BSI-05

Integrated Stirling Cooler

Product Manual v.1.0

Table of Content

I. Overview

1.1. Intended Use

BSI-05 integrated Stirling cryocooler (hereinafter referred to as the cryocooler) provides efficient and precise cooling capacity for infrared detectors, cryogenic electronic devices, medical equipment, and other applications. It is suitable for a variety of harsh environments, including airborne, vehicle-mounted, shipborne, and ground-based installations, and meets users' diverse requirements for rapid cooling and long-term stable operation.

1.2. Product Features

Designed based on the Integrated Dewar/Cooler Assembly (IDCA) concept, this cooler features a built-in digital high-precision controller integrated at the motor end, along with specialized thermal management design. The product features an integrated design that compactly combines the compressor and expander, offering advantages such as lightweight construction, high reliability, rapid start-up, and precise temperature control.

II. Working Principle and Construction

2.1. Working Principle

Driven by a brushless DC rotary motor, the compressor piston within the compression section performs reciprocating motion. This causes the pressure of the working fluid to undergo alternating high and low variations; specifically, the helium gas pressure oscillates in a sinusoidal waveform around the mean pressure.

The expansion section receives the alternating working fluid flow generated by the compressor piston. Within the regenerator, the working fluid undergoes heat exchange with the regenerative material. As a result, the temperature of the working fluid drops, ultimately achieving low temperatures at the cold end of the regenerator and generating the required cooling capacity.

2.2. Product Construction

The cooler adopts an integrated unitized design, meaning both the compressor and the expander are mounted on the same main housing and driven by a single brushless DC motor via a common crank-connecting rod mechanism. The motor stator and the cooler drive

controller are integrated into the motor stator assembly, completely isolated from the internal working fluid. Due to this integrated design, the cooler does not feature a standalone cold finger; instead, it utilizes the inner tube of the dewar coupled with the cooler as the cold finger, as illustrated in Figure 1.

Figure 1. BSI-05 Cooler

2.3. Outline, Mounting Interfaces, and Dimensions

The outline, mounting interfaces, and dimensions of the cooler are illustrated in Figure 2.

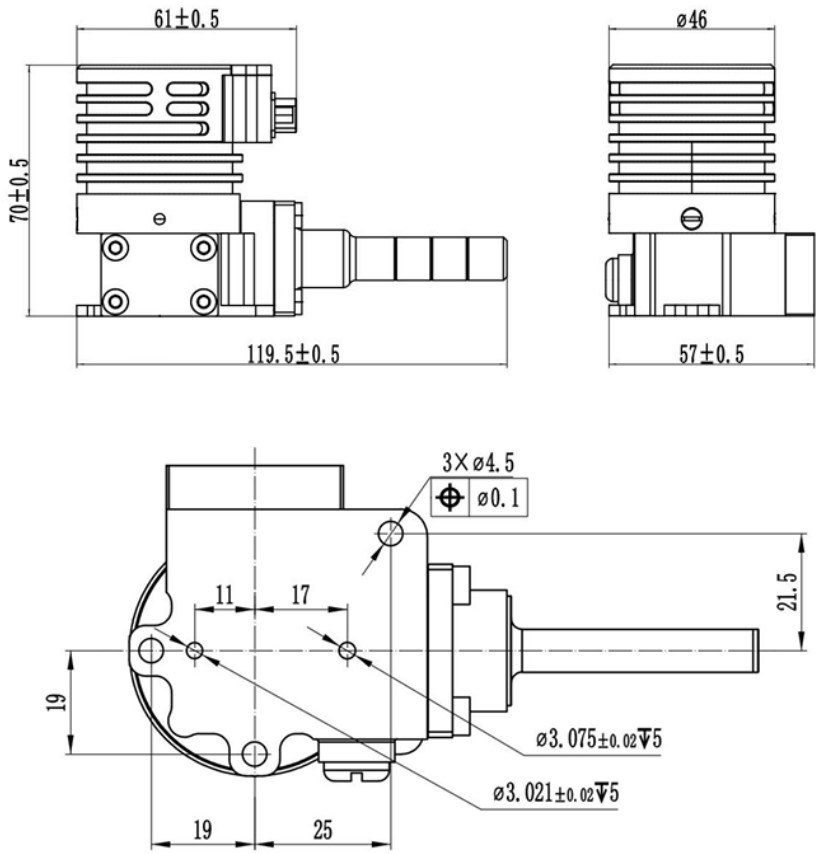

Figure 2. Outline, Mounting Interfaces, and Dimensions of BSI-05 Cooler

2.4. Mechanical Interface Requirements for Compatible Dewars

The interface of the dewar inner tube to be coupled with the cooler is illustrated in Figure 3.

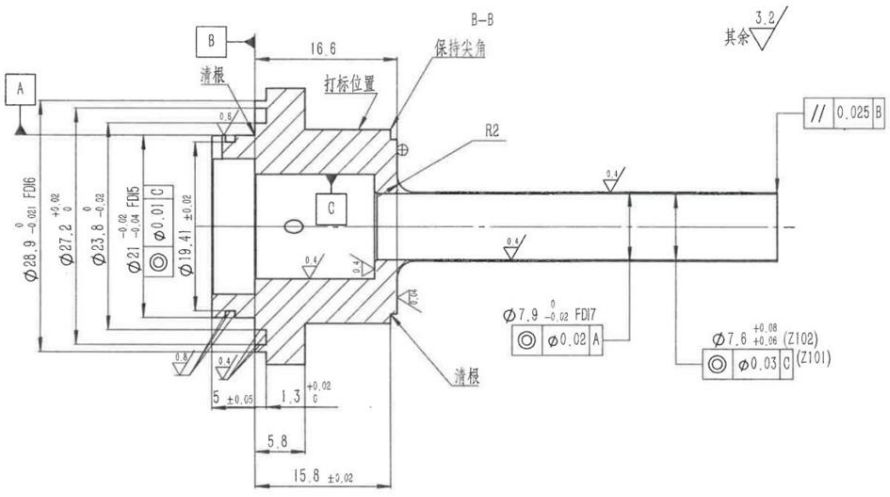

Figure 3. Dimensions of the Dewar Inner Tube Coupled with BSI-05 Cooler

2.5. Electrical Interface of the Cooler

The electrical schematic and interface of the cooler are illustrated in Figure 4. The electrical interface adopts a standard DB9 male connector. The layout and pinout definition of the connector's output terminals are also shown in Figure 4. The pin definitions for the cooler's electrical interface are listed in Table 1.

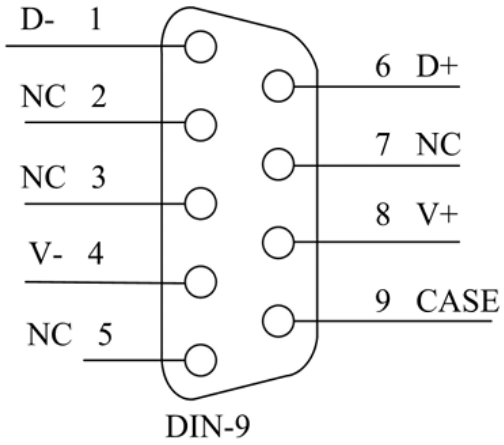

Figure 4. Schematic Diagram of the Electrical Principle and Interface of BSI-05 Cooler

Table 1. Pin Definitions of the Cooler Electrical Interface

PIN NUMBER	DEFINITION	PIN NUMBER	DEFINITION
1	Temperature Signal Negative (D-)	6	Temperature Signal Positive (D+)
2	NC (Do Not Use)	7	NC (Do Not Use)
3	NC (Do Not Use)	8	Power Supply Positive (V+)
4	Power Supply Negative (V-)	9	Case / Chassis Ground (CASE)
5	NC (Do Not Use)		

Pins 2, 3, 5, and 7 of the electrical interface are disabled; no external input signals shall be connected to them. Pin 9 (Case) must be connected to the main system's outer enclosure; please pay special attention to this during wiring.

The cooler circuit supports two operating modes: open-loop and closed-loop. However, the closed-loop mode is recommended. To operate in this mode, connect pin 1 and pin 6 of the cooler's electrical interface to the negative and positive terminals of the temperature sensing diode, respectively, before starting the cooler.

Unless otherwise specified, the required power supply for the cooler circuit is BSI-05D $12V_{DC}$±$1V_{DC}$ or BSI-05B $24V_{DC}$ ± $1V_{DC}$. The built-in drive control circuit provides a constant current output of 500 μA ± 25 μA (Pin 1 is negative, Pin 6 is positive) to serve as the bias current for the temperature sensor.

2.6. Weight

The weight of the cooler shall not exceed 450 g (excluding the coupled dewar inner tube and protective cover).

III. Main Performance and Technical Specifications

3.1. Technical Specifications

Net cooling capacity: ≥ 550mW (@+23°C±5°C, including the intrinsic heat load of the test dewar, with consideration given to the heat transfer temperature drop within the dewar);

Cool-down time: ≤ 5min (@+23°C±5°C, total thermal mass of 250J±20J @300K to 80K);

Input power: Under an ambient temperature of 23°C±5°C, the maximum input power consumption shall not exceed 14.4WDC, and the temperature control power consumption shall not exceed 6 WDC (@ 200mW @ 80K);

Leakage rate: ≤ 7.6×10^{-9} $Pa \cdot m^3/s$;

3.2. Environmental Adaptability

The cooler shall meet the following environmental adaptability tests:

Operating temperature range: -40°C to +70°C;

Storage temperature range: -55°C for 24 hours; +85°C for 48 hours;

Sinusoidal vibration: The cooler, in a non-powered state, shall pass the following vibration test.

Table 2. Sinusoidal vibration test for the cooler

WAVEFORM	FREQUENCY RANGE（HZ）	AMPLITUDE (MM) / ACCELERATION (M/S^2)	DURATION PER AXIS (MIN)	DIRECTION
Sine wave	10 ~ 58 58 ~ 2000	0.75 mm 100 m/s^2	10	X, Y, Z

Random vibration: The cooler, in a powered operating state, shall pass the following vibration test.

Table 3. Random vibration test for the cooler

DIRECTION	FREQUENCY RANGE（HZ）	ACCELERATION SPECTRAL DENSITY (G^2/HZ)	DURATION PER AXIS (MIN)
X, Y, Z	20 ~ 2000	0.1	60

Shock: The cooler, in a powered operating state, shall pass the following shock test.

Table 4. Shock test for the cooler

WAVEFORM	HALF-SINE WAVE		
Acceleration	100 m/s^2	40 m/s^2	25 m/s^2
Duration	6ms	18ms	6ms
Direction	Cooler X, Y, Z three axes, six directions		
Number of shocks	3 shocks per direction	3 shocks per direction	3 shocks per direction

IV. Packaging and Identification

4.1. Packaging

Upon passing product inspection, a charging seal protective cover shall be installed on the cold finger and charged with 10 bar high-purity helium gas.

During delivery, the product shall be placed in a dry, dust-proof, and shock-proof

packaging box. The box shall contain a Certificate of Conformity and an Operation and Maintenance Manual. The packing list is shown in Table 5.

Table 5. Packing List for Individual Cooler Unit

P/N	PRODUCT & ACCESSORIES	QTY	REMARKS
1	BSI-05 Cooler	1	
2	Charging Seal Protective Cover	1	
3	C-ring Seal	1	
4	O-ring Seal Φ19×1	1	
5	Plug Gasket	1	
6	Plug Pin	1	
7	Performance Test Report	1	
8	Operation and Maintenance Manual	1	If applicable

4.2. Identification

Product identification on the cooler shall include the product model, manufacturer's name or trademark, serial number, and date of manufacture.

V. Installation and Commissioning

The cooler must operate in conjunction with a detector dewar assembly. The coupling between the cooler and the detector dewar assembly shall be performed in a cleanroom environment provided by either the detector assembly manufacturer or the cooler manufacturer.

When leaving the factory, the protective sleeve installed on the cold finger is internally pressurized with low-pressure working fluid at 10 bar. Since this protective sleeve is not the actual dewar inner tube used during operation, it is strictly prohibited to power on the cooler before it is coupled with the detector dewar assembly or the dewar components shown in Figure 3, to prevent damage to the cold finger.

Note: When coupling and commissioning the cooler and the detector dewar assembly, proper electrostatic discharge (ESD) protection measures must be taken for the detector.

VI. Disassembly and Assembly

Except for removing the cold finger protective sleeve prior to use, disassembly of the cooler is strictly prohibited without written permission from the manufacturer.

VII. Operation

7.1. Thermal Interface of the Cooler

It is essential to ensure effective heat dissipation from the cooler. Users must provide adequate heat sinks or convective cooling to guarantee that the surface temperature of the cooler (compressor) does not exceed the ambient temperature by more than 15°C.

7.2. Drive Control Circuit of the Cooler

The cooler features a built-in drive control circuit, eliminating the need for external drive circuits. All performance indicator tests shall be conducted within an input voltage range of 12V±1V or 24V±1V.

The pins designated for temperature control operation in the cooler's electrical interface must be connected to the positive and negative terminals of the detector assembly's temperature sensor. The bias current required for the temperature sensor is provided by the cooler controller.

Upon leaving the factory, the temperature setpoint is calibrated to approximately 80 K, which is the optimal operating temperature for general infrared focal plane detectors.

Note: During the electrical connection of the cooler, ensure that the wiring complies with circuit specifications. Before making any electrical connections, please refer to the cooler's interface definition specifications.

VIII. Troubleshooting

Common fault phenomena, diagnostic methods, and troubleshooting procedures are listed in Table 6.

Table 6. Common Fault Phenomena and Troubleshooting

FAULT PHENOMENON	CAUSE ANALYSIS	DIAGNOSTIC METHOD
Prolonged cool-down time	Working fluid leakage in the cooler Insufficient working fluid	Cool-down time verification test
Failure to regulate temperature	Working fluid leakage in the cooler or failure of the controller's temperature regulation function	Cool-down time verification test; check if the operating current fluctuates
Abnormal noise from the cooler	Mechanical component damage within the cooler	Check if the operating current fluctuates; observe if operational noise increases

IX. Maintenance

9.1. Routine Maintenance

When not coupled with a detector dewar assembly and stored under specified environmental conditions, the cooler requires no specialized maintenance.

9.2. Working Fluid Replenishment

After being coupled with the detector assembly, it is recommended to replenish the working fluid gas every four years.

9.3. Disassembly of the Cooler Assembly

Do not disassemble or reassemble the cooler without full knowledge of the manufacturing process. All repair operations for the cooler must be returned to the factory.

Note: Unless equipped with dedicated charging equipment, do not open the helium charging port arbitrarily to prevent leakage of the working fluid.

X. Transportation and Storage

Please observe the following precautions during transportation and storage:

- Products shall be packed in sturdy boxes and transported according to specified methods;
- Protect from direct exposure to rain, snow, and mechanical collisions during transit;
- Store using reliable, specialized packaging;
- Maintain a storage ambient temperature of -10°C to 40°C, relative humidity not exceeding 80%, in a dry, well-ventilated area free from corrosive gases.

Note: Avoid exposing the cooler to strong magnetic fields during transportation and storage.

XI. Disposal

The disposal of marketable products shall comply with relevant confidentiality and safety regulations, or they shall be returned to the factory for disposal.

XII. Warnings

- When coupling and commissioning the cooler and the detector dewar assembly, proper electrostatic discharge (ESD) protection measures must be taken for the detector.
- During the electrical connection of the cooler, ensure that the wiring complies with circuit specifications. Before making any electrical connections, please refer to the cooler's interface definition specifications.
- Unless equipped with dedicated charging equipment, do not open the helium charging port arbitrarily to prevent leakage of the working fluid.
- Avoid exposing the cooler to strong magnetic fields during transportation and storage.