

China Experience of the Pressure Piping/Vessel Codes (for SHINE application)

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On behalf of SHINE cryomodule team

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Q1. Material:

What is the request for materials which will be used for high pressure vessel? (ex. Mechanical property)

Please describe your answer here.

Q1. Request for Materials

- China General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ)——**Special Equipment Catalogue (No. 114 of 2014)**

- **Definition of the Pressure Piping:**

- Maximum working pressure ≥ 0.1 MPa (gauge pressure)
- & Nominal diameter ≥ 50 mm
- & Media: gas, liquefied gas, steam, or liquids that are flammable, explosive, toxic, corrosive, or have a maximum working temperature $\geq$ the standard boiling point (e.g. **Supercritical He~4.5K @3bar > LHe~4.2K @1bar**)
- **Exclusions:** maximum working pressure < 1.6 MPa (gauge pressure), nominal diameter < 150 mm
- **SHINE examples:**
 - Pipes A/C/D: non-pressure piping
 - Pipes E/F: pressure piping
 - Pipe B + two-phase pipe + helium tank: NO @2K, YES @4K

- **Definition of the Pressure Vessel:**

- Maximum working pressure ≥ 0.1 MPa (gauge pressure)
- Volume ≥ 30 L
- Inner diameter ≥ 150 mm
- Fixed and mobile vessels
- **SHINE examples:**
 - Pipe B + two-phase pipe + helium tank: NO @2K, YES @4 K

附件

特种设备目录

代码	种 类	类 别	品 种
1000	锅炉	锅炉，是指利用各种燃料、电或者其他能源，将所盛装的液体加热到一定的参数，并通过对外输出介质的形式提供热能的设备，其范围规定为设计正常水位容积大于或者等于 30L，且额定蒸汽压力大于或者等于 0.1MPa（表压）的承压蒸汽锅炉；出口水压大于或者等于 0.1MPa（表压），且额定功率大于或者等于 0.1MW 的承压热水锅炉；额定功率大于或者等于 0.1MW 的有机热载体锅炉。	
1300		有机热载体锅炉	
1310			有机热载体气相炉
1320			有机热载体液相炉
2000	压力容器	压力容器，是指盛装气体或者液体，承载一定压力的密闭设备，其范围规定为最高工作压力大于或者等于 0.1MPa（表压）的气体、液化气体和最高工作温度高于或者等于标准沸点的液体、容积大于或者等于 30L 且内直径(非圆形截面指截面内边界最大几何尺寸)大于或者等于 150mm 的固定式容器和移动式容器；盛装公称工作压力大于或者等于 0.2MPa（表压），且压力与容积的乘积大于或者等于 1.0MPa·L 的气体、液化气体和标准沸点等于或者低于 60℃液体的气瓶；氧舱。	
2100		固定式压力容器	
8000	压力管道	压力管道，是指利用一定的压力，用于输送气体或者液体的管状设备，其范围规定为最高工作压力大于或者等于 0.1MPa（表压），介质为气体、液化气体、蒸汽或者可燃、易爆、有毒、有腐蚀性、最高工作温度高于或者等于标准沸点的液体，且公称直径大于或者等于 50mm 的管道。公称直径小于 150mm，且其最高工作压力小于 1.6MPa（表压）的输送无毒、不可燃、无腐蚀性气体的管道和设备本体所属管道除外。其中，石油天然气管道的安全监督管理还应按照《安全生产法》、《石油天然气管道保护法》等法律法规实施。	

质检总局关于修订《特种设备目录》的公告
(2014 年第 114 号)。

根据《中华人民共和国特种设备安全法》《特种设备安全监察条例》的规定，质检总局修订了《特种设备目录》，经国务院批准，现予以公布施行。同时，《关于公布〈特种设备目录〉的通知》（国质检锅〔2004〕31 号）和《关于增补特种设备目录的通知》（国质检特〔2010〕22 号）予以废止。《特种设备目录》由质检总局负责解释。

特此公告。

附件：特种设备目录。

质检总局。
2014 年 10 月 30 日。

Q1. Request for Materials

■ China National Standard, Pressure Piping Code: GB/T 20801.2-2020 Part 2: Materials

■ 8. Restrictions on the use of materials under low-temperature conditions

- **Cast iron:** minimum temperature $> -20^{\circ}\text{C}$, pressure $\leq 2.0\text{ MPa}$
- **Carbon steel, low-temperature steel, chromium-molybdenum alloy steel, ferritic stainless steel and duplex stainless steel:** minimum temperature $> -101^{\circ}\text{C}$
- **Austenitic stainless steel:** may be used in cryogenic temperature, such as LHe and LH2. When the service temperature is $\leq -20^{\circ}\text{C}$, a low-temperature impact test shall be conducted.
- **Nickel, Titanium, Aluminum and their alloy:** minimum working Temp. as table 7

表 7 有色金属(镍和镍基合金、钛和钛合金、铝和铝合金)的最低使用温度

材料类别	最低使用温度/ $^{\circ}\text{C}$	冲击试验要求		更低使用温度
		材料	焊接接头	
镍及镍基合金	-200	全部免除	a)如焊缝金属成分符合母材规定,无额外要求。	设计应对材料、焊缝金属和热影响区在设计温度下进行相应的试验(包括延伸率、缺口拉伸/常规拉伸比较、冲击试验等)来确定其适用性
钛及钛合金	-60		b)如焊缝金属成分不符合母材规定,按右侧更低使用温度栏要求	
铝及铝合金	-270			

- When **bolt** materials are used at low temperatures, the **impact test** may be exempted if the following conditions are met:
 - a) Standard fasteners made of carbon steel and alloy structural steel;
 - b) Standard fasteners made of austenitic stainless steel;
 - c) 0Cr18Ni9, 0Cr17Ni12Mo2 and their strain-hardened stainless steel fasteners, such as B8-2;
 - d) 25Cr2MoV steel fasteners.



Q2. Pressure test:

What kind of pressure test are required? And how much is the pressure?

Please describe your answer here.

Q2. Pressure Test

- **Special Equipment Catalogue (No. 114 of 2014 by AQSIQ)**
- **Pressure piping code in China**
 - **GB/T 20801-2020 Pressure Piping Code – Industrial Piping (overall pressure piping)**
 - **GBT 14976-2012 Stainless steel seamless tubes for fluid transport (steel grade description)**
 - **GBT 12459-2005 Steel butt-welding seamless pipe fittings (steel fittings description)**
 - **JB/T 12665-2016 Vacuum-insulated cryogenic pipe (commonly used in cryogenic plants)**
- **Pressure vessel code in China**
 - **GB/T 18442-2018 Stationary vacuum-insulated cryogenic pressure vessels (cryogenic pressure vessels)**
 - **GB 150-2011 Pressure Vessels (overall pressure vessels: materials, design, fabrication, inspection)**
 - **TSG 21-2016 Safety Technical Supervision Regulation for Stationary Pressure Vessels (pressure vessel safety technology)**
 - **GB/T 18443-2010 Performance test methods for vacuum-insulated cryogenic equipment (related testing)**

Q2. Pressure Test

- **GB/T 20801.1-2020 Part 1: General Rules**
- **4. Piping classification: safety level GC1 > GC2 > GC3**
 - Industrial pressure piping, Grade GC1:
 - Extremely hazardous media
 - Flammable media with design pressure ≥ 4.0 MPa
 - Design temperature $\geq 400^{\circ}\text{C}$ at ≥ 4.0 MPa
 - Design pressure ≥ 10.0 MPa
 - Industrial pressure piping, Grade GC2: **SHINE adopted**
 - Between GC1 and GC3
 - For conventional piping, design pressure is 1.0 MPa to 10.0 MPa
 - Industrial pressure piping, Grade GC3:
 - Transports non-toxic, non-flammable fluid media
 - Design pressure ≤ 1.0 MPa at $> -20^{\circ}\text{C}$



- **GB/T 20801.5-2020 Part 5: Inspection and Testing**
- **6. Inspection level: Level I > Level II > Level III > Level IV > Level V**
 - The piping inspection level shall be determined according to the piping grade and severe cyclic service conditions:
 - The inspection level for GC3 shall not be lower than Level V.
 - The inspection level for GC2 shall not be lower than Level IV → **The strictest grade has been adopted for SHINE with Level I** (Visual check, penetrant, ultrasonic/radiographic)
 - The inspection level for GC1 shall not be lower than Level II.

Note:

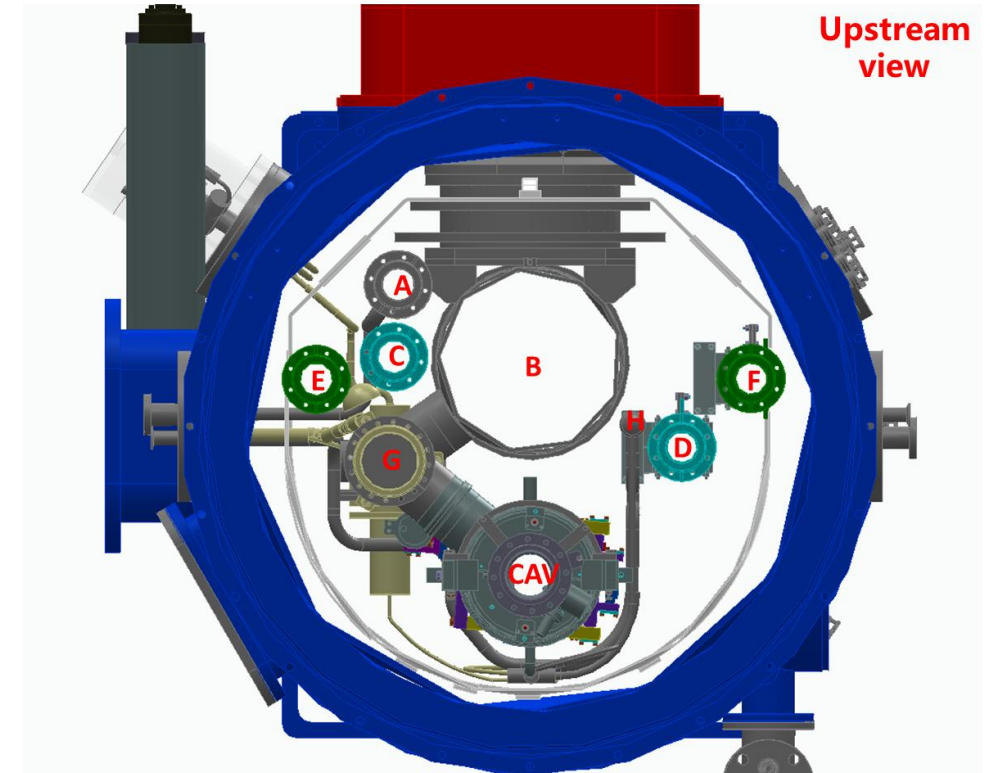
1. Butt circumferential welds with **nominal piping thickness $\leq 30\text{mm}$** shall use **radiographic testing**
2. Butt circumferential welds with **nominal piping thickness $> 30\text{mm}$** may use **ultrasonic testing** instead of radiographic testing

表 5-1 检查等级、方法和比例

检查等级 ²⁰	检查方法	焊缝类型及检查比例 %		
		对接环缝	角焊缝 ²⁰	支管连接 ²⁰
I	目视检查	100	100	100
	磁粉/渗透	100 ²⁰	100	100
	射线照相/超声波	100	/	100 ²⁰
II	目视检查	100	100	100
	磁粉/渗透	20 ²⁰	20	20
	射线照相/超声波	20	/	20 ²⁰
III	Classification for welding inspection for pressure piping/vessel			
IV				
V				
V	目视检查	10	100	100

Q2. Pressure Test

- **References:** Pressure Piping Code (GB/T 20801-2020), Cryogenic Pressure Vessels (GB/T 18442-2018), as well as ASME B31.3 from the U.S.
- **Design pressure:** $\geq$ maximum working pressure (when safety valve over pressure), **~1.05 times** may be used
- **Test pressure:** 1.1~1.33 times the design pressure
- **China Industry Code for Safety valve:**
 - Leakage pressure: $> 90\%$ of set pressure
 - **Gas overpressure: 110% of set pressure**
 - Liquid overpressure: 115% of set pressure
 - Fire-case overpressure: 120% of set pressure
- **Acceptance code**
 - **SHINE Cryomodules** (Vacuum chamber/Cryogenic pipeline/Cavity string): acceptance mainly by reference to the GC2 class industrial piping code from Pressure Piping Code (GB/T 20801-2020)



Q2. Pressure Test

Design pressure: $\geq$ maximum working pressure (under safety valve over pressure), 1.05 times may be used
Test pressure: 1.1 to 1.33 times the design pressure

Vessel /Piping	Function	OD/ID (mm)	Operating Temp.(K)	Operating Pressure (BarA)	Safety valve setting pressure (barA)	Design pressure(barA)	Factory test pressure (barA)	Remarks
Vacuum chamber	Insulating vacuum	966 / 946	-20- 40°C	<1.0E-4Pa	1.5	1.75	2.0	
LineA	2.3 K supply	60.4 / 54.8	2.3-5.5	3.0 (Max=7.0)	10.0	15.0	17.0	Minimum test pressure
LineB	2.0 K return	312 / 300	2.0-4.6	1.6bar @ 4.6K 0.031bar @ 2K	2.0 @300K 3.0 @4.5K	4.0	4.5	
LineC	4.5 K supply	60.4 / 54.8	5.5	3.0 (Max=7.0)	10.0	15.0	17.0	Minimum test pressure
LineD	8.0 K return	63.5 / 50.8	7.0	3.0 (Max=7.0)	10.0	15.0	17.0	Minimum test pressure
LineE	35 K supply	60.4 / 54.8	40	18.0	21.0	23.5	26.0	Test pressure shall follow the steel-aluminum joint design pressure of 2.5 MPa (gauge)
LineF	55 K return	63.5 / 52.5	50	18.0	21.0	23.5	26.0	Test pressure shall follow the steel-aluminum joint design pressure of 2.5 MPa (gauge)
LineG	Two-phase line	101.6 / 97.4	2.0-4.6	1.6bar @ 4.6K 0.031bar @ 2K	2.0 @300K 3.0 @4.5K	4.0	4.5	
LineH	Warm-up/cool-downline	42.0 / 39.0	2.0-4.6	2.6bar @ 4.6K 0.031bar @ 2K	-	4.0	4.5	

Q2. Pressure Test: Details in the Code

- **GB/T 20801.5-2020 Part 5: Inspection and Testing**

- **9. Testing:**

SHINE example

Design pressure: 0.40 MPa、2.00MPa

Test pressure: 0.46 MPa、2.30MPa

Pressure gauge range: 4.60 MPa

- Test preparation:

- Complete piping inspections (radiographic, ultrasonic, penetrant, magnetic particle)
- Except for joints previously tested in accordance with this code, all joints shall not be covered with insulation so they can be inspected during the pressure test. If an alternative pressure test is to be performed, all joints shall not be primed or painted.
- For piping conveying steam or gas, temporary supports shall be added where necessary to support the weight of the test fluid.
- Pressure gauges: use **two calibrated and qualified** pressure gauges with the same range. The gauge range shall be 1.5 to 3 times the test pressure, preferably **2 times the test pressure**. **Gauge accuracy shall be no lower than Class 1.6**, and dial diameter shall be at least 100 mm.

- Test requirements for pressure test:

- The pressure holding time for the **pressure test shall be at least 10 minutes, and all joints and connections shall be checked for leakage and other abnormalities.**
- The pressure test shall be performed after all heat treatment has been completed.
- When the pressure test is performed near the metal ductile-brittle transition temperature, the possibility of brittle fracture shall be considered.

Q2. Pressure Test: Details in the Code

- **GB/T 20801.5-2020 Part 5: Inspection and Testing**
- **9. Testing: pressure test**

SHINE example

Design pressure: 0.40 MPa、2.00MPa

Test pressure: 0.46 MPa、2.30MPa

Initial inspection pressure: 0.23MPa、1.15 MPa

Step pressure: 0.05 MPa、0.23MPa

Pressure relief: 0.51 MPa、2.53MPa

- Hydraulic Pressure Test

- The test fluid should generally be clean water. When testing austenitic stainless-steel piping, or piping connected to austenitic stainless-steel components or vessels, the chloride ion content in the water shall not exceed 50 mg/L. If water adversely affects the piping or process and may damage the piping, another suitable non-toxic liquid may be used. When a flammable liquid is used for testing, its flash point shall not be lower than 49°C, and the surrounding test environment shall be considered. The fluid temperature during testing shall be at least 5°C;
- The hydrostatic test pressure at any point in the system shall be no less than 1.5 times the design pressure;
- When the piping test pressure is greater than the vessel test pressure, the piping cannot be isolated from the vessel, and the vessel test pressure is not less than 77% of the piping test pressure calculated by Formula (1), testing may be performed at the vessel test pressure with approval from the owner or designer.

$$p_T = 1.5 p_{S_1/S_2} \dots\dots\dots (1)$$

- Pneumatic Pressure Test

- A **pressure relief device** shall be installed during testing, and its set pressure shall not be higher than **1.1 times** the test pressure
- For metal piping subject to internal pressure, the pneumatic **test** pressure shall be **1.15 times** the design pressure; for vacuum piping, the test pressure shall be **0.2 MPa**.
- A preliminary test shall be performed before testing, and the **preliminary test** pressure should be 0.2 MPa.
- During testing, pressure shall be increased slowly in stages. When pressure reaches 50% of **the test pressure**, an **initial inspection** shall be performed. If **no abnormality or leakage is found**, continue increasing pressure in 10% test-pressure increments; each stage shall have sufficient holding time to balance piping strain, until the test pressure is reached. Then reduce pressure to the **design** pressure and check for **leakage**.

Q3. Industrialization:

How to harmonize each regions/country (how industries comply to foreign pressure vessel codes)?

Please describe your answer here.

Q3. Industrialization

- **Special Equipment Catalogue (No. 114 of 2014 by AQSIQ)**
- **Pressure piping code in China**
 - **GB/T 20801-2020 Pressure Piping Code – Industrial Piping (overall pressure piping)**
 - **GBT 14976-2012 Stainless steel seamless tubes for fluid transport (steel grade description)**
 - **GBT 12459-2005 Steel butt-welding seamless pipe fittings (steel fittings description)**
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Q3. Industrialization

■ ASME B31.3 Process Piping- pressure piping classification: Fluid service & Piping materials

Category D Fluid Service- fluid service that meets all of the following conditions:

- ◆ The conveyed fluid is, by definition, nonflammable, nontoxic, and not harmful to humans;
- ◆ Design gauge pressure does not exceed 1030kPa (150 psi)
- ◆ Design temperature does not exceed 186°C(366° F)
- ◆ The fluid temperature caused by reasons other than atmospheric conditions is not below -29°C (-20° F).

Elevated Temperature Fluid Service - fluid service inwhich the metal temperature of the piping is continuously equal to or greater than T_{cr} ,the temperature corresponding *to the basic allowable stress* value for welded base metal governed by creep rate or stressrupture criteria.

Category M Fluid Service - a service inwhich human exposure to fluid leakage has consequences; inhalation of or bodily contactwith even a very small leakage of toxic fluid can cause serious and difficult-to-cure injury, even if treatment is provided promptly.

Category K High PressureFluid Service – fluid service specified by the owner to be designed and constructed according to the relevant standards in B31.3

Category U High Purity Fluid Service - fluid service for which fabrication, inspection, examination,and testing methods beyond the code are selected due to product cleanliness control requirements.The term is used for other specific purposes such as high-purity, ultra-high-purity, hygienic, orsterile piping systems.

Normal Fluid Service – the fluid service for most piping governed by this code; that is, service not governed by the provisions for Category D, Category M, elevated temperature, high pressure,or high purity fluid service.

Category A nonmetallic pipe and fittings: thermoplastic pipe(such as polyethylenePE pipe), reinforced thermosetting resin(RTR), reinforced plastic mortar (RPM)



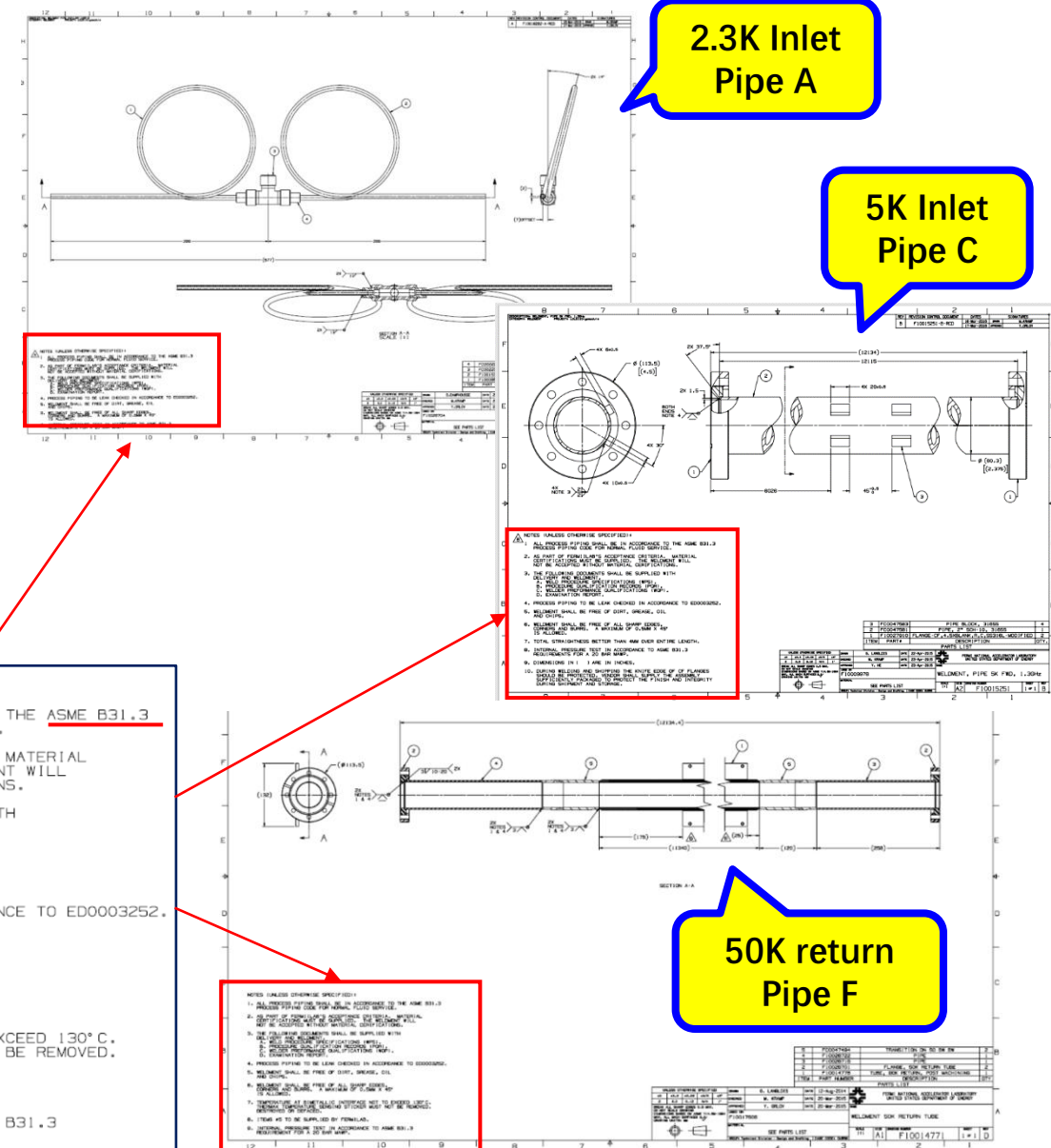
K301 管子	(109)
K302 管子、弯头及三通连接件	(109)
K303 阀门和特殊附件	(110)
K304 法兰、盲板、法兰密封面和垫片	(110)
K305 螺栓连接件	(110)
第4部分 流体工艺过程管道系统要求	(110)
K310 总则	(110)
K311 焊接接头	(110)
K312 法兰接头	(110)
K313 胀接接头	(110)
K314 螺栓接头	(110)
K315 管接头	(111)
K316 螺接接头	(111)
K317 软钎焊和硬钎焊接头	(111)
K318 特殊接头	(111)
第5部分 应力和应变	(111)
K319 应力	(111)
K320 应力	(111)
K321 管道连接件	(111)
第6部分 系统	(112)
K322 特殊管道系统	(112)
第7部分 材料	(112)
K323 一般要求	(112)
K324 其他材料	(112)
第8部分 管道附件标准	(112)
K325 附件的要求	(112)
第9部分 附件、紧固件和紧固件	(112)
K326 总则	(112)
K327 螺栓	(112)
K328 螺母	(112)
K329 垫圈	(112)

Q3. Industrialization

- Referring to the ASME B31.3 pressure piping code: LCLS-II cryogenic lines belongs to **normal fluid service piping** by optimizing the whole SC Linac working pressure

Circuit	Lines	Description
2 K piping	Lines A (supply) through G (two-phase pipe) to B (return)	Provides 2K liquid helium to the cavities with a valve for liquid supply in each module. The RF cavities are maintained within the 1.8 K to 2.1 K range by means of a stagnant bath of saturated liquid helium
Cool-down /warm-up	Lines A (supply) through H and then G (two-phase pipe) to B (return)	A cool-down/warm-up valve and closed-ended piping for cool-down /warm-up of individual module, to provide high thermal gradient during cool-down through 9.2 K transition temperature to minimize flux trapping
5 K piping	Lines C to D	A helium circuit in the temperature range of 5 K to 8 K, provides a low temperature thermal intercept for the support posts, RF power coupler, and instrumentation wires
45 K piping	Lines E to F	A helium circuit in the temperature range of 35 K to 55 K, provides conductive thermal intercepts to the thermal radiation shield, and to tuner piezo actuator wires and housing, RF power coupler, HOM absorbers, cryogenic valves, and instrumentation wires

Line	Description	Coordinates (X, Y) [mm]	Operating pressure [bar]	Design Pressure [bar]
A	2.2 K supply	219, 125.5	3.0	20.0
B	HGRP	0, 0	0.031	2.05 warm/ 4.0 cold
C	4.5 K supply	225.5, 6.5	3.0	20.0
D	5.5 K return	-252, -144.0	2.8	20.0
E	35 K supply	355, -31.0	3.7	20.0
F	55 K return	-367, -30.2	2.7	20.0
G	2 K-2 phase		0.031	2.05 warm/ 4.10 cold
H	Cool-down/warm-up		3	20



Q3. Industrialization

- Referring to the ASME B31.3 pressure piping code: LCLS-II cryogenic lines belongs to **normal fluid service piping** by optimizing the whole SC Linac working pressure

4.4 Welding

All welding process, inspection and testing of the cryogenic pipes must be in accordance to the ASME B31.3 Process Piping code for Normal Fluid Service. The welding of the support brackets and the HGRP structural welds shall be in accordance with the latest revision of ANSI/AWS D1.6, structural welding code for stainless steel, and the lengths and spacing of the welds shall meet the requirements as specified in the drawings. All welders shall be qualified to the ASME BPVC section IX. A weld map which includes each weld, welder performing the weld, by which WPS, and dated inspector signature shall be provided. All welds must conform to size called out on print. The welding filler material for stainless-to-stainless joint shall be ER308.

In addition to code requirements the vendor shall inspect interior of all pipe welds with a borescope. Vendor shall provide photographic documentation of borescope inspection of all interior welds as soon as the photos are taken.

Q4. Welding:

Which kind welding test requested?

Please describe your answer here.

Q4. Request for Welding Test

- **GB/T 20801.1-2020 Part 1: General Rules**
- **4. Piping classification: safety level GC1 > GC2 > GC3**
 - Industrial pressure piping, Grade GC1:
 - Extremely hazardous media
 - Flammable media with design pressure ≥ 4.0 MPa
 - Design temperature $\geq 400^{\circ}\text{C}$ at ≥ 4.0 MPa
 - Design pressure ≥ 10.0 MPa
 - Industrial pressure piping, Grade GC2: **SHINE adopted**
 - Between GC1 and GC3
 - For conventional piping, design pressure is 1.0 MPa to 10.0 MPa
 - Industrial pressure piping, Grade GC3:
 - Transports non-toxic, non-flammable fluid media
 - Design pressure ≤ 1.0 MPa at $> -20^{\circ}\text{C}$



- **GB/T 20801.5-2020 Part 5: Inspection and Testing**
- **6. Inspection level: Level I > Level II > Level III > Level IV > Level V**
 - The piping inspection level shall be determined according to the piping grade and severe cyclic service conditions:
 - The inspection level for GC3 shall not be lower than Level V.
 - The inspection level for GC2 shall not be lower than Level IV → **The strictest grade has been adopted for SHINE with Level I** (Visual check, penetrant, ultrasonic/radiographic)
 - The inspection level for GC1 shall not be lower than Level II.

Note:

1. Butt circumferential welds with **nominal piping thickness $\leq 30\text{mm}$** shall use **radiographic testing**
2. Butt circumferential welds with **nominal piping thickness $> 30\text{mm}$** may use **ultrasonic testing** instead of radiographic testing

表 5-1 检查等级、方法和比例

检查等级 ²⁰	检查方法	焊缝类型及检查比例 ²¹		
		对接环缝 ²²	角焊缝 ²³	支管连接 ²⁴
I	目视检查	100	100	100
	磁粉/渗透	100 ²⁵	100	100
	射线照相/超声波	100	/	100 ²⁶
II	目视检查	100	100	100
	磁粉/渗透	20 ²⁵	20	20
	射线照相/超声波	20	/	20 ²⁶
III	Classification for welding inspection for pressure piping/vessel			
IV				
V	目视检查	10	100	100

Q4. Request for Welding Test

- **GB/T 20801.4-2020 Part 4: Fabrication and Installation**

- **7. Basic welding requirements**

- Welding Methods

- **Carbon steel and alloy steel welding:** shielded metal arc welding, gas tungsten arc welding, gas metal arc welding, submerged arc welding, or gas welding;
- **Aluminum and aluminum alloy welding:** gas tungsten arc welding or gas metal arc welding;
- **Copper and copper alloys, titanium and titanium alloys, zirconium and zirconium alloys welding:** gas tungsten arc welding; brass may also use oxyacetylene welding (gas welding);
- **Nickel and nickel alloys welding:** shielded metal arc welding, gas tungsten arc welding, gas metal arc welding, or submerged arc welding.

- Welding Inspection: Determine the piping inspection level by piping class and severe cyclic conditions (I > II > III > IV > V)

- a) GC3 inspection level shall be no lower than Level V
- b) **GC2 inspection level shall be no lower than Level IV → The strictest grade has been adopted for SHINE, Level I**
- c) GC1 inspection level shall be no lower than Level II

- Weld Repair

- Before repair, **analyze the cause** of the defect and propose corresponding repair measures. Nondestructive examination may be used for confirmation when necessary.
- When repair requires weld build-up, a **qualified welding procedure** shall be used and welding shall be performed by a **qualified welder**. The groove shape and dimensions at the repair weld location shall prevent welding defects and facilitate welding.
- When the **number of repairs at the same location** (overlapping weld-repair filler metal area) **exceeds two**, repair measures shall be reformulated and may be carried out only after approval by the technical person in charge of the welding organization.
- After repair, **re-inspection** shall be performed using the original method, and the repair and inspection records shall be included in the hand over technical documents.

Q5. Testing:

What kind of tests are required for the completed high pressure vessel?

Please describe your answer here.

Q5. Testing for Completed Vessel

- **GB/T 20801.5-2020 Part 5: Inspection and Testing**

- **9. Testing:**

- Test preparation:

- Complete piping inspections (radiographic, ultrasonic, penetrant, magnetic particle)
- Except for joints previously tested in accordance with this code, all joints shall not be covered with insulation so they can be inspected during the pressure test. If an alternative pressure test is to be performed, all joints shall not be primed or painted.
- For piping conveying steam or gas, temporary supports shall be added where necessary to support the weight of the test fluid.
- Pressure gauges: use two calibrated and qualified pressure gauges with the same range. The gauge range shall be 1.5 to 3 times the test pressure, preferably 2 times the test pressure. Gauge accuracy shall be no lower than Class 1.6, and dial diameter shall be at least 100 mm.

- Test requirements for pressure test:

- The pressure holding time for the pressure test shall be at least 10 minutes, and all joints and connections shall be checked for leakage and other abnormalities.
- The pressure test shall be performed after all heat treatment has been completed.
- When the pressure test is performed near the metal ductile-brittle transition temperature, the possibility of brittle fracture shall be considered.

SHINE example

Design pressure: 0.40 MPa、 2.00MPa

Test pressure: 0.46 MPa、 2.30MPa

Pressure gauge range: 4.60 MPa

Q5. Testing for Completed Vessel

- **GB/T 20801.5-2020 Part 5: Inspection and Testing**

- **9. Testing:**

- **Pressure test:** hydraulic pressure test & pneumatic pressure test
- **Leak test:**
 - The leak test shall be conducted after the pressure test has passed. **Air** should preferably be used as the test medium;
 - The leak test pressure shall be the **design** pressure;
 - The leak test may be carried out together with the commissioning run;
 - The leak test shall focus on valve packing glands, flanges or threaded connections, vent valves, exhaust valves, drain valves, etc. The test is considered qualified if no leakage is found using a **foaming agent**;
 - Pipelines that have passed the pneumatic test and have not been dismantled after the test may be exempted from the leak test.
- **Vacuum test:**
 - After **passing the pressure test**, vacuum pipeline systems shall also undergo a **24-hour** vacuum test in accordance with the design documents. **The pressure rise rate shall be $\leq 5\%$.**
 - The pressure rise rate is calculated according to the following formula:
 - ΔP = pressure rise rate over **24 hours** (%)
 - P_1 = initial test pressure
 - P_2 = final test pressure

SHINE example

Design pressure: 0.40MPa、2.00MPa

Leak pressure: 0.40MPa、2.00MPa

$$\Delta P = \frac{P_2 - P_1}{P_1} \times 100\%$$

Backup Slides

Q2. Pressure Test

SHINE example

Nominal pressure: 0.2 MPa、 1.0MPa、 1.8 MPa

Shell test pressure: 0.3 MPa、 1.5 MPa、 2.7 MPa

Note: All above valves are in the valve box
(cryogenic plant)

- **GB/T 20801.4-2020 Part 4: Fabrication and Installation**
- **5. Inspection and acceptance of piping components and pipe supports: valve testing**
 - Valves shall undergo shell pressure tests and sealing tests according to the following requirements:
 - a) Valves used for GC1 class piping shall each undergo shell pressure testing and sealing testing.
 - **b) For valves used for GC2 class piping, 10% of each batch shall be sampled, and at least one valve shall be tested.**
 - c) For valves used for GC3 class piping, 5% of each batch shall be sampled, and at least one valve shall be tested.
 - **The valve shell test pressure shall be 1.5 times the nominal pressure.** The sealing test should be performed at nominal pressure. Holding time and sealing-surface leakage rate shall comply with the applicable standards. Valve test records shall be completed for valves that pass testing.
 - During hydrostatic testing of stainless-steel valves, chloride ion content in the water shall not exceed 100 ppm.
 - With approval from the designer or owner, **gate valves with nominal pressure $\leq$ PN100 and nominal diameter $\geq$ 600 mm may be pressure-tested together with the system.** The gate sealing test may be inspected by methods such as color printing.
 - Safety valves shall be commissioned at the set pressure specified in the design documents. **Each safety valve shall undergo at least 3 opening and closing tests,** and safety valve setting records shall be completed.

Q3. Industrialization

■ ASME B31.3 Category K high-pressure fluid service piping: inspection and testing

- (a) Except as permitted in (b) below, all circumferential welds, longitudinal welds, and branch connection welds shall receive 100% radiographic examination.
- (b) When specified by the engineering design and approved by the owner, ultrasonic examination may be used instead of **radiographic examination** for welds with **nominal thickness ≥ 13 mm (in)**.
- (c) Radiographic or ultrasonic examination of welds shall not be used as a substitute for in-process examination.

表 K341. 3. 2A 验收准则的注释

准 则		验收值范围[注(5)]
符号	量 度	
A	缺陷范围	零(无明显瑕疵)
B	内部气孔尺寸及分布	见 BPV 规范第Ⅷ卷第1册,附录4
C	夹渣或条形指示:如超过参照水平的幅值或长度超过单个长度的为不合格	$\leq \bar{T}_w \leq 19\text{mm. } (\frac{3}{4}\text{in.}), \text{ 为 } 6\text{mm. } (\frac{1}{4}\text{in.}),$ $19\text{mm. } (\frac{3}{4}\text{in.}) < \bar{T}_w \leq 57\text{mm. } (2\frac{1}{4}\text{in.}), \text{ 为 } \bar{T}_w/3$ $\bar{T}_w > 57\text{mm. } (2\frac{1}{4}\text{in.}), \text{ 为 } 19\text{mm. } (\frac{3}{4}\text{in.})$
	累计长度	在任何 $12\bar{T}_w$ 焊缝长度内, $\leq \bar{T}_w$
D	表面凹陷深度	壁厚 $\bar{T}_w$, mm (in.)
		焊缝表面凹陷深度
		$\leq 13(\frac{1}{2})$ $> 13 - \leq 51(2)$ $> 51(2)$
		$1.5(\frac{3}{16})$ $3(\frac{3}{8})$ $4(\frac{5}{32})$
E	表面粗糙度	包括焊缝补强在内的接头总厚度, $\geq \bar{T}_w$ $\bar{T}_w \leq 12.5\mu\text{m}(500\mu\text{in.}), R_a$ 按 ASME B46. 1

表 K341. 3. 2 焊缝验收准则

瑕疵类型	焊缝类型和要求的检验方法准则(A-E)[注(1)]					
	方 法		焊 缝 类 型			
	超声或目视	100%射线透照	坡口环缝	坡口纵缝[注(2)]	角缝[注(3)]	支管接头缝[注(4)]
裂 纹	X	X	A	A	A	A
未熔合	X	X	A	A	A	A
未焊透	X	X	A	A	A	A
内部气孔	...	X	B	B	NA	B
夹渣或条形指示	...	X	C	C	NA	C
咬 边	X	X	A	A	A	A
表面气孔或外露夹渣	X	...	A	A	A	A
根面凹陷(上缩)	X	X	D	D	NA	D
表面光洁度	X	...	E	E	E	E
余高或内凸起	X	...	F	F	F	F

通注: X—要求检查; NA—不适用; ...—不要求。

Q3. Industrialization

■ ASME B31.3 Category K high-pressure fluid service piping: inspection and testing

Before initial operation, each piping system shall undergo a leak test

(a) Except for bolted joints, individual gaskets used during final assembly, and pressure relief devices used during operation, each piping component and weld shall be separately subjected to hydrostatic or pneumatic leak testing. The testing organization shall ensure that adequate protective measures are in place during leak testing to prevent injury and property damage caused by flying fragments, shock waves, and other possible consequences in a pressure system.

(b) In addition to the requirements in (a), excluding pressure relief devices used during operation, the installed piping system shall also undergo **a leak test at a pressure not less than 110% of the design pressure to ensure** tightness, except as stated in (c) below.

(c) If the leak test required in (a) has already been performed on the installed piping system, the additional test in (b) is not required.

(d) With owner approval, pressure relief devices used during operation may be included in the leak test in (b). The leak test pressure may be reduced to prevent operation **or damage of the pressure relief devices**, but shall not be lower **than 90% of the set pressure of the pressure relief devices in the** system.

(e) For closure welds, the leak test required in (a) may be used in place of the examination performed according to K345.2.3 (c).