

Module Five

Maintenance and Repair versus misalignment of Rotating Equipment

Ball Bearing Maintenance and Replacement

The fundamental purpose of a bearing is to reduce friction and wear between rotating parts that are in contact with one another in any mechanism. The length of time a machine will retain its original operating efficiency and accuracy will depend upon the proper selection of bearings, the care used while installing them, proper lubrication, and proper maintenance provided during actual operation.

The manufacturer of the machine is responsible for selecting the correct type and size of bearings and properly applying the bearings in the equipment. However, maintenance of the machine is the responsibility of the user. A well-planned and systematic maintenance procedure will assure extended operation of the machine. Failure to take the necessary precautions will generally lead to machine downtime. It must also be remembered that factors outside of the machine shaft may cause problems.

Engineering and Interchangeability Data

Rings and Balls—The standard material used in ball bearing rings and balls is a vacuum processed high chromium steel identified as SAE 52100 or AISI-52100. Material quality for balls and bearing rings is maintained by multiple inspections at the steel mill and upon receipt at the bearing manufacturing plants. The 52100 bearing steel with standard heat treatment can be operated satisfactorily at temperatures as high as 250°F

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(121°C). For higher operating temperatures, a special heat treatment is required in order to give dimensional stability to the bearing parts.

Seals—Standard materials used in bearing seals are generally nitrile rubber. The material is bonded to a pressed steel core or shield. Nitrile rubber is unaffected by any type of lubricant commonly used in anti-friction bearings. These closures have a useful temperature range of -70° to $+225^{\circ}\text{F}$ (-56° to 107°C). For higher operating temperatures, special seals of high temperature materials can be supplied.

Ball Cages—Ball cages are pressed from low carbon steel of SAE 1010 steel. This same material is used for bearing shields. Molded nylon cages are now available for many bearing sizes. The machined cages ordinarily supplied in super-precision ball bearings are made from laminated cotton fabric impregnated with a phenolic resin. This type of cage material has an upper temperature limit of 225°F (107°C) with grease and 250°F (121°C) with oil for extended service. For periods of short exposure, higher temperatures can be tolerated.

Lubricant—Prelubricated bearings are packed with an initial quantity of high quality grease which is capable of lubricating the bearing for years under certain operating conditions. As a general rule, standard greases will yield satisfactory performance at temperatures up to 175°F (79°C), as long as proper lubrication intervals and lube quantities are observed. Special greases are available for service at much higher temperatures. Estimation of grease life at elevated temperatures involves a complex relationship of grease type, bearing size, speed, and load. Volume 4 of this series can provide some guidance, although special problems are best referred to the product engineering department of major bearing manufacturers.

Standardization

Bearing envelope dimensions and tolerances shown in this chapter are based on data obtained from MRC/TRW Bearing Division. They comply with standards established in the United States by the Annular Bearing Engineers' Committee (ABEC) of the Anti-Friction Bearing Manufacturers Association (AFBMA). These standards have also been approved by the American Standards Association (ASA) and the International Standards Organization (ISO). This assures the bearing user of all the advantages of dimensional standardization. However, dimensional interchangeability is not necessarily an indication of functional interchangeability. Cage type, lubricant grade, internal fitting practice, and many other details are necessary to establish complete functional interchangeability.

Ball Bearing Variations

Special purpose bearings are generally one of the types shown in Table 7-1 but with special features as noted. For ease of reference we are including Table 7-2, "Commonly Used MRC Bearing Symbols," and Table 7-3, "Ball Bearing Interchange Table."

(Text continued on page 376)

Table 7-1
Special Purpose Bearings

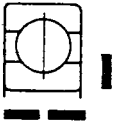
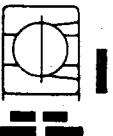
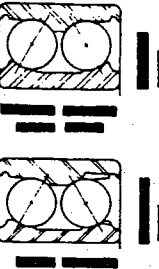
Bearing Type	Description	Load Capability	Relative Capacity
Type S Conrad Deep Groove	Ordinarily supplied with loose internal clearance. Other degrees of internal clearance may be necessary for special conditions. Outer and inner races have full depth on each side. Ball assembly is made by eccentric displacement of rings.	Has equal load-carrying capacities in either direction. Recommended for moderately heavy radial loads, thrust loads in either direction, or combination loads.	
Type M Maximum-Capacity Filling Notch	Ordinarily supplied with standard internal clearance. Other degrees of internal clearance may be necessary for special conditions. This type has a filling notch on one side of the outer and inner rings to insert full quota of balls.	Can carry heavier radial loads than Type S and heavier combined radial and thrust loads. Recommended for a majority of heavily loaded bearing positions — heavy industrial machinery, farm equipment, tractors and trucks.	
Type R Angular-Contact Counterbored Outer Ring	Supplied with loose internal clearance for normal applications. Other degrees of internal clearance may be necessary for special conditions. Counterbored outer ring. To assemble full quota of balls, rings are expanded by heating. Non-separable type.	Higher radial load-carrying capacity than Type S. Heavy thrust load in one direction only, or combined loads where radial load predominates and thrust is always against heavy shoulder of outer ring.	
7000 Series Angular-Contact Counterbored Outer Ring	Counterbored outer ring, non-separable type with initial contact angle of 29°. Two-piece steel cage for normal use or one-piece non-metallic or solid bronze cage for high speed, high operating temperature or severe vibration applications.	Very high thrust load in one direction, combined radial and thrust load where thrust load predominates.	
7000-P Series Angular-Contact Heavy Duty Type	Similar in design to 7000 Series Bearings but 40° contact angle. Ball complement and race groove depth designed for increased thrust capacity which varies with individual sizes depending on change in ball complement.	Capacity is 1.18 to 1.40 times that of 7000 Series, varies with individual sizes. Restricted to primarily thrust loads. Should not be used for radial loads only or combined radial and thrust loads where radial load is predominant.	
9000 Series Angular-Contact Split Inner Ring	Designed with solid one-piece outer ring and two-piece inner ring, maximum ball complement and one-piece machined cage.	Construction allows bearing to carry greater thrust in either direction than Type S. May be used where there is substantial radial load providing there is always sufficient thrust load present.	
5000 Series Double-Row C Type Conrad M Type Maximum-Capacity	C Type assembled by elastic displacement of rings. Does not have ball filling notches. M Type has filling notches on one side only for inserting full quota of balls. Supplied with standard clearance but tighter or looser internal clearance can be supplied to suit special service conditions.	C Type will support very heavy radial loads, and equal heavy thrust loads in either direction, or heavy combined radial and thrust loads. M Type has very heavy radial capacity. Also has heavy thrust capacity in one direction and can take light thrust load in reversing direction.	
 Sizes 5200-5203, 5300-5303 (SB suffix) made in conrad type with inverted contact angle. 5400 Series, a non-rigid type, has filling notches on both sides. Contact angles converge inwardly. 5219 thru 5222 and 5330 thru 5322 have similar construction.			

Table 7-2
Commonly Used MRC Bearing Symbols

Prefix	Suffix	Description	Prefix	Suffix	Description
CONV.	-B	Outwardly convergent contact angle when used with 5000 series (see SB, SBK)	R-		Cylindrical roller bearing
		Conveyor roll bearing	R-		Extra small, inch size bearing (was S-S)
	-D	Bearing with controlled relationship of ring faces, used in duplex sets	-R		Single-row, maximum-capacity, counterbore outer, angular-contact type bearing
	-DB	Duplex bearing, back-to-back mounting	-RJ		Angular-contact type bearing, inner and outer rings counterbored, non-separable
	-DD	Two glass fabric reinforced PTFE (polytetrafluoroethylene) seals.	-S		Single-row, deep-groove, conrad type bearing (1900, 200, 300)
	-DF	Duplex bearing, face-to-face mounting	-SB		Double-row, conrad type with outwardly convergent contact angles
	-DS	Duplex bearing, universal, preload requirement	-SBK		Double-row, conrad type bearing with outwardly convergent contact angles, standard width
	-DT	Duplex bearing, tandem mounting	-SFFC		Cartridge width bearing, conrad type with two shields
	-DU	Duplex bearing, universal, free running, no end play	-SFFCG		Cartridge width bearing, conrad type with two shields, snap ring
FB-	-F	One shield	-ST		Stainless Steel
		Flanged bearing, tapered O.D.	-SWI		Single-row, deep-groove, conrad type bearing with wide inner ring
	-FF	Two shields	-SZZC		Cartridge width bearing, conrad type with two Synthe-Seals
	-FFM	Two metal shields	-SZZCG		Cartridge width bearing, conrad type with two Synthe-Seals, snap ring
	-FFP	Two rubber-beaded shields	-U		Split inner ring bearing (9000 series)
	-FFS	Two felt seals	-UH		Split inner and split outer ring bearing (9000 series)
	-FFSG	Two felt seals and snap ring	-UK		Split inner ring bearing (9100 series)
	-FM	One metal shield	-UP		Split inner ring bearing (9000 series)
	-FP	One rubber-beaded shield	-WI		Single-row, maximum-capacity, filling notch type bearing, wide inner ring
	-FS	One felt seal	-X		Tapered bore ball bearing
F-	-FSF	One felt seal and one shield	XLS-		Single-row, maximum-capacity, counterbore outer, radial type bearing, inch dimensions
	-FSFG	One felt seal and one shield, snap ring			
G-	-WI	Shield on flush side of wide inner	XO-	-RBDS	Excello replacement bearings
	-G	Snap ring		-Y	Adapter sleeve
	-MF	Snap ring opposite side from standard shield (also G-SF)		-Z	One synthetic rubber seal
	-H	Split outer ring bearing (9000 series)		-ZZ	Two synthetic rubber seals
	-K	Standard width, double-row bearing		-ZZC	Cartridge width bearing, extra-small type, two Synthe-Seals
	-KR	Single-row, maximum-capacity, counterbore outer, radial type bearing (100-K and 7100-K series)			
	-KS	Single-row, deep-groove, conrad type bearing (100-K series)			
	-KSB	Conrad type bearing with counterbored separable inner ring			
	-M	Single-row, maximum-capacity, filling notch type bearing			
	-P	Heavy duty, angular-contact bearing			

Table 7-3
Ball Bearing Interchange Table

MRC Ball Bearing Series	B C A	Fafnir	FAG	Federal	Hoover NSK	New Departure- Hyatt	SKF
R-2	.....	33-K-3	R-2	R2	R2	R-2	EE-0
R-2-F	.....	33-KD-3	R-2-Z	R2F	7R2	7-R-2	EE-0/Z
R-2-FF	.....	33-KDD-3	R-2-ZZ	R2FF	77R2	77-R-2	EE-0/ZZ
R-2-Z	.....	.....	R-2-RS	R2R	9R2	9-R-2	EE-0/RS
R-2-ZZ	.....	.....	R-2-RSZ	R2RR	99R2	99-R-2	EE-0/RSZ
1R-2-A	.....	33-K-4	R-2-A	R2A	R2A	R-2-A	.....
1R-3	.....	33-K-5	R-3	R3	R3	R-3	EE-1
1R-4	.....	S-1-K-7	R-4	R4	R4	R-4	EEA-2
1R-4-A-4	.....	S-1-K	R-4-A	R4A	R4A	R-4-A	EE-2
1R-6	.....	S-3-K	R-6	R6	R6	R-6	EE-3
1R-8	.....	S-5-K	R-8	R8	R8	R-8	EE-4
1R-10	.....	S-7-K	R-10	R10	R10	R-10	EE-5
1R-12	.....	S-8-K	R-12	R12	R12	R-12	EE-6
1R-14	.....	S-9-K	R-14	R14	R14	R-14	EE-8
1R-16	.....	S-10-K	R-16	R16	R16	R-16	EE-9
1R-18	.....	S-11-K	R-18	R18	R18	R-18	EE-10
1R-20	.....	S-12-K	R-20	R20	R20	R-20	EE-11
1R-22	.....	.....	R-22	R22	.....	R-22	.....
1R-24	.....	.....	R-24	R24	R24	R-24	.....
XLS	XLS\$	XLS\$	XLS\$	XLS\$	.....	.....	.....
30	30	30-K	600	30	30	30	R-4
30-F	30-S	30-KD	600-Z	30-F	7030	7030	R-4-Z
30-FF	30-SS	30-KDD	600-ZZ	30-FF	77030	77030	R-4-ZZ
30-FFS	.....	30-KLL	.....	FS88030	.....	88030	.....
30-FS	.....	30-KL	.....	FS8030	.....	8030	.....
30-FSF	.....	30-KLD	.....	FS87030	.....	87030	.....
30-FZ	.....	.....	600-RSZ	.....	.....	97030	.....
30-Z	30-D	30-P	600-RS	30-R	9030	9030	R-4-RS
30-ZZ	30-DD	30-PP	600-2RS	30-RR	99030	99030	R-4-2RS
100-KR	7100-N	9100-WI	B-7000-C	.....	.....	0-L-00	7000-C
100-KRD	D7100-N	9100-WI-DU	(2) B-7000-CUO	.....	.....	0-L-00-D	(2) 7000-CG
100-KS	100	9100-K	6000	9100	3L00	3-L-00	6000
100-KSF	100-S	9100-KD	6000-Z	9100-F	73L00	73-L-00	6000-Z
100-KSFF	100-SS	9100-KDD	6000-ZZ	9100-FF	773L00	773-L-00	6000-ZZ
100-KSFFG	100-SSL	9100-KDDG	6000-ZZNR	9100-GF	773L00-G	4773-L-00	6000-ZZNR
100-KSFG	100-SL	9100-KDG	6000-ZNR	9100-GF	73L00-G	473-L-00	6000-ZNR
100-KSFZ	.....	9100-NPD	6000-RSZ	.....	973L00	973-L-00	6000-RSZ
100-KSFZG	.....	9100-NR	6000-RSZNR	9100-CG	973L00-G	4973-L-00	6000-RSZNR
100-KSG	100-L	9100-KG	6000-NR	9100-CG	3L00 G	43-L-00	6000-NR
100-KSZ	100-D	9100-P	6000-RS	9100-R	93L00	93-L-00	6000-RS
100-KSZG	100-DL	9100-PG	6000-RSNR	9100-GR	93L00-G	493-L-00	6000-RSNR
100-KSZZ	100-DD	9100-PP	6000-2RS	9100-RR	993L00	993-L-00	6000-2RS
100-KSZZG	100-DDL	9100-PPG	6000-2RSNR	9100-GRR	993L00-G	4993-L-00	6000-2RSNR
200-FFS	88500	200-KLL	.....	FS-88500	88500	88500	.....
200-FFSG	.....	200-KLLG	.....	.....	88500-G	488500	.....
200-FS	8500	200-KL	.....	FS-8500	8500	8500	.....
200-FSF	87500	200-KLD	.....	FS-87500	87500	87500	.....
200-FSFG	.....	200-KLDG	.....	.....	87500-G	487500	.....
200-M	1200	200-W	200	1200-M	M-200	1200	200
200-MF	1200-S	200-WD	200-Z	1200-MF	M-7200	7200	200-Z
200-MFF	1200-SS	200-WDD	200-ZZ	1200-MFF	M-77200	77200	200-ZZ
200-MFFG	1200-SSL	200-WDDG	200-ZZNR	1200-MGFF	M-77200-G	477200	200-ZZNR
200-MFG	1200-SL	200-WDG	200-ZNR	1200-MGF	M-7200-G	47200	200-ZNR
200-MFZ	.....	.....	.....	.....	M-97200	.....	.....
200-MG	1200-L	200-WG	200-NR	1200-MG	M-200-G	41200	200-NR
200-MZ	.....	.....	.....	.....	M-9200	9200	.....
200-R	7200-N	7200-W	B-7200-C	7200	7200-C	20200	7200-C
200-RD	D7200-N	7200-W-DU	(2) B-7200-CUO	.....	7200-C-D	20200-D	(2) 7200-CG
200-S	200	200-K	6200	1200	200	3200	6200
200-SF	200-S	200-KD	6200-Z	1200-F	7200	7500	6200-Z
200-SFF	200-SS	200-KDD	6200-ZZ	1200-FF	77200	77500	6200-ZZ
200-SFFC	W-200-CC	W-200-KLL	S-3500	W1200-FF	S-3500	.....	462200
200-SFFCG	.....	.....	S-3500-NR	W1200-GFF	S-3500-G	.....	.....
200-SFFG	200-SSL	200-KDDG	6200-ZZNR	1200-GFF	77200-G	477500	6200-ZZNR
200-SFG	200-SL	200-KDG	6200-ZNR	1200 GF	7200-G	47500	6200-ZNR
200-SFZ	.....	200-PD	6200-RSZ	1200-FR	97200	97500	6200-RSZ
200-SFZG	.....	.....	6200-RSZNR	.....	97200-G	497500	.....
200-SG	200-L	200-KG	6200-NR	1200-CG	200-G	43200	6200-NR
200-SX	.....	5500N	.....	1200-X	.....	.....	.....
200-SXY	.....	5500-N-A	.....	1200-XY	.....	.....	.....
200-SZ	200-D	200-P	6200-RS	1200-R	9200	9500	6200-RS
200-SZG	200-DL	200-PG	6200-RSNR	1200-GR	9200-G	49500	6200-RSNR
200-SZZ	200-DD	200-PP	6200-2RS	1200-RR	99200	99500	6200-2RS
200-SZZG	.....	W-200-KLL	S-3500-2RS	W1200-KK	.....	462200	6200-2RSNR
200-SZZZ	200-DDL	200-PPG	6200-2RSNR	1200-GRR	99200-G	499500	.....
300-M	1300	300-W	300	1300-M	M-300	1300	300
300-MF	1300-S	300-WD	300-Z	1300-MF	M-7300	7300	300-Z

Shielded or sealed types—to determine interchange see MRC R-2, R-2-F, R-2-FF, R-2-Z, R-2-ZZ. Add to competitive bearing number their prefix or suffix as shown opposite MRC R-2 Series. For Fafnir sealed bearing numbers, substitute P for single seal, PP for double seal in place of D or DD.

* This table indicates methods of numbering. Some sizes not in production.

§ MRC Bearing has counterbored outer ring.

Table 7-3
Ball Bearing Interchange Table—cont'd

BALL BEARING INTERCHANGE TABLE* — BASIC SERIES

MRC Ball Bearing Series	B C A	Fafnir	FAG	Federal	Hoover NSK	New Departure- Hyatt	SKF
300-MFF	1300-SS	300-WDD	300-ZZ	1300-MFF	M-77300	77300	300-ZZ
300-MFG	1300-SL	300-WDG	300-ZNR	1300-MGF	M-7300-G	47300	300-ZNR
300-MG	1300-L	300-WG	300-NR	1300-MG	M-300-G	41300	300-NR
300-MZ	1300-D	7300-W	B-7300-C	7300	M-9300	20300	.....
300-R	7300-N	7300-W-DU	(2) B-7300-CUO	.....	7300-C	20300-D	.....
300-RD	D7300-N	.....	.....	.....	7300-C-D	.....	.....
300-S	300	300-K	6300	1300	300	3300	6300
300-SF	300-S	300-KD	6300-Z	1300F	7300	7600	6300-Z
300-SFF	300-SS	300-KDD	6300-ZZ	1300FF	77300	77600	6300-ZZ
300-SFFC	W-300-CC	W-300-KLL	S-3600	W1300FF	S-3600	.....	462300
300-SFFCG	.....	.....	S-3600-NR	W1300GFF	S-3600-G	.....	.....
300-SFFG	300-SSL	300-KDDG	6300-2ZNR	1300GFF	77300-G	477600	6300-2ZNR
300-SFG	300-SL	300-KDG	6300-ZNR	1300GF	7300-G	47600	6300-ZNR
300-SFZ	.....	300-PD	6300-RSZ	1300FR	97300	97600	6300-RSZ
300-SFZG	.....	.....	6300-RSZNR	1300GFR	97300-G	497600	6300-RSZNR
300-SG	300-L	300-KG	6300-NR	1300CG	300-G	43300	6300-NR
300-SWI	.....	WIR-300-K	.....	.....	.....	4600	.....
300-SX	.....	6600N	.....	1300X	.....	.....	.....
300-SXY	.....	6600-N-A	.....	1300XY	.....	.....	.....
300-SZ	300-D	300-P	6300-RS	1300R	9300	9600	6300-RS
300-SZG	300-DL	.....	6300-RSNR	1300GR	9300-G	49600	6300-RSNR
300-SZZ	300-DD	300-PP	6300-2RS	1300RR	99300	99600	6300-2RS
300-SZZC	.....	W-300-KLL	S-3600-2RS	W1300KK	S-3600	462300	6300-2RS
300-SZZG	300-DDL	300-PPG	6300-2RSNR	1300GRR	99300-G	499600	6300-2RSNR
300-WI	.....	WIR-300-W	.....	1300MWI	.....	4300	.....
400-M	1400	400-W	.....	1400-M	M-400	1400	.....
400-MF	1400-S	.....	.....	1400-MF	M-7400	7400	.....
400-MFF	1400-SS	.....	.....	1400-MFF	M-77400	77400	.....
400-MG	1400-L	.....	.....	1400-MG	M-400-G	41400	.....
400-R	.....	.....	.....	7400	.....	20400	.....
400-S	400	400-K	6400	1400	400	3400	6400
400-SF	400-S	.....	6400-Z	1400-F	7400	7700	.....
400-SG	400-L	.....	.....	1400-CG	400-G	43400	.....
400-SZ	400-D	.....	.....	1400-L	.....	.....	.....
400-SZZ	400-DD	.....	.....	1400-LL	.....	.....	.....
1900-R	.....	.....	.....	.....	.....	.....	.....
1900-S	.....	9300-K	61900	1900	.....	3LL00	6900
5200	.....	.....	.....	5200N	.....	.....	.....
5200 F	.....	.....	.....	5200F§	.....	.....	.....
• 5200-FG	.....	.....	.....	.....	.....	.....	.....
• 5200-K	5200	5200-W†	3200†	5200	5200†	5200-W	5200†
• 5200-KF	5200-S	5200-WD†§	3200-Z†	FS5500	5200-F†	5500-W	.....
• 5200-KFF	5200-SS	.....	3200-2Z†	FS55500	5200-FF†	55500-W	.....
• 5200-KFG	5200-SL	.....	.....	FS5500CG	5200-FG†	45500-W	.....
• 5200-KG	5200-L	5200-WG†	.....	5200CG	5200-G†	45200-W	.....
• 5200-SB	.....	5200-K	3200	A5200	C-5200	5200	5200
• 5200-SBF	.....	5200-KD	3200	A5200	C-5200	5200	5200
• 5200-SBK	.....	5200-K	3200	A5200	C-5200	5200	5200
• 5200-SBKFF	.....	5200-KD§	3200-Z	FSA5500	C-5200-F	5500	.....
• 5200-SBKFFG	.....	5200-KDD§	3200-2Z	FSA55500	C-5200-FF	55500	.....
• 5200-SBKKG	.....	5200-KDG§	.....	FSA5500CG	C-5200-FG	45500	.....
• 5200-SBKZ	.....	5200-KG	.....	A5200CG	C-5200-G	45200	.....
• 5200-SBKZZ	.....	.....	.....	.....	.....	995200	.....
• 5300	5300	5300-W†	3300†	5300	5300†	5300-W	5300†
• 5300-F	5300-S	5300-WD†§	.....	5300F	.....	.....	.....
• 5300-FG	5300-SL	.....	.....	.....	.....	.....	.....
• 5300-G	5300-L	5300-WG†	.....	5300CG	5300-G†	45300-W	.....
• 5300-KF	5300-S	.....	3300-Z†	FS5600	5300-F†	5600-W	.....
• 5300-KFG	5300-SL	.....	.....	FS5600CG	5300-FG†	45600-W	.....
• 5300-SB	.....	5300-K	3300	A5300	C-5300	5300	5300
• 5300-SBF	.....	5300-KG	.....	A5300CG	C-5300-F	45300	.....
• 5300-SBG	.....	.....	3300-Z	FSA5600	C-5300-G	45300	.....
• 5300-SBKFF	.....	.....	3300-2Z	FSA55600	C-5300-FF	5600	.....
• 5300-SBKFFG	.....	.....	.....	FSA5600-CG	C-5300-FG	55600	.....
• 5300-SBKZ	.....	.....	.....	.....	.....	45600	.....
5400	5400	5400-W†	.....	.....	.....	5400	5400†
5400-F	5400-L	5400-WD†	.....	.....	.....	5700	.....
5400-G	.....	5400-WG†	.....	.....	.....	.....	.....
7100-KR	7100-A	.....	B-7000-E	.....	.....	H0-L-00	7000-C
7100-KRD	D7100-A	.....	(2) B-7000-EUO	.....	.....	H20200	(2) 7000-CG
7200	7200-A	7200-W	B-7200-E	7200	7200-A	.....	7200
7200-D	D7200-A	7200-W-DU	(2) B-7200-EUO	.....	7200-A-D	H20200-D	(2) 7200-G
7200-P	7200-J	7200-PW	7200-B	DU7200	7200-B	30200	7200-B
7200-PD	D7200-J	7200-PW-DU	(2) 7200-BUO	.....	7200-B-D	30200-D	(2) 7200-BG
7300	7300-A	7300-W	B-7300-E	7300	7300-A	H-20300	7300
7300-D	7300-A	7300-W-DU	(2) B-7300-EUO	DU7300	7300-A-D	H-20300-D	(2) 7300-G
7300-P	D7300-J	7300-PW	7300-B	.....	7300-B	30300	7300-B
7300-PD	.....	7300-PW-DU	(2) 7300-BUO	.....	7300-B-D	30300-D	(2) 7300-BG
7400	.....	7400	.....	7400	.....	H-20400	7400
7400-D	.....	7400-D	.....	DU7400	.....	H-20400-D	(2) 7400-G

* This table indicates methods of numbering. Some sizes not in production.
† MRC bearing contact angles converge inwardly.

§ On certain sizes, width may be greater than corresponding MRC Bearing.
• These double-row bearing types have been superseded by new C and M types. Interchange to new types and with other makes shown on page 50.

Table 7-3
Ball Bearing Interchange Table—cont'd

5000 SERIES DOUBLE-ROW BALL BEARINGS

Interchangeability of MRC 5000 Series Bearings with various other makes. This table indicates methods of marking. Some competitive sizes in the series are not in production.

MRC Ball Bearing Series	BCA	Fafnir	FAG	Federal	Hoover NSK	New Departure-Hyatt	SKF
5200-C	.....	5200K	.....	.....	5200	5200	5200H
5200-CF	.....	5200KD	.....	.....	.....	5500	5200Z
5200-CFF	.....	5200KDD	.....	.....	5200ZZ	55500	5200-2Z
5200-CFFG	.....	.....	.....	.....	.....	455500	.....
5200-CFG	.....	5200KDG	.....	.....	.....	45500	.....
5200-CFZ	.....	.....	.....	.....	.....	.....	.....
5200-CFZG	.....	.....	.....	.....	.....	.....	.....
5200-CG	.....	.....	.....	.....	5200NR	45200	5200NRH
5200-CZ	.....	.....	.....	.....	.....	.....	5200RS
5200-CZG	.....	.....	.....	.....	.....	.....	.....
5200-CZZ	.....	.....	.....	.....	.....	.....	.....
5200-CZZG	.....	.....	.....	.....	.....	.....	5200-2RS
5200-M	5200W	5200W	3200	A5200	3200	5200	.....
5200-MF	5200WS	5200WD	.....	FSA5500	.....	5500	.....
5200-MFF	5200WSS	.....	.....	FSA55500	3200ZZ	55500	.....
5200-MFFG	.....	.....	.....	.....	.....	455507	.....
5200-MFG	5200WSL	.....	.....	FSA5500CG	.....	45500	.....
5200-MFZ	.....	.....	.....	.....	.....	.....	.....
5200-MFZG	.....	.....	.....	.....	.....	.....	.....
5200-MG	5200WL	5200WG	.....	FSA5200CG	3200NR	45200	.....
5200-MZ	.....	.....	.....	.....	.....	.....	.....
5200-MZG	.....	.....	.....	.....	.....	.....	.....
5200-SB	.....	5200K	.....	.....	5200	5200	5200
5200-SBKF	.....	5200KD	.....	.....	.....	.....	5200Z
5200-SBKFF	.....	.....	.....	.....	.....	.....	.....
5200-SBKFG	.....	5200KDG	.....	.....	5200ZZ	.....	5200-2Z
5200-SBKZ	.....	.....	.....	.....	.....	.....	5200RD
5200-SBKZZ	.....	.....	.....	.....	.....	.....	.....
5300-C	.....	5300K	3300	.....	5300	5300	5200-2RS
5300-CF	.....	.....	.....	.....	.....	5600	5300H
5300-CFF	.....	.....	.....	.....	.....	.....	.....
5300-CFFG	.....	.....	.....	.....	.....	55600	.....
5300-CFG	.....	.....	.....	.....	.....	455600	.....
5300-CFZ	.....	.....	.....	.....	.....	45600	.....
5300-CFZG	.....	.....	.....	.....	.....	.....	.....
5300-CG	.....	5300KG	.....	.....	5300NR	45300	5300NRH
5300-CZ	.....	.....	.....	.....	.....	.....	.....
5300-CZG	.....	.....	.....	.....	.....	.....	.....
5300-CZZ	.....	.....	.....	.....	.....	.....	.....
5200-CZZG	.....	.....	.....	.....	.....	.....	.....
5300-M	5300W†	5300W	3300	A5300	3300	5300	.....
5300-MF	5300WS†	.....	.....	FSA5600	.....	5600	.....
5300-MFF	.....	.....	.....	.....	.....	.....	.....
5300-MFFG	.....	.....	.....	FSA55600	3300ZZ	55600	.....
5300-MFG	5300WSL†	.....	.....	FSA5600CG	.....	455600	.....
5300-MFZ	.....	.....	.....	.....	.....	45600	.....
5300-MFZG	.....	.....	.....	.....	.....	.....	.....
5300-MG	5300WL†	5300WG	.....	FSA5300CG	3300NR	45300	.....
5300-MZ	.....	.....	.....	.....	.....	.....	.....
5300-MZG	.....	.....	.....	.....	.....	.....	.....
5300-SB	.....	5300K	.....	.....	5300	5300	.....
5400	5400	5400W*	.....	.....	.....	5400*	5400
5400F	.....	.....	.....	.....	.....	.....	.....
5400G	5400L	5400WG*	.....	.....	.....	.....	.....

† BCA bearing contact angles converge inwardly
* MRC bearing contact angles converge inwardly

(Text continued from page 371)

"Special" bearings include:

Adapter Type—Conrad type with a tapered adapter sleeve.

Aircraft Bearings—A category by themselves. Not related to other types listed here.

Cartridge Type—Conrad type with both rings same width as a double-row bearing.

Conveyor Roll—Conrad type. Special construction, wider than standard built-in seals.

Felt Seal—Conrad type, unequal width rings.

Cleanliness and Working Conditions in Assembly Area

Many ball bearing difficulties are due to contaminants that have found their way into the bearing after the machine has been placed in operation. Contaminants generally include miscellaneous particles which, when trapped inside the bearing, will permanently indent the balls and raceways under the tremendous pressures generated by the operating load (Figure 7-1).

Average contact area stresses of 250,000 lbs per square in. are not uncommon in bearings. Due to the relatively small area of contact between



Figure 7-1. Hard, coarse foreign matter causes small, round-edged depressions of various sizes.

the ball and raceway, contact area pressures are very high even for lightly loaded bearings. When rolling elements roll over contaminants, the contact areas are greatly reduced and the pressure becomes extremely high.

When abrasive material contaminates the lubricant, it is frequently crushed to finer particles that cause wear to the ball and race surfaces. The wear alters the geometry of the balls and races, increases the internal looseness of the bearing, and roughens the load-carrying surfaces (Figure 7-2). Therefore, it is highly important to maintain a clean environment when working on all bearing applications during servicing operations.

The assembly area should be isolated from all possible sources of contamination. Filtered air will help eliminate contamination and a pressurized and humidity-controlled area is advantageous to avoid moist and/or corrosive atmospheres. Work benches, tools, clothing, and hands should be free from dirt, lint, dust, and other contaminants detrimental to bearings.

Surfaces of the work bench should be of splinter-free wood, phenolic composition, or rubber-covered to avoid possible nicking of spindle parts that could result from too hard a bench top. To maintain cleanliness, it is suggested that the work area be covered with clean poly-coated kraft paper, plastic, or other suitable material (Figure 7-3) which, when soiled, can be easily and economically replaced.

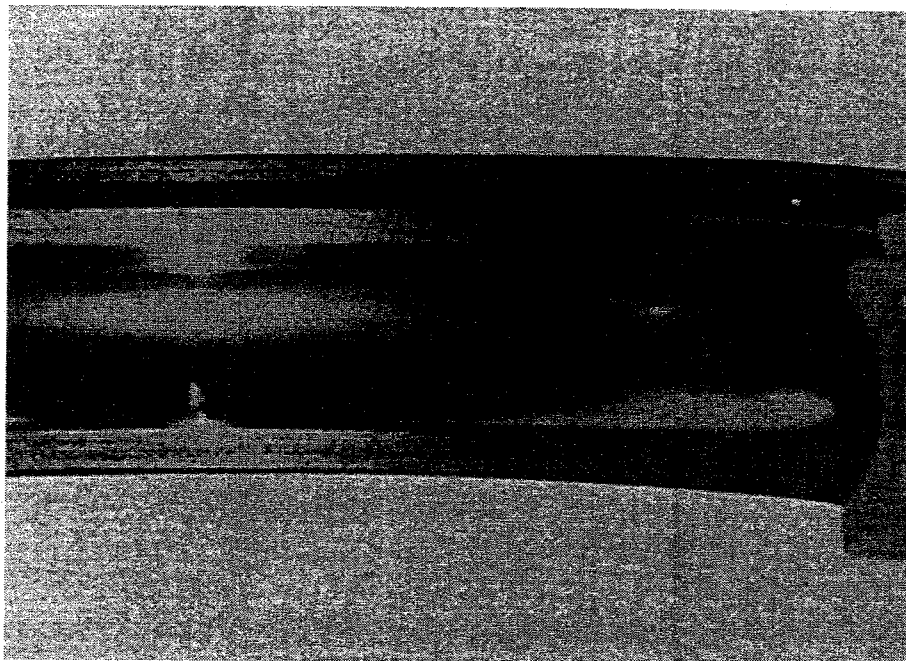


Figure 7-2. Fine foreign matter laps the ball surfaces and ball races, causing wear.

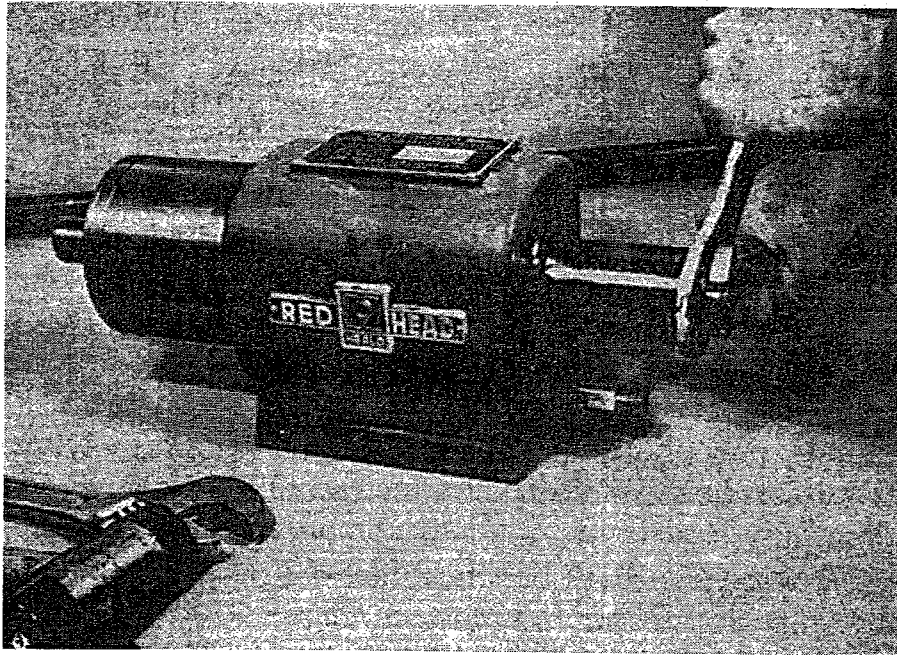


Figure 7-3. Cover workbench with clean, lint-free paper, plastic, or similar material. Also, isolate work area from contamination sources.

Removal of Shaft and Bearings from Housing

The first step in dismantling a spindle or shaft is to remove the shaft assembly from the housing. To do this, it is generally necessary to take off the housing covers from each end.

Most machine tool spindle and API pump housings are constructed with bearing seats as an integral part of the housing. This contributes to the rigidity of the spindle. However, it makes disassembly more difficult and extreme care must be taken to avoid bearing damage. Also, it is not generally possible to remove bearings from the shaft unless the shaft assembly is first removed from the housing.

On most spindle assemblies this can be done by first placing the entire spindle in an arbor press and in alignment with the press ram. Next, carefully apply pressure to the end of the shaft making sure that there is clearance for the expulsion of the shaft assembly on the press table. As pressure is applied, the shaft is forced from the housing along with the bearing mounted on the opposite end of the shaft.

The bearing on the end where pressure is applied remains in the housing. It is removed from the housing either with hand pressure or by carefully pushing it out of the housing from the opposite side with rod tubing having a diameter slightly smaller than the housing bore. The tubing should contact the bearing outer ring and should push it from the housing with little or no pressure on the balls and inner ring. Following

this procedure will help avoid brinelling of the raceways due to excessive pressure on the rolling elements and races.

Electric motor shafts are generally constructed to permit removal of one end bell, leaving the shaft and bearings exposed. The rotor or shaft assembly is then free to be removed by drawing it through the stator.

Bearing Removal from Shaft

Removal of bearings from spindle shafts is a highly important part of the maintenance and service operation. In most cases, it is far more difficult to remove a bearing from the shaft than to put it on. For this reason, a bearing can be damaged unnecessarily in the process. Every precaution must be taken to avoid damage to any of the parts including the bearings. If the bearings are damaged during removal, the damage often is not noticed and may not become known until the spindle is completely reassembled.

Bearing damage during removal from the shaft can occur in many ways, of which these are the most common:

- *The smooth, highly-polished surface of the ball raceways may be brinelled, i.e., indented, by the balls (Figure 7-4). Brinell marks on*

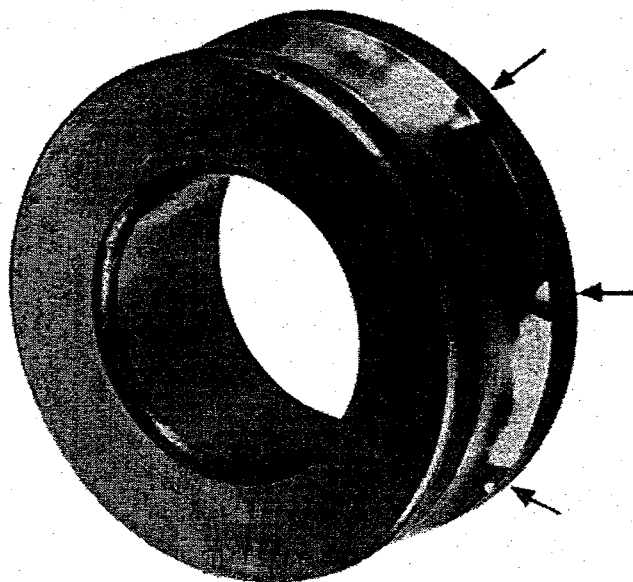


Figure 7-4. Brinell marks or nicks, indicated by arrows, are the most common result of improper bearing removal.

the surface of the races are usually caused when a bearing is forced off the shaft by applying excessive or uneven pressure through the rolling element complement. Any shock load, such as hammer blows on the inner or outer rings, is apt to cause brinelling. Major brinelling can sometimes be discovered on the job by applying a thrust load from each direction while rotating the inner or outer ring slowly. As the ring is turned through the brinelled area on either of the race shoulders, it can often be felt as a catch or rough spot. *A brinelled bearing is unfit for further use. Never put it back into service.*

- *Ball raceways may be roughened due to dirt particles or metal chips working into the bearing.* As soon as the shaft has been removed from the housing, it should be placed in a clean work area and suitably covered so that no contaminant can become lodged in the bearing prior to removal from the shaft. If contaminants enter the housing and the bearing is subsequently rotated, it is possible that they will roughen and damage the raceways.
- *The ball cage may be damaged if the bearing puller is used incorrectly.* Use of improper tools such as a hammer or chisel to pound or pry the bearing off the shaft may result in damage to the bearing in addition to the hazard of contaminating the bearing.

Removal From Shaft

Because of operating conditions or location of the shaft, bearings are often tight and resist easy removal. This holds true even though they were originally mounted with a "push" fit, usual in most machine tool spindle applications. A "push" fit means ability to press the bearing on the shaft with hand pressure.

If these conditions occur, mechanical means such as a bearing puller (Figure 7-5) or the use of an arbor press (Figure 7-6) should be employed to effect bearing removal. The hammer and drift tube method, sometimes used to pound the bearing from the shaft, generally is not recommended, especially on machine tool spindle bearings. There is always the chance that the hammer shocks conducted through the tube will cause brinelling.

For some types of bearings, electrical means of removal are possible as well. These removal methods will be described later.

Bearings are mounted on shafts or spindles in several ways so that dismounting must be accomplished by different means. Here are the most common conditions:

- The bearing is free of grease and/or other parts. Place the shaft in an arbor press in line with the ram and with the inner ring of the bearing

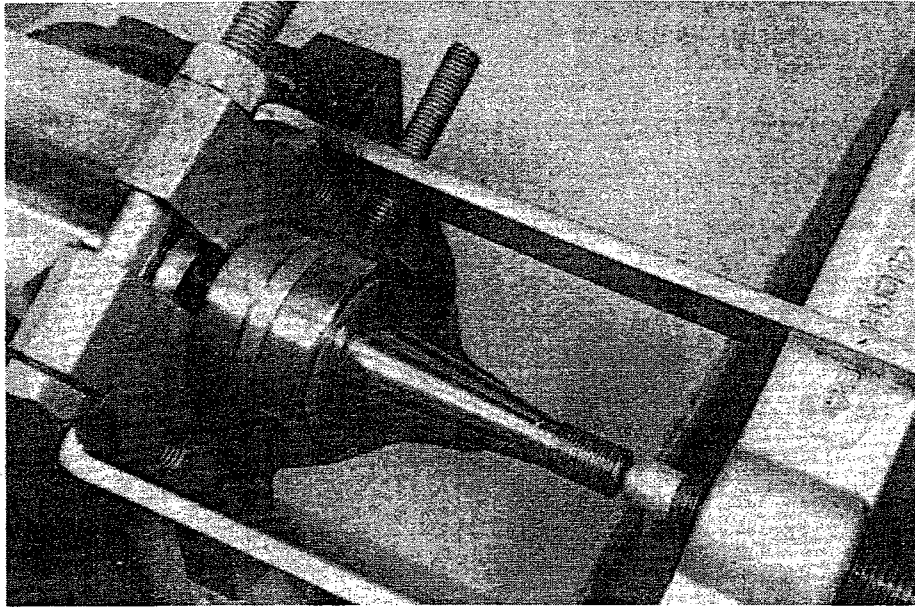


Figure 7-5. Bearing puller with two claws.

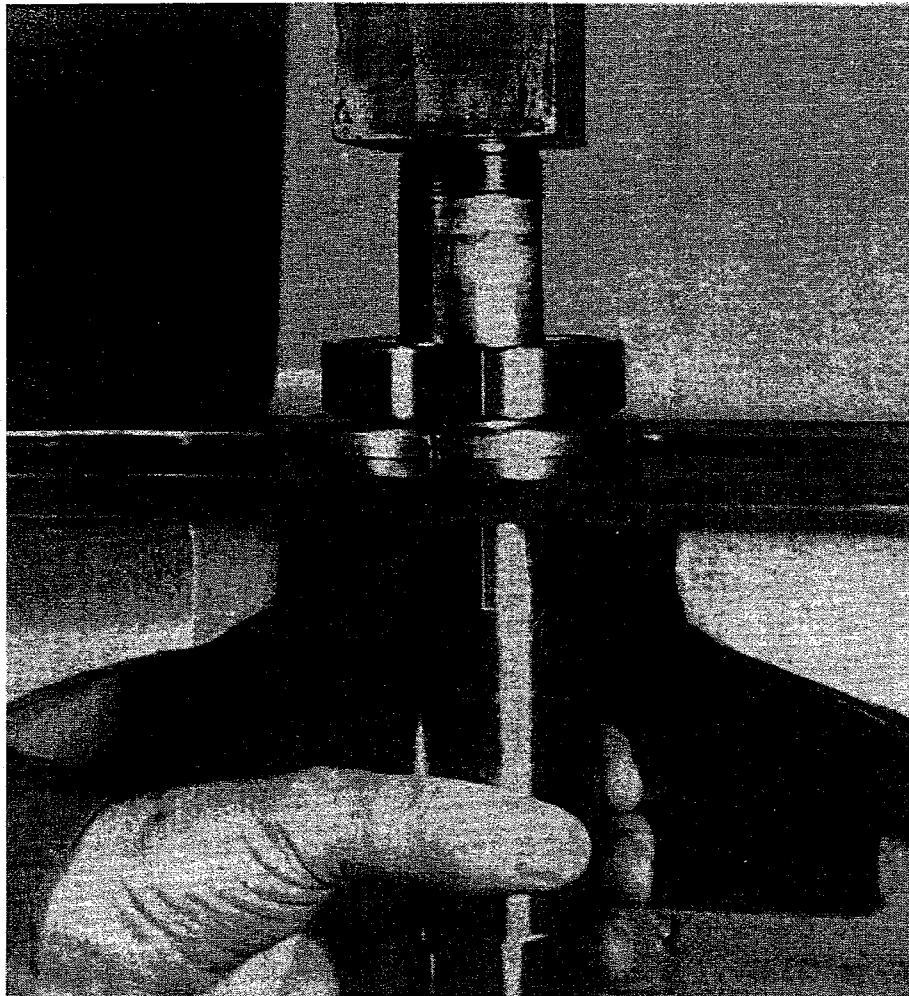


Figure 7-6. Using arbor press and split ring to remove bearing from shaft.

supported by a split ring having a bore slightly larger than the shaft (Figure 7-7). Press the shaft from the bearing with an even pressure, making sure it does not drop free and become damaged. If the split ring is not available, two flat bars of equal height could support the bearing (Figure 7-8).

Another means of removing a bearing from the shaft is by use of a bearing puller, several of which are shown in Figures 7-13 to 7-15.

- The bearing mounted with gears and/or other parts abutting it (Figure 7-9). In most cases, a bearing in this location can only be removed by a bearing puller which applies pressure on the outer ring (Figure 7-10). Extreme care must be exercised when applying pressure to

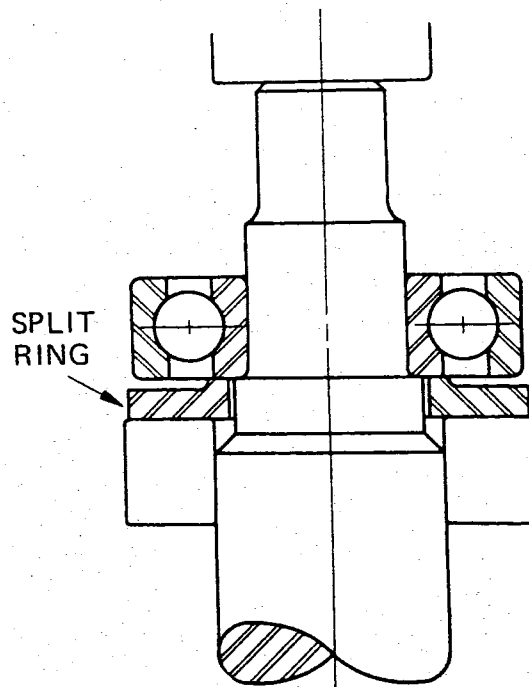


Figure 7-7. Split ring supports inner ring of bearing.

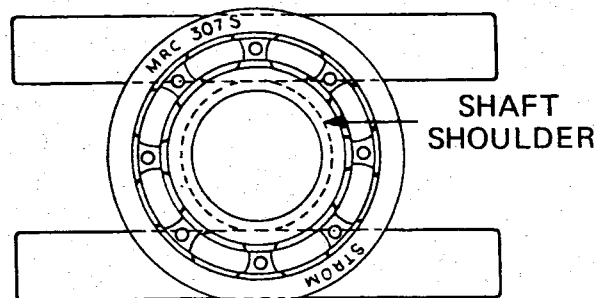


Figure 7-8. Equal height bars spaced to support both inner and outer rings.

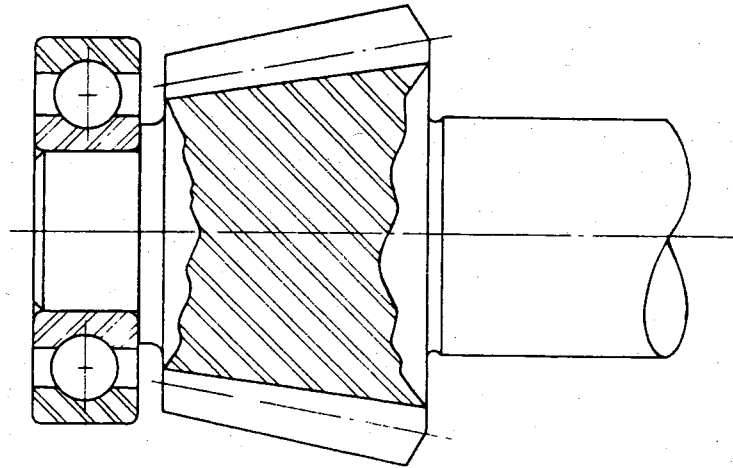


Figure 7-9. Bearing mounted with other parts abutting it.

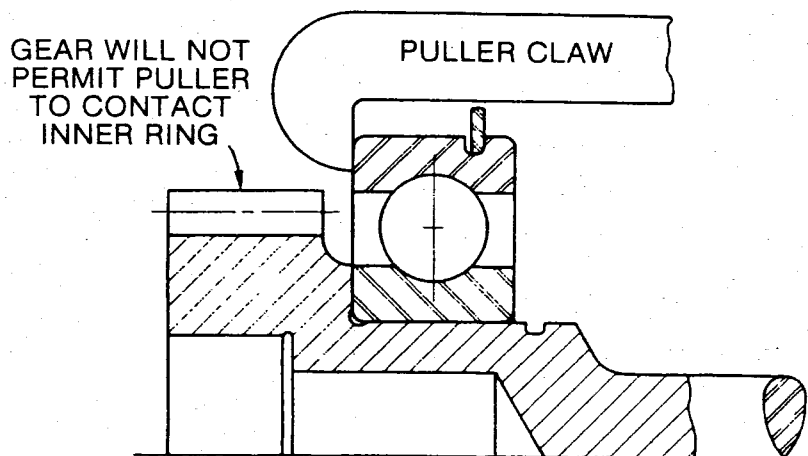


Figure 7-10. Where shaft parts obstruct inner ring accessibility, apply pressure with bearing puller on outer ring as evenly and squarely as possible. On bearings with one high and one low shoulder, pressure should be applied against the deep shoulder only.

make sure that the pull is steady and equal all around the outer ring. If the gears or other parts are removable, it may be possible to apply pressure through them to force the bearing off the shaft. An arbor press may be employed to do the job if the bearing or gear can be adequately supported while pressure is applied.

Applying Pressure with Bearing Puller

Whenever possible, bearings always should be moved from the shaft by square and steady pressure against the *tight* ring. Thus with a tight fit on the shaft, pressure should be against the inner ring; with a tight fit in the housing, pressure should be against the outer ring. If it is impractical to

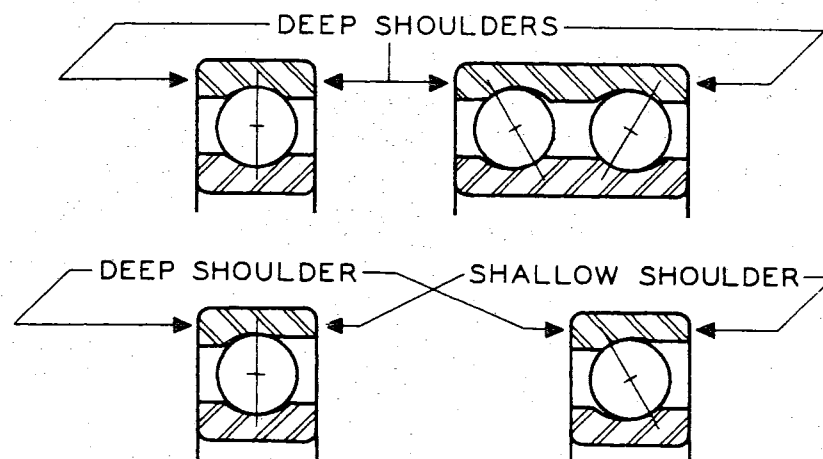


Figure 7-11. Pressure may be applied in either direction with shoulders of equal height.

exert pressure against the tight ring, and the loose ring must be used, it is imperative that the same square and steady pull method be used.

Pressure may be applied in either direction on bearings with shoulders of equal height (Figure 7-11). On counterbored bearings with one deep and one low shoulder, pressure should be applied against the deep shoulder. If pressure is applied against the low shoulder, disassembly of the bearing or serious damage may result. When the pairs of bearings on each end of the shaft are mounted in a back-to-back (DB) relationship, the counterbored outer ring is always exposed. In such cases, it will be necessary to apply the pressure against the low shoulder (counterbored ring) to effect bearing removal from the shaft even though the risk of damage to the inboard bearing is great.

Most machine tool spindles employ Type R or angular-contact bearings (7000 Series) that do not have seals or shields. However, it is possible that a Conrad type bearing equipped with seals or shields may be used in some applications. When using pullers for bearing removal, care must be exercised to avoid damage to the seal or shield (Figure 7-12). If dented and then remounted, an early bearing failure during operation could result.

Bearing removal damage can be caused by the selection of the wrong puller type as easily as it can with improper use of the correct puller. No matter which puller is used, *remember*: if the bearing is not pulled off squarely under steady pressure, it must be scrapped!

Identification and Handling of Removed Bearings

As it is possible that bearings may be suitable for remounting after servicing, it is necessary to replace them in exactly the same position on the shaft. Therefore, each bearing must be specifically tagged to indicate its

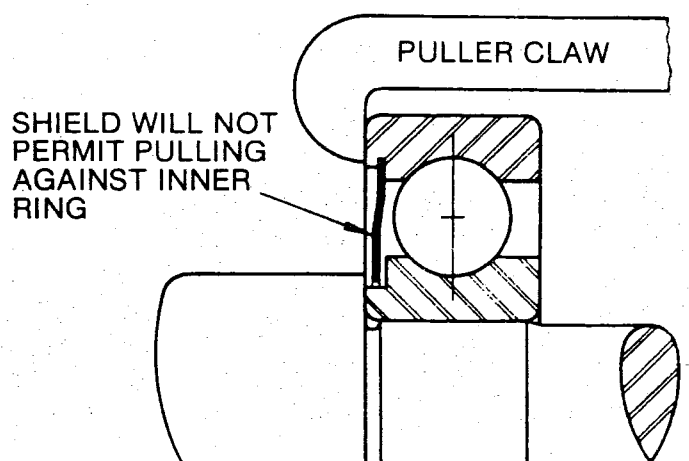


Figure 7-12. Where a shield or seal does not permit inner ring pressure, use bearing puller with extreme care to avoid denting shield or seal.

proper location. Duplex bearings should be tied together in their proper relationship, DB, DF, or DT and the tag should also indicate the relationship. If a spacer is used between duplex bearings, the tag should indicate its position and relationship to the bearings.

On jobs where the bearing is being removed because performance has not been fully successful, it is often desirable to find out why. Be sure to preserve the bearing until it is practical to examine it. The bearing frequently contains direct evidence as to the cause of failure. It should not be permitted to rust badly and the parts should be abused as little as possible during disassembly.

If the bearing is being removed for reasons other than bearing failure, be certain that it is thoroughly cleaned and oiled immediately after removal. Otherwise there is a good chance that it will get dirty and rusty, which would prevent its reuse.

Bearing Pullers

There are numerous types of bearing pullers on the market, any of which would be satisfactory to use depending upon the dismounting situation encountered. A conventional claw type is used where there is sufficient space behind the bearing puller claws to apply pressure to the bearing. In the illustration (Figure 7-13), the claws are pressing against the bearing preloading spring pack which in turn will force the duplex pair of bearings and spacers from the spindle.

Another type of puller (Figure 7-14) uses a split-collar puller plate (Figure 7-15), the flange of which presses against the inner ring of the bearing. The puller bolts must be carefully adjusted so that the pulling

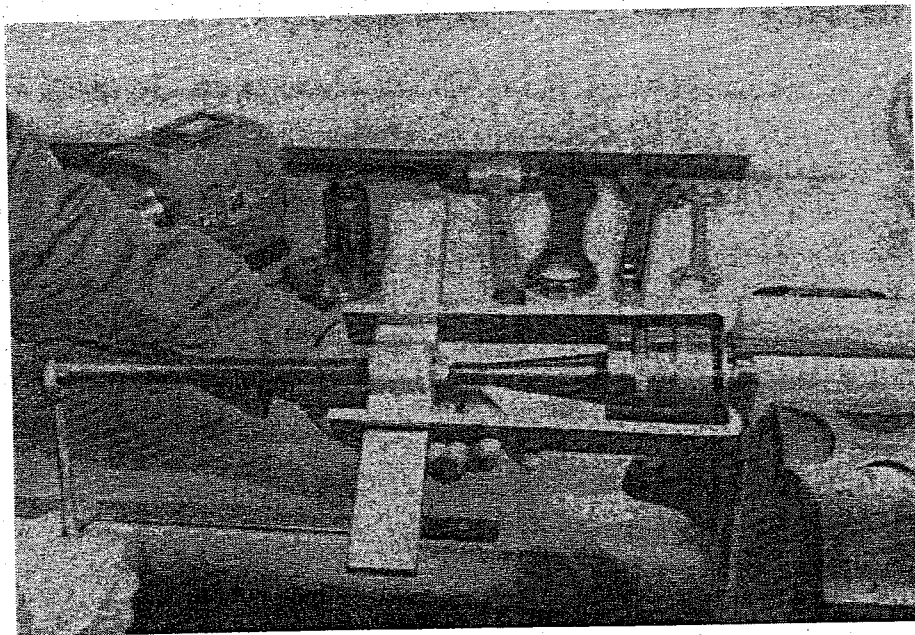


Figure 7-13. Claws pressing against the bearing spring pack will force the duplex pair of bearings and spacers from the spindle.

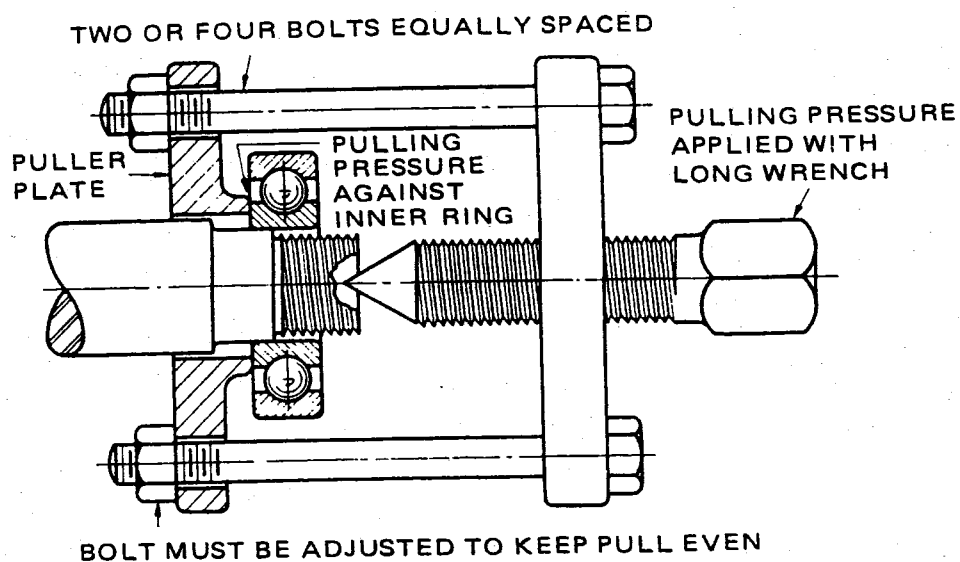


Figure 7-14. Another type of puller. Pulling pressure is applied to inner ring.

pressure is equal all around the ring. The collar must be made in two pieces so that it can be slipped behind the bearing. The collar hole should be large enough so that the two pieces may be bolted together without gripping the shaft.

Most bearing companies do not manufacture bearing pullers, but many bearing distributors stock a variety of the various pullers described above.

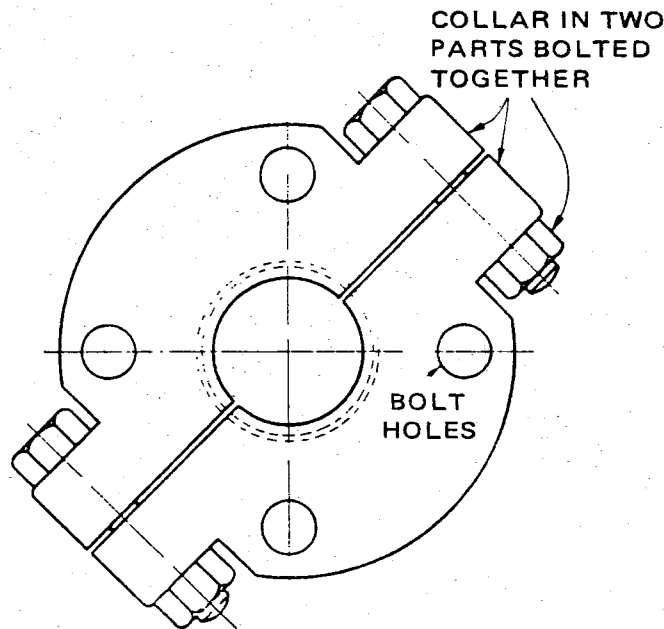


Figure 7-15. Split collar puller plate.

Bearing Removal Through Application of Heat

The application of heat via special devices provides a rather straightforward way of removing inner bearing rings without damaging shafts. The device shown in Figure 7-16 is initially heated by an induction heater (see Figures 7-59 through 7-61, later in this chapter).

To remove the inner ring from a bearing assembly [Figure 7-17(1)], the outer race and rolling elements must first be removed [Figure 7-17(2)]. The device is then heated to approximately 450°C (813°F) and slipped over the exposed ring [Figure 7-17(3)]. By simultaneously twisting and pulling [Figure 7-17(4)], the operator clamps the heated pull-off device onto the ring. Within approximately 10 seconds, the ring will have expanded to the point of looseness [Figure 7-17(5)] and can be removed.

Cleaning and Inspection of Spindle Parts

Insufficient attention is paid to small dust particles which constantly blow around in the open air. But should a particle get in one's eye, it becomes highly irritating. In like manner, when dirt or grit works into a ball bearing, it can become detrimental and often is the cause of bearing failure.

It is so easy for foreign matter to get into the bearing that more than ordinary care must be exercised to keep the bearing clean. Dirt can be introduced into a bearing simply by exposing it to air in an unwrapped

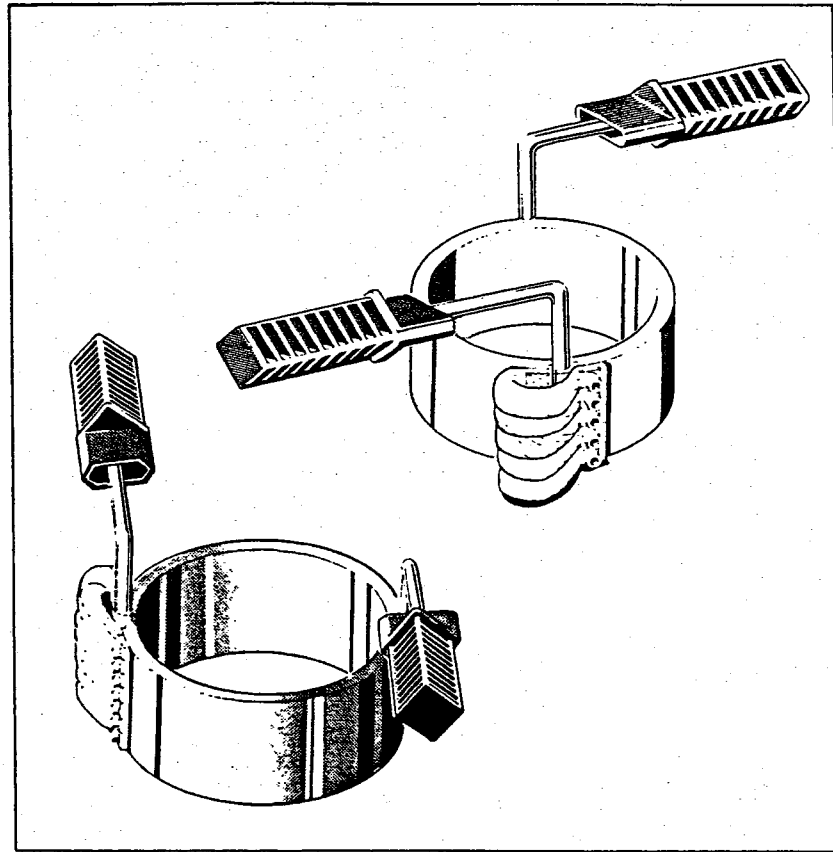


Figure 7-16. Electrically heated “demotherm” device for removal of bearing inner rings from shafts (courtesy Prüftechnik A. G., Ismaning, Germany).

state. Within a short period of time, the bearing can collect enough contaminants to seriously affect its operation. Special care must be taken when the bearing is mounted on a shaft, a time when it is most susceptible to contamination. This cleanliness requirement also extends to the handling of spindle parts, as everything must be clean when replaced in the assembly.

Cleaning the Bearing

During the process of removal from a shaft, the bearing is likely to have become contaminated. The following procedure should be used to clean the bearing for inspection purposes as well as to prepare it for possible remounting on the shaft:

1. Dip the bearing in a clean solvent and rotate it slowly under very light pressure as the solvent runs through the bearing (Figure 7-18). Continue washing until all traces of grease and dirt have been removed. *Do not force the bearing during rotation.*

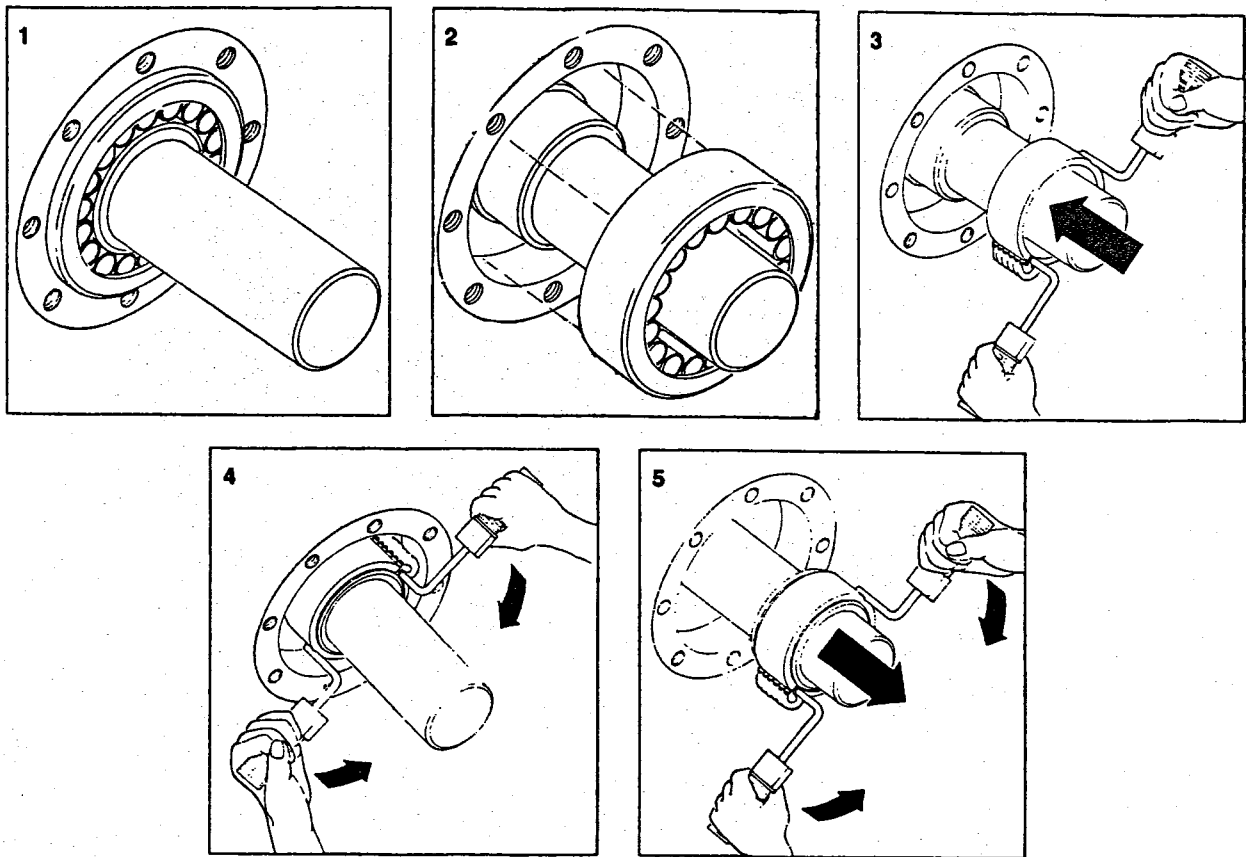


Figure 7-17. An induction-heated pull-off device will effectively remove bearing inner rings from shafts (courtesy Prüftechnik A.G., Germany).

2. Blow the bearing dry with clean, dry air while holding both inner and outer rings to keep the air pressure from spinning them. This avoids possible scratching of balls and raceways if grit still remains in the bearing. A slow controlled hand rotation under light pressure is advisable.
3. After blowing dry, rotate the bearing again slowly and gently to see if dirt can still be detected. Rewash the bearing as many times as necessary to remove all the dirt.
4. When clean, coat the bearing with oil immediately. Special attention should be given to covering the raceways and balls to ensure prevention of corrosion to the highly finished surfaces. Rotate the bearing gently to coat all rolling surfaces with oil.

After cleaning, the bearing should be wrapped with lint-free material such as plastic film to protect it from exposure to all contaminants. Unless this is done, it may be necessary to repeat the cleaning procedure immediately prior to remounting. As other spindle parts are cleaned, they also should be covered to exclude contamination which could ultimately work into the bearing.

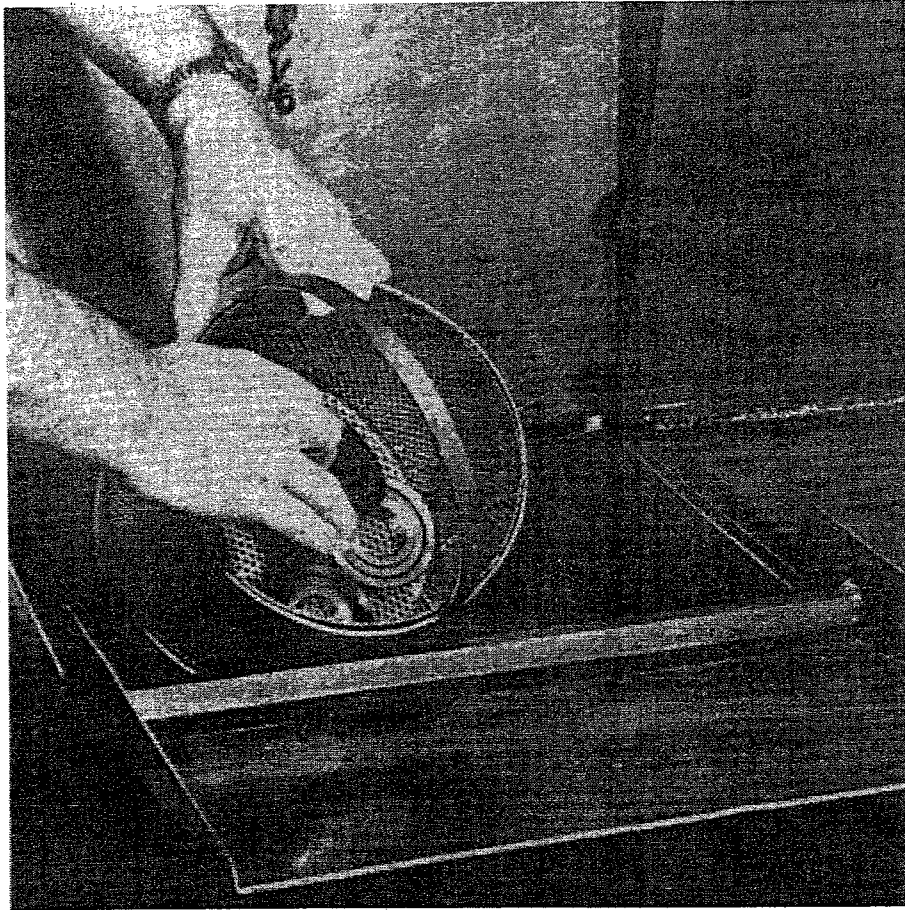


Figure 7-18. A metal basket strainer is useful when dipping bearings in clean solvent. Rotate bearing slowly with very light pressure in solvent.

Cleaning the Shaft

The shaft must be cleaned thoroughly with special attention being paid to the bearing seats and fillets. If contaminants or dirt remain, proper seating of the shaft and/or against the shaft shoulder could be impossible. Don't overlook the cleaning of keyways, splines, and grooves.

Cleaning the Housing

Care should be taken to remove all foreign matter from the housing (Figure 7-19). Suitable solvents should be used to remove hardened lubricants. All corrosion should be removed. After cleaning, inspect in a suitable light the bearing seats and corners for possible chips, dirt, and damage, preferably using low power magnification for better results.

The most successful method to maintain absolute cleanliness inside a clean housing is to paint the nonfunctional surfaces with a heat-resisting,

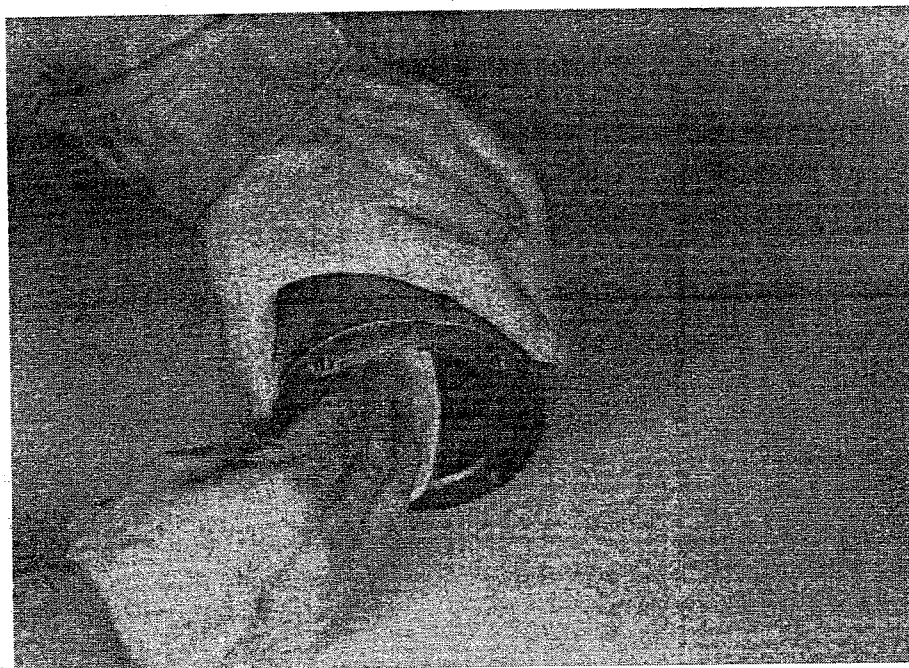


Figure 7-19. Clear bearing seats of housing thoroughly to remove all foreign matter. Then inspect bearing seats and corners for possible damage.

quick-drying engine enamel. Do not paint the bearing seats of the housing. This would reduce the housing bore limits, making it difficult, if not impossible, to mount the bearings properly. Painting seals the housing and prevents loose particles such as core sand from contaminating the bearing lubricants and eventually the bearings. It also provides a smooth surface which helps to prevent dirt from clinging to the surfaces. The housing exterior also may be painted to cover areas where old paint is worn or chipped; but do not paint any of the locating mating surfaces. This type of work should be done in a place outside of the spindle assembly area.

Keep Spindle Parts Coated with Oil

As most of the spindle parts are usually of ferrous material, they are subject to corrosion. When exposed to certain atmospheric conditions, even nonferrous parts may become corroded and unusable in the spindle. Therefore, it is important to make certain that parts are not so affected from cleaning time until they are again sealed and protected in the spindle assembly.

The best protection is to keep parts coated with a light-weight oil, covered, and loosely sealed with a plastic film or foil. Such a covering will exclude contaminants such as dust and dirt. When it is necessary to handle parts for inspection, repair, transportation, or any other purpose,

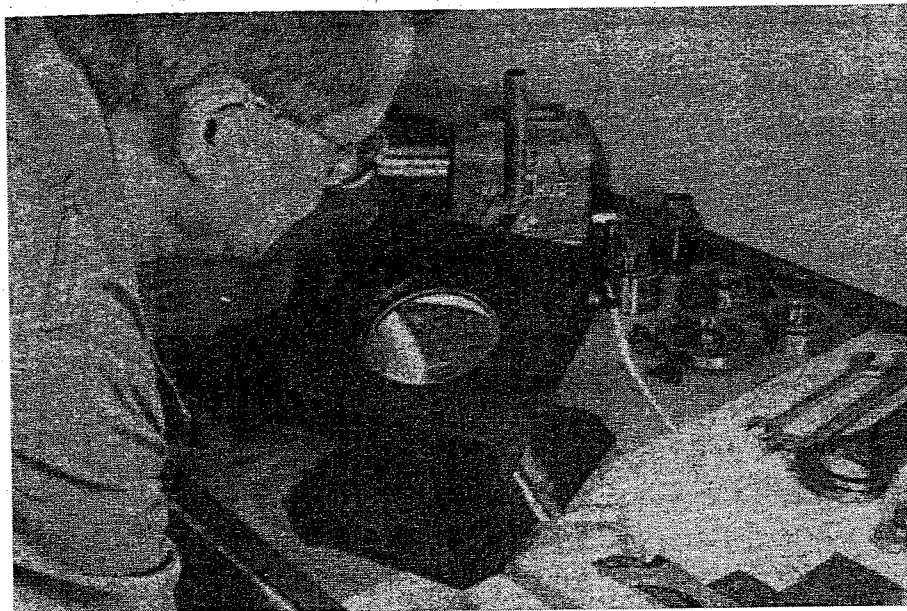


Figure 7-20. After cleaning, inspect spindle parts by visual means and under magnification. It is important that locating surfaces are free of nicks, burrs, corrosion, etc.

precautions must be taken to ensure they are recoated with oil as some may have rubbed off during handling of the part.

Inspect All Spindle Parts

After the spindle parts have been cleaned thoroughly, the various parts should be inspected visually for nicks, burrs, corrosion, and other signs of damage (Figure 7-20). This is especially important for locating surfaces such as bearing seats, shaft shoulders, faces, and corners of spacer rings if any are used in the spindle, etc.

Sometimes damage may be spotted by scuff marks or bright spots on the bearing, shaft, or in the housing. This scoring may be caused by heavy press fits or build-up of foreign matter drawn onto the mating surfaces. Bright spots may also indicate early stages of “fidgeting” or scrubbing of mating surfaces. The shaft should also be checked for out-of-round and excessive waviness on both two-point and multiple point gauging or checking on centers.

Shaft and Housing Preparation

Bearing Seats on Shaft

The shaft seat for the inner ring of a ball bearing is quite narrow and subject to unit pressures as high as 4,000 lbs per square in. Because of this

pressure, particular attention must be paid to the shaft fit to avoid rapid deterioration of the bearing seats due to creepage under heavy load and/or "fretting."

The required fit of the inner ring on the shaft will vary with the application and service. It is dependent on various factors such as rotation of the shaft with respect to the direction of the radial load, use of lock nuts, light or heavy loads, fast or slow speeds, etc. In general, the inner ring must be tight enough not to turn or creep significantly under load (Figure 7-21).

When the bearing has too tight a fit on the shaft, the inner race expands and reduces or eliminates the residual internal clearance between the balls and raceways. Usually bearings, as supplied for the average application, have sufficient radial clearance to compensate for this effect. However, when extremes of shaft fit are inadvertently combined with insufficient radial clearance, extreme overload is caused and may result in heating and premature bearing failure. Tight fits in angular-contact type bearings used for machine tools may cause changes in preload and contact angle, both of which have an effect upon the operating efficiency of the machine. Finally, rings may be split by too heavy a fit.

Excessive looseness under load is also very objectionable because it allows a fidgeting, creeping, or slipping of the inner ring on the rotating shaft (Figure 7-22). This action causes the surface metal of the shaft and bearing to fret, scrub, or wear off which progressively increases the looseness. It has been noticed that, in service, this working tends to scrub

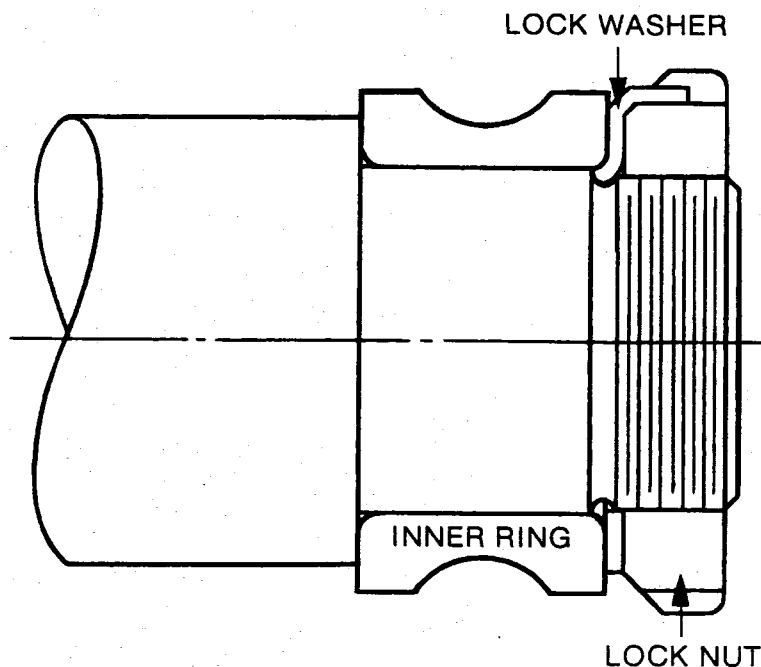


Figure 7-21. To help prevent a heavily loaded bearing from turning on a shaft, a lock nut should be used. The lock nut must be pulled up tight to be effective.

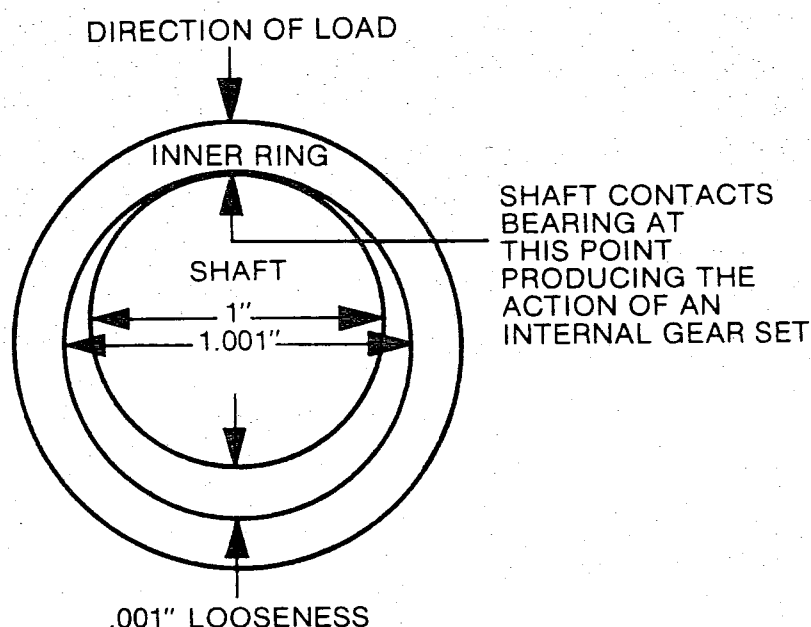


Figure 7-22. Excessive looseness under load allows fidgeting, creeping, or slipping of the inner ring on the rotating shaft.

off fine metal particles which oxidize quickly, producing blue-black and brown oxides on the shaft and/or the bore of the bearing. The bearing should be tight enough on the shaft to prevent this action.

If any of these conditions are noticed on a shaft that has been in service, it may be necessary to repair it to correct size and condition. If the shaft is machined for the bearing seat, it is important not to leave machining ridges, even minute ones. The load very soon flattens down the tops of these ridges and leaves a fit that is loose and will rapidly become looser. For best results, bearing seats should be ground to limits recommended for the bearing size and application.

Shaft Shoulders

Correct shoulders are important because abutment against the shoulder squares the bearing. The bearing is actually squared up when it is pushed home against the shaft shoulder and no further adjustment is necessary.

If a heavy thrust load against the shaft shoulders has occurred during operation, it is possible that the load may have caused the shoulder to burr and push over. Therefore, check the shoulder to make sure that it is still in good condition and square with the bearing seat. If it is not, the condition must be corrected before the spindle assembly operations are begun.

Poor machining practices may result in shaft shoulders that do not permit proper bearing seating.

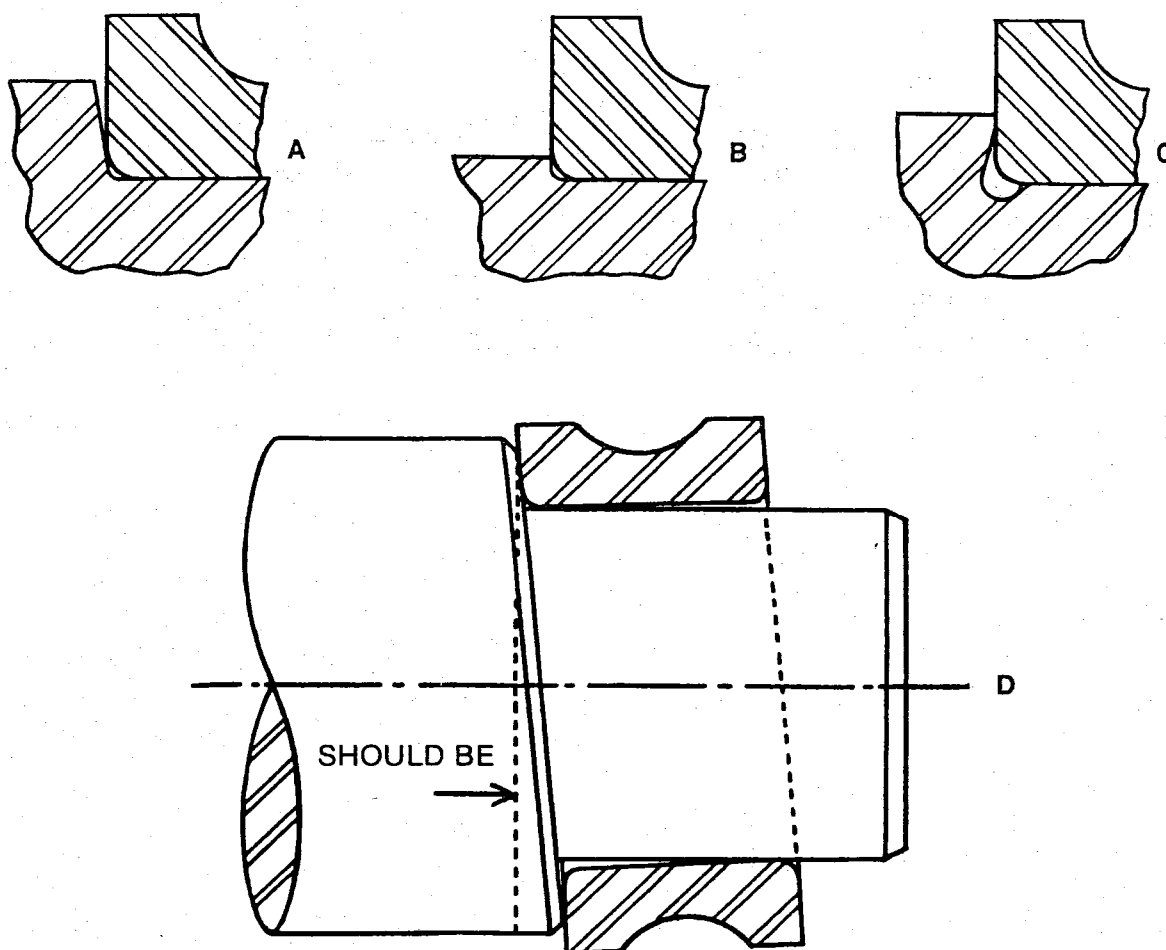


Figure 7-23. Poor seating of the bearing against the corner of the inner ring will result if the shoulder is tapered (A). In (B) the shaft shoulder is so low that it contacts the bearing corner. The condition shown in (C) illustrates that contact between the shoulder and the bearing face is not sufficient. An exaggerated distortion of the inner ring when forced against off-square shoulder is shown in (D).

The shoulder in Figure 7-23A is tapered. This results in poor seating of the bearing against the corner of the inner ring.

The shaft shoulder in Figure 7-23B is so low that the shoulder actually contacts the bearing corner rather than the locating face of the bearing.

With the condition shown in Figure 7-23C, contact between the shoulder and the bearing face is not sufficient. Under heavy thrust loads, the shoulder might break down.

Figure 7-23D is exaggerated to illustrate distortion of the inner ring when forced against off-square shoulder. An off-square bearing shortens bearing life.

Some of these conditions can be corrected when repairs are made on the inner ring seat of the shaft. Such work should be done away from the clean assembly area to avoid possible contamination of the bearing and

spindle parts by metal chips or particles from the machining or grinding operations.

The shaft shoulder should not be too high as this would obstruct easy removal of the bearing from the shaft. As described previously, a pulling tool must be placed behind the inner ring and a surface must be left for the tool. Preferably, the inner ring should project somewhat beyond the shaft shoulder to permit pulling the bearing off against this surface. This may not be possible in the case of shielded or sealed bearings where the bearing face is small.

Shaft Fillets and Undercuts

During shaft repair work, it is important to pay attention to the fillet. When it is ground, the fillet frequently becomes larger as the wheel wears, causing an oversize fillet. This in turn locates the bearing on the corner radius instead of the shaft shoulder. In other cases, the corner fillet is not properly blended with the bearing seat or shaft shoulder. This too may produce incorrect axial location of the bearing.

The bearing corner radius originally may be a true 90° segment in the turning, but when the bores, OD's, and faces are ground off, it becomes a portion of a circle less than 90° while the shaft fillet may be a true radius (Figure 7-24A).

Shaft fillet radius specifications are shown in bearing dimension tables with the heading "Radius in Inches" or "Corner Radius." This dimension is not the actual corner radius of the bearing but is the maximum shaft fillet radius which the bearing will clear when mounted. The radius should not exceed this dimension.

The actual bearing corner is controlled so that the above mentioned maximum shaft fillet will always yield a slight clearance. Figure 7-24B illustrates the conventional fillet construction at the shaft shoulder.

Where the shaft has adequate strength, an undercut or relief may be preferred to a fillet. Various types are shown in Figure 7-24 C, D, and E. Where both shaft shoulder and bearing seat are ground, the angled type of undercut is preferred.

Break Corners to Prevent Burrs

When the shaft shoulder or bearing seat is repaired by regrinding, it is desirable to break the corner on the shaft. This will help prevent burrs and nicks which may interfere with the proper seating of the inner ring face

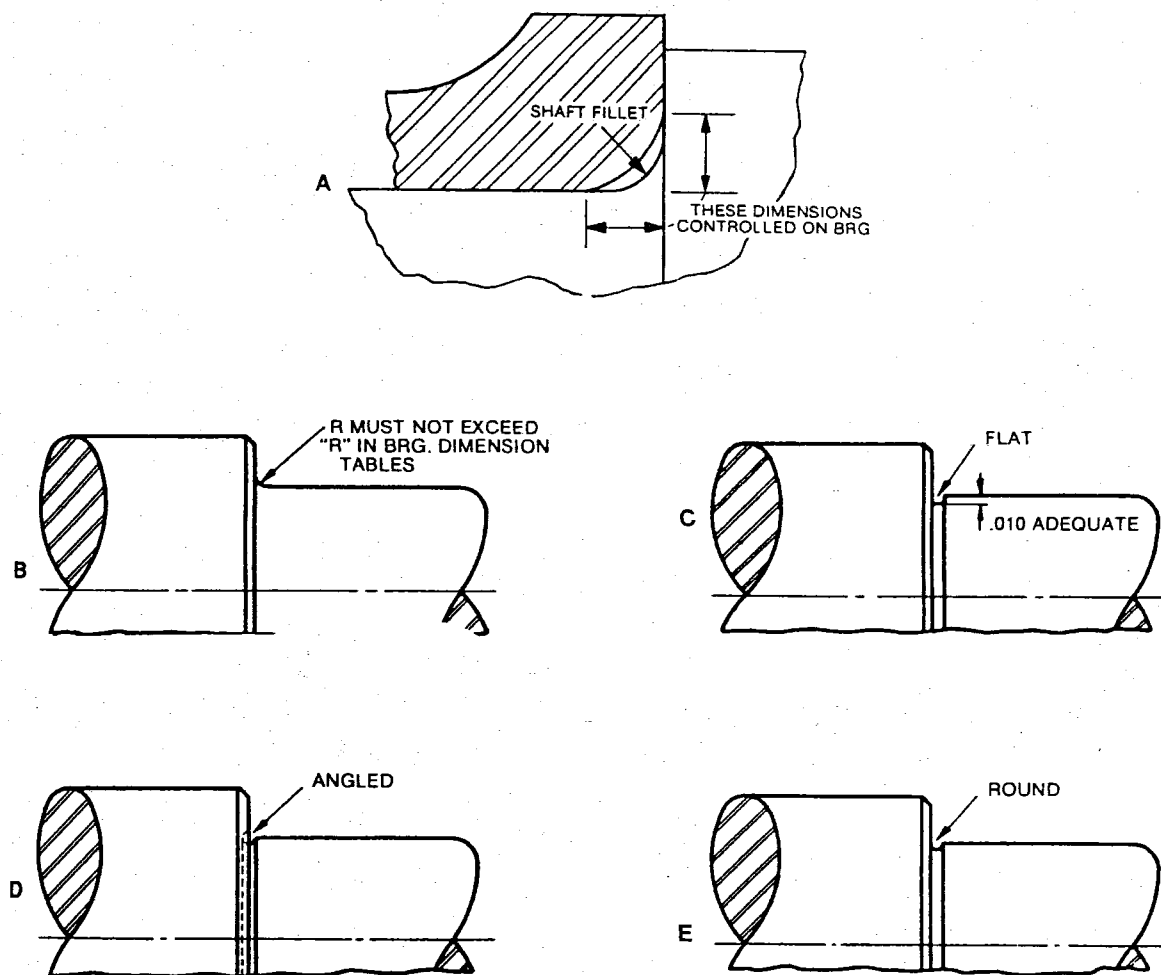


Figure 7-24. When the bores, OD's, and faces are ground off, the bearing corner radius becomes less than 90° as shown in (A). The conventional fillet construction at the shaft shoulder is shown in (B). Various types of relief are shown in (C), (D), and (E).

against the shaft shoulder (Figure 7-25). If left sharp, shoulder corners are easily nicked, producing raised portions which, in turn, may create an off-square condition in bearing location.

The usual procedure to break a corner is to use a file or an abrasive stone. This should be done while the shaft is still in grind position on the machine after regrinding the bearing seat and shoulders. The corner at the end of the bearing seat also should be broken, thus providing a lead to facilitate starting the bearing on the shaft.

If nicks or burrs are found during an inspection and no other work is necessary on the shaft, they can be removed by careful use of a file or stone (Figure 7-26). This work should be done elsewhere than in the clean assembly area. Any abrasive material should be removed from the part before returning it to the assembly area.

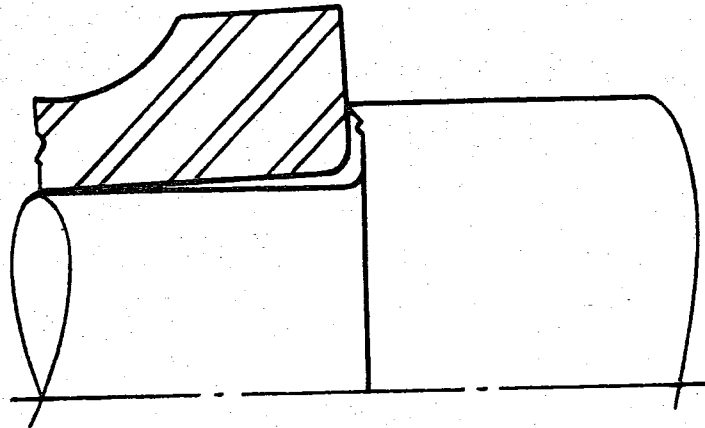


Figure 7-25. Burrs and nicks may interfere with proper seating of the inner ring face against the shaft shoulder.

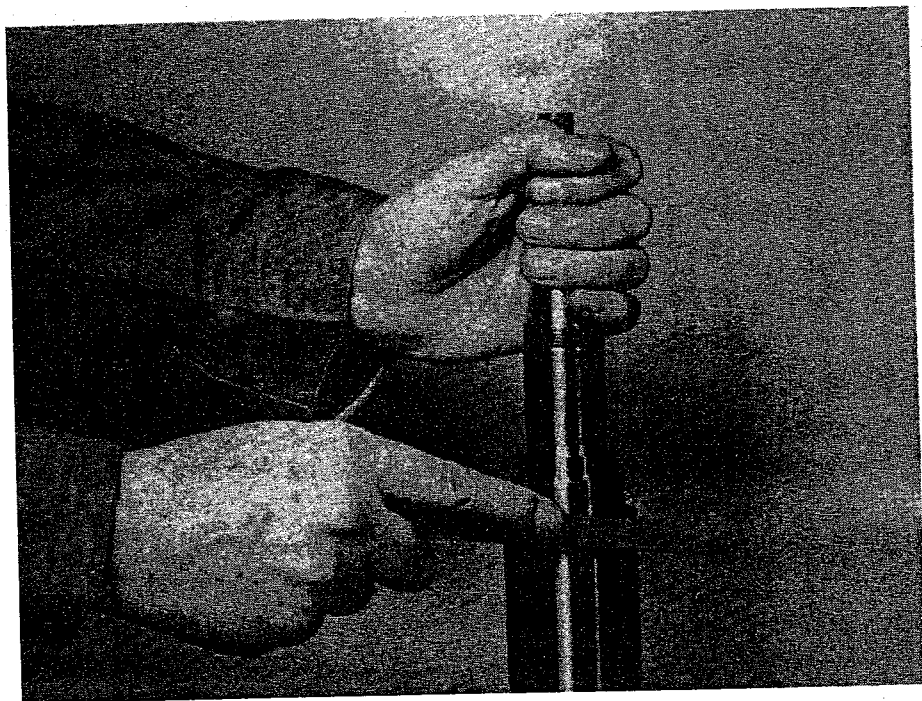


Figure 7-26. A file or stone may be used to remove nicks and burrs.

Check Spindle Housing Surfaces

In many cases, housings will require as much preparatory attention as the shaft and other parts of the spindle. Check the surfaces which mate with the machine mount. Frequently burrs and nicks will be evident and they must be removed before remounting the bearings. Failure to do so may cause a distortion in the bearing, resulting in poor operation and reduced life. These precautions apply to both bearing seats and shoulders.

Shaft and Housing Shoulder Diameters

Recommended shaft and housing shoulders (Figure 7-27) for various sizes of bearings are shown in Table 7-4.

Checking Shaft and Housing Measurements

After all repair work on the shaft has been completed, shafts should be given a final check to make sure the repairs are accurate and within the recommended tolerances. This work may be done with suitable gauging equipment such as an air gage, ten-thousandths dial indicator, electronic comparator, an accurate micrometer, and other instruments as necessary. Accuracies of readings depend on the quality of equipment used, its precision, amplification; and the ability and care exercised by the operator.

It is usually advisable to use a good set of centers which will hold the shaft and permit accurate rotation. The center points should be examined to make sure they are not scored and should be kept lubricated at all times to prevent possible corrosion. Center holes of the shaft must also be of sufficient size, clean and smooth, and free from nicks. Be sure to remove particles of foreign matter that could change the centering of the shaft on the points.

V-blocks will also be helpful to hold the shaft while making various checks. It is important that the V-blocks are clean on the area where the shaft contacts the blocks. Foreign matter and nicks will change the position of the shaft in the blocks and affect any measurements taken.

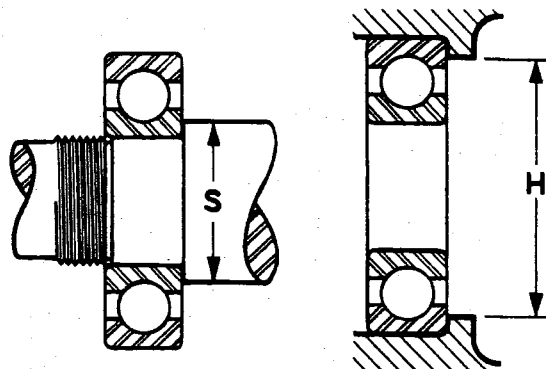


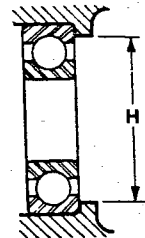
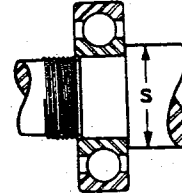
Figure 7-27. Shaft and housing shoulders.

Table 7-4
Shaft and Housing Shoulder Diameters

Shaft and Housing Shoulder Diameters

**Shoulder Diameters for Millimeter and
Inch-Size MRC brand Bearings**

The tables on these pages show Minimum Shaft Shoulder Diameters and Maximum Housing Shoulder Diameters as established by the TRW Bearings Division Product Engineering Department. However, the user may wish to modify these diameters to meet specific requirements such as assembly or disassembly problems or extremely heavy thrust loads.



Basic Brg. No.	S		H		Basic Brg. No.	S		H		Basic Brg. No.	S		H	
	Inch	MM	Inch	MM		Inch	MM	Inch	MM		Inch	MM	Inch	MM
34	.22	5.51	.56	14.2	138-K	7.95	202.0	10.95	278.0	232	6.85	174.0	10.87	276.0
35	.28	6.61	.67	17.0	140-K	8.35	212.0	11.73	298.0	234	7.40	188.0	11.50	292.0
36	.30	7.61	.67	17.0	144-K	9.21	234.0	12.84	326.0	236	7.80	198.0	11.89	302.0
37	.34	8.61	.79	20.0	148-K	10.00	254.0	13.62	346.0	238	8.19	208.0	12.68	322.0
38	.38	9.71	.79	20.0	152-K	10.95	278.0	15.04	382.0	240	8.58	218.0	13.47	342.0
39	.45	11.4	.92	23.4	156-K	11.73	298.0	15.83	402.0	242	9.13	232.0	14.13	359.0
100-K	.47	11.9	.95	24.1	160-K	12.52	318.0	17.40	442.0	244	9.37	238.0	15.04	382.0
101-K	.55	14.0	1.02	25.9	164-K	13.31	338.0	18.19	462.0	246	10.00	254.0	15.63	397.0
102-K	.67	17.0	1.18	30.0						248	10.16	258.0	16.61	422.0
103-K	.75	19.1	1.30	33.0	200	.50	12.7	.98	24.9	250	10.92	277.0	17.07	434.0
104-K	.89	22.6	1.46	37.1	201	.58	14.7	1.06	26.9	252	11.10	282.0	18.03	458.0
105-K	1.08	27.4	1.65	41.9	202	.69	17.5	1.18	30.0	256	11.89	302.0	18.82	478.0
106-K	1.34	34.0	1.93	49.0	203	.77	19.6	1.34	34.0	260	12.68	322.0	20.39	518.0
107-K	1.53	38.9	2.21	56.1	204	.94	23.9	1.61	40.9	264	13.47	342.0	21.97	558.0
108-K	1.73	43.9	2.44	62.0	205	1.14	29.0	1.81	46.0					
109-K	1.94	49.3	2.72	69.0	206	1.34	34.0	2.21	56.1	300	.50	12.7	1.18	30.0
110-K	2.13	54.1	2.91	73.9	207	1.53	38.9	2.56	65.0	301	.63	16.0	1.22	31.0
111-K	2.33	59.2	3.27	83.1	208	1.73	43.9	2.87	72.9	302	.75	19.1	1.42	36.1
112-K	2.53	64.3	3.47	88.1	209	1.94	49.3	3.07	78.0	303	.83	21.1	1.61	40.9
113-K	2.72	69.1	3.66	92.9	210	2.13	54.1	3.27	83.1	304	.94	23.9	1.77	45.0
114-K	2.91	73.9	4.06	103.0	211	2.41	61.2	3.68	93.5	305	1.14	29.0	2.17	55.1
115-K	3.11	79.0	4.25	108.0	212	2.67	67.8	3.98	101.0	306	1.34	34.0	2.56	65.0
116-K	3.31	84.1	4.65	118.0	213	2.86	72.6	4.37	111.0	307	1.69	42.9	2.80	71.1
117-K	3.50	88.9	4.84	123.0	214	3.06	77.7	4.57	116.0	308	1.93	49.0	3.19	81.0
118-K	3.84	97.5	5.16	131.0	215	3.25	82.6	4.76	121.0	309	2.13	54.1	3.58	90.9
119-K	4.05	102.0	5.35	136.0	216	3.55	90.2	5.12	130.0	310	2.36	59.9	3.94	100.0
120-K	4.23	107.0	5.55	141.0	217	3.75	95.3	5.51	140.0	311	2.56	65.0	4.33	110.0
121-K	4.53	115.0	5.91	150.0	218	3.94	100.0	5.91	150.0	312	2.84	72.1	4.65	118.0
122-K	4.72	120.0	6.30	160.0	219	4.21	107.0	6.22	158.0	313	3.03	77.0	5.04	128.0
124-K	5.12	130.0	6.69	170.0	220	4.41	112.0	6.61	168.0	314	3.23	82.0	5.43	138.0
126-K	5.51	140.0	7.48	190.0	221	4.61	117.0	7.01	178.0	315	3.43	87.1	5.83	148.0
128-K	5.91	150.0	7.87	200.0	222	4.80	122.0	7.40	188.0	316	3.62	91.9	6.22	158.0
130-K	6.38	162.0	8.39	213.0	224	5.20	132.0	7.99	203.0	317	3.90	99.1	6.54	166.0
132-K	6.77	172.0	8.98	228.0	226	5.67	144.0	8.50	216.0	318	4.09	104.0	6.93	176.0
134-K	7.17	182.0	9.76	248.0	228	6.06	154.0	9.29	236.0	319	4.29	109.0	7.32	186.0
136-K	7.56	192.0	10.55	266.0	230	6.46	164.0	10.08	256.0	320	4.49	114.0	7.91	201.0

Table 7-4
Shaft and Housing Shoulder Diameters—cont'd

Shaft and Housing Shoulder Diameters

Basic Brg. No.	S		H		Basic Brg. No.	S		H		Basic Brg. No.	S		H	
	Inch	MM	Inch	MM		Inch	MM	Inch	MM		Inch	MM	Inch	MM
321	4.69	119.0	8.31	211.0	1915	3.09	78.5	3.99	101.0	XLS-3%	3 $\frac{7}{16}$	...	4 $\frac{1}{16}$	...
322	4.88	124.0	8.90	226.0	1916	3.30	83.8	4.18	106.0	XLS-3%	3 $\frac{11}{16}$	...	4 $\frac{11}{16}$	...
324	5.28	134.0	9.69	246.0	1917	3.52	89.4	4.56	116.0	XLS-3%	3 $\frac{15}{16}$	...	4 $\frac{15}{16}$	...
326	5.83	148.0	10.32	262.0	1918	3.71	94.2	4.75	121.0	XLS-3%	3 $\frac{15}{16}$	...	4 $\frac{15}{16}$	...
328	6.22	158.0	11.10	282.0	1919	3.93	99.8	4.93	125.0	XLS-3%	4 $\frac{1}{16}$	...	4 $\frac{15}{16}$	...
330	6.61	168.0	11.89	302.0	1920	4.13	105.0	5.33	135.0	XLS-3%	4 $\frac{1}{16}$	...	5 $\frac{1}{16}$	...
332	7.01	178.0	12.68	322.0	1921	4.33	110.0	5.51	140.0	XLS-4	4 $\frac{5}{16}$	...	5 $\frac{1}{16}$	...
334	7.40	188.0	13.47	342.0	1922	4.52	115.0	5.70	145.0	XLS-4%	4 $\frac{1}{16}$	...	5 $\frac{11}{16}$	...
336	7.80	198.0	14.25	362.0	1924	4.93	125.0	6.28	160.0	XLS-4%	4 $\frac{1}{16}$	...	5 $\frac{11}{16}$	...
338	8.35	212.0	14.88	378.0	1926	5.36	136.0	6.85	174.0	XLS-4%	4 $\frac{11}{16}$	...	5 $\frac{15}{16}$	...
340	8.74	222.0	15.67	398.0	1928	5.76	146.0	7.24	184.0	XLS-4%	4 $\frac{11}{16}$	...	5 $\frac{15}{16}$	...
342	9.43	240.0	16.21	412.0	1930	6.21	158.0	7.97	202.0	XLS-4%	4 $\frac{15}{16}$	...	6 $\frac{1}{16}$	...
344	9.53	242.0	17.24	438.0	1932	6.62	168.0	8.33	212.0	XLS-4%	5 $\frac{1}{16}$	...	6 $\frac{7}{16}$	...
348	10.32	262.0	18.82	478.0	1934	7.01	178.0	8.74	222.0	XLS-4%	5 $\frac{1}{16}$	...	6 $\frac{11}{16}$	...
352	11.34	288.0	20.16	512.0	1936	7.44	189.0	9.50	241.0	XLS-5	5 $\frac{1}{16}$	...	6 $\frac{11}{16}$	...
356	12.13	308.0	21.73	552.0	1938	7.83	199.0	9.89	251.0	XLS-5%	5 $\frac{1}{2}$	...	6 $\frac{7}{8}$	...
403	.95	24.1	2.17	55.1	1940	8.27	210.0	10.61	269.0	XLS-5%	5 $\frac{3}{8}$	...	6 $\frac{7}{8}$	...
404	1.06	26.9	2.56	65.0						XLS-5%	5 $\frac{3}{8}$	...	7 $\frac{1}{8}$	...
405	1.34	34.0	2.80	71.1										
					R-2 Series					XLS-5%	5 $\frac{7}{8}$	...	7 $\frac{1}{8}$	...
406	1.54	39.1	3.19	81.0	R-2	.179	...	.325	...	XLS-5%	6	...	7 $\frac{1}{8}$	...
407	1.73	43.9	3.58	91.0	R-2-A	.179	...	.466	...	XLS-5%	6 $\frac{1}{8}$	...	7 $\frac{1}{8}$	...
408	1.97	50.0	3.94	100.0	R-3	.244	...	.466	...	XLS-5%	6 $\frac{1}{8}$	...	7 $\frac{1}{8}$	...
409	2.17	55.1	4.33	110.0	R-4	.310	...	.565	...	XLS-6	6 $\frac{3}{8}$	...	7 $\frac{3}{8}$	...
410	2.44	61.9	4.65	118.0	R-4-A-4	.322	...	.678	...	XLS-6%	6 $\frac{3}{8}$	...	8 $\frac{1}{8}$	...
411	2.64	67.0	5.04	128.0	R-6	.451	...	.799	...	XLS-6%	6 $\frac{1}{2}$	...	8 $\frac{1}{8}$	...
412	2.84	72.1	5.43	138.0	R-8	.625	...	1.025	...	XLS-6%	7 $\frac{1}{8}$	...	8 $\frac{1}{2}$	...
413	3.03	76.9	5.83	148.0	R-10	.750	...	1.250	...	XLS-7	7 $\frac{1}{2}$	...	9	...
414	3.31	84.0	6.54	166.0	R-12	.875	...	1.500	...	XLS-7%	7 $\frac{3}{4}$	...	9 $\frac{1}{4}$	...
415	3.50	88.9	6.93	176.0	R-14	1.000	...	1.750	...	XLS-7%	8	...	9 $\frac{1}{2}$	...
416	3.70	93.9	7.32	186.0	R-16	1.125	...	1.875	...	XLS-7%	8 $\frac{1}{4}$	...	10	...
417	4.06	103.0	7.56	192.0	R-18	1.250	...	2.000	...	XLS-8	8 $\frac{1}{2}$	...	10 $\frac{1}{4}$	...
418	4.25	108.0	8.15	207.0	R-20	1.375	...	2.125	...	XLS-8%	8 $\frac{3}{4}$	...	10 $\frac{1}{2}$	...
419	4.30	109.0	9.10	231.0	R-22	1.500	...	2.375	...	XLS-8%	9	...	11	...
420	4.75	120.0	9.64	245.0	R-24	1.625	...	2.500	...	XLS-8%	9 $\frac{1}{4}$	...	11 $\frac{1}{4}$	...
421	5.10	129.0	10.52	267.0						XLS-9	9 $\frac{1}{2}$	...	11 $\frac{1}{2}$	...
422	5.42	137.0	11.57	294.0						XLS-9%	10 $\frac{1}{4}$	...	12 $\frac{1}{4}$	...
					XLS Series									
1900	.44	11.2	.82	20.8	XLS-1%	1 $\frac{1}{16}$	...	2 $\frac{1}{8}$	...	XLS-10	10 $\frac{3}{8}$	...	12 $\frac{3}{8}$	...
1901	.52	13.2	.90	22.9	XLS-1%	1 $\frac{1}{16}$	...	2 $\frac{1}{2}$	...	XLS-10%	11 $\frac{1}{8}$	...	13 $\frac{3}{8}$	...
1902	.64	16.3	1.06	26.9	XLS-1%	1 $\frac{1}{16}$	...	2 $\frac{11}{16}$	...	XLS-11	11 $\frac{1}{8}$	...	13 $\frac{1}{4}$	...
1903	.71	18.0	1.14	29.0	XLS-1%	1 $\frac{1}{16}$	...	2 $\frac{15}{16}$	...	XLS-11%	12 $\frac{1}{8}$	...	14 $\frac{3}{8}$	...
1904	.85	21.6	1.39	35.3	XLS-1%	2 $\frac{1}{16}$	...	3	...	XLS-12	12 $\frac{1}{8}$	...	15 $\frac{3}{8}$	...
1905	1.05	26.7	1.57	39.9	XLS-2	2 $\frac{1}{16}$	...	3 $\frac{1}{8}$	...					
1906	1.25	31.8	1.79	45.5	XLS-2%	2 $\frac{3}{16}$	...	3 $\frac{1}{16}$	...					
1907	1.46	37.1	2.08	52.8	XLS-2%	2 $\frac{1}{2}$	...	3 $\frac{1}{16}$	...					
1908	1.68	42.7	2.34	59.4	XLS-2%	2 $\frac{3}{8}$	...	3 $\frac{1}{2}$	...					
1909	1.88	47.8	2.57	65.3	XLS-2%	2 $\frac{3}{8}$	...	3 $\frac{3}{8}$	...					
1910	2.06	52.3	2.74	69.6	XLS-2%	2 $\frac{1}{2}$	...	3 $\frac{1}{8}$	...					
1911	2.29	58.2	3.02	76.7	XLS-2%	3	...	3 $\frac{1}{4}$	...					
1912	2.49	63.2	3.22	81.8	XLS-2%	3 $\frac{1}{16}$	...	4 $\frac{1}{16}$	...					
1913	2.68	68.1	3.42	86.9	XLS-3	3 $\frac{1}{16}$	...	4 $\frac{1}{16}$	...					
1914	2.91	73.9	3.78	96.0	XLS-3%	3 $\frac{1}{16}$	...	4 $\frac{1}{16}$	...					

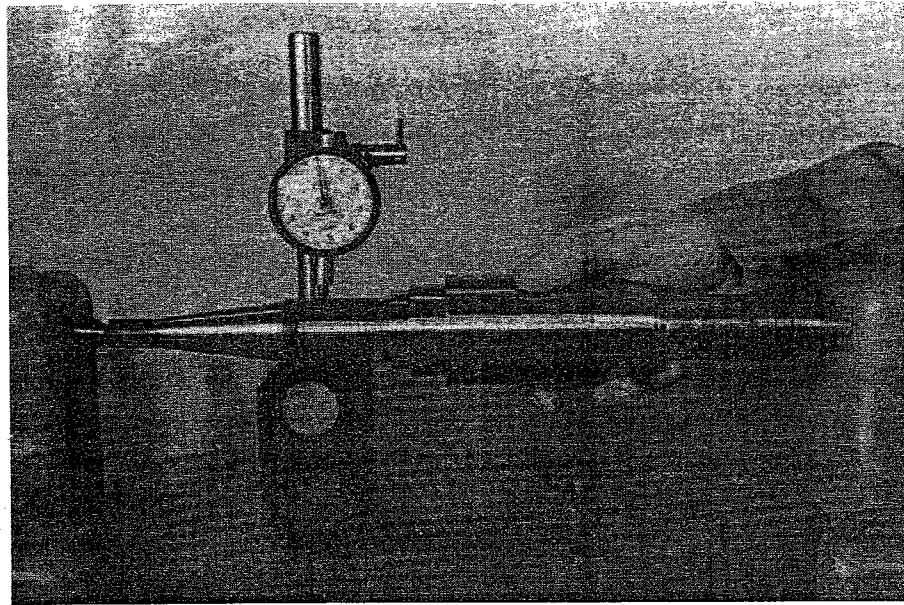


Figure 7-28. A hand gauge may be used to check the bearing seat for out-of-round.

Check Bearing Seat for Out-of-Round

A simple check may be made with a hand gage on the bearing seat (Figure 7-28). This will provide a reading at two points on the shaft 180° apart. However, it does not indicate how those points are related to other points on the shaft.

For a more accurate reading on out-of-round (radial runout) of a bearing seat, mount the shaft between centers and place a suitable indicator in a position perpendicular to the axis of the shaft and contacting the bearing seat. On rotating the shaft slowly by hand, a check is obtained on all points of the shaft which the indicator contacts (Figure 7-29).

Another method of measuring out-of-round is the three-point method using a set of V-blocks and a dial type indicator (Figure 7-30). The shaft should lay in the V-blocks and be rotated slowly while the indicator is centrally located between the points of shaft contact with the V-blocks and perpendicular to these lines of contact. This method will reveal out-of-round which would not have been found by the two-point method of gauging. Therefore, if the equipment is available, it is desirable to check bearing seats using centers or V-blocks as well as two-point gauging.

In all of these checks, the gauge should be placed in different locations on the bearing seat. This will give assurance that the seat is within the recommended tolerances in all areas. While the spindle is mounted on centers, the high point of eccentricity of the bearing seat should be located. Using a dial type indicator, find the point and mark it with a crayon so



Figure 7-29. By rotating the shaft by hand, a check is obtained on all points the indicator contacts.

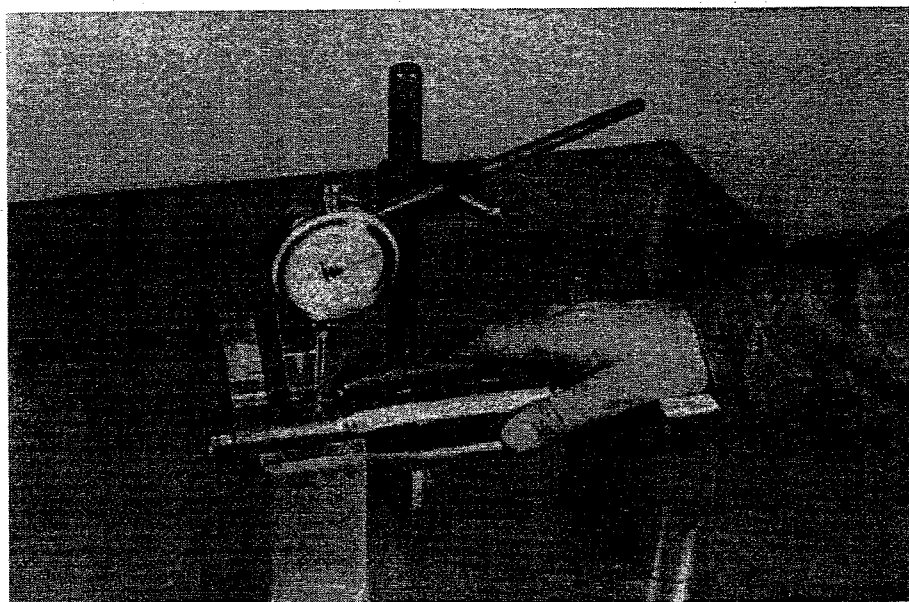


Figure 7-30. The three-point method.

that it can be easily located when the bearing is to be remounted. The high point of eccentricity is covered in more detail later.

Check Shoulders for Off-Square (Figure 7-31)

The shaft shoulder runout should be checked with an indicator contacting the bearing locating surface on the shaft shoulder while the shaft

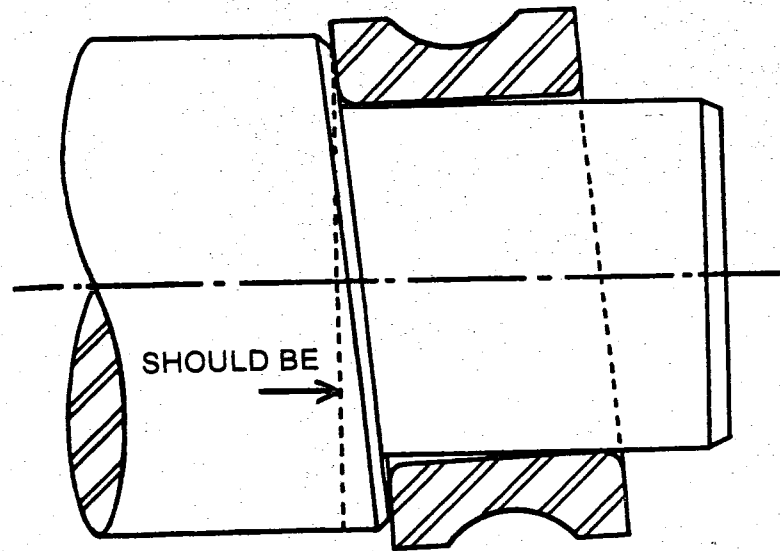


Figure 7-31. Checking shoulders for off-square.

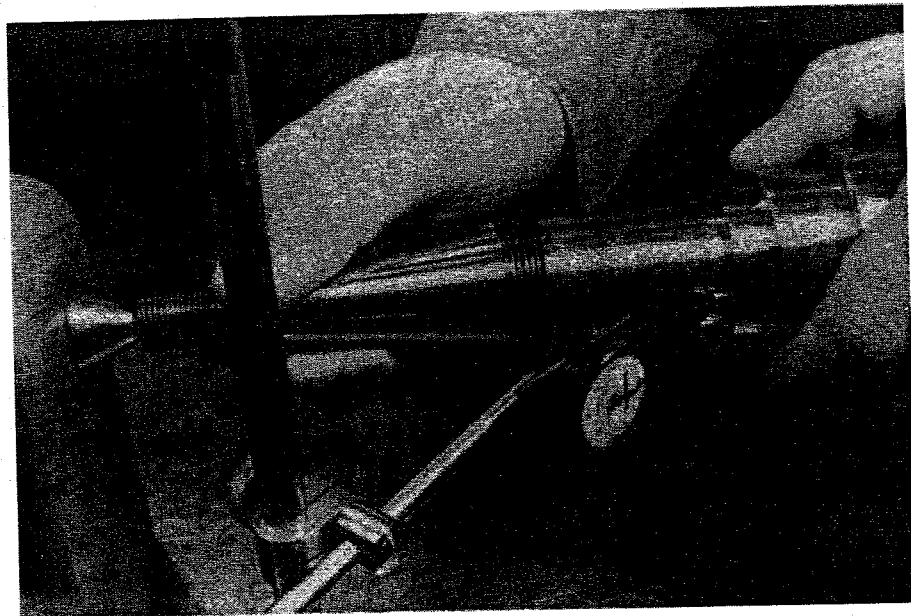


Figure 7-32. If runout is outside established tolerances, the inner ring of the bearing will be misaligned.

is still supported on centers (or V-blocks) with the center of the shaft against a stop. Tolerances have been established for this. If the runout is outside these tolerances, the inner ring of the bearing will be misaligned causing vibrations when the spindle is in operation (Figure 7-32).

Check Housing Bore Dimensions

The housing bore dimensions and shoulder should be checked to make sure that they are within the recommended tolerance for size, out-of-

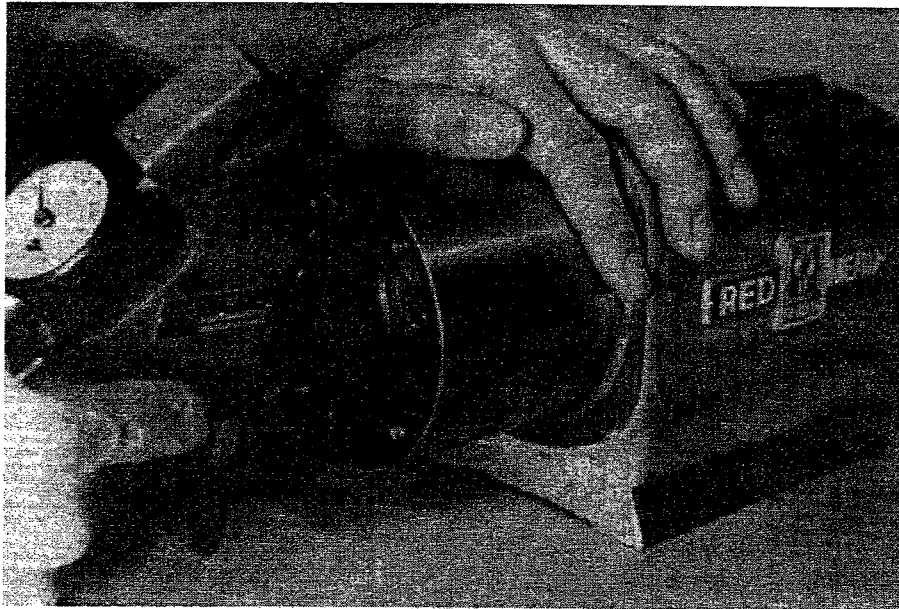


Figure 7-33. Indicator-type gauge commonly used to check housing bore dimensions.

round, taper, and off-square. The gauge commonly used for this purpose is an indicator type (Figure 7-33).

Recheck Dimensions if Necessary

It is important to be absolutely sure that all dimensions are correct before any assembly is begun. If there is any question, a recheck should be made. If variations are noted, the shaft should be repaired to obtain the correct measurements and then rechecked for accuracy and compliance with the recommended tolerances.

Duplex Bearings

Many methods are used to mount bearings because of various machine tool spindle designs. The simplest spindles incorporate two bearings, one at each end of the shaft. Others are more complicated using additional bearings mounted in specific combinations to provide greater thrust capacity and shaft rigidity. As duplex bearings are usually used in these instances, mounting arrangements for duplex bearings should be understood before actual spindle assembly is begun.

Duplex bearings are produced by specially grinding the faces of single-row bearings with a controlled relationship between the axial location of the inner and outer ring faces. A cross section of a duplex bearing set in back-to-back relationship is shown in Figure 7-34. Note that it consists of

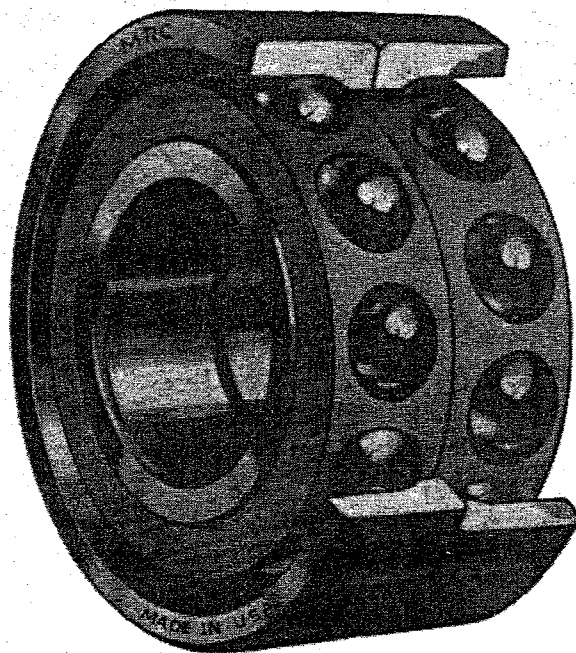


Figure 7-34. Duplex bearings set in back-to-back relationship.

two identical bearings placed side by side. The two units of the pair are clamped tightly together on the shaft with adjacent backs (or faces if DF type) of the inner and outer in actual contact.

Certain definite characteristics and advantages are derived from this mounting which make duplex bearings particularly applicable to several kinds of difficult service and loading conditions. They are recommended for carrying pure radial or thrust loads, or combined radial and thrust loads. Through their use, it is possible to minimize axial and radial deflections thereby, for example, increasing the accuracy of machine tool spindles.

Before explaining the basic mounting methods, it is necessary to understand the difference between the face and back of a bearing as well as to know what a contact angle is.

Referring to the bearing drawing in Figure 7-35, note that the counter-bored low shoulder side of the bearing is called the “face” side. The deep shoulder side (also called high side), stamped with the bearing number and other data, is designated as the “back” side.

As defined by AFBMA standards, a contact angle is the nominal angle between the line of action of the ball load and a plane perpendicular to the bearing axis (Figure 7-36). Essentially, this means that when a load is applied to a bearing, it forces the balls to contact the inner and outer raceway at other than a right angle (such as in a Type S bearing).

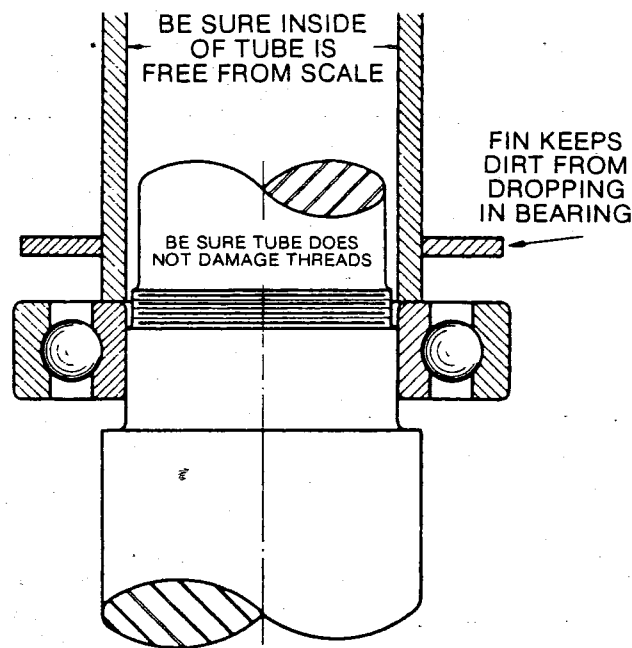


Figure 7-63. Arbor press and hollow tube method used to mount bearings on shafts when press fits are involved.

When doing so, the press and the tube should be completely clean to avoid possible contamination of the bearing. The tube must contact the inner ring when pressing the bearing on the shaft (Figure 7-64). This will avoid possible brinelling of the bearing which might occur if pressure were applied on the outer ring. The press ram, tube, and bearing axis should be in good alignment. If abnormal pressures are required, the alignment probably is not good enough. In this case, alternate application of pressure and relief may help ease the pressure required.

Exercise Caution When Starting Bearing On Shaft

To start the bearing, the shaft should have a lead and the bearing face should be square with the shaft (Figure 7-64). Pressure should be in line with the shaft and must be uniform against the face when pressing the bearing into place. If excessive binding occurs, it generally indicates an off-square condition, a burr, high spots, a tapered shaft, dirt or chips wedged under the bearing. When sticking or binding occurs, the bearing should not be forced on the shaft as the hard inner ring is apt to cut the softer metal of the shaft and raise a ridge or burr (Figure 7-65). Remove the bearing from the shaft to determine and correct the problem.

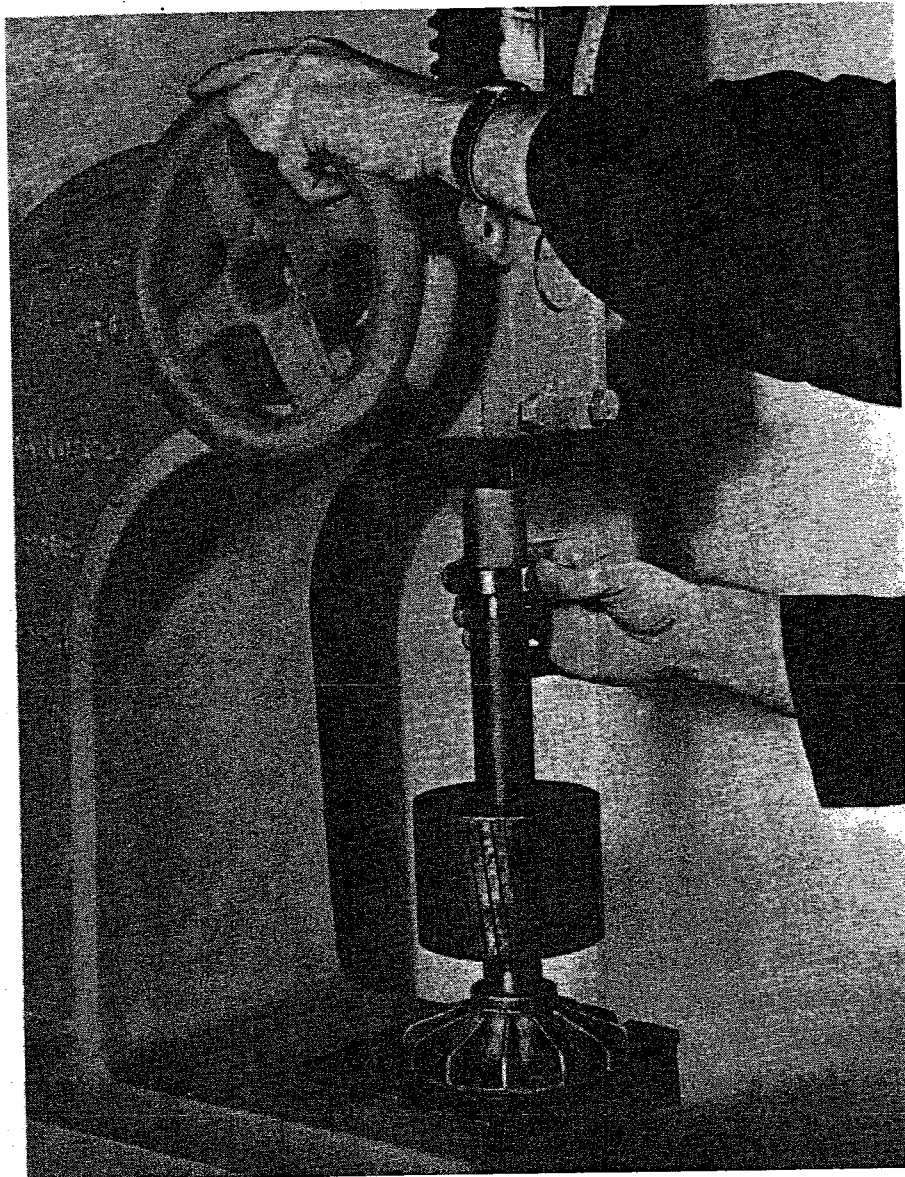


Figure 7-64. Bearing may be pressed on shaft using a tube and arbor press.

Checking Bearings and Shaft After Installation

After the bearings have been assembled on the shaft, a number of points should be checked to make certain the bearings have been correctly installed. These include visual checks and the use of various gauges to determine the accuracy of the mounting. It also may be necessary to balance the shaft assembly before insertion into the housing.

Check for Internal Clearance

The outer rings should rotate freely without binding except in unusual cases where a tight fit has been specified or where preloaded duplexed

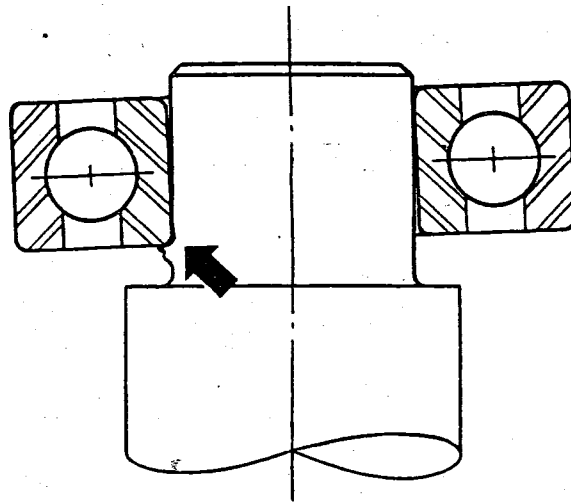


Figure 7-65. Result of starting bearing off-square.

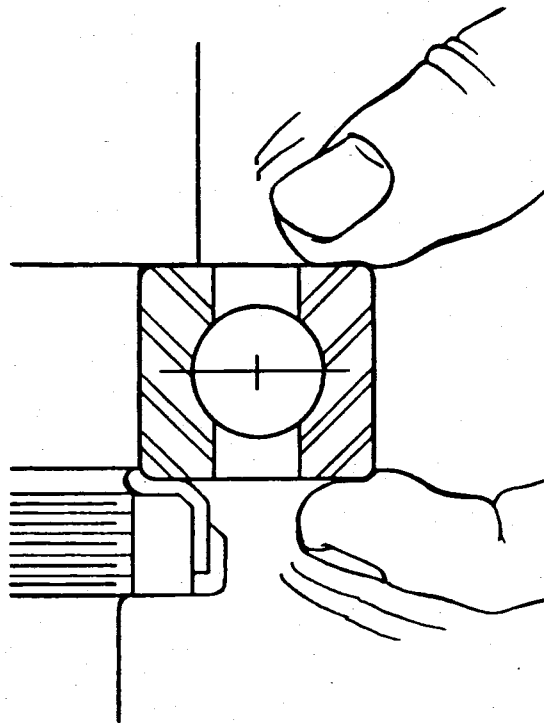


Figure 7-66. Check a mounted bearing for internal clearance by rocking outer ring back and forth.

bearing sets are used. Residual internal clearance can be felt by holding the outer ring between the thumb and forefinger (Figure 7-66) and rocking it back and forth. If the bearing is free, the ring will have a slight axial freedom of movement or "rock." This applies to all single-row bearings except a single bearing of the angular-contact type which is very loose.

Make Visual Check of Bearing

Be sure that the bearing is flush against the shaft shoulder all the way around. The best simple check for this is to hold the shaft in front of a light source such as a window or an electric light. If no light shows between the inner ring face and the shaft shoulder, the bearing may be considered in proper position. This check should be made all the way around the shaft. If light is visible at any point, carefully remove the bearing and recheck the shoulder and fillet for burrs, out-of-round or too large a radius on the fillet.

Check the height of the shoulder against the height of the inner ring. In general, it should be a minimum of about half the width of the inner ring face. If heavy thrust pressures are involved, the shoulder should be higher.

Check for Bearing Squareness on the Shaft

Check the face of the outer ring for squareness of the inner ring with the shaft using a suitable indicator (Figure 7-67). The assembled front and rear bearings or sets of bearings should be placed in V-blocks with an indicator point contacting the face of the outer ring. When the shaft and inner rings are turning, any off-square condition is transmitted through the balls to the outer ring. This will cause the outer ring to rock or tilt and shows up as a variation on the indicator reading. Readings in excess of the bearing tolerances indicate an effective misalignment, resulting from an off-square condition.

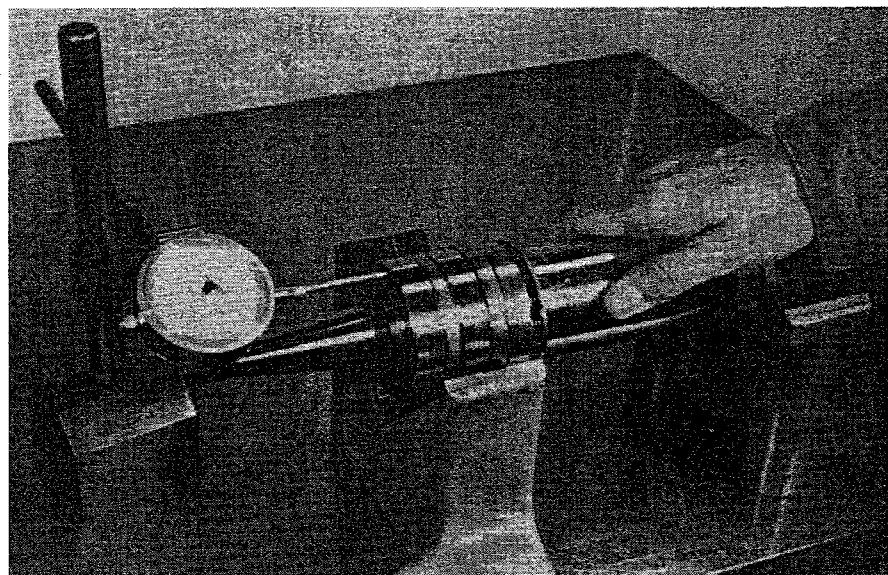


Figure 7-67. Checking for squareness of bearing on shaft.

Foreign matter between the bearings and shaft shoulder, fillet interference, a nick on the shaft shoulder, raised metal from the bearing seat, a nick on the spacer rings, and many other causes will produce this off-square condition. Under these circumstances, remove the bearing from the shaft to determine the actual cause and make the necessary repairs.

Balancing the Shaft Assembly

After the bearings and other units such as pulleys, etc., are properly seated on the shaft, the assembly should be balanced, preferably dynamically, to obtain a smooth-running spindle (Figure 7-68). All parts that rotate with the assembled spindle should be included in the balancing operation with whatever is applied to retain the bearings on the shaft.

Common Causes of Unbalance in Shaft Assemblies

Unbalance is commonly introduced through an eccentricity in some portion of the shaft assembly that has not been properly finished. Eccentricities may be present in the components affixed to the shaft. Ground bearing seats may not be concentric with turned portions of the assembly. Strains may develop in a shaft that has been heat-treated, causing warp in the shaft that may create misalignment of the bearings. In other cases, a thread may not be true to the shaft center. If the bore of the bearing spacer is too loose when used, it may not be properly centered with respect to the shaft axis. Causes of unbalance could include other factors in addition to these items.

Correction of Unbalanced Shaft Assemblies

There are several methods to correct unbalance in either hardened or soft shafts. In general, balancing consists of removing material from the heavy side of the shaft or adding material to the light side of the shaft. Any balancing operations should be conducted in an area removed from the clean assembly area.

To balance a hardened shaft, sufficient material usually is removed to create proper balance by grinding on the heavy side of the shaft nearest the end which needs to be balanced. The grinding is usually done on a portion of the shaft where the largest diameter occurs.

Several methods may be used to bring a soft shaft into balance. It is possible to apply a correct amount of weight. It may be preferable to drill

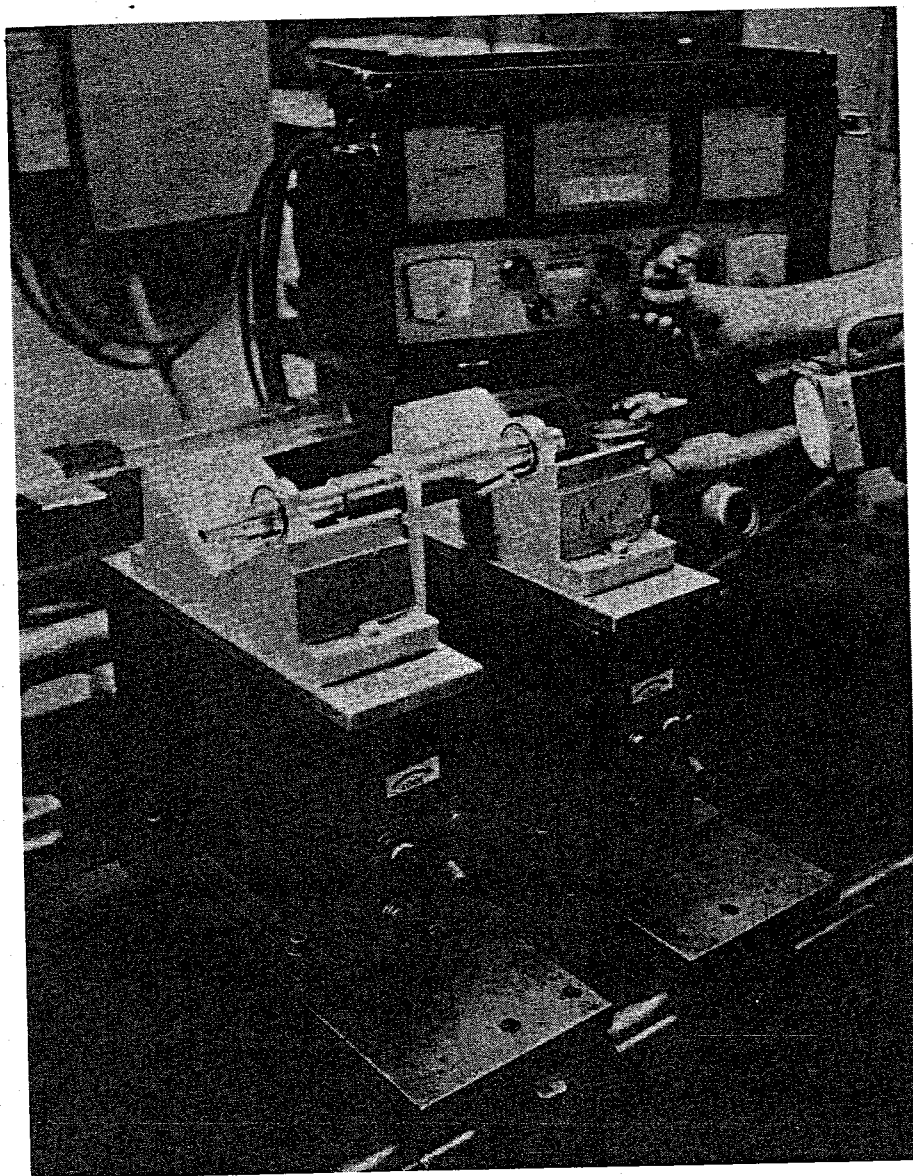


Figure 7-68. Dynamics of balancing spindle assembly. This equipment is used by TRW's Spindle Maintenance Department, but other types are available which will balance assemblies as accurately as necessary.

a hole of the correct size and depth in the shaft. Metal generally is removed from the shaft in the area of the largest diameter and at the greatest possible distance from the center of the shaft toward the end which must be balanced. Extreme care must be taken to prevent the removed metal from being introduced into the bearings mounted on the shaft.

Protect Bearings and Shaft Assembly from Contamination

After a ball bearing has been mounted on a shaft, often there is a time interval, possibly overnight, before final installation in the housing can be

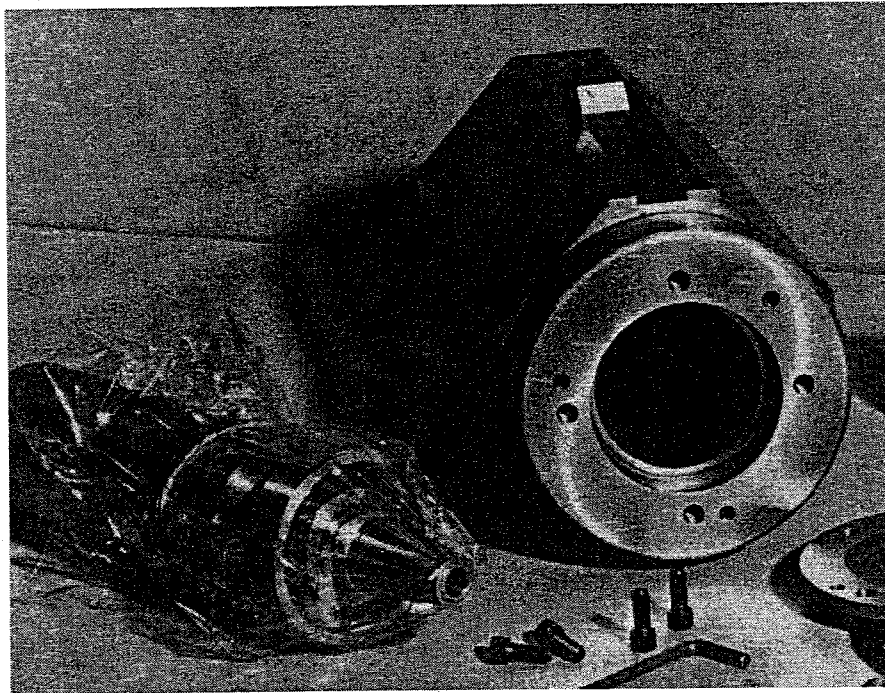


Figure 7-69. Protect bearings and shaft from contamination until assembled and completely sealed in housing. Use plastic film to cover spindle.

started. In such cases, it is advisable to wrap the bearings and shaft in plastic film to protect them from contamination (Figure 7-69). If the bearings are left exposed on the shaft, or even when installed in the housing, dust and/or other contaminants may enter the bearing. If installed in the housing, always be sure to cover the open end with film until all assembly work is completed and the housing is completely closed.

Assembly of Shaft and Bearings into Housing

After the bearings have been assembled on the shaft, checked and balanced, the entire assembly is ready for insertion into the housing (Figure 7-70) in accordance with the methods outlined in the manufacturer's manual. During this operation, care must be taken to start the bearings into the housing seats squarely to avoid damage to the bearings or housing. Any force exerted on the shaft passes through the bearings and, if excessive, can cause bearing damage.

The outer ring generally should have a slightly loose fit in the housing. This is necessary to permit the bearing axial movement to assume its normal operating position regardless of temperatures which occur during operation. If the bearing is too tight, axial movement is prevented and violent overloads could result in nonfixed radial positioning of the shaft.

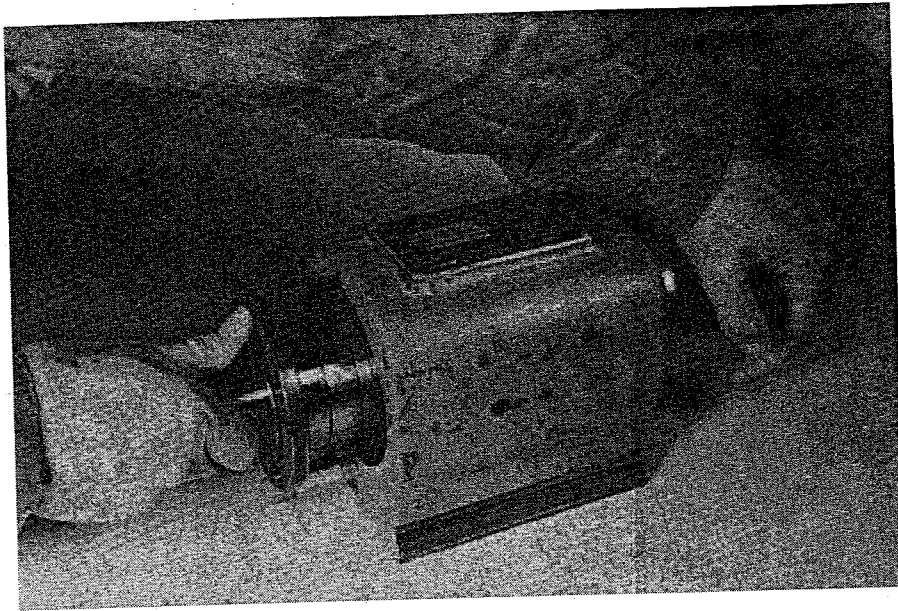


Figure 7-70. Start bearings into housing seat squarely to avoid damage to either bearings or housing. A "push" fit should be used.

This causes noisy operation, excessive fretting and pounding out of the housing seat and, occasionally, excessive spinning in the housing.

Testing of Finished Spindle

When the spindle has been completely assembled, a final check of the eccentricity should be made as follows. Place an indicator point against the center of the shaft extension on the work end of the spindle and rotate the spindle by hand (Figure 7-71). Where possible, the opposite end of the spindle also should be checked. Sometimes it is possible to detect roughness or vibration in the spindle when turning the shaft by hand. Roughness may be felt as a hitch or click. Do not attempt to run the spindle if these conditions are major. Dismantle it and find the cause of the roughness. The cause may be the application of excessively dirty lubricant or dirt that has worked its way into the bearing during assembly. Under conditions of slow rotation, necessary cage looseness also may create some binding which disappears when running to speed and under load.

Vibration is usually detected when the spindle reaches its normal operating speed. Causes of vibration include excessive runout of the pulley, a loose cap on the spindle assembly, bearings damaged in assembly, or possibly loose bearing spacers. In any case, when vibration is detected, spindle run-in should be discontinued to investigate the cause.

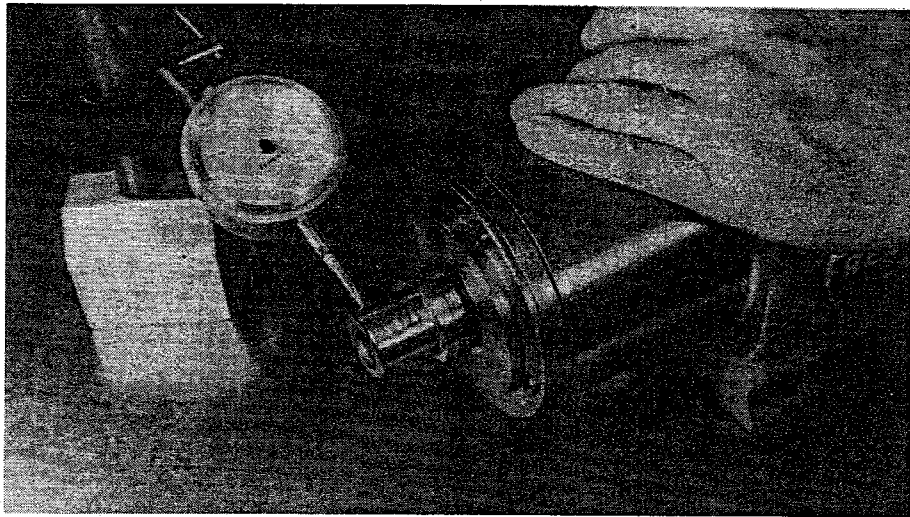


Figure 7-71. Check eccentricity of assembled bearing with indicator gage on shaft extension.

During run-in, a close check should be kept on the temperature attained, especially in the first part of the run. This is particularly true for spindles which are grease-packed. If the heat becomes excessive, over 140° to 150°F (60° to 66°C), it is usually advisable to stop the spindle and permit it to cool off. This type of excessive heat is commonly caused by insufficient channeling of the lubricant in the spindle. Stopping the spindle will allow the temperature to equalize, reducing the risk of radial or axial preloading. When restarted, the spindle usually will run at temperatures within the recommended range unless excessive quantities of grease are in the housing or if overloads are present. If the spindle continues to heat excessively, checks should be made to determine the cause.

Maintain Service Records on All Spindles

The maintenance department in any company should keep records regarding the history of each shaft or spindle serviced (Figure 7-72). All particulars should be recorded from the day the spindle was placed in operation until retirement. Such a record may be as complete and detailed as possible. It may simply record dates when the spindle or shaft was checked to correct certain conditions. In either case, it is recommended that the record state clearly the corrective actions taken to place the spindle in proper operating condition.

Shop records also will enable the maintenance department to keep a close periodic check on spindles throughout the plant. It is possible to establish a regular inspection procedure which will help assure continued

SPINDLE BALANCE DATA									
DATE REC'D		LUBRICATION		MODEL					
RPM		ORIGINAL BEARING USED		MFG. BY					
DRIVE		FRONT		HALF BEARING SIZE		MOTOR PULLEY SIZE		SERIAL NO.	
		REAR		BEARING CENTERS		CORRECTION METHOD		FRONT MRC BEARING & SPEC.	
								REAR MRC BEARING & SPEC.	
DATE REPAIRED		DATE OFF		HOURS RUN		MACH. MODEL		MRC SERIAL NO.	
								OPERATION	
								OPERATOR NO.	
								REPAIR TIME	
								REASON FOR REMOVAL	

ANALYSIS OF BEARING						
SIZE	LOCATION	ANDEROMETER READINGS			REMARKS	REASON FOR FAILURE
		LOW	MED.	HIGH		

Figure 7-72. Form provides space to record complete history of spindle from date of purchase.

spindle operation. This will reduce machine downtime, always a factor in maintaining a low cost operation.

Shaft and Housing Shoulder Diameters

Table 7-4 shows minimum shaft shoulder diameters for general purpose installations.

Bearing Maintenance Checklist

Finally, we direct your attention to Table 7-6, which summarizes all necessary bearing maintenance steps in checklist form.

Table 7-6
Bearing Maintenance Checklist

Don't	Recommended Action
Don't open the bearing box until you are ready to install the bearing.	Leave the bearing in the manufacturer's box and protective wrapping until it is necessary to remove it for installation. The package is designed to protect the bearing from contamination and keep it in factory fresh condition.
Don't work in an area having a hostile environment.	Ideally areas designated for bearing installation should have controlled humidity, controlled temperature and clean air to help prevent bearing exposure to particulate or corrosive contamination.
Don't work on bench tops that are not in good condition.	The working surface should be material that is not likely to produce contamination by abrading or chipping. Splinter-free wood, phenolic composition, hard rubber or smooth metal are satisfactory surfaces for this kind of work.
Don't work on a dirty bench top.	Make certain that the working surface is free from contamination that could find its way into the bearing or corrode the bearing surfaces.
Don't force the bearing off the shaft by uneven pressure or with hammer blows if you plan to reuse the bearing.	Use a bearing puller or an arbor press with adapters which will exert a balanced load on the inner ring face. This avoids a static load on the balls and possible shaft damage.
Don't place the shaft assembly in a dirty area when it has been removed from the housing.	After the shaft assembly has been removed from the unit it should be protected from contamination and corrosion by placing it in a clean covered container, or covered with a lint and dirt-free material such as plastic film. Rotating a contaminated bearing will damage the ball and race surfaces.
Don't strike or apply pressure to the ball cage while the bearing is being dismounted.	Select the proper removal tools and adapters to insure that a load is not applied to the balls through the cage.

(Table continued on next page)

Table 7-6
Bearing Maintenance Checklist—cont'd

Don't	Recommended Action
Don't use improper tools to remove the bearing from the shaft.	Study the assembly and select the removal method, tools and fixtures that are least likely to cause damage to the bearing or the shaft.
Don't apply pressure to the outer ring of the bearing when removing it from the shaft if it can be avoided.	Remove bearings from the shaft with pressure on the inner ring face to prevent loading the balls. In those applications where the only surface available for pulling the bearing is the outer ring face, care should be taken to pull evenly and smoothly. The bearing should then be examined for possible damage.
Don't damage seals or shields of the bearing while it is being removed.	Place bearing puller jaws on adapter or inner ring as required by the method of mounting. This will avoid damage to the seals or shields caused by possible contact with the puller.
Don't push a bearing from the housing with pressure on the inner ring in applications where the bearing is a tight fit in the housing unless it cannot be avoided.	Use a section of rod or tubing slightly smaller than the bore of the housing. This will apply pressure to the outer ring face and will not brinell the bearing by actually loading the ball assembly.
Don't overlook scuff marks, burrs, nicks or other indications of damage on the bearing locating surfaces during inspection of the shaft and housing.	Carefully inspect the bearing locating surfaces and correct any damaged areas that could prevent intimate contact between the bearing and the locating surfaces.
Don't make shaft or housing repairs which may cause contamination or produce wear products in the clean assembly area.	Remove any parts from the clean assembly area when performing procedures that produce wear products, such as reworking with abrasives. Make certain the parts are clean before reintroducing them into the clean assembly area.
Don't allow too large a fillet radius between the shaft seat and the shaft shoulder or the housing seat and the housing shoulder.	Make sure the radius in each location is no larger than recommended in the bearing manufacturer's catalog. If the radius is large enough to act as a bearing locating surface it is very likely to result in bearing misalignment or ring distortion.
Don't regrind shaft shoulders without breaking corners.	Break corners while the shaft is still mounted on centers. Removal of burrs, etc. on the corners will permit proper seating of the inner ring against the shaft shoulder. Also it makes the shaft less susceptible to damage.
Don't nick or scratch housing bearing locating surfaces.	The housing bearing locating surfaces should be examined for indications of damage. Any damage found that could prevent proper location of the bearing outer ring in the housing must be corrected.
Don't wash the original lubricant from a new bearing.	New bearings are either prelubricated with grease or protected with a preservative that is compatible with most bearing lubricants. It will continue to protect the bearing until the unit is put into service.

Table 7-6
Bearing Maintenance Checklist—cont'd

Don't	Recommended Action
Don't allow a bearing to spin rapidly when drying it with compressed air.	When drying a bearing with compressed air, hold both the inner and outer rings to prevent them from rotating. Spinning an unloaded bearing in this manner can result in ball and race surface damage caused by the balls skidding against the race surfaces.
Don't neglect to clean the shaft and housing and flush out oil lubricating systems.	Remove both free and caked-on deposits from all parts of the shaft and housing assembly. This will provide clean parts which will not contaminate bearings with dirt, etc. when the spindle is reassembled and run.
Don't paint bearing seats in housing.	It is a good practice to seal the internal surfaces of the housing using a sealer that is made for this purpose. It will reduce the presence of core sand and other particles which could contaminate the bearing lubricant. The bearing locating surfaces should not be painted.
Don't mount bearings until the high point of eccentricity of the shaft has been determined.	Align bearing high points of eccentricity and mount them 180° from the high point of eccentricity on the shaft. This practice reduces the radial runout to a minimum.
Don't mount counterbored type bearings in a manner that will allow the thrust load to be imposed on the low shoulder side of the outer ring race.	A thrust load applied to a counterbored type bearing must be applied in such a manner that it will be carried on the high shoulder side of the outer ring race. The face of the outer ring on the thrust-carrying side will be marked "THRUST HERE."
Don't use two or more bearings as a pair or set of bearings unless they have been properly duplex ground for use in this manner.	MRC brand bearings that have been duplex ground to be used as a component in a pair or set of bearings are identified by the letter "D" as a suffix to the bearing number. The suffix will be DU for bearings that have been duplexed to have no end play and no preload when mounted in a back-to-back or face-to-face arrangement. The suffix DS identifies the bearings duplex ground for either preload or negative preload (end play) when matched either back-to-back or face-to-face. Bearings mounted in a tandem arrangement must also have the same suffix.
Don't mix duplex bearings and spacers which have been removed from the shaft if old bearings are to be reused.	Replace bearings and spacers in exactly the same position as they were before removing them from the shaft. Any change in position of the components is likely to result in a change in preload in the bearing pairs or sets.
Don't use spacers which are not equal in length.	The preload ground into a pair or set of bearings will be altered in applications where spacers are used between bearings if the spacer between the inner ring faces is not exactly the same length as the spacer between the outer ring faces. It is also essential that the faces of the spacers must be ground parallel and remain free from damage.

(Table continued on next page)

Table 7-6
Bearing Maintenance Checklist—cont'd

Don't	Recommended Action
Don't attempt to adjust preload which is built into the bearings.	Use only bearings that have been duplexed for the proper amount of preload for the application. Attempts to adjust preload by using spacers that are not the same length are likely to result in unsatisfactory bearing operation or possibly premature bearing failure.
Don't use worn V-blocks or centers for measuring the geometry of shaft bearing seats.	Use a good set of centers and clean center holes for accuracy. Worn centers or V-blocks can result in misleading results when measuring the concentricity of the shaft seats to the shaft center.
Don't force a bearing on the shaft seat in applications where an interference fit between the bearing shaft seat is not specified.	In applications where an interference fit between the bearing and the shaft is not called for, either strong finger pressure or a very light press is all that should be necessary to mount the bearing. If more pressure is required the shaft bearing seat diameter should be measured to insure that it is not oversized. Too tight a fit on the shaft will remove an excessive amount of internal clearance, or may alter the preload in a pair of bearings.
Don't overheat the bearings when trying to expand the inner rings to facilitate mounting them on to the shaft seat.	Use a thermostatically controlled heat source to heat bearings. Excessive temperatures can result in softening of the parts, loss of dimensional stability and damage to non-metallic separators.
Don't hold the shaft in a metal vise without protecting the shaft from the vise jaws.	Cover the vise jaws with wood or soft metal. This will avoid marring or nicking of the shaft.
Don't press bearings onto the shaft seat in an off-square manner.	Be very careful to start the bearing onto the shaft seat squarely and to use tooling or fixtures that are accurate enough to maintain squareness between the bearing and the shaft center. Off-square mounting is likely to damage the shaft seat or the bearing. Shaft seats that are damaged in this manner would not allow the bearing inner ring to have intimate contact with the ring locating surfaces.
Don't balance spindle with parts missing that will be rotating with the spindle in the final assembly.	Balance shafts with the entire bearing and pulley assembly as well as assembled accessories. This will eliminate any possible unbalance when the unit is completely assembled.
Don't leave bearings unprotected for any significant length of time.	After the bearings have been removed from the manufacturer's package they should never be left unprotected for a significant length of time. If the bearings are not mounted they can be repackaged or protected by wrapping them in a suitable material. If they have been mounted, the entire assembly should be wrapped or covered with a suitable material such as plastic film.
Don't overlubricate the bearings.	Too much grease or oil will result in excessive heat generation and can lead to unsatisfactory operation of the bearings or shorten the bearing life.
Don't use a lubricant that hasn't been protected from contamination.	Contaminated lubricant is a major cause of premature bearing removal. Lubricants should always be stored in a clean, covered container.

Chapter 8

Repair and Maintenance of Rotating Equipment Components

Pump Repair and Maintenance*

Sealing performance, bearing, and seal life will depend to a great extent upon the operating condition of the equipment in which these components are used. Careful inspection of the equipment will do much to minimize component failure and maintenance expenses.

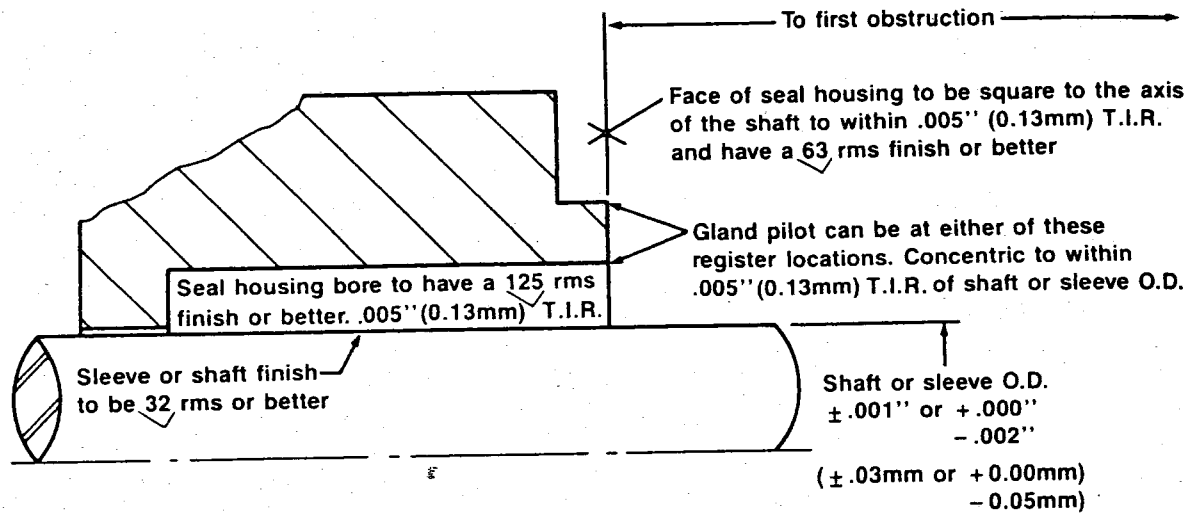
Following is a list of the major trouble spots.

1. **Seal housing.** The seal housing bore and depth dimensions must match those shown on the seal's assembly drawing within ± 0.005 in. (± 0.13 mm). Shaft or sleeve dimensions must be within ± 0.001 in. (± 0.03 mm). See Figure 8-1 for complete seal housing requirements.
2. **Axial shaft movement.** Axial shaft movement (end play) must not exceed 0.010 in. (0.25 mm) Total Indicator Reading (T.I.R.) To measure axial movement, install a dial indicator with the stem bearing against the shaft shoulder as shown in Figure 8-2. Tap the shaft—first on one end then the other—with a soft hammer or mallet, reading the results.

Excessive axial shaft movement can cause the following problems:

- Pitting, fretting, or excessive wear at the point of contact between the seal's shaft packing and the shaft (or sleeve) itself. It is sometimes helpful to replace any PTFE shaft packings or secondary sealing elements with those made of the more resilient elastomer materials to reduce fretting damage.

* Courtesy of Flowserve Corporation, Kalamazoo, Michigan 49001.



- Bearings must be in good condition.
- Maximum lateral or axial movement of shaft (end play) $-.010''$ (0.25mm) T.I.R.
- Maximum shaft runout at face of seal housing $-.003''$ (0.07mm) T.I.R.
- Maximum dynamic shaft deflection at face of seal housing $-.002''$ (0.05mm) T.I.R.

Figure 8-1. Seal housing requirements.

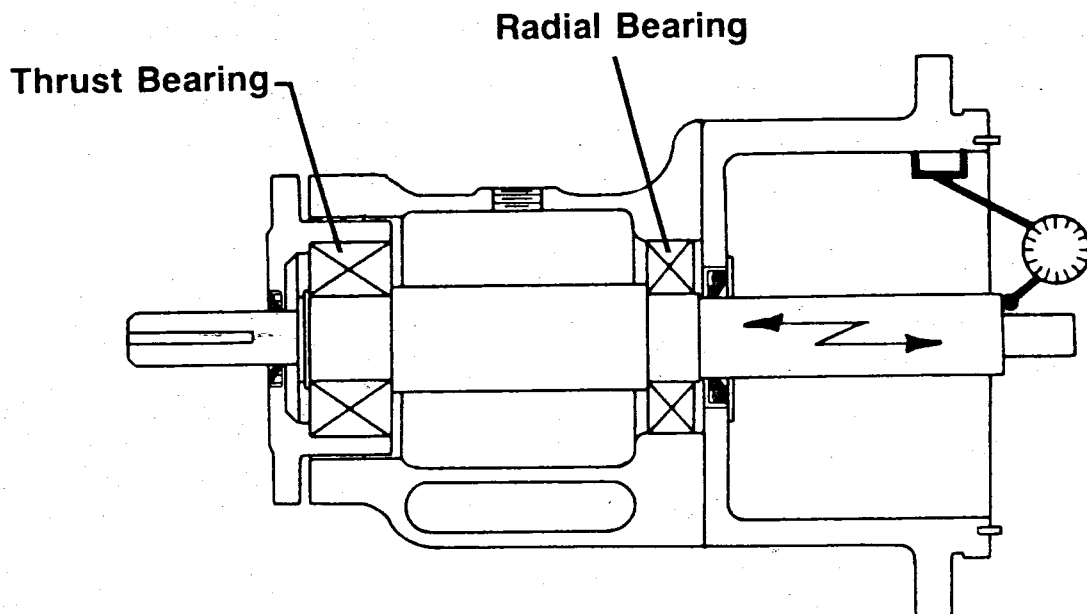


Figure 8-2. Checking for end-play.

- Spring overloading or underloading and premature seal failure.
 - Shock-loaded bearings, which will fail prematurely.
 - Chipping of seal faces. Carbon and silicon carbide faces are especially vulnerable to axial shaft movement.
3. **Radial shaft deflection.** Radial shaft deflection at the face of the seal housing must not exceed 0.002 in. (0.05 mm) T.I.R. To measure radial movement, install a dial indicator as close to the seal housing

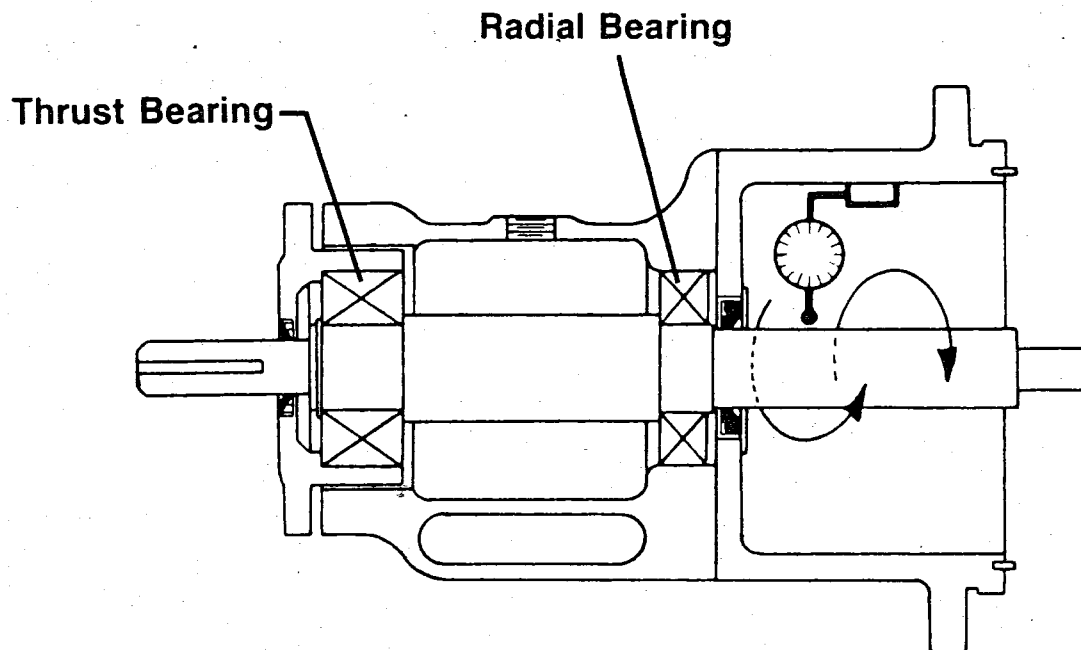


Figure 8-3. Checking for whip or deflection.

face as possible (see Figure 8-3). Lift the shaft or exert light pressure at the impeller end. If movement is excessive, examine for damaged radial bearings and bearing fits—especially the bearing cap bore.

Excessive radial shaft movement can cause the following problems:

- Fretting of the shaft or sleeve
 - Excessive leakage at the seal faces
 - Excessive pump vibration, which can reduce seal life and performance
4. **Shaft sleeve run-out.** Shaft run-out (bent shaft) must not exceed 0.003 in. (0.07 mm) at the face of the seal housing. Clamp a dial indicator to the pump housing as shown in Figure 8-4, and measure shaft run-out at two or more points on the outside dimension of the shaft. Also measure the shaft run-out at the coupling end of the shaft. If run-out is excessive, repair or replace the shaft.
Excessive run-out can shorten the life of both the radial and the thrust bearings. A damaged bearing, in turn, will cause pump vibration and reduce the life and performance of the seal.
 5. **Seal chamber face run-out.** A seal chamber face which is not perpendicular to the shaft axis can cause a serious malfunction of the mechanical seal. Because the stationary gland plate is bolted to the

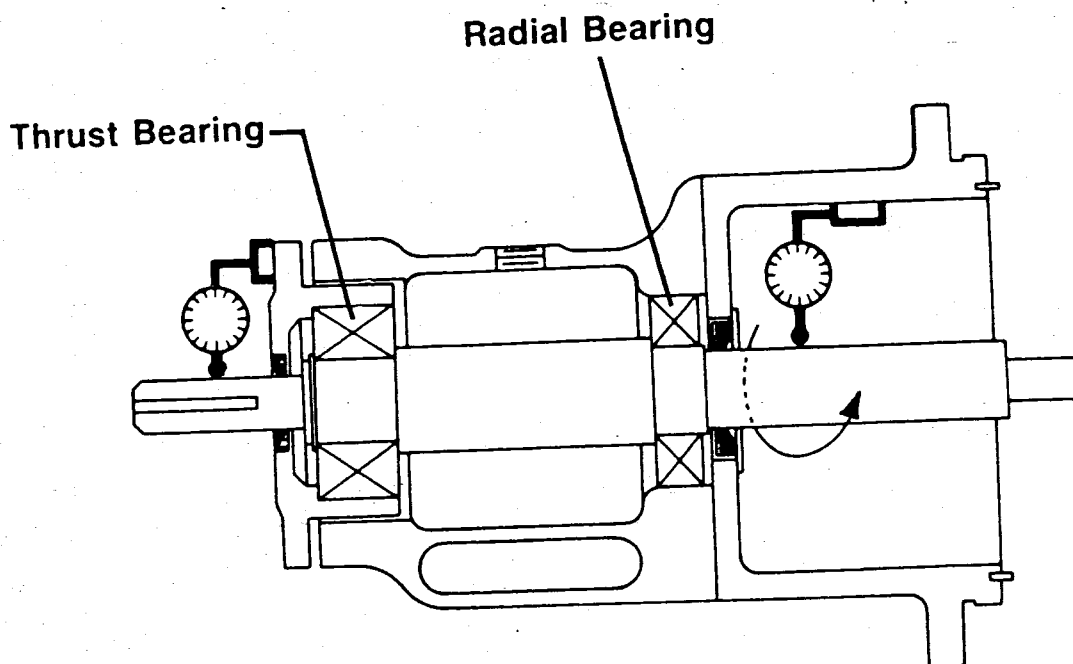


Figure 8-4. Checking for run-out.

face of the seal housing, any misalignment will cause the gland to cock, which causes the stationary element to cock and the entire seal to wobble. This condition is a major cause of fretting wear where the mechanical seal shaft packing contacts the shaft or sleeve. A seal that wobbles can also cause wear or fatigue of metal bellows or drive pins, which can cause premature seal failure.

To measure seal chamber face squareness, leave the housing bolted in place and clamp the dial indicator to the shaft as shown in Figure 8-5, with the stem against the face of the housing. The total indicator run-out should not exceed 0.005 in. (0.13 mm) T.I.R.

6. **Seal chamber register concentricity.** An eccentric chamber bore or gland register can interfere with the piloting and centering of the seal components and alter the hydraulic loading of the seal faces, resulting in reduction of seal life and performance.

To measure chamber-bore concentricity, leave the housing bolted in place and insert the dial indicator stem well into the bore of the housing. To measure the gland register concentricity, the indicator stem should bear on the register O.D. The bore or register should be concentric to the shaft within 0.005 in. (0.13 mm) of the T.I.R.

If the bore or register are eccentric to the shaft, check the slop or looseness in the pump-bracket fits at location "A" as shown in Figure 8-6. Corrosion, whether atmospheric or due to leakage at the gaskets, can damage these fits and make concentricity of shaft and housing

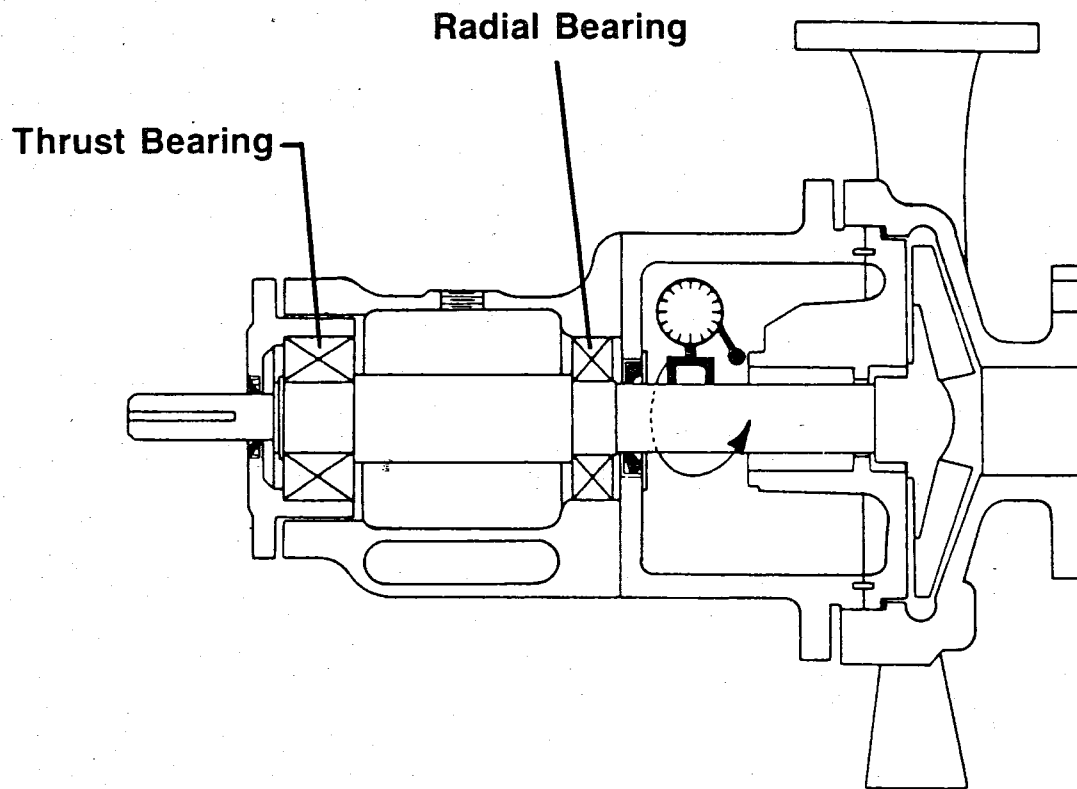


Figure 8-5. Checking for seal chamber face run-out.

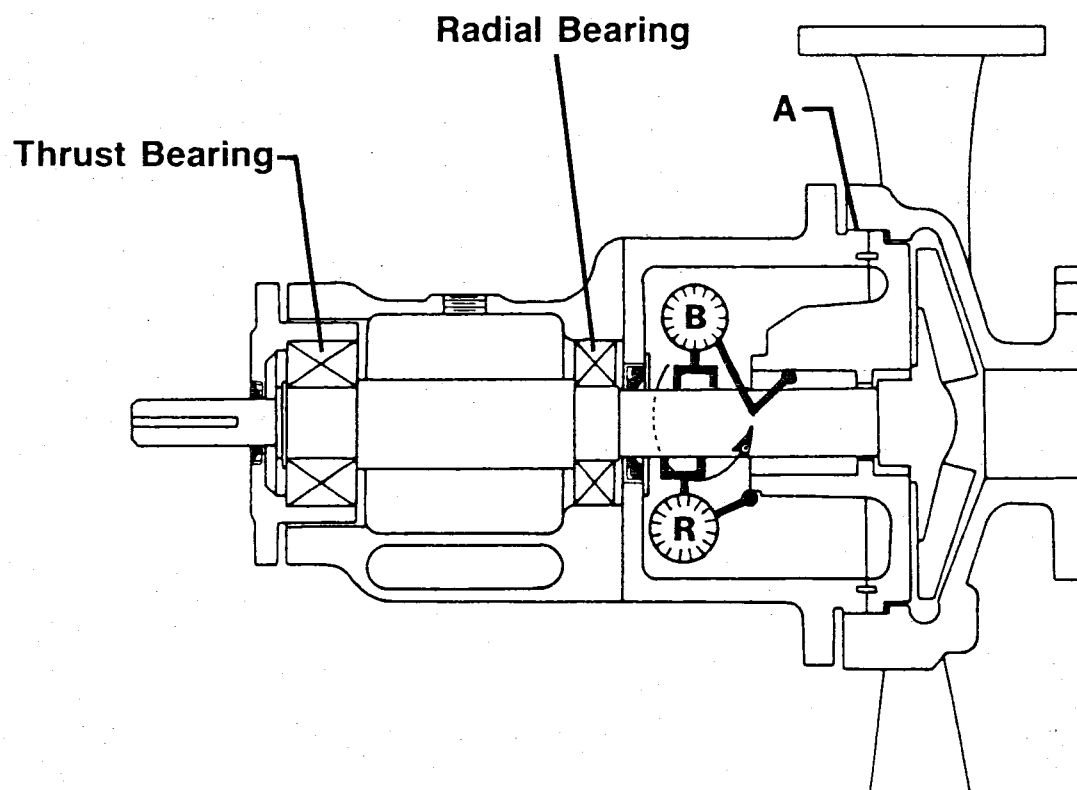


Figure 8-6. Checking for seal chamber bore concentricity.

bore impossible. A remedy can sometimes be obtained by welding the corroded area and re-machining it to proper dimensions, or by replacing the damaged parts. If this is not practicable, it may help to center the entire housing and dowel it in place.

7. **Driver alignment and pipe strain.** Regularly scheduled inspections are absolutely essential to maintain proper coupling and driver alignment. Follow the recommendation of the coupling manufacturer to check coupling alignment. Because temperature can affect coupling alignment due to thermal growth of pump parts, be sure to check pump coupling alignment at the operating temperature.

Pipe strain can cause permanent damage to pumps, bearings, and seals. Many plants customarily blind the suction and discharge flanges of their inactive pumps. These blinds should be removed before aligning the pump driver. After the blinds have been removed, and while the flanges on the suction and discharge are being connected to the piping, read the dial indicator at the O.D. of the coupling half as the flanges are being secured. Any fluctuation indicates that pipe strain is present.

Seal Checkpoints

Modern process plants use only factory-reconditioned, or brand-new cartridge and/or cassette-type mechanical seals. Therefore, only a few points need to be prechecked on both new and factory-reconditioned assemblies:

- Make sure that all parts are clean, especially the mating faces of the assembly
- Check the seal rotary unit and make sure it is free to rotate
- Check the setscrews in the rotary unit collar to make sure they are free in the threads. *Note:* Setscrews should be replaced after each use.
- Check the thickness of all accessible gaskets against the dimensions specified in the assembly drawing. An improper gasket thickness may be a safety hazard
- Check the fit of the gland ring to the equipment. Make sure there is no interference, binding on the studs or bolts, or other obstructions. Be sure any gland ring pilot has a reasonable guiding fit for proper seal alignment.
- Make sure all rotary unit parts of the seal fit over the shaft. Particular care should be given to elastomeric secondaries.

Installation of the Seal

Many seal failures can be traced to installation errors. Careful installation is a major factor in the life of a seal.

1. Read the instruction booklet and review the drawing that accompanies each cartridge or cassette-type assembly.
2. Remove all burrs and sharp edges from the shaft or shaft sleeve, including sharp edges of keyways and threads. Replace worn shaft or sleeves.
3. Make sure the seal housing bore and face are clean and free of burrs.
4. Prior to seal assembly, lubricate the shaft or sleeve lightly with silicone lubricant. Do not use oil or silicone at the seal faces. Keep them untouched and do not disassemble the unit.
5. Flexibly mounted inserts should be lightly oiled and pressed in the gland by hand pressure only. Where an insert has an O-ring mounting on the back shoulder, it is usually better to nest this O-ring into the gland cavity and then push the insert into the nested O-ring.
6. Strictly follow the manufacturer's installation instructions. They vary for different types of seals.

In the rare instances when an old-style, non-cartridge seal is used, and when the seal drawing is not available, the proper seal setting dimension for inside seals can be determined as follows for seals configured as shown in Figure 8-7.

A - Stuffing Box Face

B - Spring Gap

C - Seal Setting from
Reference Mark

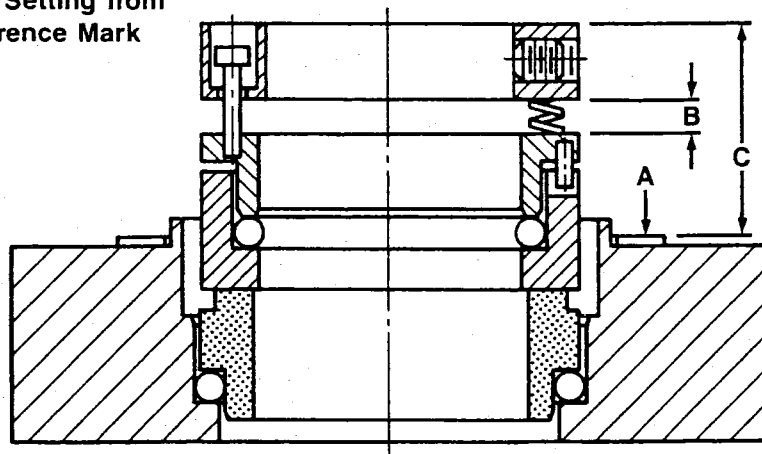


Figure 8-7. Calculation of seal collar setting.

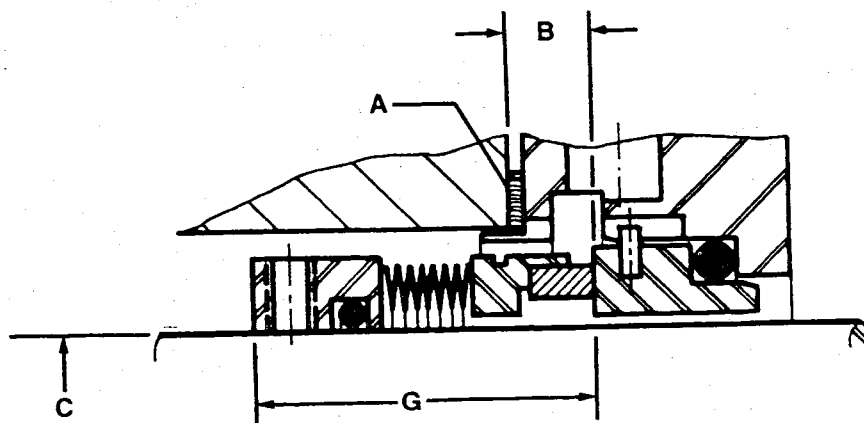


Figure 8-8. Calculation of seal collar setting.

1. Establish a reference mark on the shaft or sleeve flush with the face of the stuffing box (point "A" in Figure 8-8).
2. With the insert in place, stack up the gland and the rotary unit on a clean bench.
3. Compress the seal rotary unit until the spring gap, dimension "B" in Figure 8-8, equals the dimension stamped on the collar for pusher-type seals. This can be done by inserting an Allen wrench or piece of tool stock of the proper dimension between the collar and the compression unit before compressing the rotary unit.
4. Measure the distance "C" between the gasket face and the end of the collar. This is the collarsetting dimension.

If the seal is configured as shown in Figure 8-8, proceed as follows:

1. Measure the distance from the reference mark "A" to the face of the stationary insert in the gland plate. Be sure to include any gland gasket for proper measurement. This is shown as dimension "B" in Figure 8-8.
2. Refer to the manufacturer's instructions for the correct installed length of the rotary unit (Figure 8-8, dimension "G").
3. Subtract dimension "B" from dimension "G". This is the collar setting dimension.

Outside seals (rarely acceptable in modern process plants) should be set with spring gap ("A" in Figure 8-9) equal to the dimension stamped on the seal collar.

Cartridge seals, Figure 8-10, are set at the factory and are installed as complete assemblies. No setting measurements are needed. These assemblies contain centering tabs or spacers that must be removed after the seal assembly is bolted in position and the sleeve collar is locked in place.

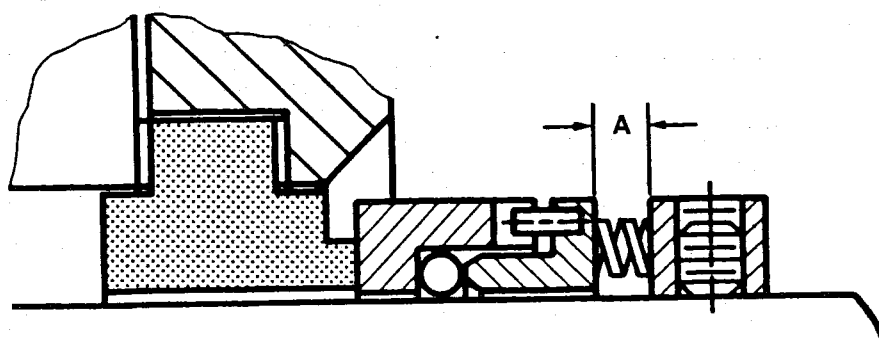


Figure 8-9. Setting for outside seal.

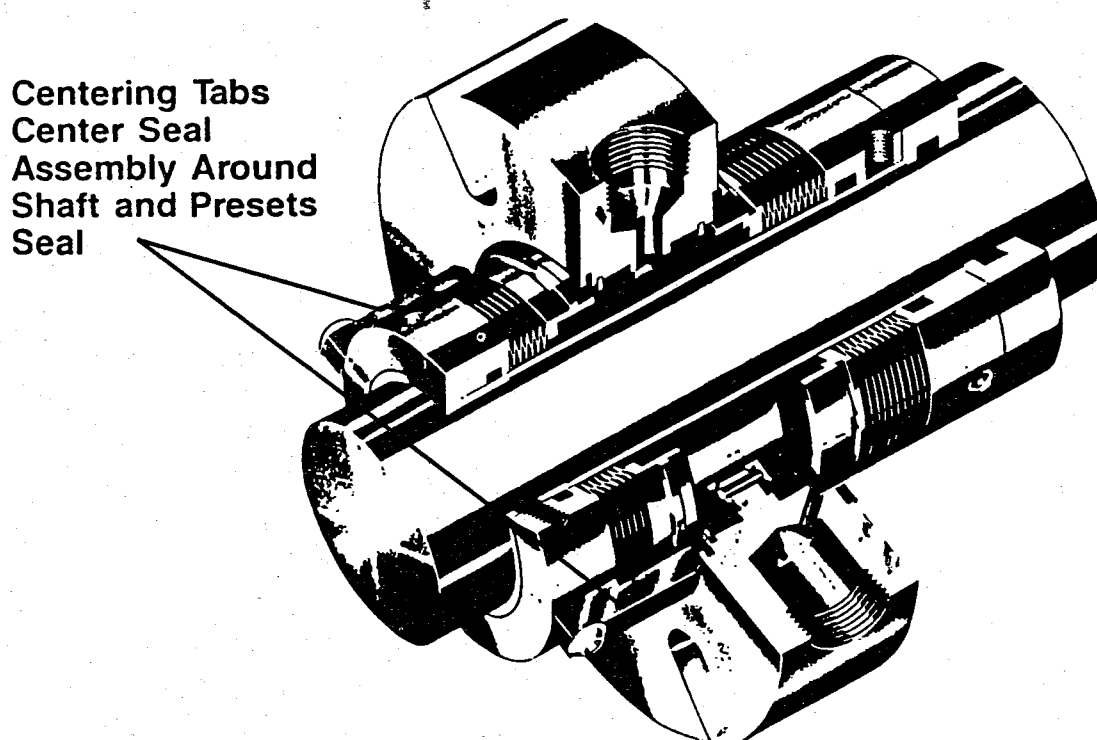


Figure 8-10. Preset cartridge seal.

Retain the tabs to be used when resetting the seal for impeller adjustments or when removing the seal for repairs.

Optical Flat

Since this text no longer advocates in-house repairs of mechanical seals, optical flats are only considered useful tools for “postmortem” failure identification and troubleshooting (see Volume 2 of this series). An optical flat is a transparent quartz or pyrex disc having at least one surface flat within 0.00001 in. to 0.00005 in. (0.025 to 0.125 microns) (see Figure



Figure 8-11. Optical flat.

8-11). The least expensive optical flats, those in the 0.000005 in. (0.025 microns) accuracy range, are suitable for measuring seal face flatness.

Select an optical flat with a diameter at least equal to the diameter of the part being measured. Optical flats in sizes up to 8 in. (200 mm) in diameter are available from most seal manufacturers. Care must be taken not to slide or lay the flat side of an optical flat on any rough surface, because it is easily scratched.

Monochromatic Light. White light from the sun is actually a combination of several colors, each of which represents a different wavelength of electromagnetic energy. If sunlight were used to measure seal face flatness, each color would generate its own pattern of bands on the optical flat. A far more practical light source for this purpose is one that provides light of only one color—a monochromatic light source.

Helium gas in a tube, when excited by an electrical charge, emits fewer colors than sunlight. One of these colors—yellow orange—is so prominent it overrides all the others. The yellow-orange wavelength is measurable and constant at 23.13 millionths of an inch (0.58 microns). A helium lamp, therefore, is described as emitting a monochromatic light of that wavelength.

Flatness Readings. After a seal part has been polished, it is placed under a monochromatic light, and an optical flat is positioned over its surface. Both the surface of the optical flat and the surface of the part must be absolutely dry and free from any particles of dirt, dust, or lint.

A pattern of light and dark lines appears where the reflection of the surface of the part and the reflection of the surface of the optical flat meet. The dark lines, called "light interference bands," will be visible every half-wavelength. Therefore, one interference band equals one-half wavelength or 11.6 micro-inches (0.29 microns). These bands are used to measure the degree of flatness of the surface. The presence either of several straight interference bands, or of a single circular interference band, indicates a surface that is flat within 11.6 micro-inches (0.29 microns).

When several curved interference bands appear, the degree of flatness is measured by plotting an imaginary straight-line tangent with one of the curved interference bands. If this straight line intersects only one interference band, the lapped surface is said to be flat within one light band. When two or more curved interference bands are intersected by this line, the degree of flatness is determined by multiplying the number of intersected bands by 11.6. Thus, if three interference bands are intersected by a straight tangent line, the surface is out-of-flat by three light bands or 34.8 micro-inches (0.87 microns).

Although a maximum tolerance of three light bands is considered adequate for proper seal face performance, seal faces from experienced manufacturers consistently exhibit a flatness between one and two light bands. Special concave or convex geometries are available if special conditions warrant.

A seal face with a diameter greater than 10 in. (250 mm) and a thin cross-section is difficult to measure precisely for flatness.

See Figures 8-12 and 8-13 for sample light-band readings. Note that when the band pattern is inconsistent or seems to be missing some bands, as in Figure 8-13(e), (f), and (g), the tangent line "AB" is drawn to connect the two points at which two imaginary radii—90° apart and perpendicular to the axis of the part—intersect with the outer circumference of the seal face.

Once flatness has been achieved, a seal face must be kept clean while being returned to service.

Installation of Stuffing Box Packing*

Maintenance of a stuffing box consists primarily of packing replacement. This may sound simple, but certain rules must be followed if the best results are to be obtained from the packing.

The following procedure should be preceded by a careful study of the pump manufacturer's instruction manual to determine the correct type and

* Source: Packing Pump Packings, H. A. Schneller, Allis Chalmers Mfg. Co.

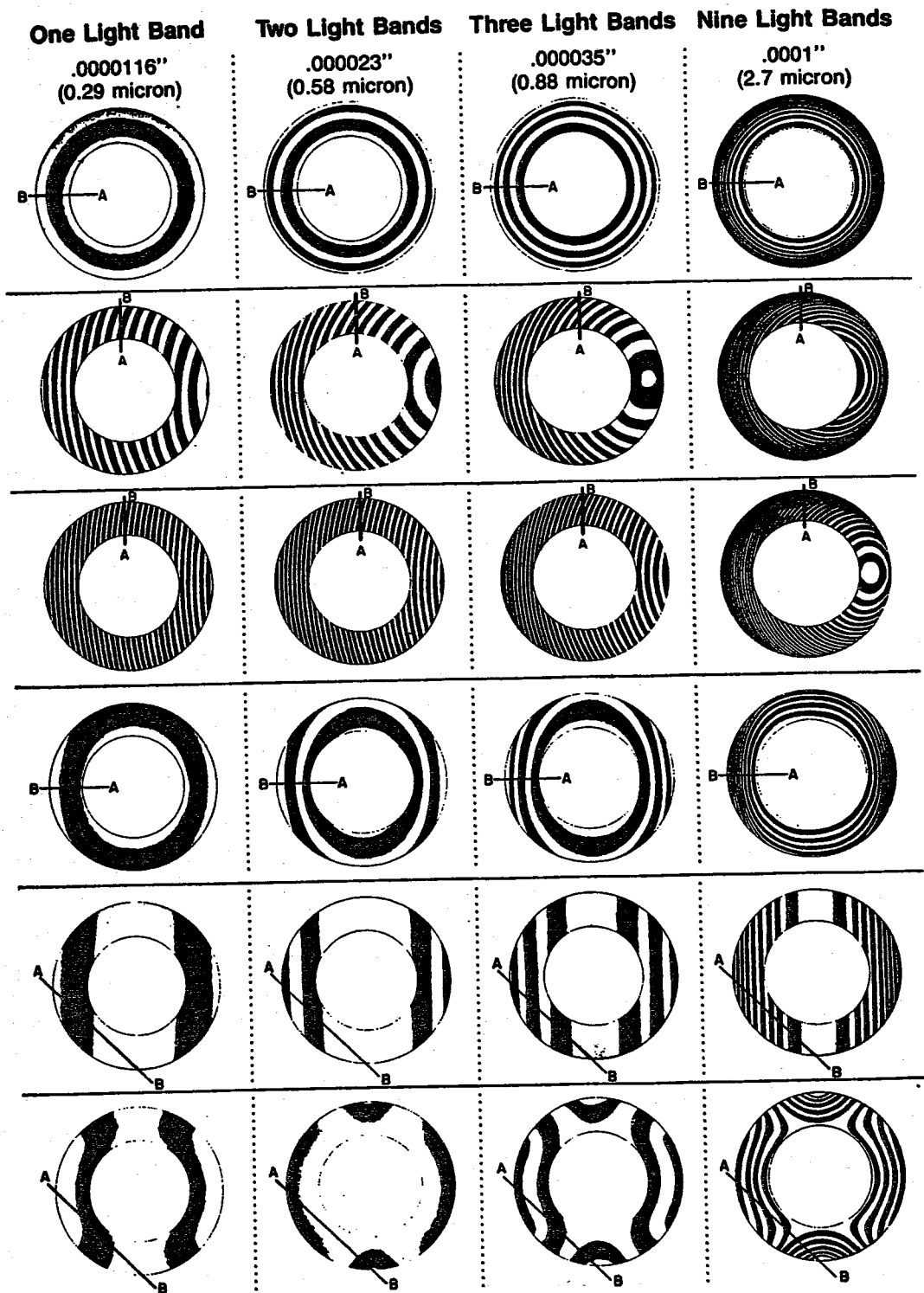


Figure 8-12. Band patterns that indicate flatness accuracy.

size, number of packing rings, location of lantern ring, and possible special features of construction, operation, or maintenance.

1. Remove gland and packing. If the box contains a lantern ring, make certain that all the packing inboard of it is also removed. Flexible packing hooks are available.

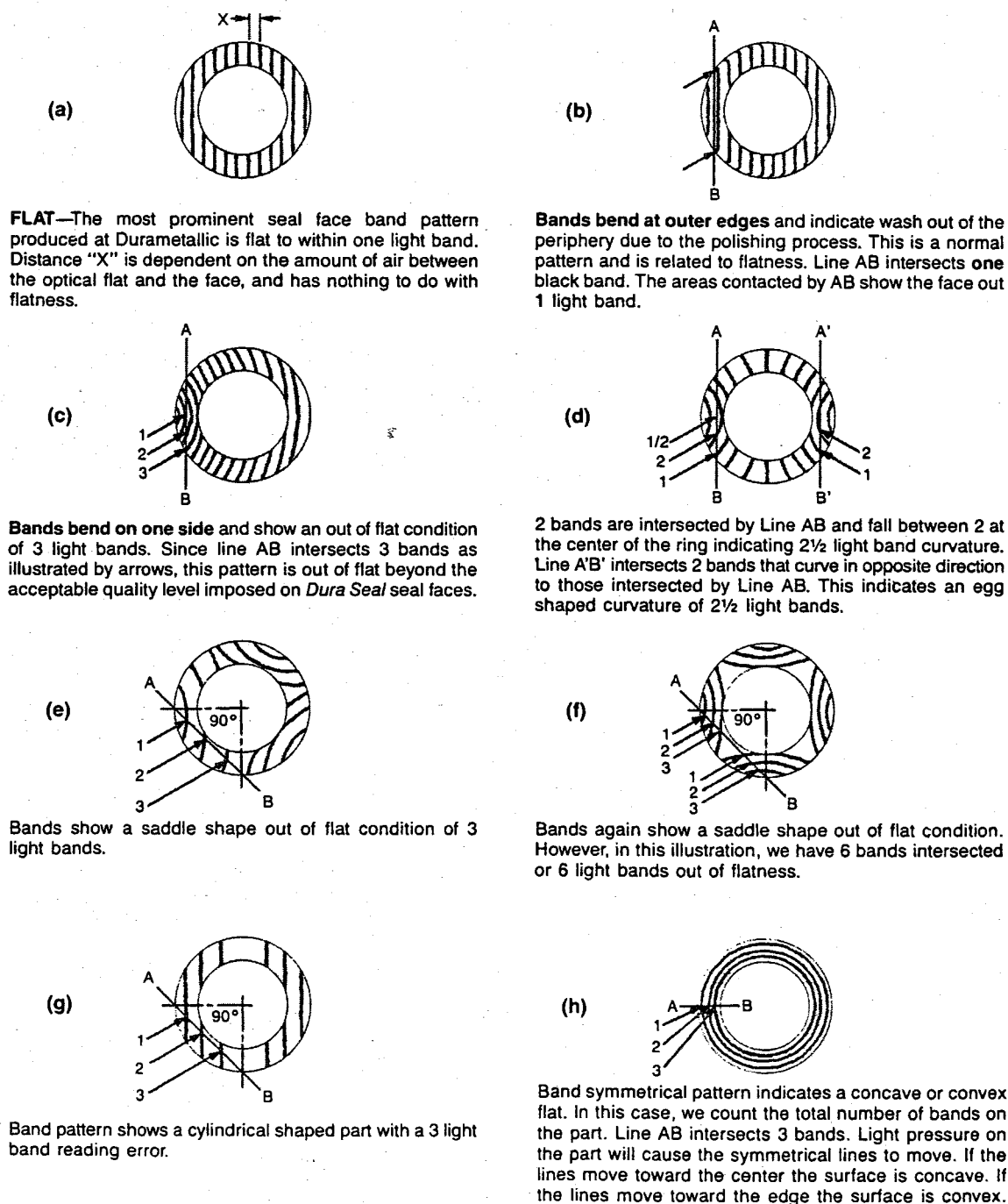


Figure 8-13. Lightband readings.

2. Inspect the shaft or shaft sleeve for score marks or rough spots. A badly worn sleeve or shaft must be replaced; minor wear must be dressed smooth and concentric. Inspect lantern ring to make sure that holes and channels are not plugged up.
3. Clean bore of box thoroughly and be sure sealing-fluid passages are open.
4. Depending on operating conditions, it is recommended that at least the outside diameter of the replacement packing rings be

lightly oiled or greased. Start by installing one end of the first ring in the box and bring the other end around the shaft until it is completely inserted. *Note:* Preformed or die-molded rings will ensure an exact fit to the shaft or sleeve and stuffing box core. A uniform packing density is an added benefit since molded rings are partially compressed. If the packing comes in continuous coil form, make sure that the ends are cut square, on a correctly sized mandrel.

5. Push the packing ring to the bottom of the box with the aid of a split bushing. Leave the bushing in place, and replace the gland. Pull up on the gland and seat the ring firmly and squarely. Ideally, the split bushing should be a slip fit over the shaft and in the bore. This precaution will prevent the formation of a lip on the packing being seated.
6. Repeat this method for each ring, staggering the joints 90° . It is especially important to seat the first few bottom rings firmly, otherwise the rings immediately under the gland will do most of the sealing.
7. The location of the lantern ring, if used, should be predetermined. This can be done via the pump manufacturer's instruction manual or by counting the number of packing rings on the inboard and outboard side of it while removing them. Proper location at the point of fluid-seal is necessary.
8. Replace the gland and tighten the gland bolts. Make sure that the gland enters the stuffing box squarely. A cocked gland causes uneven compression and can damage the shaft or sleeve when the pump is placed in operation.
9. Keep the packing under pressure for a short period of time, say 30 seconds, so that it can cold flow and adjust itself.
10. Loosen the gland; allow packing to fully expand with no fluid pressure in the pump, then tighten the gland and bring it up evenly to the packing, but this time only finger tight. The packing should be loose enough to enable you to turn the pump shaft by hand, assuming that the pump is not too large to turn by hand.
11. Precheck the lines to the lantern ring or quench gland for flow and proper pressure.
12. Start the pump. The leakage may be excessive, but do not take up on the gland bolts for the 20–30 minute run-in period. If too tight, shut pump down and repeat steps 8–11 or keep pump running and loosen gland bolts a couple of flats.
13. If leakage is still more than normal after the run-in period, tighten the gland bolts evenly, one flat or a sixth of a turn at a time. This should be done at 20–30 minute intervals until leakage is reduced

to normal. This may take several hours, but will pay for itself many times over in maximum packing and sleeve life.

Steady Leakage Flow Is a Must

Leakage must be sufficient to carry away the packing friction heat. Without sufficient leakage—a steady flow, as opposed to a drip—the packing will burn and the shaft or sleeve will be scored. It follows, then, that a planned maintenance program must be developed around the amount of leakage that is considered normal. Pumps in continuous service may require a daily, or even an hourly inspection. Inspection need be no more than a visual check to determine any deviation from the normal leakage, and make slight corrections as required.

Correct procedure and scheduled maintenance will make the repacking of a pump a predictable job rather than an emergency repair.

Consider Upgrading to Mechanical Seals

It should be pointed out that conversion from packing to well-designed mechanical seal systems is often feasible and has proven to be a cost-effective reliability improvement step. We strongly advocate such upgrading wherever feasible; it usually *is* feasible!

Welded Repairs to Pump Shafts and Other Rotating Equipment Components*

This section will highlight some of the technical aspects of welded repairs to rotating equipment, with particular emphasis on pump shafts. We believe this to be a reasonable alternative to new part installation.

Welded repairs to rotating equipment can be an extremely useful maintenance method; however, it should be emphasized that welding is *not* a panacea for all problems. In fact, many people refuse to recommend or even consider welded repairs on any rotating components. This reluctance is probably due to unsuccessful experiences in controlling distortion. However, other methods of reconditioning, such as sleeving, plating, and spraying also have their limitations.

* Courtesy of Mr. Thomas Doody, Aramco, Dhahran, Saudi Arabia. From a paper presented at the National Petroleum Refiners Association, Plant Maintenance Conference, February 8–11, 1983.

The primary problems with these alternative repair methods are the limitations on allowable coating thickness and lack of bonding with the substrate. For example, sleeving has both minimum and maximum thickness limitations and is also limited to the stepped end areas of a shaft.

The advantages of welded repairs are:

1. Full fusion of the overlay with the base material is achieved.
2. Shaft strength is maintained.
3. The corrosion or wear resistance can be improved over the original material.
4. The overlay thickness is essentially unlimited (minimum or maximum).

The only real disadvantage of welded repairs is the possibility of distortion. For many engineering applications, this is of negligible concern. However, for most rotating equipment components, this is the major concern and the reason many people recommend against attempting welded repairs. If the distortion problem can be eliminated, then welded repairs can be used with confidence as a standard maintenance procedure. The techniques discussed here are designed primarily to minimize distortion.

How to Decide if Welded Repairs Are Feasible

These questions must be answered in determining if welded repairs are suitable for a particular situation:

1. *What is the damage and what type of repair is required?*

As previously mentioned, the advantages of welded repairs must be balanced against the increased risk of shaft warpage. However, there are situations where welding is the only possible method of saving a shaft and returning it to service. A good example is damage to a coupling area, where all other repair techniques are unsuitable because of the mechanical strength and bonding requirements.

In general, the damaged area should not have reduced the shaft diameter by more than 15 percent and should not exceed 10 percent of the shaft length. The repair should be limited generally to one area or two well-separated areas. These figures are only guidelines; there is no hard information on which these values are based. Situations exceeding these restrictions may be repairable but a more careful consideration of shaft strength, possible distortion, and economics needs to be made on an individual basis.

2. What is the shaft material?

The shaft material must have good weldability. Some common shaft materials that can be included in this category are:

304 Stainless Steel
 316 Stainless Steel
 Monel 400
 Monel K-500
 Nitronic 50 (XM-19)
 Ferralium
 A 638 Gr 660
 Inconel 625

Typical compositions are listed in Table 8-1.

Table 8-1
Nominal Composition of Materials Used for Rotating Equipment Weld Repairs

	C	Mn	Fe	Cr	Ni	Mo	Cu	Other
304	.08	2.0	bal.	18.0– 20.0	8.0– 10.5	—	—	—
316	.08	2.0	bal.	16.0– 18.0	10.0– 14.0	2.0–3.0	—	—
MONEL* 400	0.12	2.0	2.5	—	63.0– 70.0	—	bal.	
MONEL* K-500	0.13	1.5	2.0	—	63.0– 70.0	—	bal.	Al 2.8 Ti 0.6
NITRONIC* 50 (XM-19)	0.06	4.0– 6.0	bal.	20.5– 23.5	11.5– 13.5	1.5–3.0	—	Cb 0.1–0.3 V 0.1–0.3 N 0.2–0.4
FERRALIUM* A 638 Gr 660	0.04 .08	0.8 2.0	bal. bal.	25.5 13.5– 16.0	5.2 24.0– 27.0	3.5 1.0–1.5	1.7 —	N 0.17 Al .35 B .001–.01 Ti 1.9–2.35 V .1–.5
INCONEL* 625	.10	0.5	5.0	20.0– 23.0	bal.	8.0– 10.0	—	Cb 3.15– 4.15 Ti 0.40 Al 0.40

*Trademarks: Monel and Inconel—International Nickel Co.
 Nitronic—ARMCO Inc.
 Ferralium—Langley Alloys Ltd.
 Stellite—Cabot Corp.

All of these materials are very ductile, do not exhibit hardened heat-affected zones, and will usually maintain adequate corrosion resistance in the "as welded" conditions.

There does appear to be a common problem with dimensional stability of the Ferralium and the 300 series stainless steel. These materials appear to creep, even under static conditions. The other materials listed do not seem to be quite as sensitive to this problem. It is obvious that welded repairs will exacerbate this situation, but it is not possible to address this problem at this time.

Shaft materials that should *not* normally be considered for welding are:

4140

4340

410 Stainless Steel

Although many companies have probably done emergency or spot repairs on shafts of these materials, it should be emphasized that welded repairs are not generally recommended.

3. *What is the overlay material?*

Given the previously mentioned shaft materials that would be considered for welded repairs, Inconel 625 (AWS A5.13 ERNiCrMo-3) would normally be selected as the filler metal. Although other materials could be used, it is easiest to standardize on one filler metal that gives a deposit of exceptional corrosion resistance. The deposit may or may not match the tensile strength of the original shaft material, but since the deposit is extremely ductile and has complete fusion at the interface, it has only a marginal effect on total shaft strength. It should be remembered that alternative repair methods require undercutting the shaft diameter, thus permanently and perhaps significantly reducing the total shaft strength.

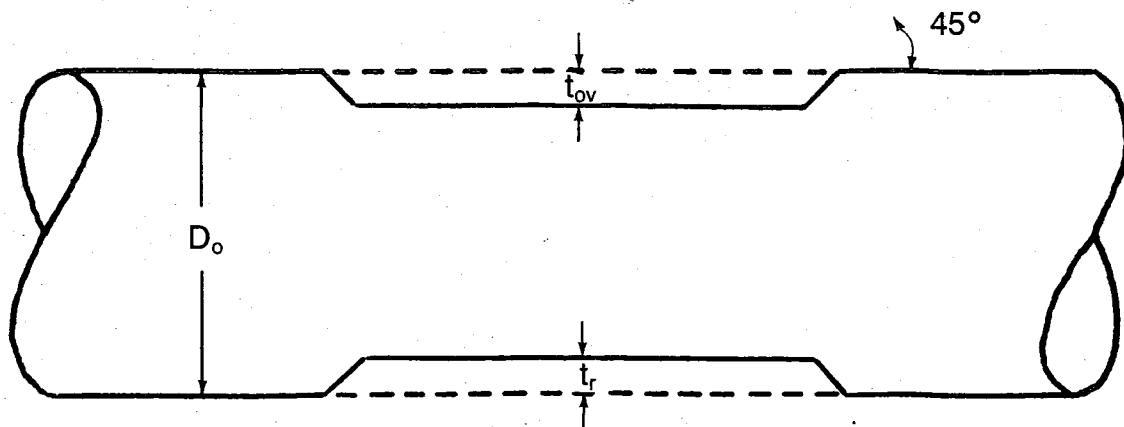
For other components, such as wear rings, Stellite 6 (AWS A5.13 RCoCr-A) can be used to give a hard, wear resistant, anti-galling deposit. The Stellite overlay requires a more careful application because the deposit is crack sensitive. As a result, the depth of overlay is restricted and repairs to the overlay may be difficult.

Other overlay materials might be required for special cases but these would need to be considered on an individual basis.

Repair Techniques

1. *Shaft Preparation* (Figure 8-14)

The damaged area should be undercut by machining the shaft, but the amount of material removed should be limited as much as possible. For a



t_{ov} = $1/32$ – $1/16$ -inch (0.8–1.6 mm) for corrosion or wear resistant overlays
 t_r = 7.5% of shaft diameter (D_o) for repair of mechanical damage

Figure 8-14. Shaft preparation by machining.

shaft with only surface-type damage—such as pitting corrosion—the depth of cut should be between $1/32$ and $1/16$ in. (0.8 to 1.6 mm). The minimum depth of cut is specified to avoid having the fusion line positioned directly on the final machined surface. The maximum depth is limited in order to reduce distortion. For mechanical damage, the depth should not have reduced the shaft diameter by more than 15 percent, i.e., depth not to exceed 7.5 percent $\times D$. The edges of all machined areas should be tapered at 45° to ensure good sidewall fusion.

The area to be welded must be thoroughly cleaned and degreased.

2. Welding Procedure

The GTAW (TIG)* process should always be used in order to limit the heat input and reduce the possibility of weld defects. The welding current should be reduced to where good fusion and adequate bead thickness are still obtained but without resorting to long dwell times. There is a trade-off between current, travel speed, and filler rod diameter. These variables need to be adjusted to give the lowest heat input in order to control distortion.

In general, a current of 100A or less (using a $3/32$ in. EWTh-2 tip) and a filler rod size of $3/32$ or $1/8$ in. (2.5 or 3.2 mm) diameter should be used.

3. Welding Technique

The shaft should be well-supported on rollers and mounted in a turner. The shaft is to be rotated at all times during welding and for 30 minutes

* Gas-Tungsten-Arc-Welding (Tungsten-Inert-Gas).

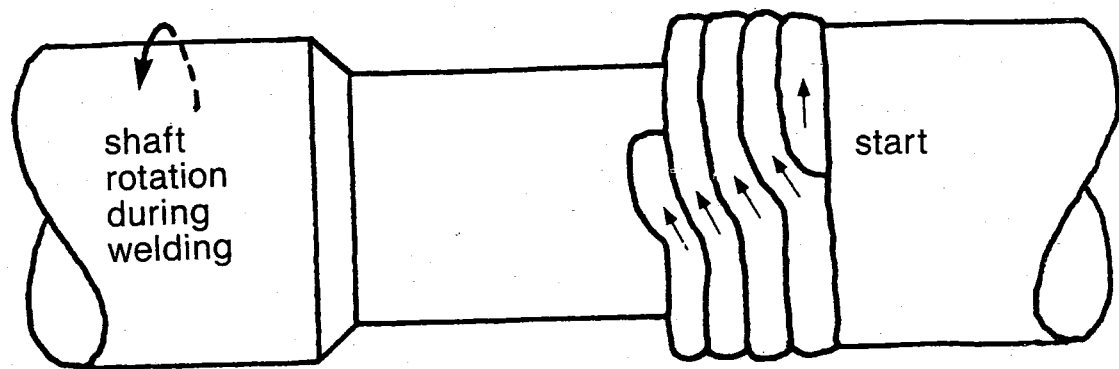


Figure 8-15. Spiral welding sequence for shafts.

after completion. The rotational speed should be set for the welding speed (2–3 in. per minute). This will usually be about 0.1–0.2 revolutions per minute for most large shafts.

The welding is always done in a spiral pattern (Figure 8-15). The undercut depth is limited in order to obtain the required thickness in one thin pass. This helps to minimize distortion by limiting the volume of weld metal and reducing the heat input. The maximum bead width should be limited to $\frac{3}{8}$ in. (10 mm). As a minimum, one complete circumferential bead should be completed before stopping or interrupting the welding sequence. In general, welding is started on the edge to be repaired closest to the middle of the shaft and should proceed toward the shaft end.

The maximum interpass temperature is limited to 350°F (175°C). This is of primary importance since the thermal profile of the heat-affected zone is a major determinant of residual stress and distortion. As heat build-up occurs, the width of the heat-affected zone increases, which increases shrinkage.

In one case, the shaft runouts were monitored during a portion of the welding. It was found that shaft end deflections (the weld area was 20 in. from the end) of up to 0.015 in. (0.38 mm) occurred during the actual welding but would return to less than 0.005 in. (0.13 mm) during cooling periods.

Some cold straightening may be required to correct any residual distortion, but this has not usually been a difficult problem.

The finish-machined shaft surface should be completely free of any defects, such as porosity or lack of fusion. Other components, such as hard-facing on wear rings or impellers, are not as critical and an acceptance criterion for rounded indications (porosity) has been adopted.