ORAL ARGUMENT NOT YET SCHEDULED

RECORD No. 16-1105(L) (consolidated with Nos. 16-1113, 16-1125, 16-1126, 16-1131, 16-1137, 16-1138, and 16-1146)

IN THE UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

NORTH AMERICA'S BUILDING TRADES UNIONS,

***Petitioner*,**

v.

OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION,
UNITED STATES DEPARTMENT OF LABOR,

***Respondent*.**

On Petitions for Review of a Final Rule of the
United States Occupational Safety and Health Administration

JOINT SUPPLEMENTAL APPENDIX

VOLUME I OF I

JA8007 to JA8026

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CERTIFICATE OF SERVICE

I hereby certify that on this 24th day of March, 2017, I served the foregoing Joint Supplemental Appendix on all registered counsel in these consolidated cases through the Court's CM/ECF system.

/s/ Bradford T. Hammock
Bradford T. Hammock

Before the
Occupational Safety and Health Administration
United States Department of Labor

Post-Hearing Comment of Jack Waggener on the Development and Application of the Binomial Distribution Methodology To Estimate the Number of Engineering Control Packages Required To Be Installed Under the Proposed Crystalline Silica Standard
Docket No. OSHA-2010-0034, 78 Fed. Reg. 56274 (September 12, 2013)

May 30, 2014

The purpose of this Post-Hearing Comment is to explain how the binomial distribution function was developed and applied in the cost model that was used by URS Corporation to estimate the costs of OSHA's proposed Crystalline Silica Standard in nineteen sectors of general industry. A prior submission in this rulemaking entitled "Critique of OSHA's Cost Models for the Proposed Crystalline Silica Standard and Explanation of the Modifications to Those Cost Models Made by URS Corporation, February 7, 2014" (particularly pages 4-9) provides much greater detail as to *why* the corrections and modifications applied by URS to the OSHA cost model were necessary and proper. The present document explains *how* one aspect of those modifications – *viz.*, the use of a binomial distribution function to estimate the number of engineering control packages required – was developed and used.

I. Overview of the Use of a Binomial Distribution to Increase the Accuracy of the Compliance Cost Estimates To Achieve the Proposed PEL

URS believes the use of the binomial distribution (BD) function is a reasonable statistical approach to simulate real-world situations that would occur at the facility level; consequently, it will produce a much more realistic assessment than OSHA's cost model of how many engineering control packages would be required to achieve the proposed PEL in the General

Industry sectors affected by the proposed rule. This was done by using the binomial distribution function in Excel to create a probable distribution of overexposed workers for different size facilities for each at-risk job in each industrial category. More than 400 BDs were created by URS for use in the URS cost model. As compared to OSHA's cost model – under which overexposed workers are deemed to be concentrated in a smaller number of facilities where engineering controls are assumed to be targeted solely to overexposed workers – the BDs take a more realistic approach of distributing the overexposed workers more broadly over a larger number of facilities where engineering controls cover a mix of both overexposed workers and workers who are not exposed above the PEL. Instead of assuming that each engineering control package found in the OSHA cost estimate will cover a full complement of overexposed workers (typically four under OSHA's approach), the URS model realistically reduces the number of *overexposed* workers covered by each control package. The control can still cover its usual complement of workers (for example, four), but some of those workers will be among those assumed *not* to be overexposed. As a result, a larger number of engineering control packages will be required.

It is important to note that the use of BDs addresses just a few of the many very significant errors found in OSHA's cost estimates. The URS cost estimate for engineering controls in general industry (on an incremental basis) is some 50 times higher than OSHA's comparable estimate, as described in URS's Critique of February 7, 2014. However, URS estimates that the incorporation of BDs accounts for a relatively small fraction of the total cost increase. (The URS cost estimate would be about three times as high as OSHA's if the only change were the use of the BD functions.)

II. Reason for Using Binomial Functions to Estimate Distributions of Overexposed Workers

As explained in URS's Critique of February 7, 2014, one significant problem with OSHA's cost estimates was the assumption that additional engineering controls would service only workers that were estimated to be overexposed, and not any other workers in a given job. OSHA priced engineering controls that were then counted as covering (typically) four overexposed workers and simply divided the estimate of the number of overexposed workers industry-wide by four to obtain the number of additional control packages required as a result of the proposed rule. This overly-simplistic approach greatly underestimates costs, and necessarily depends on several unrealistic assumptions, described in detail in the URS Critique of February 7, 2014. A few are briefly listed here:

- OSHA's approach necessarily assumes that large numbers of overexposed workers are concentrated together at a very few large facilities, and are all also in the same operation or production area, so that each control can cover most often four, and sometimes as many as eight overexposed workers. (Four overexposed workers per control is by far the most typical example, which was utilized for 73.4% of all engineering controls in the OSHA model. Other individual controls in the OSHA model had worker capacities of 1, 2, 5, or 8 workers. The percentages of controls for these capacities were 8.8%, 7.7%, 3.6%, and 6.5%, respectively.)

- Under OSHA's approach, no consideration is given to the numerous small or very small facilities having fewer than a total of four workers in a given job, let alone four overexposed workers.
- The OHSA approach unrealistically assumes that all overexposed workers can be defined from a single sampling, and can be segregated from workers in the same job description who are not overexposed at every facility. Evidence from actual sampling events referenced in the Preliminary Economic Analysis (PEA) of OSHA site visits and case histories, as well as other industry sampling events, contradicts this assumption: most often at a given job station, overexposed workers are scattered and mixed with workers found to be in compliance. (See URS's Critique of February 7, 2014, page 6, item 4 for several example citations.)
- Subsequent sampling events also frequently reveal that different workers are measured as overexposed, while formerly overexposed workers might now be in compliance. Controls therefore must often be built to cover most or even all workers in the same job category at most facilities, not just the workers that are measured to be overexposed on one given sampling event.

OSHA's cost estimating procedure very quickly matches up all of the estimated number of overexposed workers with control packages, as if they all worked together in a few very large facilities, without regard to how many *actual facilities* would have to install controls. The

URS's Critique of February 7, 2014 explains how this approach, which is keyed almost entirely to the number of overexposed workers without regard to facility distributions, leads to a large underestimate of the number of engineering controls required to comply with the proposed rule. The use of binomial distributions (BDs) helps to correct this by calculating the numbers of controls that would more likely be required at different sized facilities with different numbers of workers and different frequencies of worker overexposure. The purpose of this report is to clarify how this procedure was implemented in the URS cost model, and to provide an estimate as to the overall impact of this procedure.

III. Key BD Information obtained from the OSHA Statistics

The following is a list of the key pieces of information that URS used to generate the BDs and calculate meaningful results. This information was either obtained directly from the OSHA cost model statistics, or could be calculated based on the information provided in the OSHA statistics. This information appeared to be reliable for 19 of the general industry sectors. (For other sectors at least some of the information, usually involving the number of facilities, appeared suspect. URS did not include those sectors in its cost estimate calculations.)

- The percent of workers in each at-risk job category within each industry who are exposed above the proposed PEL of 50 μg/m^3 (or above the current PEL of 100 μg/m^3).
- The total number of at-risk workers per job category per industry.
- The total number of at-risk workers per each job category per each industry for each size category of facility.

- The estimated number of facilities for each industry within each size category.
- The average number of workers per at-risk job per facility in all three size categories within each industry.

IV. Binomial Distributions (BD) Discussion

In the URS cost model, BDs were potentially created for any combination of the following three factors:

- **Job Category** (URS used the OSHA assigned job categories for each industry in the OSHA cost model.)
- **Industrial Sector** (URS used 19 of the industry sectors identified in OSHA's cost model. These are the sectors where the data was deemed reliable.)
- **Facility Size** (3 sizes were used by OSHA and also URS—very small, small, and large)

A BD according to the on-line business dictionary "is a frequency distribution where only two (mutually exclusive) outcomes are possible." (In this case, workers can be either over or under the silica PEL.) "Therefore, if the probability of success in any given trial is known" (i.e., OSHA has supplied the percentage of overexposed workers in a job category), "binomial distributions can be employed to compute a given number of successes in a given number of trials." Relating this to the situation at hand, the two mutually exclusive outcomes are that we have either overexposed workers or workers whose exposures are in compliance with the PEL scattered among individual facilities in the same size class. Taken as a whole, the average facility contains the average number of overexposed workers. However, for individual facilities, some will have more and some will have fewer overexposed workers than the average facility, and no facility can contain a portion of a worker. A binomial distribution "distributes" the overexposed workers among the facilities based on a normal probability curve, but does it so that the smallest increment of change among the facilities must remain one whole worker.

In other words, if an average size facility has 4 workers in an at-risk job, and the overall percentage of overexposed workers in that job category is 50%, then, *on average*, there will be 2 overexposed workers in that job category at each facility. However, in a normal distribution, while most facilities will have the average of two overexposed workers in that job category, some individual facilities will have 0, 1, 3, or 4 overexposed workers. The binomial function gives a probable distribution of the overexposed workers around this average value so that some facilities have a number of overexposed workers that is larger or smaller than the average number of overexposed workers. A hypothetical example of a BD illustrating this point is given later in this report (See Attachment 1).

V. Practical Steps Taken in the URS Cost Model with Regard to the Binomial Distributions

A. Preliminary Data Evaluations Prior To Using BDs – Special Cases

In the URS cost model, the following two special cases identified from preliminary screening of the data were handled as indicated below:

1. The number of workers per facility in a given job was evaluated. Often, many very small facilities and a few small facilities averaged less than 1 worker per facility (whether

overexposed or not) in a particular at-risk job. This likely resulted from the fact that at very small facilities, one worker may perform several jobs. In these instances, the binomial distribution was not used for the URS cost estimate. URS calculated the total number of overexposed workers for this job in the appropriate facility size based on OSHA's estimate of the percentage of workers who were overexposed. Example: for a given industry, it was found that there were 500 very small facilities, and the number of workers in the forming production job category came to a total of only 100 industry-wide, or 0.2 forming production workers per facility. OSHA estimated that 50% of forming production workers in this industry were exposed above the proposed PEL of 50 $\mu g/m^3$. This would mean a total of 50 overexposed forming production workers spread across 500 facilities. It was assumed that each of these workers would be at a different facility, and that 50 set of engineering control packages would be needed, one for each of the 50 overexposed workers.

2. Preliminary screening revealed that sometimes a small or very small facility averaged at least one or more workers per facility in a given job, but the average facility would contain less than one overexposed worker in that job category. In this case, URS ran a binomial distribution as if the average was a minimum of 1 overexposed worker per facility, since BD's will not work unless the item being distributed (overexposed workers) is a positive whole number. URS then multiplied the number of facilities for each non-zero integer by the actual fraction of overexposed workers that was the average

for that job category at facilities of that size in that industry, to reduce the number of controls required. This would make the controls conform to the total number of overexposed workers present at these facilities. Example: very small facilities in a particular industry have an average of 2 workers in a particular job category, and OSHA estimated that 25% of these workers are overexposed. The average number of overexposed workers per very small facility in this example is therefore 0.5 workers. URS would assume 1 overexposed worker per facility to generate the binomial distribution, then take the number of facilities having either 1 or 2 overexposed workers and multiply them times 0.5 as a correction factor, to account for there being fewer than one overexposed worker per facility. Therefore the number of facilities requiring controls would in this case be approximately half of the number indicated by the binomial distribution.

B. Generating the Binomial Distributions

Aside from the two special cases listed above, other BDs were generated in the following manner. The total number of facilities and total number of workers for each at-risk job and facility size within each industry were known or calculated based on the OSHA data. URS used OSHA's estimated average percentage of overexposed workers as the basis for the normal probable distribution. URS used the binomial distribution function in Excel to set up the BDs based on these parameters. If the BD generated from the above conditions were represented graphically, the "x" axis would represent the number of *overexposed* workers per facility, and would extend out to a maximum that is the average *total* number of workers (including those not overexposed) in that job per facility. The "y" axis would be the percentage of the total number of facilities in that size range. Data points along the BD curve therefore indicate the percentage "y" of facilities that have "x" number of overexposed workers. The apex of the distribution curve (the highest percentage of facilities) would center at the average of the OSHA exposure estimate. (i.e. If there were an average of 12 workers per facility, and OSHA reported that 25% were over the 50 PEL, then the apex of the curve above the "x" axis would occur at 3 workers (25% of 12 workers).) This apex would represent the largest percentage of facilities. Workers to the left of the apex would be in facilities that contain a lower number of overexposed workers, workers to the right would be in facilities that contain a higher number of overexposed workers.

URS then used the BD to obtain the number of overexposed workers present in each quartile of the curve. Regardless of the location of the apex of the BD curve, the first quartile of the graph contains overexposed workers in facilities where the exposure rate of the workers is < or equal to 25% of the total number of workers in that job. Overexposed workers in the second quartile are in facilities where 26-50% of the workers are overexposed. The 3rd and 4th quartiles contain the workers at facilities where the worker overexposure is 51-75% and 76-100%, respectively.

C. A Number of Decisions Were Made Based on the Binomial Distributions

First, URS determined the worker capacity of the control(s) used by OSHA for the appropriate job description. Except in cases where an error was detected (as specifically described in URS's Critique of February 7, 2014), and in the case of very small facilities where second shifts were most often not used (the OSHA worker capacity per control was based on two shifts), the URS estimates assumed the same worker capacity as in the OSHA cost model. If the OSHA control covered four workers, URS used four workers; if OSHA used one, two, five, or eight workers per control, URS used the same. In fact, the OSHA cost model employed controls that could service exactly four workers 73.4% of the time, so in the great majority of cases, four workers was the worker capacity for the controls.

URS then examined the BD quartiles to make three decisions as to how many controls would actually be required for a facility of a particular size as follows:

1. For all overexposed workers found to be in the first quartile of exposure (< or equal to 25% of total workers exposed over the PEL) in the BD, URS assumed that over-exposure was only occasional and widely separated. Therefore, for each control having a capacity of four workers (the usual unit used in the OSHA model), only one worker (25% of the total workers covered by the control) would actually be an *overexposed* worker. Therefore, in the URS cost model, one control would be required for each *overexposed* worker in this quartile. (If the control capacity was four workers, then up to four workers could be serviced by a single control, but only one would be an overexposed worker.)

2. For all overexposed workers determined to be in the second quartile of exposure by the BD (overexposure rate ranging from 26-50% of total workers over the PEL), URS

assumed that some aggregation of overexposed workers would occur (i.e., workers over the PEL would be more likely to be at the same facility and/or in close proximity to each other). Therefore, URS assumed that each engineering control would cover *overexposed* workers amounting to half (50%) of the total worker capacity of the control. Thus, each control intended to cover four workers would actually service two *overexposed* workers; each control intended to cover eight workers would service up to 4 *overexposed* workers. Note that this URS decision exceeds the probability estimate based on the exposure range, which never exceeds 50%, but could be as low as 26%.

3. For all workers in the 3rd and 4th Quartile (exposure rates range from 51 up to 100%), URS assumed that the engineering controls could be filled up to 100% capacity with overexposed workers. However, URS also assumed that if more than 50% of the workers for a given job were currently overexposed at a facility, then the controls in place were wholly insufficient (see URS's Critique of February 7, 2014), and that a new set of controls would be required to cover all workers (for that job) at those facilities determined to be in this exposure range by the BD.

D. Hypothetical Example of a BD as used by URS and Discussion of the Information Obtained

The following describes a simplified, illustrative example of a hypothetical BD curve. (See the graph and charts on the last page of this report.) The first chart for the hypothetical example gives the relevant data used to calculate the parameters for the BD. This hypothetical example is for a job category called "mixer operators" with "Foundries" being the industrial category; the facility size depicted is the "small" OSHA category. The total number of workers in this job category for all foundry facilities of this size is 64 workers, and URS has set the total number of facilities at 16. That means each facility has an average of four mixer operators. (URS selected this value so that each worker coincides exactly with one quartile of the graph, to help simplify this illustration.) OSHA's estimated overexposure rate is 50%, so on average, 32 of these workers are overexposed, which is an average of two overexposed workers per facility. The hypothetical control selected by OSHA had a coverage capacity of four workers, and URS assumed the same capacity, which in this simple example could exactly cover all four workers at each facility.

URS employed the BD function in Excel to obtain a probable distribution of overexposed workers at these facilities. In the example, the average number of overexposed workers at a facility would be 2 workers (50%), and this will be the most frequent occurrence (the apex of the curve). However, individual facilities in this example could have 0, 1, 2, 3, or 4 overexposed workers based on probable distributions.

The second chart on the graph page divides the workers into quartiles, which for this example happens to coincide with each of the four workers at an average plant. The first two quartiles show only overexposed workers. The last two quartiles show total number of workers, because the assumption (stated above) in the URS model is that all workers would have to be covered at facilities where the exposure level is greater than 50% for a given job.

The graph on this last page shows how the overexposed workers are distributed among the facilities. The actual BD function calculates the percentage of the total number of facilities within each quartile. However, for illustrative purposes, the "y" axis for this graph (and also the third chart) has been converted to the rounded number of facilities for this particular case. (i.e., of the 16 facilities in this example, 37.5%, or six facilities contain two overexposed workers each.)

- In the first quartile, where the overexposure percentage range is 0-25%, there are four overexposed workers. Since the exposure rate is low, these workers are assumed to be scattered, either within the same facility (for larger facilities) or (as in this case) among different facilities, so that each overexposed worker gets his own control, for a total of four engineering controls.
- In the second quartile with 26-50% overexposure, the URS model assumes that a significant number of these workers will be at the same facility and together, so each control can contain 50% of its capacity in overexposed workers. For this example, one control can service two overexposed workers. There are six facilities with an estimated 12 overexposed workers in this quartile, so six controls would be required.
- In the third and fourth quartiles, the percentage of overexposed workers exceeds 50%. As stated above, the URS cost model allows controls in these quartiles to contain the

maximum of four overexposed workers. However, the URS model also assumes that all workers in a given job would require a control when the overexposure rate is greater than 50%. Therefore, sixteen workers requiring controls (at four facilities) would be in the 3rd quartile, and another four requiring controls (at one facility) are in the 4th quartile. The total number of controls (each with a capacity of four workers) required for these two quartiles combined is five.

This example shows that when worker distributions are considered, more controls are necessary than were assumed under the OSHA cost model. The OSHA model would require only 8 controls for all the mixer operators in this entire size category of this particular industry, while the URS model, based on the BD approach, would require 15. This is because OSHA's model unrealistically assumes that all 32 overexposed employees would be concentrated at only 8 facilities, containing four overexposed workers at each facility, so that each engineering control package would protect four overexposed workers (i.e., workers whose exposure otherwise exceeds the proposed PEL of 50 $\mu g/m^3$) and no workers whose exposure is below the proposed PEL. This implies that the exposures of the other 32 workers at the other eight facilities will all be under 50 $\mu g/m^3$, so that none of those facilities will need any controls. That assumption is unrealistic. The binomial distribution demonstrates that at least some overexposed workers will likely be present at 15 of the 16 facilities in this size category for this industry, and that each of those 15 facilities will require one control package.

The ratio of URS cost estimates to OSHA cost estimates varies depending on the size of the facilities, the average number of workers per facility, OSHA's estimated overexposure rate for the job category at issue, and the number of workers that can be serviced by each engineering control package. However, a URS test found that for the proposed rule as a whole, using the binomial distributions increased the number of control packages (and the resulting engineering control costs) by slightly less than a factor of three. Costs in the URS model were relatively higher on a per worker basis than OSHA's estimates under the following conditions:

- The URS estimates are higher for smaller facilities, because very few, if any small or very small facilities contained as many as four overexposed workers, and many contained less than one overexposed worker on average.
- The URS estimates are higher for facilities that have fewer workers in the job category, for the same reasons as in the above bullet.
- The URS estimates are higher for job categories where there is a lower frequency of overexposures. If only 20% of the workers are overexposed, then the apex of the curve will reside in the first quartile, where overexposed workers are scattered, and only one is covered per control.
- The URS estimates are higher when OSHA's designated engineering controls have the capacity to cover a larger number of workers. When a control can cover just one overexposed worker, there should be no difference between the OSHA and URS models due to the binomial distribution. (Obviously, in situations where URS used a larger control, a difference would be evident.) However, for OSHA controls that cover four or

eight overexposed workers, it becomes increasingly unlikely that that many overexposed workers would all be located together in the proximity of the control, or in many cases, even at the same facility.

VI. Binomial Distributions Are not the Only Factor in the URS Engineering Cost Estimates

Binomial distributions are not the only, or even the major reason for the difference between the OSHA and URS cost estimates for the proposed crystalline silica rule. Making the BD distribution corrections alone accounts for about a 3-fold cost increase over OSHA's engineering control cost estimates. The URS incremental cost estimate for engineering controls under the proposed rule (for the 19 general industrial sectors included in the URS analysis) is $3.9 billion annually, which is more than 50 times higher than OSHA's incremental cost estimate of $72 million annually. The following is a partial list of URS correction factors other than the BDs that also had a significant impact on the final cost estimate. URS's Critique of February 7, 2014 contains complete explanations of the reasoning behind each of these corrections and shows exactly what was done.

- OSHA's cost model did not always include all of the controls listed in the technological feasibility sections of the PEA.
- In the technological feasibility assessments of the PEA, types of controls were listed, but the PEA did not provide size or Local Exhaust Ventilation (LEV) cfm estimates.

- Most LEV controls used in OSHA's cost model did not even conform to the minimum face velocities required in the ACGIH manual for the high energy dispersion of respirable dust common in most target industries. Such controls certainly would not be adequate to meet the proposed PEL of 50 $\mu g/m^3$. URS calculated that, at a minimum, the cfm for every such OSHA control needed to be doubled in order to attempt to achieve the 50 $\mu g/m^3$ PEL.
- URS along with industry representatives found many instances where the size and cfm of the LEV controls used in OSHA's cost model were wholly inadequate to achieve a PEL of 50 $\mu g/m^3$ for specific industrial applications. URS therefore made such controls larger and increased the cfm in these specific cases, based on industry suggestions.
- OSHA assumed that exactly the same controls used to meet the current general industry PEL of 100 $\mu g/m^3$ would also be sufficient to meet the proposed PEL of 50 $\mu g/m^3$, when in fact much larger or more numerous controls would be needed (as discussed in previous bullets). OSHA then subtracted the *total* engineering control cost for every worker currently exposed above 100 $\mu g/m^3$ to arrive at an *incremental* cost of engineering controls that is neither accurate nor incremental.
- OSHA at times assigned the most expensive engineering controls to achieving the current PEL of 100 $\mu g/m^3$, but assumed the costs of those controls would not have to be incurred to achieve the proposed PEL of 50 $\mu g/m^3$.

- OSHA underestimated full installation and air balancing costs associated with the additional LEV required. URS increased the OSHA cost estimate of $12.83 per cfm to $22.00 per cfm for LEV, based on EPA estimates for dust collection and baghouses.
- OSHA did not account for the switch to the ISO/CEN definition of respirable dust in its cost model. URS estimated that approximately 20% more respirable dust would be collected using ISO/CEN criteria, effectively increasing the percentage of workers whose current exposures exceed the proposed PEL of 50 $\mu g/m^3$.

Attachment 1

Hypothetical Small Foundry, Mixer Operators

Item	Value
Total Workers in job	64
Overexposed workers in job	32
Number of facilities	16
Workers per facility	4
OSHA estimated probability of being exposed over the 50 PEL	50%
Maximum number of workers covered by one control	4

Quartile	Quartile range of %over PEL	%of total facilities	Facilities	Workers Requiring Controls	#of Controls	
1st	0-25%	31.25%	5	4	4	1 control per 1 overexposed worker
2nd	26-50%	37.50%	6	12	6	1 control per 2 overexposed workers
3rd	51-75%	25.00%	4	16	4	1 control per 4 total workers
4th	76-100%	6.25%	1	4	1	1 control per 4 total workers
		OSHA controls needed :		**8**		
		URS controls needed:		**15**		

Distribution of Overexposed Workers by Facility (from graph below)

#of workers exposed over proposed PEL	% of facilities	#of facilities (rounded)
0	6.25%	1
1	25.00%	4
2	37.50%	6
3	25.00%	4
4	6.25%	1