ALLOY STEEL SHAFT FORGINGS FOR CENTRIFUGAL COMPRESSOR (GR: 40 Ni Cr Mo 7)

1.0 GENERAL :

This specification governs the quality of alloy steel shaft forgings.

2.0 APPLICATION :

Centrifugal Compressor Shaft operating at speeds up to 18000 RPM. Maximum run out permitted on the shaft is 0.02 mm after final machining.

3.0 CONDITION OF DELIVERY :

The forgings shall be supplied in hardened, tempered, rough machined and stress relieved condition.

4.0 COMPLIANCE WITH NATIONAL / INTERNATIONAL STANDARDS :

This Specification Complies in general with UNI: 7874 GR: 40 Ni Cr Mo 7

5.0 DIMENSIONS AND TOLERANCES:

The forgings shall be supplied as per the dimensions and tolerances specified in the drawing.

6.0 MANUFACTURE:

6.1 The steel used for shaft forging shall be manufactured from basic electric furnace and shall be subsequently vacuum degassed. Any other process of manufacture of steel is subject to mutual agreement between BHEL and the manufacturer. The steel shall be fully killed and fine-grained.

6.2 The vacuum system shall have the capacity to maintain a vacuum of 2 torr or lesser during vacuum degassing process for sufficient time so as to lower the gas content in the steel. The actual gas levels shall be tested in the molten metal and reported in the test certificates. The Hydrogen content in the molten metal shall be less than 2.0 ppm to ensure the effectiveness of the vacuum degassing process.

6.3 If ingots are used for forging, sufficient discard shall be made from top and bottom of the ingot to ensure freedom from piping, segregation and other injurious defects.

6.4 The forging process adopted shall ensure uniform working throughout the cross – section. The Forging ratio shall be minimum 4 if ingots are used as raw material for forging and minimum 1.5 in case blooms/billets are used as forging stock. It is important to maintain the axis of the forging same as the axis of forging stock.

Note: The forge masters shall indicate the raw material source in their technical offer and the same will be reviewed by BHEL for suitability before approval. Purchase shall refer this raw material source in the order for compliance.

7.0 FREEDOM FROM DEFECTS:

The forgings shall be sound and free from Cracks, Flakes, Cavities and other harmful defects.

8.0 CHEMICAL COMPOSITION:

The steel shall conform to the following Chemical Composition.

Element		C	Si	Mn	Cr	Mo	Ni	S	P
Ladle Analysis	%Min	0.37	0.15	0.50	0.60	0.20	1.60	-	-
	%Max	0.44	0.40	0.80	0.90	0.35	1.90	0.025	0.025
Permissible Variation in (%) Product Analysis		±0.02	±0.03	±0.03	±0.05	±0.03	±0.05	+0.005	+0.005

8.1 Tramp element:

The content of tramp elements such as Cu, As, Sb and Sn shall be low enough to avoid temper embrittlement. The values actually obtain shall be reported in the test certificate for information to BHEL.

9.0 HEAT TREATMENT:

The suggested heat treatment is given below.

Hardening: The furnace loading temperature shall not exceed 350 °C. Soaking temperature in the range of 830 ° C to 850 °C followed by Oil/ Polymer quenching. Soaking time shall be ½ hour per 25 mm of maximum diameter.

Tempering: The furnace loading temperature shall not exceed 350 °C. Soaking at temperature of 570 ° C to 620 ° C followed by air cooling. Soaking time shall be 1 hour per 25 mm of maximum diameter.

Stress Relieving: The shafts shall be stress relieved in vertical or horizontal condition after rough machining. The stress relieving parameters shall be as follows:

Furnace loading temp : 350°C max.
Rate of heating : 80°C / hour
Soaking temp : 30° C below the actual tempering temperature of the forging
Soaking time : 1 hour / 25 mm of max. diameter
Rate of cooling : 40 °C /hour max. in furnace upto 400 °C, followed by still air

NOTE: (1) Press straightening if necessary may be performed before Quality heat treatment and no straightening is permitted after heat treatment.
(2) The actual heat treatment charts duly attested by BHEL representative shall be furnished along with test certificate.
(3) Stress relieving condition (horizontal or vertical) shall be mentioned in the test certificate.

10.0 TEST SAMPLES:

Each forging shall be tested for mechanical properties in tangential and longitudinal direction from both the ends using an integral test piece. The test piece locations shall be as shown in Annexure-1. The remaining integral test piece shall be sent to BHEL for further testing.

11.0 MECHANICAL PROPERTIES:

Test samples shall conform to the following Mechanical properties.

Specimen	Tensile Strength N/mm^2	0.2% proof stress N/mm^2	Elongation % L=5 d	Reduction in Area %	Impact strength ISO-V Notch, J (at room temperature)	Hardness BHN,
	min.	min.	min.	min.	min.	min.
Longitudinal	930	735	14	50	27	270
Tangential	880	685	12	40	17	

Note:

1) Tensile test shall be done as per IS: 1608 or equivalent National Standard at room temperature.
2) The Charpy impact test shall be conducted as per IS: 1757 or equivalent National standard at room temperature.
3) The minimum impact Value specified above is the average of 3 values. All the 3 values shall be reported only one value can be lower than the minimum specified, but in no case below 2/3rd of the same.
4) Hardness shall be tested on each forging on both the ends of the shaft and the hardness values shall be reported in the test certificate.

12.0 NON-DESTRUCTIVE TEST:

The shaft forging shall be subjected to following non-destructive tests.

12.1 Ultrasonic Test:

The shaft forgings shall be subjected to ultrasonic testing after all heat treatments including stress relieving are completed in final machined condition as per ordering drawing , according to pulse echo method with 2-4 MHz, normal probe (and special probe if required) over 100% of its surface. Distance Grain Size method shall be employed for evaluation of indications.

The following indications are not allowed.

i. Randomly distributed individual indications with an equivalent flaw size greater than or equal to diameter 2 mm.
ii. All individual indications which suppress back wall echo by more than 10%.
iii. All indications either linear or globular forming cluster irrespective of the size of individual indications
iv. All individual indications more than diameter 1.0mm equivalent flaw size are to be recorded in a scale drawing.

12.2 Magnetic Particle Test:

Entire surface of the shaft forging shall be subjected to MPI as per ASTM: E709. Cracks are not acceptable.

13.0 RETESTS:

If any of the selected Test specimens fail to meet the specified requirements due to some mechanical reasons, another specimen may be taken for testing. In the event of failure due to heat treatment only, then two more reheat treatments may be permitted. However re-tempering is not restricted.

14.0 FIRST PIECE QUALIFICATION REQUIREMENTS:

A comprehensive Manufacturing Process Plan (MPP) including First Piece Qualification (FPQ) requirements duly approved by BHEL is mandatory before placement of order on a vendor who has not supplied compressor shafts in the past.

The MPP shall include the stage wise detailed Manufacturing process (with control parameters at each stage) indicating the steel melting processes , ingot dimensions, forging process, forging ratio, heat treatment plan, sketches showing test sample locations and stages of inspection etc.

No process parameter changes are permitted without written approval of BHEL for subsequent supplies once the MPP referred above is frozen.

Following tests shall be performed for “First Piece Qualification” purposes on the samples taken from both the ends of the forgings which are heat treated as per Cl. 9.0 in addition to the tests which are required for production lot of this material for regular supplies:

1) Micrographic test, structure and austenitic grain, inclusions ratings
2) Hardness check on each forging

Considering the criticality of the shaft forgings from applications point of view, BHEL may incorporate further check points (in the purchase order / Quality plan) during first time supplies of this material to BHEL.

15.0 INSPECTION AT SUPPLIER'S WORKS:

15.1 BHEL representative shall have free entry and access to all areas where the manufacture of the forging is carried out. All reasonable facilities shall be extended to him including labour wherever necessary.

15.2 BHEL representative shall be given sufficient advance intimation to witness the various process tests etc. punching and identification of test coupons and forging & execution of various tests shall be done in presence of BHEL representative.

16.0 QUALITY PLAN:

16.1 Vendor shall follow the Quality Plan Ref. QP No.: BHEL/HY19365 Rev. 04 attached as annexure 'A' unless the conditions stipulated in Cl. 16.2 & 16.3 mentioned below are applicable.

16.2 In case Customer/ Project related additional requirements are applicable in the enquiry/ tender, vendor will be asked to submit a separate QP including such requirements.

16.3 In case of new vendors or first time supplies according to drawings mentioned in BHEL enquiry, QP shall be submitted for approval by BHEL.

17.0 TEST CERTIFICATE:

The suppliers shall furnish three copies of the test certificate (in English) to BHEL containing the following details.

a) BHEL Specification No: HY 19365 Rev.04
b) Material Grade: 40 Ni Cr Mo7
c) Steel melting and refining process*
d) BHEL Order No:
e) Item description.
f) Drawing No.
g) Supplier's Name.
h) Melt No.
i) Serial No. of forging
j) Approved copy of Manufacturing Process Plan (MPP)
k) Heat treatment details and chart.
l) Results of all tests stipulated in this specification.
m) Dimensional inspection report

Note- Forge Masters shall submit original mill TC indicating the H_2 content checked in molten steel during Vacuum Degassing process

The certificates shall be signed by the Chief of Inspection / Chief Metallurgist of the supplier and BHEL representative.

18.0 MARKING AND PACKING

18.1 The following details shall be punched clearly on each forging and the same shall be encircled by paint:

a) HY 19365 Rev 04
b) Melt . No.
c) Serial No. of the forging.
d) Drawing No.
e) BHEL representative's identification Stamp.
f) Supplier's Name.

18.2 The forgings shall be suitably packed & prevented from damage and corrosion during transit. In the case of overseas supplies the packing shall be seaworthy.

19.0 REJECTION AND REPLACEMENT:

In the event of the forging proving defective in the course of further processing at BHEL the same shall be rejected not with standing any previous acceptance.

The supplier shall replace the rejected forging at his own cost and the rejected forging shall be returned after all the commercial conditions are satisfied.

Annexure- I

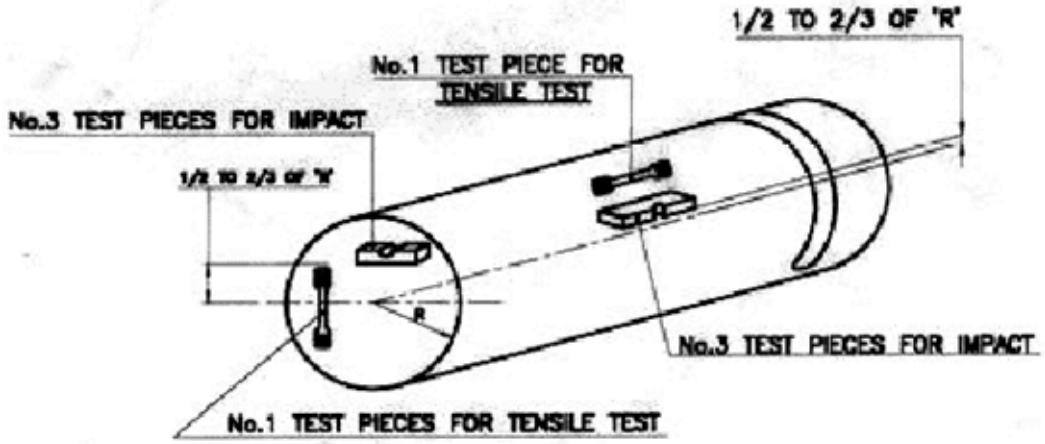

Fig.1 LOCATION OF TEST PIECES FOR COMPRESSOR SHAFT FORGING.

VENDOR'S NAME & ADDRESS			QUALITY PLAN					QP No.: BHEL/HY19365 Rev. 04					
			Customer		BHEL ENQ. No.			BHEL Spec. HY 19365 Rev. 04 PAGE 8 of 9					
			Project		Date								
			Product										
SL No.	Process	Characteristics	Class	Type of check	Quantum of Check	Reference Document	Acceptance Norms	Format of Record	* D	Agency P	Agency W	Agency V	Remarks
1.0	Raw Material Inspection												
	Ingots & blooms	Steel making process (Vacuum degassing)	Major	Verification of Steel Mill's certificate	Each Ingot	HY 19365 Rev. 04	HY 19365 Rev. 04	Steel Mill's TC	√	2	--	1	See note 1 & 2.
		Check analysis	Major	Spectro analysis of samples drawn	1 sample per heat	HY 19365 Rev. 04	HY 19365 Rev. 04	Internal report		2	--	1	
2.0	Forging	Forging steps to be followed	Major	Dimensions as per process plan	--	Forging supplier	Internal	Logbook		2	-	1	Reduction ratio to be specified in the TC
3.0	Heat treatment of forgings	HT time temp cycles	Critical	Verification of HT time temp. charts	All cycles	HY 19365 Rev. 04	HY 19365 Rev. 04	HT time temp. charts	√	2	--	1	
4.0	Stress Relieving (after rough machining as	HT time temp cycles	Critical	Verification of HT time temp. charts	All cycles	HY 19365 Rev. 04	HY 19365 Rev. 04	HT time temp. charts	√	2	--	1	
4.0	Test piece marking	Location of test specimen	Major		Each forging	HY 19365 Rev. 04	HY 19365 Rev. 04	--		2	1	-	
5.0	Mechanical testing	Tensile & yield strength, Hardness, Impact, % Elongation & RA	Major	Testing of specimen prepared	Each forging	HY 19365 Rev. 04	HY 19365 Rev. 04	Physical test report	√	2	1	-	Hardness to be checked on opposite ends of each shaft forging
6.0	Product Analysis	Chemical composition	Critical	Chemical analysis	1 sample per forging	HY 19365 Rev. 04	HY 19365 Rev. 04	Spectro report	√	2	1	-	
7.0	Non- destructive testing												
7.1	Ultrasonic testing	Internal soundness	Critical	UT testing	100% volume of each forging after rough machining & SR	HY 19365 Rev. 04	HY 19365 Rev. 04	UT report	√	2	1	-	

VENDOR'S NAME & ADDRESS			QUALITY PLAN					QP No.: BHEL/HY19365 Rev. 04					
			Customer		BHEL ENQ. No.			BHEL Spec. HY 19365 Rev. 04 PAGE 9 of 9					
			Project		Date								
			Product										
SL No.	Process	Characteristics	Class	Type of check	Quantum of Check	Reference Document	Acceptance Norms	Format of Record	* D	Agency P	Agency W	Agency V	Remarks
7.2	Magnetic particle inspection	Sub surface defects	Critical	MPI	100% surface of each forging after rough machining & SR	HY 19365 Rev. 04	HY 19365 Rev. 04	MPI report	√	2	1	-	
8.0		Dimensional inspection	Major	Dimensional checking	Each forging	As per Drawing.	As per Drawing.	Dimensional report	√	2	1	-	
9.	Identification & punching	Stamping of identification marks on the forgings	Major	Verification of the actual stamping	Each forging	HY 19365 Rev. 04	HY 19365 Rev. 04	--	-	2	-	1	
10.	Completeness of documents, test certificates, HT charts etc.		Major	Verification	Each forging	BHEL Drawing & spec.	BHEL Drawing & spec.	Endorsement of all documents by TPIA		2	-	1	Including copy of approved MPP
11.	Preservation & Packing		Major	Visual	Each forging	BHEL Drawing & spec.	BHEL Drawing & spec.			2		1	

*Notes: 1. Raw material source shall be as per BHEL order.

2. Third party inspection agency (TPIA) shall endorse Raw material test certificates indicating the balance quantities left in the lot for future use at the forging supplier works after verification of balance material.

* **(1) & (2) are applicable to forge masters who do not have in house steel melting facilities.**

Legend: P Perform; W Witness; V Verification; Indicating 1 for BHEL or BHEL nominated Inspection agency & 2 for vendor/sub vendor as appropriate against each process/characteristic under P, W & V columns. * For items marked √ (tick) in column D, test certificates shall be submitted to BHEL for

Signature of the supplier with Company

Stamp

(To be submitted along with the technical offer)