerably improved because the registers have a very high resistance to flame extinction, and also because 'cross-linking' of the fuel supply system safeguards against complete flame extinction due to pump failures or contamination. The attendant risk of explosion following flame out is, therefore, considerably reduced.

Maintenance

Deterioration of refractories should be less and, in particular, damage from impingement should be eliminated. Wear and defects of registers should be reduced because of much less frequent operation, as all registers remain flashed over the normal power range. It is expected that swirler and atomizer fouling will be virtually eliminated.

Operation

The wide turn-down achieved allows power to be varied over the full range from stand-by to full without altering the number of registers in use. This offers the possibility of reducing the number of watchkeepers as the boiler front watchkeepers are no longer required to operate registers.

Combustion

Due to more uniform distribution of air to registers and improved register performance, complete combustion should be achieved with less air. This will improve efficiency and will enable a greater degree of casing air leakage to be tolerated before combustion is affected at high powers (e.g. onset of after burning).

Remote Control

In the Y.160 *Leanders*, steam atomization will enable boilers to be operated from the machinery control room in accordance with the original design intention.

Historical Background behind Decision to Adopt Steam Atomization

The original building specification for the Y.160 *Leanders* required remote control of the boilers from the MCR and a secondary form of control from the boiler-room console using servo manual operation. Although the fuel was specified as Dieso, there was to be the capability of burning FFO. Dieso burning was in line with the general requirement at that time; all Type 12 frigates were to prepare for Dieso burning which, it was expected, would be adopted in all ships by the early 1970's.

In July, 1968, the first Y.160 *Leander*, H.M.S. *Andromeda*, joined the Fleet, burning Dieso, having conducted all her contractors sea trials with this fuel. Soon after this date, a boiler explosion occurred in the second Y.160 building at Alexander Stevens and it was concluded that the reliability of the pneumatically-operated register system was suspect.

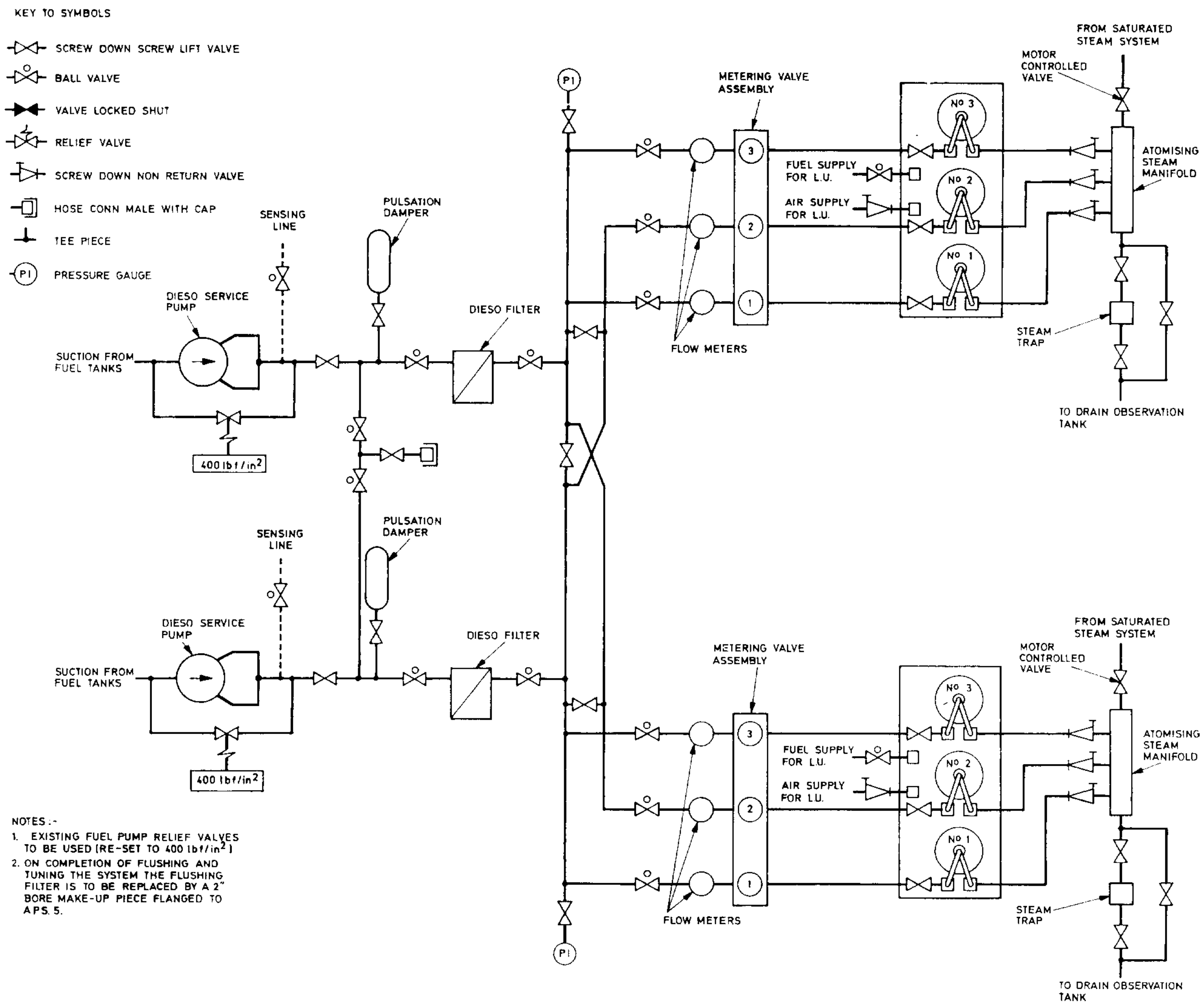

FIG. 1—SIMPLIFIED DIAGRAMMATIC ARRANGEMENT OF STEAM ATOMIZATION SYSTEM

The immediate solution to this problem was to revert to FFO burning in the Y.160s with an operating requirement to steam in local servo manual control only. This form of operation continued from 1968 to June 1972 with nine Y.160 *Leanders* entering service.

During this period, it was generally agreed that the boiler operation in the Y.160s was unacceptable. Operation in local servo manual did not meet the basic operating philosophy of Dieso burning with MCR control of the boilers. In addition, it brought with it a high boiler maintenance load as regards water washing and brickwork renewals which were occurring at intervals as short as 750 operational hours.

Various steps were taken to improve combustion in the Y.160 boilers with the On-Off register. Dieso burning was restored in the Class from mid 1972 by 'manualizing' the registers. By early 1972, it had been realized that the only realistic method of fully restoring the original operating requirements to the Y.160s was offered by a steam atomization combustion system, which also offered improved combustion, greater safety and reduced maintenance.

The AMEE had developed a fully-automatic steam atomization system (Y.181) but, for reasons of cost and complexity, it was decided that a much simpler system was required. The simplified manual system was therefore adopted as A and A 633 for the Y.160 *Leanders* and placed in their long refit list in May 1972. In January 1973, it was decided to advance its adoption to the Y.160 normal refit programme with mandatory status.

Although steam atomization was therefore proposed as a solution to the Y.160 combustion problems first, it was realized that most of the arguments put forward for its adoption were equally applicable to the Y.100 and Y.136 *Leander* frigates. At the end of February 1973, it was decided to extend A and A 633 to all Y.100 and Y.136 *Leanders* during their next refit; this has resulted in a very intensive programme of installing the system.

General Description

General

The steam atomization combustion system is designed to supply fuel to the furnace where its atomization is assisted by steam energy. In comparison with the Type 12 frigate system at present fitted, the proposed system has three registers instead of six, and a continously modulating control of the fuel supply is provided instead of an On/Off arrangement. A simplified diagrammatic arrangement of the system is given in FIG. 1.

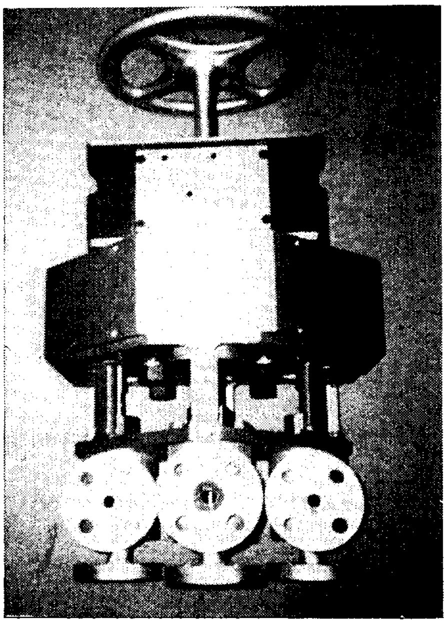

FIG. 2—FUEL METERING VALVE

The existing reciprocating fuel pumps are retained but are automatically controlled by simple pressure regulators to give a constant discharge pressure of 350 psig (+10, −0 psi).

Fuel flow to the three burners on each boiler is controlled by a ganged triple fuel metering valve (FIG. 2).

Cross connections between boilers are fitted so that:

(*a*) during normal operation, one burner on each boiler is fed from the other fuel pump discharge to act as a fully-modulating pilot burner.

(*b*) either one or both pumps can supply either or both boilers from either or both tank suctions.

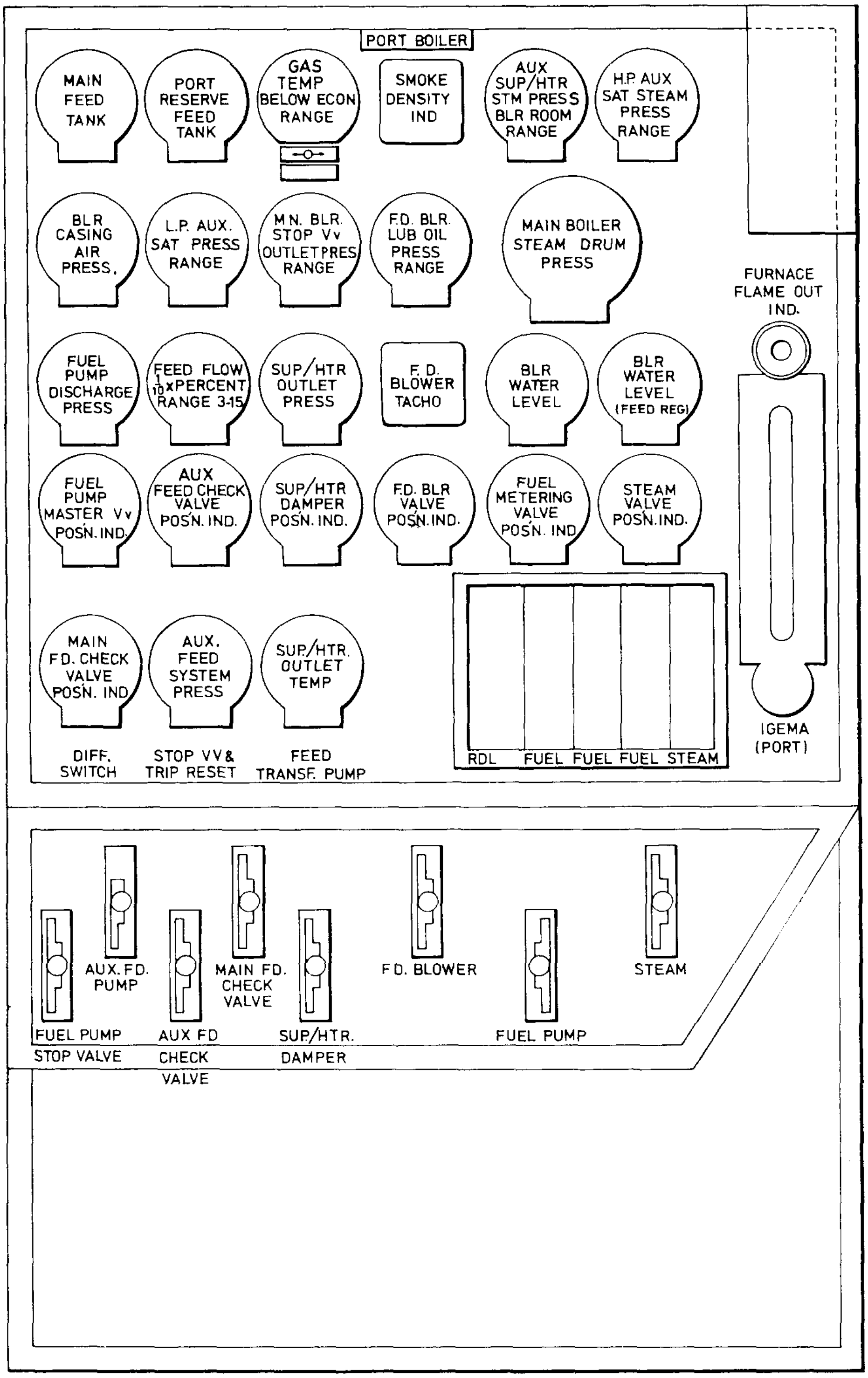

Fig. 3—Machinery control room boiler panel

If necessary, these cross connections can be shut to provide complete isolation of the systems.

The pressure of the atomizing steam is controlled by one valve per boiler and is varied in accordance with fuel flow requirements. Values are not critical and, in emergency, distillate fuel can be burned without atomizing steam.

The system is designed to burn DIESO in normal operation and AVCAT in exceptional circumstances but, due to the removal of the heating facilities, it will not be possible to burn FFO. The facility to burn FFO has already been

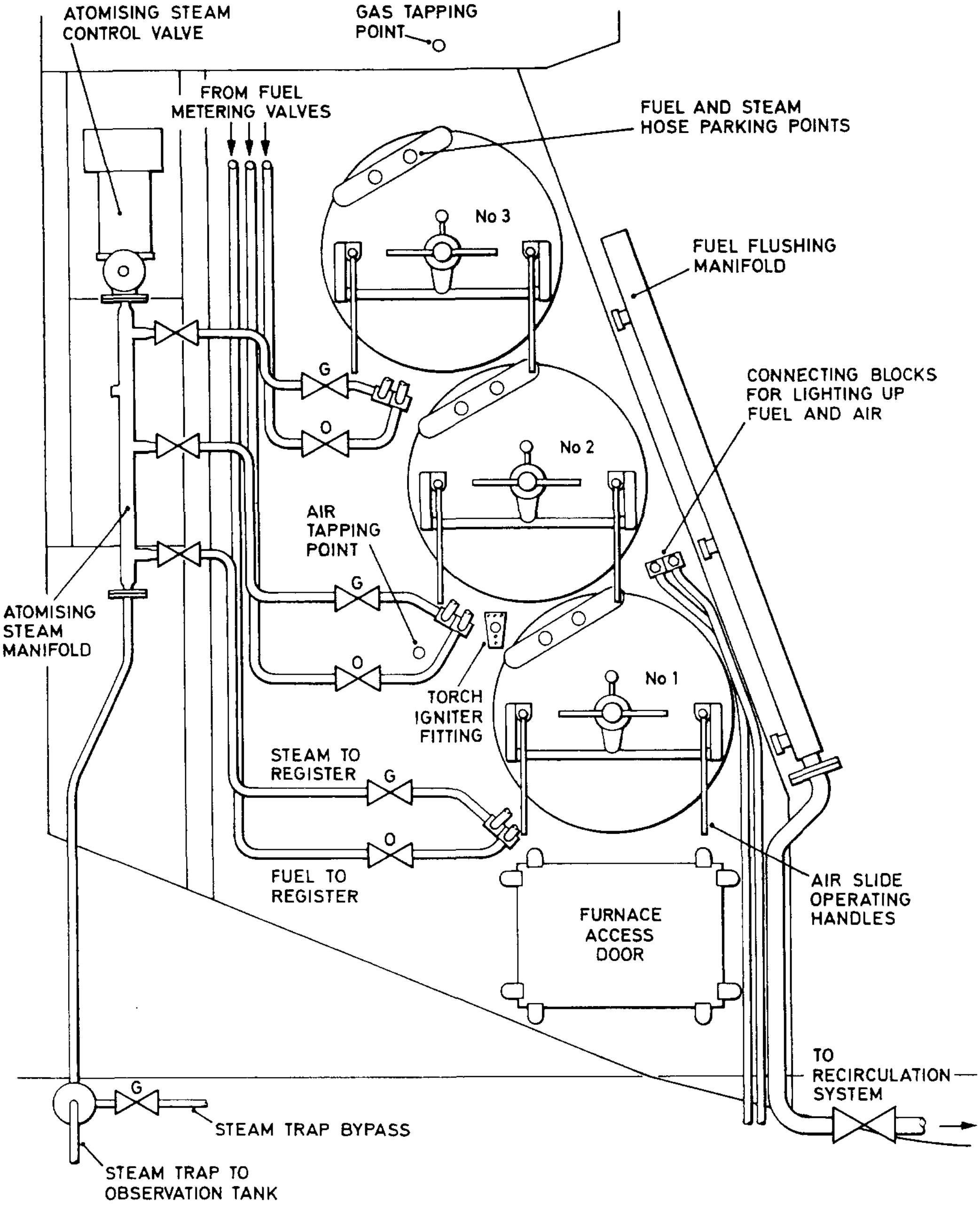

FIG. 4—ARRANGEMENT OF BOILER FRONT

removed in the Batch I and II *Leanders* by the decision to install a water-displaced fuel system.

In all three *Leander* types, manual control of the steam atomization system is to be provided from the local boiler-room panel. The operating philosophy is for one man operation of both boilers during normal operation. The boiler-room panels and valve rod-gearing will be modified to facilitate this form of operation.

In the Y.160 *Leanders*, remote control of the steam atomization system will be provided from the MCR. It is intended that MCR control will be the normal method of operation in these ships. Fuel metering valves and atomizing steam valves will be operated by Telektron air motors, and the boiler-room panel in the MCR will be modified to group controls and instrumentation for operation by one watchkeeper (FIG. 3).

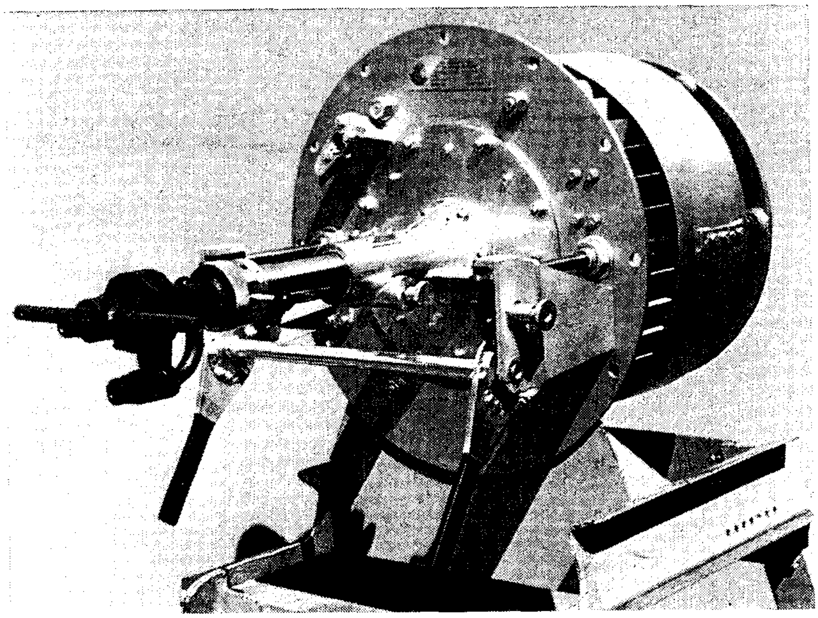

FIG. 5—STEAM ATOMIZED REGISTER

Main Boilers

The boiler front general arrangement is shown in FIG. 4. The installation of the three registers (FIG. 5) in place of the existing six needs the production of new register and brick plates; these in the case of the normal-refitting ships will be shipped into the boiler room in halves.

The combustion equipment on each boiler comprises a fuel recirculation manifold, steam supply equipment, lighting-up air and fuel supply equipment. The boiler front will be arranged to take a Lucas torch igniter positioned in a separate quarl so that it can light either the bottom or centre burner.

Fuel System Supply

As stated, the existing fuel pumps will be retained with the existing suction system. The pump discharge pressure will be controlled at 350 psig at all powers. The discharge system is shown in FIG. 1. It is important for the operation of the system that the pressure drops in each pipeline from the metering valve to the burners are as near equal as possible to avoid imbalance of flow between the three burners.

Recirculation System

During the flushing and tuning of the system and the setting up of the fuel-metering valve assembly, it will be necessary to recirculate fuel. The recirculation system will comprise a permanently mounted manifold on each boiler from which a 2-in. pipe runs for'd between the boilers to the filling trunk in the Y.160 ships and to the service tank filling line in the Y.100/Y.136 ships. This will enable the fuel to be discharged to the service tank in use. Recirculation will be achieved by disconnecting the hose from the burner and connecting it to the manifold.

Flushing of the Fuel System

Provision is made in the recirculation pipework for the installation of a temporary flushing filter. Experience gained by the AMEE shows the need for complete and thorough flushing of the system after initial light-up to avoid blocking the skew jet atomizers.

Fuel Metering Valve

An important component in the fuel supply system is the fuel-metering valve (FIG. 2) which comprises three ganged valves controlled simultaneously by a single rotary input. Each burner is supplied from an individual fuel supply line and, in order to meet the requirement for fuel flows balanced to within a 2 per cent. limit, it is essential to set up accurately the fuel metering valve assembly.

The individual valves in the assembly need to have similar flow characteristics and the specification calls for accuracies of 1 to $1\frac{1}{2}$ per cent. The accuracy of the valve profile has caused manufacturing difficulties because after consideration of the valve duty, it was agreed to change the specification from Stellite plugs and seals to stainless steel.

Fuel System Tuning

The fuel metering valve is designed to have, when passing Dieso, the extremes of range shown in TABLE I.

TABLE I

Flow lb./hr.	*Inlet Pressure psig*	*Pressure Drop psi*
330	360	350
3966	325	65

It can be seen that at low flows the fuel pressure downstream of the metering valve is extremely low and that the normal tuning procedure by balancing pressures is not feasible.

A flowmeter, not a pressure gauge, is necessary to balance the fuel flow to the burners throughout the full range; a Gilflow Orifice Meter has been specified in each burner fuel line in the system. These meters are installed upstream of the metering valve and are connected to a simple differential pressure gauge.

The fuel metering valve assembly having been initially set up at the AMEE will, therefore, be tuned to the ship's pipe system using the flowmeter measuring system with the object of achieving a 2 per cent. flow balance throughout the flow range. The metering valve is relatively simple to adjust by a lock nut on each valve spindle and, as the flow measuring system is permanently installed, it is expected that any in-service requirements for setting up will be within the capability of the ship's staff.

Atomizing Steam System

The atomizing steam supply is taken from the steam line to the redundant FFO heater. The inlet saturated steam pressure of 550 psig is reduced through the atomizing steam valve to a range of 0–185 psig. The system downstream of the valve is designed to take the 550 psig pressure. A test on a single burner has shown that flame extinction is difficult to achieve even if, with the other two burners turned off, the full steam pressure is inadvertently applied to the remaining burner. Average feed water consumption during normal steaming operation is expected to be of the order of seven tons per day.

Lighting-up Air Supply

For flashing-up purposes, a lighting-up air and lighting-up fuel supply is provided for use by either the centre or bottom burner of each boiler.

Air is taken from the existing system in the ships and fuel is supplied by the existing lighting-up pump. The skew jet atomizer fitted for main steaming is also used for lighting up.

Controls

In the Y.100/Y.136 *Leanders*, combustion control is by one operator controlling both boilers locally in the boiler room by hand (rod gearing). The local boiler-room panel will be modified to include the additional instrumentation necessary to steam the boilers.

In the Y.160 *Leanders*, two forms of combustion control are provided; these enable one operator in either the MCR or the boiler room to control the output of both boilers over their full range. In the MCR, this control is exercised by air-motorized valves and in the local position by rod gearing.

The control system was designed by Telektron Ltd. and the additional controls and indication include motorization of fuel metering valves, atomizing steam valves, and forced draught blower valves (existing).

Additional instrumentation which will also be required includes:

(*a*) Burner fuel supply pressure

(*b*) Atomizing steam pressure

(*c*) Register draught loss

(*d*) Fuel pump discharge pressure.

It is envisaged that such a major change to the MCR and local panels can only be achieved by complete removal and rebuilding. Redundant On-Off register-operating equipment and FFO heating control gear will be removed.

The control of the correct oil/fuel/atomizing steam ratio/relationship is maintained by retaining an 'in line' relationship on the special gauges manufactured by Hattersley-Newman-Hender. The three controlling parameters, register draught loss, fuel pressure, and atomizing steam pressure, are presented on edgewise gauges and by special ranging on the scales; satisfactory combustion of the boiler at all firing rates is achieved by maintaining the three gauge needles in a straight line. This very simple but effective presentation of the major combustion parameters is a major benefit of this steam atomization combustion system.

Conclusion

The steam atomization combustion system was originally conceived by the AMEE for the CVA 01 Carrier design, and was then developed as a solution to the particular operating and maintenance problems of the Y.160 *Leanders*. The system has been tested for over 2500 hours steaming in the Y.100 boiler at the AMEE, over a very wide range of conditions. It is believed that no other combustion system has received such extensive shore development and testing, and this work will now bring to all the *Leanders* the benefits of greater safety, improved maintenance and simplified operation.

Reference:

Hakluytt, Lieut.-Cdr. J. P. D., R.N. and Cooper, Lieut.-Cdr. M. D., R.N., 'The Development of Combustion Equipment for Naval Boilers'. *The Journal of Naval Engineering*. Vol. 19, No. 3.