

**SPECIFICATION FOR ICNi-4314-706C SUPER ALLOY (XH43БМТЮЛ) CASTINGS****1.0 SCOPE:**

This specification covers the quality requirements and acceptance criteria for realization of investment cast components in ICNi-4314-706C Superalloy (XH43БМТЮЛ) for Gaganyaan programme.

**2.0 APPLICABLE DOCUMENTS:**

The following standards form part of this specification to the extent specified here in. The latest issue of these documents in effect on the date of material purchase shall be applicable.

**2.1 ASTM STANDARDS:**

A488	Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
E8M	Standard Test Methods for Tension Testing of Metallic Materials
E94	Standard Guide for Radiographic Examination
E165	Standard Practice for Liquid Penetrant Examination for General Industry
E192	Reference Radiographs for Investment Steel Castings
E354	Standard Test Methods for Chemical Analysis of High Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
A370	Standard Test Methods for Mechanical Testing of Steel Products
E390	Reference Radiographs for Steel Fusion Welds
E446	Reference Radiographs for Steel Castings up to 2 inch Thickness
E1220	Standard Test Method for Visible Penetrant Examination using Solvent-Removable Process
E1417	Standard Practice for Liquid Penetrant Testing
E1473	Standard Test Methods for Chemical Analysis of Nickel, Cobalt and High-Temperature Alloys
E1742	Standard Practice for Radiographic Examination

**2.2 AMS STANDARDS:**

2175	Casting Classification
2269	Chemical Check Analysis Limits Nickel, Nickel Alloys, and Cobalt Alloys

2694	In Process Welding of castings
2750	Pyrometry
2773	Heat Treatment Cast Nickel alloy and Cobalt Alloy Parts

### 2.3 **OTHER STANDARDS**

ASME Section IX	Practice for welding procedure, qualification and personnel approval for steel castings
OCT92-1166-86	Castings, manufactured by Investment method Technical specifications
VDG 690-D1	Casting Tolerances

### 3.0 **LOT DEFINITION:**

Lot is defined as same type of castings poured from master heat of single furnace charge and heat treated together.

### 4.0 **MELTING AND POURING:**

- 4.1. Castings shall be made either from virgin alloys or melt of a master heat or re-melting of the master heat
- 4.2. Master heat is refined molten metal of a single furnace charge cast into ingots. Master heat shall be prepared from virgin alloys. Master heat ingots shall be made through vacuum Induction Melting. No reverts are allowed in preparation of master heat.
- 4.3. Fresh material of IN718 or IN706 may be used for preparation of master heat. Necessary elements will be added to maintain the chemistry.
- 4.4. If reverts or scraps are used in preparation of master heat, then master heat shall be refined by secondary refining process such as VAR. Master heat shall be approved by DEPARTMENT
- 4.5. Two master heats with composition within specified range can be blended for melting and pouring of casting.
- 4.6. Vacuum Induction Melting (VIM) / Vacuum Arc Skull Melting (VASM) technique shall be used for re-melting and pouring of the casting.
- 4.7. Record of Master Heat(s) shall be maintained for traceability. Each master heat to be evaluated for chemical composition.

**5.0 CHEMICAL COMPOSITION:**

- 5.1. Chemical composition of the alloy shall conform to the following specifications by weight, determined by wet chemical method/ spectroscopic methods in accordance with ASTM E354, E1473 or any equivalent standard (on written approval of DEPARTMENT).
- 5.2. The chemical composition shall be determined from each melt by analyzing 1 sample drawn from chemical coupon or testbars from same melt representative of the castings. The chemical composition determined shall conform to the requirements specified in Table 1.

Table 1: Chemical Composition of ICNi-4314-706C									
<b>Element s</b>	C	Cr	Ni	Nb	Mo	Ti	Al	V	
<b>Wt. %</b>	0.03-0.07	13.0-15.0	42.0-45.0	2.3-2.8	1.0 - 2.0	1.5-2.0	0.2-1.0	0.1-0.5	
<b>Element s</b>	Si	Mn	S	P	Ca	Ce	Cu	B	Fe
<b>Wt. % (Max)</b>	0.5	0.6	0.01	0.01	0.02	0.02	0.30	0.006	Bal

- 5.3. If Cerium is not added to the melt, same has to be certified by the party and need not be reported.
- 5.4. DEPARTMENT will have the right to carry out confirmatory check at its place on samples taken from castings. This will also constitute the ground for final acceptance.
- 5.5. In case of any deviations in chemical composition AMS 2269F shall be referred for acceptance.

**6.0 VISUAL AND DYE PENETRANT EXAMINATION:**

- 6.1. All the castings are to be subjected to visual and dye penetrant examination for surface defects. DP shall be carried out in as-cast and HT conditions. General guidelines for the visual examinations are given below:
- 6.1.1. Casting offered for visual inspection should be free from foreign materials etc. Cleaning should be done by grit blasting. After grit blasting, the castings should be thoroughly washed under water jet and dried to remove contaminants, if any, in cracks and crevices, before DP test. Surface roughness shall confirm to the requirement of drawings.
- 6.1.2. For removal of any ceramic shell deposits in in-accessible areas, chemical cleaning may be carried out after getting DEPARTMENT approval for the process.
- 6.1.3. Through cavities and porosities, cracks, oxide scales, hot tears, cold shuts, and negative core seams etc. are not permitted on the surface of the casting.
- 6.1.4. Gating system residue shall be ground flush with the casting surfaces.

- 6.1.5. Surface marks, traces from the ejector pins or model joints of upto 0.5 mm height shall be allowed on casting surface except for flow areas and areas specified for surface finish requirement. Whereas such marks are not allowed in flow areas and specified areas, surface finish shall meet the drawing requirement.

**6.2. Standard to be followed for DP Test:**

- 6.2.1. ASTM E165 / E1220 is to be followed for dye penetrant (DP) testing.
- 6.2.2. Solvent Removable chemicals (dye and developer) such as 'Magnaflux' or equivalent, are to be used for DP test.
- 6.2.3. Thorough post-DP test cleaning is to be carried out for complete removal of DP chemicals.

**6.3. Personnel Training and Certification:**

- 6.3.1. DP Test should be carried out only by skilled and trained personnel and under the supervision of ISNT level – II / DEPARTMENT approved NDT inspection personnel only.
- 6.3.2. Reporting is to be done by ISNT Level II / DEPARTMENT approved NDT inspection personnel only.

**6.4. Acceptance Standard:**

- 6.4.1. Maximum allowable discontinuity size and distribution for DP inspection shall be as per Table 2. This will be valid for all zones except intersections/Junctions of vanes/ribs.
- 6.4.2. In addition to clause 6.4.1, Non-linear DP indications of size less than 4.8 mm shall be acceptable as per ASTM A903. This will be applicable irrespective of section thickness of the zone.
- 6.4.3. DP indication at intersections/Junctions of vanes/ribs shall be Grade B or better as per AM2175 as per Table 3.
- 6.4.4. Depth of any surface defect can be estimated by any suitable means at the disposal of the manufacturer i.e. by inserting pins, by pressing modeling clay or by local templates.
- 6.4.5. Through cavities, porosities, cracks, laps, folds, cold-shut, oxidation scales are not permissible on the castings.
- 6.4.6. Gouging/fettling may be attempted to ascertain the depth of defect without local thinning of wall beyond the machining allowance or drawing tolerances, wherever feasible.
- 6.4.7. Visual discontinuities may also be evaluated as per the criteria of Table 2.
- 6.4.8. Any type of discontinuity appearing on opposite sides of a wall and which are interconnected, are not acceptable.
- 6.4.9. Any linear indication is not acceptable. Linear indication is defined as a discontinuity whose length is equal to or greater than three times its width.

**Table 2: Acceptance Criteria for Visual and DP Inspection of Castings**

Wall thickness of casting	Discontinuity dia., or length	Discontinuity Depth, mm	No. of Discontinuities over an area of 5 cm <sup>2</sup>	Min Distance between defects, mm	Allowable Indication size (mm)
upto 2 mm	0.5 to 1.5	upto 0.5 mm	2	10	Less than or equal to 4.8 mm
2 - 5 mm	1.5 to 3.0	1/3rd of the wall thickness or 3 mm, whichever is less.	3	10	
> 5 mm	1.5 to 3.0	1/3rd of the wall thickness or 3 mm, whichever is less.	5	15	

**Table 3 : Acceptance Criteria for DP Inspection of intersections/Junctions of vanes/ribs**

Discontinuity Type	Allowable Size / Number of Discontinuities	
Random-Individual Discontinuities (Gas Holes, Inclusions, Discrete Shrinkage cavities), Non Linear	1/3 <sup>rd</sup> of the wall thickness or 1.27 mm in diameter whichever is less	
Cracks, Hot Tears, Cold Shuts or Through Wall Discontinuities	None	
Micro-shrinkage or Shrinkage Sponge, Non Linear	Up to 3.05 mm in diameter	
Micro-shrinkage or Shrinkage Sponge, Linear	0	
Number of Discontinuities Allowed Within a 50 x 50mm Area	Random-Individual Discontinuities	Maximum 3
	Micro-shrinkage or Shrinkage Sponge	Maximum 1

6.4.10. Unacceptable defects on machinable surfaces shall be removed by grinding/machining.

6.4.11. In general, random raised metal shall be limited to a height of 0.38 to 0.76 mm in an area 3.2 x 3.2 mm and no more than one per square inch (650 mm<sup>2</sup>). However in flow areas and specified area, surface finish shall be maintained as per the drawing requirement.

### 6.5. Generation of Report:

6.5.1 Visual & DP reports are to be generated based on actual observation of all types, location & dimension of defects.

6.5.2 Acceptance should be as per norms mentioned above.

6.5.3 Defect locations are also to be identified with respect to the casting drawing or with respect to standardized radiographic surface identifications.

### 7.0 RECTIFICATION OF VISUAL & DP DEFECTS BY DRESSING/FETTLING:

7.1. Un-acceptable defects on all surfaces, revealed in visual & DP examinations, shall be

dressed within the limits of dimensional tolerance.

- 7.2. It's allowed to meet the geometry of casting by machining/dressing.
- 7.3. In the presence of defects on the edge of blade/vane, dressing shall be carried out along the edge in the tip diameter only.
- 7.4. Castings shall not be repaired by peening or plugging.

## **8.0 RADIOGRAPHIC INSPECTION:**

- 8.1. X- ray radiographic inspection shall be carried out on each casting as well as test samples (to be tested for mechanical properties evaluation) as per approved shooting sketches provided by the DEPARTMENT.
- 8.2. All the exposures of the casting shall be identified with respect to a common reference point on the casting.

### **8.3. Following ASTM Standards are to be followed for radiography:**

ASTM E94 - Guide for Radiographic Testing

ASTM E1742 - Standard Practice for Radiographic Examination

ASTM E192 - Reference Radiographs for Investment Steel Castings

ASTM E390 - Reference Radiographs for Steel Fusion Welds.

ASTM E446 - Reference Radiographs for Steel Castings Up to 2 inch (50.8 mm)

### **8.4. Following Personnel Skill & certification is required for carrying out radiography:**

- 8.4.1. ISNT Level I / DEPARTMENT approved NDT inspection personnel only– For set-up, radiography and development of film
- 8.4.2. ISNT Level II / DEPARTMENT approved NDT inspection personnel only– For interpretation of defects.
- 8.5. **Acceptance Standard:** ASTM Standards E192, E446 are to be followed for reference radiographs. Details of the acceptance limits for different type of defects are mentioned below (Table 4 and 5) for all the castings and for all zones.

## **9.0 RECTIFICATION OF DEFECTS BY WELDING:**

- 9.1.1. Standards to be followed: ASTM A488 / AMS 2694/ ASME section IX.
- 9.1.2. It is allowed to rectify the defects by welding after removal of defect by dressing / gouging. Removal of defects shall be confirmed by RT & DP.
- 9.1.3. Weld repair of casting is allowed only after generation of qualified Welding Procedure (WPS & PQR) and approval of the same by DEPARTMENT. Filler Wire (ER FeNiCr2 / IN718 or parent material) can be used for repair of castings.

**Table 4: Maximum Permissible Radiographic Severity Levels for Discontinuities for castings up to 1 inch wall thickness**

Type of Discontinuity	Grade (as per ASTM E192)		
	1/8 inch wall thickness	3/8 inch wall thickness	3/4 inch wall thickness
Gas holes	3	3	3
Shrinkage, Dendritic	2	2	2
Shrinkage, filamentary	None	None	1
Shrinkage cavity	1	1	2
Shrinkage Sponge	2	2	2
Foreign Mat. (less dense)	3	3	3
Foreign Mat. (More dense)	3	3	3
Cold shut, Hot tear, or Cold crack	NONE		
Mis-run	NONE		
Core shift or Mold Ridge	NOT TO EXCEED DRAWING TOLERANCE		
Mold Buckle, Positive or Negative			
Excess Metal in Cracked Core			
Surface irregularity			
Mottling / Columnar	To be confirmed by taking an additional RT shot to eliminate presence of any defect		

**Table 5 : Maximum Permissible Radiographic Severity Levels for Discontinuities for castings with wall thickness greater than 1 inch**

Code or Category	Discontinuity	Acceptable Max. Severity Level as per ASTM E446
A	Gas Porosity	1
B	Sand and Slag Inclusions	1
CA	Shrinkage type CA	1
CB	Shrinkage type CB	1
CC	Shrinkage type CC	1
CD	Shrinkage type CD	1
D	Crack	None
E	Hot tear	None
F	Insert	None
G	Mottling/Columnar	To be confirmed by taking an additional RT shot to eliminate presence of any defect.

- 9.1.4. Weld repair can be carried out in as cast condition or Solution Treated Condition (as per WPS). Successfully welded components are to be given post-weld heat treatment as per the specification
- 9.1.5. Weld beads are to be ground flush with the surface of casting. Surface roughness at dressed location shall be as per drawing. Any weld repair should not violate the contour or the dimension specified for the casting.
- 9.1.6. NDT evaluation (DP & RT) of weld repaired locations is mandatory. Thickness of weld repaired location may be measured, if required.

## **9.2 Acceptance of welding:**

- 9.2.1. Surface cracks, warpage, undercut, burn-through, excessive spatter, lack of fusion, lack of penetration are not allowed in the weldment region.
- 9.2.2. However, porosity, gas-hole, shrinkage, inclusion in the weldment are to be graded as per reference radiograph E192, E446 depending on the thickness and acceptance to be determined against specified DP and radiographic standard of casting, considering the weldment area as a part of it. Reference radiographs E390 to be followed for identification/grading of typical welding defects.

## **9.3 Weld repair report:**

- 9.3.1. All the weld-repaired locations are to be identified against the casting drawing and DP/RT reports.
- 9.3.2. Approval for weld repair shall be taken by party from DEPARTMENT and weld repair report shall be submitted.

## **10.0 HIPING OF CASTING:**

- 10.1. HIPing shall be carried out for defect healing / improving reliability of the casting as per established procedure by the manufacturer.
- 10.2. HIPing operation shall be carried out in 1000 - 1250°C temperature range, 1000 - 1800 bar pressure for a duration of 1 - 4 hours. Use of step cycle is permitted in the HIPing operation.
- 10.3. Hipping shall be followed by DP and radiography of unacceptable defective locations, if any.
- 10.4. HIPing report shall be generated and supplied along with the castings.

## **11.0 HEAT TREATMENT:**

- 11.1. Heat treatment shall be carried out at a vacuum level of  $1 \times 10^{-2}$  mbar or better. Cooling shall be done at air cooling rate by Argon gas quenching (1 - 5 bar). Aging cycles of Heat treatment can also be carried out in electrically heated air furnace followed by air cooling.
- 11.2. All furnaces used for Heat treatment shall be qualified / calibrated as per AMS 2750E.



- 11.3. The recommended Heat Treatment cycle for the XH43 alloy casting:
- i) **Homogenization:** at 1125 +15°C -10°C for 3 hours <sup>+30.0/-0.0 mins</sup> followed by argon gas quenching within furnace at air cooling rate.
  - ii) **Solution Annealing:** at 1020 ±10°C for 3 hours <sup>+30.0/-0.0 mins</sup> followed by argon gas quenching within furnace at air cooling rate.
  - iii) **Ageing1:** at 750 ± 10 °C for 8 hours <sup>+30.0/-0.0 mins</sup> followed by argon gas quenching within furnace at air cooling rate.
  - iv) **Ageing2:** at 650 ± 10 °C for 8 hours <sup>+30.0/-0.0 mins</sup> followed by argon gas quenching within furnace at air cooling rate.
- 11.4. Post weld heat treatment for this alloy includes Solution Treatment followed by two steps of aging if welding is carried out in Solution treated condition. If welding is carried out in as-cast condition, full HT cycle will be carried out.
- 11.5. Castings and test bars processed from the same melt shall be subjected to this heat treatment cycle together. Every HT batch shall be represented by testbars from the same melt.
- 11.6. Proper cleaning of castings shall be carried out by suitable method prior to vacuum heat treatment, to remove all foreign material like grease, oil, ink, rust or metal particles.
- 11.7. Heat treatment Report: Report of HT cycle along with chart shall be maintained and supplied to the DEPARTMENT.
- 11.8. Castings shall be subject to 100% RT after heat treatment.

## 12.0 **MECHANICAL PROPERTY EVALUATION:**

- 12.1. Mechanical properties shall be determined on specimens fabricated from separately cast & radiographically sound test bars, poured and Heat treated along with actual casting (from same melt). Test bars size shall be as per the standard practice of investment casting.
- 12.2. Three Specimens each for Tensile at RT and Stress rupture shall be tested for acceptance of castings. All specimens shall meet minimum mechanical properties specified in the Table 6 .
- 12.3. Test bars shall be fully heat-treated along with the castings. For castings being heat-treated in multiple batches, mechanical properties shall be evaluated for each heat-treatment batch. Adequate number of test bars shall be poured in such a case.
- 12.4. Technology for manufacture of test bars shall be same as that of casting.
- 12.5. RETEST:
- 12.5.1 If any test specimen shows defective machining or develop flaws, it may be discarded and substituted by another specimen.

12.5.2 If one specimen fails to meet the specification requirements, retest shall be done on double the number of specimens. Each of the retest results shall conform to the specified requirements.

12.5.3 If more than one specimen fails at the first instance or any specimen fails after re-test as per Section 12.5.2, the lot shall be subjected to re-heat treatment after obtaining concurrence from department.

12.5.4 Results of all tests shall be reported.

<b>Table 6: Mechanical Properties</b>				
<b>Test Temperature</b>	<b>UTS (MPa) Min.</b>	<b>Y.S. (MPa) Min.</b>	<b>%Elong. Min. (GL=5D)</b>	<b>% Red. in Area Min.</b>
RT	785	590	5	5
650 °C	Stress rupture test shall be carried out at 540 MPa load and life of sample shall be equal to or more than 30 Minutes.			

12.6. RE-HEAT TREATMENT: If the representative specimens fail to conform to the mechanical requirements, either during the first test or retest, the material may be re-heat treated. The producer may re-heat treat the material on metallurgical evidence that the cause of failure is curable after obtaining concurrence from the department. On re-heat treatment, the quality of the material in respect of all other properties shall not be affected and shall conform to the specification herein. Such heat treatment shall be allowed only once.

12.7. If mechanical test results fails after the Re-heat treatment also than that casting shall not be considered for Gaganyaan programme.

12.8. Mechanical Property evaluation shall be carried out as per A370, E8M.

12.9. Mechanical properties shall be evaluated from one number of cut casting of each type. Samples shall be drawn from location shown in the casting drawing. If no location is shown in the casting drawing, minimum 2 nos of samples shall be drawn from sections representing both thin and thick portions of the casting.

### **13 HYDRAULIC PRESSURE TEST:**

13.1. Casting shall be pressure tested as per approved pressure test plan.

13.2. All fixtures, fasteners and other technical requirements shall be as per approved assembly drawings.

13.3. Hydraulic pressure test shall meet the following requirements:

S.No	Casting	Gauge Pressure (bar)	Holding Time, Minutes, Minimum
1	LH2 Turbine Exhaust Casing	11.5	5
2	LOX Turbine Exhaust Casing	6	5

#### **14 SURFACE TREATMENT:**

- 14.1. **Grit Blasting** with proper grade is to be carried out to achieve the required surface finish after HT. Cleaning medium must be free from iron particles/scales. Re-use of grit is advised only after proper cleaning.
- 14.2. **After DP test:** Trace of developer shall be properly cleaned for protection against functional requirements.
- 14.3. **Before HT** in vacuum, castings shall be properly cleaned to remove traces of grease, dirt and loose particles.

#### **15 DIMENSIONAL INSPECTION**

- 15.1. **Each casting** shall be dimensionally inspected.
- 15.2. The first lot of castings manufactured with new equipments / change / rework in tool-die must be fully inspected. For inspection of inaccessible places, 1 no. of casting shall be cut for dimension inspection during casting development phase.
- 15.3. Castings shall be subjected to dimensional inspection after final HT, grit blasting / surface treatment.
- 15.4. Datum surfaces of the castings shall be pre-machined as per approved plan supplied by DEPARTMENT before any dimensional inspection. Dimensions shall be inspected as per approved dimension inspection plan only. All dimensions can be numbered on the drawing and measured in a regular and standard fashion. Proper calibration and precision of measuring equipment shall be maintained.
- 15.5. Minimum & maximum dimensions shall be reported wherever applicable. Area of local thinning and minimum thickness at dressed/fettled areas shall be reported.

#### **16 SUPPLY CONDITION:**

- 16.1. Castings shall meet all the requirements of respective drawing and specification laid down in this document.
- 16.2. Distortion of shape is not allowed.
- 16.3. Castings shall be dispatched in rust/ pit free condition.

**17 CERTIFICATION AND REPORTS:**

The manufacturer shall furnish certified reports indicating the purchase order number, heat / melt number, batch number, stage of inspection and quantity (countersigned by DEPARTMENT Quality Surveyor) for the following:

- Chemical analysis
- Welding report (as per format)
- Visual & DP Report (as per format)
- Mechanical properties (with specimen dimensions)
- Dimensional inspection report
- Heat Treatment Report (as per format, along with chart)
- Radiography report + Radiography films
- HIPing report
- Pressure test reports
- Check list before packing

**18 IDENTIFICATION, PACKING AND DESPATCH:**

- 18.1.** Each casting shall bear proper identification number for traceability. Melt and Serial number shall be engraved in the zone shown in the respective drawing.
- 18.2.** Packing shall be checked and certified by the manufacturer as per the approved check list and the packing shall contain one copy of the check list. The casting shall be dispatched only after obtaining dispatch clearance from DEPARTMENT.
- 18.3.** Material shall be preserved, packaged and dispatched so as to ensure no damage occurs to the material during storage and shipment.
- 18.4.** Castings shall be prepared for shipment in accordance with standard practice and in compliance with applicable rules and regulations pertaining to handling, packaging, and transportation of the castings to ensure carrier acceptance and safe delivery.

**19.0 REJECTION:**

Castings not conforming to the drawing & specification or to modifications authorized by DEPARTMENT will be subject to rejection.

**20.0 PRE-PRODUCTION CHECKS AND APPROVAL FOR PRODUCTION RUN:**

- 20.1. Dimensions in inaccessible locations are to be measured and confirmed after cutting a sample casting. Radiographically unacceptable casting can be used for dimension check.
- 20.2. Sample casting shall meet the requirements of drawing & specification. In case of unsatisfactory results of any test / check, corrective actions shall be taken and tests shall be

repeated. All control factors are to be frozen before taking up production batch. DEPARTMENT may ask for process audit at supplier's site if necessary.

- 20.3. In case of change of control factors for the process during production run, supplier has to submit a statement of the proposed change to DEPARTMENT. DEPARTMENT may review the process all over again. Any change of die/tooling that may affect the dimension/defect level also warrants re-approval of Product for affected dimensions.