The IBM Clean Room Comes of Age

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INTRODUCTION

Today at IBM's Space Systems Center in Huntsville, Alabama, there is a modern, efficient, clean room complex. This complex originated as a direct result of IBM's requirement to fabricate, assemble, and test NASA's Apollo/Saturn Instrument Unit.

The Instrument Unit is the control center for both Saturn IB and Saturn V launch vehicles. Every part that goes into the Instrument Unit is critical, because the three-foot high, 21.7-foot diameter ring contains the advanced electronic and electrical equipment needed to guide, navigate, and control the vehicle from liftoff to Apollo spacecraft separation.

Through the clean room complex flows a steady stream of tubing, valves, fittings, and other highly critical components and subassemblies used less than diam of human hair

in the operation of the Instrument Unit. The flow is smooth and trouble-free. Cleanliness requirements, even down to the "no particle above 20 microns" level, are easily met (Table 1). To the casual observer, the entire operation appears to have been well engineered for maximum efficiency with minimum expenditure of space and effort. This is true now, but it was not always that way.

The first IBM/Huntsville clean room had its beginning in the early part of 1964. Because of contract schedule requirements, time and floor space were critical factors in all decisions. The clean area had to be built to do a specific cleaning job, as well as to meet the requirements of Marshall Space Flight Standard 246 (Table 2).

DEVELOPMENT OF CLEAN ROOM COMPLEX

There are two systems in the Instrument Unit which require absolutely clean components. These are the air-bearing supply system, which utilizes an inert gas, and the liquid coolant system, which utilizes a water-methanol combination. In both systems, a large amount of tubing, as well as fittings, filters, valves, regulators, and other hardware, is necessary. The internal surfaces of these items (i.e., areas which will be in contact with the gas or liquid) are referred to as critical surfaces.

The liquid system contains tubing fabricated from 6061-T6 aluminum, which must be cleaned to the levels specified in Marshall Space Flight Center Specification No. 164 (Table 1). This is not difficult to meet, comparatively speaking, since it permits a per-square-foot particle population of one particle between 700 and 2500 microns, and five particles between 175 and 700 microns. For most items within the Instrument Unit, this specification has been amended to read, "no particle greater than 175 microns."

The gaseous system which contains tubing fabricated from Type 304 stainless steel must meet the requirements of Marshall Space Flight Center Drawing No. 10419906 (Table 1). This is extremely difficult to meet because the allowable particle population is limited to eight particles between 8 and 20 microns, with none greater than 20 microns.

When the initial clean room was designed, it was obvious that tube cleaning would require an area set up specifically for this operation. The first consideration was the amount of available floor space. A total of 1216 square feet was allotted for the clean room complex: the assembly clean room, 384 feet; the No. 2 clean room, 279 feet; the airlock, 48 feet; the locker room, 96 feet; and the tube cleaning room, 409 feet (Figure 1).

The second consideration was the various methods available for providing a Class IV clean room environment. The two choices were to build a clean room complex which would meet the requirements of Marshall Space Flight Center Standard 246 (Table 2) or to devise a method of utilizing prepackaged clean areas, such as laminar flow benches and roomettes.

After a thorough review of all factors involved, the decision was made to build all our clean rooms to Class II levels (Table 2) and use clean benches to provide Class IV environment. Three standard laminar flow benches; one special, ventilated laminar flow bench; and a fully enclosed 8-foot by 10-foot laminar flow roomette were obtained. Each of these units provides a minimum air flow of 100 cubic feet per minute, and contains filters which remove all particles above a half micron in size. These units operate continuously (24 hours a day) and contribute substantially to the overall cleanliness of their area. Conversely, the fact that these units were installed in a Class II clean room contributed substantially to their own cleanliness, and lengthened the life of the filters by a considerable margin.

A tube cleaning unit, which cleaned the internal surfaces of tubing and other components, was built and installed. This is accomplished by pumping various cleaning chemicals through a series of filters and through the tubing, then back to the storage tanks. By arranging the inlet and outlet connection so that they exit under a laminar flow bench, the cleaned parts remain clean through disconnect, test, and packaging. This proved feasible even where 20-foot-long tubing was involved, provided that the ends of the tubing remain in the laminar flow area when open, and are not removed until safely packaged. This arrangement provided a great deal of latitude in design and furniture arrangement, including a ceramic tile floor in the tube cleaning area, which was impervious to the attacks of spilled chemicals and solvents.

Because of space limitations, it was necessary to set up a small quality control laboratory in the same room, where particle counts and solvent testing could be done.

In the ensuing two years, we found that the clean room complex worked well. The daily particle count showed that the tube clean room normally met Class III requirements, with occasionally drops to Class II. The assembly clean room normally met Class IV requirements, with an occasional Class III reading. Since we had designed the rooms to Class II levels, these readings were more than satisfactory.

Continuous checking on the laminar flow benches and the roomette has shown that Class IV requirements were consistently met, with some readings approaching zero.

A "think clean" training program for all personnel having duties inside the clean area has been credited as being a major factor in achieving the high level of cleanliness which was maintained during the life of this complex.

In spite of the generally satisfactory performance of this complex, many problems were encountered, and with the expansion of the overall facility in 1966, it was decided to build a new clean room complex.

Factors leading to this decision included the following:

1. All plumbing, wiring, air conditioning, and other service supply lines were in the ceiling. This caused continuous problems when a leak occurred, or when service was required for any reason, since opening the ceiling destroyed the integrity of the clean room, and much time and painstaking effort were required to restore it.
2. Since the clean room complex was located in the center of the building, drainage from the tube cleaning console had to be piped under the floor to a treating tank. This caused problems with clogged lines and underfloor leaks.
3. Exhaust ducting necessarily included many bends in order to vent corrosive vapors through the second floor to exit on the roof. This led to condensation conditions and other problems.
4. The de-ionized water system was inadequate for sustained operations and needed replacing.
5. The solvent filter unit required rebuilding and relocating.
6. It was felt that the Quality Control Laboratory and personnel should be in a separate area, even though no serious trouble had been encountered by having combined facilities.

NEW FACILITIES

The new facilities took approximately six months to complete. Comprising 1584 square feet of floor space as opposed to 1216 square feet in the original area, the new complex was carefully engineered from the start of the construction, to take full advantage of space and layout.

The complex consists of four areas: the Quality Control Analysis Laboratory, 528 square feet; the main clean room, 480 square feet; the pre-clean room, 556 square feet; and the airlock, 20 square feet (Figure 2).

The Quality Control (Q.C.) area is a Class I area, completely equipped with chemical analysis and particle monitoring facilities. This room is connected to the main clean room by a 2-foot by 2-foot pass-through. All particle counts and other critical tests are performed under a Class IV laminar flow bench located in the Q.C. area. With this arrangement, samples may be taken in the clean area, and, after being placed in clean, particle-free packages, are passed into the Q.C. Laboratory for testing. Thus the Q.C. personnel need never enter the clean room.

The pre-clean area is also a Class I area. This eliminates the need for personnel to wear clean room clothing, and allows all the pre-cleaning and other rough operations to be performed with a minimum of clean room controls. In this area are the tube cleaning console, degreaser, and ultrasonic cleaning unit. The pre-clean room is connected to the clean room by a pass-through and a personnel airlock. Both openings have double interlocking doors to prevent the entrance of contaminating particles, even though a positive pressure is always maintained in the clean room. This room, built as a custom prefabricated unit and brought to the IBM facility in sections, was installed in the selected locations.

The clean room air handling system is composed of modules mounted along the entire wall, above a stainless steel work bench. This provides, in effect, a 20-foot laminar flow bench with a face velocity of 100 cubic feet per minute. The bench is equipped with an integral sink and service outlets for hot and cold de-ionized water, super-clean solvent, and super-clean gaseous nitrogen. The sink has a partition which allows recovery of water-free solvent.

Other facilities include super-clean nitrogen gas outlets, built-in vacuum cleaning outlets, vacuum connections for the clean vacuum drying oven, recessed lighting, and a special speak-through communications device.

Light fixtures are located above a drop ceiling of translucent panels. The space between the drop ceiling and the room ceiling acts as the return air plenum. Part of the returning air is passed through an air conditioning unit which controls the temperature and humidity within the clean room. Recorder charts show that the temperature is maintained at 72°F ±° and the relative humidity is maintained at 40 ± 2%.

Filter units, vacuum pumps, and the new de-ionized water supply system are all serviced from outside the room, thanks to service corridors behind the rooms.

CONCLUSION

With this clean room complex, it is possible to keep a continuous flow of work moving through the system. Tubing and fittings arrive at the pre-clean room exposed, oily, and otherwise contaminated, and enter the clean room in a nearly spotless condition. Final cleaning and testing are performed, and the clean packaged parts are sent on their way to the clean assembly area. The area has been in continuous operation for 12 months with no shutdowns. Class IV conditions are consistently met in the clean room, and overall performance by the complex has been more than satisfactory.

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Table 1

SPECIFICATION COMPARISON CHART

	Marshall Space Flight Center Specification 164	Marshall Space Flight Center Drawing No. 10419906
Particle Size Limitations Per Square Foot of Surface Area	175 to 700 microns 5 700 to 2500 microns 1 Over 2500 microns 0 (For most IBM hardware, this is amended to no particles above 175 microns.)	8 to 20 microns 10 Over 20 microns 0
Demineralized Water	Specific Resistance, 50,000 ohms minimum	Specific Resistance, 50,000 ohms minimum
	Particle Size, no particle over 175 microns	Particle Size, no particle over 20 microns
Gas or Air	Particle Size, no particle over 100 microns	Particle Size, no particle over 20 microns
	Hydrocarbon, 3.0 ppm maximum (weight) Moisture, 24 ppm maximum volume)	Hydrocarbon, 0.3 ppm maximum (weight) Moisture, 24 ppm maximum volume)
Nonvolatile Residue	Oxygen - .001 gr per ft^2 maximum Fuel - N/A Onboard Pneumatic - no visual evidence GSE Pneumatic - .001 gr per ft^2 maximum	.001 gr per ft^2 maximum
Surface pH	6 to 8	6 to 8

Table 2

CLEAN ROOM CLASSIFICATION MSFC STANDARD 246

	Class I	Class II	Class III	Class IV
Particle Count Per Cubic Foot	N/A	5-25μ 300 25-100μ 150 Over 100μ 0 Fibers 30	5-25μ 180 25-100μ 30 Over 100μ 1 Fibers 1	5-25μ 20 25-100μ 5 Over 100μ 1 Fibers 1
Temperature	Comfortable	72 ± 5°F	72 ± 3°F	72 ± 1°F
Humidity	Comfortable	40% ± 10%	40% ± 5%	40% ± 5%
Sampling Frequency	N/A	Once per week	Once per day	Twice per day
Clothing	Optional	Smocks	Smocks, Caps and Boots	Suits, Caps, Boots and Gloves
Filters Required	N/A	85% (>0.3μ)	99% (>0.3μ)	99% (>0.3μ)

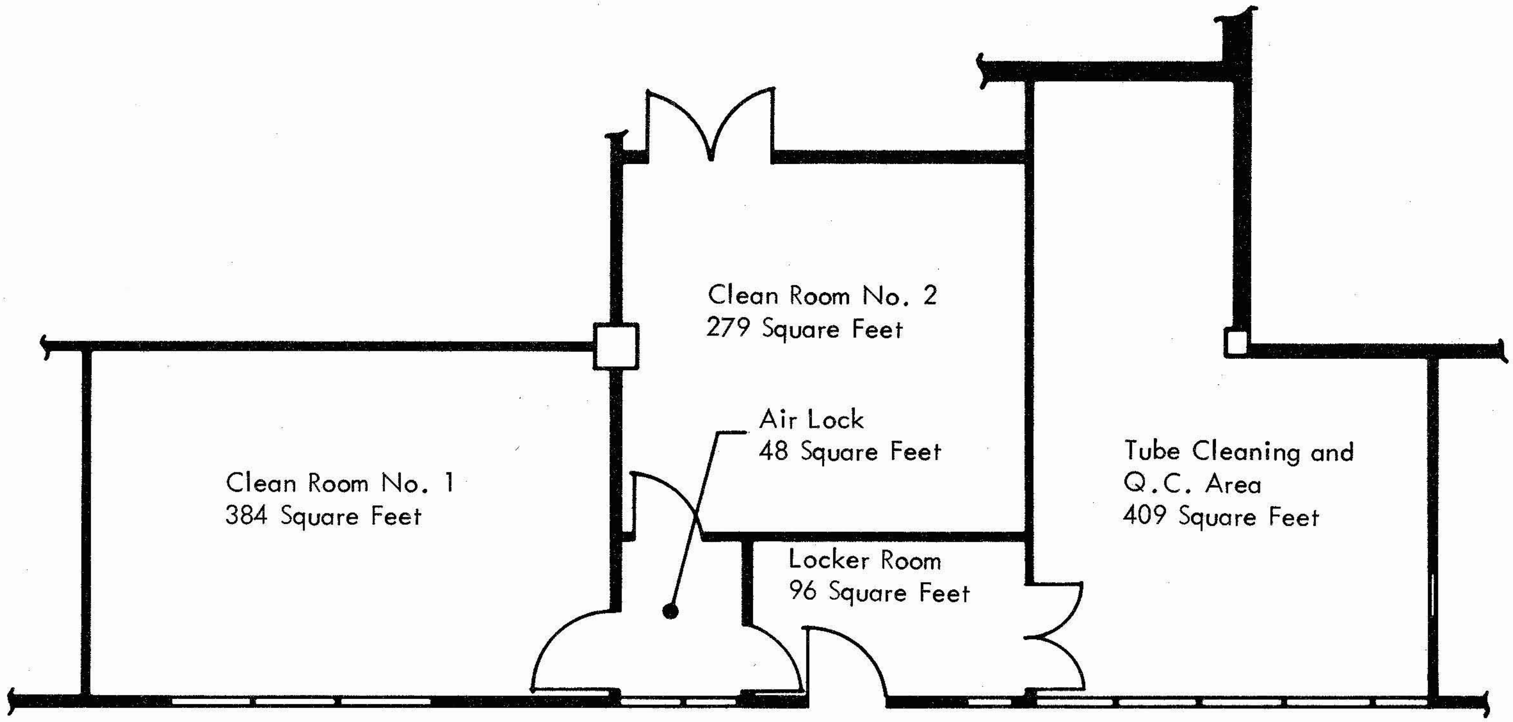

Figure 1. Original Clean Room Complex

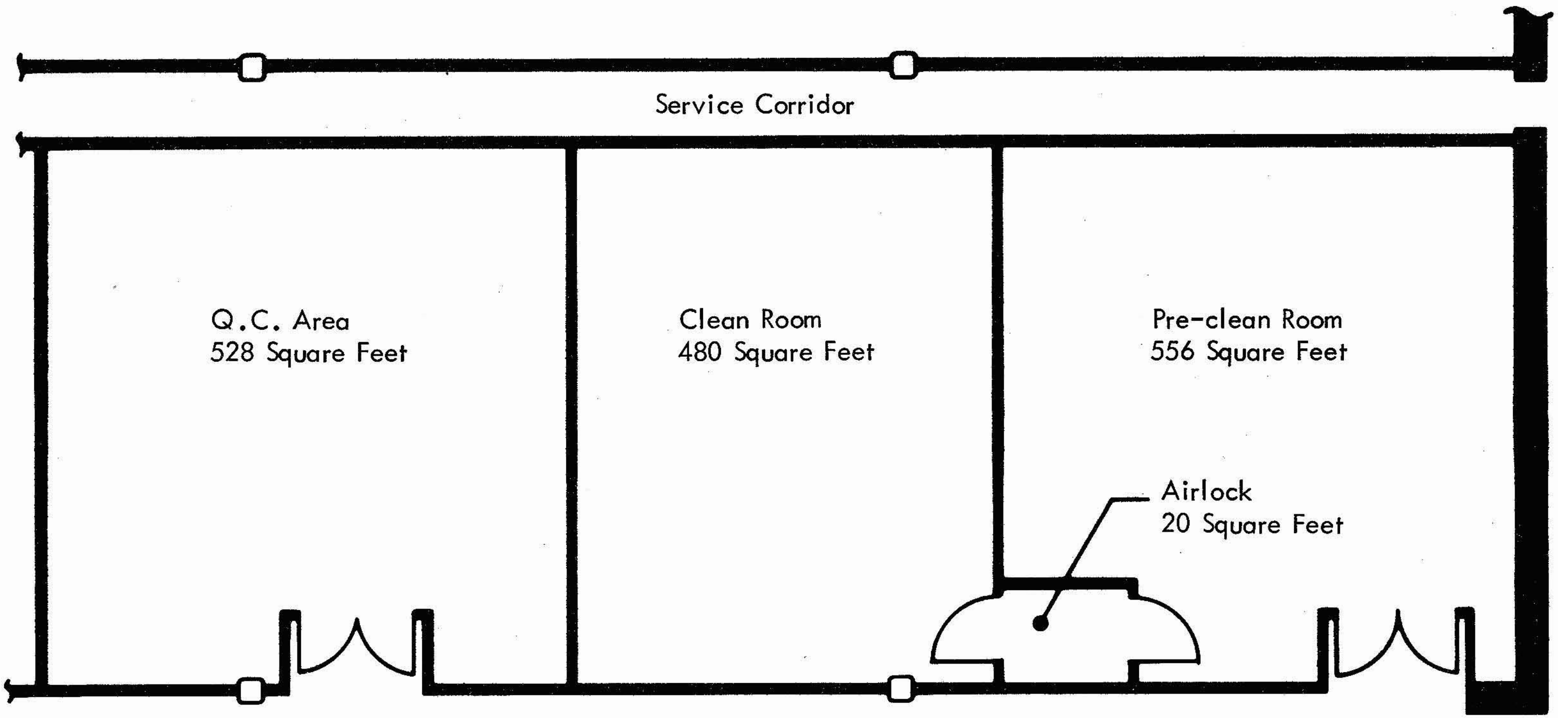

Figure 2. New Clean Room Complex

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