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Wrought Superalloy - Seamless Tube

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Foreword

This document was drafted in accordance with GB/T 1.1-2020, *Directives for Standardization - Part 1: Rules for the Structure and Drafting of Standardizing Documents*.

This document replaces GB/T 15062-2008, *Superalloy Tubes for General Use*, and GB/T 28295-2012, *General Technical Requirements for Superalloy Tubes*. It is based mainly on GB/T 15062-2008 and incorporates GB/T 28295-2012.

Compared with GB/T 15062-2008, in addition to structural adjustments and editorial changes, the principal technical changes are:

a) alloy melting methods have been added (see 5.1); b) seven alloy grades - GH1131, GH3128, GH3535, GH3617, GH3625, GH4080A and GH4169 - and their corresponding technical requirements have been added (see Clause 6).

Attention is drawn to the possibility that some elements of this document may be the subject of patent rights. The issuing organizations shall not be held responsible for identifying any or all such patent rights.

This document was proposed by the China Iron and Steel Association and is under the jurisdiction of SAC/TC 183, the National Technical Committee on Steel.

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Wrought Superalloy - Seamless Tube

1 Scope

This document specifies ordering information, manufacturing processes, technical requirements, inspection rules, packaging, marking and quality certificates for wrought-superalloy seamless tubes, and describes the corresponding test methods.

It applies to wrought-superalloy seamless tubes manufactured by cold drawing (rolling), hereinafter referred to as tubes.

2 Normative References

The following documents are indispensable for the application of this document. For dated references, only the cited edition applies. For undated references, the latest edition, including amendments, applies.

GB/T 222 - Steel and alloys - Permissible tolerances for chemical composition of finished products
GB/T 223 (all parts) - Methods for chemical analysis of iron, steel and alloy
GB/T 228.1 - Metallic materials - Tensile testing - Part 1: Method at room temperature
GB/T 228.2 - Metallic materials - Tensile testing - Part 2: Method at elevated temperature
GB/T 230.1 - Metallic materials - Rockwell hardness test - Part 1: Test method
GB/T 231.1 - Metallic materials - Brinell hardness test - Part 1: Test method
GB/T 241 - Metallic tubes - Hydrostatic test method
GB/T 242 - Metallic tubes - Drift-expanding test method
GB/T 246 - Metallic materials - Tube - Flattening test
GB/T 2039 - Metallic materials - Uniaxial tensile creep testing method
GB/T 2102 - Acceptance, packing, marking and quality certification of steel pipes
GB/T 2975 - Steel and steel products - Sampling locations and preparation of test pieces for mechanical testing
GB/T 4340.1 - Metallic materials - Vickers hardness test - Part 1: Test method
GB/T 5777 - Automated full-peripheral ultrasonic testing of seamless and welded steel tubes for longitudinal and/or transverse imperfections
GB/T 6394 - Determination of estimating the average grain size of metal
GB/T 7735 - Automated eddy-current testing of seamless and welded steel tubes for imperfections
GB/T 11170 - Stainless steel - Determination of multi-element contents - Spark discharge atomic emission spectrometric method
GB/T 13298 - Inspection methods of microstructure for metals
GB/T 14992 - Designation and chemical composition of superalloys and intermetallic materials
GB/T 20066 - Steel and iron - Sampling and preparation for chemical analysis
GB/T 20123 - Steel and iron - Determination of total carbon and sulfur content
GB/T 20124 - Steel and iron - Determination of nitrogen content - Thermal conductimetric method after fusion in inert gas
GB/T 20127 (all parts) - Steel and alloy - Determination of trace elements
GB/T 30062 - Terminology of steel tubes
GB/T 38939 - Nickel-base alloys - Determination of multi-element contents - Spark discharge atomic emission spectrometric method
HB 5220 (all parts) - Methods for chemical analysis of superalloys
HB 20241 (all parts) - Spectrometric analysis methods for chemical composition of superalloys

3 Terms and Definitions

The terms and definitions given in GB/T 14992 and GB/T 30062 apply.

4 Ordering Information

Contracts placed under this document should state: a) document number; b) alloy grade; c) melting method; d) delivery condition; e) dimensions and tolerance class; f) fixed or multiple lengths, when required; g) mass or number of pieces; h) ultrasonic acceptance level; and i) other special requirements.

5 Manufacturing Process

5.1 Alloy melting methods

Alloy melting methods shall comply with Table 1. Other melting methods capable of meeting all requirements may be used by agreement between supplier and purchaser. The method used shall be stated in the contract and quality certificate.

Table 1 - Alloy Melting Methods

No.	Grade	EAF + ESR	EAF + VAR	Non-vacuum induction + ESR	Non-vacuum induction + VAR	VIM + ESR	VIM + VAR	VIM + ESR + VAR	VIM + VAR + ESR
1	GH1131	●	-	●	-	-	-	-	-
2	GH1140	●	-	●	-	-	-	-	-
3	GH3030	●	-	●	●	●	-	-	-

No.	Grade	EAF + ESR	EAF + VAR	Non-vacuum induction + ESR	Non-vacuum induction + VAR	VIM + ESR	VIM + VAR	VIM + ESR + VAR	VIM + VAR + ESR
4	GH3039	●	●	●	●	●	-	-	-
5	GH3044	-	●	●	●	-	●	-	-
6	GH3128	-	-	●	-	●	-	-	-
7	GH3535	●	●	●	●	●	●	-	-
8	GH3536	●	-	●	-	●	●	-	-
9	GH3617	●	●	●	●	●	●	-	-
10	GH3625	●	●	-	-	●	●	-	-
11	GH4080A	-	-	●	●	●	●	-	-
12	GH4163	-	-	●	●	●	●	-	-
13	GH4169	-	-	-	-	●	●	●	●

Note: ● indicates a recommended melting method.

5.2 Tube manufacturing method

Tubes shall be manufactured by hot extrusion followed by cold drawing (rolling), or by hot piercing followed by cold drawing (rolling).

5.3 Delivery condition

5.3.1 Tubes shall be delivered solution-treated and pickled, or solution-treated in a protective atmosphere. By agreement and when stated in the contract, they may also be delivered cold-drawn or cold-rolled.

5.3.2 Recommended solution-treatment schedules are given in Table 2.

Table 2 - Recommended Solution-Treatment Schedules

No.	Grade	Solution-treatment schedule
1	GH1131	1120-1160 °C, water cooling
2	GH1140	1050-1080 °C, rapid cooling or water cooling
3	GH3030	980-1020 °C, water cooling
4	GH3039	1050-1080 °C, rapid cooling or water cooling
5	GH3044	1120-1210 °C, rapid cooling
6	GH3128	1140-1180 °C, rapid cooling
7	GH3535	1170-1190 °C, rapid cooling or water cooling
8	GH3536	1130-1170 °C, rapid cooling
9	GH3617	1150-1230 °C, rapid cooling or water cooling
10	GH3625	1093-1180 °C, rapid cooling or water cooling
11	GH4080A	1100-1150 °C, rapid cooling or water cooling
12	GH4163	1140-1160 °C, rapid cooling or water cooling
13	GH4169	955-1020 °C, rapid cooling or water cooling

6 Technical Requirements

6.1 Grades and chemical composition

6.1.1 The chemical composition (ladle analysis) of alloys shall comply with Table 3. 6.1.2 Permissible deviations in the chemical composition of finished tubes shall comply with GB/T 222.

Table 3 - Alloy Grades and Chemical Compositions (mass fraction, %)

No.	Grade	Unified designation	C	Cr	Ni	Co	W	Mo	Al	Ti	Al+Ti	Fe	Nb	Si	Mn	P	S	Cu	B	Ag	Bi	Pb	Ce	Other
1	GH1131	H11131	≤0.10	19.00-22.00	25.0-30.0	-	4.80-6.00	2.80-3.50	-	0.70-1.20	-	Balance	0.70-1.30	≤0.80	≤1.20	≤0.020	≤0.020	-	-	-	-	-	-	N:0.15-0.30
2	GH1140	H11140	0.06-0.12	20.00-23.00	35.0-40.0	-	1.40-1.80	2.00-2.50	0.20-0.60	-	≤1.75	Balance	-	≤0.80	≤0.70	≤0.025	≤0.015	-	≤0.010	-	-	-	≤0.050	-
3	GH3030	H30300	≤0.12	19.00-22.00	Balance	-	-	-	≤0.15	0.15-0.35	-	≤1.5	-	≤0.80	≤0.70	≤0.015	≤0.020	-	-	-	-	-	-	-
4	GH3039	H30390	≤0.08	19.00-22.00	Balance	-	-	1.80-2.30	0.35-0.75	0.35-0.75	-	≤3.0	0.90-1.30	≤0.80	≤0.40	≤0.015	≤0.012	≤0.20	-	-	-	≤0.01	-	-
5	GH3044	H30440	≤0.10	23.5-26.5	Balance	-	13.0-16.0	≤1.50	≤0.5	0.30-0.70	-	≤4.0	-	≤0.80	≤0.50	≤0.013	≤0.013	-	≤0.008	≤0.0005	≤0.0001	≤0.0020	-	Ca≤0.05
6	GH3128	H31280	≤0.05	19.00-22.00	Balance	-	7.50-9.00	7.50-9.00	0.40-0.80	0.40-0.80	-	≤2.0	-	≤0.80	≤0.50	≤0.013	≤0.013	-	≤0.005	≤0.0005	≤0.0001	≤0.0020	-	Zr≤0.06
7	GH3535	H35350	0.04-0.08	6.00-8.00	Balance	≤0.20	≤0.50	15.00-18.00	-	-	≤0.50	≤5.00	-	≤1.00	≤1.00	≤0.015	≤0.020	≤0.35	-	-	-	-	-	V≤0.50
8	GH3536	H35360	0.05-0.15	20.5-23.0	Balance	0.50-2.50	0.20-1.00	8.00-10.00	≤0.50	≤0.15	-	17.00-20.00	-	≤1.00	≤1.00	≤0.025	≤0.015	≤0.30	≤0.010	-	-	-	-	-
9	GH3617	H36170	0.05-0.15	20.0-24.0	≥44.5	10.0-15.0	-	8.00-10.00	0.80-1.50	≤0.60	-	≤3.00	-	≤1.0	≤1.0	-	≤0.015	≤0.50	≤0.006	-	-	-	-	-
10	GH3625	H36250	≤0.10	20.0-23.0	Balance	≤1.00	-	8.00-10.00	≤0.40	≤0.40	-	≤5.00	3.15-4.15	≤0.50	≤0.50	≤0.015	≤0.015	-	-	-	-	-	-	-
11	GH4080A	H40801	0.04-0.10	18.0-21.0	Balance	≤2.00	-	-	1.00-1.80	1.80-2.70	-	≤1.50	-	≤0.80	≤0.40	≤0.015	≤0.015	≤0.20	≤0.008	≤0.0005	≤0.0001	≤0.0020	-	-
12	GH4163	H41630	0.04-0.08	18.0-21.0	Balance	19.0-21.0	-	5.60-6.10	0.30-0.60	1.90-2.40	2.40-2.80	≤0.70	4.75-5.50	≤0.40	≤0.60	≤0.015	≤0.007	≤0.20	≤0.005	≤0.0005	≤0.0001	≤0.0020	-	-
13	GH4169	H41690	≤0.08	17.0-21.0	50.0-55.0	≤1.00	-	2.80-3.30	0.20-0.80	0.65-1.15	-	Balance	4.75-5.50	≤0.35	≤0.35	≤0.015	≤0.015	≤0.30	≤0.006	-	-	-	-	Mg≤0.01

Notes from the source table: calculated contents are not analyzed; boron is analyzed for information only; trace elements are analyzed only when specifically noted. Where shown, 'Balance' denotes the remainder.

6.2 Mechanical Properties

6.2.1 Room-temperature tensile properties of tubes shall comply with Table 4.

Table 4 - Room-Temperature Tensile Properties

No.	Grade	Heat-treatment condition	OD D / mm	Wall S / mm	Rm / MPa	Rp0.2 / MPa	A / %
1	GH1131	Delivery condition (solution-treated)	—	—	≥735	—	≥32
2	GH1140	Delivery condition (solution-treated)	≤30	≤3.0	≥635	—	≥40
			>30	>3.0	≥590	—	≥35
3	GH3030	Delivery condition (solution-treated)	≤30	≤3.0	≥635	—	≥35
			>30	>3.0	≥590	—	≥35
4	GH3039	Delivery condition (solution-treated)	≤30	≤3.0	≥685	—	≥40
			>30	>3.0	≥635	—	≥35
5	GH3044	Delivery condition (solution-treated)	—	—	≥685	—	≥30
6	GH3128	Delivery condition (solution-treated)	≤10	≥0.5	≥735	≥330	≥40
7	GH3535	Delivery condition (solution-treated)	—	—	≥690	≥280	≥40
8	GH3536	Delivery condition (solution-treated)	—	—	≥690	≥310	≥25
9	GH3617	Delivery condition (solution-treated)	—	—	≥665	≥240	≥35
10	GH3625	Delivery condition (solution-treated)	—	—	≥690	≥275	≥30
11	GH4080A	Delivery condition (solution-treated) aging ()+ , aging (750±10)×4h, air cooling	—	<0.5	≥1030	—	—
			—	0.5~1.0	≥1030	≥640	≥15
			—	>1.0	≥1030	≥640	≥20
13	GH4169	Delivery condition (solution-treated)	—	—	≤1070	≤655	a ≥30
		Delivery condition (solution-treated) aging ()+ , aging (720±10)×8h, 50/h air cooling (620±10), 8h,	—	—	≥1200	≥1000	a ≥12
50mm							

a) The original gauge length for elongation after fracture is 50 mm.

6.2.2 Elevated-temperature tensile properties of GH4163 tubes shall comply with Table 5. By agreement and when stated in the contract, other alloy tubes may also be tested; results shall comply with Table 5.

Table 5 - Elevated-Temperature Tensile Properties

No.	Grade	Heat-treatment condition	Wall / mm	Test temp. / °C	Rm / MPa	Rp0.2 / MPa	A / %	Z / %
1	GH1131	Delivery condition (solution-treated)	—	900	≥186	—	≥35	—
				1000	≥108	—	≥45	—
2	GH1140	Delivery condition (solution-treated)	—	800	≥225	—	≥40	≥50
3	GH3030	Delivery condition (solution-treated)	—	700	≥295	—	≥30	≥40
4	GH3039	Delivery condition (solution-treated)	—	800	≥245	—	≥40	≥50
6	a GH3128	Delivery condition (solution-treated)	—	950	≥175	≥110	≥40	—
9	GH3617	Delivery condition (solution-treated)	—	650	≥490	≥195	≥30	—
				700	≥445	≥190	≥30	—
12	GH4163	Delivery condition (solution-treated) aging ()+ , aging air cooling :(800±10)■×8h,	<0.5	780	≥540	—	—	—
			≥0.5	780	≥540	≥400	≥9	—
13	GH4169	Delivery condition (solution-treated) aging ()+ , aging :(720±10)■×8h, ■■■ 50■/h (620±10)■, ■■■ air cooling 8h,	—	600	≥1000	≥900	b ≥12	—

No.	Grade	H when S < 1.0	H when S ≥ 1.0
12	GH4163	nearly flat	S 5

6.6 Hydrostatic Test

6.6.1 GH1140, GH3030, GH3039, GH3044 and GH4080A tubes shall be hydrostatically tested. The allowable stress is 40% of the room-temperature tensile strength. Test pressure is calculated by $P = 2SR/D$. No leakage, bulging, pinholes, cracks or other defects are permitted. P is maximum test pressure (MPa); R is allowable stress (2/3 of the minimum yield-strength requirement or 1/4 of the minimum tensile-strength requirement, MPa); S is minimum wall thickness (mm); D is nominal outside diameter (mm).

6.6.2 GH3536 and GH3625 tubes shall be hydrostatically tested using $P = R(D^2 - d^2)/(D^2 + d^2)$, where R is Rp0.2, D is nominal outside diameter and d is nominal inside diameter. No leakage, bulging, pinholes, cracks or other defects are permitted; permanent radial deformation of 0.002 mm/mm in the diameter direction is permitted.

6.6.3 GH3535 tubes shall be hydrostatically tested at not less than 6.9 MPa and not more than the pressure calculated by the formula in 6.6.1. No leakage, bulging, pinholes, cracks or other defects are permitted.

6.7 Grain Size

Tubes shall be inspected for grain size in accordance with GB/T 6394. Acceptance levels shall comply with Table 9.

Table 9 - Grain Size

Grade	Grain size
GH1131	Grades 5-8; individual Grade 4 permitted
GH1140	Actual value
GH3030	Actual value
GH3039	Actual value
GH3044	Grade 5 or finer
GH3128	Actual value
GH3535	Grades 2-5; grade difference not greater than 3 grades
GH3536	For nominal wall S ≤ 1.0 mm: Grade 6 or finer; for S > 1.0 mm: Grade 5 or finer
GH3625	Grade 5 or finer; individual Grade 3 permitted
GH4169	Grade 5 or finer; individual Grade 3 permitted

6.8 Ultrasonic Testing

Tubes shall be ultrasonically tested. The acceptance level shall be agreed between supplier and purchaser and stated in the contract.

6.9 Eddy-Current Testing

By agreement and when stated in the contract, tubes may be eddy-current tested. The acceptance level shall be stated in the contract.

6.10 Surface Quality

The inner and outer surfaces shall be smooth and free from pores, cracks, laps, crazing, delamination, scabs and similar defects. Local imperfections shall be completely removed, except on tubes intended for machining. After removal, outside diameter and wall thickness shall not exceed the negative tolerances. Other minor surface imperfections within the permissible deviations need not be removed. The permissible depth of straight-line marks shall not exceed 4%. For tubes with wall thickness below 1.4 mm, the permissible depth of straight-line marks shall not exceed 0.05 mm, with a maximum depth not exceeding 0.3 mm.

6.11 Over-Pickling

When GH3536 tubes are delivered after pickling, their inner and outer surfaces shall show no over-pickling. On an unetched specimen examined at not less than 500× magnification, maximum corrosion depth shall not exceed 0.013 mm.

6.12 Dimensions, Shape and Mass

6.12.1 Dimensions and permissible deviations

6.12.1.1 Nominal outside diameter D and wall thickness S shall comply with Table 10. Other sizes may be supplied by agreement, with permissible deviations stated in the contract.

Table 10 - Tube Outside Diameter and Wall Thickness (mm)

Nominal OD D	0.5	0.75	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
4~7	●	●	●	●								
>7~9		●	●	●	●							

Nominal OD D	0.5	0.75	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
>9~15			●	●	●	●						
>15~20			●	●	●	●	●					
>20~30				●	●	●	●	●				
>30~40				●	●	●	●	●	●	●	●	
>40~57					●	●	●	●	●	●	●	●

● indicates a listed size combination.

6.12.1.2 Outside-diameter and wall-thickness tolerances shall comply with Table 11. If no tolerance class is stated in the contract, normal accuracy applies. Other tolerances may be agreed and stated in the contract.

Table 11 - Permissible Deviations of Outside Diameter and Wall Thickness (mm)

Dimension	Nominal size	Normal accuracy	Higher accuracy
Outside diameter D	4-6	±0.15	±0.10
	>6-10	±0.20	±0.15
	>10-30	±0.30	±0.20
	>30-50	±0.40	±0.30
	>50	±0.9%D	±0.8%D
Wall thickness S	0.50-1.0	±0.12	±0.10
	>1.0-3.0	+15%S / -12%S	+12%S / -10%S
	>3.0	+12%S / -10%S	±10%S

6.12.1.3 Normal tube length is 1000-7000 mm. Fixed and multiple lengths shall be within this range. The permissible deviation for fixed length is +15/0 mm. Each multiple length shall include 5-10 mm cutting allowance. Fixed and multiple lengths shall be stated in the contract.

6.12.2 Shape

6.12.2.1 Straightness shall not exceed 2 mm per metre.

6.12.2.2 Out-of-roundness and wall-thickness nonuniformity shall each not exceed 80% of the outside-diameter and wall-thickness tolerances, respectively.

6.12.2.3 Both tube ends shall be cut square and perpendicular; burrs shall be removed.

6.12.3 Mass

Tubes shall be delivered by actual mass.

7 Test Methods

7.1 Chemical-composition analysis shall be carried out according to GB/T 223 (all parts), GB/T 11170, GB/T 20123, GB/T 20124, GB/T 20127 (all parts), GB/T 38939, HB 5220 (all parts), HB 20241 (all parts), or other generally accepted methods. In arbitration, the method shall be agreed between supplier and purchaser.

7.2 Inspection items and test methods shall comply with Table 12.

Table 12 - Inspection Items, Sampling Quantity, Sampling Location and Test Methods

No.	Inspection item	Sampling quantity	Sampling location/method	Test method
1	Chemical composition	1 / heat	GB/T 20066	7.1
2	Room-temperature tensile	2 / batch	Different tubes and GB/T 2975	GB/T 228.1
3	Elevated-temperature tensile	2 / batch	Different tubes and GB/T 2975	GB/T 228.2
4	Creep properties	2 / batch	Different tube blanks	GB/T 2039
5	Stress-rupture properties	2 / batch	Different tube blanks	GB/T 2039
6	Delivery hardness	5%, at least 2 / batch	Different tubes	GB/T 230.1, GB/T 231.1, GB/T 4340.1
7	Flaring	2 / batch	Different tubes	GB/T 242, 6.4
8	Flattening	2 / batch	Different tubes	GB/T 246
9	Hydrostatic test	Each tube	Whole tube	GB/T 241
10	Grain size	2 / batch	Different tubes	GB/T 6394
11	Ultrasonic testing	Each tube	Whole tube	GB/T 5777
12	Eddy-current testing	Each tube	Whole tube	GB/T 7735
13	Over-pickling	1 / batch	Any tube	GB/T 13298, 6.11
14	Dimensions and shape	Each tube	Whole tube	Measuring instruments meeting accuracy requirements
15	Surface quality	Each tube	Whole tube	Visual

8 Inspection Rules

8.1 Inspection and acceptance

Tube acceptance shall be carried out by the supplier's technical supervision department. The purchaser has the right to inspect tubes in accordance with this document.

8.2 Batch Rules

Tubes shall be submitted for acceptance in batches. Each batch shall consist of tubes of the same grade, melting heat number (sub-heat number), dimensions, manufacturing method and heat-treatment furnace batch (schedule). For electroslag-remelted alloys, batching by parent heat number is permitted.

8.3 Inspection Items, Sampling Quantity, Sampling Location and Test Methods

Sampling quantities and locations shall comply with Table 12.

8.4 Determination and Retest Rules

8.4.1 If chemical-composition analysis is nonconforming, a new sample shall be taken from the original sampling location and the nonconforming element retested. If the retest remains nonconforming, the heat shall be rejected.

8.4.2 If any room-temperature tensile, elevated-temperature tensile, elevated-temperature creep, stress-rupture, hardness, flaring, flattening, grain-size or over-pickling inspection is nonconforming, twice the original number of specimens may be taken from the batch of tubes or tube blanks, including the originally nonconforming tube or blank, for retesting. If even one retest specimen is nonconforming, the batch shall be rejected.

8.4.3 Tubes failing room-temperature tensile, elevated-temperature tensile, creep, stress-rupture, hardness or grain-size inspection may be re-heat-treated by the supplier and resubmitted as a new batch, with this stated in the quality certificate. Re-heat treatment is permitted only once.

8.4.4 If dimensions, shape, surface quality, ultrasonic testing or hydrostatic testing is nonconforming, the individual tube shall be rejected.

9 Packaging, Marking and Quality Certificate

Packaging, marking and quality certificates for tubes shall comply with GB/T 2102.

Translation note: This is an unofficial English translation prepared from the supplied Chinese standard. In case of discrepancy, the Chinese original governs.