Debswana Specification

Electrical:

Requirements for Shafts for Electric AC Induction Machines with Frame Sizes 355 and Larger

1 SCOPE

This specification details the requirements for the design of new shafts and the reconditioning of damaged shafts on electric AC induction machines for frame size 355 and larger. Winder motor shafts are excluded from this specification.

2 TECHNICAL REQUIREMENTS TO BE SPECIFIED BY THE ENGINEER

The following requirements shall be specified on every invitation to tender, contract or order:

- Title, reference number, date and issue of this specification
- The scope of the work to be carried out on the shaft

3 DEFINITIONS

APPROVED/ACCEPTABLE	:	Approved by and acceptable to the Engineer in writing
ENGINEER		The responsible technical person or appointed representative as defined in the contract documentation
BS	:	British Standard
BS EN	:	Central European Norm
IEC	:	International Electrotechnical Commission
MICROWELDING	:	Specialised submerged-arc process using filler wire of diameter less than 1.2mm
NDE	:	Non destructive examination
QAP	:	Debswana Quality Assurance Procedure
Ra	:	Average deviation from the mean surface, measured in micrometres in accordance with BS 1134
THERMAL METAL SPRAYING	:	Process in which a filler wire/powder is passed through a heat source such as a flame or plasma arc, whereby the molten particles are propelled towards and fused onto the substrate
UMP	:	Unbalanced Magnetic Pull

The following terms are defined in the General Conditions of Contract:

- Debswana, Company, Contractor, Engineer

4 REQUIREMENTS

4.1 DESIGN OF SHAFTS

The Contractor shall satisfy himself that any shaft supplied for a machine in accordance with the requirements of this specification is adequate for the intended duty.

4.1.1 Fatigue design

The motor shaft shall be designed for a minimum 15 year operating life at 100% utilisation at the rated speed with a 50% probability of failure in accordance with the provisions of BS 5400: Part 10.

The Contractor shall show by means of suitable calculations that any alternating stress in the shaft, at any particular detail on the shaft, complies with the above requirements.

4.1.2 Shaft deflection

The Contractor shall by means of suitable calculations show that the maximum deflection of the shaft, with its self-weight and the UMP acting in the same direction, does not exceed 10% of the air gap.

4.1.3 Critical speeds

4.1.3.1 **The Contractor shall determine**: by calculation, the first 2 critical speeds of the shaft assembly, complete with core, windings, fans and any other attachment. In performing these calculations the effect of the UMP, bearing stiffness and approximate stiffness of the casing must be accounted for. Foundations shall be treated as rigid unless the properties of the foundations are known in which case these properties shall be used in calculations.

4.1.3.2 **No shaft critical speed**: shall be permitted in the range 70% to 120% of the operating speed(s).

4.1.3.3 **Vibration levels on run up to or run down from the operating speed for shafts which are required to pass through a critical speed:** shall not exceed 3 times the limits specified in BS 4999 Part 142 Grade R when tested in accordance with Clause 6.2

4.1.3.4 Design of potential stress concentration details

4.1.3.5 **The stress concentrations**: created by changes in shaft diameter shall be taken into account in the fatigue calculations. Here a shoulder occurs at a change in diameter of the shaft, an appropriate fillet radius shall be specified according to "Stress Concentration Factors" by R.E. Peterson.

4.1.3.6 **The drilling of any holes in the shaft**: shall be avoided wherever an alternative method of fixing or location is available. Where the use of a hole is unavoidable, the hole shall:

- Be perpendicular to the surface of the shaft except in the case where holes at an angle are required for up-shaft cables
- Be as small and shallow as practicable
- Have the intersection of the hole with the surface of the shaft dressed to remove all burrs, rough edges or any other possible crack initiation sites

4.1.3.7 **Any tapped holes required in the ends of the shaft: shall** be in accordance with the requirements of IEC 72A.

Holes required for tachometers or for balancing purposes shall be permitted. These holes shall be drilled so that the diameter of a circle drawn concentrically with the centre of the shaft and encompassing the outer perimeter of all the holes does not exceed 80% of that shaft end diameter.

4.1.3.8 **Motor shaft extensions**: shall be standardised to comply with the requirements of IEC 72A (including the keyway). BS 4235 shall be used for preferred lengths, radii and any supplementary information required.

4.1.3.9 **Any key and keyway**: required on the shaft other than that used for the output of motor power shall comply with BS 4235: Part I.

4.1.3.10 **No circumferential grooves, such as for circlip location**: shall be permitted between the bearing centres except where such grooves are required for core location. All circumferential grooves shall comply with the requirements of BS 3673: Part 4.

4.1.4 Material

4.1.4.1 **The shaft**: shall be designed and manufactured from one of the following materials.

BS 970: Part 1 : 070M20

BS 970: Part 1 : 080M40

BS 970: Part 1 : 070M55

BS 970: Part 1 : 150M19

BS 970: Part 1 : 709M40

BS 970: Part 1 : 826M40

DIN 17200 : ST442S

No welding is permitted on BS 970 grades, 080M40 or 070M55 material.

4.1.4.2 **Where the shaft has welded-on arms**: the arms shall be manufactured from steel to BS 4360 grade 43A or to SANS 1431 grade 300WA.

4.1.5 Fabrication

4.1.5.1 **No welding shall be permitted**: on new motor shafts except where required for the attachment of arms.

4.1.5.2 **Weld design**: shall be such that the weld toes at the end of the arms do not coincide with any other stress-concentrating feature such as a change in shaft diameter. The weld toe shall not be closer than the change in diameter from a change in shaft diameter.

4.1.5.3 **Welding**: shall be continuous around the ends of the arms. The weld toes and profile shall be dressed around the ends of the arms and back from the ends for a distance not less than the arm thickness

4.1.6 Machining

4.1.6.1 **Surface roughness**: shall not exceed 12.5Ra. This surface roughness includes all radiused surfaces i.e. fillets etc.

4.1.6.2 **Bearing journals**: shall have a surface roughness as specified in the bearing manufacturer's catalogue for the appropriate type and size of bearing.

4.1.6.3 **Any other component**: mounted on the shaft shall have an acceptable surface finish specified.

4.1.6.4 **Other shaft extensions**: shall have a surface roughness not exceeding 1.6Ra.

4.1.6.5 **The eccentricity**: between the bearing journals or between any shaft extension and a bearing journal shall not exceed 0.02mm.

4.1.7 Bearing location on shaft

Where rolling element bearings are used, the bearing shall be secured to the shaft by means of screwed locking rings or a shrink fit. Where a shrink fit is used this shall be on a tapered bore with provision for oil injection for bearing removal.

OR

Where rolling element bearings are used, the bearing shall be located on the shaft by means of an interference fit between the shaft and bearing inner ring. The locating bearing shall be prevented from moving axially by circlips.

4.2 MANUFACTURE OF SHAFTS

4.2.1 **If an engineering detail drawing** of the shaft does not exist, one shall be generated to enable manufacture to take place. Any required design modifications resulting from any failure analysis shall be incorporated into the drawing, previously existing or newly generated.

4.2.2 Materials

4.2.2.1 **Shaft material mechanical and chemical properties**: shall comply, and be tested, in accordance with the specified requirements.

Note: Allowance shall be made for additional material to be removed for mechanical and chemical specimens when procuring the shaft and arm material.

4.2.2.2 **Shaft material and hard stamp traceability**: to the material supplier's cast and heat number shall be maintained at all times by hard stamping on the non-drive end.

4.2.2.3 **Shaft material results of NDE**: shall comply with the requirements of Debswana Specification DS 999006.

4.2.2.4 **Arm material mechanical and chemical properties**: shall comply with the requirements of BS 4360 or SANS 1431.

4.2.2.5 **Arm material results of NDE**: shall comply with BS 5996 grade LC4ES.

4.2.2.6 **No building up**: of undersized diameters shall be permitted on new shafts.

4.2.3 Fabrication

4.2.3.1 **Welders**: shall be approved to BS EN 287 and the welding procedure shall be approved to BS EN 288.

4.2.3.2 **Stress relieving**: of welded shafts shall take place prior to final machining.

4.3 EXAMINATION OF EXISTING SHAFTS

4.3.1 **Shafts which have failed**: the cause of failure shall be determined so that the design may be reviewed to prevent the replacement shaft from failing in a similar mode.

4.3.2 **Shafts which may be reconditioned**: The entire shaft shall be subjected to a full dimensional inspection and Magnetic Particle and Ultrasonic test in accordance with Debswana specification DS 999006.

4.3.3 **Shaft material**: shall be identified by the chemical analysis of drill swarf taken from the shaft. The swarf shall be taken from the non-drive end of the shaft.

4.3.4 **Surface hardness**: shall be measured.

4.4 RECONDITIONING OF SHAFTS

4.4.1 **Where the journals**: or shaft extensions have been damaged in service and can be made fit for purpose, two repair options are available:

(i) Machine the journal or shaft extension undersize and fit the corresponding bearing shell or coupling.

(ii) Machine the journal or shaft extension undersize and build up material enabling the journal or shaft extension to be re-machined to the original size.

Option (i) is technically superior and the Contractor should, after considering safety and production criticality and the interchangeability of spares, specify this wherever possible.

4.4.2 **Reconditioning of damage**: other than surface damage in the journal or coupling, areas shall be considered on an individual basis by the Engineer, based on the NDE report, the location and nature of the defect and the proposed repair scheme.

4.4.3 **No building up**: shall be permitted closer to any change in shaft diameter than as follows:

(i) **For rolling element bearings**: 1.5 (Rs), where Rs is the bearing chamfer radius as specified in the relevant bearing manufacturer's catalogue.

(ii) At any other change in shaft diameter: 2 (R), where R is the fillet radius specified at the change in shaft diameter.

4.4.4 Where shafts are built up: the process shall be either:

- Micro welding

  (The Contractor shall submit the Weld Procedure Qualification and the Procedure Qualification Record for approval)

  Or

- Thermal metal spraying

  Thermal metal spraying may be carried out using an automated flame, arc or plasma process. Arc or plasma processes are preferred. The maximum build-up using thermal metal spraying techniques shall be 1.5mm in thickness.

4.4.5 **Materials**: in accordance with the requirements of BS970 grades 080M40 and 070M55 shall only be built up by means of thermal metal spraying.

4.4.6 **No building up**: of previously built up areas shall be permitted unless the shaft is machined to remove all previously built up material. In the case of weldments a further 1mm shall be machined to remove the high temperature heat affected zone.

4.4.7 **The removal of material**: to enable build-up of the shaft diameter shall not reduce the diameter to less than 0.975 of the original diameter unless the Contractor furnishes detailed calculations showing that the shaft would not be overstressed, based on the reduced shaft diameter.

4.4.8 **The organisation performing the building up**: shall be approved.

4.4.9 **Stress relief**: of built up areas is not recommended due to the possibility of distortion of the entire shaft and damage to other components on the shaft should these not have been removed. The Contractor may, at his discretion and risk, use localised stress relief techniques. In general lagging to limit the cooling rate, is to be preferred. The Weld Procedure Specification and Weld Procedure Qualification Record shall include the procedure to be adopted.

4.4.10 **At least 72 hours**: after the completion of the build up and re-machining of the shaft the Contractor shall, using surface crack detection methods, examine the built up area which shall be free of crack like indications.

4.4.11 **Reconditioned shafts**: shall comply with the requirements of Clause 4.2, Manufacture of shafts.

5 QUALITY ASSURANCE PROVISIONS

5.1 QUALITY MANAGEMENT SYSTEM

The Contractor's quality management system shall comply with the requirements of BOS ISO 9001.

Debswana QAP 100 shall apply.

5.2 DOCUMENTATION

The Contractor shall submit the following for approval:

5.2.1 A report on the condition of the existing shaft (if applicable).

5.2.2 A fully dimensioned drawing of the shaft.

5.2.3 A fully dimensioned drawing of the assembled rotor.

5.2.4 Proposed material specifications for all components including mechanical and chemical properties.

5.2.5 Calculations for fatigue, shaft deflection and critical speeds (if applicable).

5.2.6 Weld Procedure Specification, Weld Procedure Qualification Record and copies of welder qualifications (if applicable).

5.2.7 A detailed quality plan.

5.3 APPROVAL

Reconditioning or manufacture shall not commence before all of the documentation, is approved by the Engineer.

6 INSPECTION AND TESTING

6.1 NON-DESTRUCTIVE EXAMINATION

The Contractor shall examine the shaft in accordance with the requirements of Debswana DS 999006 at the following stages:

Magnetic Particle	**Ultrasonic**
*On receipt of the billet and plates	X
*After preliminary machining	X
*72 hours after the completion of any welding and stress relieving	
*After final machining	X

Note: All non-destructive testing shall take place with the material in an unpainted condition; no shot blasting prior to inspection shall be permitted. Any scale shall be removed by hand wire brushing or chemical cleaning. The rough shaft billet shall be machined on the ends to permit the required ultrasonic examination.

6.2 VIBRATION LEVELS ON RUN UP OR RUN DOWN

Unfiltered vibration measurements shall be taken in the radial, lateral and axial directions with the machine bolted down on a heavy flat base and shall not exceed the limits specified in BS 4999 part 142 quality grade "R" (reduced) in Table 1 for machines with shaft height up to and including 400mm and column 1 of Table 2 for shaft heights in excess of 400mm.

For the purpose of this test the motor shall be bolted down solidly in order to eliminate any parasitic vibrations.

7 MARKING AND PACKING

7.1 MARKING

The following markings shall be stamped on the non-drive end of the shaft to ensure traceability to the relevant documentation:

- The Contractor's name or logo
- The Contractor's job number
- The material cast and heat numbers

7.2 PACKING

The shaft shall be protected against damage and adverse climatic conditions during transportation and storage.

APPENDIX A: RELATED DOCUMENTS

SANS 9001	:	Quality management system – requirements
Debswana QAP 100	:	Quality management systems for critical and major products
Debswana DS 999006	:	Non destructive examination for wrought steel materials
BS 970 - 1	:	Specification for wrought steels for mechanical and allied engineering purposes
BS 1134	:	Assessment of surface texture
BS 3673 - 4	:	Specification for spring retaining rings; Carbon steel circlips – metric series
BS 4235 - 1	:	Specification for metric keys and keyways
BS 499 - 142	:	General requirements for rotating electrical machines: Specification for mechanical performance
BS 5400 - 10	:	Steel concrete and composite bridges: Code of practice for fatigue
BS 5996	:	Methods for ultrasonic testing and specifying quality grades of ferrite steel plate
BS EN 287 - 1	:	Approved testing of welders for fusion welding of steels
BS EN 288- 3	:	Specification and approval of procedures for fusion welding of metallic materials
SANS 60072-1	:	Dimensions and output series for rotating electrical machines – Part 1 : Frame numbers 56 to 400 and flange numbers 55 to 1080
SANS 60072-2	:	Dimensions and output series for rotating electrical machines – Part 2 : Frame numbers 355 to 1000 and flange numbers 1180 to 2360
SANS 143	:	Standard specification for weldable structural steel
DIN 17200	:	Steels for quenching and tempering: Technical delivery conditions

APPENDIX B: RECORD OF AMENDMENTS

Issue 0	:	Based upon De Beers specification