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DIESEL-ENGINE CLUTCH USED IN THE GERMAN SUBMARINE "U-117"

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The purpose of this paper is to give to American builders of Diesel engines the benefit of the author's knowledge of German Diesel-engine clutches obtained at the time of the dismantling of ex-German submarines in the United States. The U-117's clutch is described in detail and other types of German Diesel-engine clutches are covered generally.

THE submarine *U-117* was commissioned by the Germans in 1917 and operated off our North Atlantic coast in that summer and in the summer of 1918. It is known that this submarine took part in the sinking of coal barges and fishing boats in the vicinity of Nantucket and it is supposed that she is responsible for the planting of mines off the Long Island Shore, one of which sank the U. S. Cruiser *San Diego*.[2]

2 The *U-117* is a large mine-laying and -operating submarine. Her overall dimensions are: length, 275 ft.; beam, 17 ft.; and draft, 10 ft. She has a carrying capacity of 20 torpedoes and 45 mines. The armament consists of a 6-in. rapid-fire gun forward and a 5-in. gun aft, both on the main deck. There are four torpedo tubes in the compartment forward, and two mine tubes in the compartment aft.

3 The engine equipment consists of a port and a starboard Diesel oil engine, four-cycle, six-cylinder with two air-compressor cylinders of 1200 i.hp. at 450 r.p.m. for surface cruising and battery charging. The bore of the working cylinder is 17.73 in. and the stroke 16.5 in. The complete engines weigh 57,000 lb. each.

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[2] The *U-117* was recently used as a target and sunk off the Virginia Capes in the U. S. Army airplane bombing experiments.

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4 There are also the port and starboard main motors, each rated at 600 hp. at 332 r.p.m., for submerged operation. In general, the design of the motor comprises two compound interpole assemblies in one frame with the armatures in tandem on the same shaft, motor-generator fashion. The motors receive their power from two 124-cell 248-volt storage batteries. When the boat is under

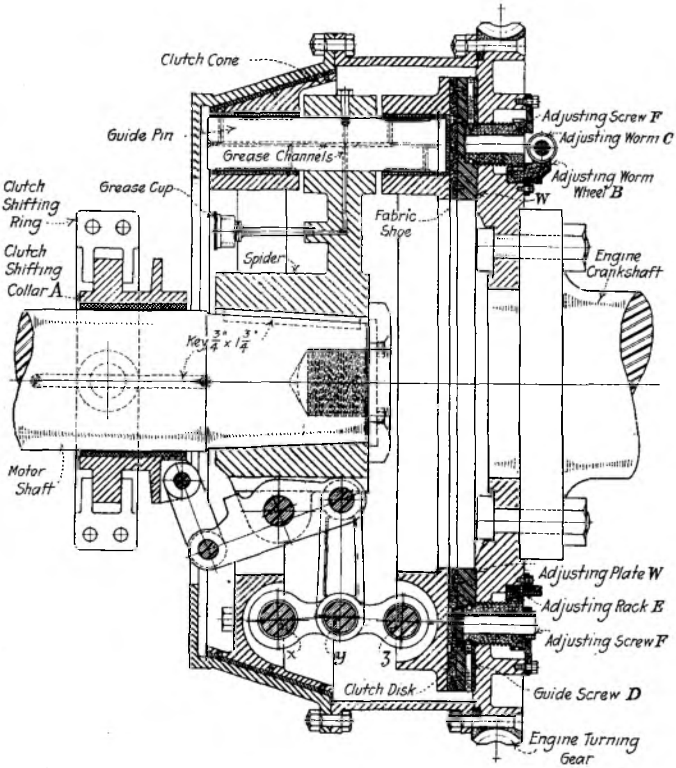

Fig. 1 Sectional View of Diesel-Engine Clutch Used in the German Submarine *U-117*

way on the surface, each motor unit is driven as a generator by the Diesel oil engines, using the excess power of the engine to recharge the batteries and carry the auxiliary power load.

5 The log of the *U-117,* her general description, and the description of her propelling machinery give some idea of the work performed by her clutches.

DETAILS OF THE *U-117* MAIN ENGINE CLUTCH

6 The clutch is located between the Diesel oil engine and the main motor, both port and starboard. It is of the single cone and disk friction dry type, constructed of semi-steel and cast iron, and operated by compressed air. The clutch was built to metric measure. All dimensions given in this paper, however, are in nearest inches or fractions of an inch.

7 The outer casing, adjusting plate, worm wheel, and adjusting screws, which serve as a flywheel, are carried on the engine crankshaft. The casing as shown in Fig. 1 is made of two

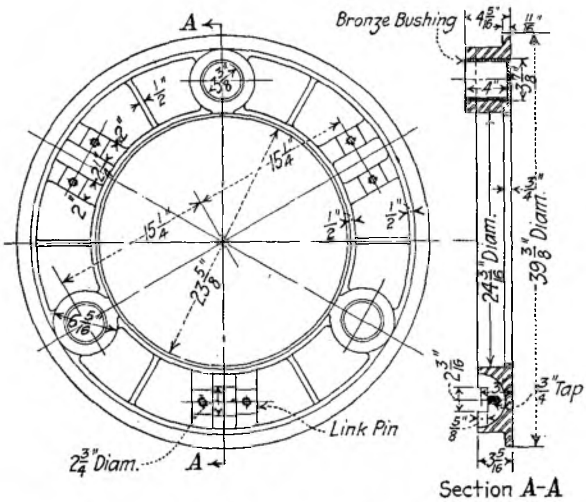

FIG. 2 CLUTCH DISK

parts bolted together. The inner surface of the after casing is machined to a cone surface; the forward casing is a straight sleeve or spacer for power transmission only. The extreme outside diameter of the casing is 45 in.

8 The inner clutch cone or male cone and clutch disk are carried on the guide pins of the spider, on which they are a sliding fit. They are of semi-steel and the outer surface of the male cone is finished to conform to the conical surface of the female or flywheel part. The forward surface of the clutch disk is finished for contact on the fabric shoe of the adjusting plate. Figs. 2 and 3

are detail sketches of the male cone and the clutch disk carried by the spider. The taper of the cone surfaces is about 14 deg. The cone and disk are bronze-bushed for the guide pins.

9 To the outer surface or periphery of the male cone there is attached, by means of countersunk machine screws, a fiber shoe as shown in Figs. 1 and 3. The shoe is ¼ in. thick and is made up in four sections, the divisions being in the direction of the axis of the guide pins or shaft. It is the surface of the fiber shoe

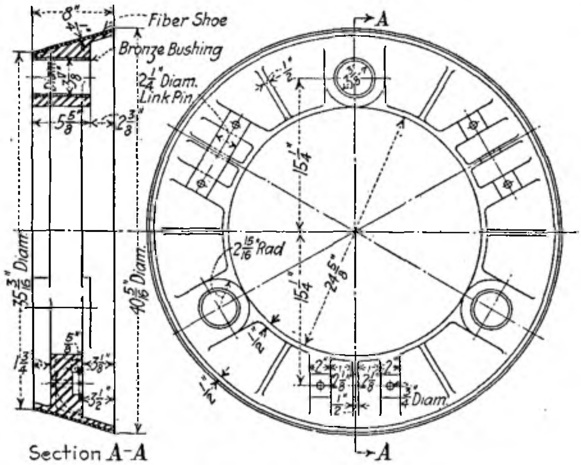

FIG. 3 CLUTCH CONE

that contacts with the metal surface of the female or outer casing when the clutch is thrown in.

10 The spider, attached to the motor shaft by a single key and a retaining screw has three guide pins parallel to the axis of the engine and motor shafts and extending through the spider on either side as shown in Figs. 1 and 4. The guide pins are steel forgings and are shrunk in the spider.

11 The clutch is thrown in by forcing the male cone and the disk apart until the male and female cone surfaces engage and the disk surface engages the fabric shoe of the adjusting plate; and by drawing the male cone and the disk together and thus releasing the surfaces the clutch is thrown out. The male cone and the disk are drawn together or forced apart by a series of links and toggles actuated by a sleeve or collar (*A* in Fig. 1) sliding on the

motor shaft. The shifting collar is shown in detail in Fig. 5. It is babbitted for a sliding fit on the motor shaft and is single-keyed thereto.

12 Referring to the lower half of Fig. 1, the center x is shown fixed to the male cone and center z to the disk. The clutch is en-

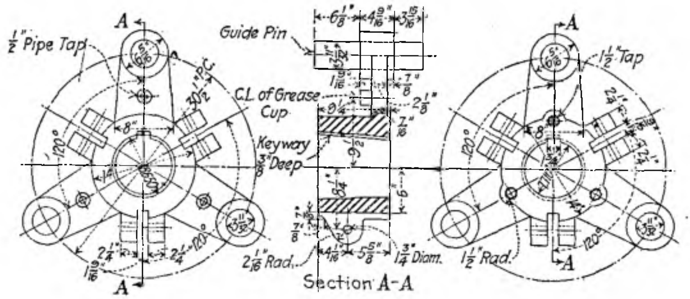

FIG. 4 CLUTCH SPIDER

gaged by separating centers x and z and by forcing center y up to a line adjoining centers x and z. There are three sets of operating links and toggles equally spaced between guide pins of the spider as shown in Fig. 4.

13 To the after side of the worm wheel there is attached by means of six adjusting screws a steel disk or adjusting plate faced

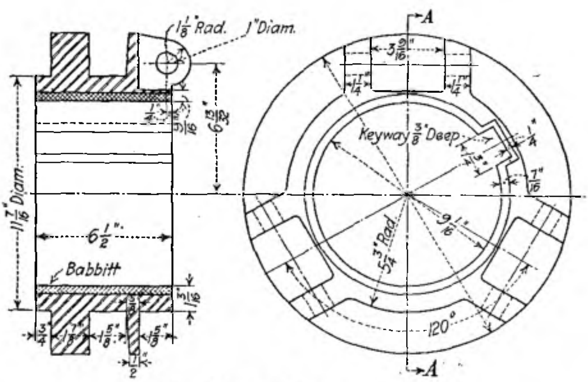

FIG. 5 CLUTCH-SHIFTING COLLAR

with fabric. The fabric is $\frac{7}{16}$ in. thick and serves the same purpose as the fiber shoe of the male cone. The fabric is also in four sections and is secured by means of countersunk machine screws.

The sectional divisions of the fabric are radial. When the clutch is engaged, the forward surface or finished surface of the clutch disk has contact with the fabric shoe.

14 The fore-and-aft movement of the male cone and disk is $\frac{3}{8}$ in., or a total of $\frac{3}{4}$ in. The fiber and fabric shoes have some flexibility and it is these surfaces that absorb the load shocks and transmit the power of the engine. The design of this clutch differs in this respect from the clutch used with the 3000- and 1750-hp. engines, in that those clutches have, when engaged, a metal-to-metal contact on lubricated surfaces. The fabric and fiber shoes may be renewed when worn.

15 The adjusting worm wheel is carried on the engine turning gear (see *B* in Fig. 1) and is rotated by the adjusting worm (*C*) which is hand-operated from either end of the worm shaft by means

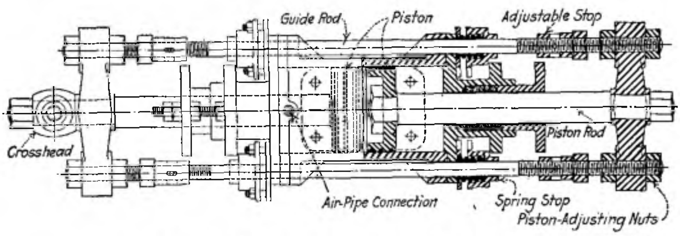

FIG. 6 CLUTCH-SHIFTING CYLINDER

of a wrench. The adjusting worm is bracketed to the engine turning-gear cover plate. Any movement of the adjusting worm is transmitted through the rack (*E*) and rotates the adjusting screws (*F*) which are threaded through the worm wheel. There are six adjusting screws equally spaced, three of which are secured to the adjusting plate by means of the guide screws (*D*). The other three adjusting screws have contact only on the forward surface of the adjusting plate; their ends are flat and do not penetrate the plate. The sketches do not show the short adjusting screws. By means of the adjusting mechanism there is a movement of $\frac{9}{16}$ in. between the disk and the fabric shoe, the adjusting plate moving aft from the turning gear that distance at the surfaces marked *W* in Fig. 1.

16 The guide pins of the spider are lubricated by means of three grease cups attached to its arms by a length of pipe. The guide pins and spider arms are drilled for the passage of grease

and the former are grooved for its distribution. Plugs are inserted in the blind ends of drilled holes. The circumferential force or centrifugal force of the clutch should carry sufficient grease to the pins without attention to the grease cups except for occasional filling.

17 The clutch shifting cylinder shown in Fig. 6 is of semi-steel. The bore is 7 in. and the stroke is from $7\frac{1}{2}$ to 8 in., depending on the setting of the pistons. The pistons may be set for long or short stroke by means of the piston adjusting nuts. To prevent pistons from striking cylinder heads when operating, adjustable stops are provided on the guide rods and spring stops are

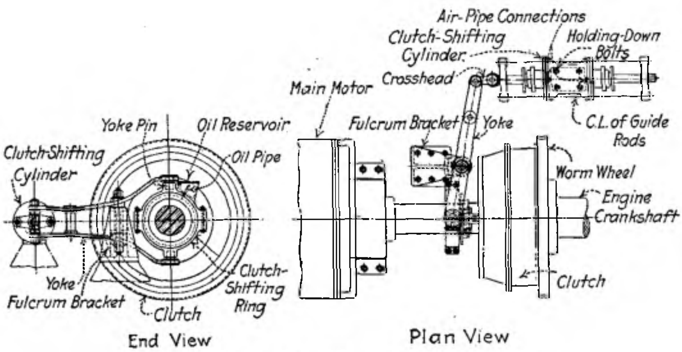

Fig. 7 General Arrangement of Clutch

secured to the cylinder heads. The springs at either end of the cylinder absorb the shocks when throwing the clutch in or out.

18 The general arrangement of the clutch is shown in Fig. 7. The clutch operating cylinder is placed alongside the engine with its center line parallel with the axis of the crankshaft.

19 The clutch cylinder is operated by air pressure and transmits its power through the crosshead, yoke, and fulcrum to the clutch.

20 The fulcrum bracket is of semi-steel and is carried on a foundation from the ship's floor. It is estimated that the load at the fulcrum is about 16,000 lb.

21 The clutch shifting ring is held in its position by the yoke pins and is lubricated for contact with the clutch shifting collar by means of a wick in the oil reservoir.

22 The engine-turning gear carried with the clutch consists of a worm wheel carried on the engine crankshaft flange and a

hand-operated worm which is locked out of position when not in use. The diameter of the turning gear is 46⅝ in., which is the extreme outside dimension of the assembled clutch.

23 Fig. 8 shows diagrammatically the arrangement of the clutch-shifting piping. Compressed air for the operation of the clutch is supplied from the main engine air-starting flasks at 160 atmospheres (metric measure) or about 2275 lb. per sq. in. It is noted that the air is drawn from the top of the flasks by means of an internal pipe to prevent water that may be collected in the

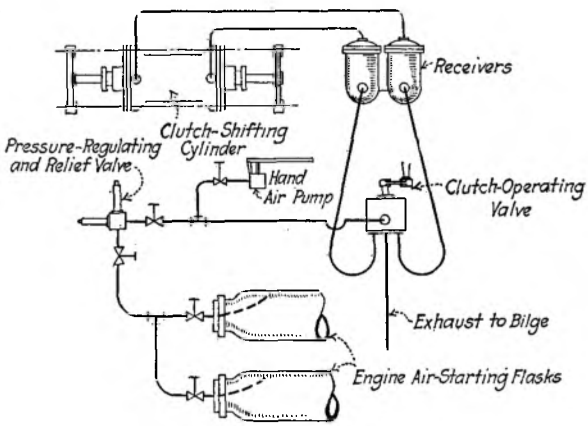

FIG. 8 DIAGRAM SHOWING ARRANGEMENT OF CLUTCH-SHIFTING PIPING

flasks from passing through to the shifting cylinder and damaging it.

24 There is a pressure-regulating and relief valve in the pipe from the air-starting flasks, with stop valves on either side and at the flasks. The air passes through the clutch-operating valve to the receivers and then to the clutch-operating cylinder.

25 The clutch-operating valve is so designed that its ports take care of the exhaust air from the opposite end of the clutch-operating cylinder by a single movement of the handle, exhausting the air and entrained water to the ship's bilges.

26 When the clutch is thrown in, it is self-locking, as shown by position of links and toggles in lower half of Fig. 1. It is to be noted that this locking is accomplished by forcing center y slightly above centers x and z. Air may then be shut off from the

clutch-shifting cylinder until it is necessary to throw the clutch out. The centrifugal force of the clutch will not throw it out. The advantage of the self-locking feature lies in the assurance that the holding power of the clutch does not depend on a constant pressure of air in the cylinder. Where air pressure would be used for holding the clutch in, there would be the possibility of leaks or fluctuations and the release of the clutch.

27 All air piping is ½ in. in inside diameter and of seamless drawn steel with steel rings brazed to the ends for making up the joints. The pipes are secured in forged-steel fittings by means of a male nut placed on the pipe back of the brazed ring, the nuts then being screwed into the female joint of the fittings. Gaskets are either fiber or copper, placed within the fitting. All pipes and fittings tested to 3000 lb. hydrostatic pressure per sq. in.

28 For emergency there is a hand pump for the operation of the clutch.

CLASSIFICATION OF GERMAN DIESEL ENGINES AND CLUTCHES

29 The German Diesel oil engines were generally classified as follows:

10-cylinder, 4-cycle, 3000 i.hp., for large cruisers (submarine)
6-cylinder, 4-cycle, 1750 i.hp., for large operating submarines
6-cylinder, 4-cycle, 1200 i.hp., for large mine-laying and operating submarines
6-cylinder, 4-cycle, 550 i.hp., for mine-laying and coastal submarines.

30 Clutches for the 3000- and 1750-i.hp. engines were of the double-cone, friction, lubricated type, operated by compressed air or electric motor.

31 Clutches for the 1200- and 500-i.hp. engines were of the single-cone and disk, friction, dry type. The 1200-i.hp. engine clutches were operated by air and are described in detail in this paper. The 550-i.hp. engine clutches were operated by hand through worm and gear.

32 The details of design of the German Diesel-engine clutches were practically unknown in this country prior to the surrender of the German submarines, and considerable difficulty was experienced in dismantling them.

33 At the time of the arrival of the submarine freighter *Deutschland* at New London, when an appointed board of naval officers and civilians inspected her to establish her status, it is

known that much interest was shown in her clutches, the construction of which was considered remarkable in so far as so small a diameter of clutch was capable of transmitting such large horsepower. No information of value was then obtainable, but later, when the surrendered German submarines arrived in this country, the clutches were one of the first mechanisms to be investigated.

34 It is believed that many improvements can be made in the design of American clutches by adopting some of the principles of the German clutches. The author has had some experience with American clutches and has found them to be of the tooth or positive-drive type, or of the friction-jack type. These clutches have been the source of trouble and are constantly in need of repair. The tooth type does not allow the flexibility of shaft speeds required in maneuvering a ship that a friction type allows, and from experience it has been found that the friction types are not of sufficient strength and rigidity to transmit heavy loads. During the war one of our American submarines went below her depth by accident and it was necessary to insert emery paper in the clutch before the jaws would take hold and allow her motors to operate the shaft-driven bilge pump. Such delays may cause the loss of a ship and many lives.

35 The friction-jack types are usually thrown in by hand through a series of levers and therefore lack the holding power of an air-operated clutch.

36 With the friction-jack type of clutch there is nearly always a misalignment of shafts when the clutch is in, due to improper setting of the jack screws or adjusting screws. The screws are placed radially and must be adjusted from time to time to take up wear. It requires a skilled operator to properly adjust such a clutch.

37 In the German clutches the adjustment is fore and aft along the axis of the shaft, and with a proper alignment of shafts when machinery is first installed there is little possibility of misalignment when the clutch is in.

38 The author will be glad to give any further information desired by clutch manufactures or engineers that will help to improve our American clutches.