Chapter Seventeen

COMPRESSOR, TURBINE, AND WHEELCASE SERVICING AND MAINTENANCE

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THIS CHAPTER is allotted to the main structural components of the engine including the main rotating assembly. The general information contained in chapter 5 should be referred to as necessary.

MAGNESIUM ALLOY CASTINGS

If the permanent protective finish is removed from any part of the magnesium alloy castings, such as the diffuser casing, the exposed metal should be reprotected in the following manner. Remove all traces of dirt, loose paint, and grease from the bare metal and the adjacent paint work. Carefully clean the area, using a clean rag soaked in cellulose thinners, and apply a coat of SX44 primer (which is supplied by Cellon Ltd.) and allow the priming coat to dry for not less than 15 minutes and not more than one hour before applying the lacquer. Apply a coat of black cellulose lacquer to British specification D.T.D.63A (D.087 which is supplied by Cellon Ltd.) and allow it to dry for at least four hours. Although an application of selenious acid to the bare metal, before priming, would give slightly better protection, the use of this acid 'in the field' is not recommended or considered necessary.

Where the primer and lacquer can be applied by spraying, the following recommendations should be noted:- air pressure 60-70 lb. per sq. in.; surfaces where lacquer is not required should be masked, and female threads protected by plugs; the lacquer should be diluted with thinners to a minimum of 50 per cent by volume and the spraying viscosity should be 20-25 seconds in a Ford No. 4 cup; wherever possible, degreasing should be carried out by immersion in a trichorethylene vapour degreaser until the parts to be treated have attained the temperature of the vapour.

DEFLECTOR ASSEMBLIES, EXAMINATION IN SITU

Whenever the combustion chambers are removed, opportunity should be taken to examine the twenty deflector, or cascade, assemblies which are situated in the diffuser casing. As far as possible without removing the assembly, each vane should be examined for cracks and damage, and checked for security in the deflector casing; any signs of movement of a vane warrants rejection of that particular deflector assembly. Pay particular attention to the tightness and security of the ten 2 B.A. nuts and studs which secure the deflector cover in the front of the diffuser casing.

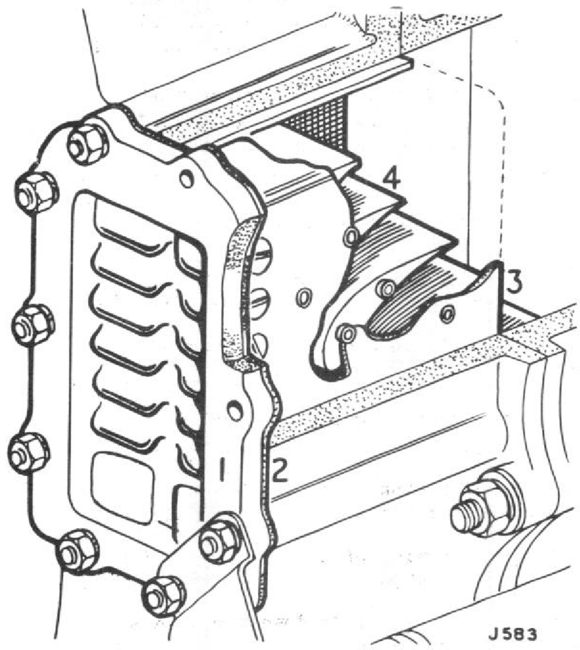


Fig. 1 Deflector assembly in diffuser casing.

1. Deflector cover
2. Deflector cover washer
3. Deflector casing
4. Deflector vanes

CENTRE CASING, EXAMINATION IN SITU

Whenever the combustion chambers are removed, opportunity should be taken to examine the centre casing as thoroughly as possible without further dismantling of the engine. Carefully examine the welding at the junction of the front and rear flanges with the front support cone, at the junction of the front flange with the supporting cylinder, and the welding of the longitudinal seams; there will be two or five of these seams according to the method of manufacture.

AIR FILTERS, REAR-BEARING AIR-COOLING

To remove the air filter elemen' for

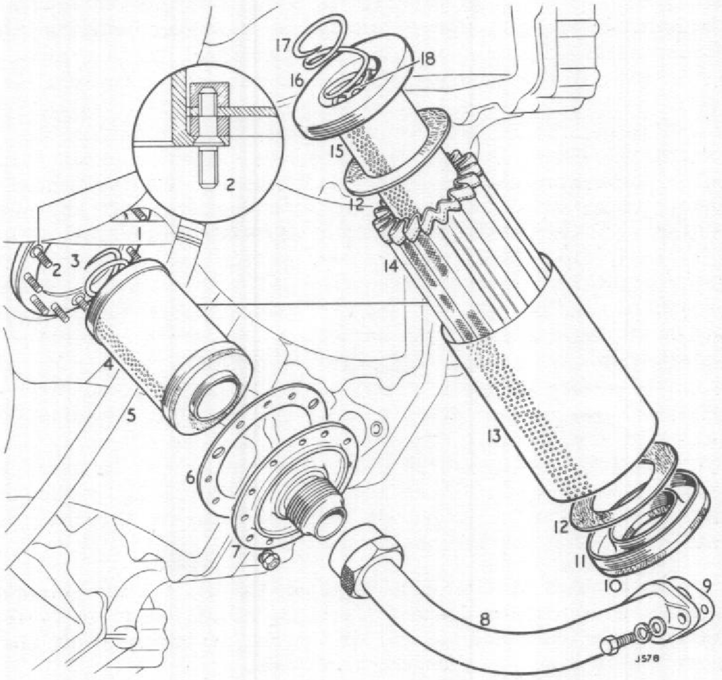


Fig. 2. Rear-bearing air-cooling air filter.

1. Rigid pipe which need not be removed
2. Special studs which also retain filter body
3. Filter body in centre casing
4. Filter insert assembly
5. Combustion chamber drain pipe
6. Hallite cover joint
7. Filter cover
8. Air pipe, diffuser casing to air filter
9. Klingerit joint washer
10. Felt joint ring, stuck to top cap
11. Top cap
12. Insert pad
13. Outer perforated sleeve
14. Felt element
15. Inner perforated tube)
16. Bottom cap)
17. Spring) Do not dismantle
18. Spring retaining clip)

examination, pre-mod.278, Vokes type, proceed as described in the following paragraphs. To remove the mod.278, Tecalemit, filter element refer to Fig.31 and the instructions given on page 18. It is not necessary to remove either the adjacent combustion chambers (No.7 and 8), nor the adjacent rigid pipe, as there is sufficient clearance between the ends of the studs which secure the filter cover and this pipe for the removal of the cover.

There are two types of rear-bearing air filter in service, pre-mod.278 the Vokes type, and when mod.278 has been embodied the Tecalemit type. Although externally the two types are similar, internally they are quite different. Briefly, the spring in the Vokes filter is situated at the outlet end of the element (insert) assembly, whilst in the Tecalemit filter it is at the inlet end. The method of filtering is different also, the air flow through the Vokes element passing from the inside to the outside, and in the Tecalemit from the outside of the element to the inside. This difference should be borne in mind when examining these filter elements for foreign matter.

Remove the two $\frac{1}{4}$" B.S.F. set-bolts and spring washers which secure the flanged end of the air pipe to the diffuser casing rear cover. Unscrew the union nut which secures the air pipe to the air filter and remove the pipe; there is a Klingerit joint washer between the pipe flange and the diffuser casing rear cover. Blank off the air-pipe opening in the diffuser casing rear cover before proceeding.

The remaining operations should be carried out with the engine in its normal installed attitude - with the main shaft horizontal - so that any bits or dirt which may be dislodged fall out of the filter body and not into it and thence into the air pipe inside the centre casing whence eventually they may be blown into the rear bearing. Unscrew the twelve 2 B.A. plain nuts which secure the filter cover and remove the twelve spring washers; three of the studs, on which these nuts are screwed, are special studs and also retain the filter body in the centre casing. Remove the filter cover and withdraw the filter insert assembly. If the filter cover is stuck, temporarily reconnect the air pipe, by means of its union nut, to the cover and use the pipe as a handle to pull the cover off.

Holding the filter insert assembly by the bottom cap, to which the spring is attached, carefully remove the top cap complete with the felt joint ring, the first insert pad, the outer perforated sleeve, the felt element, and the second insert pad. The felt joint ring should be attached to the top cap with Bostik D (off white) cement. Experience has shown that contact with kerosene affects the adhesive properties of white Bostik. Misplacement of the felt joint ring could cause a restriction in the supply of cooling air to the rear bearing with, possibly, serious consequences. For this reason, whenever this air filter is dismantled, carefully examine the top cap to ensure that the felt joint-ring is firmly secured to it. If any doubt exists as to its security, remove the existing felt ring, thoroughly clean and degrease the metal cap, and affix a new felt joint ring using James Walker's "TICO" cement which is a more suitable adhesive. It is essential to fit a new felt ring as it has been found impossible to remove all traces of any previous adhesive from these felt rings and that even traces of the original adhesive has an adverse effect upon the adhesive efficiency of "TICO". This examination should be made even though it is known that that felt joint ring has been affixed with "TICO". These instructions do not apply when mod.278 (Tecalemit type air filter) has been embodied. Do not attempt to separate the inner perforated tube, the spring or its retaining clip from the bottom cap.

No attempt must be made to clean the air filter element. If excessive foreign matter is present a new filter element (Part No. A19035) must be fitted. Similarly, if either of the insert pads (Part No. A19036) or the Hallite cover joint (Part No. 19030) is in any way unserviceable a new part should be fitted.

Reassembly and refitting is largely a reversal of the instructions given already. A new Klingerit joint washer (Part No. N1227) should be used between the flanged end of the air pipe and the diffuser casing rear cover if the original joint washer is in any way unserviceable, and the blanking must be removed from the diffuser casing rear cover.

Before refitting the air pipe to the filter cover, a check must be made to ensure that the inner perforated tube is correctly located within the recess in the filter cover. It is very easy to trap the tube against the face of the cover if care is not exercised, and should this occur the filter will be rendered partially ineffective. It will be found that the inner perforated tube can be checked for centralisation by inserting a finger and feeling round the recess in the filter cover. It can also be seen with the aid of a good light when looking into the filter through the air entry.

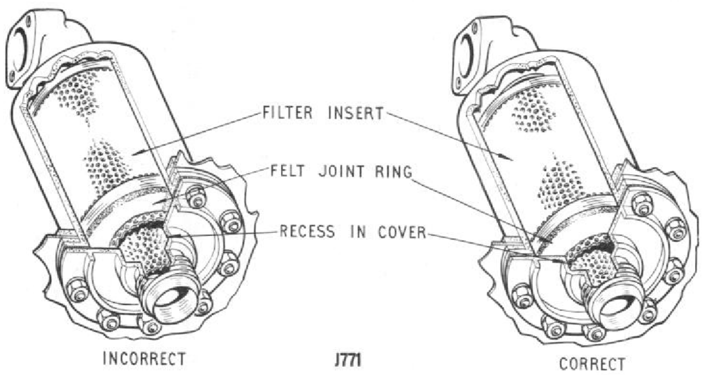


Fig. 3. Incorrect and correct way of fitting the rear bearing air filter insert pre mod.278.

The filter body cannot be removed from the centre casing until the engine is dismantled for complete overhaul as it is not possible to obtain access to the air pipe connections within the centre casing whilst the latter is attached to the engine.

IMPELLER EXAMINATION, IN SITU

At the intervals specified in the Maintenance Schedule, the impeller must be cleaned and examined as thoroughly as possible without removing it from the engine.

Blending out of damage impeller

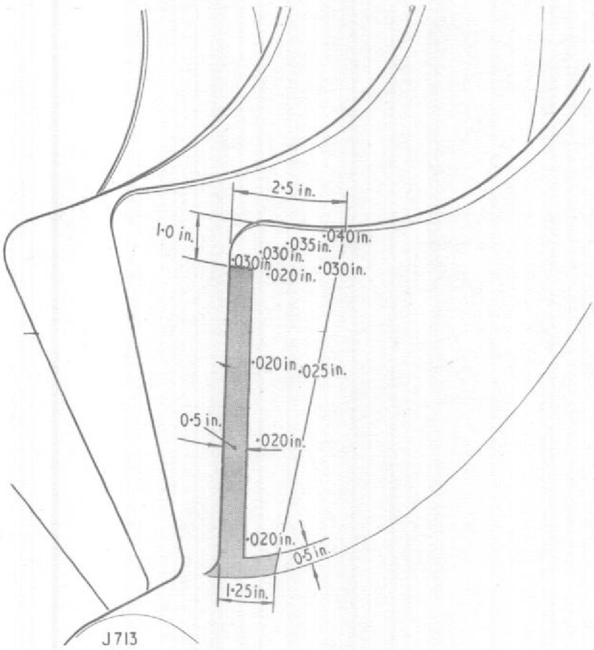


Fig. 4. Impeller damage, acceptance limits.

SHADED AREA: Smooth indentations, such as might be expected from impact with smooth rounded objects, only: maximum depth 0.030 inches. No indentations caused by irregular shaped objects permitted.

UNSHADED AREA: Indicates maximum permissible depth of indentations caused by impact with irregular shaped objects; permissible depth increases, within prescribed limits, according to position relative to leading edge and root of vane. Neither ragged nor torn edges, nor rapid unradiused changes of contour permissible.

vanes in situ cannot be permitted. Owing to the high rotative speeds, the removal of even small amounts of metal from the vane tips can cause severe out of balance, and it then becomes necessary, therefore, to determine the extent and position of the out of balance in order that a reasonably accurate state of balance can be restored by the removal of metal from a predetermined position. These operations can, obviously only be done when the engine has been dismantled completely. Furthermore, the removal of the anodic film creates a condition which is conducive to inter-crystalline corrosion. The coating of any areas after removal of the anodic film, by chemical or lacquer compounds, fails to provide effective protection over a period of running. Consequently, after any operations involving the removal of portions of the anodic film, the impeller has to be vapour blasted and anodised again.

Very roughly, damage to the impeller can be divided into two categories. Damage which is known to be acceptable damage and which may be left untouched, and damage which is considered to be repairable upon removal of the impeller from the engine. When examining the impeller in situ only the first category need be considered as any other damage will entail removal of the engine from the aircraft and its return to a fully equipped repair depot.

Owing to the need for very close examination and direct measurement, acceptable damage as a whole is confined to the areas indicated in Fig. 4. There are two categories of acceptable damage, but strict attention must be paid to the limitations indicated on Fig. 4.

1. Smooth indentations such as might be expected from impact with smooth rounded objects.

2. Indentations caused by impact with irregular shaped objects but which, when examined under a magnifying glass, have left neither ragged nor torn edges, nor rapid unradiused changes of contour.

Normal abrasive pitting may be ignored. 'Normal abrasive pitting' means that light even 'sand blasted' effect which is found on the impeller vanes after even a few hours running. The affected area should be carefully examined under a powerful magnifying glass, say X16, and the damage accurately graded into one of the two categories mentioned in the preceding paragraph. The presence of cracks, or damage marks with torn edges or unradiused rapid changes of contour at any position, or the presence of any indentations caused by impact with irregular shaped objects in the areas shaded on Fig. 4 will automatically reject the impeller and necessitate its removal for further examination. It is, of course, probable that the damage can be rectified at a repair depot.

TURBINE BLADES EXAMINATION, IN SITU

The turbine blades can be examined to a limited extent only, with the aid of a portable spot light up the exhaust cone, whilst the exhaust cone is attached to the engine. The nozzle (static) blades can only be seen, under these conditions, through the spaces between the turbine blades, and can, therefore, only be examined very superficially. Any indications of damage observed during such routine examination without removing the exhaust cone, will necessitate dismantling the engine to the extent indicated in the next paragraph for closer examination.

DISMANTLING NECESSARY FOR CLOSE EXAMINATION OF TURBINE AND NOZZLE BLADES

To examine the turbine blades, the fireguard and exhaust cone must be removed. Since under these conditions, the nozzle (static) blades can be examined only between the turbine blades, opportunity must always be taken to examine them more thoroughly whenever the combustion chambers are removed. For a still more detailed examination of the blades, the turbine shroud can be removed, after taking out the sixty nuts and bolts which secure it and the rear lifting eye and the fireguard support ring to the nozzle shroud. This will, of course, entail re-setting the turbine shroud clearance.

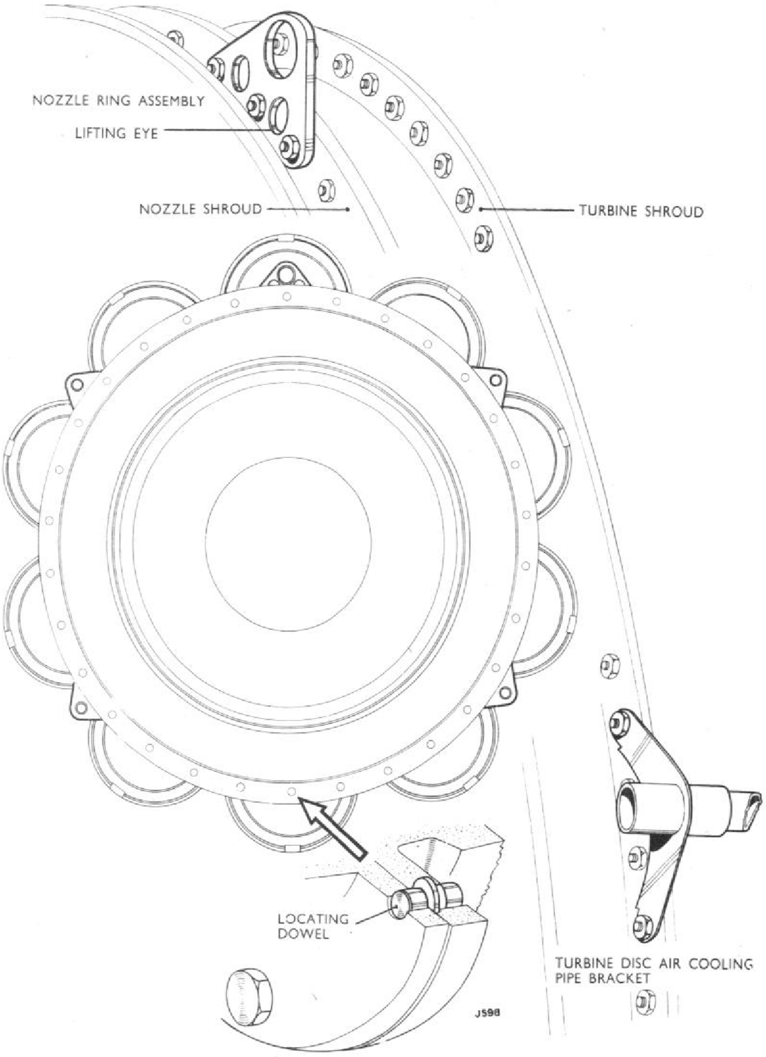


Fig. 5. Location of dowel, lifting eye and air cooling pipe support bracket on nozzle ring assembly

Except to the extent indicated in the following paragraphs neither nozzle (static) nor turbine (rotating) blade repair can be carried out on an installed engine. The removal of any blade, nozzle or turbine, renders it unserviceable and it must be replaced by a new blade. In the case of the turbine disc, this, in turn, necessitates the rotating assembly being dynamically balanced again.

TURBINE BLADES, ACCEPTABLE DAMAGE AND REPAIR AT 50 HOUR INSPECTIONS

The notes given in the paragraphs which follow have been prepared as a guide to the maximum extent of turbine blade damage and minor repair which may be permitted at 50 hour inspections for continued flight life. Figs. 6, 7, and 8, are diagrammatic sketches indicating the nature of the damage which may be encountered in service and the appropriate repair action and limitations. Figs. 9, 10, 11, 12, and 13 are photographs illustrating actual examples of the damage which may be found. For convenience, the turbine blade is considered to be divided into three sections: outer, middle, and inner thirds of the blade as shown in Fig. 6.

Outer third of turbine blade. In the outer third of the turbine blade, minor damage, such as bruises, indentations, etc., up to a depth of 0.040 inch may be accepted and left, provided that there are no sharp edges or nicks. Any sharp edges or nicks must be blended perfectly smooth in position. If either, or both, of the tip section corners are bent as indicated in Fig. 7, provided that the bend does not exceed 0.200 inch (see Fig. 8) and that not more than one third of the total number of blades are affected, the blade is acceptable for further life. If more than this number of the blades is affected, the limitations indicated on Fig. 7 apply. Apart from blending any torn edges the blade should be left undisturbed; straightening is NOT permissible. Fig. 9 is an example of a turbine blade with tip corner damage which is not acceptable for further flight life at either 50 hour inspections or at overhaul. Figs. 10, and 11 are typical examples of damage which is acceptable at 50 hour inspections. Fig. 12 is a good example of the maximum tip corner damage which is acceptable at 50 hour inspections, provided that the sharp tip shown in the photograph is removed and blended smooth.

Middle third of turbine blade. The information given in the preceding paragraph is equally applicable to the middle third of the turbine blade, except that minor damage up to a depth of 0.020 inch only is acceptable, provided that it is smooth. Any sharp nicks may be blended, within the limits specified on Fig. 6. Fig. 13 shows upstream (leading) edge damage which is just within the middle third of the blade. Both this damage and the tip corner damage is smooth with no sharp edges or nicks and the blade illustrated is acceptable, at 50 hour inspections, for continued flight life as it stands.

Inner third and fillet region of turbine blade. As it is almost impossible to work on the inner third of the turbine blade without removing the turbine disc from the engine, no damage of any kind is acceptable generally at inspection 'in the field', but where it is found possible to blend out the damage efficiently it is permissible to do so to the extent indicated on Fig. 6. No damage of any kind is acceptable in the fillet region under any consideration.

All repairs must be polished free of file marks and scratches. No cracks are permissible. Turbine blades may, occasionally, be found to be slack in the turbine disc, provided that this does not permit more than 0.030 inch movement at the tip of the blade in a circumferential direction, or more than 0.010 inch fore-and-aft (axial) movement at the root, the slackness will be taken up by thermal expansion when the engine is running. Slackness in excess of these amounts justifies rejection of the engine.

NOZZLE BLADES, ACCEPTABLE DAMAGE AND REPAIR AT 50 HOUR INSPECTIONS

The notes given in the paragraphs which follow have been prepared as a guide to the maximum extent of nozzle blade damage and minor repair which may be permitted at 50 hour inspections for continued flight life. In general, nozzle blades, being lightly stressed, may suffer a fair amount of damage before they need be rejected. Typical forms of damage and the extent to which repair is permitted are described in the paragraphs which follow. Fig.14 indicates the limits of repair, and Fig. 15 the preferred method of blending out damage.

Downstream (trailing) and upstream (leading) edges. Damage to the edges of the nozzle blades can be accepted up to 0.050 inch deep, provided that the edges are smooth. Any sharp edges or nicks must be smoothed out and polished so as to avoid the formation of cracks. Bowing of the upstream edge is acceptable up to 0.040 inch from the straight line of the edge, and buckling of the downstream edge is acceptable up to 0.1875 inch from the straight line of the blade edge, provided that no cracks are present. Figs. 16 and 17 show examples of the maximum amount of buckling and bowing of the nozzle blade edges which can be accepted for continued flying at 50 hour inspections. As a contrast, Figs. 18 and 19 are obvious examples of buckling and bowing which cannot be accepted under any circumstances for further flight life.

Cracks in nozzle blades. Small cracks which are just perceptible to the naked eye are acceptable as they are, and will last until the next inspection period. More pronounced cracks may be blended out in position; if necessary, remove the turbine disc, and remove the minimum amount of metal, up to a maximum depth of 0.250 inch, provided that only isolated blades are concerned. Fig. 20 shows an example of cracks in the downstream edge of a nozzle blade which is acceptable at 50 hour inspections for continued flying, provided that the cracks can be blended out without removing metal to a depth in excess of 0.250 inch and that the adjacent blades in the assembly are undamaged; if adjacent blades are damaged the limits given on Fig. 14 must be adhered to.

Damage to nozzle blades due to impact. Local damage due to impact may be left provided that its depth is not more than one third of the blade thickness. Any sharp edges or nicks that may be present must be blended smooth. Fig. 21 shows an example of damage to the blade edge due to impact. This blade is quite acceptable as it is shown for further flight life.

Nozzle blade tip. Bent corners on the tip of the downstream edge of the nozzle blade may be left provided that the bend does not exceed 45 degrees and is no more than 0.250 inch in length from the blade corner to the start of the bend. All sharp corners must be blended smooth. No straightening is permissible.

When assessing the acceptability of the nozzle blade and rings assembly for a further period of operation, the general condition of the blades should be taken into consideration. Quite severe damage is permissible on isolated blades but should the majority of the blades be damaged to a similar extent, engine performance will suffer with a consequent rise in operating temperatures followed by rapid deterioration. All repairs must be polished free of file marks and scratches. The nozzle blades are in groups (blades and one of the outer ring segments) of four (80 blade assemblies) and groups of five (70 blade assemblies) and if damage exists in the majority of the blades in any one group, a change of group is recommended rather than the repair of the individual blades in the group. Any damage which cannot be repaired within the limitations given, indicates that that blade must be rejected.

NOZZLE AND TURBINE SHROUDS, EXAMINATION IN SITU

Cracking of the nozzle shroud and turbine shroud flanges from the bolt holes to the periphery of the flange is unlikely but the engine is acceptable and may remain in service provided cracking is between the bolt holes and the periphery of the flange only, cracking from hole to hole is not permissible. Distortion of the turbine shroud rear face up to 0.030 in. is permissible.

TURBINE SHROUD CLEARANCE CHECK AND ADJUSTMENT

At the intervals specified in the Maintenance Schedule, or upon receipt of a new or reconditioned engine as a check against rough handling in transit, the turbine blade tip clearance should be checked. To check the clearance between the tips of the turbine blades and the inner diameter of the turbine shroud, proceed thus. Insert feeler gauges into the gap between the turbine disc blade tips and the turbine shroud and rotate the disc to find the blade which gives the least clearance; mark that blade with chalk. Insert feeler gauges between the marked blade and the turbine shroud at ten points, measure the total feeler thickness with a micrometer and check that the blade tip clearance is nowhere less than the minimum specified in the next paragraph. If the clearance is less than this minimum at any point, advantage may be taken of the clearance in the turbine shroud bolt holes to equalise the blade tip clearance. Before attempting to adjust the position of the turbine shroud the ten clearances, which were measured, should be written down on a 'clock face' diagram so that the position may be considered and the direction in which the turbine shroud must be moved ascertained. Just slacken each of the bolts fastening the turbine shroud to the nozzle shroud, and gently coax the turbine shroud until the clearance is as near equal as possible at all ten points and is nowhere less than the minimum stated. If the clearance cannot be obtained, the engine must be removed from the aircraft and returned to a repair depot. When satisfactory conditions have been attained, retighten the bolts and nuts, and recheck the clearance at all ten points to ensure that the turbine shroud has not been displaced whilst tightening the bolts.

The minimum turbine blade tip clearance to which an engine may be accepted for a new life following a complete overhaul is 0·079 in. but, as will be appreciated, running subsequent to initial manufacture or overhaul will cause some blade creep and shroud distortion which will reduce the running clearance. In view of this fact a smaller minimum clearance of 0·055 in. is permitted for engine in service.

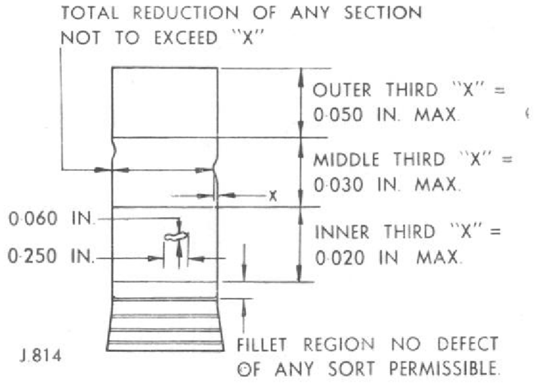


Fig. 6. Division of turbine blade for inspection and repair purposes, indicating maximum limits of repair.

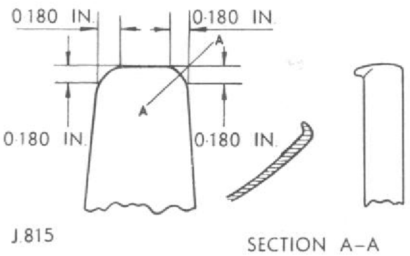


Fig. 7. Bending of turbine blade tip corners, indicating maximum limits of repair.

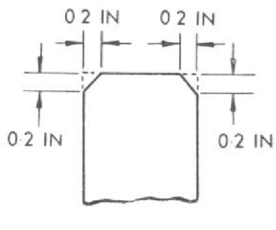


Fig. 8. Bending of turbine blade tip corners, indicating maximum dimension of bend for acceptance at 50 hour inspections; not more than one-third of the total number of blades may be affected.

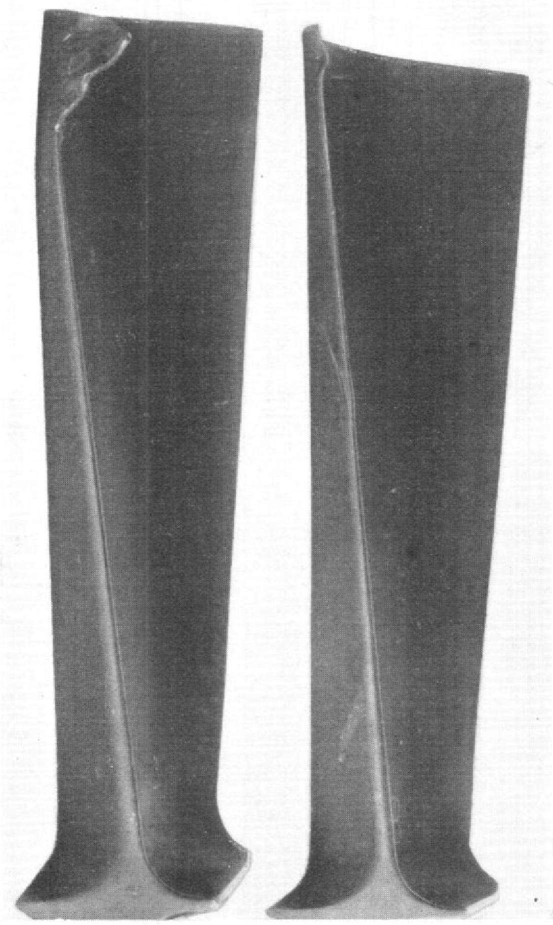
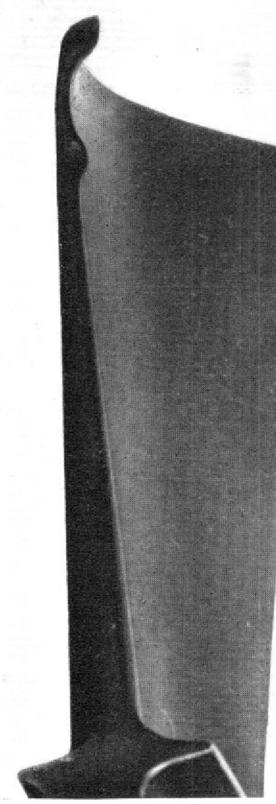


Fig. 9 (left). Turbine blade tip corner damage which is not acceptable.

Fig. 10 (right). Acceptable damage to turbine blade.



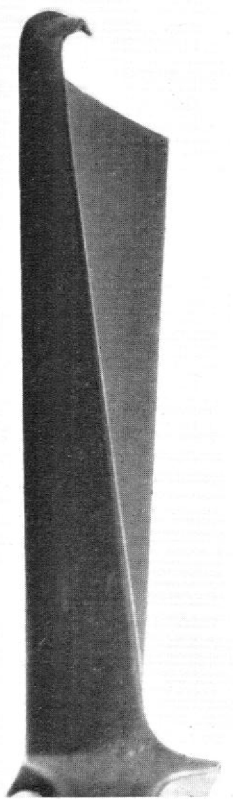


Fig. 11 (left). Acceptable damage to turbine blade.

Fig. 12 (right). Maximum turbine blade tip corner damage; sharp tip must be removed and blended smooth.

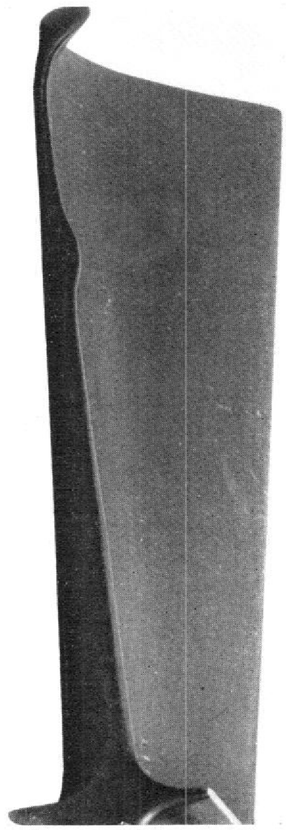


Fig. 13. Damage to upstream edge of turbine blade which is just inside the middle third of the blade; both this and the tip damage shown is acceptable.

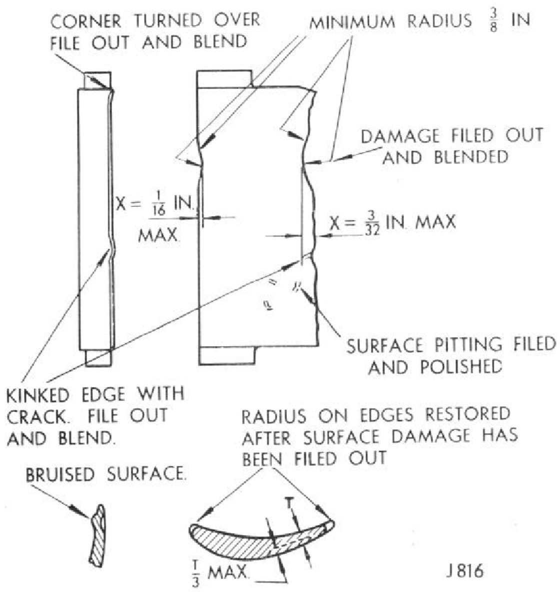


Fig. 14. Limit of repair to nozzle blades.

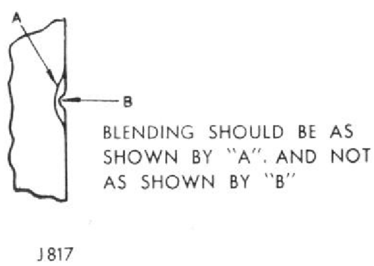


Fig. 15. Preferred method of blending out damage in nozzle blades.

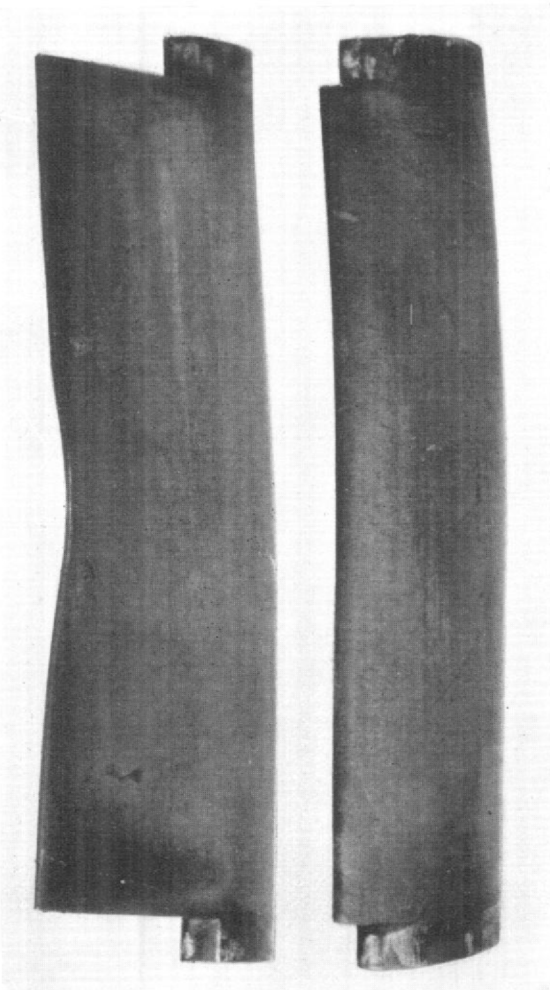


Fig. 16 (left). Maximum acceptable buckling of nozzle blade edge.

Fig. 17 (right). Maximum acceptable bowing of nozzle blade edge.

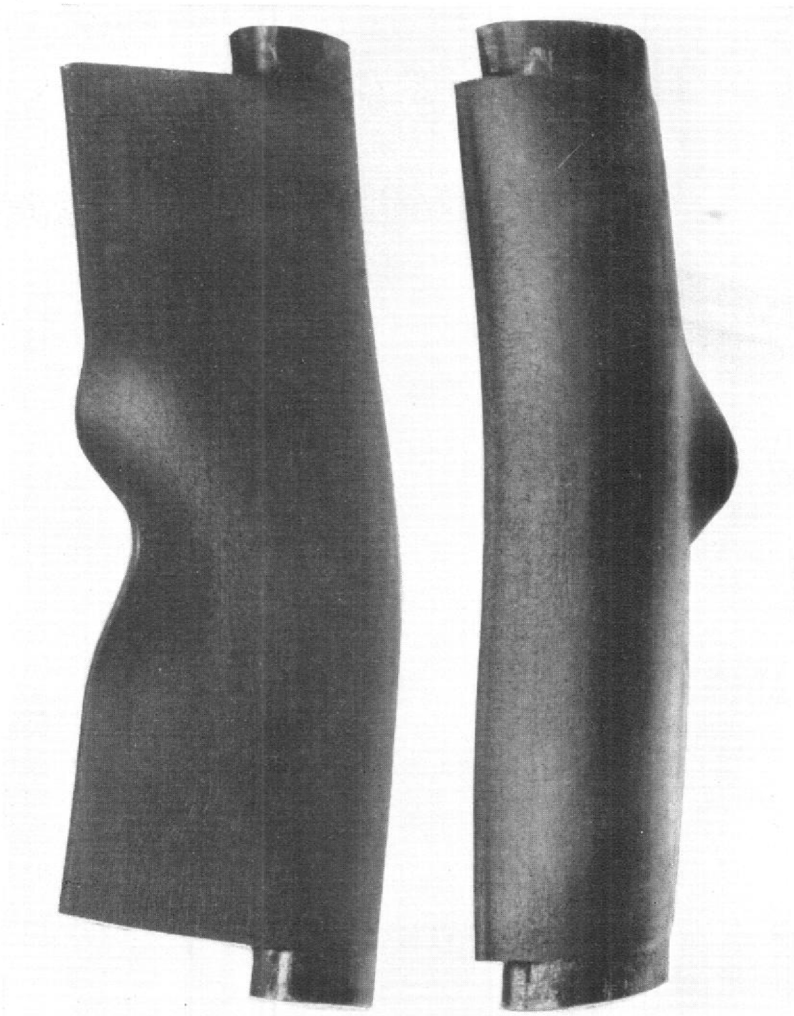


Fig. 18 (left). Buckling and bowing of nozzle blade which is not acceptable.

Fig. 19 (right). Buckling and bowing of nozzle blade which is not acceptable.

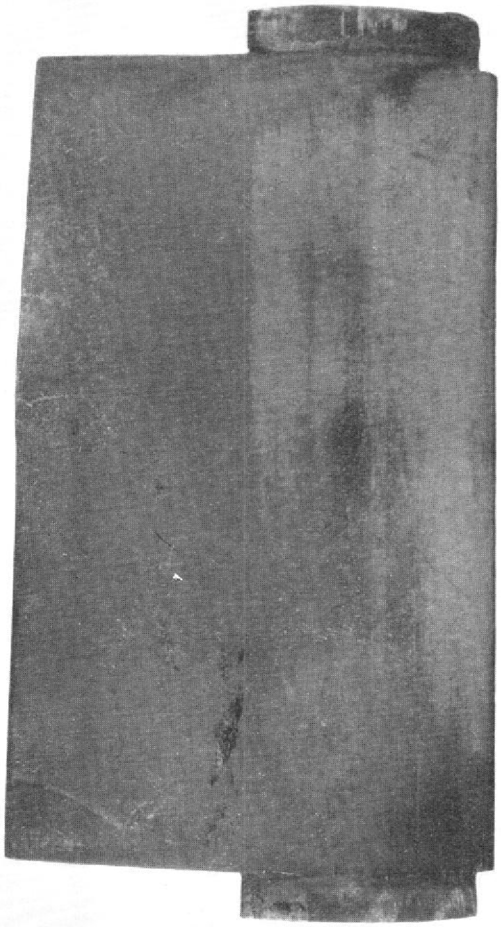


Fig. 20. Cracking of nozzle blade downstream edge which is acceptable subject to the provisos given on page 7.

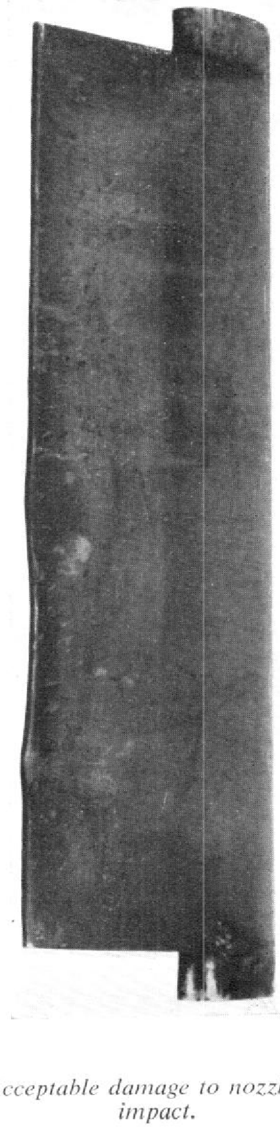


Fig. 21. Acceptable damage to nozzle blade due to impact.

TURBINE DISC, REMOVAL AND REFITTING

The following paragraphs contain instructions for removing and refitting the turbine disc. Removal of the disc is necessary to enable certain turbine blade repairs described in this chapter to be effected and also to gain access to the nozzle blades for the same purpose. The turbine disc is secured to the hub shaft by ten bolts; eight of which are positioned so that they project rearwards through the hub shaft flange and turbine disc. These bolts are fitted with nuts to retain the disc. The remaining two bolts are fitted from the rear in diametrically opposite positions, pass through the disc and screw into threads in the hub shaft flange, as shown in fig. 22. The nuts

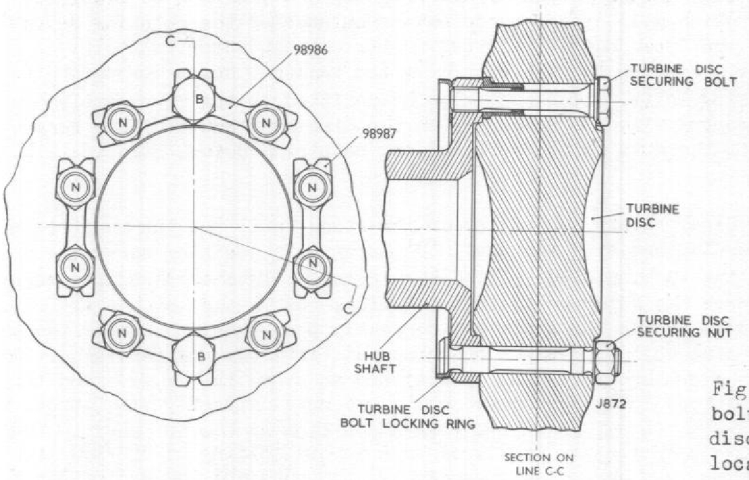


Fig. 22. Arrangement of bolts which secure turbine disc to hub shaft showing location of locking devices.

in the illustration have been marked with an "N" and the bolt heads with a "B", to assist in identification; the parts are not inscribed thus in practice.

Before the turbine disc can be removed, the fireguard and exhaust cone assembly must be removed as described in chap. 18. The engine should then be mounted in the erecting stand T75592, in a horizontal position.

Turn down the turbine disc nut and bolt tab-washers and, using a suitable ring spanner, remove the eight nuts and two tandem tab-washers and slacken the two bolts which secure the turbine disc to the hub shaft. Using the stand turning handle, rotate the engine until the turbine disc is uppermost; remove the two turbine disc bolts and tab-washers, and fit the combined extractor and lifting fixture T74810 to the turbine disc in the following manner (Fig. 23). Swing the large 'C' latches clear of the outer extractor bolts and, with a suitable spanner, turn the upper, smaller hexagons, to engage the threads of the inner extractor bolts in the hub shaft until the smaller, upper, 'C' latches prevent further engagement of the bolt threads. Unscrew the inner bolts half-a-turn and swing the upper 'C' latches out of engagement. Screw in, with a suitable spanner, the outer extractor bolts by means of the lower, larger, hexagons; applying half a turn to each alternately, tighten the outer extractor bolts to remove the turbine disc. When the disc is released from the hub shaft, unscrew the inner bolts until they are clear of the hub shaft threads and unscrew the outer bolts sufficiently to enable the large 'C' latches to be swung into engagement with the extractor bolts, which are then re-tightened to hold the latches in position.

Connect the hook of the lifting tackle to the lifting eye of the extracting fixture and lift the turbine disc clear of the engine. It should then be transferred to the felt lined box T72575 unless it is intended to carry out repair to the turbine blades, in accordance with the instructions contained in

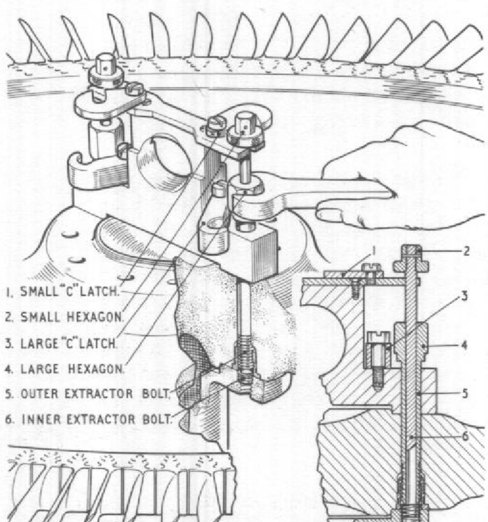


Fig. 23. Combined extractor/lifting fixture in position on turbine disc.

this chapter, when it should be placed in stand T72831. Carefully examine the turbine disc bolt locking ring for any signs of damage caused by the bolt heads turning during the removal of the turbine disc securing nuts. If the locking ring is damaged, the engine must be rejected, as it is not possible to fit a replacement ring without stripping the main shaft assembly, which would necessitate re-balancing the rebuilt assembly.

When refitting the turbine disc, it must be mounted on the hub shaft with the marks, placed on these components during initial build of the engine, aligned to correspond. It is essential to ensure correct assembly, as unless the marks are aligned, the disc can be displaced 180 deg. from its correct position, which will cause severe out-of-balance of the rotating assembly. Similarly, it is essential that each nut is refitted to its correct numerical bolt. A number is etched on the turbine disc, adjacent to each bolt hole and each nut has a corresponding number. The two turbine disc securing bolts, which must also be refitted during re-assembly are numbered in the same way, to correspond with the numbering on the disc adjacent to their respective bolt holes. During assembly of the nuts to the turbine disc retaining bolts, Ragosine L.M. Paste should be used.

To refit the turbine disc, rotate the engine in the stand until the hub shaft is uppermost. Place the extractor on the disc and with the small 'C' latches in position screw the inner bolts through the bolt holes in the turbine disc. With the large 'C' latches also in engagement with their respective bolts, screw the outer bolts into the disc, until the latches are nipped. The disc should then be lifted on to the hub shaft and correctly positioned. Remove the extractor, and refit the two turbine disc bolts and eight securing nuts with two new tab-washers (Part No. 98986) and two new tab-washers (Part No.98987), positioned as shown in Fig.22, and turn the engine to a horizontal position. Tighten on the bolts and nuts uniformly with torque wrench Fig.24, to ensure that the disc is pulled squarely into position on the hub shaft. When all the securing nuts and bolts have been finally tightened to a torque loading of 850/950 lb. in., turn up the locking tabs of the tab-washers. After assembly, the nuts and the end of the bolts should be coated with a clear, heat-resisting, nitro-cellulose lacquer.

The turbine shroud/turbine disc tip clearance check must then be carried out as previously described in this chapter. If the specified clearance is not obtainable at all ten positions, rectification may be possible by utilizing the clearance provided in the turbine shroud bolt holes to equalise the all round tip clearance. Before altering the position of the turbine shroud, the ten clearances obtained should be reproduced on a 'clock face' diagram, and the direction in which the turbine shroud has to be moved ascertained. Slacken the turbine shroud securing bolts, and adjust the turbine shroud to increase the clearance at the position of minimum value. If the minimum specified clearance is still unobtainable at all ten positions, the following remedial action should be taken.

The sixty nuts and bolts securing the turbine shroud to the nozzle shroud should be removed, thus permitting the removal of the turbine shroud. An attempt should be made to restore as far as possible the concentricity of the turbine shroud, by the judicious use of a cramp and a shaped wooden block as shown in Fig. 25. Frequent dimensional checks should be carried out during this operation with the aid of a vernier gauge, until it is considered that the maximum possible restoration has been effected.

When refitting the trued shroud ring, difficulty may be experienced fitting some of the retaining bolts, so as to ensure an even, all round, turbine blade tip clearance. To overcome this difficulty it is permissable to slightly elongate the relevant bolt holes, to a maximum of 1/32 in. Replace all turbine

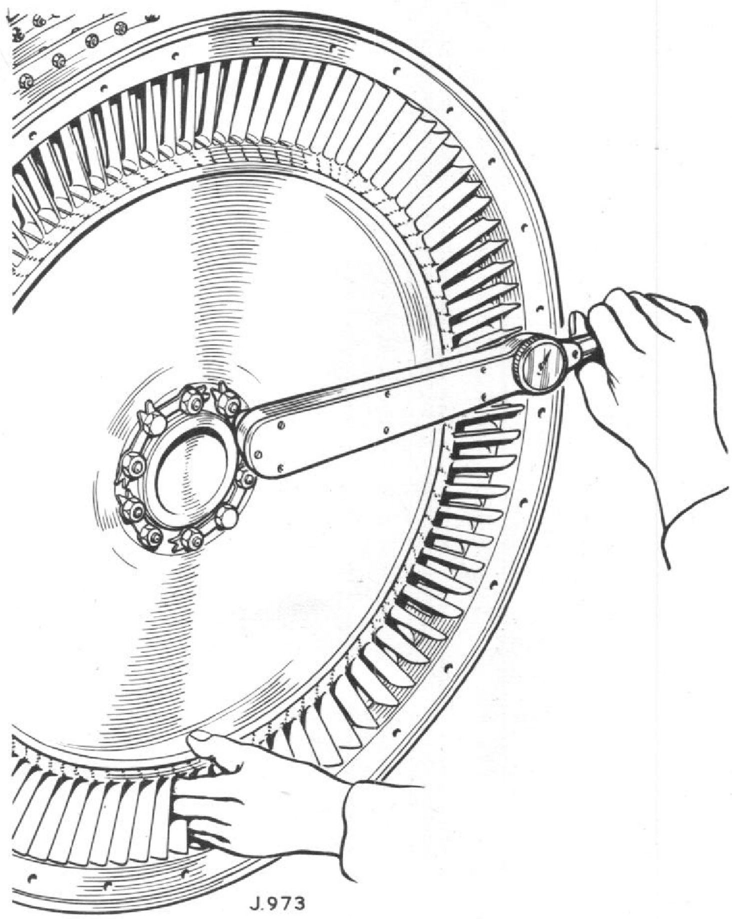


Fig. 24. Using torque wrench to tighten turbine disc bolts and nuts.

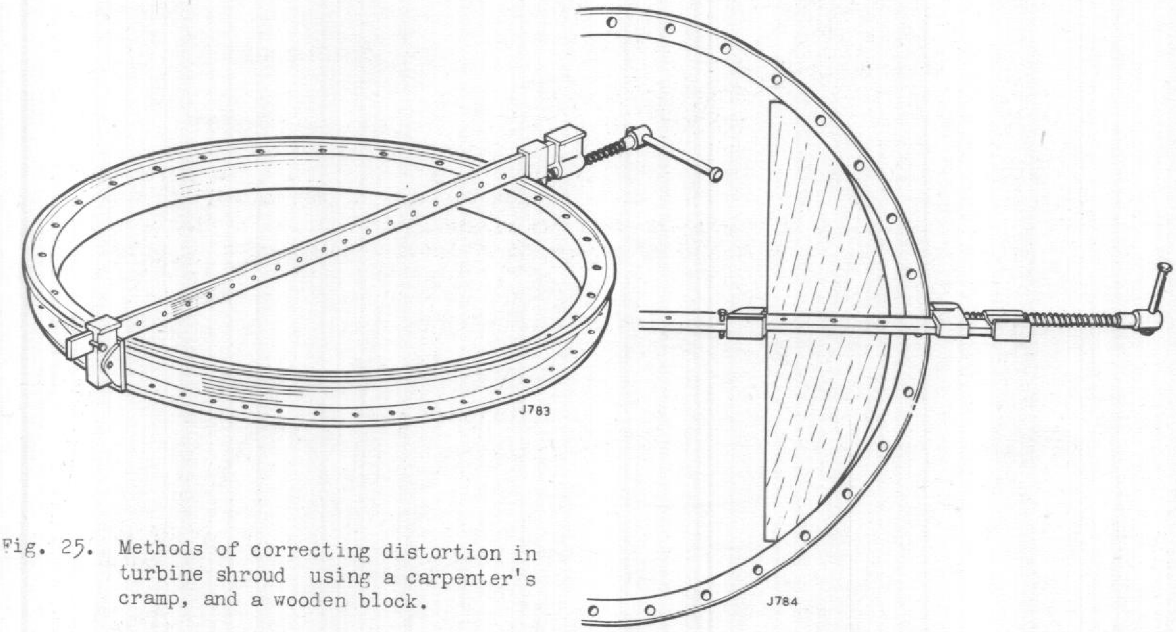


Fig. 25. Methods of correcting distortion in turbine shroud using a carpenter's cramp, and a wooden block.

shroud ring securing bolts and nuts, but before finally tightening, carry out the turbine tip clearance check as previously described. When satisfactory conditions have been attained, re-tighten the securing nuts, and re-check the clearance at all ten points to ensure that the turbine shroud has not been displaced during the tightening operation. If correct clearance is still unobtainable, a replacement shroud ring must be fitted.

NOZZLE RING ASSEMBLY, REMOVAL AND REFITTING

Replacement of individual nozzle blades or packs of blades necessitates the removal and complete dismantling of the nozzle ring assembly and the use of a special jig and squeeze-riveting fixture when refitting the replacement blades. In consequence this must be regarded as an operation to be undertaken by a fully equipped repair depot only. Any blade damage therefore which is outside the specified limits of repair given in this chapter, will call for the rejection and replacement of the complete nozzle ring assembly.

To remove the nozzle ring assembly, Fig. 26, it will be necessary first to remove the combustion chambers, as described in chap. 16. The turbine disc must also be removed in accordance with the instructions contained in this chapter.

Detach the turbine shroud by removing the sixty nuts and bolts securing it to the nozzle shroud, and remove the nozzle ring assembly, complete with the support cylinder in the following manner.

With the engine vertical in stand T75592 (Fig. 27), and the rear end uppermost, remove the twelve $\frac{1}{4}$ in. B.S.F. insulating plate retaining bolts and six twin tab-washers. This will enable the insulating plate to be turned circumferentially, to clear the locking lugs on the baffle ring, and removed. The rear bearing cooling muff, secured by the same bolts, should also be removed.

Remove the nineteen 5/16 in. B.S.F. bolts securing the nozzle ring diaphragm to the rear bearing housing, complete with the thermocouple, support bracket and locking washer, and the one single and eight twin locking washers. The twenty $\frac{3}{8}$ in. B.S.F. strut nuts and bolts on the support cylinder attachment flange must now be removed, together with the ten 5/16 in. B.S.F. nuts, spring washers and bolts securing the support cylinder to the rear cone. Finally, remove the support cylinder retaining nuts and spring washers from the ten studs that secure the front and rear cone, and the complete nozzle ring assembly can now be lifted from the engine by attaching lifting sling T72780 as shown in Fig.28.

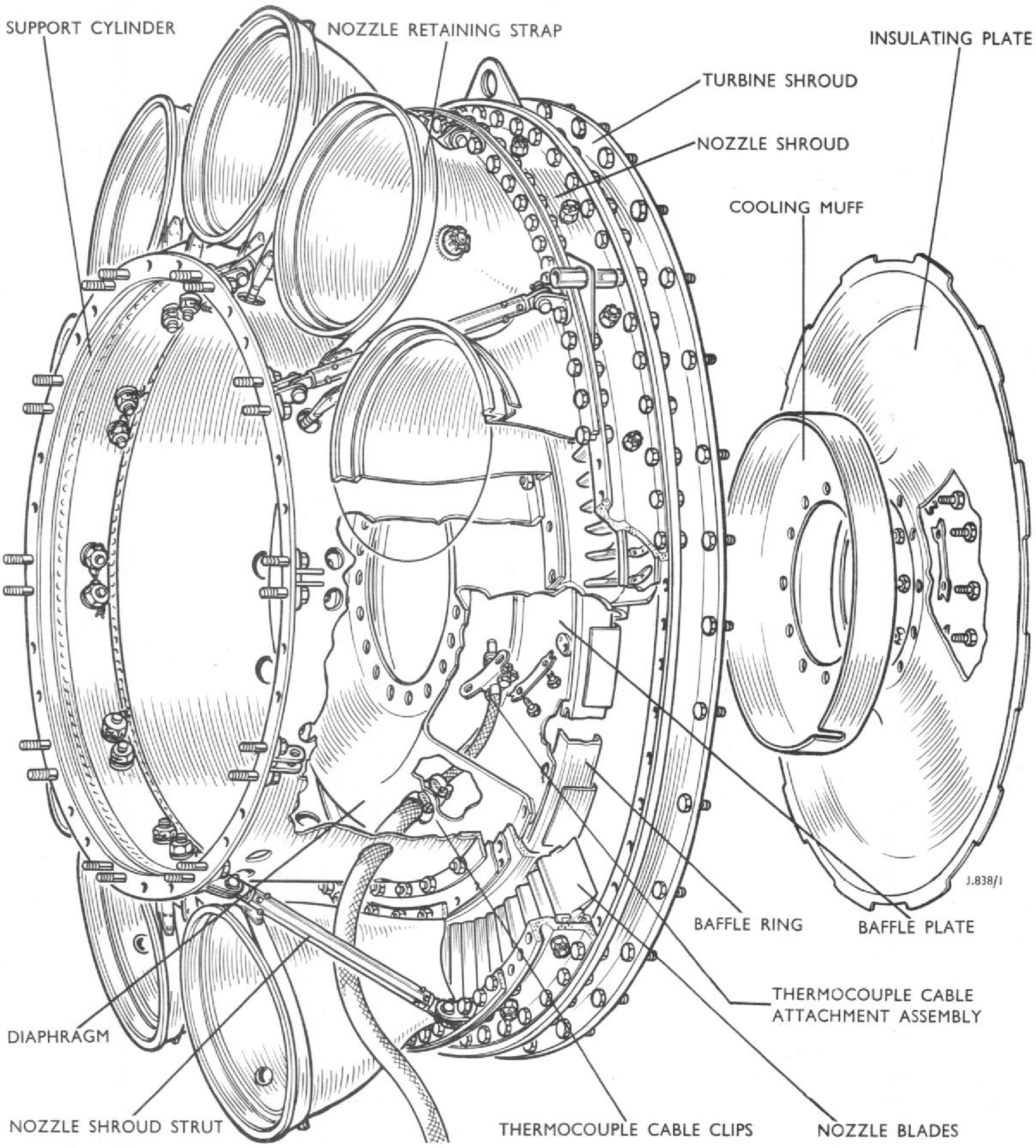


Fig. 26. Nozzle ring assembly.

Refitting the nozzle ring assembly is fundamentally a reversal of the removal precedure and in addition, certain checks for alignment and position are carried out in the following manner. Lift the replacement assembly on to the engine, and refit the spring washers and nuts to the front and rear cone securing studs, and tighten.

Before proceeding further with the reassembly a check must be made for combustion chamber alignment, by offering up a combustion chamber in its correct numerical position on either side of the engine. With the combustion chamber in position, but not secured, check that the entry flanges are registering squarely on their corresponding mating surfaces on the diffuser casing rear cover (Fig. 29). Insert a feeler gauge between first one entry flange and the diffuser casing rear cover and then the other, to ensure that there is no serious variation between the two clearances, denoting a twist in the nozzle ring assembly. Repeat the check with a combustion chamber in the diametrically opposite position. Should it be necessary to correct alignment, it may be effected by slackening the thirty nozzle ring retaining nuts, and turning the whole nozzle ring assembly slightly about the longitudinal axis of the engine. When correct alignment has been established a new set of tab-washers must be fitted to the nozzle ring retaining bolts and nuts and the nuts re-tightened and locked. It is recommended that during

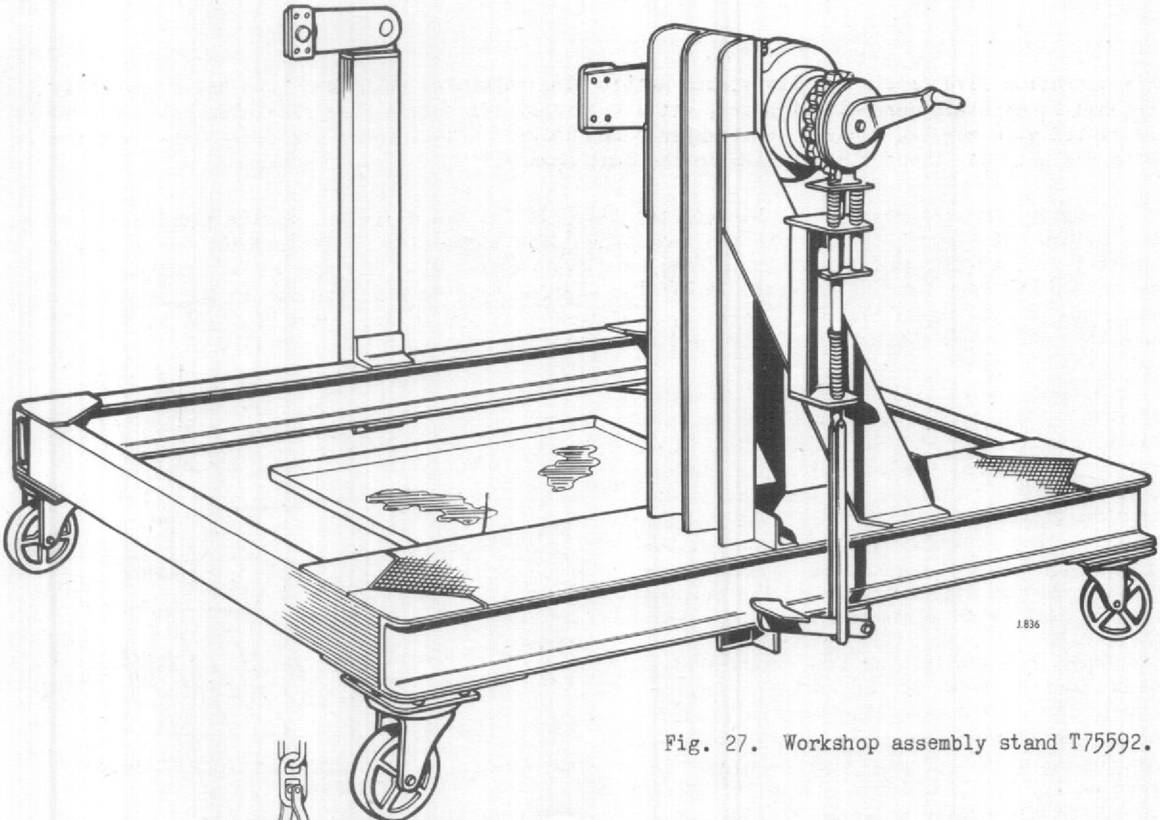
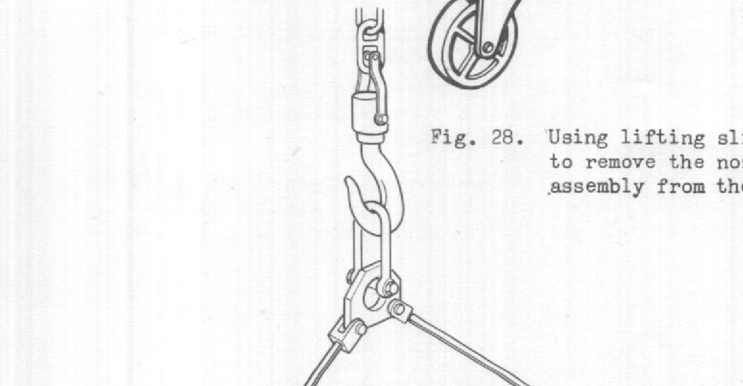


Fig. 27. Workshop assembly stand T75592.

Fig. 28. Using lifting sling T72780 to remove the nozzle ring assembly from the engine.



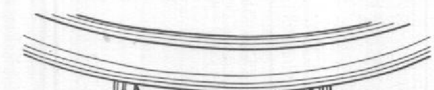


Fig. 29. Using feeler gauge to check alignment.

this operation five or six equally spaced nozzle ring retaining bolts and nuts are temporarily tighened to maintain correct alignment, while the remaining nozzle ring retaining bolts and nuts are fitted with new tab washers, re-tightened and locked. The five or six previously tightened bolts and nuts can then be dealt with in the same manner.

Complete the reassembly by replacing the ten 5/16 in. B.S.F. bolts, spring washers and nuts that secure the support cylinder to the rear cone, and tightening. Replace the thermocouple bracket, cooling muff and insulating plate, and secure them with the appropriate bolts and tab washers to the rear bearing housing. Refit the thermocouple to its location in the rear bearing housing. Refit the nozzle shroud struts, together with the shims, part No.25756 as required to enable the shackle pin to be fitted and locked with a split pin (AGS.784-11).

During the initial build and at major overhaul, the nozzle retaining straps are positioned and adjusted to a jig, but in an emergency, where the requisite jig is not available, it is recommended that the strap-nuts are adjusted to give finger-tight tension and then wire locked. Instructions for the reassembly of the combustion chambers are given in chapter 16; refitting of the turbine disc is dealt with elsewhere in chapter 17.

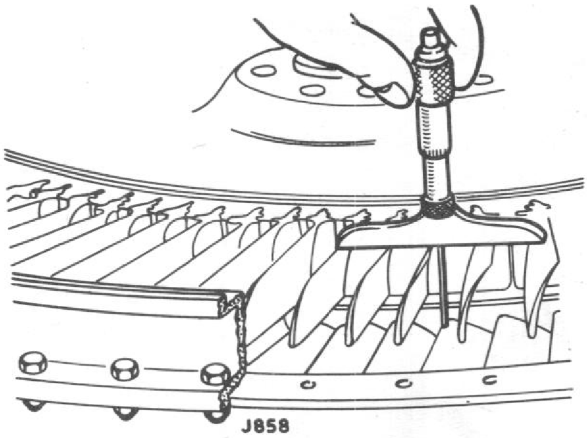


Fig. 30. Using micrometer depth gauge to assess the axial clearance between the nozzle and turbine blades.

When reassembly has been completed a check must be made of the axial clearance between the nozzle and the turbine blades. For reference when measuring this clearance, the nominal width of the turbine blade is taken as 1.380 in. Using a micrometer depth gauge, in the manner shown in fig.30, at a point as near to the root of the turbine blades as possible, measure the distance between the trailing edge of the turbine blades and the rear edge of the nozzle blades. The resultant measurement, less 1.380 in., will indicate the clearance, which should be between 0.270 in. and 0.550 in. Without turning the turbine disc, this clearance should be checked at four points, at approximately 90 deg. around the turbine disc.

TECALEMIT AIR FILTER
(REAR-BEARING COOLING)

As mentioned on page 3 although externally the Tecalemit rear-bearing air filter, which is fitted when mod.278 has been embodied, is similar to the pre-mod. type, the filter element assembly is different; compare Fig.31 with Fig.2.

Remove the filter element assembly in the manner described on pages 3 and 4.

There is no dismantling of the Tecalemit filter element, as once it has been withdrawn from the filter body, the felt element and perforated tube, and the pressure plate assembly are free to be separated. The guide and pressure plate are brazed together, and the bridge piece is riveted and soldered to the guide, and, therefore, this sub-assembly cannot be dismantled in any way. If, however, the retaining spring is removed from the pressure plate assembly,

Fig. 31. Tecalemit type rear-bearing air filter.

for any reason, care must be taken to ensure that it is refitted with its smaller end "screwed" on to the bridge piece which is in the bottom of the "well" formed by the guide.

No attempt must be made to clean the air filter element. If excessive foreign matter is present a new filter element (Part No. FG.2420) must be fitted. Similarly if the Hallite cover joint (Part No. 19030) is in any way unserviceable a new part should be fitted.

Refitting is a direct reversal of the removal but do not forget that the pressure plate and spring must must be at the outboard (inlet) end of the element as illustrated in Fig. 31. The blanking must be removed from the outlet in the diffuser casing rear cover, and a new aluminium joint washer (Part No. 600596) should be used between the flanged end of the air pipe and the diffuser casing rear cover if the original joint washer is in any way unserviceable.

DISCHARGE NOZZLE ASSEMBLY, Turbine Entry Duct

Whenever the combustion chambers are removed for routine examination, the discharge nozzle assembly should be examined thoroughly, both internally and externally. If the period between routine examinations of the combustion chambers exceeds 75 hours, an external examination of the discharge nozzle assembly should be made at intervals not exceeding 75 hours; without either dismantling the engine or removing it from the aircraft. This external examination may not be very easy to carry out efficiently but, by using a suitable light, any serious cracks can be discovered.

The nature of defects to be looked for and the maximum limits of damage which can be accepted for further service, are detailed in the paragraphs which follow and are illustrated in Fig. 32 to 36. It is emphasized that a certain amount of experience is necessary in order to decide whether to accept or reject a damaged component as, in a publication such as this, it is impossible to give more than a general guide. This information is not applicable to engines being overhauled or repaired and, in such instances, the discharge nozzle assembly must be repaired in accordance with the instructions contained in chapter 28.

Cracks in the corners of the nozzles, occurring at the junction between the nozzles and the support rings (Fig. 32), are usually quite short and irregular in shape. Such cracks grow very slowly and may be accepted, in any number, up to an inch long, provided that they are not opening-up or tending to turn back upon themselves in such a manner that a small piece of metal might break away. Fig. 32 and 33 illustrate typical examples of cracks which may be accepted for further service. Fig. 34 shows a development of this type of defect where the crack has progressed across the support ring; where a crack has developed to this extent, the discharge nozzle assembly should be rejected.

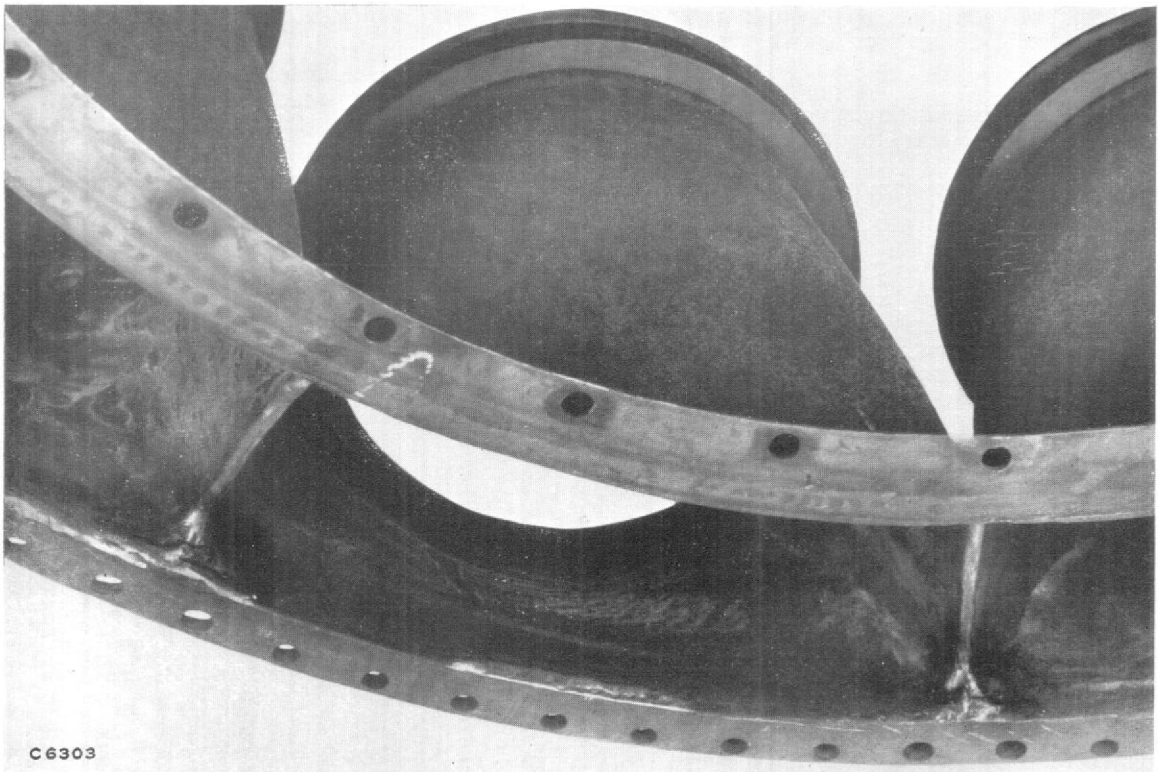


Fig. 32. Cracks in the corners of the discharge nozzles — acceptable for further service.

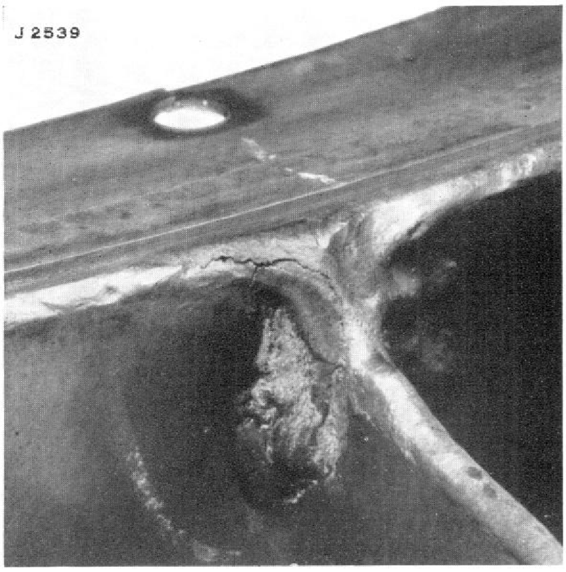


Fig. 33. Acceptable crack in the corner of the discharge nozzle.

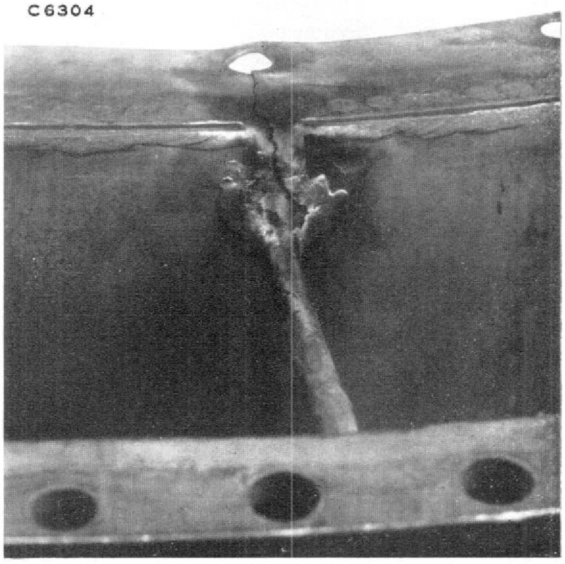


Fig. 34. Crack extending across the support ring; not acceptable.

Circumferential cracks, such as those illustrated in Fig. 35 and 36, are found at the weld line of the outer support ring. Such cracks are acceptable, but are limited by the following conditions:—

(*a*) A crack must not exceed 4 inches in length.

(*b*) If a crack extends through a web, any radiating crack which extends up the web must be on one side of the weld only, and must not cross the weld.

(*c*) If a crack extends through a web, no adjacent web may be cracked circumferentially.

(*d*) A crack must not have opened up to the extent that a 0·002 inch feeler can be inserted from the external side.

Provided that these cracks are fairly well distributed and are within the limit specified, up to a total of five cracks per complete assembly may be accepted. Where a crack at the junction between the nozzles and the support ring follows the line of a circumferential crack and appears likely to develop into a single crack of considerable length, as in the example illustrated in Fig. 36, care must be exercised, as such a defect will, generally, justify rejection of the assembly.

Cracks at bolt holes. Cracks from the holes to, or towards, the free edge of the support rings are not important, and the assembly may be accepted even though there are such cracks from every hole. Cracks in the outer flange which extend across bolt holes inwards to the weld are acceptable, provided that a bolt hole so affected is not adjacent to a web, and that a crack has not turned from the flange into the weld line of the flange. The general condition of the support rings should, however, be taken into consideration and if the material around the holes is torn or unduly distorted, the assembly should be rejected.

Distortion. A considerable degree of distortion is permissible provided that:— The alignment of the combustion chambers is satisfactory; the combustion chamber sealing rings are properly housed within the discharge nozzles; and that the discharge nozzle assembly satisfactorily mates with the nozzle shroud and nozzle blade assemblies.

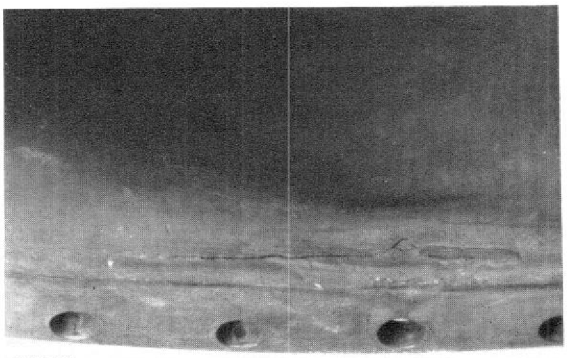


Fig. 35. Circumferential crack.

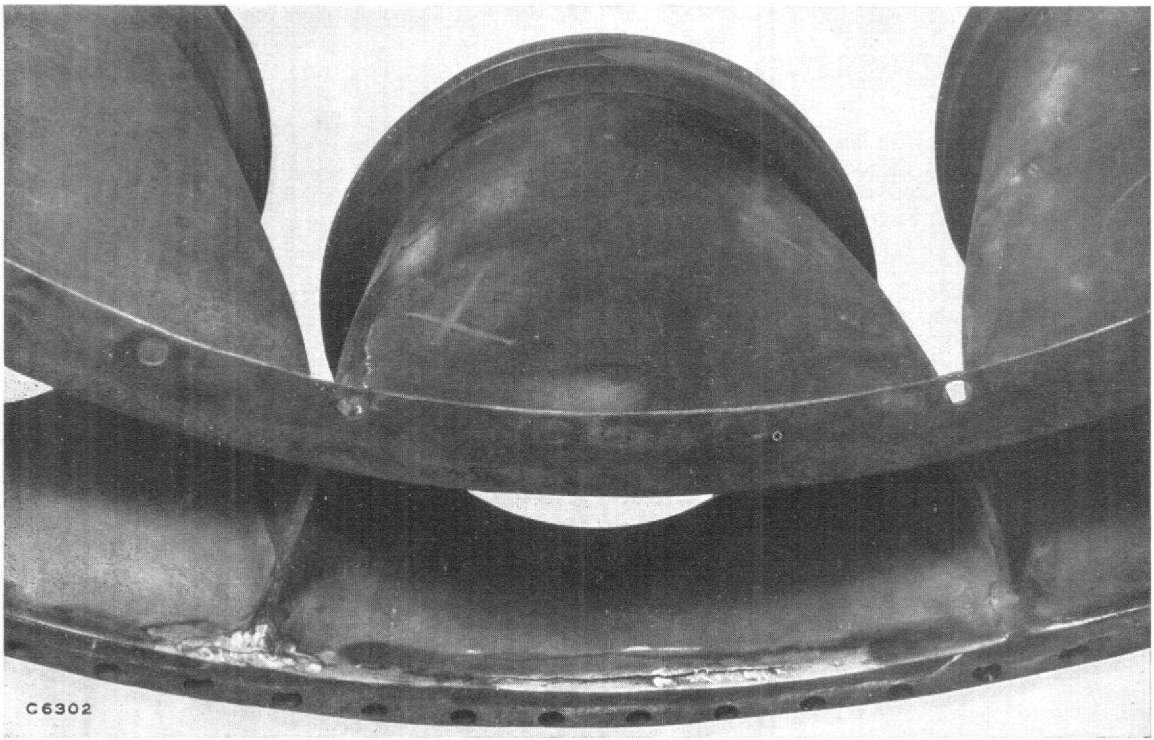


Fig. 36. Circumferential crack and crack at corner of nozzle, tending to develop into a single crack; generally, not acceptable.

Impeller examination overleaf

IMPELLER

CLEANING, AND PROTECTION AGAINST CORROSION

The impeller may be cleaned with kerosene, or with gasolene (petrol) (leaded or unleaded), or with white spirit, regardless of whether it has been anodised only or has been anodised and coated with Rockhard lacquer. It should then be wiped over lightly with temporary rust preventative to British Specification D.T.D. 121D, or with clean engine oil, to ensure protection against corrosion. Trichlorethylene must not be used for cleaning this component, except, of course, during overhaul when it is to be vapour-blasted and re-anodised without delay. Whenever the engine will be inoperative for any length of time, even though it may be defective and being returned for overhaul, the impeller must be protected against corrosion as laid down in chapter 20. Even slight traces of surface corrosion can quickly initiate intercrystalline corrosion and, because of the high stress to which the impeller is subjected during operation, cracks may easily develop from such corrosion. These precautions are doubly important where any portion of the anodic film or Rockhard lacquer has been removed. Where this has occurred, the bare surface of the metal must be given additional protection by the application of a suitable lacquer; two coats of Anaco 'B' varnish are suitable. This additional protection must be applied to all damaged areas whether the engine is to be run or not. If in an emergency it is necessary to run the engine after such damage has occurred, the coating of lacquer must be renewed at each subsequent inspection. If the previous coating of lacquer has commenced to peel, it should be removed before the new coating is applied.

FREQUENCY OF INSPECTIONS, RECORDING DAMAGE, AND EQUIPMENT

The impeller vanes should be inspected between flights, with the aid of an electric torch, and a record made of any damage discovered. If this record is maintained progressively, new damage will become easily recognisable. At each Check 2 Inspection, the impeller vanes should be critically examined, using the electric magnifying lens, which is provided in the tool kit, or an electric torch and a mirror, and the damage accurately graded into one of the two categories as detailed in the paragraph headed Examination, and Acceptance Standards.

CRACK DETECTION

It is recommended that impellers should be subjected to the Ardrox Dye Penetrant Crack Detection Process at combustion chamber inspections and at engine overhaul; this process can be applied to uninstalled engines (method 1), or to installed engines (method 2). Should any damage, however, be observed during a "between flights" inspection, a more detailed examination of the affected area must be carried out, and, if any doubt exists as to the serviceability of the impeller, crack detection in accordance with method 2 should be applied. On some impellers, marks may be found which resemble pencil lines running from the impeller hub down to the root of the blade. These marks appear, initially, as cracks, but it is unlikely that they will be confirmed as cracks when checked by the Ardrox process. It has been determined that these marks are due to the chalk content in the water bath, in which the impellers are washed after the Anodic treatment; such marks should be carefully examined to prevent unnecessary repetition of the Ardrox treatment. The process involves the thorough cleaning of the impeller, and the application of a red coloured penetrant fluid, which creeps into all surface voids, such as cracks, etc. Excess penetrant is then removed from the surface of the impeller, and the defect is developed by the application of a spray of fine white powder in a solvent. Cracks, and other flaws, will be shown up as irregular red lines, or as a series of red dots, on a white background. Such defects will be observed readily if they exist on the main surfaces of the impeller backplate and vanes, but will be more difficult to locate at the roots and outer edges of the vanes, and at the periphery of the backplate, Fig. 36A. Every effort should be made to ensure that these difficult areas do not escape examination. When either method of the process is being applied, all cleaning and spraying should be carried out through the starboard air-intake in the top left-hand area between the 9 and 12 o'clock position, and inspection should be carried out through both air-intakes, using an extended inspection lamp and mirror.

The following tools and materials will be required:—

Ardrox 996–P Penetrant
Ardrox 996–D1 Developer
Ardrox 996–SL Flaw Detection Kit
White Spirit

Uninstalled engines (method 1)

During each of the following operations, the impeller should be gently rotated to ensure that all accessible surfaces are dealt with. Proceed as follows:—

1. Thoroughly clean the impeller, using clean rag soaked in white spirit, and make certain that all traces of contamination are removed.

2. Using clean rag, or a jet of compressed air, thoroughly dry the impeller.

3. Using a brush, or the spray which is issued in the crack detection kit, apply Ardrox 996–P Penetrant to the impeller. Allow the Penetrant to remain for a minimum period of 20 min.

4. Use a rag soaked in white spirit to remove all Penetrant from the surface of the impeller. It is most important that this operation should be carried out thoroughly, otherwise spurious indications will be given when the next operation is required.

5. By means of the spray apparatus which is contained in the kit, apply Ardrox 996–D1 Developer to the impeller; this should be allowed to stand for 5–10 min.

6. Using a suitable means of illumination, carefully and thoroughly inspect the impeller for defects.

7. Repeat Op. 1 and 2 to remove the Developer.

Installed engines (method 2)

When applying this method, the aircraft should be positioned within easy reach of a compressed air supply which is capable of delivering pressure up to 60 lb. per sq. in., and of a source of electricity for the operation of a hand lamp. To guard against a possible fire risk, due to the presence of unevaporated white spirit used for the final cleaning of the impeller, it is recommended that no attempt be made to start the engine for at least ½-hour after completion of the impeller check. To apply this method, proceed as follows:—

1. Attach the Ardrox 996 Venturi spray unit to the special 6 ft. 9 in. spray gun, connect the gun to the compressed air supply, and spray the impeller with white spirit at a pressure of 60 lb. per sq. in. The white spirit should be supplied from a one-gallon tin standing on the wing of the aircraft.

2. Thoroughly brush the impeller with the nylon brush, making sure that all accessible surfaces are cleaned.

3. Respray the impeller with white spirit.

4. Disconnect the supply of white spirit, and use the spray gun to thoroughly dry the impeller with compressed air. Ensure that all surfaces of the impeller are dried completely.

5. Attach the Penetrant spray tin to the gun, and, using a reduced air pressure of 25–30 lb. per sq. in., thoroughly spray all accessible surfaces of the impeller with Ardrox 996-P Penetrant. Allow the Penetrant to remain for a minimum period of 20 min.

6. Re-attach the Venturi spray unit to the gun, and spray the impeller with white spirit at a pressure of 60 lb. per sq. in. to remove all Penetrant from the impeller surfaces.

7. Thoroughly dry the impeller with compressed air.

8. Attach the Developer spray tin to the gun, and, using a reduced air pressure of 25–30 lb. per sq. in., apply a thin, even film of Ardrox 996–D1 Developer to all accessible surfaces of the impeller; over-application must be avoided, or fine cracks may be masked. Allow the Developer to stand for 5–10 min.

9. Using a suitable means of illumination, and an extension mirror, carefully and thoroughly inspect the impeller for defects.

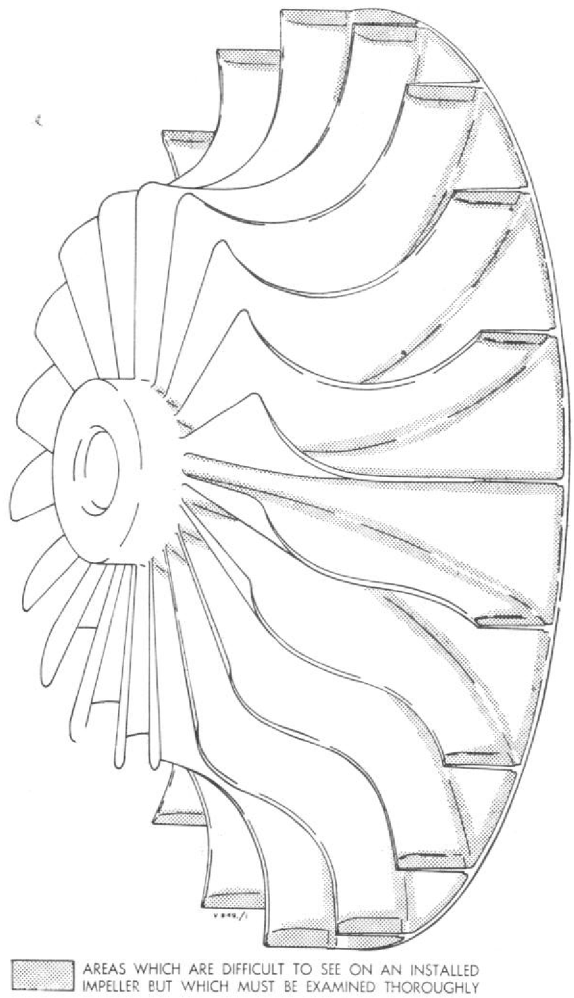


Fig. 36A. Diagram indicating areas which must be examined carefully even though they are difficult to see on an installed impeller.

10. Repeat operations 1, 2, 3, and 4 to remove the Developer.

EXAMINATION, AND ACCEPTANCE STANDARDS

The information contained in the paragraphs which follow is intended as a guide in assessing the acceptable limits of damage to impeller vanes which may have occurred as the result of impact with foreign matter whilst in service. The assessment of damage will depend to a great extent upon the experience of the assessor, and the accompanying photographs (Fig. 39 to 56) can, therefore, only serve as a guide since no two types of damage are identical. Normal abrasive pitting may be ignored; ‘normal abrasive pitting’ means that light even ‘sand blasted’ effect which is found on the impeller vanes after even a few hours running.

Alleged oil leakage from the front bearing may be due to the appearance of the Rockhard lacquer. This resinous finish gives an impression, partic-

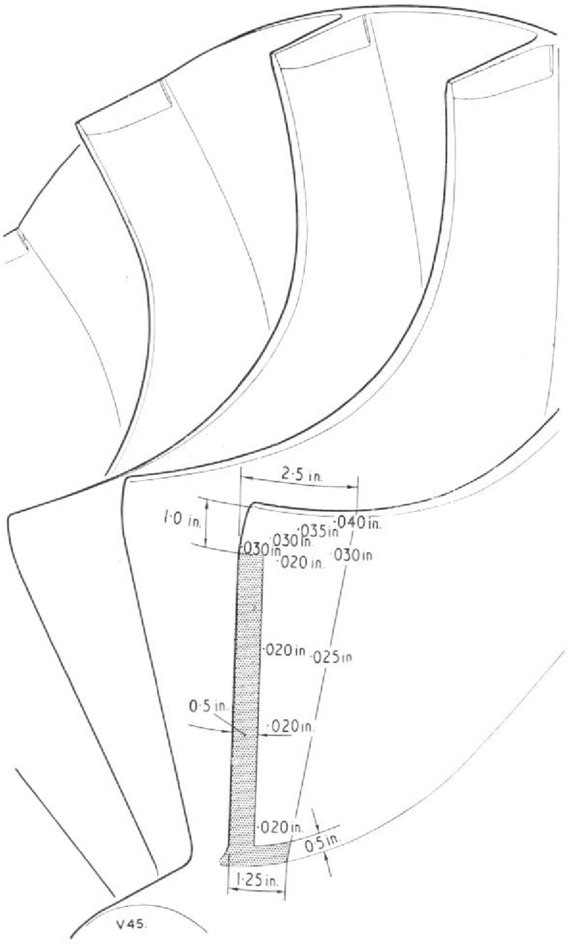


Fig. 37. Impeller damage, acceptance limits at in situ examination.

SHADED AREA. Smooth indentations only, up to a maximum depth of 0·020 inch but, along the leading edge smooth indentations up to a maximum depth of 0·030 inch. No irregular indentations permissible.

UNSHADED AREA. Maximum depth of damage, whether smooth or irregular, increases within the prescribed limits according to the position of the damage in relation to the root and leading edge of the impeller vane.

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ularly when an engine is new or newly overhauled, of a thick film of fresh oil. Therefore, before rejecting an engine for oil leakage at this point, ensure that the apparent oil film is really oil and not Rockhard lacquer.

Damage can be divided into two categories.

(1) Damage which may be blended out in situ, or which, where such blending would mean introducing excessive out-of-balance forces, may, in an emergency, be retained in service without blending. Damage in this category can be subdivided into two types.

(a) Smooth indentations—possibly the result of impact by small rounded objects.

(b) Indentations caused by impact with irregular shaped objects but which, when examined under a magnifying lens, do not reveal ragged, torn, or unradiused edges. Such damage is unacceptable in the critical area, which is indicated by shading on Fig. 37.

(2) Damage which can be blended out at overhaul only. This includes all indentations with ragged profiles which may cause areas of high stress.

The convex side of the impeller vanes can be viewed reasonably clearly by looking up the port and starboard air-intakes above and below the horizontal webs respectively; and vice-versa to view the leading edges. In the case of an installed engine, if the main aircraft fuel is removed it

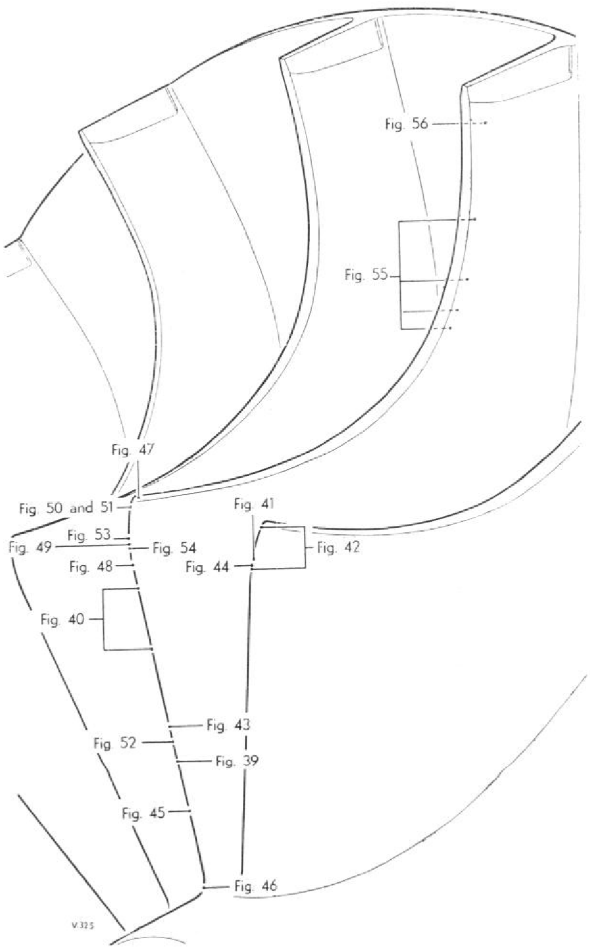

Fig. 38. Diagram showing position of damage illustrated in Fig. 39 to Fig. 56 inclusive. The damage indicated by Fig. 55 and 56 is on the concave side of the vane.

is possible to enter the tank bay and to examine the impeller through the engine air-intakes.

Where the impact has caused the material to spread so that it protrudes above the convex face of a vane, the consequent interruption in the air flow will result in the formation of a black oily deposit with every appearance of a crack running at right angles to the leading edge. All trace of this deposit must be removed, with the aid of a rag soaked in one of the fluids mentioned on page 21, and the area re-examined for evidence of cracking; the cleaning rag must be attached to a length of rod **securely.**

It is important to differentiate between damage of an acceptable standard which has resulted in smoothly flowing contours on the leading edge, and that which causes a sharp notch effect which would serve as a point of severe stress concentration on the surface of the vane.

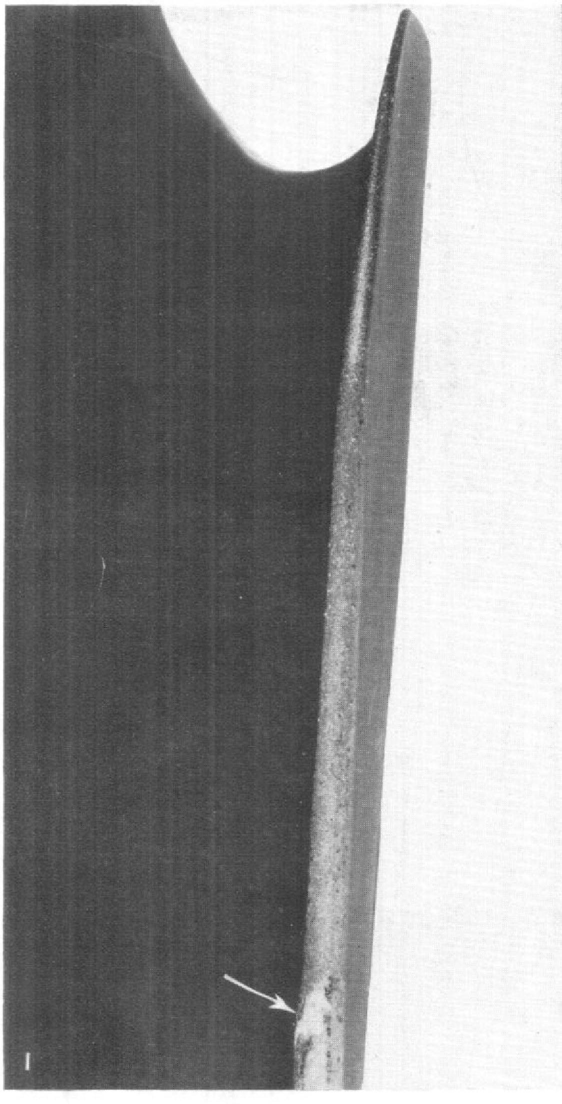

Fig. 39. Damage in the nature of a bruise resulting in little penetration (indicated by arrow), acceptable. Shows also the 'normal abrasive pitting' which has taken place along the whole of the leading edge.

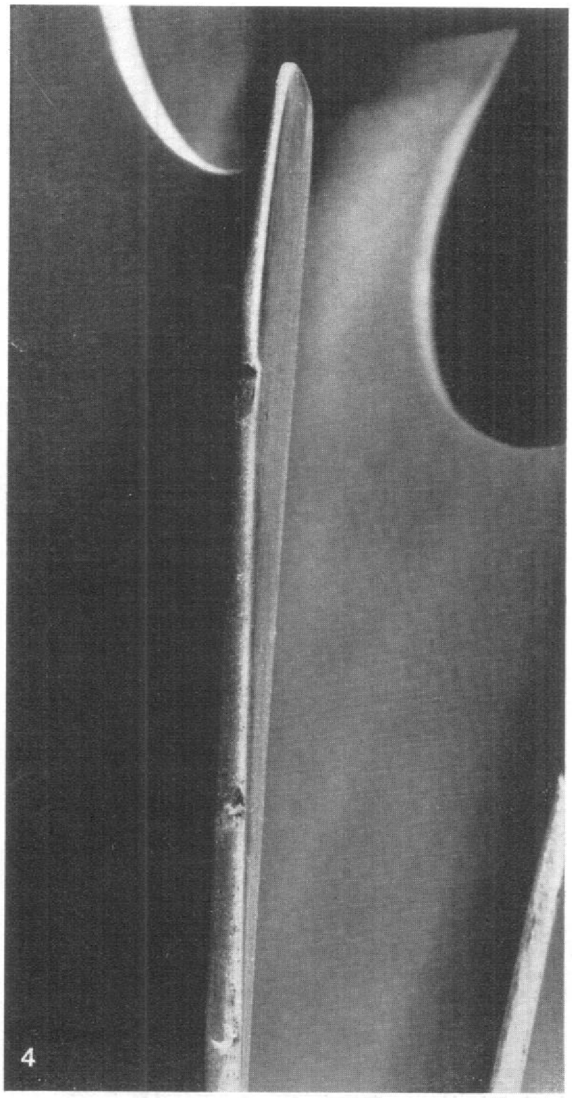

Fig. 40. Indentations of a smoothly flowing nature which need only be blended when the engine is being overhauled, acceptable.

It must be borne in mind that, due to the high rotational speed of this component, any impact damage may give rise to a point of high stress concentration. Therefore, a thorough examination of any damage must be carried out with the aid of an electric torch and a mirror, or, preferably, with a powerful electric magnifying lens such as that referred to on page 21, to ensure that there are no cracks, ragged or torn edges, or rapid unradiused changes of contour. If any of these defects are discernible, the engine must be rejected and returned for overhaul and a more thorough inspection than is possible with the impeller in situ.

Fig. 37 indicates the limits of damage which is acceptable at in situ examination of the impeller. In the shaded area, smooth indentations only up to a maximum depth of 0·020 inch are permissible, but along the leading edge, smooth indentations up to a maximum depth of 0·030 inch are permissible. No irregular indentations (sub-para. 1, sub-para. b, on page 22) are permissible in these critical areas. In the unshaded area, damage of both types (sub-para. 1) is permissible and the permissible depth increases, within the limits indicated, according to the position of the damage in relation to the root and leading edge of the vane.

Fig. 38 indicates the location of the damage illustrated in the photographs—Fig. 39 to 56.

At in situ examination, damage of the nature illustrated in Fig. 39 to 43 may be accepted. The 'normal abrasive pitting' which has taken place along the whole of the leading edge is clearly visible in Fig. 39. The damage indicated by the arrow in Fig. 39 is in the nature of a bruise resulting in little penetration, and the indentations shown in Fig. 40 are of a smoothly flowing nature, such damage is acceptable and need only be blended when the engine is being overhauled, after its

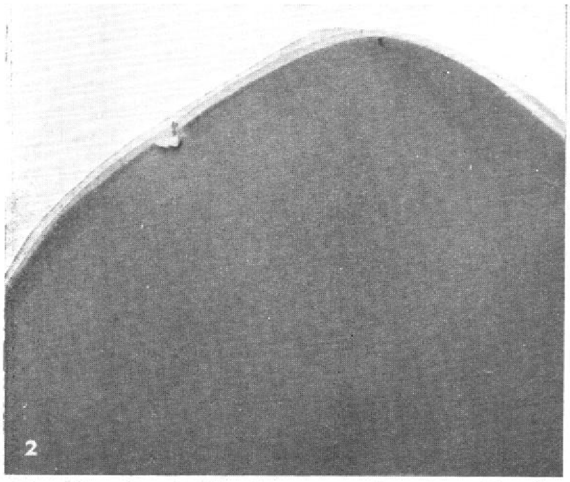

Fig. 41. Acceptable damage, only minor blending needed to remove burrs from sides of the vane; protect bared metal with lacquer.

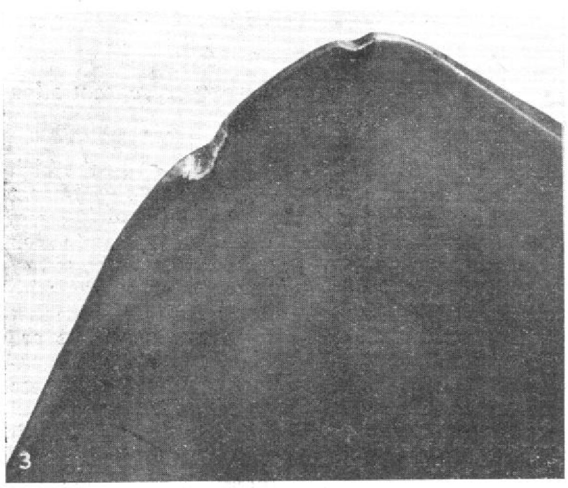

Fig. 42. Maximum acceptable damage, only minor blending needed to remove burrs from sides of the vane; protect bared metal with lacquer.

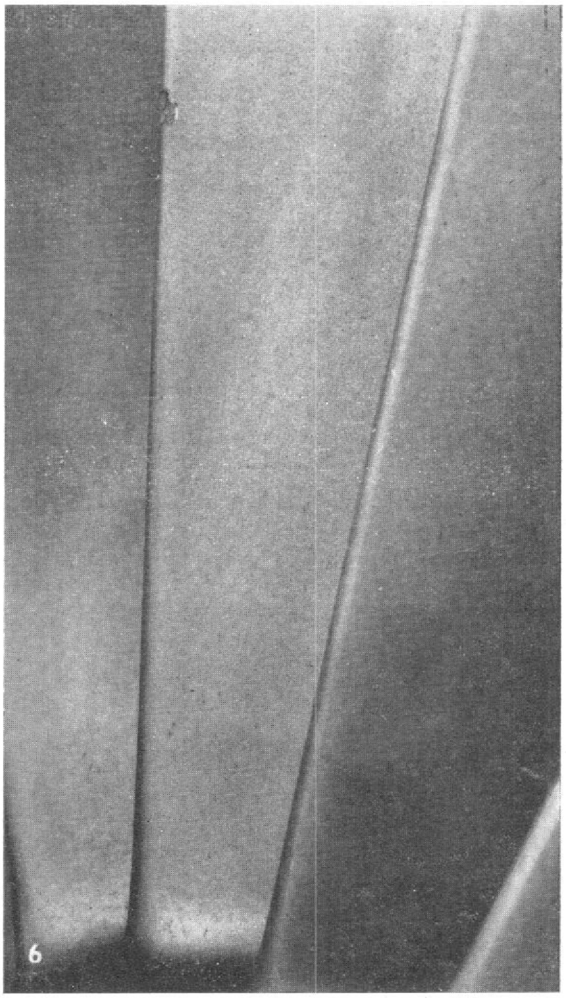

Fig. 43. Acceptable damage, only minor blending needed to remove burrs from sides of the vane; protect bared metal with lacquer.

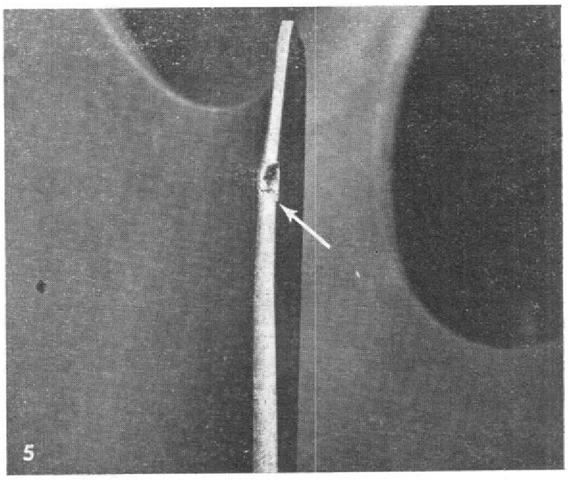

Fig. 44. Damage acceptable in an emergency only; the damage has formed a 'pocket' (indicated by the arrow) in the leading edge of the vane, which could possibly lead to a point of high stress concentration.

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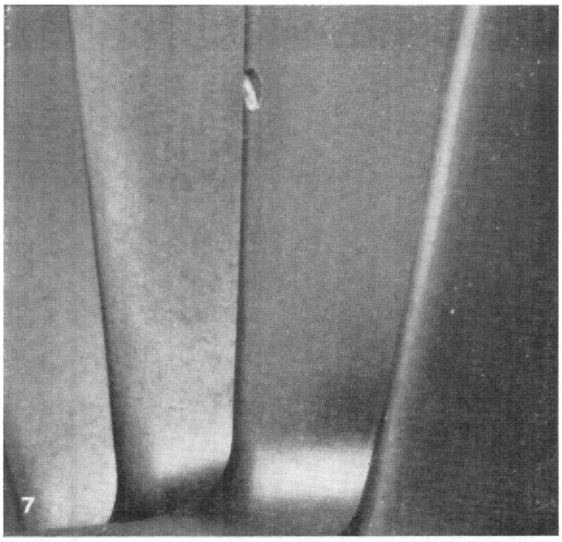

Fig. 45. Damage acceptable in an emergency only; this damage is of the same type as that illustrated in Fig. 44. Sharp edges should be removed and any bared metal covered with lacquer.

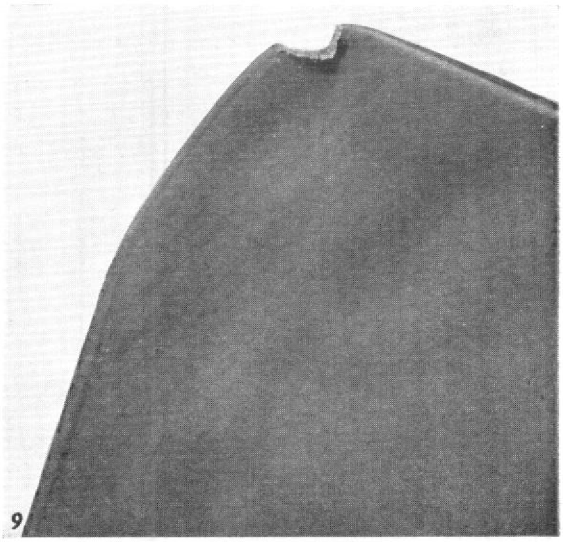

Fig. 47. A typical example of damage caused by a sharp-edged object, not acceptable; severe spreading has taken place over the side of the vane and when this is rectified at overhaul, special attention must be given to this area for hairline cracks.

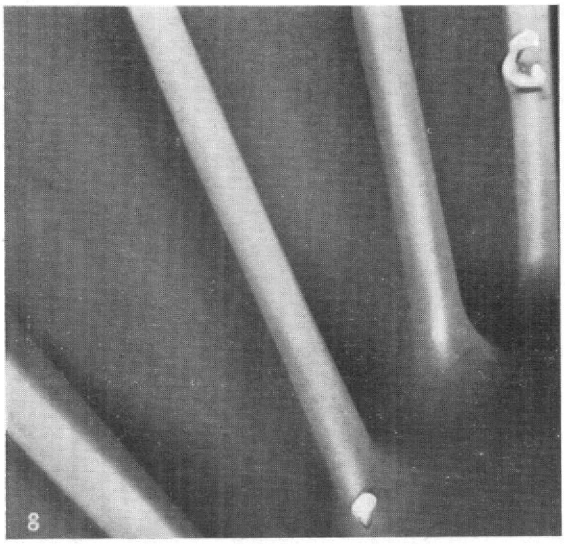

Fig. 46. Damage which is not acceptable for further running as it occurs at a point of high stress concentration and can be blended out at overhaul only; the depth of the damage illustrated is 0·030 inch.

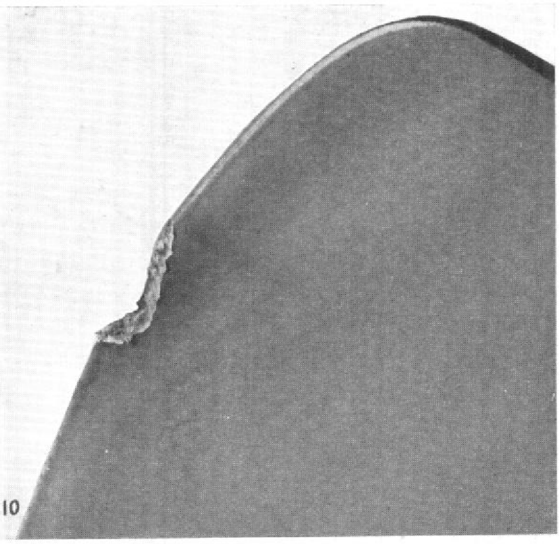

Fig. 48. Another example of damage caused by a sharp-edged object, not acceptable; see also caption to Fig. 47.

normal period between overhauls has been completed. Damage of the nature illustrated in Fig. 41, 42, and 43, is acceptable subject to minor blending in situ to remove the burrs from the sides of the vane—in each of these instances, after blending, the bared surface of the metal must be protected by a coating of lacquer.

Fig. 44 and 45 illustrate examples of damage which may be accepted in an emergency only. The damage shown in Fig. 44 has formed a 'pocket' (indicated by an arrow) in the leading edge of the vane, which could possibly lead to a point of high stress concentration. In such instances the sharp edges should be removed and any bared surface of the metal protected with lacquer. It is essential that, before any emergency running commences, the ragged profile of the damaged section should be removed, wherever possible, with the removal of the minimum amount of material, and that a close inspection be made for cracks. Engines in which the impeller has sustained damage of this nature should be withdrawn from service at the earliest opportunity.

Damage of the nature shown in Fig. 46 to 51 inclusive is not acceptable at in situ examination,

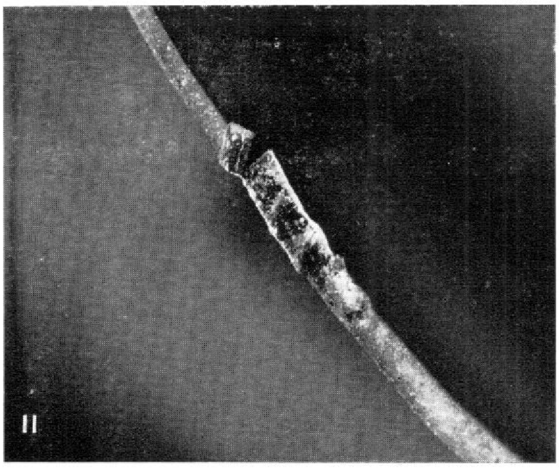

Fig. 49. This is a clear example of the type of damage described as 'indentations with ragged, torn, and unradiused edges'; not acceptable.

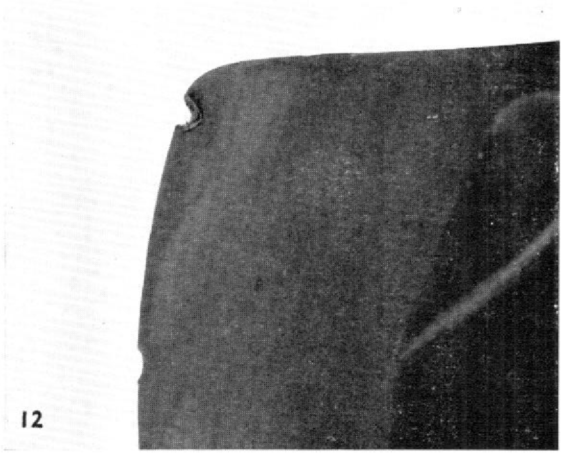

Fig. 50. A further example of damage caused by a sharp-edged object—see also Fig. 47—not acceptable; the impact of the object has bent back the vane tip and during overhaul the surrounding area must be inspected closely for hairline cracks.

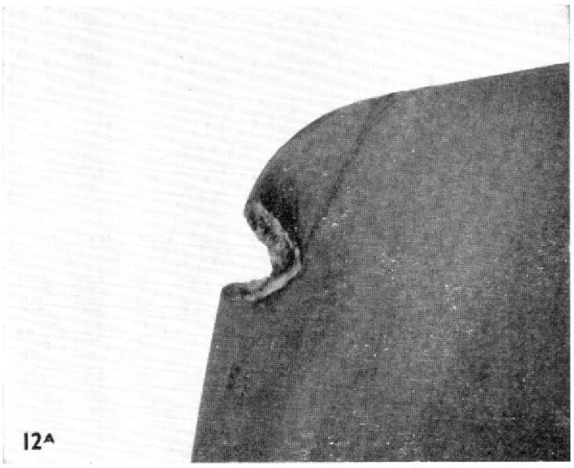

Fig. 51. An enlarged view of the damage shown in Fig. 50 (magnification × 4) which enables the ragged nature of the indentation to be seen clearly.

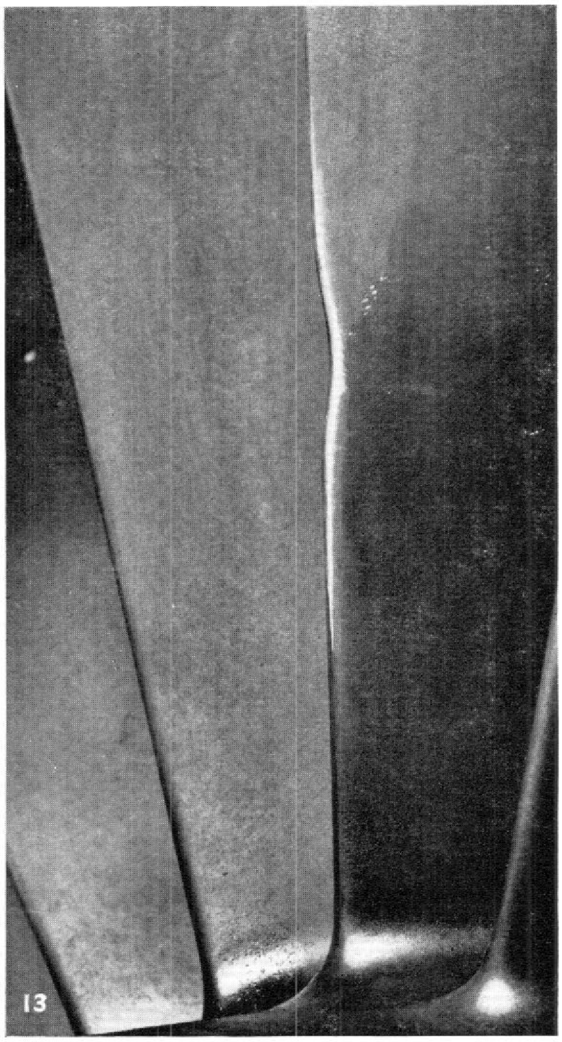

Fig. 52. Damage which has been bleanded out during overhaul; the depth of damage was the maximum permissible at this position.

and engines having impellers damaged to this extent must be rejected and overhauled.

Fig. 52, 53, and 54 illustrate examples of impeller vanes which have had damage rectified by blending during overhaul. The arrow on Fig. 54 indicates a defect which, on initial examination in situ, was thought to be a fold in the material. The engine was, correctly, rejected and during the subsequent overhaul the impeller was submitted to X-ray examination. This X-ray examination proved the defect to be a slag inclusion and the impeller was scrapped. This is an unusual defect but may be of some interest.

Fig. 55 and 56 show examples of damage to the side of an impeller vane. Where such damage is found, the engine must be rejected, particularly if the damage is of the type shown in Fig. 55, due to its position near the forward edge of the

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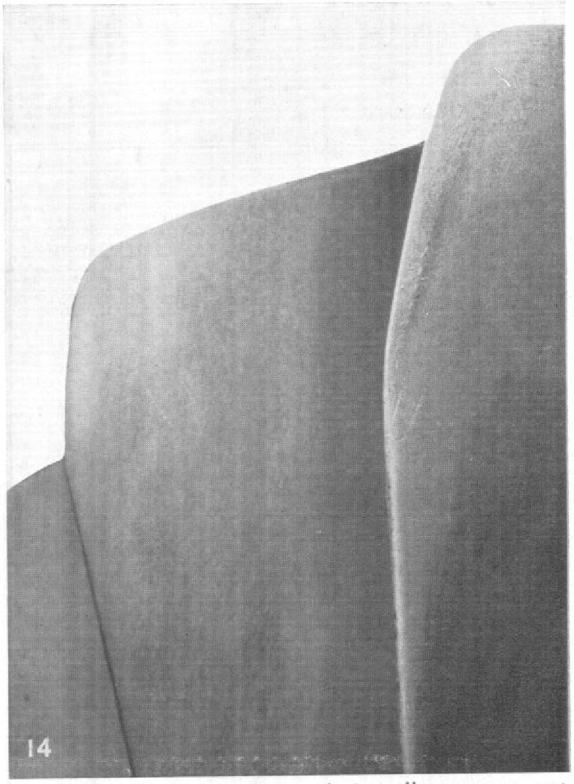

Fig. 53. Leading edges of impeller vanes cut back within the permissible limits during overhaul.

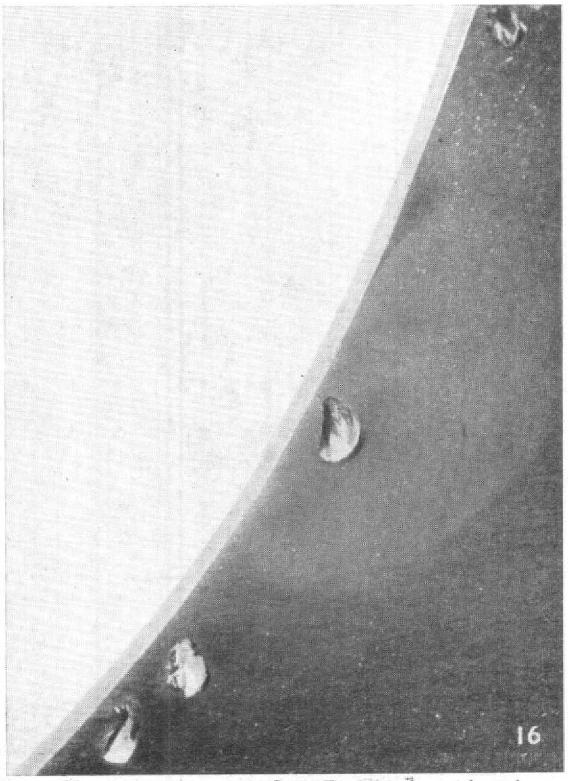

Fig. 55. Unacceptable damage on the side of an impeller vane near to its edge; can be rectified at overhaul.

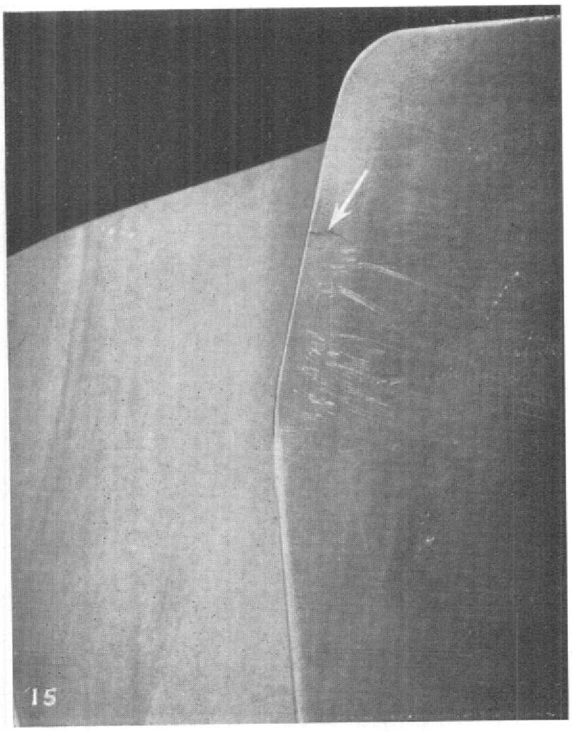

Fig. 54. What appears to be a crack or fold (indicated by arrow) in the material; subsequent X-ray examination showed this to be a slag inclusion; not acceptable either at in situ examination or at overhaul.

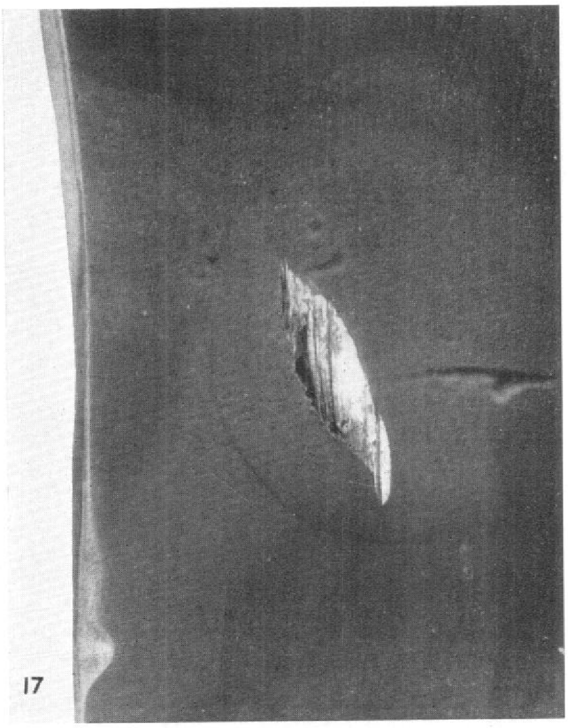

Fig. 56. Unacceptable damage on the side of an impeller vane; can be rectified at overhaul.

The small numbers at the bottom of these photographs are the Publisher's reference numbers.

vane ; part of this edge will have to be removed to carry out correct blending.

When examining the impeller, it should be remembered that the rear face of the impeller pivot flange is cut back, with the effect that, when the pivot is fully home in the impeller, there is a space, slightly more than $\frac{3}{64}$ inch wide and $\frac{1}{4}$ inch deep, between the edge of the pivot flange and the impeller hub. This gap, which is used for tooling purposes during manufacture and overhaul, is intentional and does not indicate that the pivot has moved away from the impeller.

RECTIFICATION OF DAMAGE IN SITU

To be acceptable for further running, the depth of impact damage must not exceed the limits specified on Fig. 37 and must not, when examined under a magnifying lens, have any ragged, torn, or unradiused edges.

Minor blending only may be carried out on this type of damage. No more than two damaged vanes in consecutive positions and a total of not more than 8 damaged vanes on any one impeller may be blended for further service ; this is to avoid an excessive out of balance resulting from the minor blending.

Rectification of damage by minor blending in situ should be carried out as follows.

(1) Blend out the damage using super-fine files, smooth emery cloth, and metal polish, in the order given. The removal of the material is partly controlled by the amount of anodic treatment and Rockhard lacquer which may have to be removed. When blending out damage in situ, the amount removed should be as little as possible as the removal of these protective finishes leaves the material of the impeller vane open to intercrystalline corrosion. If it is necessary to remove material from the tip of the leading edge, this must be the minimum possible, as the performance of the engine is greatly affected by the removal of material at this position. When removing burrs from the side of the vanes care should be taken to reduce the vane thickness as little as possible ; and the maximum depth of blending indentation must not exceed one quarter of the initial thickness of the vane at the point of damage.

(2) Give temporary protection to the bared surface of the metal by applying a suitable lacquer ; two coats of Anaco 'B' varnish are suitable.

Where damage has been blended previously, the protective lacquer may have commenced to peel off, and if this has occurred, the original coating of temporary lacquer should be removed and a fresh coating applied.

It cannot be too strongly emphasised that it is essential to keep accurate records of all blending which may be carried out so that the cumulative effect of repeated minor blending does not result in the limits laid down being exceeded.

RENEWAL OF TURBINE BLADES "IN THE FIELD"

These instructions for the renewal of turbine blades "in the field" are issued under the authority of a memorandum from the Chief Engineer's Department, reference DTP/FW, dated 5.1.1956. Pending further practical experience, they should be regarded as being in the nature of a draft, and any comments the reader may wish to make as a result of having carried out this work practically, should be sent to The de Havilland Engine Company so that they may be considered for inclusion in these instructions. Instructions for renewing turbine blades during overhaul are contained in chapter 28C.

RENEWAL OF DAMAGED TURBINE BLADES

Although, as described on page 13, the turbine disc can be removed and refitted "in the field", it cannot be exchanged for another one, as the turbine discs are not interchangeable because :-

(1) They are balanced as part of the complete main shaft assembly.

(2) The bolt holes are line-reamed in conjunction with their individual hub shaft.

(3) The holes in the turbine disc and in the hub shaft may have been line-reamed oversize and oversize bolts fitted, under the authority of an approved repair.

(4) The spigot on the turbine disc and its mating recess in the hub shaft may be undersize, as the result of the application of an approved repair.

EQUIPMENT

In order to renew damaged turbine blades "in the field", the following equipment, the majority of which is either standard equipment or can be manufactured locally on the lines suggested in the illustrations in this chapter, will be required :-

(1) A rigid bench capable of supporting the turbine disc, which weighs approximately 220 lb., at a convenient height for driving out the damaged blades and for peening the replacements. This bench must provide a solid foundation to support the turbine disc whilst the damaged blades are being driven out, and whilst peening their replacements.

(2) A stout wooden frame, such as that illustrated in Fig. 57, about 13 inches square and 4 inches deep, to support the disc with the turbine blades clear of the bench.

(3) A thick metal plate upon which to rest the hardwood blocks used to support the disc whilst driving out damaged blades, and the peening anvil whilst peening their replacements.

(4) A 2 lb. hammer.

(5) Two hardwood blocks, Fig. 58, to support the disc whilst driving out damaged blades.

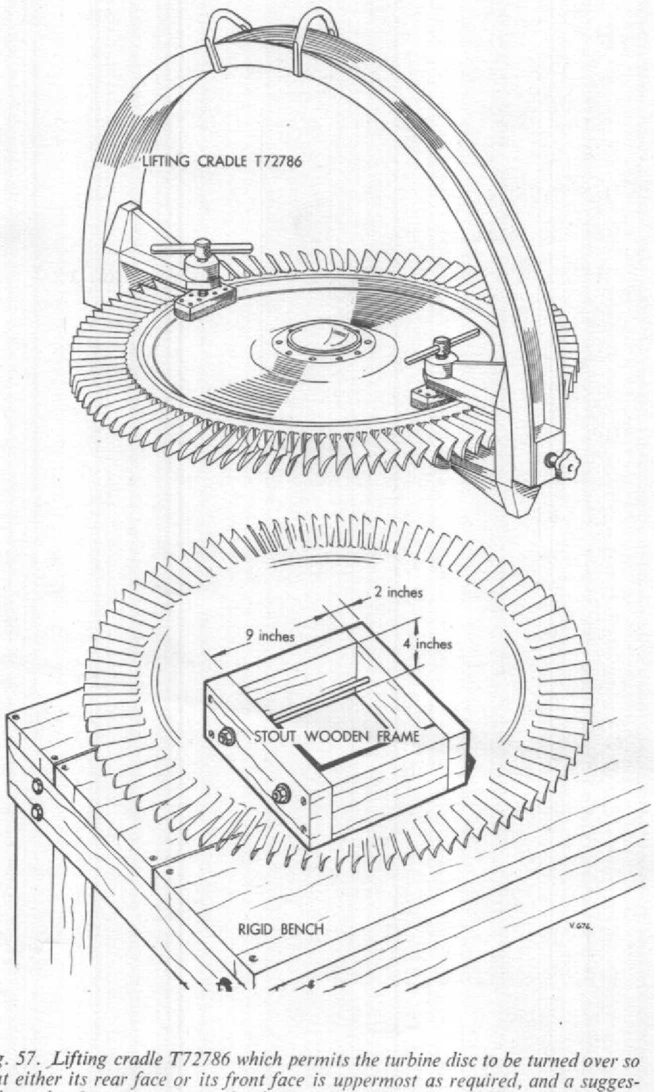

Fig. 57. Lifting cradle T72786 which permits the turbine disc to be turned over so that either its rear face or its front face is uppermost as required, and a suggested wooden frame to support the disc so that the blades are clear of the bench.

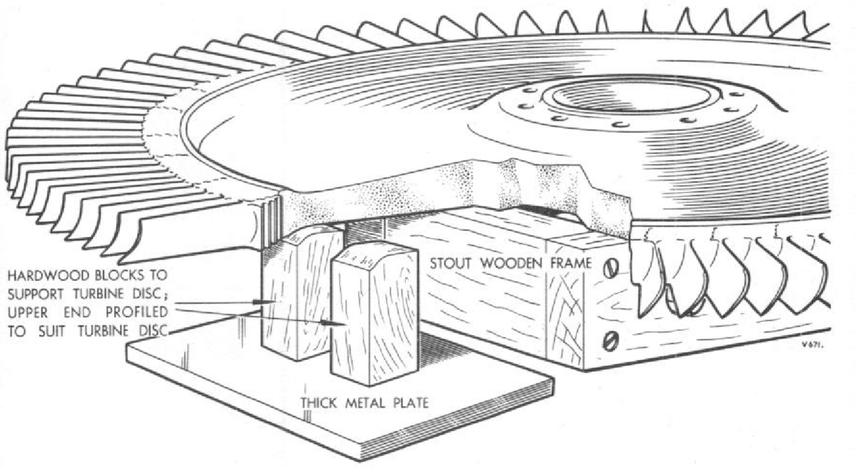

Fig. 58. Suggested hardwood blocks to support the turbine disc whilst damaged blades are being driven out.

(6) A soft-metal punch, Fig. 59, for driving out damaged blades; a suitable tool is available ready-made under tool number T 70864.

(7) A tool, Fig. 60, for driving back the peening on the damaged blade roots before driving the blades completely out of the disc.

(8) A simple balance beam, Fig. 61, for comparing the effective moment weight of a damaged blade with that of the proposed replacement, and to enable the effective moment weight of the latter to be adjusted until it is the same as that of the blade which it is replacing.

(9) A peening anvil and punch, Fig. 62.

(10) A number of hard-rubber blocks, Fig. 63, to wedge between the blades whilst peening, to reduce vibration and fretting.

(11) A profile gauge, Fig. 64, to act as a guide when trimming replacement blades.

(12) Superfine files, emery cloth, and a smooth stone for trimming replacement blades, and for adjusting their effective moment weight.

(13) A dial test indicator and associated equipment.

(14) A vernier caliper.

Where sufficient machining facilities are available, and where the number of engines in service warrants its provision, a peening fixture such as that illustrated in Fig. 65 could replace items 2, 3, and 9, and would facilitate the work.

Whilst removing the damaged blades, and whilst peening their replacements, it is necessary to turn the disc, at least twice, through 180 degrees; so that the rear and front faces of the disc are successively uppermost. Although this can be done without the aid of special lifting

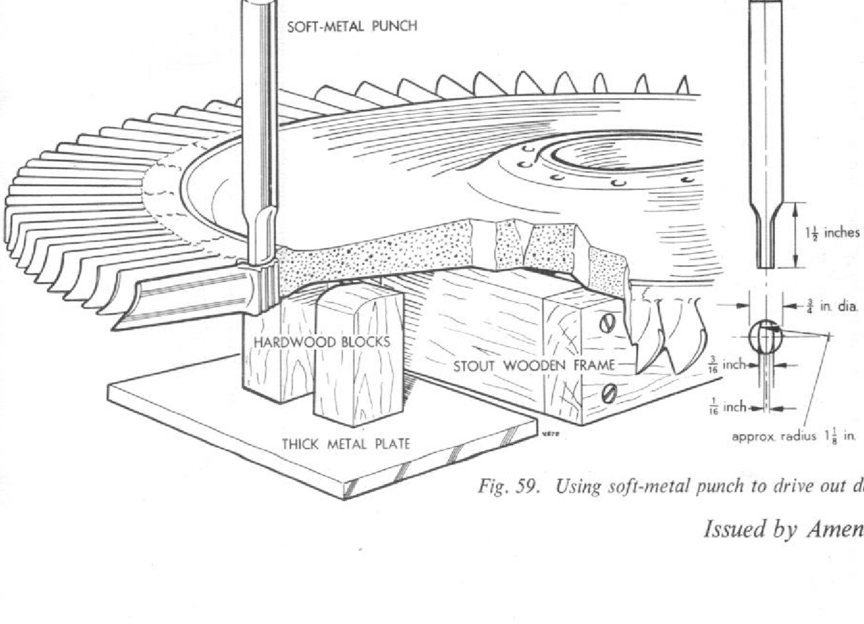

Fig. 59. Using soft-metal punch to drive out damaged blades.

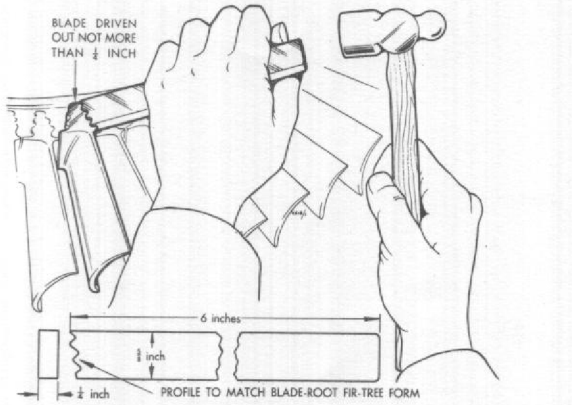

Fig. 60. Driving back peening on blade root before driving blade completely out of disc.

tackle, this involves considerable risk of damage to the component and of serious injury to personnel; as the bladed disc weighs about 220 lb. and is difficult to manhandle without either damaging the turbine blades or cutting the fingers on their relatively sharp edges. For these reasons, it is strongly recommended that lifting cradle T 72786, Fig. 57, should be used for this purpose. With the aid of this lifting cradle, and a suitable portable crane or hoist, blade renewal can be accomplished single-handed.

LIMITS OF TURBINE BLADE RENEWAL "IN THE FIELD"

It is not permissible to renew more than six adjacent turbine blades, and the total number of blades renewed in any one disc "in the field" must not exceed 20. The renewal of a blade which has broken off is not permissible, as such fracture is very rare and may be accompanied by damage to the main bearings. It is essential to keep an accurate record of all blades renewed "in the field" so that the cumulative effect of successive renewals does not result in these limits being exceeded. This record should be made in the engine log book to ensure that the information is available wherever the engine may be sent, and at the subsequent overhaul.

To retain, as far as possible, the original balance of the disc, each replacement blade must be compared, by means of a suitable balance beam, with the damaged blade which it is replacing; and be adjusted by filing until it has the same effective moment weight as that of the damaged blade. This operation should be combined with the trimming of the tip to conform to the peripheral profile of the adjacent undamaged blades. The term "moment weight of the blade" is used to refer to the difference between the moment weight of a nominal standard blade about the centre of the turbine disc and that of any other blade. During initial manufacture the value of this "moment weight", in ounce-inches, is etched on one side of the blade root, and

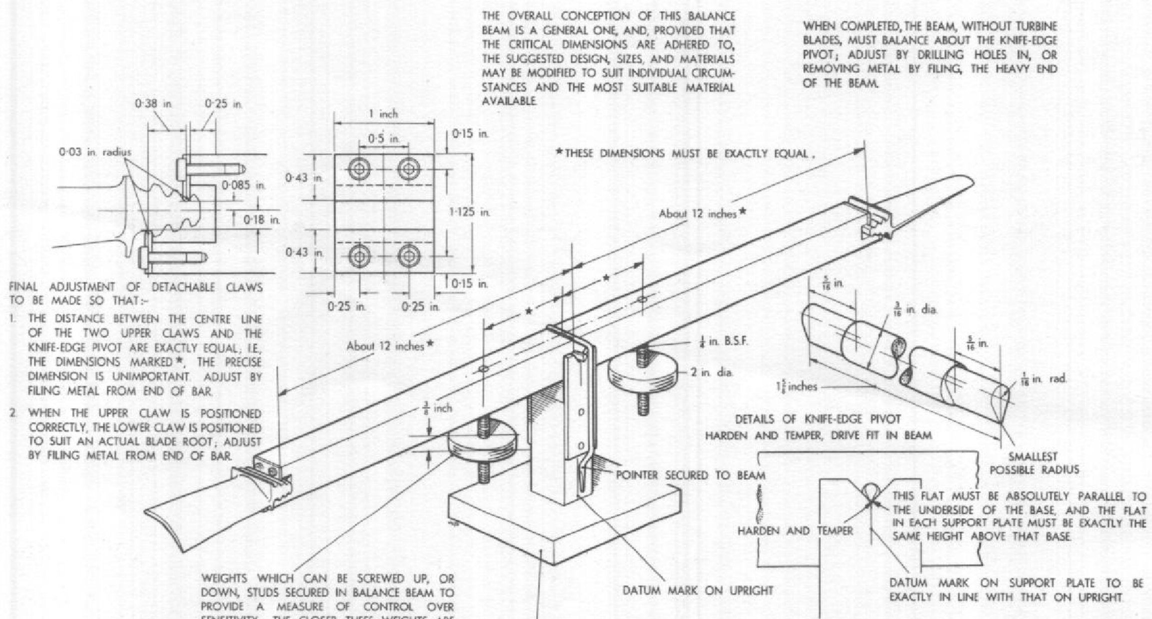

Fig. 61. Suggested balance beam for comparing effective moment weight of proposed replacement blade with that of damaged blade removed from disc.

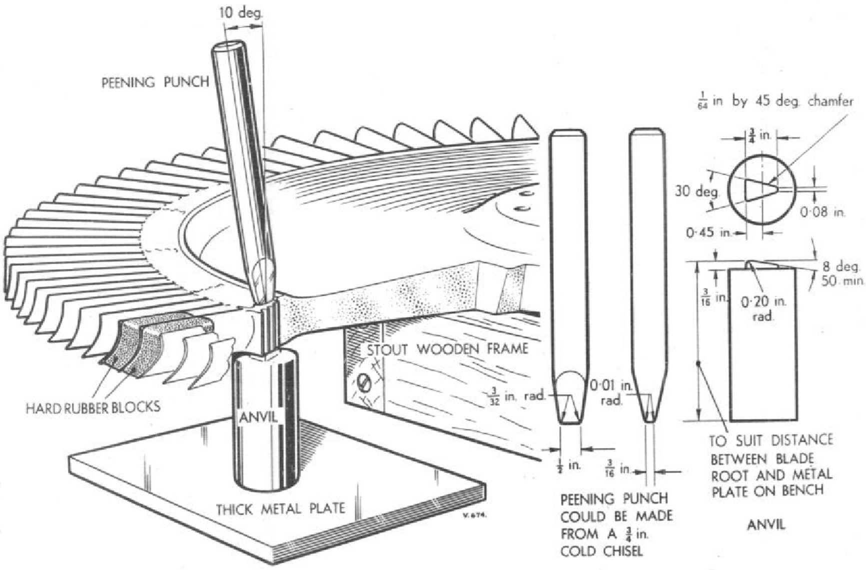

Fig. 62. Using locally-made peening punch and anvil to peen blade root.

is prefixed "plus" or "minus" to indicate its relationship to the nominal moment weight. The moment weight as etched on the side of the blade root, is the moment weight as measured before final grinding, or trimming of the blade tips during initial assembly, or subsequent overhaul, and, therefore, will not tally with the actual moment weight of a damaged blade which has been removed. In this chapter, the latter is referred to as the "effective moment weight".

IDENTIFICATION OF TURBINE BLADES

To enable the record, referred to in the preceding paragraph, to be made, each blade must be identified and allotted a number. The blades should be regarded as though they were numbered in sequence in the direction of rotation; that is, in a clockwise direction when viewed from the rear of the disc. No. 1 blade is indicated by an arrow etched on the front face of the turbine disc, and, incidentally, this is the only blade whose root is bisected by a line passing through the centres of two diametrically opposite bolt holes. Therefore, if, as a result of prolonged engine running, the etched arrow has been obliterated, No. 1 blade can be identified thus, Fig. 66; since, in this diagram, the turbine disc is shown as though viewed from the front the blades are numbered in a counter clockwise direction in this illustration. Place a straight-edge diametrically across the disc so that its edge passes through the centres of two diametrically opposite bolt holes. By trial and error, discover in which of the five alternative positions one end of the straight-edge also bisects one of the blade roots. As there are 97 blades and ten bolt holes, only one blade root can be truly symmetrical about a diameter which also passes through the centres of two diametrically opposite bolt holes, and this will be No. 1 blade. Having identified No. 1 blade, mark the slot in the turbine disc with chalk, soapstone; or some similar substance which will not leave any carbon deposit. From this datum, number each damaged blade which it is proposed to replace, and its slot in the turbine disc, in a similar manner.

REMOVING DAMAGED TURBINE BLADES

Having removed the turbine disc from the engine as described on page 13, transfer it to a wooden frame, such as that illustrated in Fig. 57, mounted on a substantial bench; or to a fixture such as that suggested in Fig. 65. At this stage the turbine disc will be rear face uppermost. Remove the combined lifting and extracting fixture which was used to remove the disc from the engine. Before commencing to remove any blades, identify and number them, and their slots in the disc, as described in the preceding paragraph. Remove each damaged blade as follows :-

(1) Place the thick metal plate on the bench immediately under the blade which is to be removed.

(2) Supporting their lower ends on the metal plate, position the two hardwood blocks

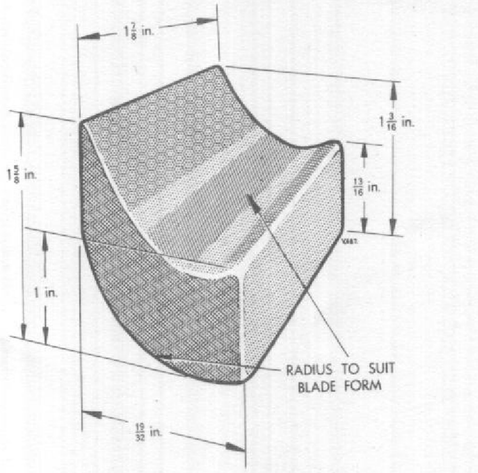

Fig. 63. Hard-rubber blocks, to be wedged between adjacent blades to prevent vibration and fretting during peening.

under the disc, close to and on either side of the root of the blade which is to be removed. These hardwood blocks should be a snug fit between the turbine disc and the metal plate on the bench, so that they will effectively support the disc during the subsequent operations; if necessary, use metal packing to ensure this.

(3) Use the 2 lb. hammer and the soft-metal punch, Fig. 59, to drive out the damaged blade until its root projects <u>not more</u> than $\frac{1}{4}$ inch from the under face of the disc.

(4) Use lifting cradle T 72786, Fig. 57, and a suitable crane or hoist, to raise the disc off the bench. Rotate the disc, in the cradle, until it is horizontal with its front face uppermost, and return it to the bench. Where lifting cradle T 72786 is not available, place several thicknesses of closely-woven cloth or felt, over the turbine blades to protect the operator's hands, and, with the aid of at least two assistants, turn the disc over so that its front face is uppermost. During this operation, great care must be taken to ensure that neither the turbine blades nor the disc are damaged in any way.

(5) Use the tool illustrated in Fig. 60, to drive back the peening from both edges of the exposed blade root; this is to reduce the risk of damage to the slot in the disc, and to reduce the effort required, when driving the blade completely out of the disc. This operation is most important as, unless the peening is thoroughly dressed back in this manner, the slot in the disc is liable to be opened out to a greater extent than is normally experienced, each time a blade is removed, and this shortens the useful life of the disc.

(6) Thoroughly clean the disc and the blades, to remove all traces of swarf or dust; so as to minimize the risk of scoring the slots in the disc as the blades are driven out.

(7) Reposition the two hardwood blocks as described for operation 2, and use the hammer and the soft-metal punch to drive the damaged blades back into the disc and continue driving them in the same direction until they have been driven completely out of the disc.

(8) Using a superfine file, remove any burrs or sharp edges, which may have been caused by the removal of the blades, from the slots in the disc; during this operation great care must be taken to ensure that the surface of the disc is not scratched and, afterwards, all file marks and scratches must be polished out with fine emery cloth.

(9) Make a record of the damaged blades removed.

SELECTING REPLACEMENT TURBINE BLADES

In order to preserve, as far as possible, the original balance of the complete main shaft assembly, each replacement blade must be of the same effective moment weight as the damaged blade which it replaces. Moment weight must not be confused with actual weight. Two blades of identical weight may due to differences in profile have the mass of metal distributed differently, and therefore have different moment weights. At the same time, standard or oversize blades must be selected as necessary to obtain the correct tip rock (circumferential movement of the blade tip relative to the turbine disc) before peening. To obviate the need to stock an infinite number of blades of varying moment weights and oversizes, the following procedure has been devised to permit the effective moment weight of replacement blades to be adjusted to match that of the damaged blades removed.

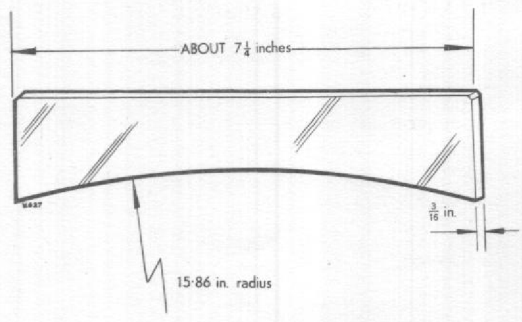

Fig. 64. Profile gauge to act as guide when trimming replacement blades.

Replacement blades are available as follows :-

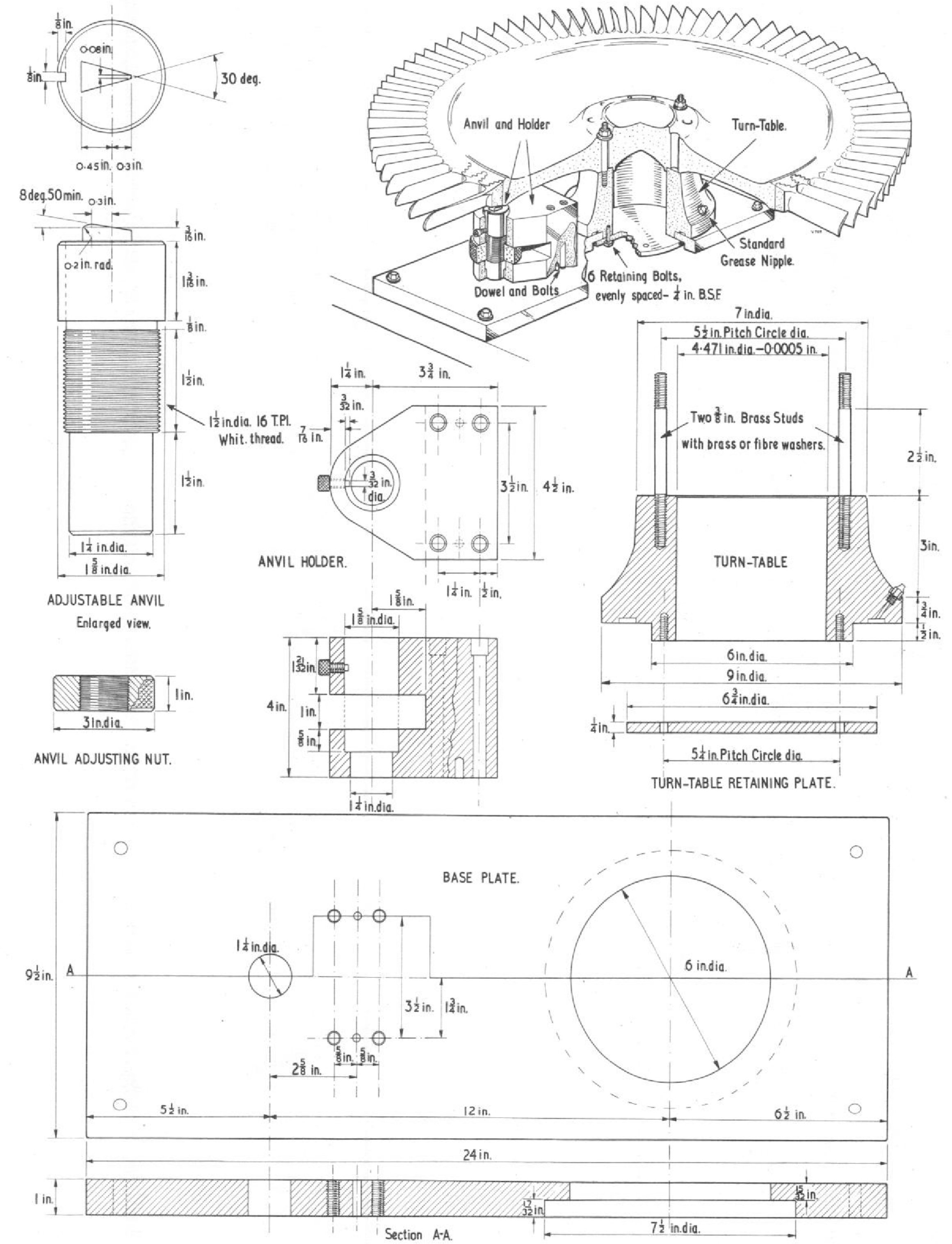

Fig. 65. Suggested peening fixture which could be made up where machining facilities are available, and where the number of engines in service warrants this. The overall conception of this fixture is a general one and, provided that the critical dimensions are adhered to, the suggested design, sizes, and materials may be modified to suit individual circumstances and the most suitable material available.

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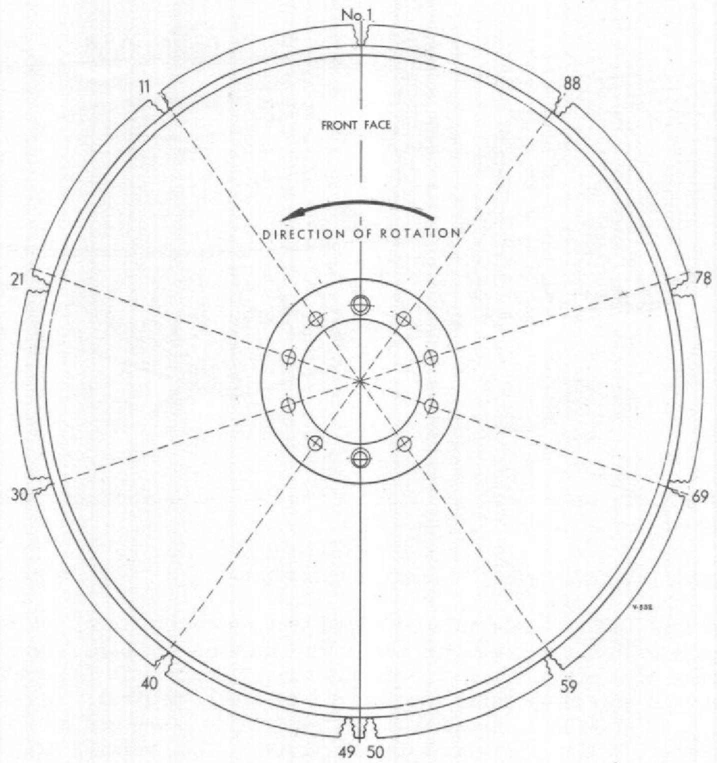

Fig. 66. Diagram to indicate method of identifying No. 1 turbine blade when the marking on the disc is obscure.

Part No.		Turbine Blade	
600637	.. ..	Standard, mod. 731	
or			
600637-1	.. ..	0.002 in. oversize)	) mod. 761
or			
600637-2	.. ..	0·004 in. oversize)	
or			
600637-3	.. ..	0·007 in. oversize	mod. 1225
or			
600635	.. ..	Standard, mod. 731	
or			
600635-1	.. ..	0·002 in. oversize)	) mod. 761
or			
600635-2	.. ..	0·004 in. oversize)	
or			
600635-3	.. ..	0·007 in. oversize	mod. 1225
or			
95486	.. ..	Standard)	
or			
95486-1	.. ..	0·002 in. oversize)	mod. 886
or			
95486-2	.. ..	0·004 in. oversize)	
or			
95486-3	.. ..	0·007 in. oversize	mod. 1225

Until all pre-mod. 871 turbine disc assemblies have been replaced by modified assemblies, it will be necessary to trim the tip of each replacement blade to bring the overall diameter of the bladed turbine disc within the limits. Mod. 871 makes this unnecessary, by reducing the length of the blades and by stricter control of the position of the serrations, which are broached in the turbine disc, relative to the centre of the disc; this second feature making it impossible to embody this modification retrospectively. When dealing with pre-mod. 871 assemblies, this trimming to length should be combined with the adjustment of the effective moment weight as described in the next paragraph; where mod. 871 has been embodied, adjustment ground, the final acceptance must depend upon its behaviour in flight. The first flight, after this repair has been carried out, should be made by a test pilot who is well acquainted with these engines and with the degree of vibration normally experienced. During this test flight he should pay particular attention to engine vibration under all conditions of flight, and decide whether the engine can be accepted for further service or not. Where an Avery type 7208, 20-2000 lb. electro-dynamic balancing machine and the necessary equipment is available, the engine can be checked for balance, without dismantling it, and if necessary the balance can be corrected, in the manner described in chapter 36C.; engines which are rejected as a result of the test flight should be sent for checking to a depot which has this equipment.

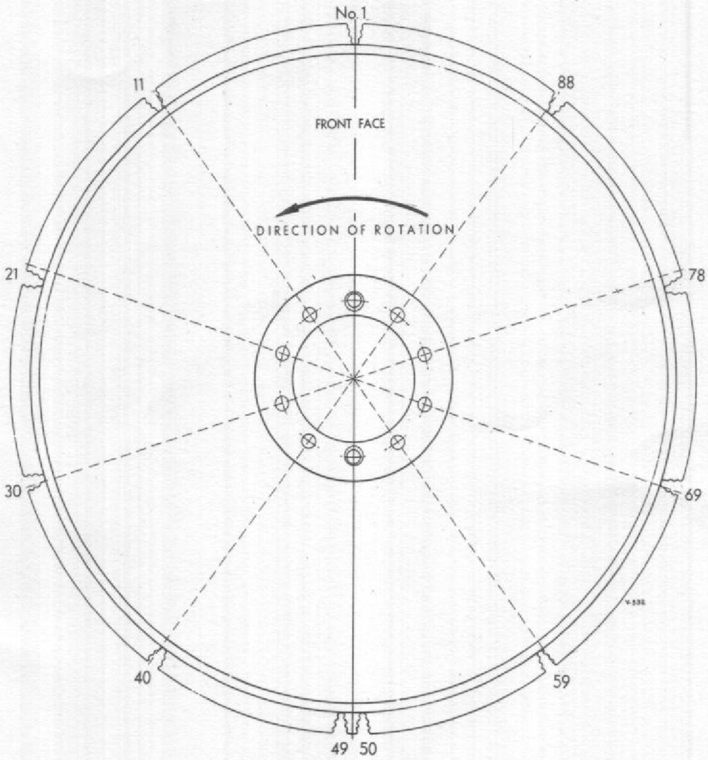

Fig. 66. Diagram to indicate method of identifying No. 1 turbine blade when the marking on the disc is obscure.

Part No.		Turbine Blade	
600637	.. ..	Standard, mod. 731	
or			
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or			
600637-3	.. ..	0·007 in. oversize	mod. 1225
or			
600635	.. ..	Standard, mod. 731	
or			
600635-1	.. ..	0·002 in. oversize)	) mod. 761
or			
600635-2	.. ..	0·004 in. oversize)	
or			
600635-3	.. ..	0·007 in. oversize	mod. 1225
or			
95486	.. ..	Standard)	
or			
95486-1	.. ..	0·002 in. oversize)	mod. 886
or			
95486-2	.. ..	0·004 in. oversize)	
or			
95486-3	.. ..	0·007 in. oversize	mod. 1225

Until all pre-mod. 871 turbine disc assemblies have been replaced by modified assemblies, it will be necessary to trim the tip of each replacement blade to bring the overall diameter of the bladed turbine disc within the limits. Mod. 871 makes this unnecessary, by reducing the length of the blades and by stricter control of the position of the serrations, which are broached in the turbine disc, relative to the centre of the disc; this second feature making it impossible to embody this modification retrospectively. When dealing with pre-mod. 871 assemblies, this trimming to length should be combined with the adjustment of the effective moment weight as described in the next paragraph; where mod. 871 has been embodied, adjustment

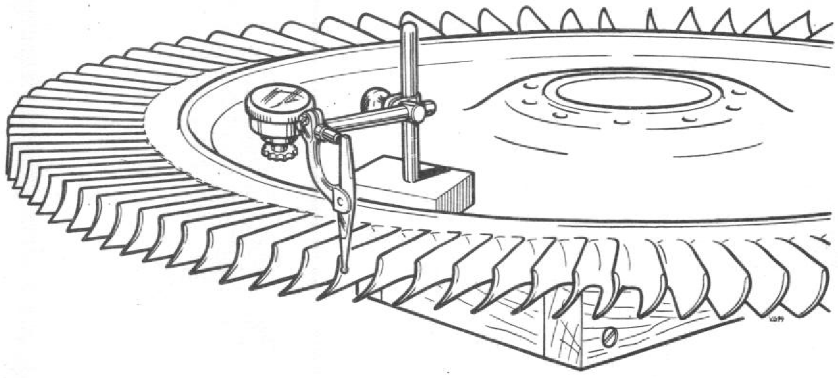


Fig. 67. Using dial test indicator to check tip rock.

may be made by reducing the length of the blade up to the maximum amount specified in the next paragraph, operation 4.

Select and adjust the replacement blades as follows :-

(1) Position the locally-made balance beam on a perfectly level surface, and check, by reference to the pointer on its beam and the datum mark on its base, that the beam balances truly about its knife-edge pivot. If a perfectly level surface is not available, the base of the balance beam must be packed up until the upright is truly vertical; unless levelling screws have been provided. If necessary, metal must be removed from one end of the beam, or plasticine added to the other, until the beam balances truly. The working of this apparatus is greatly affected by air currents and, therefore, it should be used in a sheltered place free from draughts. The adjustable weights on the beam provide a measure of control over the sensitivity of the apparatus. The closer these weights are to the beam, the nearer the centre of gravity of the complete mass is to the point of balance and the greater the sensitivity; conversely, the further the weights are below the beam, the greater the stability, but with a corresponding reduction in the sensitivity. Both weights should be approximately the same distance below the beam.

(2) Place the damaged blade is the claw fitting at one end of the beam, and the proposed replacement blade in the other. The beam will then show which blade has the greater effective moment weight; it will appear to be the heavier of the two blades. To obtain an accurate comparison of the moment weights, each blade must be at exactly the same distance from the point of balance and similarly disposed with regard to it. To ensure this, always engage the upper claw of the end fitting on the beam in the first serration from the inner end of the blade root. To ensure consistency of results, it is suggested that all blades should be fitted into the balance beam with the convex face uppermost.

(3) Select a replacement blade which complies with the following requirements :-

(a) Is an easy push fit in the slot in the turbine disc and has a total tip rock (circumferential movement of the blade tip relative to the disc), before peening, which is within the limits specified in the Table of Fits and Clearances contained in chapter 38. Use a dial test indicator to check this as illustrated in Fig. 67. To overcome excessive tip rock, either select a "larger" standard blade by taking advantage of the manufacturing tolerances, or select a suitable oversize blade.

(b) Conforms to the peripheral profile of the bladed disc; use the suggested profile gauge, Fig. 64, to check this. Normally, metal must be trimmed off the blade tip to achieve this condition, and this trimming is combined with the achievement of the next requirement.

(c) Has the same effect moment weight as the blade which it is replacing. Normally, the operator should select a replacement blade which is "too heavy" and too long, and adjust its effective moment weight and its length simultaneously by filing metal off the tip of the blade; see also the next paragraph.

(4) Using a superfine file, with the aid of the profile gauge as a guide, trim the blade to length and simultaneously adjust its effective moment weight until it matches that of the blade which is being replaced, by filing metal off the tip of the blade until it is the required length and exactly balances the blade which it is to replace, when compared with the latter in

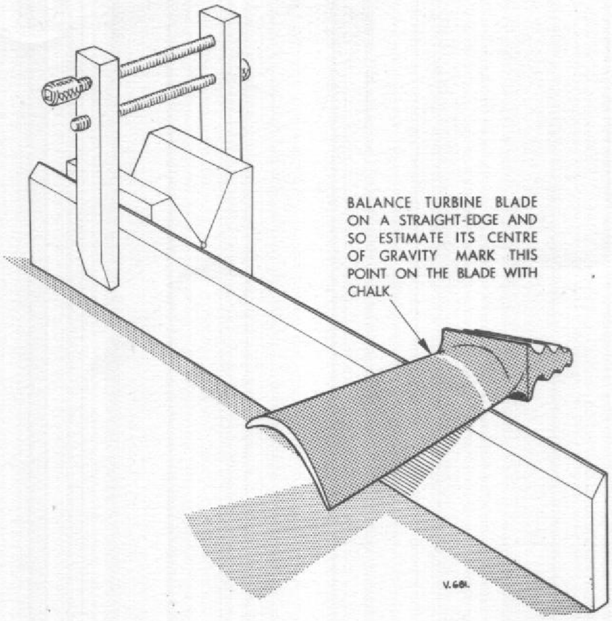


Fig. 68. Estimating centre of gravity of damaged blade.

the balance beam. Using the superfine file and fine emery cloth, radius all corners 0·015/0·020 inch; stone and polish out all sharp edges and scratches. Attainment of the correct effective moment weight is more important than the exact length of the blade and, therefore, it is permissible to trim the blade up to 0·050 inch below the peripheral profile of the original untouched blades in the disc. Sometimes, it may be possible to select a replacement blade which is of the required effective moment weight and which requires no trimming to length; in such instances this operation may be ignored.

(5) Mark each selected blade so that it will be fitted into the correct slot in the turbine disc.

If a laboratory balance is available, a close approximation of the amount of metal which must be removed from the blade tip to attain the desired moment weight may be made as follows :-

(1) Balance the damaged turbine blade, convex face uppermost, across a straight-edge, and so estimate the centre of gravity of the blade; mark this point on the blade with chalk, Fig. 68.

(2) Using a vernier gauge, measure the overall length of both the damaged blade and of its proposed replacement, and make a note of these two dimensions.

(3) Place the damaged blade in the claws at one end of the balance beam (Fig. 61) and the proposed replacement blade at the other.

(4) At the centre of gravity marked in operation 1, add plasticine to the damaged blade until it balances the proposed replacement.

(5) Remove the plasticine from the damaged blade and weigh it on the laboratory balance.

(6) By reference to the graph (Fig. 69) ascertain the approximate amount in inches by which the overall length of the replacement blade must be reduced to make its effective moment weight equal to that of the damaged blade, e.g. - if the plasticine weighs 1.5 grammes the overall length of the replacement blade must be reduced by about 0·075 inch.

(7) Subtract the amount in inches as ascertained from Fig. 69 from the overall length of the replacement blade, and compare the resultant length with that of the damaged blade; this must neither exceed the length of the damaged blade nor be more than 0·050 inch less than the length of that blade if the conditions specified in the preceding paragraph, operation 4, are to be met. If the blade will not trim to the desired length, select other new blades and repeat operations 2 to 7 until a suitable one is found.

(8) When the conditions are satisfied, using a superfine file, with the aid of the profile gauge as a guide, trim the blade to length as described in operation 4 of the preceding paragraph.

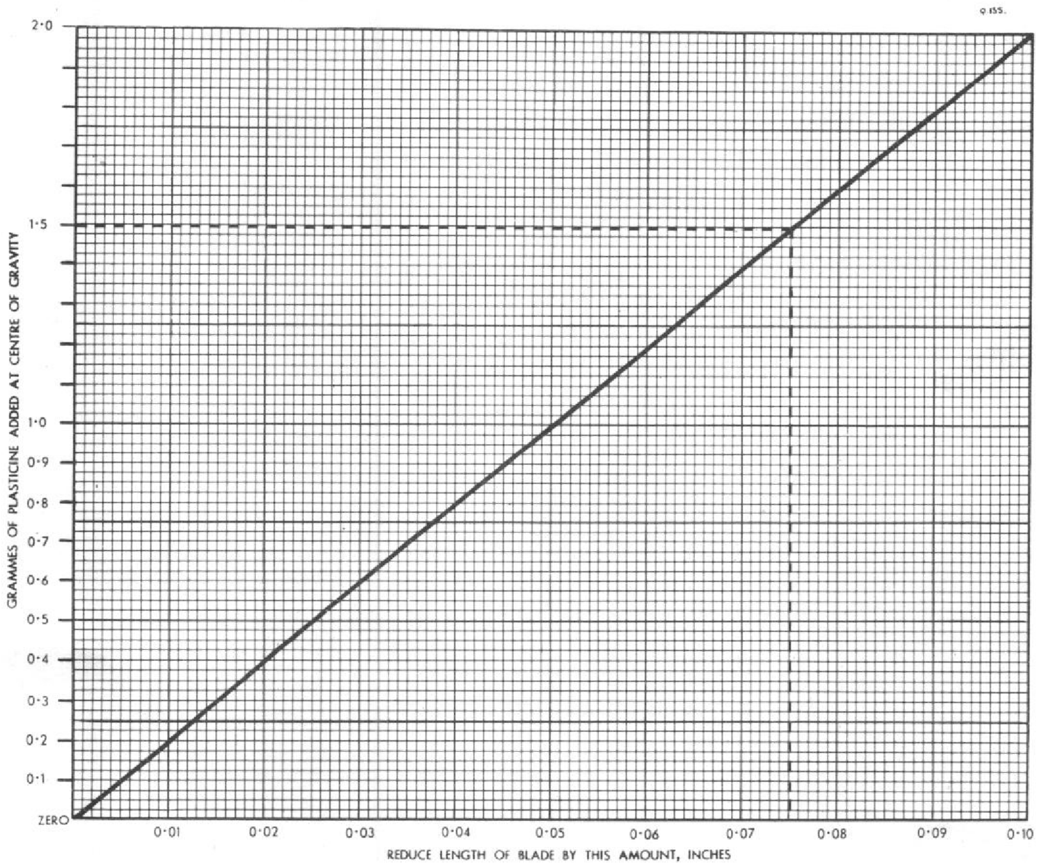


Fig. 69. Use this graph to determine the amount by which the length of the proposed replacement blade must be reduced to make its effective moment weight equal to that of the damaged blade which it is to replace.

FITTING AND PEENING REPLACEMENT TURBINE BLADES

Having selected and adjusted each replacement blade, fit and peen them as follows :-

(1) Smear the root of each replacement blade with Esso high temperature grease No. 2., and fit the blades into the appropriate slots in the turbine disc. This grease is employed to prevent fretting during the peening operation. Ensure that the blades are fitted the correct way round.

(2) Place the thick metal plate on the bench immediately under the blade which is to be peened, and support the blade root on the locally-made peening anvil; the metal plate is to prevent the foot of the anvil being driven into the wooden bench top during peening. Ensure that the blade root is solidly supported by the anvil, and that it projects equally, within ± 0·005 inch, from either side of the disc, with a minimum projection of 0·017 inch; use a dial test indicator to check this. If necessary, adjust the height of the anvil to attain these conditions.

(3) Tightly wedge the hard-rubber blocks, Fig. 63, between the blades to be peened and those adjacent to them; this is to reduce vibration and fretting during peening.

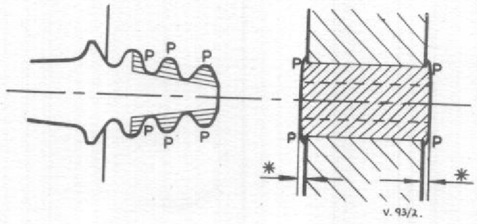
(4) Holding the locally-made peening punch at an angle of about 10 degrees to the vertical, Fig. 62, use the 2 lb. hammer to peen the inner 2 to $2\frac{1}{2}$ fir-tree serrations, Fig. 70. To minimize the work-hardening of the blade root material, use the fewest number of hammer blows which will produce the desired peening. During this operation, great care must be taken to ensure that the face of the turbine disc is neither marked nor damaged in any way, and, for this reason, the working end of the punch should be ground as shown in Fig. 62. The required

standard of peening can be assessed by reference to the peening on the original untouched blade roots.

(5) When each replacement blade has been peened satisfactorily on one side of the turbine disc, turn the disc over as described already.

(6) Use the dial test indicator to ensure that there is at least the specified minimum blade root protrusion. If the protrusion is less than the minimum, lightly tap the blade root from below to take up axial movement, until the desired protrusion is obtained. Peen the blade roots on the second side of the disc by repeating operations 2, 3, and 4.

(7) Carefully inspect the peening of each replacement blade root; looking particularly for any signs of cracks. Ensure that the correct replacement blade has been fitted in each slot; on this depends the degree to which the balance of the main shaft remains unchanged. If a blade root has been peened unsatisfactorily, repeening cannot be permitted due to the risk that work-hardening of the blade material may cause cracks to develop; unsatisfactory blades must be removed and new blades fitted.



P—PEEN HERE

* 0·017 in. PROTRUSION MINIMUM

Fig. 70. Blade root peening.

(8) Use the locally-made profile gauge to check that the new blades conform, within minus 0·050 inch, to the peripheral profile of the adjacent original blades.

(9) Check all new blades generally and ensure that each blade change has been recorded in the engine log book.

(10) Attach combined lifting and extractor fixture T 74810 to the turbine disc, and refit the disc to the engine, as described on page 14. Do not attempt to use this lifting fixture if the turbine disc is front face uppermost, as with the disc in this attitude the load can pull the eccentric nuts out of the disc; and if this happened during the moment of lift, major damage to the disc would result.

SPECIAL ENGINE RUNNING CHECKS

After this repair has been carried out and the engine has been re-installed in the aircraft, it must be checked and subjected to the complete normal ground running check as described in chapters 8 and 9. During this ground running check, particular attention must be paid to any abnormal vibration of the engine; excessive vibration might be the result of refitting the turbine disc 180 degrees out of position relative to the main shaft and this should be checked before proceeding; refer also to chapter 11 (eleven). It is impossible to lay down standards for vibration, and the final decision to accept or reject the engine must rest with the test pilot. Provided that the test pilot considers the engine acceptable when running on the

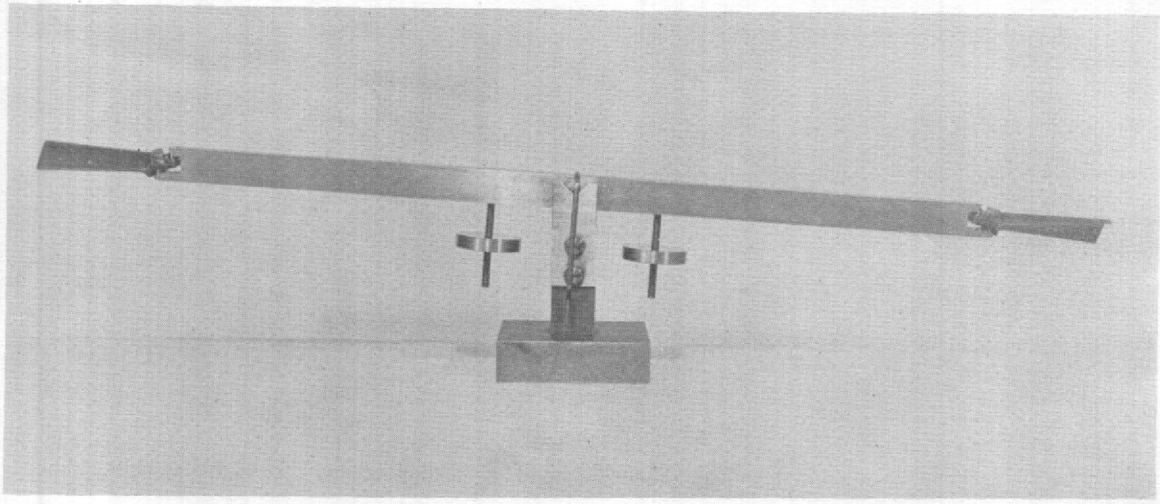


Fig. 71. Example of balance beam made by trade apprentices in the de Havilland Technical School.

ground, the final acceptance must depend upon its behaviour in flight. The first flight, after this repair has been carried out, should be made by a test pilot who is well acquainted with these engines and with the degree of vibration normally experienced. During this test flight he should pay particular attention to engine vibration under all conditions of flight, and decide whether the engine can be accepted for further service or not. Where an Avery type 7208, 20-2000 lb. electro-dynamic balancing machine and the necessary equipment is available, the engine can be checked for balance, without dismantling it, and if necessary the balance can be corrected, in the manner described in chapter 36C.; engines which are rejected as a result of the test flight should be sent for checking to a depot which has this equipment.

REPAIR OF TURBINE BLADES "IN THE FIELD"

These instructions for the repair of turbine blades "in the field" are issued in accordance with a scheme prepared by the Engineer-in-Charge, Development Department, dated 22.1.58.

Turbine blades which have sustained minor damage may be repairable within the limits described on page 6, and such repairs do not necessitate the correction of any resulting unbalance. Damage which is beyond those limits, and the extent to which repair is permissible in service, is described in the following paragraphs. These repairs, however, involve the correction of resulting unbalance in the turbine disc assembly, and this operation is also described. Damage which is in excess of the repairable limits will necessitate blade renewal, as described on page 29, or the return of the engine to a repair depot. Ghost 53 Mk. 1 turbine discs are interchangeable without checking the balance of the engine and, therefore, on these engines it is permissible to change the turbine disc assembly.

It is important to note that damage which is due to excessive operational temperatures cannot be rectified by the application of these instructions. Furthermore, it is not permissible to use these repair methods at overhaul, as the existing repair scheme (T.R.151) must then be applied, and any blades which may have been rectified in service beyond the T.R. limits must be renewed.

When carrying out any of the major repairs described below, it is preferable to remove the turbine disc assembly from the engine.

Final acceptance of the balance of an engine, to which any of these repairs has been applied, will depend on engine run, and in some cases on flight, to ascertain that the engine is sufficiently smooth, and that the maximum jet pipe temperature is within the limits.

ACCEPTANCE OF DAMAGE WITHOUT BLENDING

A turbine blade in which damage is of a smooth nature, i.e., bruises, and bent corners which are free from sharp indentations, or nicks, is acceptable without repair, provided that such damage is within the limits described in the following paragraphs.

BENT TIP CORNERS

A blade is acceptable if the corner of its tip is bent, provided that the angle of bend does not exceed 90 deg., and that any nicks are smoothed out. It is not permissible to straighten a bent corner.

Where the corner is nicked severely, or is bent to an angle greater than 90 deg., the damaged portion of the blade may be filed off and blended up to the limitations shown in Fig. 72, so that the original blade section is restored. The removal of the maximum permissible amount from a number of blades, however, may result in an increase in fuel consumption, accompanied by a rise in jet pipe temperature, and, therefore, not more than one third of the total number of blades may be blended to the maximum permissible extent.

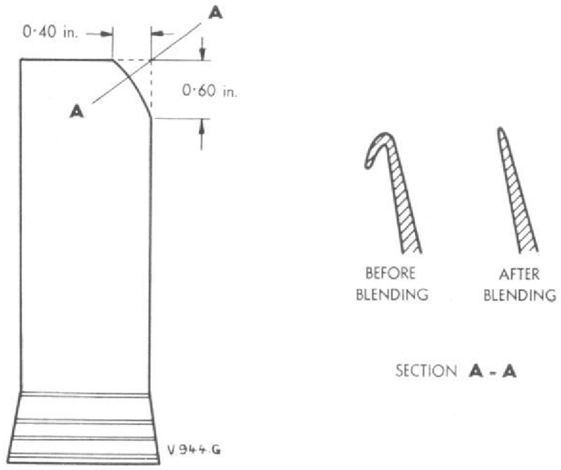


Fig. 72. Limits of blending on blade tip corner.

SMOOTH BRUISES IN BLADE EDGES

Smooth bruises in the edge of a blade, Fig. 73, are acceptable only in the middle, and outer third, provided that any such bruise does not exceed a depth of 0·060 inch in the middle third, or 0·100 inch in the outer third. Where major bruises exist,

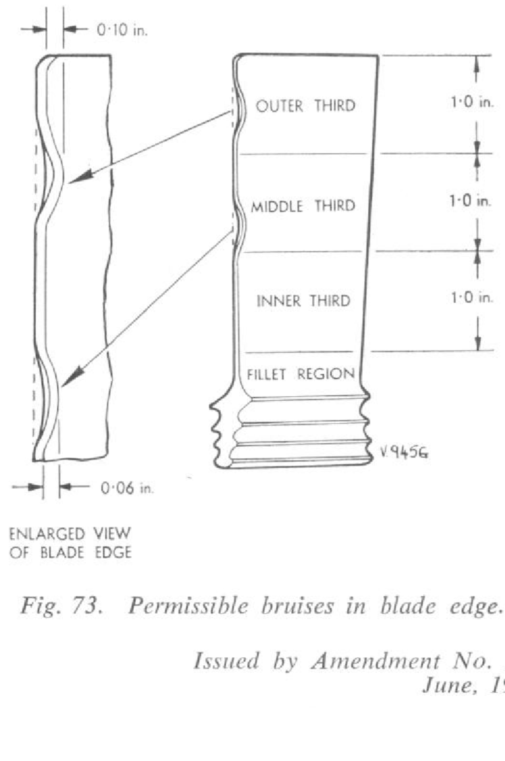


Fig. 73. Permissible bruises in blade edge.

they may be blended into a smoother form, as described in the following paragraph, but the depth of any bruise which remains after such blending must not exceed the limits stated above.

INDENTATIONS IN BLADE EDGES

A blade which has sustained impact damage to its edges, Fig. 74, may be filed and blended, but the depth of blending must not exceed the limitations shown in the following table.

Position on blade edge	*Maximum depth of blending in inches (**X** in Fig. 74)*
Tip	0·060
1 inch from tip	0·045
2 inches from tip	0·030
3 inches from tip	0·015

No damage whatever is permissible below the 3 inch position, i.e., in the fillet region of the blade. All blending must be carried out evenly and progressively between the specified positions, and, if necessary, the blade may be blended along its edge for the entire 3 inches.

Normally, impact damage occurs on the leading edge of a blade, but where damage is found on the trailing edge, this may also be blended, provided that the total reduction in the blade width does not exceed the stated limitation for dimension X at any point.

Where isolated blades have sustained damage which cannot be repaired within the limits shown in Fig. 74, blending is permissible to the extent shown in Fig. 75. It must be understood, however, that such major blending, if applied to a number of

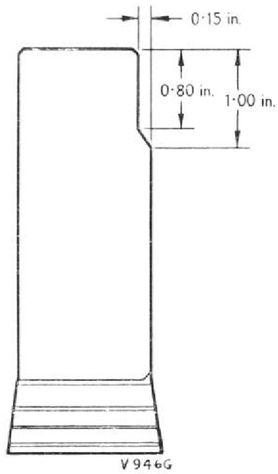


Fig. 75. Major blending limits in blade edge.

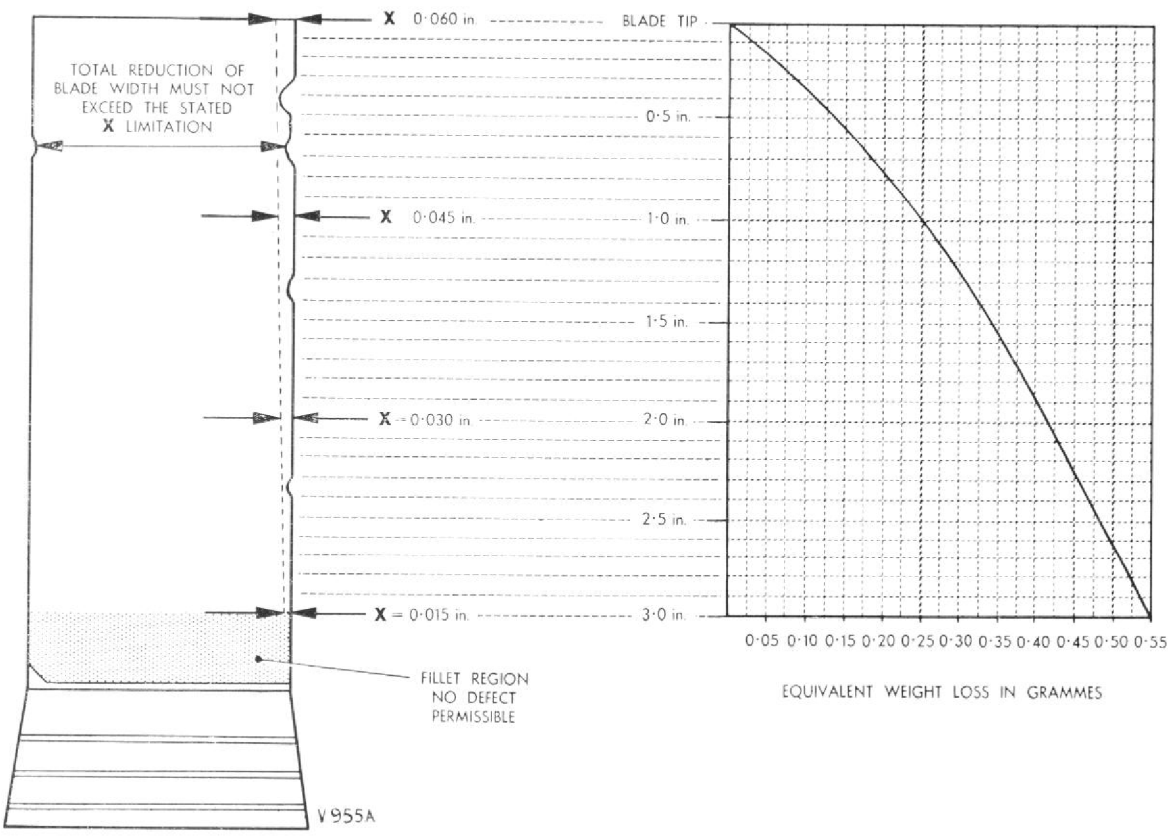


Fig. 74. Blending limits for impact damage in blade edge, and graph for calculating weight loss.

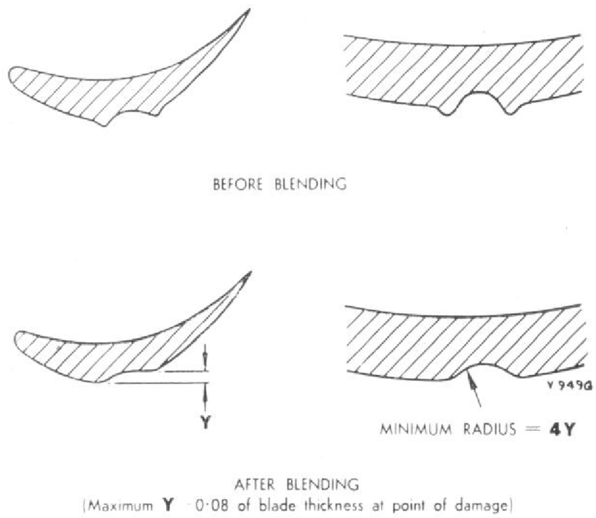


Fig. 76. Damage to convex surface of blade.

blades, may cause a considerable increase in fuel consumption, together with a rise in jet pipe temperature, and, therefore, not more than 10 blades may be rectified in this way. Furthermore, any blades which have been blended in this manner must be included as part of the permissible total number of blades in which bent tip corners have been filed off.

INDENTATIONS AND BRUISES IN THE CONVEX SURFACE

Indentations and bruises in the convex surface of a turbine blade are acceptable without repair, provided that they are smooth in nature, and that their maximum depth does not exceed 0·080T, where T equals the thickness of the blade section at the point of damage. Where this type of damage is accompanied by sharp nicks, etc., it will be found, generally, that a build-up of metal occurs around the edges of the indentation, or bruise.

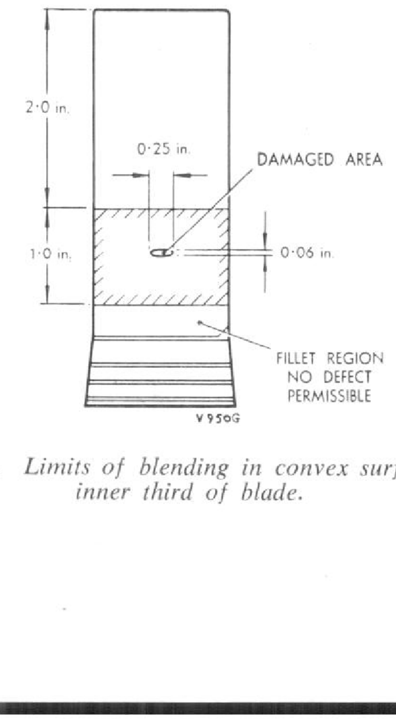


Fig. 77. Limits of blending in convex surface of inner third of blade.

This metal must be filed off, and blended, and the sharp nicks must be blended, within the limits shown in Fig. 76. Normally, damage of this nature is difficult to repair in the inner third of a blade which is in position on the turbine disc, but where such repair is possible, the blended area must not exceed the limits shown in Fig. 77.

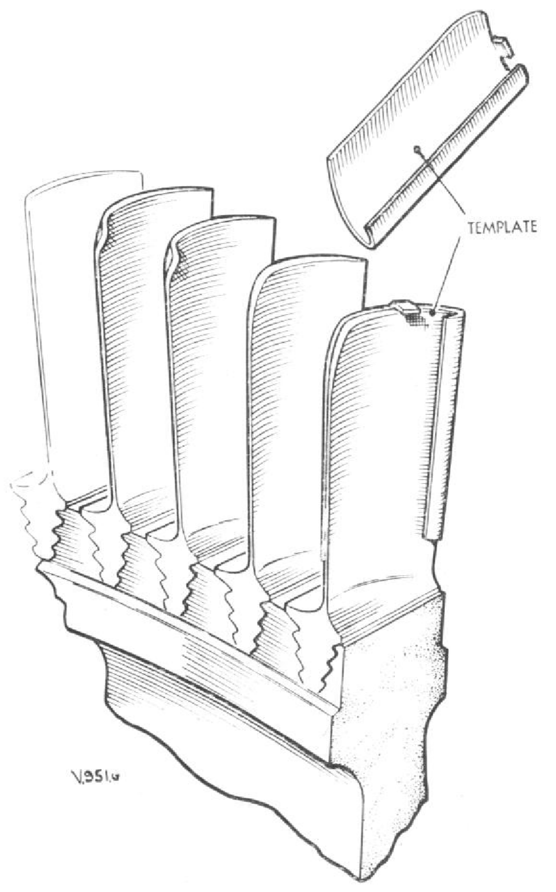


Fig. 78. Template for checking blade.

FINISH

In all blending operations, the original curvature of the blade edges must be restored. All repairs must be carefully finished and polished using Cloth 00, and all file marks must be removed.

TEMPLATE FOR BLEND LIMITATIONS

To facilitate the identification of repairable damage, a simple template, Fig. 78, may be made up from local sheet metal resources. Such a template may be used to check that damage to a blade is within the repairable limits, and also to check that the finished repair is within the acceptable limits. The use of three templates is recommended, one each to meet the requirements of the limits of repair shown in Fig. 72, 74, and 75.

EFFECT OF REPAIR ON BALANCE OF MAIN SHAFT ASSEMBLY

The rectification of turbine blade damage may cause unbalance in the main shaft assembly, and, after all the necessary repairs have been carried out, additional blades may have to be blended to reduce the unbalance to a minimum.

The amount of metal removed from a turbine blade produces a corresponding unbalancing effect at the balancing ring. This unbalance is referred to as weight loss, and its varying values have been calculated. The following paragraphs describe the method of ascertaining the weight loss, according to the nature of the repair which has been carried out.

UNBALANCE DUE TO MINOR BLENDING

Where blades have been repaired within the limits indicated in Fig. 74, reference must be made to the graph in that figure, which shows the relevant weight loss according to the length of blend. To use this graph, work from the blade tip, and note the point at which the blend commences. Follow the horizontal line across from this point to the position where it meets the curve, and read downwards to the equivalent weight loss. Repeat this procedure from the end of the blend. The difference between the two readings obtained indicates the overall weight loss for the entire blend. Application of the graph is shown in the following detailed examples:—

1. A blend which commences at the blade tip, and is taken to the full permissible depth for a distance of 1 inch along the leading edge, will produce an unbalance of 0·25 gramme.

2. A blend commencing 1 inch from the blade tip, and taken to the full permissible depth for a distance of 1 inch down the leading edge, will produce an unbalance of 0·175 gramme. This figure is obtained by subtracting the weight loss reading at the 1 inch position (start of blend) from the reading at the 2·0 inch position (end of blend), i.e., 0·425 minus 0·25 gramme.

3. A blend along the entire 3 inches of the leading edge, taken to the full permissible depth, will produce an unbalance of 0·55 gramme.

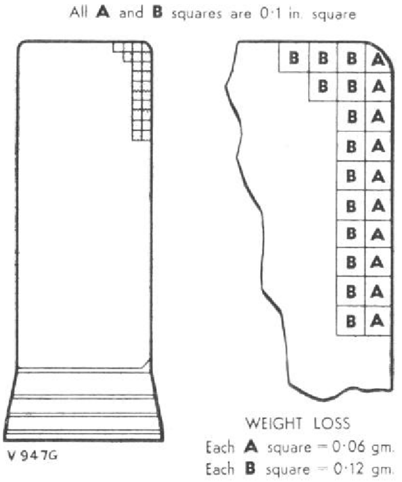


Fig. 79. Diagram for calculating weight loss due to major blending.

UNBALANCE DUE TO MAJOR BLENDING

Unbalance due to blending within the limits shown in Fig. 72, or 75, may be calculated by reference to Fig. 79. Each of the squares marked A, and B, in Fig. 79, represents a square of 0·1 inch, and has an equivalent weight loss as indicated. By measuring the extent of the blend, and identifying these measurements with the appropriate A, and B squares, the weight loss due to blending can be calculated. The following examples show how this method of assessing unbalance may be applied.

1. A blade corner which has been blended, within the limits shown in Fig. 72, for a distance of 0·3 inch along the tip edge, and of 0·4 inch along the leading edge, will include 3·5 squares marked A, and approximately 2 squares marked B; each A square representing a weight loss of 0·06 gramme, and each B square a weight loss of 0·12 gramme. Therefore, in this instance, the total unbalance will be 0·45 gramme (i.e. $3{\cdot}5 \times 0{\cdot}06 + 2 \times 0{\cdot}12$).

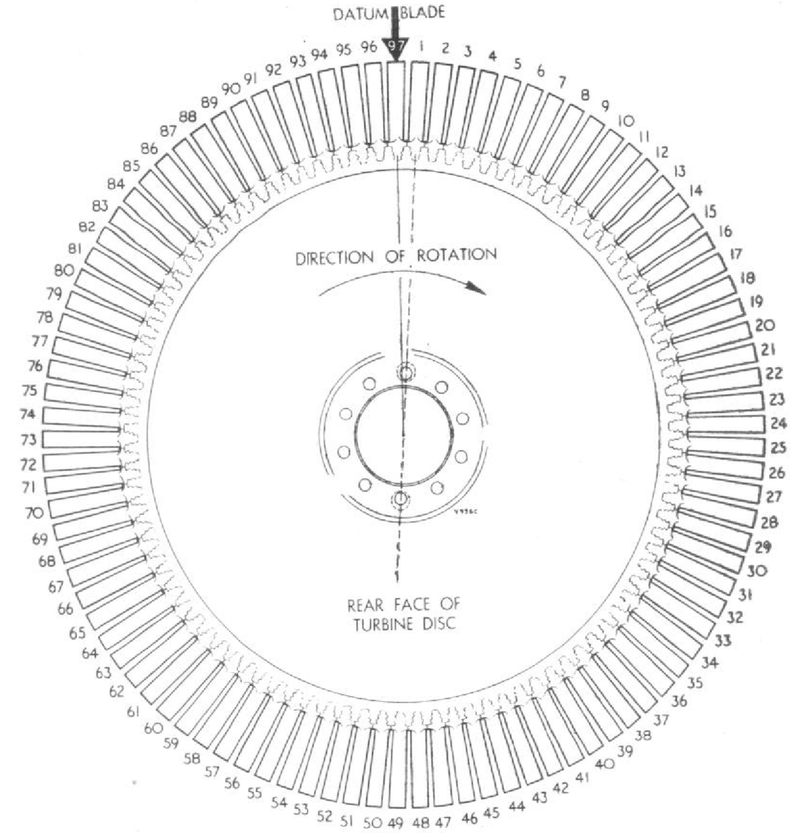
2. The leading edge of a blade which has been blended within the limits shown in Fig. 75, for a distance of 0·6 inch, and to a depth of 0·15 inch, will include 5·5 squares marked A, and approximately 5 half-squares marked B. The total unbalance, therefore, will be 0·63 gramme (i.e., $5{\cdot}5 \times 0{\cdot}06 + 2{\cdot}5 \times 0{\cdot}12$).

A blade which has been blended to the full limit shown in Fig. 72, will produce an unbalance of 0·85 gramme. Similarly, a blade which has been blended to the full limit shown in Fig. 75, will produce an unbalance of 1·00 gramme.

CORRECTION OF UNBALANCED CONDITIONS

It will be understood that no appreciable unbalance will result where two blades, which are situated approximately diametrically opposite, have been blended by an equal amount. Similarly, a blade to which major blending has been applied, may be balanced by two or three diametrically opposite blades in each of which only minor blending has been necessary. Therefore, when all the weight losses have been calculated, those blades which may be said to balance each other out, should be marked with chalk. The remaining blended blades (unmarked) will have a cumulative effect on the balance of the turbine disc as a whole, and to assess this effect it will be necessary to construct a related, simple diagram of force.

When constructing such a diagram, the angular position of the blades concerned may be obtained by reference to Fig. 80, and, although in this figure



Blade No.	Degrees	Minutes	Blade No.	Degrees	Minutes
DATUM	ZERO		—	—	—
1	3	42	49	181	18
2	7	24	50	185	00
3	11	06	51	188	42
4	14	48	52	192	24
5	18	30	53	196	06
6	22	12	54	199	48
7	25	54	55	203	30
8	29	36	56	207	12
9	33	18	57	210	54
10	37	00	58	214	36
11	40	42	59	218	18
12	44	24	60	222	00
13	48	06	61	225	42
14	51	48	62	229	24
15	55	30	63	233	06
16	59	12	64	236	48
17	62	54	65	240	30
18	66	36	66	244	12
19	70	18	67	247	54
20	74	00	68	251	36
21	77	42	69	255	18
22	81	24	70	259	00
23	85	06	71	262	42
24	88	48	72	266	24
25	92	30	73	270	06
26	96	12	74	273	48
27	99	54	75	277	30
28	103	36	76	281	12
29	107	18	77	284	54
30	111	00	78	288	36
31	114	42	79	292	18
32	118	24	80	296	00
33	122	06	81	299	42
34	125	48	82	303	24
35	129	30	83	307	06
36	133	12	84	310	48
37	136	54	85	314	30
38	140	36	86	318	12
39	144	18	87	321	54
40	148	00	88	325	36
41	151	42	89	329	18
42	155	24	90	333	00
43	159	06	91	336	42
44	162	48	92	340	24
45	166	30	93	344	06
46	170	12	94	347	48
47	173	54	95	352	30
48	177	36	96	356	12

Fig. 80. Diagram showing numbering and angular position of turbine blades.

blade No. 97 is shown as the datum, any one of the blended blades may be identified as the datum blade.

A diagram must be drawn showing the positions of the unmarked blades on the disc, and from this figure a force diagram is built up. The upper drawing in Fig. 81 shows a typical diagram of a turbine disc in which blended blades A, B, C, and D are to be considered.

To assess the cumulative effect of unbalanced blades, such as the four blades shown in Fig. 81, proceed as follows:—

1. Selecting any one of the blades as a datum (blade A in the upper diagram in Fig. 81), construct a diagram with this blade at T.D.C., and mark in the weight loss caused by blending. Draw a vertical line from the blade to the centre of the disc, point X.
2. Mark on the diagram the positions of the remaining blended blades (B, C, and D), and their respective weight losses.
3. Refer to the lower diagram in Fig. 81 and, using a convenient scale, draw a line oa, parallel to the line AX, whose length is equal in magnitude to the weight loss caused by the blending of blade A.
4. Proceed clockwise around the disc to blade B, and draw a line ab, which is equal in magnitude and direction to the weight loss caused by the blending of blade B.
5. Proceed to blade C, and draw a line bc, equal in magnitude and direction to the weight loss of blade C.
6. Continue to blade D, and draw a line cd, equal in magnitude and direction to the weight loss of blade D.
7. Join the points o and d.
8. On the upper diagram, mark a line PE, which passes through the centre of the disc, and which forms an angle with the datum line AX equal to the angle aod.
9. The length of the line od represents the total magnitude of the unbalance in the turbine disc caused by the blending of blades A, B, C, and D. Therefore, the disc is light at point E by this amount. Point P, being diametrically opposite to point E, indicates the position on the disc where balancing corrections must be made to the blades.
10. Where the total amount of unbalance is less than 1·5 grammes, no further work is necessary. If, however, the unbalance is greater than this figure, one or two blades at point P must be blended by an amount which is sufficient to reduce the unbalance to below 1·5 grammes.

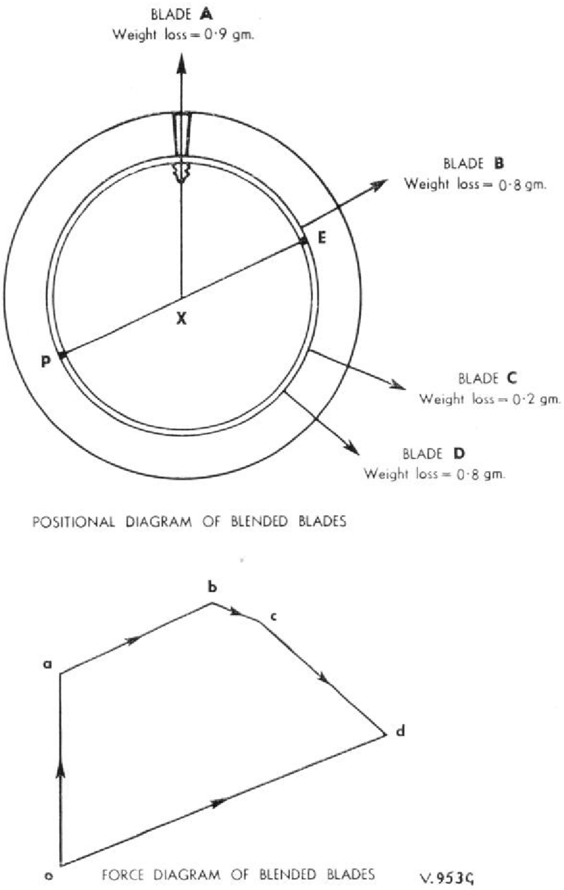


Fig. 81. Diagram for calculating unbalance in turbine disc assembly.