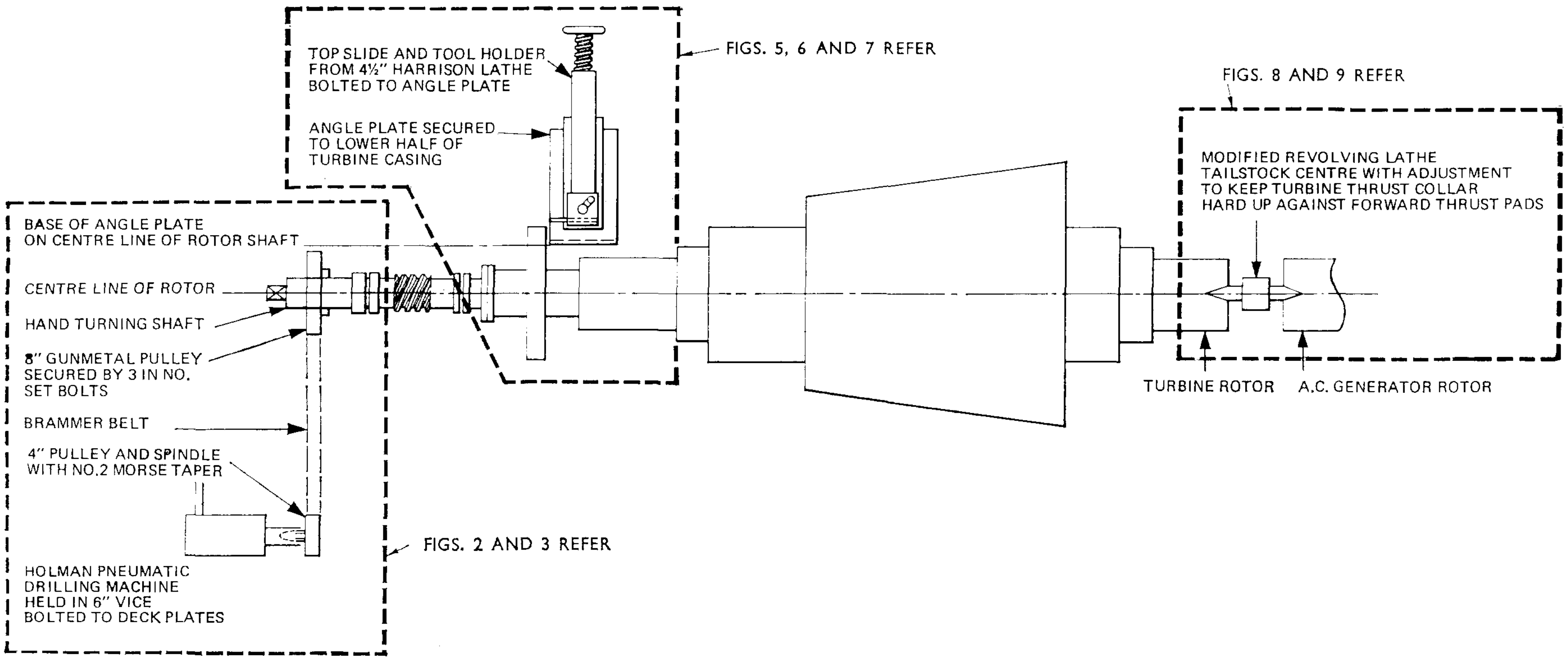

FIG. 1—LAYOUT OF TURBO GENERATOR FOR MACHINING OF THRUST-COLLAR

IN SITU REPAIR OF TURBINE ROTOR THRUST-COLLARS

BY

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While carrying out routine planned maintenance in a submarine, severe scoring of the aftermost face of the thrust-collars of both turbo generator turbine rotors was discovered. The depth of scoring was estimated to be between 0·010 and 0·020 inches on the port rotor and between 0·040 and 0·060 inches on the starboard rotor.

As the diameter of the largest row of turbine blades was larger than the largest pressure hull opening, the possibilities for repair were as follows:

(*a*) Cut a hole in the pressure hull to remove the rotors from the submarine for machining in a workshop ashore.

(*b*) De-blade sufficient rows to enable the rotors to pass through the normal hatches.

(*c*) Attempt an *in situ* repair.

Method (*a*) was discarded as requiring a docking plus a very complicated hull insert re-weld in wake of an already complicated job. Method (*b*) was discarded because of the added complexity. Both these methods would have been costly in time, manpower, and money; it was, therefore, decided to attempt method (*c*) and machine the damaged thrust-collars with the turbine rotors resting in their lower-half journal bearings.

The problems that had to be overcome to carry out this repair were as follows:

(*a*) Motive power to rotate the rotors.

(*b*) Special rig to machine the damaged collars.

(*c*) Exclusion of swarf.

(*d*) Prevention of axial movement of the turbine rotors.

(*e*) Lubrication of journal bearings and forward thrust-pads.

(*f*) Prevention of movement of the lower halves of the turbine journal bearings and forward thrust-pad carriers.

Each problem was tackled as follows:

(*a*) See FIGS. 2 and 3

An air-driven portable drilling machine (AP 0278–4030) was fitted with a 4-inch diameter Vee-belt pulley welded to a short shaft with a morse taper to suit the morse socket in the drilling machine. The male shaft being lightly tack-welded to the drill socket to prevent any possibility of the pulley shaft falling out.

A 8-inch diameter gun-metal Vee-belt pulley was manufactured and secured by three set screws to the hand turning-gear shaft of the turbine.

The portable drilling machine was firmly held in a normal 6-inch vice (AP 0276–910–6593), the vice in turn being secured to the deck plate and support framing at the forward end of the TG.

The $\frac{1}{2}$-inch wide Brammer link-type belting used to transmit the drive gave a simple method of adjusting belt tension and as the drilling machine could be moved in the vice, the problem of any slight pulley misalignment was easily overcome.

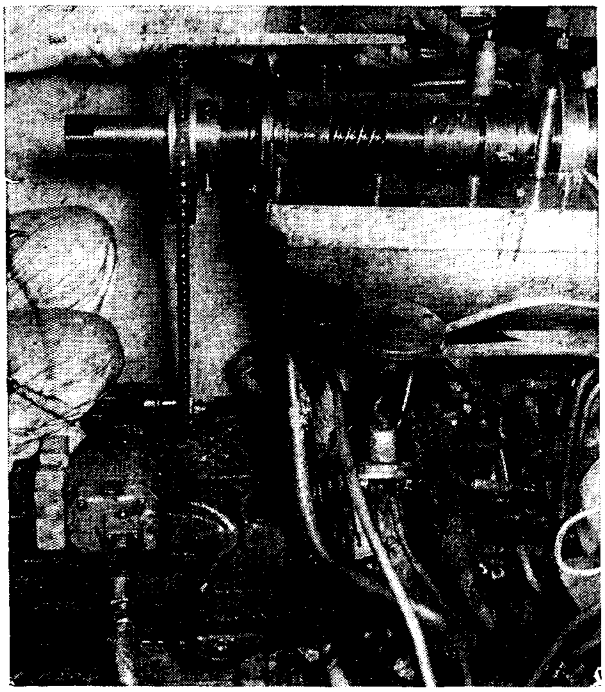

FIG. 2—ROTOR DRIVING ARRANGEMENTS—LOOKING OUTBOARD

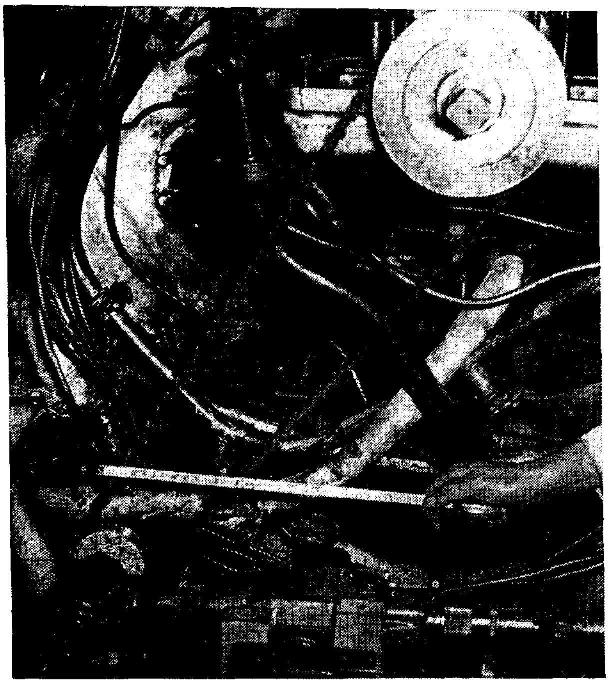

FIG. 3—ROTOR DRIVING ARRANGEMENTS—LOOKING AFT

The submarines 100 p.s.i. emergency breathing system supplied the air for the drill and, with a small stop valve fitted in the air supply line, gave a finer speed control than would have been available with the drilling machines twist-grip throttle valve.

The turbine rotor was successfully rotated at a speed of 20 to 40 r.p.m., the aim having been to rotate the rotor at 30 r.p.m.

Note: The normal hand turning-gear ratchet handle was used to start the turbine rotor moving.

(*b*) See FIGS. 4, 5, 6, and 7

A $\frac{5}{8}$-inch-thick mild steel angle-plate, $8\frac{1}{2}$ inches high $\times$ $6\frac{1}{2}$ inches deep $\times$ $5\frac{3}{4}$ inches wide with a suitable stiffener, was manufactured. The dimensions of the angle-plate and holding-down bolt-hole positions were chosen:

(*i*) To suit a top slide and tool post of a $4\frac{1}{2}$-inch Harrison lathe.

(*ii*) To locate the final tool position directly in line with vertical centre line of the turbine rotor shaft, at the same time keeping the whole assembly as rigid as possible.

(*iii*) To utilize the forward shaft journal top-half bearing securing stud-hole positions and bearing/governor support housing cover stud-hole positions to hold the angle-bracket in place.

(*c*) See FIG. 5

Swarf exclusion and collection was achieved with comparative ease by using an industrial vacuum cleaner, with its suction hose adjacent to the cutting tool, and various pieces of CAF jointing to deflect any loose swarf away from the shaft journal and the forward side of the thrust-collar.

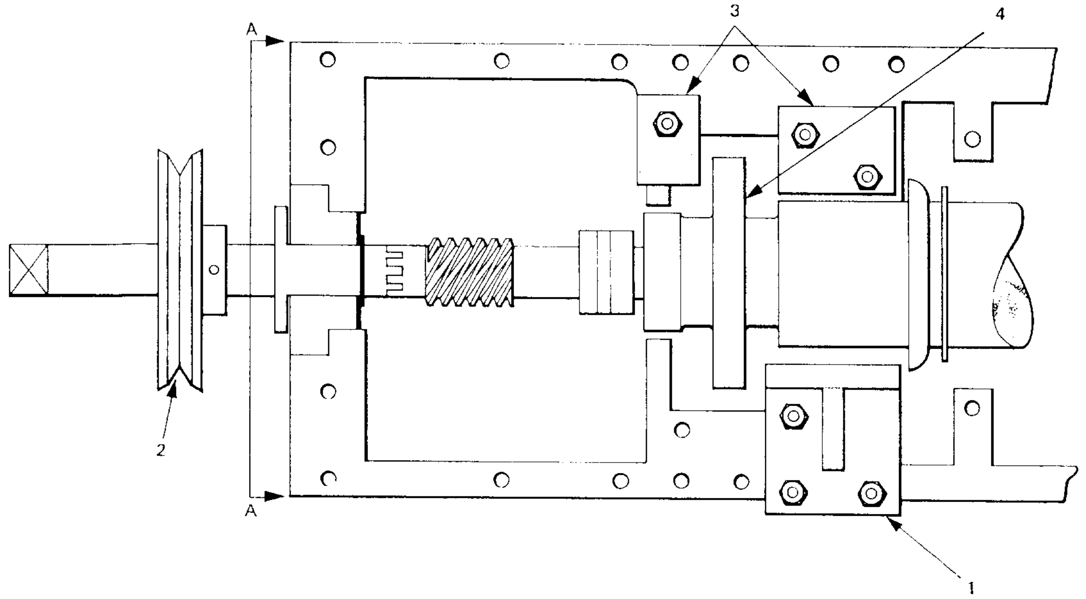

FIG. 4—PLAN OF ROTOR SHAFT AND BEARING HOUSING
(1) BRACKET TO CARRY LATHE TOP-SLIDE
(2) PULLY SECURED TO SHAFT
(3) PLATES PREVENTING ROTATION OF BEARING AND THRUST-PAD CARRIER
(4) DAMAGED THRUST-COLLAR FACE

FIG. 5—LATHE TOP-SLIDE HELD BY ANGLE-BRACKET

Two magnets provided a means of holding the CAF jointing and an additional means of swarf collection.

(*d*) See FIG. 8 and 9

To prevent axial movement of the rotor shaft during the actual machining, a lathe tailstock revolving centre was modified to provide a double-ended thrust arrangement. This was fitted between the centre hole in the after end of the turbine rotor and the centre hole in the forward end of the AC generator rotor. This arrangement successfully kept the turbine rotor still axially within $\pm$ 0·00025 inches.

Note: The loose flexible coupling had to be removed to facilitate the fitting of this thrust arrangement.

(*e*) Lubrication of the turbine shaft in way of the forward and after journal bearings, the forward thrust-collar and thrust-pads, and the modified tailstock revolving centre which held the turbine rotor hard up against

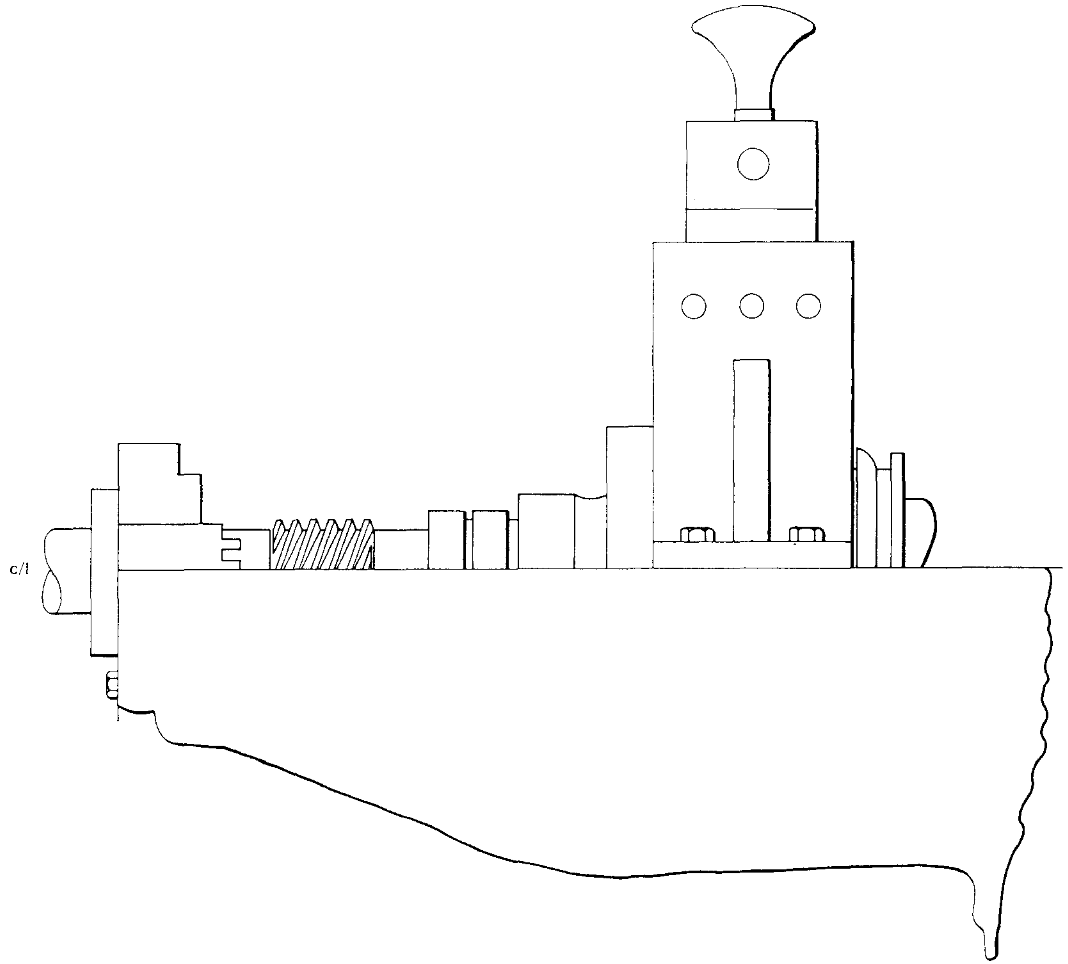

FIG. 6—SKETCH SHOWING POSITION OF ANGLE-BRACKET

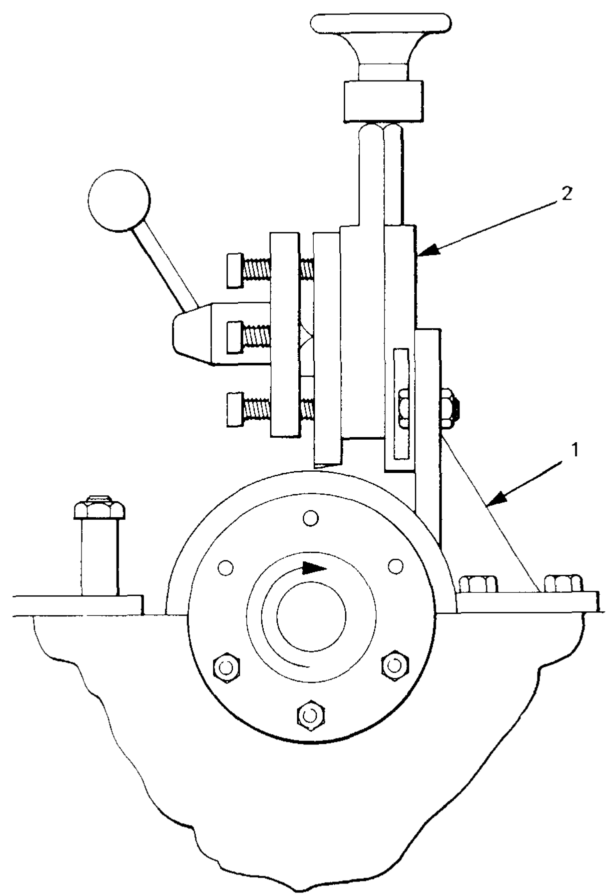

FIG. 7—LOOKING AFT AT SECTION A- -A OF FIG. 4
(1) ANGLE-BRACKET
(2) LATHE TOP-SLIDE

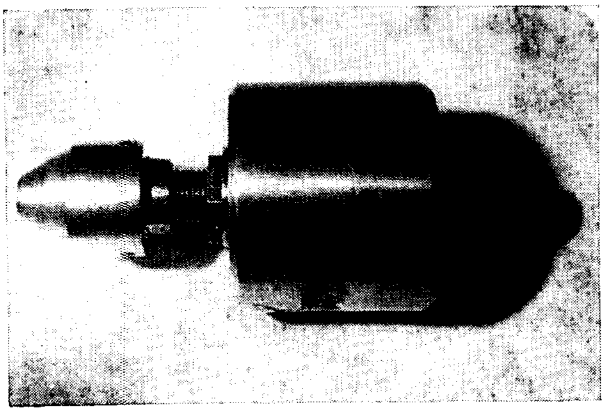

FIG. 8—MODIFIED TAILSTOCK REVOLVING CENTRE

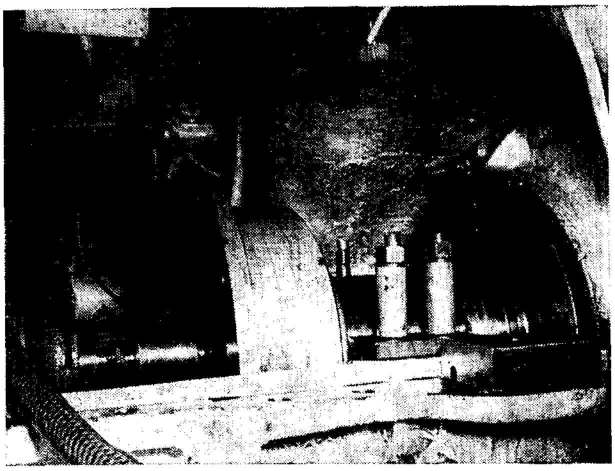

FIG. 9—MODIFIED CENTRE IN PLACE TO MAINTAIN AXIAL POSITION OF ROTOR

FIG. 10—PLATES PREVENTING ROTATION OF JOURNAL BEARING AND THRUST-PAD CARRIER RING

the forward set of thrust-pads was achieved by use of hand-held pressure-type oil feeders using OM 750.

(*f*) See FIGS. 4 and 10

The lower halves of the forward and after journal bearings and the forward lower-half thrust-pad carrier-ring were prevented from turning out by small plates bolted to the bearing pedestal.

Before machining the damaged thrust-collar faces, the special angle-plate and associated lathe top slide was set up in the base workshop on a large lathe to machine a simulated thrust-collar face.

The forward and undamaged face of the thrust-collars were used to set up the angle-bracket and lathe top slide onboard.

The actual machining was started with cuts up to 0·010 inches with finishing cuts of 0·002 to 0·003 inches. The very slight gramophone effect produced by the hand feed of the cutting tool was polished out by fine abrasive paper.

The radius at the root of the thrust-collars created a slight problem, particularly on the starboard side, where the radius tool 'dug in'. Eventually the final machining of the radius on both rotors was done using a high-speed air-driven rotary drill fitted with a ⅜-inch hemispherical burr. This drill was mounted on the same angle-bracket and top slide as for the face machining operation.

The final thickness of the thrust-collars on completion of the machining operations was as follows:

Port 1·112 in. (0·013 in. undersize)

Starboard 1·083 in. (0·042 in. undersize)

On completion of the machining operations, the forward and after bearing pockets (including the thrust-collar area) were thoroughly flushed out with Gamlen.

New turbine rotor journal bearings and forward and after thrust-pads were fitted to both TG's, shims being manufactured to compensate for the material machined from the after thrust-face.

The final axial floats of the turbine rotors were:

Port	0·0065 in.	Design 0·006 in.—0·010 in.
Starboard	0·006 in.	

Both TG's were run on 'No load' with the oil temperature kept at 100° to 110°F for one hour to allow replacement bearings to bed in. The starboard TG thrust-collar and thrust-pads were examined after 16 hours on load and found to be satisfactory. The port TG thrust-collar and thrust-pads were examined after seven days on load and were also found to be satisfactory.

The total time to effect the repair, working from 0800 to 2000 daily was 9½ days.