



OMNI

Omni Testing Ltd.

10 Erie St., Box 338
Swampscott, MA 01907
(781) 598-4333
FAX (781) 592-8232

CLEANROOM PARTICLE SHEDDING

ANALYSIS REPORT

REPORT #C13058ML-2

NABCO

GT SYSTEM 1175 WHISPERSLIDE DOOR

AUGUST 2019

By

OMNI TESTING, LTD.



I. ABSTRACT

The Nabco GT System 1175 WhisperSlide door underwent particulate shedding testing for use in a cleanroom environment. As a result of the testing, the GT system 1175 WhisperSlide door is suitable for use in all cleanrooms classified under Federal Standard 209E – Imperial or Metric as well as for any room classified as ISO 14644-1:2015 Class 2.

II. INTRODUCTION

This report, C13058ML-2, is issued as a subsequent update to the original report C13058ML in February 2013 to comply with the most recent revision of ISO-14644-1:2015. OMNI TESTING LIMITED, Swampscott, MA, was selected by NABCO, INC. to conduct particle shedding and cleanroom compatibility testing of its **GT SYSTEM 1175 WhisperSlide** automatic sliding door. OMNI TESTING, LTD. maintains a 12'8" x 8'4" x 7'11" high, open plenum supply, perforated raised floor, vertical unidirectional flow cleanroom in its Swampscott, MA facility. The room is capable of performing cleaner than ISO 14644-1:2015 – Class 1.5¹ at a 0.2 µm particle size.

NABCO provided a fully functional, reduced-size, 2-leaf, sample door, of approximately 76" long and 38" high complete with a fully operable drive mechanism, 2 door position sensors, and local control system. The door was center-positioned inside of the cleanroom and framed with (2) 2" x 7" anodized aluminum tubular feet – resting on the floor, stabilized with two each triangulating aluminum brackets. The OMNI testing technician could operate the door with a local push – button opening switch while remaining out of the way of both sampling air stream and the door installation. The local ON/OFF switch allows the door continuously to cycle repeatedly. The OMNI test technician was not present in the room during either the background or operating testing. The door was delivered by NABCO and set up and installed by OMNI personnel in the Swampscott, MA facility. Unpacking, installation and preliminary 70% I.P.A. cleaning required approximately 90 minutes, accomplished on 13FEB13.

OMNI TESTING personnel were responsible for cleaning the door with non-linting wipes, 70% Isopropyl Alcohol and removing any hard-to-reach dust with 1,1 Difluoroethane. The testing was conducted over five days, beginning Thursday, 14FEB13 and finishing Thursday, 21FEB13. No client representatives were on-site during the independent testing. Cleanroom background particulate levels were monitored prior the door assessment on 14FEB13 and 18FEB13. All instrumentation used in the analysis of both the cleanroom and door were in current N.I.S.T. calibration. One particle counter, with sampling capability of particle sizes ranging from 0.2 µm up to 5.0 µm was utilized to measure the door particulate shedding. Reported data is in both the 0.2 µm and 0.3 µm size ranges although no significant data was obtained at any size larger than

¹ Updated classification for 2015 revision of ISO 14644-1:2015

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0.2 μm , and no data was obtained at 0.5 μm or larger. The conclusions and results are all based on the 0.2 μm size. This decision is due also to the fact that ISO 14644-1:2015- Class 1.0 is only specified at 0.1 μm and 0.2 μm^2 , it is always more difficult to certify at the larger of the two particulate sizes due to the decreasing exponential threshold with increasing particle size. That is to say; many more particles are allowed at the 0.1 μm size than at 0.2 μm .

Background particulate sampling was accomplished at six (6) locations, approximately 6" above the finished perforated floor (A.F.F.). Two, distinct, 70.6-minute, 2.0 M^3 , 70.6 FT^3 background "samples" were taken at each of the 6 locations, "A" through "F," at the 6" A.F.F. elevation. These samples were reiterated as necessary with multiple cleaning efforts to eliminate any transient, spurious releases of particulate. To facilitate capture of any shed particulate, a 12" x 15" GORPLER™ aerosol sampling array was utilized which covers a relatively broad area (~1.25 FT^2) to avoid missing particulate traveling in the vertical streamlines of the unidirectional flow air-stream. The GORPLER™ was manually relocated by the OMNI test technician from locations A through F, in between sampling.

Once the background data was successfully captured, the identical protocol was observed, this time with the door set up for continuous, automatic cycling. Consequently, during one, 70.6-minute trial sample, the door underwent approximately 385 complete cycles. Overall, including background and operating sample testing, 1694.4 FT^3 (48 M^3) of clean air was sampled in conducting this analysis.

III. SETUP

Figure #1 shows the cleanroom vertical, unidirectional velocities in feet per minute (fpm) taken 2" from the ceiling, line "egg crate" acrylic diffusers. The average velocity of the cleanroom was 108 fpm during the test. The cleanroom certification report had been conducted on 17FEB12. Figure #2 shows the GORPLER sampling setup relative to the door and cleanroom position. Figure #3 illustrates the six chosen sampling locations at 6" A.F.F. during the background testing with the door not operating and also during the door-operating testing.

² In 2013, ISO-14644-1 class 1 was specified at 0.1 and 0.2 micron.



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85	98	117	82	110	97	122	117	
109	118	128	107	128	119	125	112	
102	111	146	110	109	120	148	117	
95	92	120	102	114	112	117	121	
104	133	107	103	120	129	112	112	
107	112	CLEANROOM	109	88	89	140	115	106
101	107	102	108	110	97	100	107	
103	93	109	93	107	107	102	102	
99	101	102	112	102	90	85	113	
102	112	100	104	108	102	118	117	
123	92	98	110	105	100	101	103	
132	107	94	102	95	98	107	119	
85	95			97	96			
78	101			88	120			
103	100	GOWN ROOM		101	110			
115	105			87	107			

Fig.1



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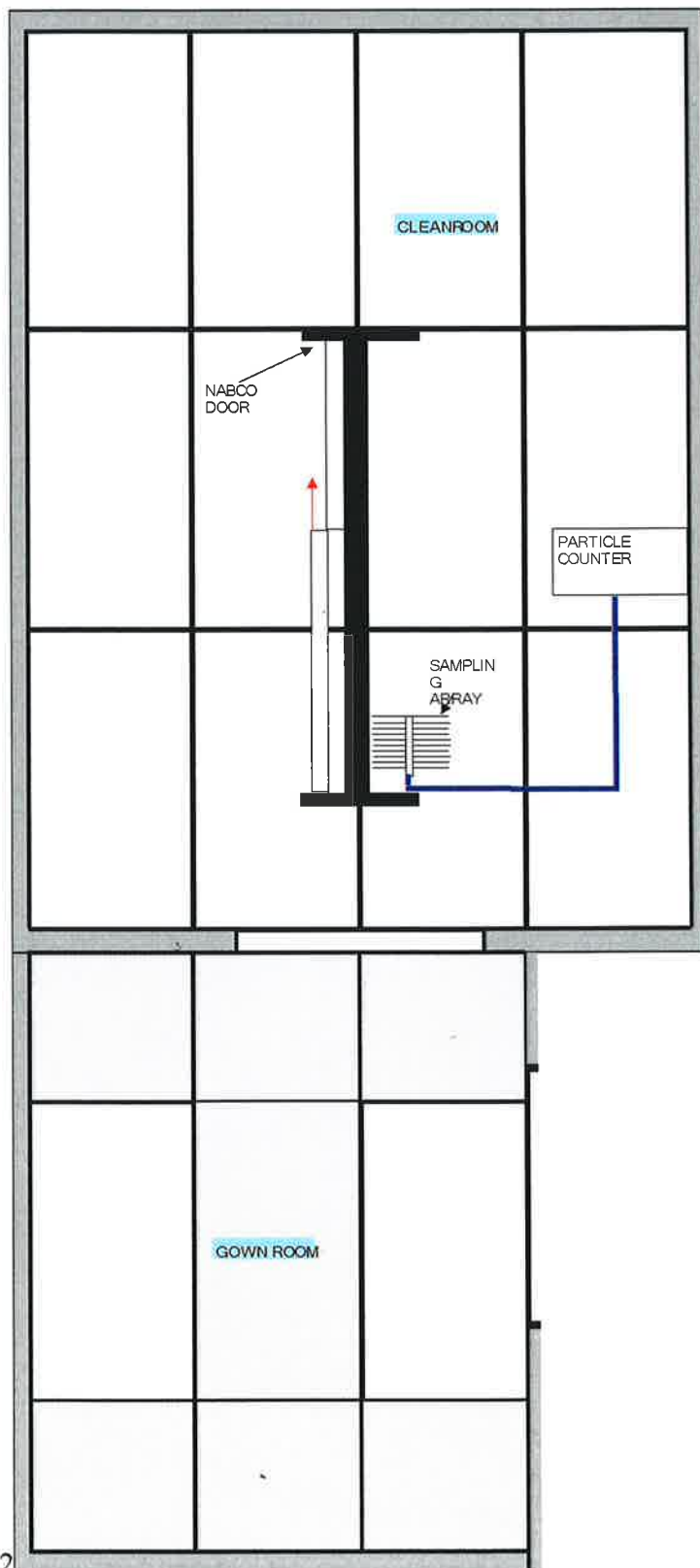


Fig. 2



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Swampscott, MA 01907
(781) 598-4333
FAX (781) 592-8232

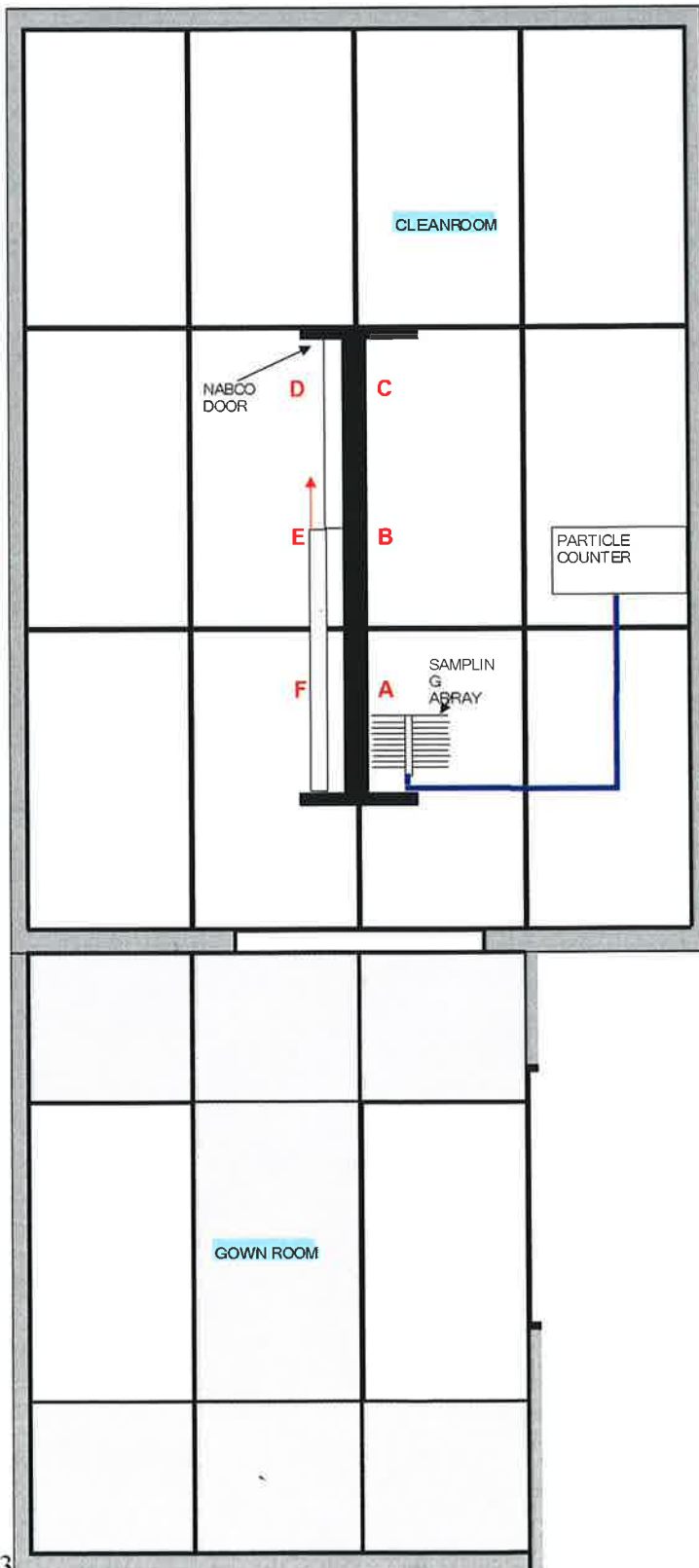


Fig. 3



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The door had been set up by NABCO, INC., to have an approximate 11 second cycle time with a 4.0 second opening time, 2.0-second hold-open and a 5.0 second closing time. The total travel of the sliding leaf was 30.5". The average travel speed was consequently 7.6 inches/sec. upon opening and 6.1 inches/sec. upon closing. A MET-ONE Model A2200-C-2-1-115-1 having a 1.0 CFM sampling rate and connected to the GORPLER™ sampling array, having 60 precision-bore sampling points over the 1.25 ft² sampling area, was utilized for both the background and door-operating data gathering. Instrumentation specifics are found in the Instrumentation Calibration section of this report.

ILLUSTRATION #1 GT SYSTEM 1175 WHISPERSLIDE TEST SETUP





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IV. DESCRIPTION PROTOCOL

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Before beginning any sampling, an initial cleaning of the door & installation was conducted with 70% IPA and cleanroom wipes. The glazing was cleaned with an ammonia-based glass cleaner. The aluminum frame was wiped down with moist cleanroom wipes.

The particle count data for all six background efforts and six door-operating trials are individually presented in the following section. There are two sheets presented for both the background and operating data. The raw data sheet shows particulate data for all six size channel thresholds captured. The analysis sheet is limited to the particle size(s) of interest. Each trial includes the Sample letter identifier, Sample volume (ft^3), date, elevation above floor and $0.2 \mu\text{m}$ and $0.3 \mu\text{m}$ sizes presented in both British & Metric units.

The analysis was conducted at two parameters, Maximum, and Average (X). For convenience, classifications were conducted and calculated according to 3 standards: ISO 14644-1:2015, Federal Standard 209E (Metric) and Federal Standard 209E (Imperial), the latter two being presently obsolete. The two analysis sheets show data at both $0.2\mu\text{m}$ and $0.3\mu\text{m}$. Where a blue parenthesis appears after the Classification, the collected data is cleaner than allowed for by the volume sampled, V_s , (Please refer to Eq. 1 in the Data Analysis section of this report). A chart (Figure #4) is presented at the end of the Presentation of Data section of this report illustrating the OMNI background cleanroom and the GT SYSTEM 1175 WhisperSlide contribution shown against the recognized ISO 14644-1:2015 classifications.



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V. PRESENTATION OF DATA

10 Erie St., Box 338
 Swampscott, MA 01907
 (781) 598-4333
 FAX (781) 592-8232

NABCO WHISPERSLIDE

RAW BACKGROUND SAMPLE DATA

			METRIC						IMPERIAL					
LOCATION	VOLUME SAMPLED (FT ³)	DATE	SIZE	SIZE	SIZE	SIZE	SIZE	SIZE	SIZE	SIZE	SIZE	SIZE	SIZE	
			THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD	THRESHOLD
			(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)
			0.2	0.3	0.5	1.0	3.0	5.0	0.2	0.3	0.5	1.0	3.0	5.0
			(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)
A	70.6	18-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A	70.6	14-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
B	70.6	14-Feb-13	6	0	0	0	0	0	0.0850	0.0000	0.0000	0.0000	0.0000	0.0000
B	70.6	18-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	70.6	14-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	70.6	14-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D	70.6	18-Feb-13	5	0	0	0	0	0	0.0708	0.0000	0.0000	0.0000	0.0000	0.0000
D	70.6	18-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
E	70.6	18-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
E	70.6	18-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
F	70.6	18-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
F	70.6	18-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000



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 ANALYSIS RAW BACKGROUND
 DOOR NOT OPERATING

10 Erie St., Box 338
 Swampscott, MA 01907
 (781) 598-4333
 FAX (781) 592-8232

SAMPLE NUMBER LOCATION	SAMPLE VOLUME (FT ³)	DATE	SAMPLE ELEVATION (inch above Floor)	IMPERIAL		METRIC	
				0.2 μm (qty./ FT ³ ≥0.2μm)	0.3 μm (qty./ FT ³ ≥0.3μm)	0.2 μm (qty./ M ³ ≥0.2μm)	0.3 μm (qty./ M ³ ≥0.3μm)
A	70.6	18-Feb-13	6	0.000	0.000	0.0	0.0
A	70.6	14-Feb-13	6	0.000	0.000	0.0	0.0
B	70.6	14-Feb-13	6	0.085	0.000	3.0	0.0
B	70.6	18-Feb-13	6	0.000	0.000	0.0	0.0
C	70.6	14-Feb-13	6	0.000	0.000	0.0	0.0
C	70.6	14-Feb-13	6	0.000	0.000	0.0	0.0
D	70.6	18-Feb-13	6	0.071	0.000	2.5	0.0
D	70.6	18-Feb-13	6	0.000	0.000	0.0	0.0
E	70.6	18-Feb-13	6	0.000	0.000	0.0	0.0
E	70.6	18-Feb-13	6	0.000	0.000	0.0	0.0
F	70.6	18-Feb-13	6	0.000	0.000	0.0	0.0
F	70.6	18-Feb-13	6	0.000	0.000	0.0	0.0
Σ	847.2						
n				12	12	12	12
X				0.013	0.000	0.458	0.000
CLASS ISO 14644-1:2015	X			0.3 (0.5)	<1.0		
CLASS 209E (M)	X			-1.2	<0.0		
CLASS 209E(E)	X			0.0	0.0		
CLASS ISO 14644-1:2015	MAX			1.1 (1.5)	<1.0		
CLASS 209E (M)	MAX			-0.4	<0.0		
CLASS 209E(E)	MAX			0.0	0.0		

NABCO WHISPERSLIDE
 RAW DATA
 DOOR OPERATING

LOCATION	VOLUME SAMPLED (FT ³)	DATE	METRIC						IMPERIAL					
			SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	SIZE THRESHOLD	
			(μm)	(μm)	(μm)	(μm)	(μm)	(μm)	(μm)	(μm)	(μm)	(μm)	(μm)	(μm)
			0.2	0.3	0.5	1.0	3.0	5.0	0.2	0.3	0.5	1.0	3.0	5.0
			(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./2M ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)	(qty./FT ³)
A	70.6	19-Feb-13	1	0	0	0	0	0	0.0142	0.0000	0.0000	0.0000	0.0000	0.0000
A	70.6	19-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
B	70.6	19-Feb-13	2	0	0	0	0	0	0.0283	0.0000	0.0000	0.0000	0.0000	0.0000
B	70.6	19-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	70.6	19-Feb-13	3	0	0	0	0	0	0.0425	0.0000	0.0000	0.0000	0.0000	0.0000
C	70.6	19-Feb-13	1	0	0	0	0	0	0.0142	0.0000	0.0000	0.0000	0.0000	0.0000
D	70.6	20-Feb-13	20	3	0	0	0	0	0.2833	0.0425	0.0000	0.0000	0.0000	0.0000
D	70.6	20-Feb-13	5	0	0	0	0	0	0.0708	0.0000	0.0000	0.0000	0.0000	0.0000
E	70.6	20-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
E	70.6	20-Feb-13	1	0	0	0	0	0	0.0142	0.0000	0.0000	0.0000	0.0000	0.0000
F	70.6	20-Feb-13	5	0	0	0	0	0	0.0708	0.0000	0.0000	0.0000	0.0000	0.0000
F	70.6	20-Feb-13	0	0	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

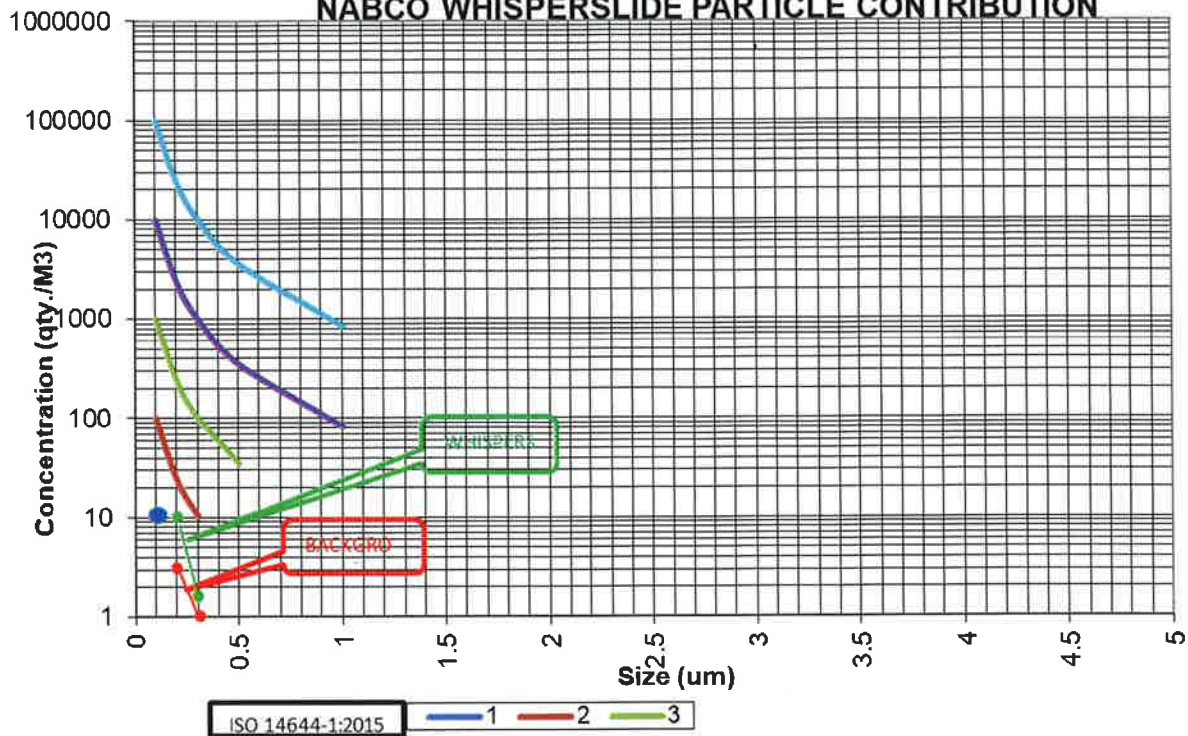


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 ANALYSIS DOOR OPERATING

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 Swampscott, MA 01907
 (781) 598-4333
 FAX (781) 592-8232

SAMPLE NUMBER LOCATION	SAMPLE VOLUME (FT ²)	DATE	SAMPLE ELEVATION (inch above Floor)	IMPERIAL		METRIC	
				0.2 μm (qty./ FT ² ≥0.2μm)	0.3 μm (qty./ FT ² ≥0.3μm)	0.2 μm (qty./ M ² ≥0.2μm)	0.3 μm (qty./ M ² ≥0.3μm)
A	70.6	14-Feb-13	6	✔ 0.014	✔ 0.000	✔ 0.5	✔ 0.0
A	70.6	14-Feb-13	6	✔ 0.000	✔ 0.000	✔ 0.0	✔ 0.0
B	70.6	14-Feb-13	6	✔ 0.028	✔ 0.000	✔ 1.0	✔ 0.0
B	70.6	14-Feb-13	6	✔ 0.000	✔ 0.000	✔ 0.0	✔ 0.0
C	70.6	14-Feb-13	6	✔ 0.042	✔ 0.000	✔ 1.5	✔ 0.0
C	70.6	14-Feb-13	6	✔ 0.014	✔ 0.000	✔ 0.5	✔ 0.0
D	70.6	18-Feb-13	6	✔ 0.283	✔ 0.042	✔ 10.0	✔ 1.5
D	70.6	18-Feb-13	6	✔ 0.071	✔ 0.000	✔ 2.5	✔ 0.0
E	70.6	18-Feb-13	6	✔ 0.000	✔ 0.000	✔ 0.0	✔ 0.0
E	70.6	18-Feb-13	6	✔ 0.014	✔ 0.000	✔ 0.5	✔ 0.0
F	70.6	18-Feb-13	6	✔ 0.071	✔ 0.000	✔ 2.5	✔ 0.0
F	70.6	18-Feb-13	6	✔ 0.000	✔ 0.000	✔ 0.0	✔ 0.0
Σ	847.2						
n				✔ 12	✔ 12	✔ 12	✔ 12
X				✔ 0.045	✔ 0.004	✔ 1.583	✔ 0.125
CLASS ISO 14644-1:2015	X			0.8	0.1 (1.0)		
CLASS 209E (M)	X			-0.7	-1.3		
CLASS 209E(E)	X			0.0	0.0		
CLASS ISO 14644-1:2015	MAX			2.0	1.5 (1.5)		
CLASS 209E (M)	MAX			0.1	-0.3		
CLASS 209E(E)	MAX			0.0	0.0		

FIGURE #4
NABCO WHISPERSLIDE PARTICLE CONTRIBUTION



VI. DATA ANALYSIS

The NABCO Analysis Background sheet summarizes & tabulates all the results of the six background efforts. Background sampling was conducted at the 6” elevation. Sampling volumes were 70.6 ft³. This selection was not arbitrary. Following ISO 14644-1:2015 and the now obsolete standard Federal Standard 209E, a sufficient statistical sample, adequate to capture 20 particles is necessary for classification.

Eq. 1. $V_s = \frac{20}{C_n} ; V_s \{C_n\} .$



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10 Erie St., Box 338
Swampscott, MA 01907
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Where V_s is the volume sampled (m^3), and C_n is the threshold limit for the desired classification at a chosen particle size (qty./ m^3). As a hypothetical, ISO 14644-1:2015 Class 1.0 specifies an upper limit of 2.37 particles per cubic meter at 0.2 μm . The resultant quotient, V_s , is 8.438 m^3 or 298.5 ft^3 . The chosen sampling volume for the testing herein of 70.6 ft^3 is sufficient to demonstrate Classification as clean as ISO 14644-1:2015 Class 1.6. The average, X, parameter mentioned above has a total sample volume of 847.2 ft^3 which is enough air volume sampled to classify 0.2 μm at any designated ISO 14644-1:2015 class.

Eq. 2. $C_n = 10^N * \left(\frac{0.1}{d}\right)^{2.08}$; $C_n \{N, d\}$

Equation 2 shows the relationship between concentration threshold, C_n (qty. / m^3), ISO 14644-1:2015 classification designator, N, and size diameter, d, in microns. For a $d = 0.2\mu m$ particle size, at ISO Class $N = 1$, $C_n = 2.37 / m^3$ or, approximately, 0.067/ ft^3 .

Table #1 below reveals that the Omni Testing, Ltd. cleanroom background, at a 95% upper confidence is 0.72/ M^3 or 0.020/ ft^3 at 0.2 μm . This level of cleanliness corresponds with a level at least as clean as ISO 14644-1:2015 Class 1 (N=1), disregarding V_s . ISO 14644-1:2015 Class 1 is defined at both 0.1 μm and 0.2 μm particle sizes, but no larger. Since ISO 14644-1:2015 Class 1 is the lowest recognized classification, any particles above the 0.021/ ft^3 level are considered to be contributed by the GT SYSTEM 1175 WhisperSlide door.

The cleanroom background results³ were, at 0.2 μm :

TABLE #1 OMNI CLEANROOM BACKGROUND CLASSIFICATIONS

	AVERAGE (X)	MAXIMUM
ISO 14644-1:2015 (N)	0.3 (0.5)	1.1 (2.0)
Federal Standard 209E (M)	-1.2	-0.4
Federal Standard 209E (N _c)	0.0	0.0

Equation #3 shows the relationship between concentration threshold, C_e , class designator, N_c , and particle diameter, d, in microns from the older, obsolete, Federal Standard 209E in British (Imperial) units of $C_e = (qty./ft^3)$.

Eq. 3. $C_e = N_c * \left(\frac{0.5}{d}\right)^{2.2}$; $C_e \{N_c, d\}$

Where C_e is the number of particles per cubic foot and is equal to ($C_n/35.3$). N_c is the class designation (for instance “Class 10,000” OR “Class 1,000”, etc.) and d is the particle diameter in

³ Calculated values based on empirical data, not actual allowed classifications as they were cleaner than any recognized class.



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Swampscott, MA 01907
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microns. The metric version of this relationship from Federal Standard 209E is expressed in equation 4.

$$\text{Eq. 4. } C_n = 10^M * \left(\frac{0.5}{d}\right)^{2.2}; C_n \{M, d\}$$

Where C_n , as before, is (qty. /m³), M is the metric class designator (For example “Class M3.5”, “Class M5”, etc.) and d is the particle diameter in microns.

The distinction between the various class designators, M, N_c , and N is crucial to understand as it impacts the results in the CONCLUSION section of the report.

Equations, 4, 5 & 6 show the interrelationships between the obsolete, Federal Standard 209E Metric, British- N_c , and the contemporary ISO 14644-1:2015 Classifications, N.

$$\text{Eq. 5. } N_c = \left(\frac{0.0010827 * 10^N}{\frac{1}{d}^{(3/25)}}\right); N_c \{N, d\}$$

$$\text{Eq 6. } N = 0.43429 * \ln(923.653 * N_c) - 0.0521 * \ln(d); N \{N_c, d\}$$

As a final comment, it should be noted that the range of cleanroom classifications between the older, obsolete, Federal Standard 209E (British) and the ISO 14644-1:2015 varies significantly. The lowest (British) class allowed under Federal Standard 209 was “Class 1”, $N_c = 1$. The lowest class allowed under ISO 14644-1:2015 is also “Class 1”, however, it is designated as $N = 1$.

As illustrated by Equation 5 above, an ISO 14644-1:2015 Class 1; ($N=1$, @ $0.2\mu\text{m}^4$) would result in a hypothetical⁵ Federal 209E Classification of $N_c = 0.009$, or more than 2 log scales below the minimum allowable class.

The test data from the NABCO GT SYSTEM 1175 WhisperSlide door shows that over 4,620 door opening cycles, the average concentration was 0.045 particles/ft³ at the $0.2\mu\text{m}$ size (1.59 particles/M³). Using two standard errors (SE) as a 95% Upper confidence limit, the data reveals that the NABCO GT SYSTEM 1175 WhisperSlide door did not contribute more than 0.05 particles/ft³ at $0.2\mu\text{m}$ (1.77/M³).

⁴ Each classification designator has a defined range of particle sizes which may be ignored in the hypothetical discussion.

⁵ Extrapolating outside of the allowable classifications is prohibited but is presented as a hypothetical for illustrative purposes.



TABLE #2 WHISPERSLIDE DOOR-OPERATING CLASSIFICATIONS

The door operating results were, at 0.2µm:

	AVERAGE (X)	MAXIMUM
ISO 14644-1:2015 (N)	1.0	2.0
Federal Standard 209E (M)	-0.7	0.1
Federal Standard 209E (N _c)	0.0	0.0

VII. CONCLUSIONS

Based on the data collected, at 0.2µm, the NABCO GT SYSTEM 1175 WhisperSlide door, when tested in a cleanroom environment, cleaner than ISO 14644-1:2015 - Class 1.0 (0.5), is cleaner than ISO 14644-1:2015 Class 2.0⁶ and is suitable for all cleanrooms classified under Federal Standard 209E – Imperial or Metric, at the more stringent particle size of 0.2 µm. The NABCO GT SYSTEM 1175 WhisperSlide door is also suitable for any room classified as clean as ISO 14644-1:2015 Class 2.

VIII. INSTRUMENT CALIBRATION

UNIT	MANUF	MODEL	SERIAL	CAL DATE	DUE DATE
PARTICLE COUNTER	MET-ONE	A2200-C-2-1-115-1	010100464	15NOV2012	15NOV2013

DATE: 24AUG2019

Matthew C. Lemieux
FOR: OMNI TESTING, LTD.

⁶ Classifications have been updated to nearest half-integer class per 2015 revision of ISO 14644-1.