RETUBING MAIN CONDENSERS BY SHIP'S STAFF.

The repair facilities available in H.M. ships are adequately arranged to cover practically any eventuality but are not intended to deal with major repairs usually carried out by dockyard labour. It occasionally happens, however, that force of circumstances necessitate the undertaking of work far beyond the normal scope of the engine-room personnel. The following article shows how such a job was tackled in an aircraft carrier in the space of 28 days and reflects great credit on the engineer officers and engine-room staff.

From the very start of the commission there had been an increasing number of condenser tube failures which reached a total of eight in the first five months. All failures were of the same type, local corrosion, and after two failed simultaneously in different condensers with such heavy consequential priming that it was necessary to change over the steaming boilers at sea, it was decided to retube all main condensers.

The ship was coming in hand for a self-refit, and it was necessary to complete the work in 28 days. During this period it was also decided to remove the tube plates and examine the stays as trouble with stay failures had recently been experienced in a battleship.

By arrangement with the dockyard, which had too much work on hand to undertake the complete retubing of the condensers, it was agreed that two condensers would be undertaken by the shore staff, while the other two would be tackled by the ship's staff assisted by fleet labour. As the ship was badly fitted for lifting heavy items and space most restricted, it was further agreed that experienced slingers from the dockyard would give assistance with heavy lifts.

Each condenser had 8882 tubes 9 ft. 6 in. long, and no tubes of this length were available, but by calling in all stocks from the fleet and dockyard for cutting to the required length, sufficient material with the exception of the stays was collected.

During the retubing period the dockyard staff worked in two 12-hour shifts with a stand off from 0700 each Sunday for 24 hours. The ship's staff worked in four watches continuously. The ship had to dock and undock and self-refit during the 28 days which meant a certain amount of interference with the job. It will be therefore appreciated that even seconds were precious. With this in view, a plan of work was prepared and issued to each rating (see below) together with sketches (Figs. 1 and 2) showing the route to be taken between engine room and hangar and the relative position of old and new tubes, ferrules, etc., when occupying temporary storage space.

PLAN OF OPERATIONS ISSUED TO EACH RATING.

"Team work, combined with a certain amount of competition should be a feature of the job, as this is a great opportunity for *all* to show, once again, that the engineering branch of the service is capable of doing a big job in an emergency and also of producing a *first class* job. It is hardly necessary to say that the ship is a very important unit of the fleet and any long period out of action is unacceptable, so that from the first to last, the job of retubing should be tackled with a good heart and unavoidable inconvenience accepted in a good spirit, in order to make the job as short and interesting as possible.

Continuity, both of labour and material is of utmost importance to avoid delay and as an example, the loss of one minute per tube means a delay of

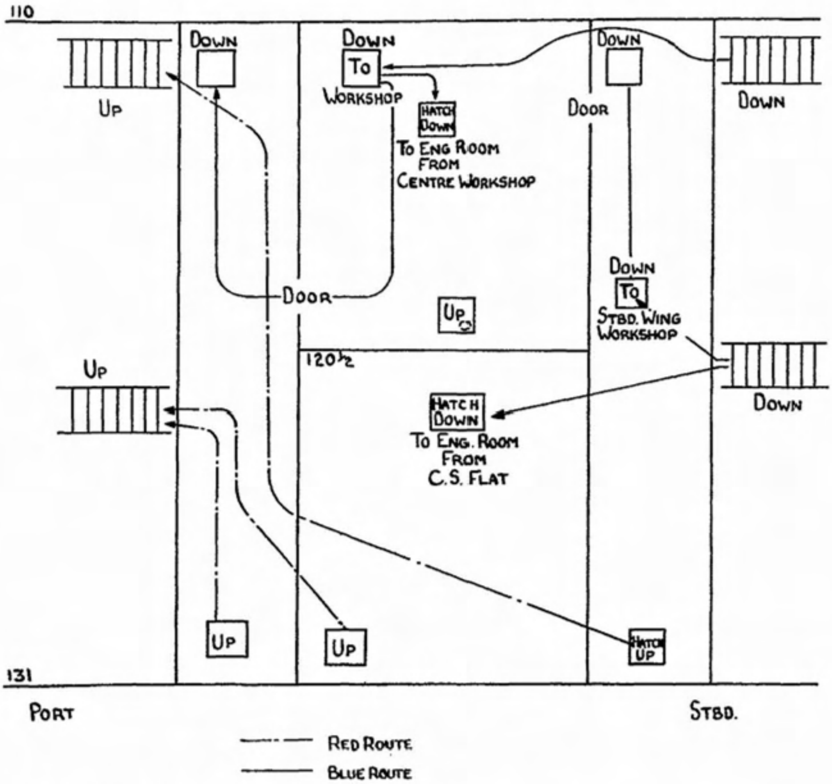

Fig. 1.—Route taken between engine room and hangar

approximately 12 days. The supply of material and tools has been discussed and it is hoped that the arrangements made will preclude any delay. The hands will work in four watches and the routine will provide for the maximum of leave and comfort possible when on and off duty.

An engineer officer is always to be available during the progress of the job and the engineer officers of the ship will work in watches—as arranged by the senior watchkeeper.

The engineer officer is to be in touch with the job throughout his watch, and is to see that progress is maintained, any delay or prospect of delay to be reported to the Commander (E) and senior engineer at once, so that remedial measures can be taken. At the end of each watch, the engineer officer will fill in the log of work done and also make up the progress chart which will be kept in the engineer's office.

An occasional visit to the starboard side to ensure that the dockyard staff have all the facilities and assistance that the ship can give them is most desirable.

To retube two condensers by combined ship's staff and fleet assistance, 16 E.R.A.'s will be required on *each* condenser, i.e., four per watch. Leading stokers and stokers will work in four watches as detailed and will carry out the duties of E.R.A.'s mates and transport parties.

The removal of the condenser doors, pipes and gratings, etc., is to be done by naval ratings with slinging assistance from the dockyard. When the doors

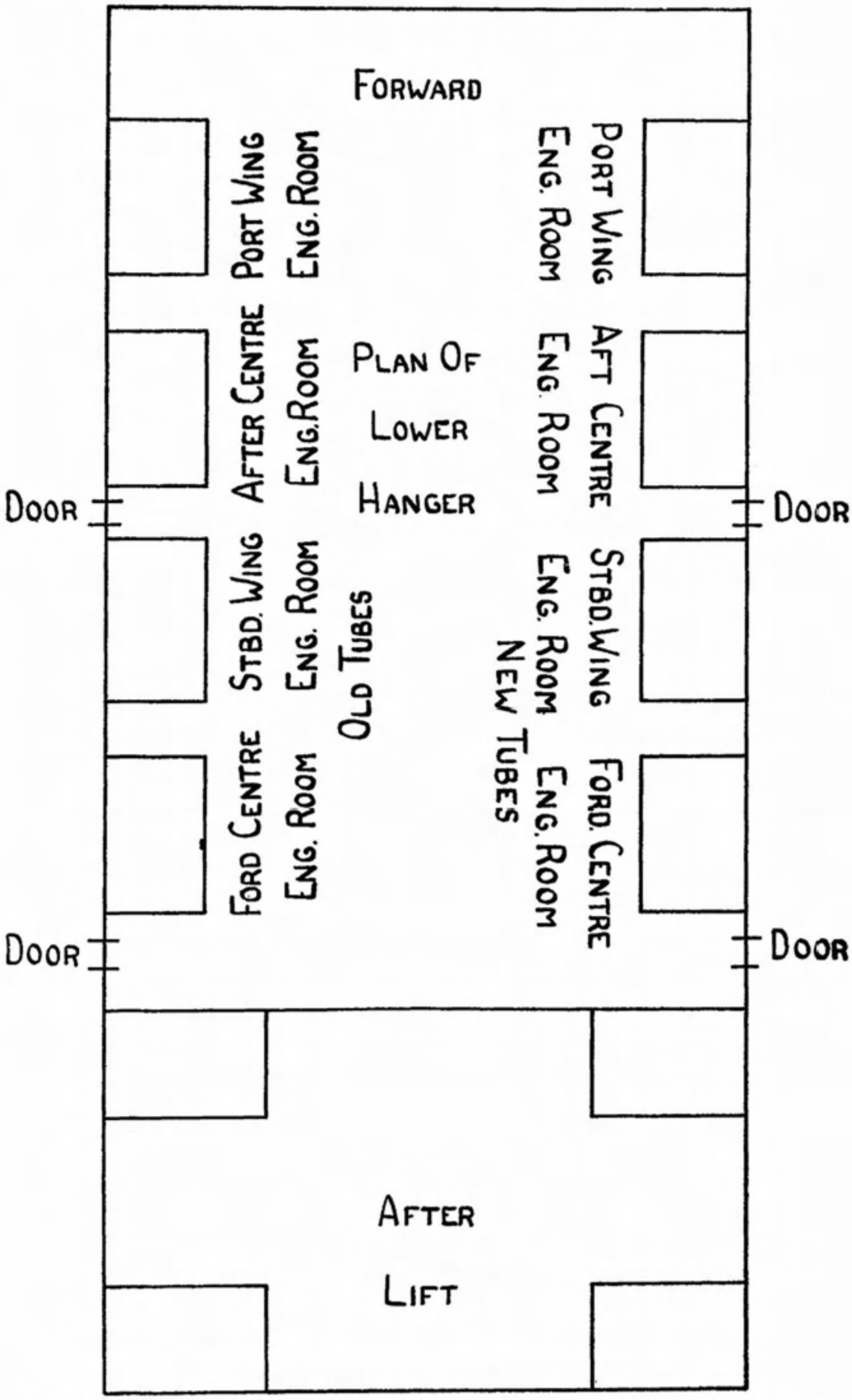

Fig. 2.—Plan of hangar showing positions allocated to old and new tubes

are clear and slung in their *rest* positions, the tube plates are to be cleaned down and made ready for starting. All tools are to be mustered in boxes and kept in the engine rooms, care being taken that tools dropped in bilges, etc., are recovered immediately. Any tools becoming defective are to be put on one side in a separate box and taken to the dockyard each morning for repair. E.R.A.'s mates are to be responsible on changing watches that their outfits of tools are correct and mustered.

Two E.R.A.'s at each end of the condenser will work from one side and centre removing ferrules, then grommets and finally tubes. The tube plates are being removed for examination and renewal of stays and collar studs as found necessary. As ferrules are removed, they are to be strung on spunyarn about 4 ft. in length, so that they can be removed for running down and pickling. Drums or buckets will be provided for the old grommets.

As old tubes are removed they are to be carried away from the engine rooms by the transport parties who will always follow the same route, i.e., RED ROUTE in Fig. 1. New tubes, ferrules, grommets, etc., are always to be taken down by the same route, i.e., BLUE ROUTE in Fig. 1.

The new tubes will be placed in the hangar on the starboard side and taken through the hangar door to the appropriate down hatches on the starboard side. Old tubes, etc., will be brought up from the engine rooms through the up hatches on the port side and placed in the hangar on the port side. Appropriate spaces are marked off in the hangar for old and new tubes for each engine room, as shown in Fig. 2.

All the secondary lighting is to be kept filled and trimmed ready for use in case of failure of the dockyard lighting.

Extra fans (D.B. or portable electric) and hoses, etc., will be obtained and placed two at each end of each condenser to supplement the normal engine room ventilation.

A supply of hot and cold water is to be available in the bathrooms at the end of each watch. During the period of retubing, fresh drinking water and some lime juice will be available during the day and cocoa during the night watches.

The aim is to reach at least 400 tubes per day, this means one every $3\frac{1}{2}$ minutes. If one visualises that this means unscrewing the ferrules, removing two grommets, driving the old tube out, tapping two holes, cleaning up generally, positioning the new tube, placing two grommets and screwing up ferrules it will be seen that every second is of great importance.

On completion, the condensers will be water pressure tested to 10 lb. per sq. in. This will entail rigging the doors in eduction trunks and it is hoped that one test only will be necessary."

Helpful liaison.

Details of work and progress given in this article refer to the condensers undertaken by ship and fleet labour only, though there was a most satisfactory and helpful liaison and interchange of ideas between the dockyard and engine room personnel which resulted in such smooth and rapid progress. Work was commenced one forenoon watch and by the following morning watch the doors at one end of each condenser had been removed, all pipes, etc., cleared away and the removal of ferrules begun.

The main inlet and discharge pipes were blanked and while 2 E.R.A.'s and 2 stokers removed ferrules, the remainder of the watch was employed on drilling out broken studs in the various flanges, running down all nuts and bolts, removing alternate nuts and collar studs from the tube plate joints and drilling deck beams for shackles for lifting off the water-boxes and tube-plates. Tight ferrules were left and removed last, as a matter of fact only about a dozen broke and had to be drifted out. Very few of the old tubes presented any difficulty in driving out. After the tubes were cleared the holes were tapped and cleaned out.

When full numbers could not be employed externally, hands were sent inside. The turbine drains were plugged to prevent dirt lodging therein, the end blading covered with canvas and the whole of the internal surfaces of condenser, diaphragms, tube plates, were cleaned down and blackleaded where necessary.

When all tubes were removed the condenser shells were shored in six positions against possible distortion when tube-plates were removed. Trammels were made and measurements taken from fixed points so that any distortion of the

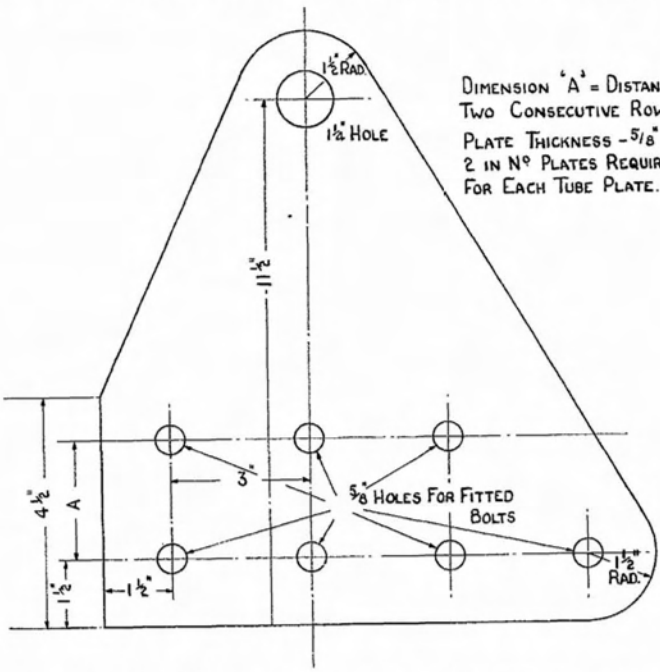

FIG. 3.—SPECIAL LIFTING BRACKET FOR TUBE PLATES

shell could be recorded and possibly corrected by jacks before replacing the tube-plates. The eduction pipes were also shored up to relieve the load on the condenser shells. This precaution was very necessary, owing to the flexibility of the ship, especially when docked. In the centre engine rooms it was found when breaking the eduction joints before docking that these joints opened at the top some 1¼ in. as the ship took the blocks.

As a result no difficulty was found in removing or replacing the tube-plates except that there was no lifting gear, so the special brackets shown in Fig. 3 were made, these being secured to the tube-plate by fitted bolts passing through old ferrules thus protecting the threads in the tube-plate. The ends of the stays were then examined and all but four were fit for further service. Two were renewed and owing to shortage of material the other two were reinforced by welding. Most careful attention was given to the stay ends, the threads being run down, the radii on the stay end and tube-plate faired and the stay nut landings faced up.

This work was well repaid at the test, as was similar work on the collar studs, 50% of which it was necessary to renew. In all cases the landings of these

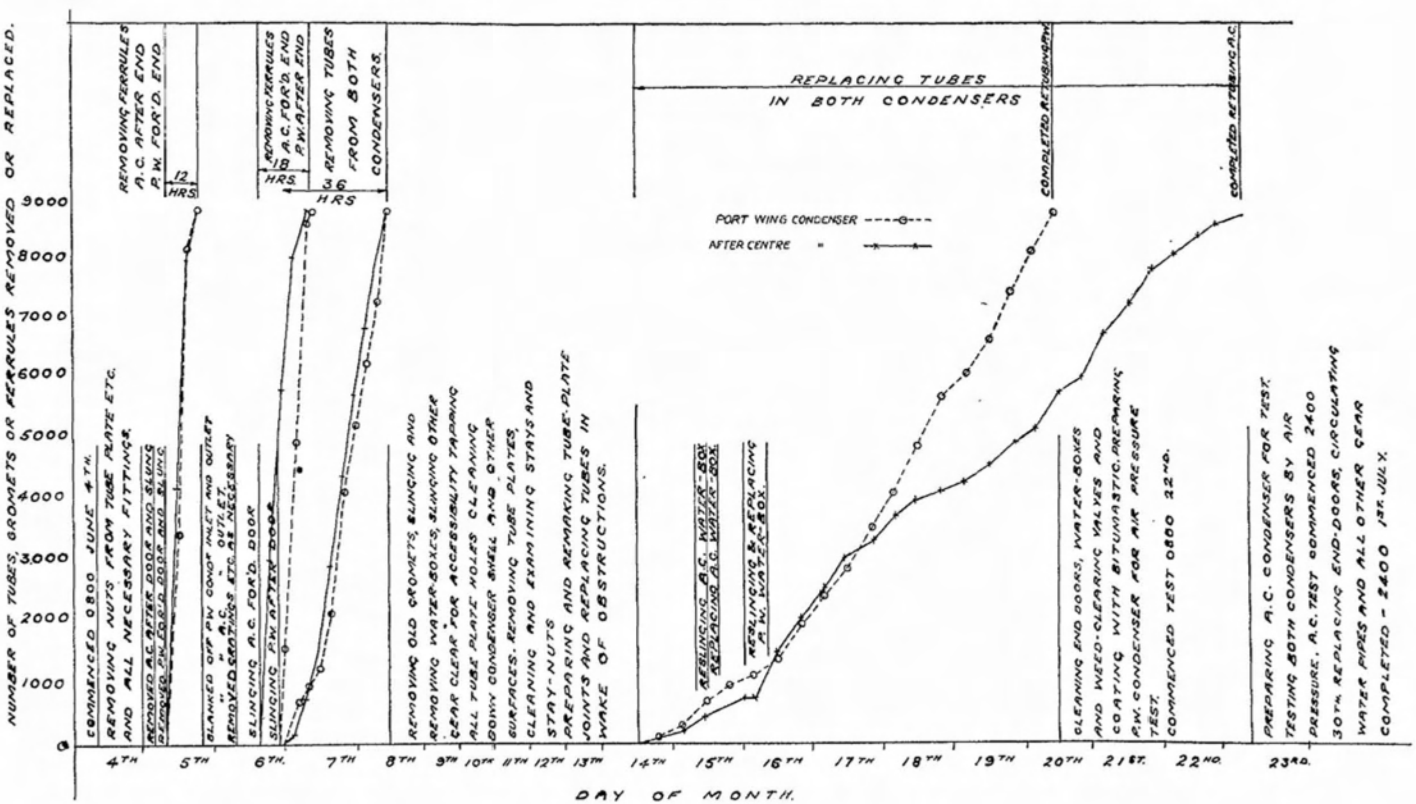

FIG. 4.—PROGRESS CHART OF PORT WING AND AFTER CENTRE CONDENSERS

studs were faced with a rose cutter. The tube-plates were then replaced, the joint being made with red-lead putty; instead of hammering up the nuts a long well-fitting spanner was used, this enabled a steady pull to be given.

Owing to the varying thickness of the tube-plate it was only then possible to estimate the final cutting length of the new tubes. A sample tube was tried in varying positions over the plate and it was found that if the tubes at the widest part were about $\frac{1}{16}$ in. proud at each end, the maximum overlap was $\frac{3}{16}$ in. This was accepted and the dockyard coppersmith's shop went into continuous production of tubes.

As the tubes were delivered to the ship, a further check was made before they were passed to the engine rooms. A wooden trough was made in which the new tubes were sighted, the burrs removed from each end and a small radius filed on one end to facilitate threading through the diaphragm plates. They were finally gauged for the second time both internally and externally. The tubes were then carefully passed to the engine rooms and a grommet passed over one end and threaded into the condenser. It was found that the grommeted end would pass freely into the stuffing box.

Few rejects.

After threading a row or group the tube was " centred " until the overlap on both tube plates was approximately the same. A ferrule was then screwed lightly on the grommeted end until it compressed the grommet sufficiently to hold the tube. A grommet was then placed on the other end and pushed home and a ferrule screwed on. When the second ferrule was compressing its grommet, the men at both ends started screwing up both ferrules of the same tube together, the necessary pressure required being soon found by experience. As soon as the batch was completed in this manner, the internal gauge was again tried in each tube as a precaution against collapse or " necking." Any tubes which thus failed were promptly removed. As a matter of interest during the whole of the retubing, only six tubes were rejected for this cause.

Great care was required in threading the grommets as should they not be pushed home properly they tended to tear and portions found their way into the threads, thus giving a false impression of tightness.

At the start, of the 32 E.R.A.'s employed, there were some 31 methods of retubing, but the above sequence with careful following up of material supplies by the " mates " gave the most satisfactory result. Maintenance of the retubing tools in perfect condition was of the greatest value. The progress chart (Fig. 4) which illustrates the increase of output with experience, is for ship and fleet labour only. It is most satisfactory how this compared so favourably with the dockyard labour.

Satisfactory progress.

All this progressed well within the scheduled dates, even though at one period the combined demand of ship and dockyard exceeded the full output of the tube shop. As it was not possible to test the inner condenser while in dock owing to the eduction bend joint being " open," the wing condenser was manned up at the expense of the inner and the surplus labour diverted to preparing for test. The air pump suctions were blanked and the main test doors fitted to the L.P. turbine, while the stoker ratings were employed on cleaning down the tube plates where the linseed oil from the grommets had exuded. The grommets had been soaked for some 48 hours and this was far too long, judging by results, as a quick dip into oil just before use was proved by the dockyard side to be sufficient.

Before test, the water box end was replaced and ferrules made from boiler tube drilled to show up leaks, fitted over the collar studs at the opposite end, to prevent distortion of the tube-plate joints under test. On account of the humidity of the atmosphere it was necessary to keep the water in the condenser at about 10° F. above the temperature of the engine room throughout the test. This was arranged through suitable steam connections being made and fitted. Test gauges were fitted to top and bottom of the condenser as the weight of water gave 4 lb./sq. in. on the bottom rows. The condenser was filled with hot water to 6 in. above the top tubes and an air pressure of 8 lb./sq. in. applied.

Obvious leaks were stopped by tightening the ferrules and always after tightening, the internal gauge was again tried; these leaks were remarkably few. Test was continued for some 27 hours, a most monotonous proceeding, causing temporary eye-strain, but it was worth it. The minor "weeps" were located by continual application of french chalk sprayed on to the tube-plate by the "Insecticide" gun supplied for the extermination of cockroaches. It was found that a water leak gave a very slight tinge of blue to the chalk which could be distinguished from the stain caused by the linseed oil.

The dockyard side had meanwhile made similar tests and their condensers were finally accepted by the ship's officers. All gear was then replaced in preparation for a basin trial, which took place satisfactorily exactly 28 days from commencing the work. Two days were then spent embarking aircraft stores, etc., during which time the condensers were used for "auxiliary" in turn and the engine rooms cleaned up.

On the third day the ship sailed for normal flying duties and speeds up to 28 knots were reached, an average of over 20 knots being maintained over the whole period. As a very slight cloud appeared in one condenser a prolonged "Canterbury" test was applied but no leaks were found, there was, however, an area under suspicion, so the ferrules were slightly tightened and again gauged. From that date there have been "clear" tests under all conditions at sea.

The lessons learned were many, but the successful conclusion can be attributed to the following four causes:—

(i) The zeal, energy and interest shown by the ratings employed.

(ii) Maintenance of continuity of supply of materials, and allocation of work so that there was no overlapping of labour or idle hands.

(iii) The continuous and most strict supervision.

(iv) The abnormally prolonged final tests.

In order to get the best results in the shortest possible time, the work must of necessity follow an organised programme.