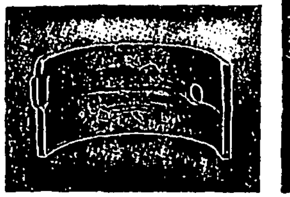
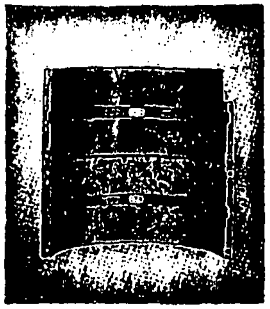
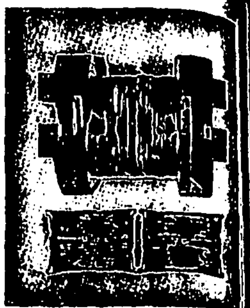
SOME TYPICAL DIESEL-ENGINE BEARING FAILURES



EXCESSIVE DIRT in the engine assembly or in the lubricating oil caused rapid *shaft wear and this bearing failure*



FATIGUE FAILURE shown here resulted from overloading the bearing material. *Note the typical condition of the surface*



OIL-FILM FAILURE allowed metal-to-metal contact in this illustration. Re*sulting seizure caused condition shown*

ating conditions distort engine structures. This may produce edge contact between bearing and shaft. Heat generated by the *metal-to-metal* contact may be sufficient to cause bearing failure. If the metal can conform, it adjusts itself to the new condition. Even if the bearing fails, ability to conform will often prevent shaft damage.

The qualities of embedability and conformability have been combined by Underwood as "deformability" and he lists bearing materials in increasing order of deformability as follows: (1) bronzes (2) silver and copper (3) aluminum alloys (4) copper-lead with tin or silver (5) thin babbitt overlays (0.003-in. or less) (6) copper-lead (7) cadmium alloys and (8) lead- and *tin-base babbitts.*

Seizure Resistance. More time has been spent testing bearing materials for *seizure resistance than for any other* property. Unfortunately, laboratory bearing-test rigs are so rigid and accurately made, to secure reproducible results, that interpreting their data in actual serviceability is extremely difficult. Such tests serve, however, to rank materials roughly and to eliminate those clearly unsuitable.

Seizure-resistance data can be of value when measured in periods of high overstress in actual engine service. If bearing engineers and users could compare notes when seizure does occur, it would add greatly to our knowledge. Unfortunately a crankshaft is damaged in the process and since the information applies to only one engine it is expensive knowledge to obtain.

On the basis of seizure resistance of an actual bearing in an engine, without any overlay of lead-tin for "run-in," Esarey ranks the materials during periods of overstress as follows: (1) lead-base babbitt (2) tin-base babbitt (3) copper-lead on steel back (4) centrifugally cast tin-lead bronze (5) silver with small additions, electro deposited (6) cadmium-silver (7) copper with small silver additions. Gridding the surface and filling it with babbitt and providing a lead-tin run-in surface markedly improves seizure resistance of silver, centrifugally cast lead-bronze and copper-clad steel-back bearings.

Corrosion Resistance. Studies of corrosion resistance bring out the point that nearly all bearing materials can be corroded by some set of conditions, depending on type of acid and temperature. In general, operating temperatures and changes in oil conditions of present-day engines are such that bearings with a *lead-tin or lead-indium* overlay give satisfactory corrosion resistance, or have this resistance as an inherent characteristic. Originally developed as a run-in surface for silver bearings in aircraft engines, the lead-tin and lead-indium overlays provide complete coverage of bearings for surprisingly long service periods.

Bondability. Ability to obtain consistently strong bonds between lining and back is largely a matter of carefulness and manufacturing procedure if suitable materials are used. With modern methods in which the human element is removed as much as possible (for example, by centrifugal casting under electrical control) good bonds result consistently. The Kolene process *for steel* or cast-iron backs gives perfectly satisfactory bonds if care is taken to follow the instructions. Ability to obtain strong chemical bonds permits the present-day elimination of dovetails and other mechanical bonds.

Over-all suitability of a material for bearing service may be summed up as *wear resistance*, defined by Gillett, Russell and Dayton as "the resultant of fit and finish, seizure propensities, behavior with grit, corrosion resistance (formation of corrosion products that are wiped off shows up as wear) and strength and hardness. It is vastly affected by how the bearing is operated as to temperature, nature of loading and cleanliness of oil, and especially the relative number of stops and starts, that is the opportunity for seizure."

Babbitts. Invention of babbitt metal as a lining for bearings represented a tremendous advance. In general, we can still say that within their strength lim*its, babbitts are* acknowledged the best bearing materials. They are tolerant of dirt and work well with all normal types of shafting material. They endure insufficient or intermittent lubrication and considerable distortion. Tin-base babbitts are well known, and have enjoyed general usage in perhaps more varied applications than any other lining material. High-lead babbitts, the general substitute for tin babbitts because of tin shortages, comprise several general groups differing mainly in the minor constituents added for hardening. Tin-antimony, silver, arsenic and alkali earths are used.

When babbitts are stressed or pounded too heavily, they fail in fatigue. Thus it has proved necessary to develop stronger materials to meet more severe demands. In general, these stronger alloys require harder shafts, more and cleaner lubricant, better journal-surface finish and greater constructional accuracy.

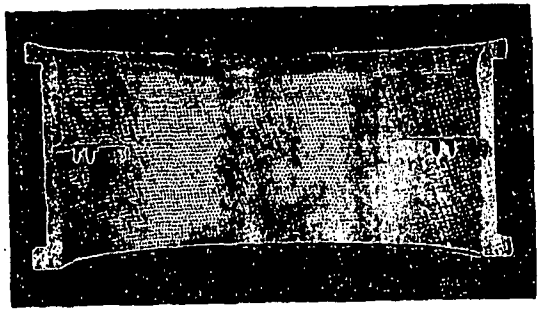
Lead-Bronze Bearings. Several general groups of alloys have found application as bearing linings where loads are too high for babbitts. One group comprises the lead bronzes, with 18 to 22% lead added to the copper-tin alloy that is bronze. Development of centrifugally cast lead-bronze came about just before the war period when steel tubing became increasingly short in supply. It was believed that a material of good conductivity and uniform throughout would eliminate the weaknesses of a bonded bearing and lead-bronze seemed suited for the job. Good results were obtained.

To extend the life in heavy-duty service, lead-bronze bearings were gridded, that is, the bearing surface was indented and filled with silver-lead babbitt. It was found that shape and depth of indentations, and relative proportion of gridded area to parent metal are not critical. Economical manufacturing methods were developed for gridding. It improves embedability, provides conformability and removes need for hardening the shaft. In periods of great overstress the babbitt melts out of the grooves to form a running surface and prevent seizure. Addition of an 0.002-in. run-in surface of electroplated lead-tin further improves seizure resistance and increases *corrosion resistance.*

Copper-Lead Alloys. Some mixtures of *copper and lead* have been used as bearing materials for some years and are by the nature of their structure suited for high loadings. A sacrifice in conformability and the need for a hardened or treated shaft of 300 brinell or harder are characteristics of these bearings.

Where soft shafts must be used, or where extremely high speeds are met, only the white metals will serve. It is also known that load-carrying ability of white metals, their weak point, can be increased by decreasing lining thickness drastically. This led to the so-called micro bearing, with a few thousandths of babbitt *on a steel back*, and the trimetal bearing, with a steel back, an intermediate layer of leaded bronze and a surface layer of babbitt.

Cutting the babbitt thickness to about 0.001 in. in thickness and using a copper-lead intermediate layer permits still further increase in load-carrying ability. The steel back and intermediate layer are formed and machined, complete to precision limits. The surface layer of white metal is precision plated so no further machining is required.



GRIDDED BEARING is made of lead-bronze, in one piece. Surface indentations are filled with a silver-lead babbitt. This construction improves the embedability and conformability, and eliminates the necessity for hardening the shaft, journals

In the early days of such bearings there was some concern about operating on the intermediate *copper-lead* layer after the plated white metal had disappeared. Considerable experience *proves* that the soft overlay adjusts itself to off-conditions of assembly and distortion so that when the overlay goes the load is carried over the entire length of the bearing with resulting satisfactory performance.

Other Lining Materials. Cadmium linings, of which the popular alloys are cadmium-silver copper and cadmium-nickel, are capable of high loadings. They require a minimum shaft hardness of about 250 brinell. In this connection shaft surfaces should, in general, be as hard as possible, regardless of the lining material. Since hardnesses above those normal to customary shafting materials involve heat treatment or other special processing, they present problems to the engine manufacturer. *It is thus desirable* to hold shaft hardness to the minimum consistent with the all-round requirements of the engine application.

Wartime requirements popularized silver, bonded to a steel back, for high-load-carrying bearings in aircraft engines. A plated run-in surface of lead-tin or lead-indium is required to provide satisfactory performance. Since dirt is an enemy of such a hard bearing material, even with an overlay, this material is not normally recommended for diesels, where service conditions are apt to be severe.

Aluminum Bearings. Considerable interest attaches to the recent development of bearings made of aluminum alloyed with tin and other minor additions. Most builders have tested or are testing such materials and at least one manufacturer is using aluminum alloy bearings in a commercial engine. The alloy on which most work has been done consists of commercially pure aluminum with a 6.5% tin, 1% copper and 1% nickel. Another alloy, having the same composition except for the addition of silicon, shows improved resistance to scuffing and has been released on an experimental basis. Both alloys may be given a stabilizing heat treatment after casting, or may be cold-worked. The cold-working improves load-carrying ability. The alloy with silicon is recommended *only where* shaft hardness is over 300 brinell and can be used to advantage where doubtful lubrication conditions exist.

Aluminum-alloy bearings are normally fabricated from a single piece of material—the mono-alloy construction pictured in last month's article. Such bearings seem to have high load-carrying ability, good embedability and conformability, high resistance to seizure and corrosion. The inherent good heat-transmitting ability of aluminum should result in lower temperatures.

On the other hand, aluminum has a relatively high coefficient of thermal expansion, and ample room-temperature oil clearance must be provided. Clearance should be at least 0.001 in. per in. of journal diameter and preferably 0.00125 in. per in. Clean and positive lubrication are desirable in any bearing operation, but for best results with aluminum alloys special care should be taken to insure a clean engine at the start and positive *lubrication.*