RECLAMATION OF WORN INTERNAL COMBUSTION ENGINE COMPONENTS

by

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The reclamation of worn parts is a subject which is of considerable interest and which, in times of emergency, becomes one of paramount importance.

It is, however, not always possible, and certainly undesirable, to have to carry out investigations during war-time but essential that they be completed, and any difficulties in method and technique overcome, in less arduous times.

Material recovery has always been, and is, carried out in ships and H.M. Dockyards but co-ordination of methods employed and results obtained have been, to a very large extent, non-existent, with the result that conclusive information of the relative merits or demerits of the various processes is not available.

The increased numbers of internal combustion engines in naval service and the introduction of the policy of refit by replacement has accentuated the importance of material recovery and increased the urgency of the investigations into the methods to be adopted.

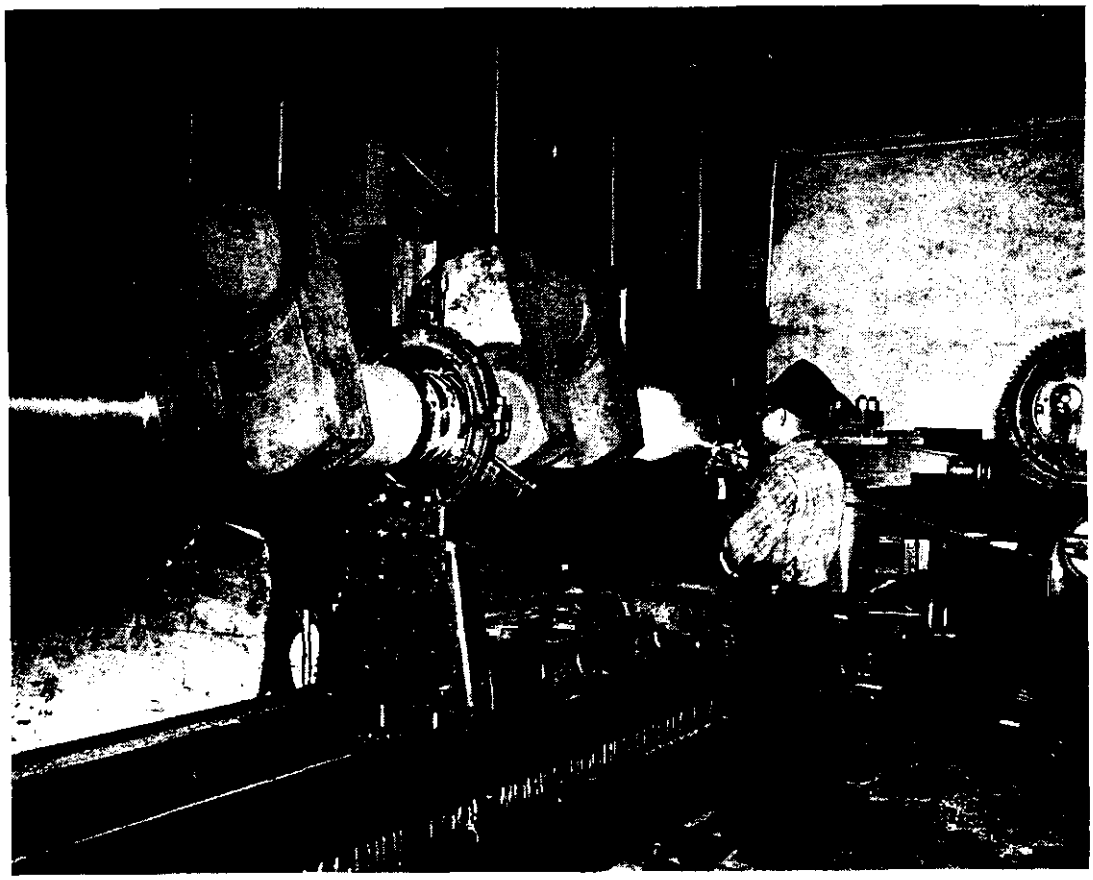
The introduction of batch and line overhaul methods together with the present shortage of spare parts, due to the export drive, has given the investigations additional priority.

Many parts may be reclaimed by welding and this process, carefully carried out, returns strength to the part treated and is capable, in certain circumstances, of repairing fractures.

Electrodeposition and metal spraying are also used extensively for adding metal to worn surfaces but as a general rule add little, or in the case of the latter, no strength to the part reclaimed.

The main inconvenience of electrodeposition is that the parts must be treated in a vat which necessitates size limitation. However, the process is cold whereas the heat generated during welding is liable to set up distortion and to produce weaknesses in areas near, but not at, the weld. There is, however, the risk of 'hydrogen embrittlement' when plating certain steels used for highly stressed components.

Metal spraying has two great advantages. First, that the process is cold and, secondly, the apparatus used is comparatively mobile and does not necessitate the use of chemicals in vats.



COMPLETELY METALLIZING PINS AND BEARINGS OF LARGE CRANKSHAFT, USING METCO TYPE 2E METALLIZING GUN AFTER FUZEBONDING. (AMERICAN PHOTOGRAPH)

No one process is suitable for all types of reclamation as each has its limitations.

It is not proposed to discuss the technical details or methods of the various processes, nor to discuss their relative merits from the technical point of view but merely to show what action has been taken and what investigations are being carried out. The investigations at present in hand are part of a long term policy and are being carried out with a view to the recovery of wearing parts, as opposed to fractured parts, and these will be described in order of relative importance.

One may be tempted to question the policy of considering the reclamation of wearing parts only, but repeated fractures, such as cylinder head cracks are a design problem which are better eliminated by design improvement.

Efforts will be made to reclaim items, such as instruments, which cannot be classified as wearing parts but which are subject to failure.

Crankshafts

The bottleneck in crankshaft production during the war brought the question of reclamation to the fore.

Crankshafts are most economically reclaimed by grinding to an undersize and fitting undersize bearings. This method obviously has its limitations and complicates spare parts organization.

To minimize the confusion which inevitably arises from the acceptance of an unlimited number of undersize bearings the total numbers of undersizes to be employed in service has been limited to a maximum of three which, in the case of crankshafts, will be standard –0.010, –0.020, –0.030, unless otherwise specified.

The other approach to the problem is reclamation by the addition of metal in order to return all worn crankpins and journals to standard dimensions.

It is probable that both these methods will have to be employed but it is the latter method which will be discussed, as it is clearly the more desirable if it can be satisfactorily carried out.

The points in favour of the reclamation of crankshafts are :—

(i) Alleviation of unavoidable bottlenecks in supply in emergency, and economy of skilled man power.

(ii) Cost of replacement crankshafts can be heavy (English Electric 6H crankshaft, £325).

(iii) An essential requirement where administrative or production difficulties preclude the use of undersize bearings.

(iv) A vast simplification of spare parts distribution and supply.

From war-time reports, which were regrettably few, it would appear that Ford V8 and Paxman TPM12 crankshafts were successfully reclaimed in large numbers. Other types reclaimed were the Hall Scott, Scripps V8, and Chrysler Crown crankshafts which were done in small numbers but reports on the operation of these shafts were not entirely satisfactory.

As a start to the formation of a post-war policy an approach was made to Messrs. Fescols Limited, Metallization Limited and The Metallizing Equipment Company Ltd. to discuss the methods to be adopted in the investigation of the problems of crankshaft reclamation.

The approach to this problem has been divided into two parts. One, the reclamation of soft crankpins and journals (up to 400 Brinell Hardness) and the other, that of hard crankpins and journals (over 400 Brinell Hardness).

Soft Crankshafts

Metal spraying is the method normally adopted for the reclamation of soft crankshafts.

General experience to date has been that metal spraying is not satisfactory for use with copper lead bearings and that shafts running in this type of bearing must be reclaimed by electrodeposition of chromium or nickel flashed with chromium, but not with nickel only. It would appear, however, that lead flashed copper lead bearings are satisfactory on metal sprayed surfaces.

Considerable doubt exists as to the best method of shaft preparation. It is essential in the preparation of a surface for metal spraying that it should be perfectly clean, and roughened to assist the bond between parent metal and the sprayed deposit.

Shafts must be machined to the required dimension to permit a minimum deposit of 0.040 inch on the diameter.

In this country the surface is then prepared for spraying by grit blasting. In America it is the practice either to electrically prepare by the Fuze-bond Process, groove and knurl or even rough thread. In this country, it is considered that American methods are a possible source of stress raisers, but there can be little doubt that they do provide a better bond. In American experience the majority of failed sprayed shafts have been those metallized on to a grit blasted surface whereas few shafts have failed in fatigue due to stress raisers. The assumed danger of rough threading or grooving and knurling has yet to be proved in practice.

In the investigations detailed below the less drastic method of grit blasting for surface preparation has, as a first action, been employed.

War-time experience of the grit blasted method of surface preparation was that failures of sprayed surfaces could often be attributed to the lack of strict adherence to detail and cleanliness.

Trials at present in progress on the reclamation of shafts by metal spraying are detailed below.

Two firms, Metallization Limited and The Metallizing Equipment Company Limited (a subsidiary of The Metallizing Engineering Company Incorporated of New York) are carrying out the work. These two firms who are the leading exponents of metal-spraying in this country, employ different equipment and methods.

The Metallization Ltd. spray gun, ungoverned, sprays at a relatively low rate while the Metallizing Equipment Company's governed gun sprays at a considerably higher, but controlled rate.

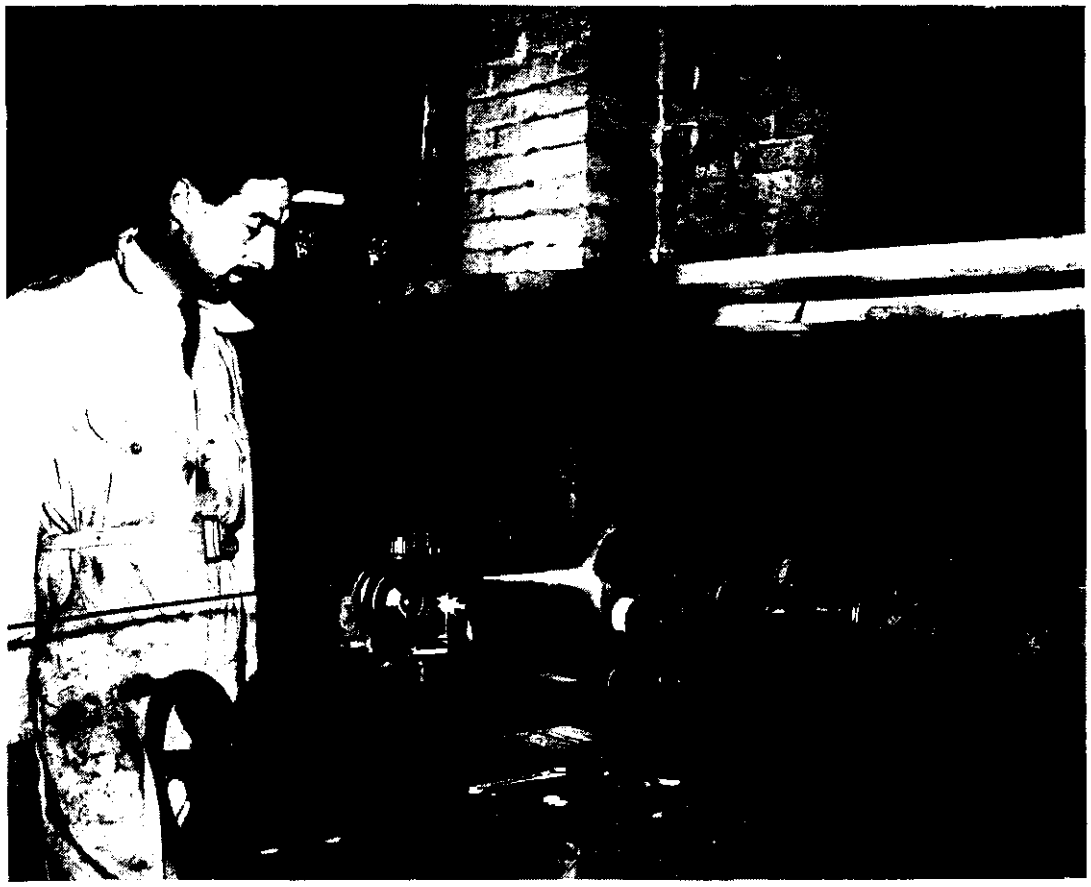
Both firms are reclaiming the shafts listed in Table 1.

TABLE 1

Engine manufacturer and type	Crankshaft material	Bearing material	No. of shafts to be reclaimed by each firm
Scammell RN2	Cast iron	Whitemetal	3
Dorman 2DSM	Meehanite	Whitemetal	3
Dorman 4DSM	Forged steel	Whitemetal	3
Paxman 4RQ	Forged steel	Whitemetal	3

Shafts selected for reclamation were worn shafts which had not been machined below standard dimensions and which had been proved free from cracks by test on a crack detector. These were then machined to dimensions standard −0.040 inch on all crankpins and journals in accordance with the specification given later.

After spraying, the crankpins and journals were finished ground by the Dockyards in accordance with the recommendations of the firm undertaking the spraying, who were permitted to be associated with this operation should they wish.



METCO TYPE Y METALLIZING GUN SPRAYING 0.8% CARBON STEEL ON CRANKSHAFT. (RATE OF DEPOSITION UP TO 20 LB. STEEL PER HOUR)

All shafts reclaimed by spraying will be suitably marked to indicate that they have been reclaimed by this method, giving date and firm's identification mark.

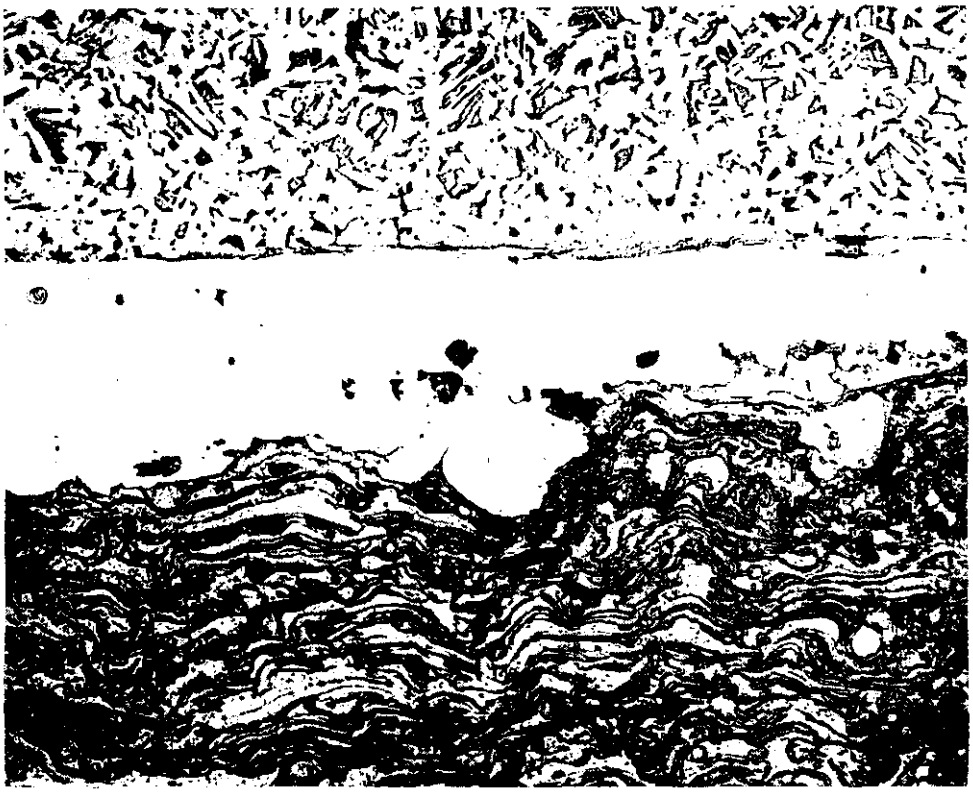
Prior to assembly in engines undergoing refit all shafts are to be carefully gauged on crankpins and journals and full details of method of treatment, name of firm undertaking reclamation, and dimensions of pins and journals recorded on the History Sheet D318.

All engines will be subjected to the normal test specification laid down in the overhaul Fleet Orders and, to avoid confusion in engines selected for these trials arrangements will be made to mark them in a prominent position with white stencil on a vermilion background as follows—TEST ENGINE.

Instructions to proceed on these trials were given in August, 1948, and a number of these test engines are now in service.

A copy of the Admiralty Specification for the reclamation of worn crankshafts is included as an Appendix to this article from which details of shaft preparation and spraying can be obtained.

In the above trials the two firms have not been tied down to this specification but the general procedure adopted will be very close to that shown.



SECTION THROUGH TYPICAL FUZEBOND

Hardened Crankshafts

These comprise crankpins and journals above 400 Brinell Hardness.

Little work appears to have been carried out on the reclamation of hardened crankshafts but that which has appears to have been successful.

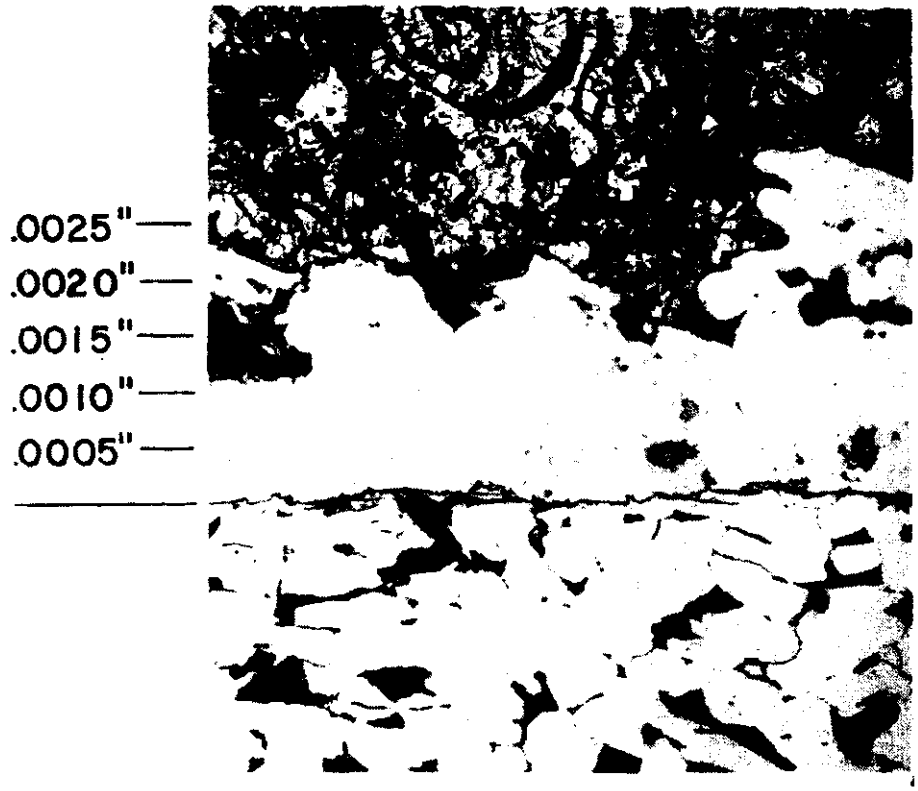
At present the possibility of metal spraying a hardened surface is ruled out for it is impossible to prepare the surface by grit blasting according to specification. Rough threading or groove and knurling are not included in the specification and therefore the electrodeposition of metal has to be resorted to as an alternative.

There are however two methods of preparation of hardened surfaces for metal spraying—Fuze-bonding and Sprabonding.

In the Fuze-bond method the surface is roughened by stroking with an electrode, or electrodes, connected to a low voltage high current supply. Small craters are formed in the parent metal which provide a good anchorage for the subsequent sprayed coat. Up to six electrodes may be carried in the electrode holder. Fuze-bonding is a patented process licenced in Great Britain by The Metallizing Equipment Co. Ltd., of Chobham, Woking.

With the Sprabond process the surface, after cleaning, is sprayed with a non-ferrous high-molybdenum alloy to a depth of about 0.0015 in.-0.002 in. The sprayed surface is then ready to receive the normal sprayed coating of high carbon steel. The *Sprabond layer is joined to the parent metal by

* Sprabond is the trade-name owned by the Metallizing Engineering Co. Inc. and applied to the special material for producing a bond between sprayed metal and the base material.



SECTION THROUGH TYPICAL SPRABOND (SHOWING STEEL BASE WITH SPRABOND LAYER AVERAGE .002 THICK AND METALLIZED STEEL COATING BONDED TO IT)

a physico-chemical bond while it is anchored to the subsequent sprayed steel in the same way as the bond that exists between layers in the ordinary sprayed coating.

The Fuzebond process is being investigated by the Department of the Engineer-in-Chief and the danger of induced stresses incurred during the welding operation borne well in mind. It is however employed by the U.S. Bureau of Ships.

It is hoped shortly to have Fuze and Sprabonded crankpins and journals subjected to a metallurgical examination but in the meantime no operational service investigation will be made.

One may well question the desirability of spraying a hardened shaft in view of a possible reduction in hardness of the finished surface. It is not possible to state the hardness of a sprayed surface accurately due to the porous nature of the deposit but it can be in excess of 600 Brinell Hardness if required. A further consideration, which must be borne in mind, is the increased lubricating property of the porous surface which may well make amends for any reduction of hardness when put to the test.

Investigations are however in hand on the reclamation of shafts by means of electrodeposition of chromium and nickel.

The relative merits and demerits of nickel and chrome deposition are :—

Nickel

(i) No difficulty is experienced in the deposition of thick or thin coats, adhesion being very good in either case. The deposited metal may be machined, ground, or polished by the usual workshop processes.

(ii) The Brinell Hardness of deposited nickel is usually about 160. Harder deposits can be obtained but, owing to the difficulty of control under commercial conditions, are not normally applied.

(iii) Thickness of nickel deposit has no deleterious effect on fatigue strength of the base metal.

(iv) The co-efficient of expansion is about equal to that of steel.

(v) The co-efficient of friction is higher than that of steel.

(vi) It is not advisable to use nickel in contact with lead bronze or similar bearing materials.

Chromium

(i) Chromium is very hard and can only be finished machined by grinding in which case machining difficulties arise particularly at the radii and in deeply recessed pins or journals. It is recommended that deposits requiring polishing only should be made.

(ii) There is a definite limit to the thickness of deposit—one to two thousandths of an inch being recommended. Thicker deposits are inadvisable as this may have a tendency to cause embrittlement of high tensile steels owing to the occlusion of hydrogen.

(iii) Chromium has poor throwing power, *i.e.*, it is difficult to obtain an even coat as the deposition tends to build up on male corners and centre portions of deep re-entrants, such as crankpins, whilst the inner corners and internal fillets are starved. Once this eccentricity starts it is accentuated as the deposit becomes thicker. For this reason it is difficult to obtain an even deposit on the inside portions of the crankpin where the pin length is short compared with the length of the adjacent web.

(iv) Chromium has very good bearing properties with a low coefficient of friction.

It has one great disadvantage in that oil will not wet it and a good oil supply is therefore necessary.

It is evident from the above that if chromium were to be adopted for the reclamation of crankshafts they would have to be withdrawn from service at a lower wear figure than is normal at present unless shafts could first be built up with a thick nickel deposit followed by a thin deposit of chrome.

To date no experience has been gained of nickel and chromium deposits under heavy load conditions. There is a possibility that the nickel deposit may deform under load resulting in the collapse of the chromium.

Trials on the reclamation of soft and hardened crankshafts by the electro-deposition of nickel, chromium, and nickel and chromium are being carried out in the following engine types. The work of reclamation is being undertaken by Messrs. Fescols Ltd.

Shafts to be reclaimed as laid down in Table 2 were required to be within the following tolerances of wear :—

TABLE 2

Engine manufacturer and type	Crankshaft material	Bearing metal	No. of shafts to be treated			New shafts to be fitted for comparative test purposes against reclaimed shafts
			State of wear			
			(*a*)	(*b*)	(*c*)	
			By chromium	By nickel	By nickel and chromium	
Perkins S6M	Forged steel, Tocco hardened	Copper lead	3	—	3	3
Paxman TPM12	Forged steel, soft	Copper lead, lead flashed	3	—	3	3
Dorman 2DSM	Cast steel	White metal	3	3	3	3
Dorman 4DSM	Forged steel, soft	White metal	3	3	3	3
Dorman 8VRM	Forged steel, soft	Whitemetal large end ; copper lead, main	3	3	3	3
Gardner 6LW	Forged steel, soft	White metal	3	3	3	3

(*a*) New, or not more than 0.001–0.002 inch below standard diameter, and round to permit not more than 0.001–0.002 inch deposit on the diameter to return the bearing surfaces to standard diameter.

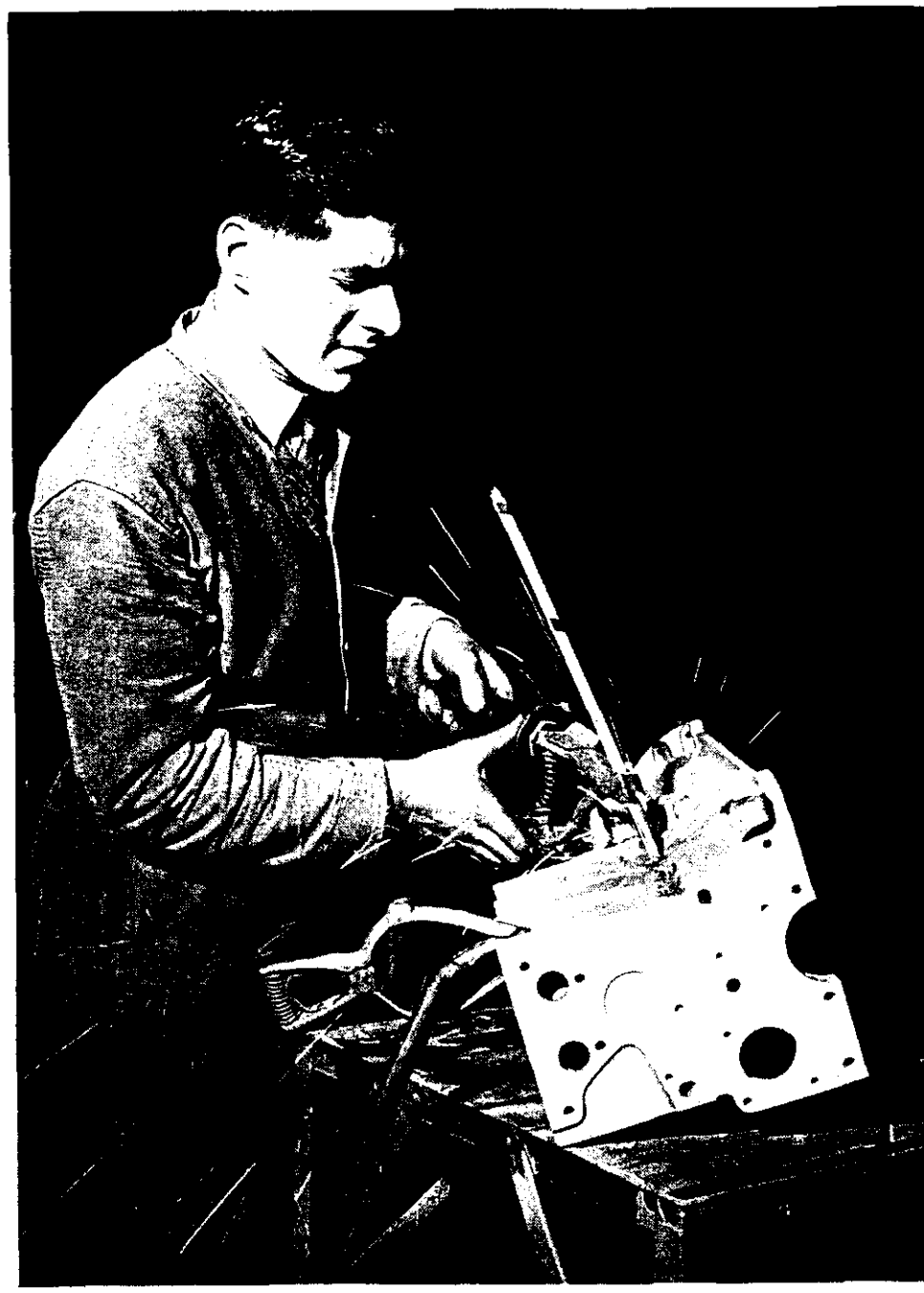
(*b*) Round or oval to permit a deposit of 0.005–0.010 inch of nickel on the diameter to return the bearing surfaces to standard diameter.

(*c*) Round or oval to permit a deposit of 0.005–0.010 inch of nickel plus 0.001–0.002 inch of chromium on the diameter to return the bearing surfaces to standard diameter.

It should be noted that the journals or crankpins must be truly circular about their original axis prior to the deposit of chromium being added owing to the undesirability of machining the chromium surface.

The same action as was detailed for shafts reclaimed by metal spraying prior to installation will be made for these crankshafts and the History Sheet, D318, notated.

Instructions to proceed on these trials were given in May, 1948, and a number of these engines are already in service.



FUZE-BONDING A CRACKED CYLINDER BLOCK BEFORE METALLIZING

The foregoing story covers the planned investigations that have been put in hand but does not completely cover the picture, for as defective crankshafts are thrown up from service they are being reclaimed by one or other of the above processes in order that as much information as possible may be obtained without delay.

Subject to satisfactory trials of crankshafts reclaimed by these methods the Director of Dockyards then intends to consider the possibility of establishing a crankshaft reclamation centre at one of the Dockyards.

Bearings

Investigations into the problems connected with the reclamation of bearings have been treated with the same priority as that accorded to crankshafts.

Portsmouth Dockyard have made a thorough investigation of this subject and report that bearing reclamation is limited by the following facts :—

(*a*) Shell distortion makes it inadvisable to re-metal bearings of which the crown thickness is $\frac{1}{8}$ inch or less.

(*b*) It is impossible to re-metal copper lead bearings owing to the high temperatures necessary which would distort the finished shells.

It is recommended that whitemetal bearings should be metalled with that originally used by the bearing manufacturer.

The report states further that " It is felt that in all cases virgin metal should be used, for although metal made from virgin metal and arisings may produce the correct chemical analysis, the danger of including traces of oxides cannot be too strongly stressed. Following on this point it is therefore important, before metalling, that each consignment must be chemically analysed, physically tested, and examined for microstructure, the latter point being perhaps the most important."

Further investigations of methods of technique for re-metalling (hand pouring with rapid cooling on the shell by water spray ; pressure die casting ; centrifugal casting) and machining have been made. Action is now in hand to obtain the necessary equipment.

In the interim period a large number of bearings are being reclaimed by the Glacier Metal Company but as the Portsmouth Dockyard reclamation centre becomes established so it will take over the reclamation of all reclaimable bearings within a specified range.

A survey of all I.C.E. bearings in service has shown that the majority of bearings are metalled with Glacier Findlay Motor Metal L1 and therefore this metal has been added to the Rate Book for the use of the Portsmouth reclamation centre. A large number of bearings are metalled with Hoyts Metal 11R which is already a Rate Book article. All bearings will, and should always be as far as possible, re-metalled with the metal originally employed.

As mentioned earlier, the use of undersize crankpins and journals raises acute problems in connection with the stocking of undersize bearings. As a first step towards the minimization of this complication the main bearings of certain removable type engines are stocked rough bored to enable any undersize to be obtained from one shell. The necessity for line boring of main bearings is however the prime reason for this measure which will be extended to cover as many engine types as possible, each type being considered on its merits.

Fuel Injection Equipment

Preliminary investigations have been carried out on the questions associated with the reclamation of fuel injection equipment but final recommendations have not been made.

All home dockyards are equipping themselves for the reclamation of injector nozzles and needle valves and much good work has already been accomplished in this direction.

Consideration is being given to the introduction of methods of reclaiming worn plungers and barrels of fuel pumps elements by the introduction of under and over size plungers and barrels. This action is at present held up pending

the manufacture of hydraulic test equipment for the measurement of leakage between plunger and barrel.

Camshafts

A little work has been undertaken on the reclamation of camshafts but a detailed investigation will be made shortly into methods to be adopted.

Possible avenues of investigation are :—

(i) The regrinding of worn cams or journals and flashing with chromium and

(ii) Reduction of the cam profile, fitting of a strap, welding and regrinding.

The issue of A.F.O. 1347/49—*Engines, Internal Combustion—Return of Defective Engine Parts to S.P.D.C. at Home and Abroad*—will, it is anticipated, with the return of defective parts and such sub-assemblies as worn water pumps, give an indication of the direction in which investigations, other than those mentioned, must be directed.

While the introduction of organized methods of reclamation are an essential part of the organization for the maintenance of machinery in the Fleet the presence of such an organization does not relieve Authorities of their responsibilities of utilizing spare parts with the greatest economy compatible with reliability.

Any excessive use of spare parts necessitated either as a result of fair wear and tear or failure should be reported on the Internal Combustion Engine Report S1550.

The establishment of the S.P.D.C. organization has enabled usage rates of each item to be found and this information, together with the reports from ships and other authorities, will assist the Internal Combustion Engine Section of the Engineer-in-Chief's Department in its efforts to improve the reliability and availability of all internal combustion engines.

APPENDIX I

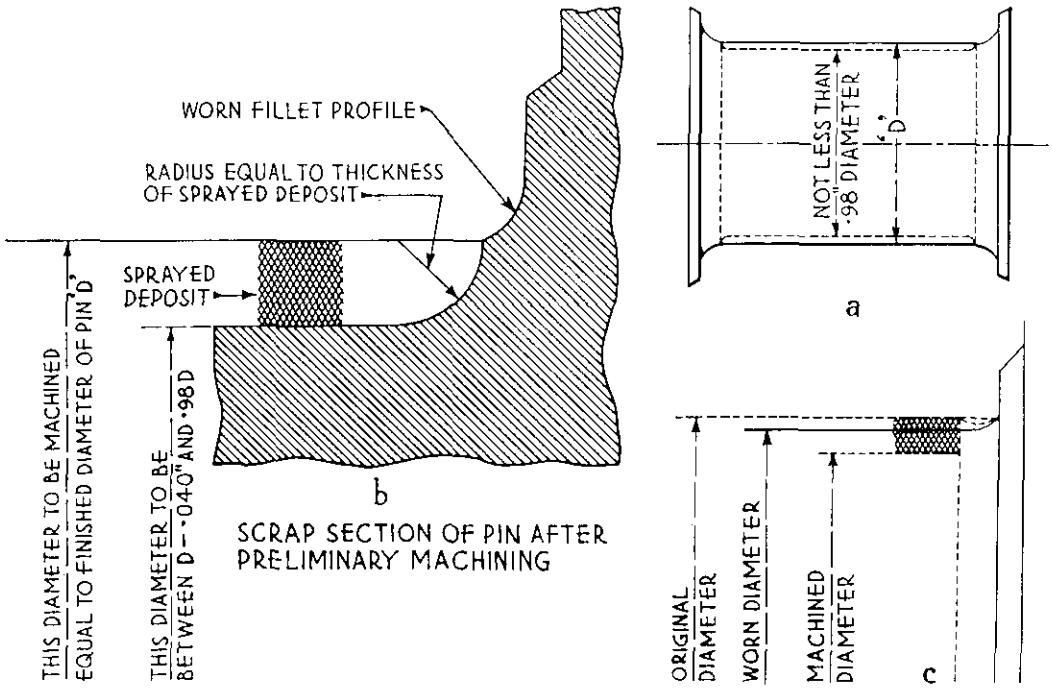
SPECIFICATION FOR RECLAIMING WORN CRANKSHAFTS OF STEEL OR CAST IRON BY METAL SPRAYING

General

Only worn crankshafts of approved types are to be reclaimed by metal spraying. Crankshafts which have been hardened by the Tocco process, or which have crankpin or main bearing journal surfaces of a Brinell Hardness number greater than 400 (423 Vickers, 59 Sclerescope), are not to be reclaimed by this method.

Approval of Firms

Reclamation is only to be carried out by firms specializing in the metal spraying of crankshafts, and approved by the Admiralty. Approval will normally be confined to firms with equipment for all the processes given in this specification. In certain circumstances approval may be given for crack detection and machining to be sub-contracted by the metal sprayers to firms approved by the Admiralty.



Drawing Number EN12/216E

Appendix B to the Specification for reclaiming Worn Crankshafts of Steel or Cast Iron by Metal Spraying.

Inspection and Cleaning of Crankshafts before Reclamation

All crankshafts intended for repair are to be de-greased in a stabilized trichlorethylene plant; and tested for freedom from cracks by a method approved by the Admiralty. (A list of apparatus approved for crack detection is given in Appendix A to this specification.)

Preparation

Preliminary Machining. (The term " pin " is to be taken to include both crankpins and main bearing journals.)

The crankshaft is to be set up in a lathe or grinding machine so that the pin rotates about its original centre. The diameter of the pin is to be reduced, preferably by grinding, by an amount not less than .040 inch, as shown on drawing number EN12/216E. In no circumstances is the pin diameter to be reduced below 98% of the nominal diameter when new (0.98 D, on drawing number EN12/216E (*a*)).

After the preliminary machining operation the junction of fillet radius in the end of the reduced parallel portion of the pin, and the fillet radius between the pin and the web, should be as shown on drawing number EN12/216E (*b*).

The fillet radius in the end of the reduced parallel portion is to be equal to the thickness of the sprayed deposit after the final grinding operation.

Journals without fillets are to be machined and sprayed as shown on drawing number EN12/216E (*c*).

Grit Blasting. Manufacturers' markings on the webs, and the fillet radii and oil holes, are to be stopped off by suitable protectors and plugs. Pins are to be blasted until they are of a dull grey appearance, and considerable and uniform pitting is evident to the naked eye.

Angular steel grit, size number 18 to 20 or C and D, or an equivalent size of aluminous abrasive is to be used. It is to be frequently screened through a 24 mesh sieve, particles passing through being rejected.

The operating air pressure is to be not less than 70 lb per sq. in.

A $\frac{5}{16}$ inch nozzle is to be used. It is to be replaced when its diameter has increased to $\frac{3}{8}$ inch.

Spraying

The spray gun is to be of a type approved by the Admiralty. (A list of approved types of gun is given in Appendix II.)

Gas. The gas used for spraying is to be of a type approved by the Admiralty. The oxygen pressure is to be as recommended by the manufacturers of the spray gun for the diameter and composition of the wire being sprayed. (A list of approved types of gas is given in Appendix II.)

Compressed Air. The air is to be as free as practicable from oil and water. The pressure is to be as recommended by the manufacturers of the spray gun for the diameter and composition of the wire being sprayed.

Wire. Carbon steel wire of 0.70 to 0.90% carbon content, especially drawn for metal spraying, is to be used. The diameter of the wire should be as recommended by the manufacturers of the spray gun. The wire should be fed to the gun evenly and without kinks.

Pressure Gauges. Pressure gauges of the special types developed for metal spraying are to be used.

Method. Oil holes are to be countersunk before spraying, and stopped with rubber plugs, the heads of which should not stand proud of the nominal diameter of the pin when new by more than 0.010 inch. The total included angle of the countersink is to be 60° and its depth parallel to the radius of the pin .030 in. The plugs are to be removed after the final grinding operation and the excess sprayed metal cleaned off the surfaces of the countersunk parts of the oil holes by grinding. The fillet radii are to be stopped off by suitable protectors.

The pin is to be rotated about its axis at the speed recommended by the manufacturers of the spray gun. The spray is to be directed normally to the surface under treatment. The whole deposit is to be sprayed in one operation without a break.

Finishing

General. The surface of the metal sprayed deposit is to be finished to size by wet grinding.

Cleaning. The crankshafts are to be washed in paraffin, the oil ways being cleaned with rods, and blown through with compressed air.

Corrosion Protection and Packing. Details of the corrosion protection to be applied, and the manner of packing, will be given with the despatch instructions.

Identification and Marking of Reclaimed Crankshafts. Complete records are to be kept by all approved firms for all metal sprayed crankshafts. All reclaimed crankshafts are to be marked, in a position adjacent to the manufacturers' markings, with the name of the firm of sprayers and the word " SPRAYED."

APPENDIX II

Apparatus Approved by the Admiralty for Crack Detection in Crankshafts intended for Reclamation by Metal Spraying

(*a*) Magnetic crack detector.
(*b*) Fluorescent method.
(*c*) X-ray.

Types of Spray Gun Approved by the Admiralty for Metal Spraying Crankshafts

(*a*) Metallization Mark 16.
(*b*) Metallization Equipment Co's Metco 2E.
(*c*) do. Metco E.

Gas Approved by the Admiralty to be used in the Metal Spraying of Crankshafts

(*a*) Propagas.
(*b*) Propane.
(*c*) Acetylene.
(*d*) Hydrogen.
(*e*) Compressed coal gas.