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An example of an Accuracy Controlled Enterprise 3T (Target-Tolerance-Test) Procedure with reliability standards to install taper spherical roller bearings on adaptor sleeves in Plummer blocks with taconite seals for 30mm-250mm diameter conveyor shafts

Abstract:

Example ACE 3T (Target-Tolerance-Test) Procedure with Reliability Standards: Machine performance is totally dependent on human beings. To address the problem of human error causing equipment failure, an Accuracy Controlled Enterprise sets best practice quality standards and uses 3T Target-Tolerance-Test work task quality control that assures high quality workmanship for high reliability results. Their work procedures are standardised so everyone follows the same methods to produce the same results, their training teaches people how to do craftsmanship work that creates outstandingly reliable plant and machinery. They create the reliability they want and as a result achieve operational excellence.

Keywords: precision job procedures, maintenance work quality assurance,

High equipment reliability requires parts made to precise sizes and assembled to precision standards. Our machines and equipment are dumb, lifeless objects that cannot tell they are suffering and in trouble. They cannot adjust their behaviour when stress and strain gets too much. They just brake and die. It is up to us to make machines work properly by ensuring they are made well and kept healthy. If we want high equipment reliability we need to use the skills, methods and processes that produce high equipment reliability.

Maintenance work processes that deliver better than 3-sigma quality accuracy (7 errors per hundred opportunities for error) are uncommon in industry. Most maintenance and repair work processes range from 2-sigma to 2-1/2-sigma, or 30 to 10 errors respectively per 100 opportunities[1]. You can truly say that due to human error maintenance destroys the equipment that it is meant to maintain reliably. To address that problem an Accuracy Controlled Enterprise creates high quality work procedures full of double-checks and measurable task quality standards that must be met. An example ACE 3T Procedure with work reliability quality standards for mounting spherical roller bearings on shaft adaptor sleeves in Plummer blocks follows.

With an ACE 3T procedure high maintenance work quality is assured. It also brings many other wonderful benefits to organisations that chose to become great at operational excellence. It sets standards that everyone must adhere to, from equipment vendor to subcontractor to employee to professional engineer. It allows workmanship skills to be trained for targeted reliability outcomes. It drives continuous reliability improvement as people reach higher and higher workmanship quality standards and become an Accuracy Controlled Expert. ACE 3T procedures are written at three levels of work quality performance. The lowest work quality level is the best of current site practices; it is 'bronze medal' level performance. The third level is set at world class reliability standards and tells everyone where they need to be if they want to deliver 'gold medal' results reliability (To be that good takes training in precision maintenance skills, use of quality control proof-tests and a mindset that values high quality workmanship.). In-between is the intermediate level, which is a hard stretch target above the best existing level of work quality; it is 'silver medal' standard.

Writing an ACE 3T maintenance procedure takes a lot of research into the fine technical details of what delivers ultra-high reliability, you need to appreciate and understand exacting engineering standards and be able to decide which apply in a situation, it needs a good grasp of the reliability of a design and of materials of construction issues. It is the work of technically competent and engineering knowledgeable persons working together with trade savvy people to create a document that helps technicians to do expert, masterly work first-time, every-time.

Best regards,

Mike Sondalini
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[1] Smith, Dr, David J., Reliability, Maintainability and Risk, Seventh Edition, Appendix 6, Elsevier, 2005

It is best to have a procedure for each shaft size because one procedure for multiple sizes ensures that human error will happen at some point. I have covered multiple sizes for the sake of giving you an example of the ACE 3T method. In reality I would use this as a master document and then create each shaft size procedure from it.

An example of an Accuracy Controlled Enterp (Target-Tolerance-Test) Procedure to install taper spherical roller be ngs on adaptor sleeves in Plummer blocks with taconite seals for 30mm-250mm diameter conveyor shafts

NOTE: This is an example ACE 3T procedure. **Do not use the procedure without exact details that apply to your equipment.** Each organisation must research, develop and approve all procedures used on their plant and machines.

Installation Procedure M0234

Work Order Number: _____

Description: Mounting spherical roller bearings of C2, CN, or C3 internal clearance on adaptor sleeve in a Plummer block with taconite seals for ϕ30 to ϕ250mm (inclusive) conveyor pulley shafts

Your Responsibility on this Job: This procedure explains how to properly install a spherical roller bearing with a sleeve adaptor on a shaft. It is vital for the success of this operation that you do quality work that produces long, reliable bearing life measured in decades. You are responsible for the work you do and to use the master craftsman skills such great performance needs.

This procedure is provided for you to follow and to record your actions and findings as you do the job. The completed procedure becomes a record of the job and proof of workmanship quality. It is our current best-practice and includes careful engineering detail and peoples' learning and experience over many years. It is the best way yet found to do the job right-first-time to top-class quality. Follow the tasks described in this document and ask if you are not certain how to get the needed results. We want you do expert work and will help you to do so. If you have a problem that you cannot solve correctly please see your supervisor immediately and do not progress with the job until the issue is properly fixed.

If after you master this procedure you believe that you know of improvements, please bring them forward for discussion. You can test your ideas and compare them to the procedure. If a suggestion proves to be better, it will become the new way to do this job throughout the company.

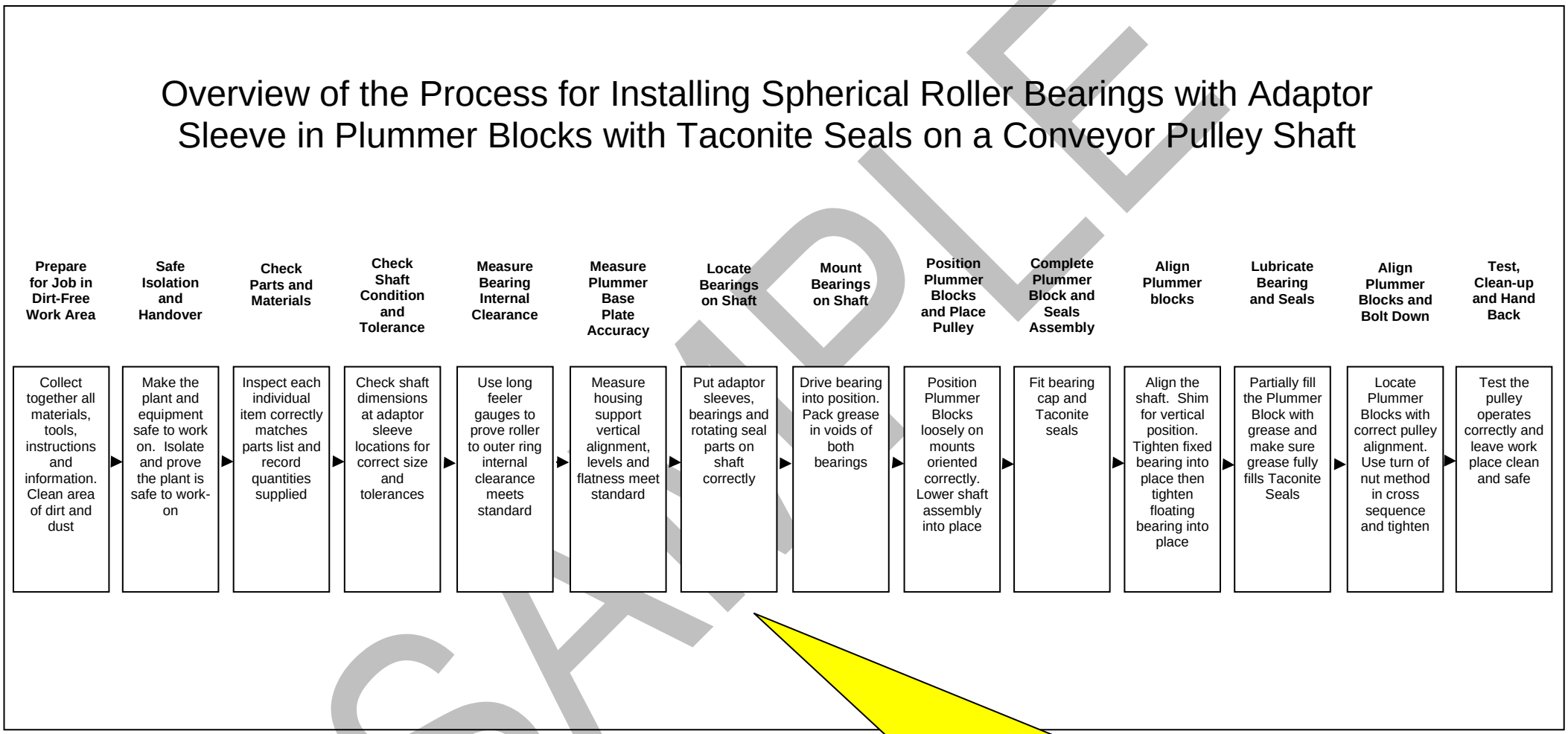
This information is used for planning and to check what is actually used on the job.

Necessary Parts, Equipment and Tools:

No	Identification Number	Item Description	No for Job	Number Supplied
1	*Part ID number*	Bearing ,spherical roller, ??mm bore, ??mm wide, 1:12 taper	2	
2	*Part ID number*	Adaptor sleeve, ??mm bore, 119mm wide, c/w locking tab washer	2	
3	*Part ID number*	Plummer block, closed, capped end, ??mm shaft, c/w two Taconite seals	1	
4	*Part ID number*	Plummer block, open, ??mm shaft, c/w one Taconite seals	1	
5	*Part ID number*	Studs, lengths to suit Plumber block and support base thickness	8	
6	*Part ID number*	Spacer ring, gap type, ??mm bore	2	
7	*Part ID number*	M??mm nuts and M?? washers	16	
8	Ring spanners	NOTE: Do not use adjustable shifters and pipe wrenches as they damage corners of bolt heads and nuts making their removal dangerous and unsafe	As required	
9	*Part ID number*	Shim Set, 316SS, each of 3mm, 2mm, 1mm, 0.6mm thick shims	2	
10	Micrometer/Vernier	??mm to ??mm		
11	Feeler gauges	Long series feelers, 316 stainless steel, 0.02mm thinnest	1	
12	Grease / Oil	?? grade	1kg tube	
13	Mounting Paste	??	1 tube	
14	Bearing remover	Hydraulic oil pressure unit	As required	
15	Hydraulic nut	To suit bearings size (for 80mm and over), Hydraulic oil pressure unit	As required	
16	C-spanner	To suit bearing nut size	As required	
17	Marker pen	Permanent Marker, 0.2 mm, felt tip, black	1	
18	Marker pen	Permanent Marker, 0.2 mm, felt tip, white		
19	Precision edge ruler	Ruler, precision straight edge, 1 meter long	1	
20	Precision level	Level, precision, bubble, 1 meter long	1	
21	Tape measure	Tap measure, 5m long, 19mm wide tape, metric	1	
22	Bearing restrainer	Slotted bearing restrainer c/w bolt for shaft end to stop bearing flying off on hydraulic oil removal	As required	

Job Process Summary

A summary of the work process for doing the job is shown below. Be familiar with the workflow when preparing to do the job. The fully detailed procedure follows.



The paper size used to print the procedure can be up to A3 size. It should be easy to read text and to record measurements and readings

This flow chart does several things:
- It is a 'picture' of the job that can be discussed with people
- It makes the job into a process that delivers a measurable output
- You can now build performance KPIs into the process and measure effectiveness
- It allows you to do Lean value stream mapping for efficiency improvements

Engineering and Accuracy Standards For This Procedure

ITEM	DESCRIPTION	STANDARD REQUIREMENT	METHOD and TARGET	TOLERANCE ON TARGET
Mounting Bolts	High Strength Structural Class 8.8 bolt and nut	**Bolt Tension** 220 kN (minimum)	**Bolt Tension Accuracy** Use Turn-of-Nut method: Half (½) turn from fully snug tight	**Tolerance on Turn-of-Nut** One twelfth turn over (30°)and nil under half turn
Fits	Hole (Bore Diameter) / Shaft (Diameter under adaptor sleeve)	H8 / h9	Finely machined to ISO 286 tolerance	Stay within respective International Tolerance (IT) Grade limits
Shaft Cylindricity	A three-dimensional geometric tolerance that controls how much a feature can deviate from a perfect cylinder	Defined in ISO 1101and identical to the mating part cylindricity tolerance	Finely machined to IT5	Stay within IT7 tolerance
Measuring Temperature	Item's average body temperature at time of taking a measurement reading	5C to 35C	Measure item temperature if amb… temperature is outside…	…the

In this table you specify the internationally accepted standards used in the procedure; you set the quality standard for your site, you set the target and the outer tolerance you will accept for each standard.

Follow this Detailed Procedure Exactly and Record What You Find and See

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards			Reading / Result	Action if Out of Tolerance	Sign off
						Good	*Better*	*Best*			
	Person	*4-5 words*	*Include diagrams and pictures*		*Inc diagrams and pictures*						
1.	Technician	Prepare for the job	Gath… ther all parts, materials, job work order, …nt danger tags, handover permit, special …ctions, PPE…	…essary …s. Equip …ist	All parts, equip… and tools are … …kface bef… the job	Request and collect issued items from store	Planner arranged all items ready for issue from Store	Planner … all items at … ready for use		Only start once all requirements are at the job site	
					…part, equipment and …t is present and every item meets its engineering …fications and is in a …for use	All items are on-hand and visually inspected	All items … hand … against their …cation	All items on-hand & all are pre-certified to specification. A random inspection …		Immediately inform the Job Supervisor if the parts are wrong or they are not to specification	
3.	Plant Operator	Make workplace safe	Equipment …		…ental… done to procedure			…ing work		Only start when there is a safe handover	
4.	Technician and Plant Operator	Safe isolation and handover	Contact Operations personnel responsible and place personal danger tags at isolation points and only accept plant handover after proving isolations have de-energised equipment and removed hazards	Danger Tags	Isolation procedure is correctly done and isolations proven safe by testing	Operator and Technician walk process & identify, prove & tag isolation points	Operator previously isolated plant & tagged isolations with out-of-service tag & proves to Technician that the isolation are effective	Operator provides isolation point drawing & walks process with Technician to show prior tagged isolations & prove plant safe for work		Only start when equip is proven safe to work-on & handover procedure is properly completed	
5.	Technician	Position equipment safely	Do Take 5 hazard analysis and address all risks over Low Move and/or lift the pulley into a safe and comfortable working position and chock it into place If possible ensure a line-of-sight between Plummer blocks to allow easy measurement later.	20T Crane, timber chocks, timber blocks	Task done safely. Equipment to be worked-on is firmly secured, unable to fall even if heavily knocked by accident	Task done safely	Task done safely and restraints properly located	Task done safely, restraints properly located and tested to prove safe		Report safety concerns or removal problems or damage to Job Supervisor	
6.	Technician	Match mark and measure assembly	Before removing any items and stripping the assembly use a white marker to match-mark all parts for identical reassembly. Take measurements and record the position of all bearing centres from the ends of the shaft as a datum for	Tape measure	Hand sketch showing measurements from datum or general assembly drawing with site measurements marked on it	Measure from datum, record distances	Measure from datum, record distances and double check	Measure from datum, record distances and get someone else to double check			

Describe the task in full detail and include diagrams and pictures. You want to help people do great work.

Specify the proof-test used to decide whether the task is acceptable and is completed correctly

You use these columns to specify the quality standards that will deliver the reliability and performance that you want. 'Best' is world-best, which you may have to research to find.

This column is a record of what was found and the standard to which the task was performed.

In this column we tell people what to do if the minimum task quality standard is not met.

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
			reassembly.								
7.	Technician	Remove Plummer blocks	For 80mm bearings and above use hydraulic oil bearing remover to pop the bearing off the adaptor sleeves once the bearing restrainer is in place. Follow the separate instructions for doing hydraulic bearing removal safely and correctly. For bearings less than 80mm use the correct size C-spanner to remove the lock nut once the bearing restrainer is in place. Match-mark all mating parts with the white or black marker for easy and correct reassembly later. Keep all old bearings and DO NOT CLEAN them until after full inspection and reporting on condition	Hydraulic nut remover and C-spanners. Marker – white and	Remove locknut safely without harm to people or equipment	Nuts removed and Plummer blocks removed safely and retained parts cleaned thoroughly	Nuts removed and Plummer blocks removed safely and old parts kept for later inspection and retained parts cleaned thoroughly	Nuts removed and Plummer blocks removed safely. Old parts immediately inspected for evidence of problems and report completed. thly clean		Report safety concerns or removal problems or damage to Job Supervisor	
8.	Technician	Recover usable parts	Layout all parts to be reused in a dirt-free area in orderly fashion after cleaning thoroughly and safely with de-greasing agent and drying-off. Check part numbers are correct with parts list		All reused parts cleaned spotless, inspected for quality to remain in service and part number identified as correct with parts list	Parts are clean and correct	Parts are clean and correct and tagged with part number	Parts are clean, correct, tagged with part number and double checked for condition			
9.	Technician	Check Shaft Condition and Tolerance	With a micrometer measure the dimensions of the shaft location in three planes where the adaptor sleeves sit and check them for suitability. From the end of the shaft measure to where the adapter sleeve will finally sit and mark the shaft with a black felt tip marker at 0^o, 45^o, 90^o and 135^o in the planes corresponding to the ends of the adapter sleeve and its mid-way point. The diagram below shows the positions under the adaptor to measure, along with a table showing the required tolerances that the shaft must meet.	Suitably sized and vernier callipers or micrometer	The section of shaft under the adaptor sleeves simultaneously meets the minimum requirements for shaft tolerance and for taper, roundness and cylindricity grade	Use vernier callipers or micrometer to measure shaft tolerance, taper, roundness and cylindricity are all within tolerance limits	Use vernier callipers or micrometer to measure shaft tolerance, taper, roundness and cylindricity are all within tolerance limits and repeat measurements to confirm results	Use vernier callipers or micrometer to measure shaft tolerance, taper, roundness and cylindricity are all within tolerance limits and get another person to check and confirm the results		Replace shaft with new if maximum limits exceed allowed requirement for shaft tolerance, taper, roundness and cylindricity	

Do attach other instructions, guides and procedures where necessary. To include a description of hydraulic oil of bearing removal in this procedure would make the document too large. But there does need to be a procedure for hydraulic bearing removal.

The three standards, Good-Better-Best, need to be identified and set for each task, along with the proof-test and the corrective action should the test prove below minimum standard results. Your technicians and engineers can help in compiling the standards. You can also get information from the manufacturer and from recognised international standards. The 'Best' standard must be approved by the senior technical expert in the organisation, as it is the standard the company is striving for and against which everything else is judged.

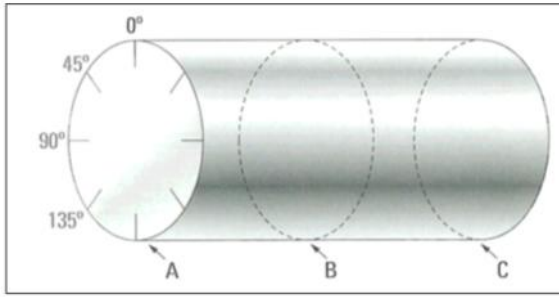
No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards (Good / Better / Best)	Reading / Result	Action if Out of Tolerance	Sign off
10.									

International Tolerance Grades

Basic Sizes (mm)		Measuring Tools			Materials									
Over	Including	IT 05	IT 06	IT 07	IT 08	IT 09	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16	IT 17
		Fits for parts in precision and general engineering							Large Manufacturi				Fabrication	
1	3	0.004	0.006	0.010	0.014	0.025	0.040	0.060	0.100	0.140	0.250	0.400		
3	6	0.005	0.008	0.012	0.018	0.030	0.048	0.075	0.120	0.180	0.300	0.480	0.75	
6	10	0.006	0.009	0.015	0.022	0.036	0.058	0.090	0.150	0.220	0.360	0.580	0.900	
10	18	0.008	0.011	0.018	0.027	0.043	0.070	0.110	0.180	0.270	0.430	0.700	1.100	1.
18	30	0.009	0.013	0.021	0.033	0.052	0.084	0.130	0.210	0.330	0.520	0.840	1.300	2.10
30	50	0.011	0.016	0.025	0.039	0.062	0.100	0.160	0.250	0.390	0.620	1.000	1.600	2.500
50	80	0.013	0.019	0.030	0.046	0.074	0.120	0.190	0.300	0.460	0.740	1.200	1.900	3.000
80	120	0.015	0.022	0.035	0.054	0.087	0.140	0.220	0.350	0.540	0.870	1.400	2.200	3.500
120	180	0.018	0.025	0.040	0.063	0.100	0.160	0.250	0.400	0.630	1.000	1.600	2.500	4.000
180	250	0.020	0.029	0.046	0.072	0.115	0.185	0.290	0.460	0.720	1.150	1.850	2.900	4.600
250	315	0.023	0.032	0.052	0.081	0.130	0.210	0.320	0.520	0.810	1.300	2.100	3.200	5.200
315	400	0.025	0.036	0.057	0.089	0.140	0.230	0.360	0.570	0.890	1.400	2.300	3.600	5.700
400	500	0.027	0.040	0.063	0.097	0.155	0.250	0.400	0.630	0.970	1.550	2.500	4.000	6.300
500	630	0.032	0.044	0.070	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400	
630	800	0.036	0.050	0.080	0.125	0.200	0.320	0.500	0.800	1.250	2.000	3.200	5.000	
800	1000	0.040	0.056	0.090	0.140	0.230	0.360	0.560	0.900	1.400	2.300	3.600	5.600	
1000	1250	0.047	0.066	0.105	0.165	0.260	0.420	0.660	1.050	1.650	2.600	4.200	6.600	
1250	1800	0.055	0.078	0.125	0.195	0.310	0.500	0.780	1.250	1.950	3.100	5.000	7.800	
1800	2000	0.065	0.092	0.150	0.230	0.370	0.600	0.920	1.500	2.300	3.700	6.000	9.200	
2000	2500	0.078	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400	7.000	11.000	
2500	3160	0.093	0.135	0.210	0.330	0.540	0.880	1.350	2.100	3.300	5.400	8.000	13.500	

This reference standard is needed for this procedure because in covers sizes from 30mm to 250mm. Reference tables are normally appended to the back of the procedure but shown here because this is an example of what to do to create ACE 3T procedures. If this was an individual shaft size procedure (which I recommend you do) the tolerance values would be selected, double-checked and shown for each task.

11. Technician — Check Shaft Condition and Tolerance



Shaft Diameter mm		Tolerance h9 µm		Form IT5 µm	Form IT7 µm
over	incl	high	low	max	max
18	30	0	-52	9	21
30	50	0	-62	11	25
50	80	0	-74	13	30
80	120	0	-87	15	35
120	180	0	-100	18	40
180	250	0	-115	20	46
250	315	0	-130	23	62

Such tables are developed specifically for each procedure so the technician on the job does not have to stop and work the details out themselves under stressful conditions and difficult work situations. The details they need are researched, doubled-checked to be correct and provided in the procedure.

Thanks to Rod Bennett of Bluescope Steel and CBC Bearings, Australia for the method www.conbear.com

An example of using the table for a 150mm diameter shaft is shown below.

Tolerance Evaluation

	0°	45°	90°	135°	Plane Average	Required Tolerance h9
Plane A	149.98	149.99	149.98	149.99	149.99	0.000 to -0.100
Plane B	149.97	149.94	149.98	149.95	149.96	
Plane C	149.98	149.98	149.95	149.99	149.98	
Max-Min	-0.03	-0.06	-0.05	-0.05	-0.04	-0.10

Shaft tolerance is met

Cylindricity Evaluation

	0°	45°	90°	135°	Plane Average	Required IT Grade 5
Plane A	149.98	149.99	149.98	149.99	149.99	0.018
Plane B	149.97	149.94	149.98	149.95	149.96	
Plane C	149.98	149.98	149.95	149.99	149.98	
Max-Min	0.01	0.05	0.03	0.04	0.03	0.018

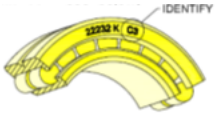
Shaft is not sufficiently cylindrical

Provide examples of how to complete the tables and do the analysis that needs to be made.

Replace shaft with new if maximum limits are exceeded on any requirement for shaft tolerance and IT Grade (if IT Grade is exceeded it means the taper, roundness or cylindricity are not right for the bearing to have a long and reliable life)

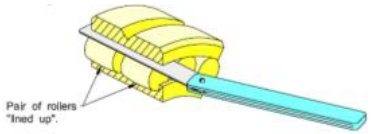
No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
12.	Technician	Evaluate Fixed Bearing Shaft Tolerance	<table><tr><th></th><th>0°</th><th>45°</th><th>90°</th><th>135°</th><th>Plane Average</th><th>Required Tolerance h9</th></tr><tr><td>Plane A</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane B</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane C</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Max-Min</td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>Enter appropriate high and low shaft tolerance value from the table above in the right hand side column. e.g. 0.000 to -0.100 for 150mm nominal bore bearing Record final measurements in the table above then subtract the smallest value from the largest value and note if 'Pass' or 'Fail' in the Result Column			Use vernier calliper to measure shaft tolerance within h9 and double-check it again. Measure to second decimal place accuracy.	Use micrometer to measure the shaft tolerance is within h9 and double-checks it again. Measure to second decimal place accuracy.	Use micrometer to measure shaft tolerance is within h9 and gets another person to measure and double-check values match. Measure to second decimal place accuracy.		Replace shaft with new if minimum tolerance is exceeded	
13.	Technician	Evaluate Fixed Bearing Cylindricity Tolerance	<table><tr><th></th><th>0°</th><th>45°</th><th>90°</th><th>135°</th><th>Plane Average</th><th>Target IT Grade 5</th><th>Tolerance IT Grade 7</th></tr><tr><td>Plane A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane B</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane C</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Max-Min</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>Enter appropriate maximum IT value from the table above in the two right hand side columns. e.g. IT5 of 0.018 and IT7 of 0.040 for 150mm nominal bore bearing Record final measurements in the table above then subtract the smallest value from the largest value and note if 'Pass' or 'Fail' in the Result Column			Use vernier calliper to measure and record measurements then double-check them again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT7	Use micrometer to measure and record measurements then double-check it again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT6	Use micrometer to measure and record measurements then get another person to measure and double-check values match. Measure to second decimal place accuracy. Tolerance Grade is within IT5		Replace shaft with new made to IT5 tolerance if IT7 Grade is exceeded	
14.	Technician	Evaluate Floating Bearing Shaft Tolerance	<table><tr><th></th><th>0°</th><th>45°</th><th>90°</th><th>135°</th><th>Plane Average</th><th>Required Tolerance h9</th></tr><tr><td>Plane A</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane B</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane C</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Max-Min</td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>Enter appropriate high and low shaft tolerance value from the table above in the right hand side column. e.g. 0.000 to -0.100 for 150mm nominal bore bearing Record final measurements in the table above then subtract the smallest value from the largest value and note if 'Pass' or 'Fail' in the Result Column			Use vernier calliper to measure shaft tolerance within h9 and double-check it again. Measure to second decimal place accuracy.	Use micrometer to measure the shaft tolerance is within h9 and double-checks it again. Measure to second decimal place accuracy.	Use micrometer to measure shaft tolerance is within h9 and gets another person to measure and double-check values match. Measure to second decimal place accuracy.		Replace shaft with new if minimum tolerance is exceeded	
15.	Technician	Evaluate Floating Bearing Cylindricity Tolerance	<table><tr><th></th><th>0°</th><th>45°</th><th>90°</th><th>135°</th><th>Plane Average</th><th>Target IT Grade 5</th><th>Tolerance IT Grade 7</th></tr><tr><td>Plane A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane B</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane C</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Max-Min</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>Enter appropriate maximum IT value from the table above in the two right hand side columns. e.g. IT5 of 0.018 and IT7 of 0.040 for 150mm nominal bore bearing Record final measurements in the table above then subtract the smallest value from the largest value and note if 'Pass' or 'Fail' in the Result Column			Use vernier calliper to measure and record measurements then double-check them again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT7	Use micrometer to measure and record measurements then double-check it again that values match. Measure to second decimal place accuracy. Tolerance Grade is up to IT6	Use micrometer to measure and record measurements then get another person to measure and double-check values match. Measure to second decimal place accuracy. Tolerance Grade is within IT5		Replace shaft with new made to IT5 tolerance if IT7 Grade is exceeded	

Provide a place to record the findings and do the analysis so there is evidence it was correctly done.

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
16.	Technician	Confirm bearing is correct	See part number for internal clearance suffix. If no suffix the clearance is 'normal'. If suffix is present the clearance is special for the situation e.g. C3 clearance is one group greater than 'normal'  *Thanks to CBC Bearings, Australia for the image www.conbear.com* Suffix K means 1:12 taper; Suffix K30 means 1:30 taper. Record the bearing number including taper and clearance range designations in table below.	New spherical roller bearing	Part provided is identical to listed part	Record bearing number including taper and clearance designations	Record bearing number including taper and clearance designations	Record bearing number including taper and clearance designations and double check correct		If bearing is not the same as on the parts list immediately inform the Job Supervisor	
17.	Technician	Confirm bearing bore is correct	Calculate the bearing bore size by multiplying the last two digits of the part number by 5 and record the nominal bore in the table below. e.g. 23134 has a bore 34 x 5 = 170mm	Steel ruler with graduation marks clearly readable	The bearing's small bore matches the calculated bore size	Calculate bore and record value.	Calculate bore and measure bearing small end bore with steel ruler within 1mm accuracy	Calculate bore and measure bearing small end bore with steel ruler within 1mm accuracy and double check size		If bore is wrong size immediately inform the Job Supervisor	
18.	Technician	Identify allowed internal clearance	Record the details of the equipment and bearing in the table below and record the minimum and maximum permitted clearance values from the clearance table Equipment Number: _____ Bearing Location: _____ Bearing Number: _____ Bearing Nominal Bore (mm): _____ Internal Clearance Range i.e. C#?: _____ (Located anywhere on bearing) Minimum / Maximum Allowed Bearing Internal Clearance: [ ] [ ]								

Use pictures and images to make it clear what needs to be done and how it is done right.

Include tables and lists to guide in recording necessary information that the technician must use.

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good* *Better* *Best*			Reading / Result	Action if Out of Tolerance	Sign off
			Nominal bearing bore diameter (d) A / Initial Clearance B / Required reduction in radial clearance C Normal: over 30 incl. 40: min 0.035 max 0.050; over 40 incl. 50: min 0.045 max 0.060; over 50 incl. 65: min 0.055 max 0.075; over 65 incl. 80: min 0.070 max 0.095; over 80 incl. 100: min 0.080 max 0.110; over 100 incl. 120: min 0.100 max 0.135; over 120 incl. 140: min 0.120 max 0.160; over 140 incl. 160: min 0.130 max 0.180; over 160 incl. 180: min 0.140 max 0.200; over 180 incl. 200: min 0.160 max 0.220; over 200 incl. 225: min 0.180 max 0.250; over 225 incl. 250: min 0.200 max 0.270; over 250 incl. 280: min 0.220 max 0.300 C3: over 30 incl. 40: min 0.050 max 0.065; over 40 incl. 50: min 0.060 max 0.080; over 50 incl. 65: min 0.075 max 0.095; over 65 incl. 80: min 0.095 max 0.120; over 80 incl. 100: min 0.110 max 0.140; over 100 incl. 120: min 0.135 max 0.170; over 120 incl. 140: min 0.160 max 0.200; over 140 incl. 160: min 0.180 max 0.230; over 160 incl. 180: min 0.200 max 0.260; over 180 incl. 200: min 0.220 max 0.290; over 200 incl. 225: min 0.250 max 0.320; over 225 incl. 250: min 0.270 max 0.350; over 250 incl. 280: min 0.300 max 0.390 C4: over 30 incl. 40: min 0.065 max 0.085; over 40 incl. 50: min 0.080 max 0.100; over 50 incl. 65: min 0.095 max 0.120; over 65 incl. 80: min 0.120 max 0.150; over 80 incl. 100: min 0.140 max 0.180; over 100 incl. 120: min 0.170 max 0.220; over 120 incl. 140: min 0.200 max 0.260; over 140 incl. 160: min 0.230 max 0.300; over 160 incl. 180: min 0.260 max 0.340; over 180 incl. 200: min 0.290 max 0.370; over 200 incl. 225: min 0.320 max 0.410; over 225 incl. 250: min 0.350 max 0.450; over 250 incl. 280: min 0.390 max 0.490 Required reduction in radial clearance C: over 30 incl. 40: min 0.020 max 0.025; over 40 incl. 50: min 0.025 max 0.030; over 50 incl. 65: min 0.030 max 0.040; over 65 incl. 80: min 0.040 max 0.050; over 80 incl. 100: min 0.045 max 0.060; over 100 incl. 120: min 0.050 max 0.070; over 120 incl. 140: min 0.065 max 0.090; over 140 incl. 160: min 0.075 max 0.100; over 160 incl. 180: min 0.080 max 0.110; over 180 incl. 200: min 0.090 max 0.130; over 200 incl. 225: min 0.100 max 0.140; over 225 incl. 250: min 0.110 max 0.150; over 250 incl. 280: min 0.120 max 0.170 *Thanks to CBC Bearings, Australia for the table www.conbear.com*							
19.	Technician	Measure internal clearance	Stand bearing vertical on a clean, dust-free, solid surface. Ensure both rollers are lined-up side-by-side at the top of the bearing and pinch them between the thumb and pointer finger and firmly hold them. Measure top internal radial clearance of new bearing with long feeler gauges by pushing them axially between rollers and outer ring, as shown in the picture.  *Thanks to CBC Bearings, Australia for the image www.conbear.com* Select feelers of a combined thickness that will fit the clearance gap. For large bearings use two feelers together and for small bearings use three together so they slip over each other as they are fed between rollers and raceway. For example, on a 23134 K C3 bearing the internal clearance shown in the clearance table below for a C3 clearance allows 0.200mm to 0.260mm gap in an unmounted bearing and you would select long feelers that as a pair, would fit that range, say start with a 0.1 and a 0.15 (or a 0.25) and test if it fits between rollers and outer race, if not then use the 0.1 with a 0.12 and so on. **Wear gloves when forcing feelers between rollers and race.** Progressively increase the thickness of the feeler gauges until the rubbing resistance makes it very difficult to push the feelers in and out of the clearance gap. Feed the feelers into the gap 4-5mm at a time with your fingers. The feelers have to totally fill the clearance and it requires firm pushing of the feelers to get them through to the other side of the bearing. Under no circumstances rotate the	Clean 'long-series' feeler gauges free of rust with every feeler in complete shape and every thickness identification clearly readable	Measured initial internal clearance is within tolerance shown on standards table for bearing clearance group	Measure top clearance between rollers and outer ring with feeler gauges accurately and record measurement	Measure top clearance between rollers and outer ring with feeler gauges accurately and repeat again. Record measurement	Measure top clearance between rollers and outer ring with feeler gauges accurately. Get another person to measure and double-check values match, and record measurement.		If the clearance is out of the range immediately inform the Job Supervisor	

This is another reference table better kept as an appendix, but shown here to indicate where the internal clearance information is found.

The data in the table comes from the bearing manufacturer's catalogue for the bearing type and bearing size.

I'm trying here to indicate when the technician knows they have got the measurement right. To get 'the feel' takes practice and involves teaching your brain what is the correct sensation that equates to the proper measurement using feeler gauges.

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
			bearing to 'roll' feelers through. Record in the table below the 'hard' internal clearance measured with the feelers								
20.	Technician	Calculate fitted internal clearance	Measured Internal Clearance with Feelers (mm) — Minimum required reduction of internal clearance (mm) — Maximum possible fitted clearance (mm) [ ] minus [ ] = [ ] Maximum required reduction of internal clearance (mm) — Minimum possible fitted clearance (mm) [ ] minus [ ] = [ ] Check: Subtract values above — Check: Subtract values above *Thanks to CBC Bearings, Australia for the calculation method www.conbear.com* Calculate the required internal clearance reduction when the bearing is correctly fitted. Use the required reduction values in the table below for the bearing size. As an example, for a bearing of bore 170mm read across the row 'over 160 including 180' and for C3 clearance see that it must be reduced by between 0.080mm and 0.110mm. In other words the residual clearance left in the bearing between roller and outer raceway after it is fitted and tightened on the adapter sleeve is between: 0.260 minus 0.080 = 0.180mm and 0.260 minus 0.110 = 0.150mm			Show hand calculation of required reduction range and double check mathematics is correct Subtract values in boxes and note it in the space under the boxes. Check both results are identical	Show hand calculation of required reduction range and double check mathematics with a digital calculator Subtract values in boxes and note it in the space under the boxes. Check both results are identical	Show hand calculation of required reduction range, double check with digital calculator Subtract values in boxes and note it in the space under the boxes. Check both results are identical Get a second person to do the calculation independently and confirm values are same			
21.											

In this case the technician has to calculate the tolerances they must work to. I would not normally do it this way but instead have one shaft size and one bearing type and list the required reduction and fitted clearance just for that specific circumstance. As soon as I see that people have to make decisions and select from tables as part of doing the job, I know that someone will get it wrong someday.

Nominal bearing bore diameter (d) A		Initial Clearance B						Required reduction in radial clearance C		Axial Displacement Taper 1:12 D				Axial Displacement Taper 1:30 D				Minimum permissible residual clearance E		
		Normal		C3		C4				Shaft		Sleeve		Shaft		Sleeve				
over	including	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	Normal	C3	C4
30	40	0.035	0.050	0.050	0.065	0.065	0.085	0.020	0.025	0.350	0.400	0.350	0.450	-	-	-	-	0.015	0.025	0.040
40	50	0.045	0.060	0.060	0.080	0.080	0.100	0.025	0.030	0.400	0.450	0.450	0.500	-	-	-	-	0.020	0.030	0.050
50	65	0.055	0.075	0.075	0.095	0.095	0.120	0.030	0.040	0.450	0.600	0.500	0.700	-	-	-	-	0.025	0.035	0.055
65	80	0.070	0.095	0.095	0.120	0.120	0.150	0.040	0.050	0.600	0.750	0.700	0.850	-	-	-	-	0.025	0.040	0.070
80	100	0.080	0.110	0.110	0.140	0.140	0.180	0.045	0.060	0.700	0.900	0.750	1.000	1.700	2.200	1.800	2.400	0.035	0.050	0.080
100	120	0.100	0.135	0.135	0.170	0.170	0.220	0.050	0.070	0.700	1.100	0.800	1.200	1.900	2.700	2.000	2.800	0.050	0.065	0.100
120	140	0.120	0.160	0.160	0.200	0.200	0.260	0.065	0.090	1.100	1.400	1.200	1.500	2.700	3.500	2.800	3.600	0.055	0.080	0.110
140	160	0.130	0.180	0.180	0.230	0.230	0.300	0.075	0.100	1.200	1.600	1.300	1.700	3.000	4.000	3.100	4.200	0.055	0.090	0.130
160	180	0.140	0.200	0.200	0.260	0.260	0.340	0.080	0.110	1.300	1.700	1.400	1.900	3.200	4.200	3.300	4.600	0.060	0.100	0.150
180	200	0.160	0.220	0.220	0.290	0.290	0.370	0.090	0.130	1.400	2.000	1.500	2.200	3.500	4.500	3.600	5.000	0.070	0.100	0.160
200	225	0.180	0.250	0.250	0.320	0.320	0.410	0.100	0.140	1.600	2.200	1.700	2.400	4.000	5.500	4.200	5.700	0.080	0.120	0.180
225	250	0.200	0.270	0.270	0.350	0.350	0.450	0.110	0.150	1.700	2.400	1.800	2.600	4.200	6.000	4.600	6.200	0.090	0.130	0.200
250	280	0.220	0.300	0.300	0.390	0.390	0.490	0.120	0.170	1.900	2.600	2.000	2.900	4.700	6.700	4.800	6.900	0.100	0.140	0.220

Thanks to CBC Bearings, Australia for the table www.conbear.com

22.	Technician	Determine sleeve axial	From the table above read the axial displacement for a bearing mounted on a tapered sleeve to be properly seated to get the required final fitted clearance and record it in the boxes below. As an example, for a bearing of nominal bore 170mm read across the row 'over 160 including 180' and for sleeve with 1:12 taper see that						

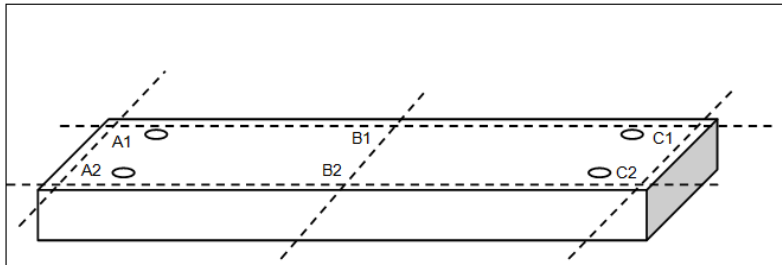
No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
		drive-up displacement range	the bearing must be displaced up the sleeve from snug fit on the taper by between 1.4mm and 1.9mm. From the table above read and record the minimum permitted fitted clearance below which it cannot be allowed to go. For example, for a bearing of bore 170mm read across the row 'over 160 including 180' and for a C3 internal clearance see that it must not be less then 0.1mm final minimum fitted clearance. Axial Drive-up Displacement Range for 1:12 taper Sleeve (mm) [ ] to [ ] Minimum permissible fitted clearance (mm) [ ] *Thanks to CBC Bearings, Australia for the calculation method www.conbear.com*								
23.	Technician	Get fixed bearing parts	Review the fixed bearing assembly drawing and identify all parts that go into the bearing assembly and Plummer Block and gather them together in order of installation.	Bearing parts	Parts protected from damage and ordered for ease of installation on a clean layout area						
24.	Technician	Mark position of adaptor sleeve	From the installation drawing, or from measurements of the distance on the original assembly, determine how far along the shaft the adaptor sleeve will be located in its final position and draw a mark on the shaft with a black marker where the rear and front ends sit as guidance of where to slide the adaptor sleeve.		Bearing final position after axial displacement brings it in the middle of the bearing housing	Centred to within ±2mm	Centred to within ±1.5mm	Centred to within ±1mm		Identify why the bearing cannot be centred and rectify the problem.	
25.	Technician	Smear mounting paste	Clean the shaft and thinly smear a level teaspoon amount of mounting paste around the shaft from the rear of the adaptor sleeve to the end of the shaft to help parts slide up the shaft								
26.	Technician	Slip rear labyrinth onto shaft	Slide the inner labyrinth seal down the shaft with its o-ring outward t								
27.	Technician	Slip rear V-seal onto shaft	Slide the rear V-seal down the shaft with the V toward the bearing								
28.	Technician	Slip rear wear plate onto shaft	Slide the V-seal wear plate onto the shaft with the running side against the V-seal seat								
29.	Technician	Slip adapter sleeve onto shaft	Slip the adapter sleeve onto the shaft with the taper toward the end of the shaft and move the sleeve to about 5mm before its final position.								
30.	Technician	Snug bearing onto adaptor sleeve	Slide the bearing over the shaft and push it firmly onto the adapter sleeve taper								
31.	Technician	Move adaptor sleeve into place	With a copper wedge dolly tap the adapter sleeve into its final position between the rear and front black marks								
32.	Technician	Get floating bearing parts	Review the fixed bearing assembly drawing and identify all parts that go into the bearing assembly and Plummer Block and gather them together in order of installation.								

I didn't get a chance to complete these columns because I ran out of time. But they need to be done.

Here is a great spot to get the technicians involved in compiling the procedure by asking them what they currently do and letting them suggest ways of getting even better results, then including them in the procedure where possible. But the 'best' column is a standard the company must set and approve as its target performance. That decision cannot be done by the technicians alone.

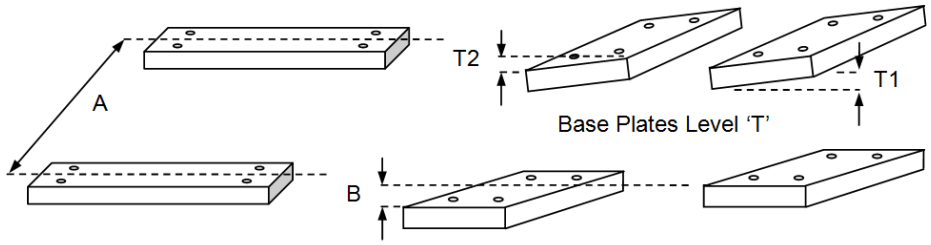
Keep each part to itself as proof the task was done right. Don't start saying 'repeat the above steps for this item', even if they are identical steps.

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
33.	Technician	Mark position of adaptor sleeve	From the installation drawing, or from measurements of the distance on the original assembly, determine how far along the shaft the adaptor sleeve will be located in its final position and draw a mark on the shaft with a black marker where the rear and front ends sit as guidance of where to slide the adaptor sleeve.		Bearing final position after axial displacement is in the middle of the bearing housing	Centred to within ±2mm	Centred to within ±1.5mm	Centred to within ±1mm		Identify why the bearing cannot be centred and rectify the problem.	
34.	Technician	Smear mounting paste	Clean the shaft and thinly smear a level teaspoon amount of mounting paste around the shaft from where the rear of the adaptor sleeve will be to the end of the shaft to help parts slide up the shaft without damage and to prevent fretting corrosion when in service.								
35.	Technician	Slip rear labyrinth onto shaft	Slide the inner labyrinth seal down the shaft with its o-ring outward								
36.	Technician	Slip rear V-seal onto shaft	Slide the rear V-seal down the shaft with the V toward the bearing								
37.	Technician	Slip rear wear plate onto shaft	Slide the V-seal wear plate onto the shaft with the running side against the V-seal seat								
38.	Technician	Slip adapter sleeve onto shaft	Slip the adapter sleeve onto the shaft with the taper toward the end of the shaft and move the sleeve to about 5mm before its final position.								
39.	Technician	Snug bearing onto adaptor sleeve	Slide the bearing over the shaft and push it firmly onto the adapter sleeve taper								
40.	Technician	Move adaptor sleeve into place	With a copper wedge dolly tap the adapter sleeve into its final position between the rear and front black marks								
41.	Technician	Check fixed bearing base plate flatness	Check the base plate flatness for the fixed bearing by placing a straight edge across the entire base from end to end. With feeler gauges measure the gap at each hold-down bolt area and the middle of the Plummer Block and record them in the table	Straight edge, short feeler gauges	Thickest feeler gauge that fits between the straight edge and base plate at any point is less than IT7 maximum	Tolerance Grade is up to IT7. Ensure base plate is stiff and cannot flex more than IT7/10 under full load	Tolerance Grade is up to IT6. Ensure base plate is stiff and cannot flex more than IT6/10 under full load	Tolerance Grade is up to IT5. Ensure base plate is stiff and cannot flex more than IT5/10 under full load		Get base plate machined flat to IT5. Ensure base plate is stiff and cannot flex more than IT5/10 under full load. Stiffen-up base structure & supports by bracing. Any site work required to stiffen the base is a change and must be	

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
										assessed for safety and engineering requirements before making the change	
42.	Technician	Check bearing base plate flatness									
43.	Technician	Assess fixed bearing base plate flatness	Length of Base (mm): _____ Width of Base (mm): _____								
44.	Technician	Check floating bearing base plate flatness	Check the base plate flatness for the floating bearing with a straight edge and feeler gauges at the 3 locations shown in the sketch – under each hold-down bolt area and the middle of the Plummer Block – and record them in the table	Straight edge, short feeler gauges	Thickest feeler gauge that fits between the straight edge and base plate at any point is less than IT7 maximum	Tolerance Grade is up to IT7. Ensure base plate is stiff and cannot flex more than IT7/10 under full load	Tolerance Grade is up to IT6. Ensure base plate is stiff and cannot flex more than IT6/10 under full load	Tolerance Grade is up to IT5. Ensure base plate is stiff and cannot flex more than IT5/10 under full load		Get base plate machined flat to IT5. Ensure base plate is stiff and cannot flex more than IT5/10 under full load. Stiffen-up base structure & supports by bracing. Any site	

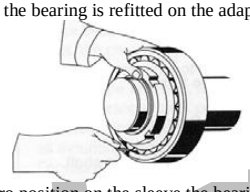
Length mm over	Length mm incl	Flatness IT5 µm max	Flatness IT7 µm max
80	120	15	35
120	180	18	40
180	250	20	46
250	315	23	62
315	400	25	57
400	500	27	63
500	630	30	70
630	800	35	80
800	1000	40	90

	Point 1	Point 2	Max-Min	Plane Average	Target IT Grade 5	Tolerance IT Grade 7
Plane A						
Plane B						
Plane C						
Max-Min						

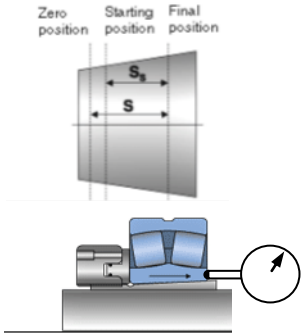
<table>
<tr><th>No</th><th>Task Step Owner</th><th>Task Step Name</th><th>Task Description</th><th>Matl, Tools & Their Condition</th><th>Test for Correctness</th><th colspan="3">Reliability and Quality Standards
Good Better Best</th><th>Reading / Result</th><th>Action if Out of Tolerance</th><th>Sign off</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>work required to stiffen the base is a change and must be assessed for safety and engineering requirements before making the change</td><td></td></tr>
<tr><td>45.</td><td>Technician</td><td>Assess floating bearing base plate flatness</td><td colspan="9">Length of Base (mm): _____
Width of Base (mm): _____
<table><tr><th></th><th>Point 1</th><th>Point 2</th><th>Max-Min</th><th>Plane Average</th><th>Target IT Grade 5</th><th>Tolerance IT Grade 7</th></tr><tr><td>Plane A</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane B</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Plane C</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Max-Min</td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>46.</td><td>Technician</td><td>Check Base Plate Orientation</td><td colspan="9">Base Plate Orientation
 
</td></tr>
<tr><td>47.</td><td>Technician</td><td>Check base plate vertical alignment</td><td>Measures the distance ‘A’ between centres of the Plummer block bases and record it below.

‘A’ Ctr-toCtr distance of bases (mm): _____
Use a string line and a precision level to measure the vertical alignment between bases. Place the precision level on top the highest base and centre the bubble. Pull the string line tight and bring the string line up to the underside of the level until the string is also level.</td><td>String line and precision bubble level or Surveyor’s laser</td><td>See the Tolerance Grade Table for maximum allowable vertical height difference for IT15 tolerance over the distance between bases and record the Maximum allowed measurement gap B (mm)</td><td>Maximum allowed IT15 distance</td><td>One-half of the maximum allowed IT15 distance</td><td>One-quarter of the maximum allowed IT15 distance</td><td>Actual gap B measured (mm)

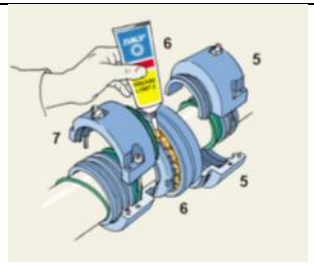
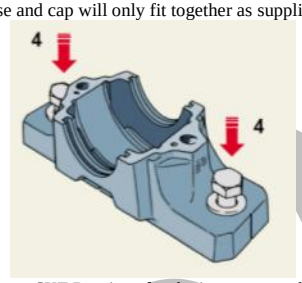
_____</td><td>Shim-up the lowest Plummer block to within one-quarter of the maximum allowed vertical misalignment distance</td><td></td></tr>
</table>

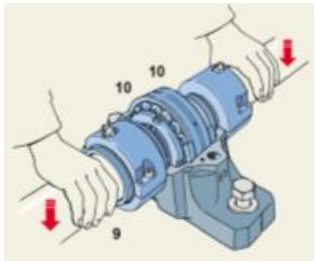
No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
			Measure the gap from the underside of the string line to the lowest base. (If there is no line-of-sight then transfer the datum to suitable points.) 'B' Vertical height difference of bases (mm): _____		Max allowed gap B (mm) _____						
48.	Technician	Fixed bearing base plate level	Measure the Plummer block base width and record it below. Place a precision level across fixed bearing base plate and bring it level with the bubble centred. Measure distance T with the end of a vernier calliper. 'T' Measured width of Plummer base (mm): _____	Precision level and vernier callipers	Use Tolerance Grade value for IT12 as the maximum allowable level difference over the base width. Max allowed gap T (mm): _____	Maximum allowed IT12 distance	One-half of the maximum allowed distance	One-quarter of the maximum allowed distance	Actual gap T measured (mm) _____	Shim-up the lowest Plummer block to within one-quarter of the maximum allowed vertical out of level distance	
49.	Technician	Floating bearing base plate level	Measure the Plummer block base width and record it below. Place a precision level across fixed bearing base plate and bring it level with the bubble centred. Measure distance T with the end of a vernier calliper. 'T' Measure width of Plummer base (mm): _____	Precision level and vernier callipers	Use the Tolerance Grade Table value for IT12 as the maximum allowable level difference over the base width. Max allowed gap T (mm): _____	Maximum allowed IT12 distance	One-half of the maximum allowed distance	One-quarter of the maximum allowed distance	Actual gap T measured (mm) _____	Shim-up the lowest Plummer block to within one-quarter of the maximum allowed vertical out of level distance	
50.	Technician	Prepare fixed end bearing	The fixed bearing now needs to be driven up the taper into its final position on the adaptor sleeve. Check the adaptor sleeve is still in the right position between the front and back lines marked on the shaft and that it will sit in the middle of the Plummer block bearing seat when finally positioned. Tap adapter sleeve back into place with a copper dolly if necessary. Check the bearing is snugly seated on the taper with no clearance between sleeve and bearing.								
51.	Technician	Lock-up fixed end bearing on adaptor sleeve	The final position is the distance up the taper that produces the final residual internal clearance for the bearing. Once in location the internal clearance is checked to be above the minimum and within the residual clearance tolerance. If necessary the bearing is refitted on the adaptor sleeve.  From the zero position on the sleeve the bearing is first moved into the start position. At this point the sleeve is tight on the shaft. From the start position the bearing is moved further up the taper by the required axial displacement to its final position, at which point the internal clearance is reduced to its final residual clearance. On bearings less than 80mm bore use C-spanners. Bearings 80 mm and over use a hydraulic nut with oil pressure to drive a piston. Once correctly located the bearing is fixed in place with the tab washer and nut. The nut is driven tight with a C-								

The three standards, Good-Better-Best, need to be identified and set for each task, along with the proof-test and the corrective action should the test prove below standard results. Again the technicians can help in compiling the standards. You can also get information from the manufacturer and from recognised international standards.

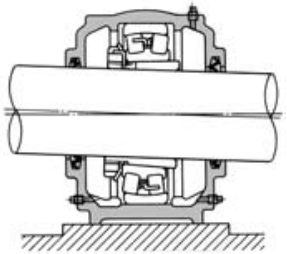
No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
			spanner and hammer and a tab is bent into the slot in the nut to fix the assembly in-place. **Do not attempt to tighten the locknut with hammer and drift.** The locknut will be damaged and chips can enter the bearing.  A dial gauge is installed against the inner ring at the no-nut side of the bearing to measure the axial displacement. If there is not space for a dial gauge clamp a clean stainless steel flat bar across the inner and outer rings and transfer the datum to a convenient location. Once in position the tab washer and nut hard against the inner rung. Follow the separate instructions for doing hydraulic nut mounting.								
52.		Grease the fixed bearing	Completely fill the fixed bearing with grease. The remainder of the recommended grease quantity is later put in the housing base at the sides								
53.	Technician	Prepare floating end bearing	Check the adaptor sleeve is still in the right position between the front and back lines marked on the shaft and that it will sit in the middle of the Plummer block bearing seat when finally positioned. Tap adapter sleeve back into place with a copper dolly if necessary. Check the bearing is snugly seated on the taper with no clearance between sleeve and bearing.								
54.	Technician	Lock-up floating end bearing on adaptor sleeve	From the zero position on the sleeve the bearing is first moved into the start position. At this point the sleeve is tight on the shaft. From the start position the bearing is moved further up the taper by the required axial displacement to its final position, at which point the internal clearance is reduced to its final residual clearance. Repeat the procedure used for the fixed end bearing.								
55.		Grease the floating bearing	Completely fill the bearing with floating grease. The remainder of the recommended grease quantity is later put in the housing base at the sides								
56.	Technician	Mount fixed bearing Taconite seals	On the no-nut side of the Plummer block place the bottom Taconite split ring over the V-ring and labyrinth then fit the top half ring and screw them together. The two halves of this split ring are not interchangeable. Check to see that they carry the same identification.								

All these tasks must have reliability standards set for them, along with the proof-test and the corrective action.

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good* *Better* *Best*	Reading / Result	Action if Out of Tolerance	Sign off
			 *Thanks to SKF Bearings for the image www.skf.com* Repeat the above for the nut side of the Plummer block.						
57.	Technician	Mount floating bearing Taconite seals	On the no-nut side of the Plummer block place the bottom Taconite split ring over the V-ring and labyrinth then fit the top half ring and screw them together. The two halves of this split ring are not interchangeable. Check to see that they carry the same identification. Repeat the above for the nut side of the Plummer block. If the housing is to be used at a shaft end, the second seal is omitted and an end cover inserted in the housing base instead.						
58.	Technician	Mount fixed bearing Plummer block	Temporarily position the floating bearing Plummer block on its base frame and fit hold-down bolts loosely. Locate the housing so the grease nipple on one side of the housing cap is at the no-nut side, opposite to the sleeve nut. It is necessary to consider the whole Plummer block as the base and cap will only fit together as supplied.  *Thanks to SKF Bearings for the image www.skf.com* With the Plummer block in position on the base check for 'softfoot' gaps under the base with feeler gauges. The allowed flatness tolerance is IT7 for the distance between bolt centres. If the 'softfoot' gap is above tolerance replace the Plummer block.			All these tasks must have reliability standards set for them, along with the proof-test and the corrective action.			
59.	Technician	Mount floating bearing Plummer block	Install the floating bearing Plummer block on its base and fit hold-down bolts loosely. Locate the housing so the grease nipple on one side of the housing cap is at the side opposite to the sleeve nut. It is necessary to consider the whole Plummer block as the base and cap will only fit together as supplied. With the Plummer block in position on the base check for 'softfoot' gaps under the base with feeler gauges. The allowed flatness tolerance is IT7 for the distance between						

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
			bolt centres. If the 'softfoot' gap is above tolerance replace the Plummer block.								
60.	Technician	Position fixed bearing in Plummer block	Fit the locating bearing into the lower Plummer block housing, together with the seals.  *Thanks to SKF Bearings for the image www.skf.com* Fit the split locating rings both sides of the drive-end bearing to fix it in the Plummer Block so it cannot move axially	Locating rings with gap	Drive end bearing is axially fixed firmly within the housing	Maximum total indicator run-out at drive end of shaft of 0.018mm	Maximum total indicator run-out at drive end of shaft of 0.010mm	Maximum total indicator run-out at drive end of shaft of 0.005mm			
61.	Technician	Position floating bearing in Plummer block	Fit the locating bearing into the lower Plummer block housing, together with the seals and adjust the position to centre the bearing in the bearing seating. If the Plummer block is to be used in a high temperature environment, carefully position the bearing considering the direction for thermal expansion of the shaft.								
62.	Technician	Grease the fixed bearing housing cavity	The recommended volume of grease to put into the Plummer blocks cavity each side of the bearing is 1/2 the empty cavity space. The volume of grease should be carefully selected as it can lead to overheating of the bearing, outward leakage from the seal, or ingress of dust.								
63.		Grease fixed bearing Taconite seals	Rotate the shaft and supply grease into the Taconite seal via the nipple until it exudes from the labyrinth rings. Use the same grease as that used for the bearings.								
64.		Grease the floating bearing housing cavity	The recommended volume of grease to put into the Plummer blocks cavity each side of the bearing is 1/2 the empty cavity space. The volume of grease should be carefully selected as it can lead to overheating of the bearing, outward leakage from the seal, or ingress of dust.								
65.		Grease floating bearing Taconite seals	Rotate the shaft and supply grease into the Taconite seal via the nipple until it exudes from the labyrinth rings. Use the same grease as that used for the bearings.								
66.	Technician	Align floating bearing	Once the bearing is correctly located, check the squareness of the Plummer block relative to the shaft (make sure the face of bearing inner ring is parallel with that of the outer ring and the shaft is central in the seals). Carefully align the housing base so that the circumferential gap around the seal is uniform right around. If the housing must be lifted, install shims under the Plummer blocks that are 100% the full size of the Plummer block base. Remember a large mounting error can cause the seal to fail or the shaft to flex								

All these tasks must have reliability standards set for them, along with the proof-test and the corrective action.

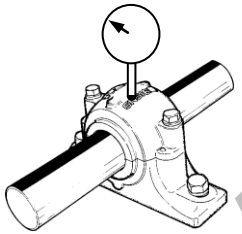
No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
			the bearing bore and rollers. If such a problem occurs, correct the Plummer block housing alignment.  *Thanks to NTN Bearings for the image www.ntn.co.jp*								
67.	Technician	Align fixed bearing									
68.	Technician	Install fixed bearing cap	The housing cap should be placed over the base and the cap bolts (to join cap and base) tightened to the torque Specified. The cap and base are not interchangeable with those of other housings. Checked to see that they bear the same identification.								
69.	Technician	Install floating bearing cap	The housing cap should be placed over the base and the cap bolts (to join cap and base) tightened to the torque Specified. The cap and base are not interchangeable with those of other housings. Checked to see that they bear the same identification.								
70.	Technician	Tighten hold-down bolts	Only when both bearing alignments are complete do you fully tighten the hold-down bolts. Pull-up bolts snug tight in cross tightening sequence. Sung means in firm contact under about 20% of final bolt torque. It is obtained by the full effort of a well-built man pulling on a ring spanner until it can no longer be moved by hand. It can also be achieved by use of an impact wrench. When the spinning nut turns to blows, count three blows, and the bolt will be snug tight[2].								
71.	Technician	Match mark fasteners	Match-mark nut position with a pencil when all nuts on both flanges are snug.	Pencil	Scribed marks in correct position and easily observable	Match-mark the nut and base	Clearly match mark the nut and base within 1 minute	Clearly match-mark the nut and base within 45 seconds			
72.	Technician	Tighten fasteners	Turn each nut an extra 1/3 of a turn to final position in cross tightening sequence. Re-tension continuously until all nuts are equally tight. No rotation of stud is permitted while tightening the nut.			Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence.	Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence in 5 minutes.	Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence in 4 minutes.		If a stud rotates it indicates that the nuts were not snug. Immediately stop and undo all studs and repeat nut snug tensioning procedure	
73.	Technician	Commissi on and test equipment operation	Once the bearing arrangement has been assembled, check the assembly has been done correctly by following the procedure below. (1) First, turn the bearing by hand to check that the bearing and seal are free from any irregularities. a. Non-smooth touch: Trapped dust or scratch b. Irregular torque: Abnormal interference								

All these tasks must have reliability standards set for them, along with the proof-test and the corrective action.

This bolting method does not need a tension wrench. A tension wrench has at best a ±15% accuracy, and as bad as ±25% accuracy. Best of all is to use shank length extension tensioning with an accuracy of ±5%.

These activities often are found in the manufacturer's literature and in machinery handbook and engineering standards.

[2] Sheppard, Alan T., 'High Strength Bolting', The DuRoss Group, Inc.

No	Task Step Owner	Task Step Name	Task Description	Matl, Tools & Their Condition	Test for Correctness	Reliability and Quality Standards *Good*	*Better*	*Best*	Reading / Result	Action if Out of Tolerance	Sign off
			c. Excessively large running torque: Too small bearing clearance, poor flatness of mounting seat (2) Next, run the bearing by power. Begin with no load, and at lower speed check. a. Abnormal noise: Dust, dent mark, or poor lubrication b. Vibration: Greater misalignment, or excessively large residual clearance (3) Run the bearing under normal operating conditions to check for temperature rise on the bearing. The possible causes to abnormal temperature rise with bearings are as follows: a. Allowable speed has been exceeded. b. Overloading c. Too small residual clearance d. Negative clearance owing to excessive expansion or compression with the shaft e. Warped Plummer block owing to poor flatness with the mounting base f. Poor lubrication (excessive or insufficient lubricant, inappropriate lubrication method of lubricant) g. Too great tightening allowance for the contact seal, or interference with rotating components such as those around the labyrinth seal If any irregularity is found as a result of running inspection, determine and remove the cause. Then redo the running inspection to make sure the bearing runs normally.								
74.		Measure base plate start-up load flexing	 *Thanks to NTN Bearings for the image www.ntn.co.jp* Mount a free-standing digital dial gauge (i.e. mounted so it is separate to the base plate) with the dial gauge tip touching the top of the Plummer block. When the equipment starts-up note and record the tip movement. When the equipment is in operation under full load note and record the tip movement.					Ensure base plate and support is stiff and cannot flex more than IT5/10 under full load		Stiffen-up base and support frame by strong cross bracing. Ensure welding does not distort the base	
75.	Technician	Clean and hand back	Safely clean-up, hand-back, complete job record and sign-off and record Work Order history		All equipment, tools and waste removed - area left spotlessly clean	Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use	Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use	Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use			

After such an amount of intrusive maintenance is done on equipment it is necessary to write a commissioning plan with the tests to be performed and places to record the evidence that the equipment is performing correctly.

This proof-test can only be done when the equipment is operating. It is vital that it is done to check that deformation under load is not able to destroy the bearings.

Bibliography

1. SKF SNL Plummer block housings publication
2. NTN Plummer blocks publication 2500/E
3. CBC Bearing drawings CBC-DC-01B, CBC-DC-02B, CBC-DC-03B, CBC-DC-04B, CBC-DC-11A
4. ISO 286International Tolerance Grade Table