

Basic Lunar Environment Simulator System (BLESS™)

Introduction

Basic Lunar Environment Simulator System (BLESS™) is designed for pumping out using a single turbo pump, has one door for servicing and installing and replacing samples and a platform for fixing samples, heating and cooling them. This design allows you to increase the size of the vacuum chamber, install a second door on it, additional testing equipment and an additional turbopump. The BLESS™ system is designed to use a standard *lunar soil/lunar dust simulant*, JSC-1A_F or similar.

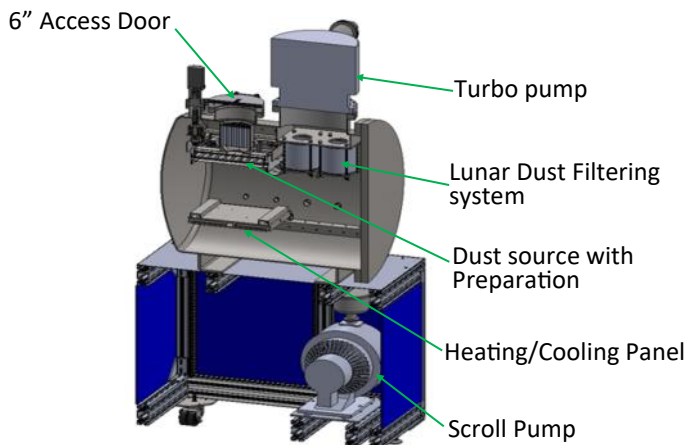
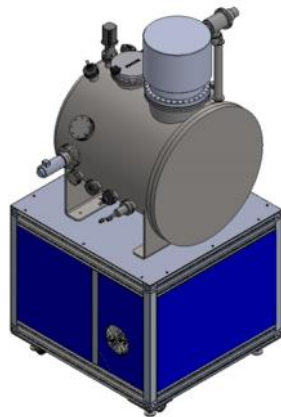


Figure 1: General view of BLESS™ System

Design of BLESS™ System

The design of BLESS™ shown in Figure 1 consists of a vacuum chamber that is pumped out by two vacuum pumps (one turbo pump and one scroll pump). Inside the vacuum chamber are:

- Filtration system that protects the pumps from dust ingress;

Table 1. Technical specifications of BLESS™ System

BLESS™ Parameter	Specification
BLESS™ Dimensions (length x width x height)	4' x 3' x 5'
Pressure in the vacuum chamber (without dust)	5×10^{-7} Torr
Time to reach the working vacuum level	1 hour
Minimum room size for BLESS™	8' x 10' (80sq.ft.)
Electrical Power	One phase, 120V 30A, or 220V 15A
Dimensions of the surface covered with dust	12" x 12"
Uptime before maintenance	40-60 hours

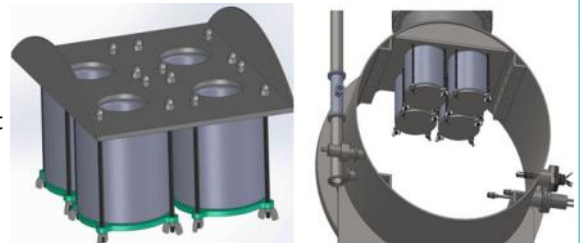
- Dust source combined with a dust preparation device;
- Two VUV lams for charging dust using ultraviolet light;
- Heating/Cooling platform for mounting and thermal treatment of samples; and
- Or some other device chosen by the Customer.

Technical specifications of the BLESS™ system are given in the Table 1.

Design of Lunar Dust Filtering System

The filtering system of the pumped-out atmosphere from dust is an extremely important component of any simulator of the lunar environment. The filters used should not severely cut the pumping speed and be able to work for a long time without replacement. Filters should be easily removable and have a reliable dustproof seal. Four 5-micron Polyester elements are included. The holder of these four filters is tightly welded to the vacuum chamber.

Figure 2: Design of Lunar Dust Filtering System



Design of Dust Source

The dust source consists of two units: a dust preparation unit and the dust sprinkling mechanism. The main essence of this difference lies in the absence of a separate chamber for preparing the dust for work (see Figure 3). This was achieved using a special cellular dust cleaning system. These technical problems should primarily include the following:

- An independent dust cleaning system requires the creation of devices for delivering dust to the source. In this case, a large number of mechanical components are required, which work extremely poorly in a dust atmosphere and require complex protection from dust ingress.

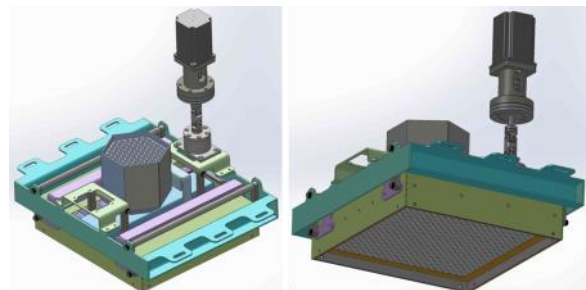


Figure 3: Design of Lunar Dust Filtering System

- The application of a gate valve between two chambers (dust preparation and testing chambers) sharply reduces the service life. This is due to the ingress of dust particles on the working surface of the gate valve and, as a result, its rapid failure.
- Difficulty in determining the amount of dust entering the dust sprinkling mechanism, and as a result, overloading or under loading of its hopper.
- The need for an independent pumping system for the dust preparation chamber. This system must also have a sophisticated filter system to prevent dust from entering the pumps.

Figure 4 shows the appearance and section of cellular dust cleaning system.

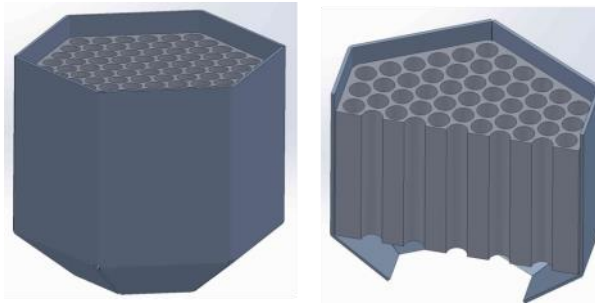


Figure 4: Cellular dust cleaning system

Dust sprinkling mechanism is designed so that dust does not spill into the chamber when this mechanism switched off. Then the upper door is closed and the chamber is pumped out to a pressure of $\sim 10^{-5}$ Torr. When this pressure is reached, the cellular dust cleaning system is heated up at a temperature of 200°C for several hours. The criterion for the completion of dust cleaning is the pressure stability in the vacuum chamber (not worse than 10^{-5} Torr) when the cellular dust cleaning system is heated to $+200^{\circ}\text{C}$. After successful preparation of the dust and the cellular dust cleaning system driven by a stepper motor starts to spill the dust on the top diffuser of the two-mesh system (see Figure 5). When the cellular dust cleaning system is operated, the top layer of the mesh becomes covered with a uniform layer of dust, which is created due to a special design of an internal slotted plate.

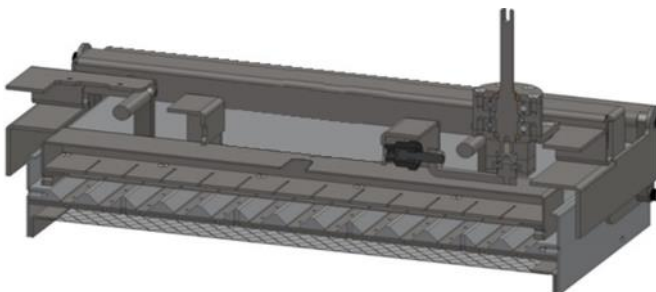


Figure 5: The cross-section of dust sieving sub-system of the dust sprinkling mechanism

At that time, the mesh starts to vibrate at pre-defined frequencies and amplitudes. Effectively, the dust cloud is formed, whose uniformity can be achieved by a proper selection of the vibration parameters for both mesh diffusers. Moreover, changing the vibration parameters (frequency, amplitude) can be used to modify and adjust the shape of the dust cloud to the conditions of the experiment. The dust sprinkling mechanism allows to uniformly covering an area of $12'' \times 12''$ with dust.

Heating/Cooling Platform

The Heating/Cooling Platform is an ultra-high vacuum set-up installed inside the simulator chamber and designated for sample holding and fast sample exchange. Differences in technical specifications of the platforms can be seen from Table 2.

Table 2: Specifications of Heating/Cooling Platforms

Parameter	Stainless Steel Platform	Aluminum Alloy Platform
Temperature range, $^{\circ}\text{C}$	$150 \leq T \leq 450$	$150 \leq T \leq 200$
Temperature rate, $^{\circ}\text{C}/\text{min}$	3-4	6-10
Dimensions used for the samples placing, inch	16x12	12x12
Temperature control accuracy	± 1	± 3
Electrical Power, kW	1.5	1.0
Weight, kg	23	12

Vacuum Tribometer

SimulTek is able to offer a unique, vacuum- and dust-compatible tribometer, which allows testing the samples at the conditions as close as possible to those of the lunar planetary environment. The installation of the tribometer in the of BLESS™ vacuum chamber is shown in Figure 6.

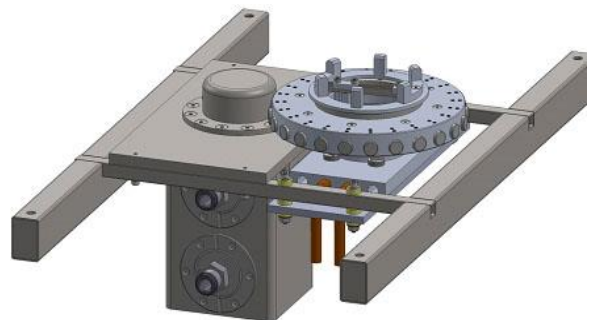


Figure 6: Design view of the vacuum tribometer

Basic Lunar Environment Simulator System (BLESS™)

In addition to the functions of a conventional tribometer, our design allows to provide testing under the following conditions and Eight main parameters in Table 3:

- High vacuum conditions (up to 10^{-8} Torr);
- Wide temperature range ($-180^{\circ}\text{C} \leq T \leq +250^{\circ}\text{C}$); and
- Constant, controlled, flow of electrically charged dust simulant particles.

Table 3: Eight main parameters for Vacuum Dust Protected Temperature Tribometer

Main Parameters	SimulTek Tribometer
Vacuum Rate	10^{-8} mbar
Friction Force Range	0.01-15N
Rotating Speed Range	0.1-800rpm
Radius	0.1mm-40mm
Maximum Torque	850mN.m
Wear Depth	Up to 2.5mm
Temperature Range	$-90^{\circ}\text{C} \leq T \leq 150^{\circ}\text{C}$
Dust protection Rate	100%

The design of tribometer is consists of two main parts as shown in Figure 7:

- Rotating head of tribometer mounted on a plate for heating and cooling the sample, and
- Rotary driver used to rotate a rotating head.

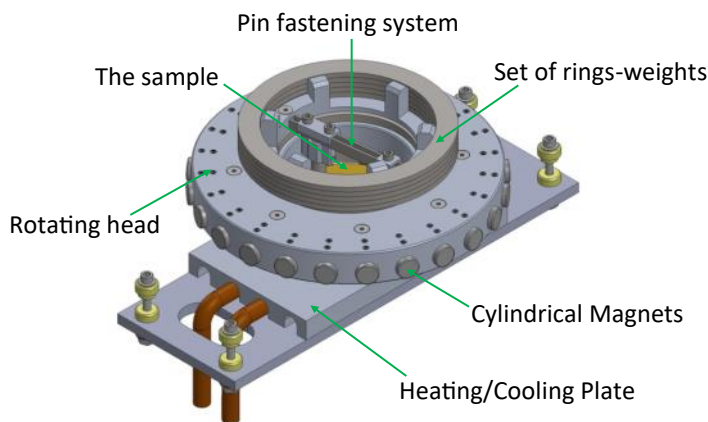


Figure 7: Rotating head of tribometer with a plate for heating and cooling the sample

A distinctive feature of this tribometer is that it allows installing the sample on the heating/cooling panel and ensuring good thermal contact between them, and also automatically cleaning the sample surface from excess simulant dust. Liquid nitrogen is supplied through cryogenic tubing by opening an automated cryo-valve. This allows temperature to be sustained with an accuracy of $\pm 3^{\circ}\text{C}$.

Sample Holder with Piezoelectric Cleaning for Dust Mitigation

A special Sample Holder allows cleaning their surfaces using high-frequency (kHz) vibrations. A piezoelectric element is used to create these vibrations. The frame is a dust-proof design and reliably protects the piezo transducer from dust. The ends of the frame are also closed to prevent dust from entering. On top of the frame is a corner preventing dust from entering the space between the frame and the sample holder. The design and general view of this Sample Holder is shown in Figure 8. This piezoelectric transducer used in this set-up has the following characteristics:

- Power -----100W
- Resonant frequency -----28 kHz
- Vibration amplitude -----0.8 mm

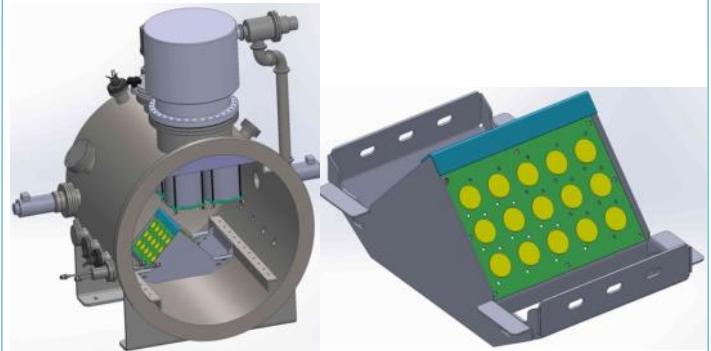


Figure 8: A Sample Holder with piezoelectric sample cleaning

Summary

The BLESS™ system is a new generation lunar environment simulator offered by SimulTek. This conclusion can be made thanks to new solutions that have not yet been used on other models of the lunar environment simulators. These solutions include primarily the following:

- Lack of an additional chamber for dust preparation and a gate valve between it and the main vacuum chamber.
- Application of a new filtration system to protect vacuum pumps from dust ingress. This system is compact, fully dustproof and easy to service.
- The ability to use a unique vacuum tribometer that has no analogues in the world.
- Use of a self-cleaning sample holder based on the use of a piezoelectric transducer.

This allowed to create an inexpensive, compact, and reliable system, which is the BLESS™.