Johnsen ULTRAVAC INC.

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BB-18 Black Body System - Technical Description

- Available for use as a fixed cold target at 80°K or variable target, at 180°K - 360°K.
- The possibility to control to +/- 0.1°K is inherent in the mechanical and thermodynamic design ultimate control quality will be determined by the availability of stable and accurate temperature sensors and controllers.
- Guaranteed active area 16" square – other sizes on request.

1	Design Principles

A. Main body

The main body will be copper with approximate mass of 120 Kg so that evaporation of a single pulse of liquid nitrogen will change the temperature no more than 0.1°K. An auto tuning on/off dedicated PID temperature controller will release a pulse of liquid Nitrogen, up to 10 times/min.

B. Liquid Nitrogen Evaporation

The liquid nitrogen evaporation system comprises of a proprietary nitrogen cooling system.

C. High Capacity Liquid Nitrogen Cold Plate

To achieve 80°K in a reasonable time from room temperature a second cold plate with 3 times the surface area and 100 cc capacities LN is added between the controls cold plate and heater plate. Cool down from 300°K to 80°K can be achieved in approximately 2.5-3 hours.

The control system will automatically enable the feed solenoid to this plate if the plate temperature is a programmable number of degrees above the set point.

D. Heater System

The heater system consists of multiple quarts tube insulators with Nichrome wire heater in the tube. During operation the heater is limited to 100 Watts to provide stability.

If the process temperature is a programmable number of degrees below target temp the 500 Watts mode is enabled. Heat up time is approximately 5 hours.

E. Mechanical Lid for Aperture

The system is supplied with a polished 304 SS sheet metal body.
A hinged lid is provided for this system. A manual mechanical handle is installed on the Johnsen supplied pass-through flange which via a Bellows connection and SS cable can open or close the lid. Only 1 handle is supplied to open or close, this will conserve nitrogen if the system is idle at low temperature and allow for rapid set point changes with the lid closed.

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F. Wiring System

Wiring will exit the vacuum chamber via a single JUV supplied flange. Three multi-wire connectors are provided on each side of this flange. System is hard wired from the connector plug to the controllers. This flange also contains the liquid N_2 supply and gas return using Swagelock connectors and liquid N_2 pass throughs.

Internal wiring will be standard ultra high vacuum bare wire with each wire separated by custom ceramic discs mounted on a thin wall tube to make rigid 1 meter sections. Each section has a 45° flexible joint with ceramic bead insulation – ie. 5-90cm sections with 6 flexible joints. A multi-wire connector is provided at the black body. Ultra high vacuum wire compatible wire at no extra cost.

G. Liquid N_2 Reservoir

A standard 4L liquid N_2 reservoir will be supplied. This system is equipped with a non-contact level sensor and controller. This system will be enclosed in a small vacuum vessel and mounted on a stand pipe on the wiring mounting flange. Liquid N_2 and gas return pipes extend in the stand pipe from the N_2 reservoir into the vacuum test chamber to connect to the tubing to the black bodies.

Liquid N_2 rated solenoid valves with extended stems activate the N_2 supply and high and low flow to each black body. The high and low flow solenoids are custom calibrated with outlet flow restrictions to supply the required flow rate. They are rated at 5,000,000 cycles.

The reservoir is equipped with gas relief valve set at 0.1 PSIA higher than the highest barometer pressure common. This assures a common non-variable boiling point.

H. Black Body Storage Container

- A storage and shipping container is available as an option
- Each container is as Aluminium tube with reinforced flat ends O ring seal lid closure and 4-3” Casters – 36” DIA- 4’long.
- Each system is equipped with 0-5 PSIG pressure regulator 1 PSI relief valve and 4L 100 PSI travel bottle and connector to Customer’s supplied dry N_2 bottle.
- A separate 20’ Aluminium tube is provided for each wiring bundle. This is equipped with regulator; relief valve and travel bottle the same as the black body storage vessel.

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I. Black Body Mechanical Details

➢ Details are shown in the exploded view and assembly drawings.

Features

- Guaranteed active area 16" square.
- Target plates 50 cm x 50 cm.
- Opening 18" square aperture on can 36" with depth of 36" ie. Ratio 2:1
- 3cm fins 1 cm apart on Blackbody surface to capture radiation with a minimum of 4 reflections to assure 99% emissivity.

1) Aeroglaze 302 Spacular paint (high gloss urethane).

   Emissivity 75-90%-depending on wavelength – This coating can be cleaned and replaced.

2) 4 Bounce absorbance
   - ➢ At 75% = 98.81% Aeroglaze paint has absorbancy and emissivity
   - ➢ At 90% = 99.952% of 0.90 - 0.96 depending on frequency

3) Cavity is equipped with fins to capture stray radiation. Fins are black on top and gold plated on bottom.

4) Surface of finned plate is V grooved at 60 degrees to trap incident radiation.

5) 3cm fins are V grooved to create a non-constant honeycomb. V's are6 mm high 45° stagger 2mm between adjacent plates cells are 1.6mm long. This helps trap radiation with horizontal angles since fins are vertical.

6) Heater: Nichrome wire with copper cold pins to join segments. Wires are inserted into 1/8" DIA Quartz tubes. Maximum power 500 Watts.

7) Cold Plates: A two stage system the high cool plate accepted 100cc N_2 to fill per cycle and cools systems 1°K with 120 Kg total plate weight.

8) Maximum cooling capacity of fast cool plate is calculated at 462 Watts/Hr in the 80-90°K range. At higher temperature this cooling capacity increases rapidly. The slow cool plate cooling power is 144 BTU/Hr. The aperture lid can be closed during cool down.

   As temperature rises the cold plate capacity can increase by a factor of 10.

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1. Design Principles *(continued…)*

This provides a cool down of less than 2.5-3 hours.

500 Watts = 1706 BTU/Hr. will reheat to 300°K in about 5 hours.

9) An aluminum base plate is provided for mounting the instrument on a horizontal or vertical support plate

System must be level +/- 1° and may be tilted up or down 30°.

A horizontal level will be installed.

J. Radiometer

A Radiometer will be supplied for non contact measurement of black body surface temperature, emissivity measurement is available as an extra cost option.

2. Calculations:

A. Heat Capacity of System 80°K.

Heat of vaporization N_2
- 85.28 BTU/Lb.
- 55.1 Watt Hrs./Kg.

Black body
- Estimated weight 120 Kg. (264.5 Lb).

Heat capacity copper
- 80°K 0.05 BTU/Lb °F
- 300°K 0.09 BTU/Lb °F

B. Calculations

The slow liquid N_2 distribution plate is designed for a capacity of maximum 10cc hence plate temperature will drop less than 0.1°K per liquid nitrogen injection from the on/off PID control.

Since this liquid is distributed evenly the temperature distribution in the plate will be less than 0.1°K by design as long as heat input to the black body surface is distributed reasonably evenly.

Heat transfer from boiling liquid N_2 to copper is expected to be greater than 40 BTU/Hr. ft^2 degree F.

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2. Calculations (*continued…*)

C. Heat Input

With a black body surface which is larger than the aperture radiating at the black body at 30°K.

Maximum heat input would be $P = \varrho AT4$

$\varrho = 5.67 \times 10^{-8} \times 300^4$

$= 459.27$ Watts/m^2

For our 18" exposed area

$= 0.324$ m^2 area

Max heat input =

0.324 * 459.20 = 148.8 Watts

148.8 * 3.412 = 502 BTU

Hence controlled cooling (144 BTU/Hr.) will only remove 1/3 of the required heat load but it is very unlikely for the surface facing the black body. Using reflective metal surfaces and white or light gray paints – emissivity of the experimental package should always be less than 0.3. It is assumed that the temperature of the test package is equal to or less than 300°K.

D. Cool Down Time

System weight 264.5 Kg

Heat capacity Avg. 80-300°K = 0.075 BTU/Lb. °F

Total heat removal required 300-80°K = 220 * 1.8 * 0.075 * 264.5

= 7856 BTU

Heat transfer will increase linearly with plate temperature until a max boil condition occurs with the limit at a full vapor surface between metal and liquid.

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2. Calculations (*continued…*)

E. Hot Plate and Finns

- The 3 cm long 1.4 mm thick fins are glued to the saw tooth pattern on the heater plate.

  Glue area = 1 cm wide * 50 cm long * 50 fins

  = 1 * 50* 50 = 2500 cm^2

  Glue is less than 0.001" thick. Thermal conductivity of hydrocarbon plastic is generally 1-1.5 BTU/Hr. ft^2 °F inch

  For fins = $\frac{2500 * 1.0}{2.84 * 2.54 * 194} * \frac{1}{0.001}$

  = 2777.8 BTU/Hr. TT^2 °F

  Our maximum heat flux is 144 BTU

  Heat flux in glue joint $\frac{144}{2.778}$ = 51.8 BTU/Hr. ft2 °F

  $\Delta T = \frac{51.8}{2777.8} * 1.8 = 0.034°K$

  This is not detectable.

F. Heater

- The heater provides 500 Watts max, giving a heat up time 80-300°K.

  For heating 80-300°K = 7856 BTU = 2302 Watt/Hrs. @ 500 Watts = 4.6 Hrs.

  Degrees K per minute $\frac{220}{4.6 * 60}$ = 0.79°K/min.

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3. System Performance

Performance

a) Absolute temperature sensor accuracy.

b) Minimum black body surface temperature uniformity +/- 0.5°K.

c) Expected black body surface temperature uniformity (inherent in design) +/- 0.1°K.

d) The BB-18 is programmable as a variable 78 – 100 °K cold target or variable 180 - 360°K.

e) Cool down time ≈ 3 hours 300 - 80°K with lid closed.

f) Heat up time ≈ 5 hours

g) Maximum cold target energy absorption 300°K radiating surface with 30% emissivity.

Secondary cooling must be activated at higher emissivity and temperature variation plus now uniformity may reach 1 as DEG K.

h) All components have 10 year life except PC's, printer, and optional UPS – 5 years.

i) Emissivity will be over 99.9 % at all required wavelengths.

TXR radiometer will provide required non contact surface temperature measurement. Calibration to NIST traceable standard.