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# Apollo 11 Moon Rocks Revisited

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Life Member/Fellow ASHRAE

**O**n July 20, 1969, astronauts Neil Armstrong and Edwin (Buzz) Aldrin Jr. landed the Apollo 11 lunar module Eagle on the Moon's Sea of Tranquility. Hours later Armstrong descended a ladder and became the first human to walk on the lunar surface. Astronaut Michael Collins remained in lunar orbit aboard the command ship, Columbia, during the balance of the mission.

Among the least publicized aspects of the Apollo 11 mission were the elaborate simultaneous preparations underway at laboratories around the world to analyze the first lunar samples to be returned to earth. Lunar sample studies have inspired the development of new methods for chemical and isotopic analysis and have honed the skills of two professional generations of scientists and a third generation is undergoing training.

Lunar (moon rock) samples were collected by the astronauts using tongs, scoops, a hammer and core tubes as they traversed with EVAs (extraterrestrial vehicular activities) in an area approximately 100 m (330 ft) from the landing site. The combined 21 kg (46 lb) lunar samples then were placed in vacuum-type containers by the astronauts. The samples were destined for extensive scientific investigations upon their return to Earth, to determine their composition, origin, etc., and to ascertain whether or not life then existed or had ever existed there.

The Apollo 11 mission required not only the successful retrieval of the lunar rocks, but also the ability to examine them in a thoroughly clean environment to settle many perplexing questions, such as what were the early conditions that may have affected life on Earth.

As last minute preparations for the Apollo 11 mission were underway, our M/E/P firm was busily immersed in the final punch list checkout of critical mechanical systems then installed at the Geology Clean Laboratory<sup>1</sup> constructed at the University of California, Santa Barbara, (UCSB) located in Goleta, Calif.

## Geology Clean Laboratory

About one year prior to the scheduled Apollo 11 lift-off, our firm was retained by the UCSB, to design a state-of-the-art laboratory facility (i.e., assigned to the UCSB Geology Department) for analysis of some of the lunar samples. The Geology Clean Laboratory was designed as a total facility for researching the structure of pre-Paleozoic life forms and the parallel examination of extraterrestrial materials. It was thought that if samples returned from other parts of the solar system contained evidence of vital processes, they would probably resemble life forms known to have existed on earth between 0.7 and 3 billion years ago, as evidenced by then available pre-Paleozoic (earth) rocks.

Ultramicroscopic studies required the construction of a Class 100 laminar downflow clean area and a Class 10,000 clean area for the chemical and mechanical preparation laboratory and the scanning and transmission electron microscope rooms. Remaining areas included a dirty preparation laboratory, darkroom, faculty and graduate offices, study rooms, etc. The scanning and high-resolution transmission electron microscopes and related equipment required the reduction of airborne contamination to be an absolute minimum. Following several meetings with university engineering and operating personnel, project design and operating criteria indicated in *Table 1* were established.

## Laminar Downflow Areas

The Class 100 clean areas, comprising a laminar downflow laboratory and airlock are identified in *Figure 1*, respectively as 1111E and 1111D. The areas are served by both AHU-1 and AC-1 operating cooperatively as shown in section and plan views respectively in *Figures 2* and *3*. Notice that in *Figure 3* that recirculating air from the sealed return air plenum that was formed below the perforated floor panels splits into two separate airstreams upon reaching the roof. Thirty percent of this air is mixed with outside air (i.e., required for ventilation, pressurization, and fume hood makeup) prior to being drawn through AC-1. The balance of the airflow bypasses AC-1 as shown.

Subsequently, both airstreams were combined prior to passing through a high efficiency filter bank within AHU-1, which is then discharged into the ceiling supply air plenum and from there, directly through HEPA filters as shown in *Figure 2*. Strategically placed manual volume dampers located at AHU-

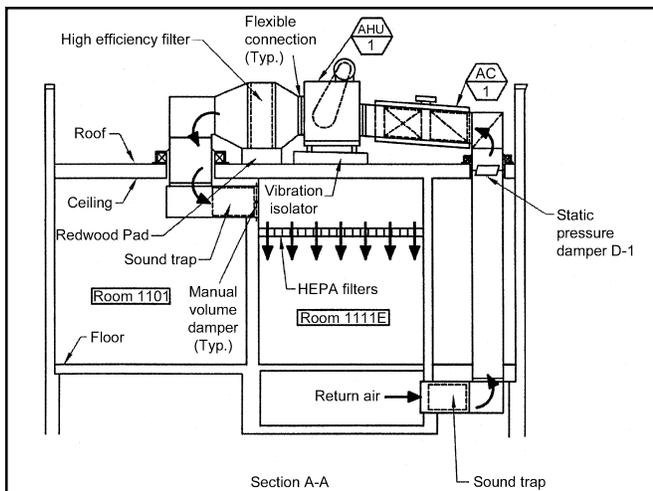
## About the Author

**Milton Meckler, P.E.**, is president of the Meckler Engineers Group, Encino, Calif.

Location	Temperature, °F		Relative Humidity, %	Pressure, in. w.g. <sup>3</sup>	Airflow, fpm	Air Changes per hr.
	Dry Bulb	Wet Bulb				
Outdoor: Summer Winter	87 30	67 21	35 10	— —	— —	— —
Class 100 areas <sup>2</sup>	72±2	60	50±5	+0.20	90+15, -10	—
Class 10,000 areas <sup>2</sup>	72±2.5	60.5	50 max	+0.10	—	30
All other areas <sup>3</sup>	75	61	50 max	+0.03	—	20

1. With respect to predetermined ambient at facility reference point.
2. As defined by Federal Standard 209A, August 10, 1966.
3. Conditioned areas only.

**Table 1: Laboratory design and operating criteria.**



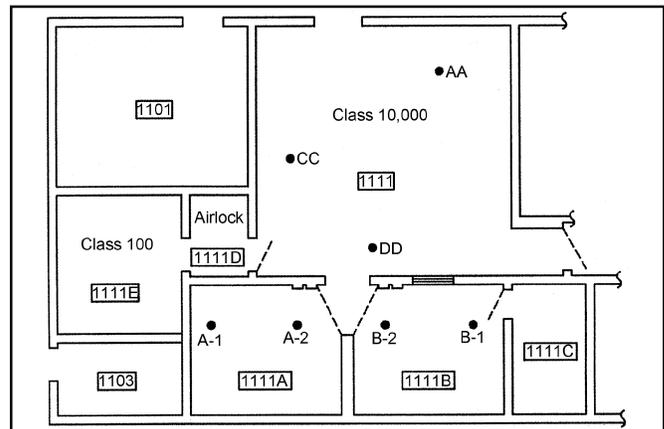
**Figure 2: Section view illustrates AHU-1 and AC-1.**

1 discharge meter air through the bypass ductwork to maintain the required airflow.

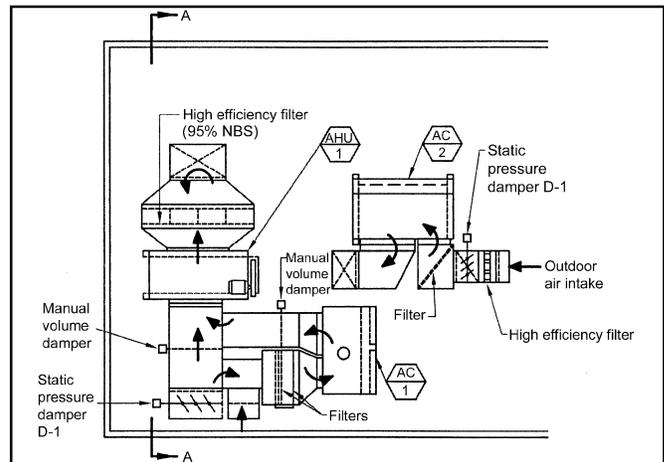
AC-1 was actuated by a three-stage temperature controller located in the return air plenum and provided either supplementary heating through two-stage, high low-fire control of gas solenoid valves or cooling through the cycling of the unit's compressor. A field-installed hot gas bypass capacity unloader control was added to AC-1 to minimize short cycling. Interlocked static pressure dampers D-1 (shown in Figures 2 and 3) also were placed in the return air ductwork leading to AC-1 and AC-2 to maintain minimum required space pressure differentials during occupant passage through the vestibule airlock.

With approximately 30% of the total recirculated air passing through AC-1 and with the flywheel effect of the larger recirculating bypass airstream, etc., space temperature swings are minimized, thus permitting use of a less costly two-position control mode. Humidity is maintained by means of an electrically heated pan-type humidifier.

The floor consisted of nominal 2 ft by 2 ft (0.6 m by 0.6 m) panels arranged in a modular grid pattern supported on pedestals. Two types of floor panels were used. One had individually operable (from above) volume dampers and retainer baskets



**Figure 1: Location of laboratory areas and sampling sites for certification tests.**



**Figure 3: Plan view shows Class 100 and Class 10,000 roof areas.**

below, in which variable density pre-filters were placed. The other had blank panels placed below floor-mounted equipment such as fume hoods. The HEPA filter ceiling<sup>2</sup> consisted of three basic sizes: 30 in. by 12 in. (0.76 m by 0.30 m), 36 in. by 48 in. (0.9 m by 1.2 m), and 24 in. by 24 in. (0.6 m by 0.6 m), all arranged in a grid pattern. Support points in the wood framed roof structure were dimensionally coordinated with the prefabricated ceiling grid to mate with turnbuckle supports. Wall-mounted lighting fixtures with reflector assemblies as shown were used in lieu of recessed ceiling troffers to minimize disturbances to downstream laminar airflow patterns.<sup>3</sup>

For example, if nominal 2 ft by 4 ft (0.6 m by 1.2 m) lighting troffers had been used with the 8 ft (2.4 m) floor-to-ceiling height, recovery of a laminar flow pattern would have required a depth approximately three times the intercepted fixture width (or down to a point approximately 24 in. (0.6 m) above the floor), essentially destroying its integrity. Use of wall-mounted fixtures required only a 6 in. (15 cm) reflector projection into the laminar airstream. This resulted in the complete recovery of the laminar flow pattern within 9 in. (23 cm) below the fixture reflector, (or approximately 54 in. (1.4 m) above the finished floor), as confirmed by subsequent measurements.

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Room 1111D functions primarily as a laminar flow airlock and gowning area. This permitted personnel movement with a minimum of constraint from adjacent Class 10,000 space while maintaining the integrity of Room 1111E by positive pressurization (+0.10 in. wg [25 kPa]) and accompanying flushing action and filtration of re-circulated air.

### **Class 10,000 Areas**

The Class 10,000 area, identified collectively as Rooms 1111, 1111A and 1111B in *Figure 1*, include the chemical and mechanical preparation laboratory and the two electron microscope rooms described earlier. All of these rooms were provided with perforated, high capacity, minimal aspirating type ceiling diffusers having relatively low outlet velocities (e.g., 200 fpm to 250 fpm [1 m/s to 1.3 m/s]). Air returns were placed low, and with 30 air changes per hour, a modified air piston effect was achieved.

AC-2, which served the Class 10,000 area, was controlled in a manner similar to that described earlier for AC-1, except that a three-stage, two-position thermostat was used in lieu of a return plenum stat. As shown in *Figure 3*, outside air for ventilation, pressurization, and fume hood makeup was drawn through high efficiency filters, mixed with return air, and then passed through a medium efficiency filter prior to entering AC-2.

Remaining laboratory areas of the structure, such as the dirty preparation laboratory, offices, study rooms, corridor, etc., were

served by standard package air-conditioning units (not shown) that were interconnected with conventional ceiling-mounted (i.e., aspirating type) supply diffusers and return air registers. Fume hoods, miscellaneous exhaust fans, and packaged air-conditioning unit fans were electrically interlocked to run continuously. All of the critical environmental control systems were monitored by means of a central control panel containing associated instrumentation, gages, etc.

### **Testing For Microorganisms**

It was necessary to develop special test procedures to validate the reduction in the concentration of airborne viable organisms and to certify the Class 100 and 10,000 areas, for compliance with Federal Standard 209A. The microbiological requirement was that the maximum number of viable organisms could not exceed 2 per cubic foot of air based on the arithmetic average of a minimum of nine test samples taken on not less than three separate days. Equipment used in testing and/or monitoring Class 100 and 10,000 areas included: a particle counter, a sensitive hot wire anemometer (calibrated at each use); a velometer (calibrated at each use); a smoke and dust photometer (calibrated at each use); a smoke generator; and a sampler (calibrated at 28.3 liters of air per minute [or 1 cfm]).

Perhaps the most interesting phase of the testing involved the development of procedures for the biological certification

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tests. It soon became apparent that if a distinction was to be made between bacterial and mycological (fungi) organisms, a more selective nutrient might be required for the latter. While it was felt that most fungi would thrive on the all-purpose medium trypticase soy agar, planned for incubation of bacteria, it was thought advisable to also use an additional medium particularly suited to the growth of fungi, which was sabourauds agar.

The procedure involved using a sampler adjusted to a normalized flow rate of 1 cfm for the series of 12 samples taken in Rooms 1111I and 1111F. Each of these samples required six petri dishes, requiring a total of 72 agar plates. The sampler employed was found to be particularly useful in areas of low contamination. It was a cascade type, handling six plates per load, and had a succession of perforated discs between petri plates. The perforations decreased in size so that the smallest particles tended to be concentrated in the bottom two plates. Each sample was taken for a period of 10 minutes, giving the equivalent of 10 ft<sup>3</sup> (0.28 m<sup>3</sup>) of air intake per sample.

In addition, eight trypticase soy agar plates and eight sabouraud agar plates were exposed with the lids removed for one-hour periods at various points around the room. Bacterial cultures were incubated at 37.5°C (99.5°F) for a period of not less than 72 hours and mycological cultures were incubated at 30°C (86°F) for not less than 10 days. Counts for the total number of organisms per plate were made at the end of each incubation period. In accordance with Federal Standard. 209A, all HEPA filters were maintained in operation for at least 15 minutes before entering the area to test. In addition, one extra set of trypticase soy agar plates was exposed and one extra sampling run made immediately after entry into 1111D. This sample was taken to demonstrate the effectiveness of clean room entry precautions, including dressing.

Before commencing these tests, each sampler was cleaned and thoroughly decontaminated, then placed in a sterile four-ply plastic bag. Similarly, other equipment, including flow meter and stand, timing clock, and extension cord, etc. were wiped with alcohol swabs and then bagged in sterile plastic in sets of six as they were to be used. The small bags then were packed in a large four-ply sterile plastic bag, which also was sealed. Sterile laboratory coats, masks, gloves and caps were provided for each day's work. All of these were packed in a similar large plastic bag.

At the entrance to Room 1111D, the exteriors of these bags were liberally swabbed with alcohol and then set inside the Class 100 room without having the tester step in. Sterile paper towels were laid on the floor outside the room. The tester then removed and bagged his street shoes, pulled on sterile boot socks, and stepped from the sterile paper towels into the room.

Once inside 1111D, the tester opened the large plastic bags and put on protective clothing, including heavy plastic sterile bags over the sterile boot socks, secured well up on the operator's legs. After dressing, the preliminary sampling was made to check on the adequacy of entry and these precautions, and to determine the effect on microorganism contamination of opening

Room No.	Average particle count per ft <sup>3</sup> air sample			Average pressure in. w.g.	Temperature °F	Humidity gr per lb dry air	Average Velocity	
	Station	5.0 micron	0.5 micron				At ceiling inlet	Near table-top
1111	AA	4835	17	0.11	—	—	—	—
1111	CC	5300	33	0.11	—	—	—	—
1111	DD	4755	23	0.11	—	—	—	—
1111A	A-1, A-2	6620	33	0.11	—	—	—	—
1111B	B-1, B-2	5280	17	0.11	—	—	—	—
1111D	—	0	0	0.2	72	41	—	—
1111E	—	0	0	0.2	72	41	105	125

Table 2: Summary of test results.

the door to 1111D three times to place equipment and supplies inside and a fourth time for the tester to enter.

Preliminary samples taken for this purpose showed a very low increase over the average for the regular samples taken subsequently, thus demonstrating the effectiveness of the procedures and techniques used.

Each of the 36 samples was exposed to 10 ft<sup>3</sup> (0.28 m<sup>3</sup>) of air. Therefore, a total of 360 ft<sup>3</sup> (10 m<sup>3</sup>) of air was metered through the sampler. The contaminants thus measured were found to be 343–360, or less than one viable organism per cubic foot of air sampled. A summary of particle counts, pressures, temperatures, humidities, etc., recorded at the various locations shown in Figure 1 in both Class 100 and Class 10,000 areas during certification is shown in Table 2.

The Geology Clean Laboratory presented a unique challenge at the time due to the air sterility and budgetary constraints. This made the use of low-cost packaged air-conditioning equipment virtually mandatory. The laboratory was constructed at the relatively low cost of \$55 per square foot of gross area.

### Postscript 30 Years Later

Despite persistent budgetary problems and a lengthy plumbers' strike during construction, the Geology Clean Laboratory was completed and certified within budget substantially on schedule and in time to receive some of the Apollo 11 lunar samples. One of the most challenging aspects of this project was providing a relatively high order of cleanliness within close environmental limitations. In addition, inexpensive laminar downflow floor and ceiling systems suitable for assembly within our wood framed structure were not commercially available at that time, and had to be developed. Also, operation procedures for handling work around laboratory fume hoods had to be developed, so as not to affect laminar flow patterns when in use.

Geologic samples from all of the Apollo lunar surface exploration missions (1969–72) and associated data records are preserved at the Johnson Space Center in Houston. The lunar samples are available to approved scientists and educators. A total of 382 kg (173 lb) of lunar material, comprising 2,196 individual specimens returned from the Moon, has been processed

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to meet scientific requirements into more than 97,000 individual cataloged samples.

To fill in missing data about the Earth's origin and early history after the Apollo 11 mission, we returned to the Moon. Although no evidence of life forms was found among any of the lunar samples, the Moon's origin was resolved as a direct result of information learned from Apollo 11 and subsequent Apollo missions. Yet, certain details still remain sketchy.

For example, is there a source of water sufficient to sustain currently planned NASA exploration efforts? More samples from key locations in the lunar highlands would allow scientists to unravel the processes that operated inside a complicated magma ocean body. Furthermore, it appears that the bombardment history of the moon may never be fully understood without additional samples from identifiable impact deposits taken from inside craters, etc. Yet, only by continuing the legacy of the Apollo program<sup>4</sup> can we ever hope to complete our understanding of our place in the solar system.

Although I have been fortunate over the years to have been involved in many space-related clean room and laboratory building programs extending from early Voyager missions to present space power studies,<sup>5</sup> the Apollo 11 mission still remains to this day one of the most emotional highs for me. As we demonstrated in 1969, our HVAC&R industry is up to space-age challenges.

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