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The Efficiency of Protective Hoods Used by Sandblasters to Reduce Silica Dust Exposure

BEHZAD SAMIMI, Ph.D., ARTHUR NEILSON, B.Sc., HANS WEILL, M.D. and MORTON ZISKIND, M.D.

Department of Medicine, Pulmonary Diseases Section, Tulane University School of Medicine, New Orleans, Louisiana

Several types of respiratory protective hoods used by sandblasters were investigated in two steel fabrication yards. MSA Gravimetric Dust Samplers were used to collect respirable dust samples outside and inside hoods during sandblasting. Colorimetric and x-ray diffraction techniques were applied to the samples for free-silica determination. The majority of the sandblasters, who wore various types of air-supplied hoods, were exposed to an average level of silica dust several times higher than the TLV. Sandblasters wearing non-air-supplied hoods were at the greatest risk. Modern well maintained and properly worn air-supplied hoods offered fair protection during sandblasting periods, but the concentration of suspended respirable dust in ambient air during non-blasting intervals exceeded the TLV by several times.

Introduction

SANDBLASTING WAS INTRODUCED INTO INDUSTRY in 1904 and is widely used in shipbuilding, oil rig and platform manufacture and maintenance and in other metal industries. It is a method by which a stream of silica sand is projected by compressed air to prepare a clean surface suitable for subsequent treatment. Large quantities of finely fragmented respirable particles of silica are created, which when inhaled, are responsible for accelerated silicosis in sandblasters and their associated workers. Exposure to respirable silica is intensified when blasting takes place in an enclosed area and is particularly dangerous for unprotected individuals.

Silicosis in sandblasters runs a rapidly progressive course in which the appearance of roentgenographic and functional abnormalities encountered in chronic forms of the disease is accelerated and evidence of autoimmune disturbance is common. Superimposed infection by mycobacteria and fungi is a frequent occurrence. The average duration of exposure in fatal sandblaster's silicosis is ten years. Small series of cases and individual patients have been reported with duration of exposure prior to symptoms less than three years. This rapidly developing disease is often called acute silicosis. In the United Kingdom, the high morbidity and early fatality associated with sandblasting led to its prohibition in 1949.[1]

An additional danger in sandblasting is the impact of the abrasive material as it rebounds off the blasting surface. Strong helmets, which protect head and shoulders and adequate respiratory protection, are needed to reduce the hazards of silica exposure.[2] In this study, which has been carried out in two fabrication yards, (called Yard 1 and Yard 2) the efficiency of several hoods used by sandblasters was examined.

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Requests for reprints should be addressed to Morton M. Ziskind, M.D., 1430 Tulane Avenue, New Orleans, Louisiana 70112.

Trade names used in this paper are for identification only and do not constitute either endorsement or disapproval of the devices.

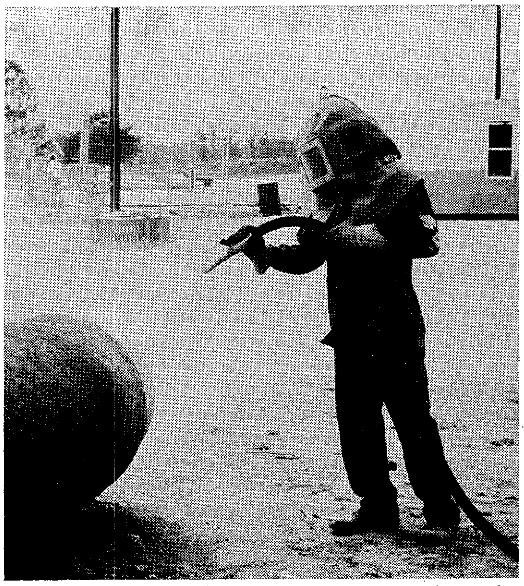

Figure 1. A sandblaster wearing regular (non-air-supplied) hood.

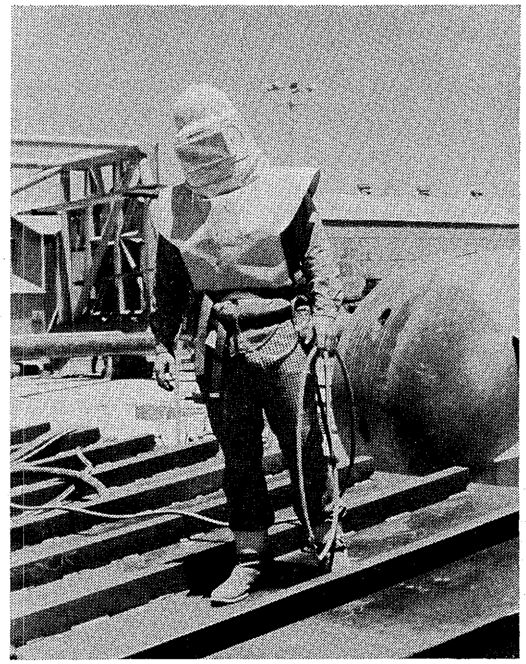

Figure 2. A sandblaster wearing Bullard 77-D (DH) Air-Supplied Hood is carrying two gravimetric samplers, one for sampling inside and the other for sampling outside the hood.

Materials and Methods

1. *Non-air-supplied hood:* This is the so-called regular hood, which does not have an air line. It lacks underarm or shoulder straps (Figure 1) and the cape of the hood is loose. This hood was used mainly in Yard 1. We were informed that sandblasters wearing these hoods were supplied with Wilson Dust Respirators when they began to work in Yard 1 but in many instances did not wear them under the hoods.

2. *Pulmosan air-supplied hood:* This hood is equipped with an air line attached to a compressed air tank. It is made of a strong canvas fabric and is equipped with two underarm straps. Three to four hoods are usually fed from a single air manifold. The air flow through the hood is significantly affected by the number of hoods connected to the air manifold, the size of the orifice of the air valve (controlled by sandblaster) and the length and diameter of the air line. An air pressure gauge is connected to the air manifold to indicate the air pressure transmitted to the hoods, but the air pressure within each hood is unknown. The air pressure in the manifold is about four pounds per square inch. The underarm straps should be fastened while blasting, but during the summer of 1972, it was observed that the straps were left unfastened. This type of hood was mainly used in Yard 2. A dust respirator is usually not worn beneath this hood.

3. *Bullard 77-D (also 77-DH) air-supplied hoods:* This is a protective hood which was recently issued to sandblasters in Yard 2 (Figure 2). The upper part of the hood consists of a relatively large hard hat made of plastic with a front view window. The cape consists of an outer layer coated with nylon and an inner layer of stretchable cloth with comfortable knitted neck piece fastened by a zipper to prevent the dust from entering the hood. Air is supplied to the hood in the same manner as in Pulmosan hoods. Positive air pressure is maintained in the hoods by air flowing at a pressure of 3-4 psi from the air manifold. Air flow inside the hood varies from 6-15 cubic feet

Figure 3. An old fashioned and worn-out air-supplied hood worn by a sandblaster.

per minute (cfm) with a noise level, inside the hood, of 72-76 decibels,[3] (according to the company's manual). In Yard 2, the sandblasters complained of the intensity of noise inside the hoods and tried to limit the noise by reducing air flow to the lowest rates possible.

4. *Other types of hoods:* A small number of other types of air-supplied hoods were occasionally used in Yard 1 by sandblasters (Figure 3). The hoods were older models and some were worn-out. Information concerning the manufacturer, model and other specifications was not available.

Analytical Methods

To study the efficiency of protective hoods, MSA Gravimetric Respirable Samplers were employed. Millipore 0.8 μm pore size hydrophobic filters with a 37 mm diameter were used for collecting the samples of respirable dust.[4-7] The determination of the percentage of silica in the samples was made either by the colorimetric method.[8,9] or x-ray diffraction.[10,11]

Fifty-one samples of respirable dust were collected within the breathing zone inside various types of hoods. Nineteen respirable dust samples were also collected with samplers attached at the sandblaster's chest outside the hood.

For proper comparison, the samples were classified into three operational categories: slow, moderate and busy representing up to 2½ hours, 2½-5 hours and over 5 hours of blasting respectively.

For sampling outside the hoods, the cyclones were hooked to the sandblaster's chest. These samples were collected continuously during the working day, during blasting and non-blasting intervals and represented the potential time-averaged concentration of respirable dust in ambient air at the blasting site.

For sampling inside the hoods, the cyclones were hooked either to the collar of the workers (in case of Pulmosan hoods) or were attached in vertical position to the inner layer of the hood (in case of Bullard 77-D hoods) close to sandblasters' mouth.

Various procedures were used for dust sampling:

1. For the study of Bullard 77-D (DH) air-supplied hoods, two samplers were attached within the sandblaster's breathing zone. Sampler No. 1, which was attached inside the hood, operated only during actual sandblasting periods. The cyclone of the other sampler (No. 2) was attached to the sandblaster's clothing near his breathing zone and sampled only during the non-blasting periods. Each sandblaster was instructed to turn pump No. 1 on immediately after putting on his hood; at the same time pump No. 2 was turned off. When blasting ceased, he was to turn pump No. 1 off and activate pump No. 2 before removing the hood.

The same instructions were observed during the entire sampling period. The workers were supervised by the investigators throughout the sampling period to assure the proper operation of the samplers. This procedure made it possible to collect separate dust samples during sandblasting and non-blasting periods.

In another sampling group, the cyclones were removed from the sampling line and the filter holders were attached inside the hoods. These samplers operated continuously during the working day collecting "total dust" during both the sandblasting (inside the hood) and non-blasting (ambient air) periods.

2. In the investigation of Pulmosan and other types of air-supplied hoods, the samplers operated continuously during the entire working period while sandblasters were engaged with blasting or other work. The samples collected measured the actual exposure of sandblasters to respirable silica dust throughout the day.

Results

Concentration of Respirable Dust Outside the Hoods

Nineteen gravimetric respirable dust samples were collected outside the hoods. Since the samples were collected continuously during the working period in blasting and non-blasting intervals, the results represent a time-averaged concentration of respirable dust in the ambient air at the blasting site. They do not indicate the concentrations during the actual blasting period which must have been much higher.

The results showed an average concentration of 2.0 (1.4-2.4), 6.9 (5.3-8.3) and 37.2 (16.8-53.4) milligrams of respirable dust per cubic meter of air (mg/m^3) for slow, moderate and busy operations respectively. The average percentage of free-silica was 67.4 (26.0-90.0), 54.5 (20.7-90.5) and 83.6 (65.2-100.0) for the three states of operational activity. The average concentration of respirable dust outside the hoods exceeded the Threshold Limit Value[12] (TLV) by 20.0 (5.5-21.4) times in slow, 34.5 (19.0-59.2) times in moderate and 372.8 (339.6-437.4) times in busy operations. These figures indicate a heavy concentration of respirable dust created at the blasting site.

Concentration of Dust Inside the Non-Air-Supplied Hoods

The time-averaged concentration of respirable dust within non-air-supplied hoods (also called regular hoods) was calculated for 23 samples collected continuously during the working hours as described earlier.

An average respirable dust concentration of 1.3 (0.5-2.1), 2.8 (2.3-3.5) and 11.0 (7.8-14.1) mg/m^3 was obtained for slow, moderate and busy operations respectively. The sandblasters were supposed to wear an approved dust respirator when using non-air-supplied hoods, but during the study it was observed that 35% of them either did not observe this precaution or did not have a dust respirator. The percentage of silica in these samples was 30.8 (6.0-68.0), 42.2 (13.4-64.0) and 70.3 (18.0-100.0) for slow, moderate and busy operations respectively. The average concentration of respirable dust samples exceeded the TLV by 4.3 (0.4-10.4) times in slow, 14.1 (3.6-23.3) times in moderate and 110.0 (15.5-119.7) times in busy operations. In only two of 23 samples was the respirable dust concentration lower than the TLV. These samples were obtained during a slow operation in which the blasting time was less than two and one-half hours of the total working period of eight hours.

Investigation of Pulmosan Air-Supplied Hoods

During the summer of 1972, gravimetric respirable samples collected inside two Pulmosan air-supplied hoods showed concentrations of 0.3, 2.6 (2.0-3.3) and 4.4 mg/m^3 for slow, moderate and busy operations respectively. It should be noted that the sandblasters had not fastened the underarm straps of their hoods, because of the hot weather and that the capes of the hoods were loose. Sampling was continuous during the working hours in blasting and non-blasting intervals. The results therefore express the actual exposure of sandblasters to respirable silica dust during the working day. The percentage of silica in these samples were 54.8, 77.2 (75.0-79.4) and 42.3 for slow, moderate and busy operations. The average concentration of respirable dust exceeded the TLV by 1.5 times in slow, 26.0 (16.4-25.2) times in moderate and 22.0 times in busy operations.

When eight samples were collected, during spring of 1973, inside Pulmosan air-supplied hoods, the sandblasters were instructed by the employer to fasten the underarm straps of their hoods. These samples were collected continuously during the working hours as described above. There was an average respirable dust concentration of 0.3 (0-2-0.5) mg/m^3. All of these samples were in the "slow operation" category (less than 2½ hours blasting time during the working day). The average percentage of free silica in the samples was 33.4 (15.6-87.5). Fifty percent of samples exceeded the calculated TLV (1.0); the range extended from 1.2 to 3.3 times the TLV. The ratio of concentration to TLV in samples below the TLV varied from 0.5 to 0.8.

Although these results did not show that the Pulmosan hoods were totally inffective in preventing the respirable dust from entering the hoods, they clearly indicated that even in a slow operation (less than 2½ hours blasting) a significant number of sandblasters were exposed to amounts of respirable silica dust up to 3.3 times the TLV during the working day. Both the number of workers excessively exposed and the degree of exposure increased as the activity of the sandblasting operation was extended.

The excessive exposure of sandblasters to silica dust may have been caused by any one or combination of the following factors:

(a) Since the personal gravimetric samples were collected continuously during the working hours (from inside the hoods during blasting and from ambient air during non-blasting periods), a considerable portion of the respirable dust might have been picked up during non-blasting periods from the ambient air due to the presence of suspended dust transmitted from nearby sandblasting sites.

(b) Persistence of suspended dust in the air at the blasting site after removal of hoods at the cessation of blasting.

(c) Defects (cracks, holes) and misfits of hoods.

(d) Defects in air-supplying and air-purifying equipment such as faulty filters.

Investigation of Miscellaneous Hoods

Calculations based upon samples collected continuously during working days from workers wearing air-supplied hoods other than Pulmosan and Bullard 77-D showed an average respirable dust concentration of 1.2 (1.5-1.0) and 7.4 (2.2-14.8) mg/m^3 for slow and busy operations respectively; no samples were collected in moderate operations. The average percentage of silica was 19.6 (12.5-26.6) and 68.0 (39.0-100.0) for slow and busy operations respectively. The concentration of respirable dust in these samples exceeded the calculated TLV in all cases. The average dust concentration exceeded the average TLV (using the average free silica percent) by 2.4 (1.4-4.2) times in slow and 74.0 (22.3-60.6) times in busy operations. All of the hoods, as mentioned earlier, were old fashioned and were usually worn-out and/or defective.

Examination of Bullard 77-D Air-Supplied Hoods

The samplers inside the Bullard 77-D hoods operated only during sandblasting periods. Calculations based upon four samples showed an average dust concentration of 0.4 (0.2-0.6) mg/m.^{3} The percentage of silica was quite low in these samples ranging from 1.0% to 15.0% with an average of 5.7% and the concentration of respirable dust fell below the calculated TLVs. The ratio of concentration to TLV ranged from 0.05 to 0.70 with an average of 0.30. Although the amounts of respirable dust collected on the filters inside the Bullard 77-D hoods were relatively small (0.05 to 0.2 mg), the low percentage of silica in these samples raises the question of the identity of the non-silica portion of the samples. No additional analyses were performed on the samples to identitfy the non-silica particulate matter, but we may assume that the particulate matter was brought onto the filters from any one or combination of the following sources:

a) Penetration of rust, oil, grit, mist, fumes, and other particulate matter through the air compressing system because of a defective filter or malfunction of air purifying system.

(b) Penetration of more submicronic non-silica particles through the hood than silica particles. The latter are relatively larger in size and form a smaller fraction of particles within the submicronic size range; the percentage of silica in particles 0.4-0.6 μm size (stage #7 of Andersen Non-Viable Sampler) was 16.0% at the blasting site.[11]

(c) Droplets and nuclei produced by coughing and/or sneezing of the workers inside the hood.

Exposure of Sandblasters to Silica Dust During Non-Blasting Period

Personal gravimetric respirable samples were collected in the breathing zone of the same sandblasters on the same days but only during non-blasting periods after Bullard 77-D hoods had been removed. An average respirable dust concentration of 0.8 (0.4-1.3) mg/m^3 was computed for the non-blasting periods. The percentage of silica in the samples varied from 11.9 to 48.9% with an average of 32.0%. The concentration of respirable dust exceeded the TLV in three out of four cases (75%) with an average ratio of 2.7 (0.8-4.3) times the TLV. These sandblasters were usually engaged in related work such as painting in the vicinity of other blasting sites for most of the non-blasting periods and wore no respiratory protective devices.

Overall Exposure of Sandblasters Wearing Bullard 77-D Hoods to Silica Dust

The average respirable dust concentration of 0.8 (0.3-1.3) mg/m^3 was obtained as the overall time-averaged exposure of sandblasters wearing Bullard 77-D hoods, to respirable silica dust. The percentage of free silica in the samples varied from 8.5% to 44.3% with an average of 25.5%. The concentration of respirable dust exceeded the TLV with an average ratio of 2.2 (0.4-6.1) times the TLV. Of four workers studied, the concentration of respirable dust did not exceed the TLV in only one case in which the ratio of concentration to TLV was 0.4.

Two total dust samples collected continuously during working hours (from inside the hoods during blasting and from ambient air during non-blasting periods) showed total dust concentrations of 3.5 and 3.3 (average = 3.4) mg/m.^{3} The percentage of free silica in these two samples was 80.9% and 51.8% (average = 66.3%). The average concentration of total dust exceeded the corresponding TLV with a ratio of 7.9 times the TLV.

The results of the various hood dust sampling studies are summarized in Table I and Figures 4 and 5.

Discussion and Conclusions

The results of this study indicate that the protection of sandblasters exposed to high concentrations of respirable silica dust has not yet been satisfactorily achieved. Sandblasters wearing non-air-supplied hoods were at the highest risk of exposure to silica dust. Thirty-five percent of these workers did not wear dust respirators under their hoods. The other 65% wore respirators but there was no regular maintenance and/or inspection of valves, filters and fitting of the respirators.

The Bullard 77-D air-supplied hood and the well maintained and properly worn Pulmosan air-supplied hood offered fair respiratory protection during the blasting period, but the average concentration of suspended dust in the ambient air inhaled by the same sandblasters during the unhooded non-blasting period exceeded the TLV by several times.

TABLE 1
Mean Concentration of Dust in mg/m^3 of Air, Mean Percentage of Silica, TLV and the Ratio of Conc./TLV in Personal Gravimetric Samples Collected at Sandblasters Breathing Zone Wearing Various Types of Respiratory Protective Hoods

Types of Samples and/or Types of Hoods	Slow Operation (up to 2½ hr sandblasting)					Moderate Operation (2½ to 5 hr sandblasting)					Busy Operation (5 hr up sandblasting)				
	No. samples	Mean Conc. (mg/m^3)	Mean Silica (%)	TLV	Ratio Conc./TLV	No. samples	Mean Conc. (mg/m^3)	Mean Silica (%)	TLV	Ratio Conc./TLV	No. samples	Mean Conc. (mg/m^3)	Mean Silica (%)	TLV	Ratio Conc./TLV
Respirable, Continuous, Outside Hoods	6	2.0	67.4	0.1	20.0	6	6.9	54.5	0.2	34.5	7	37.2	83.6	0.1	372.0
*Respirable, Continuous, Inside Non-Air Supplied Hoods	12	1.3	30.8	0.3	4.3	7	2.8	42.2	0.2	14.1	4	11.0	70.3	0.1	110.0
†Respirable, Continuous, Pulmosan Air Supplied Hoods	1	0.3	54.8	0.2	1.5	2	2.6	77.2	0.1	26.0	1	4.4	42.3	0.2	22.0
Respirable, Continuous, Inside Various Air Supplied Hoods	2	1.2	29.6	0.5	2.4	—	—	—	—	—	4	7.4	68.0	0.1	74.0
‡Respirable, Continuous, Pulmosan Air Supplied Hoods	8	0.3	33.4	0.3	1.0	—	—	—	—	—	—	—	—	—	—
Respirable, Inside Bullard 77-D Air Supplied Hood															
Blasting Only	4	0.4	5.7	1.3	0.3	—	—	—	—	—	—	—	—	—	—
Non-Blasting	4	0.8	32.0	0.3	2.7	—	—	—	—	—	—	—	—	—	—
Daily Exposure	4	0.8	25.5	0.4	2.0	—	—	—	—	—	—	—	—	—	—
Total Dust, Continuous, Bullard 77-D	2	3.4	66.3	0.4	8.5	—	—	—	—	—	—	—	—	—	—

*35& of sandblasters did not wear respirator under hoods. †Underarm straps unfastened.
‡Underarm straps fastened.

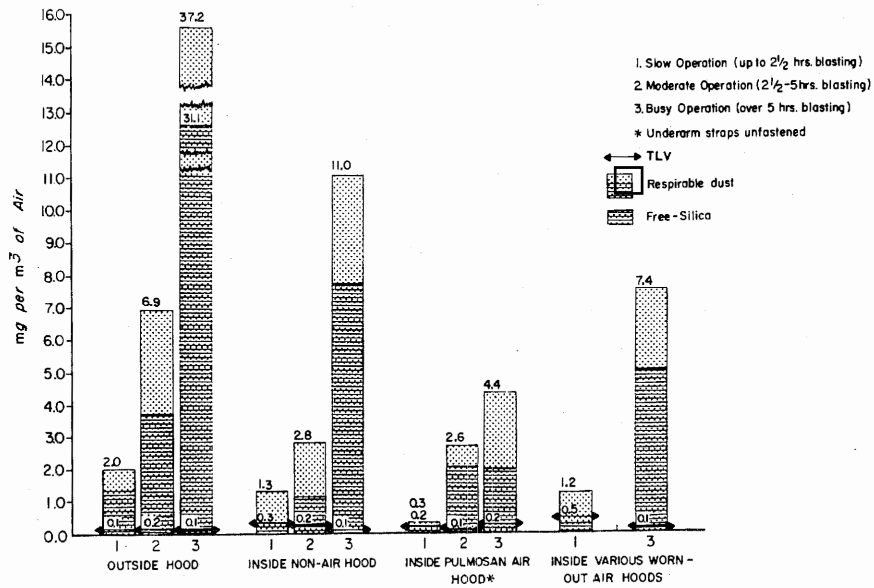

Figure 4. Comparison of mean concentration of respirable dust in mg/m^3 of air, fraction of free-silica and TLV in personal gravimetric samples collected outside hoods and inside various types of hoods.

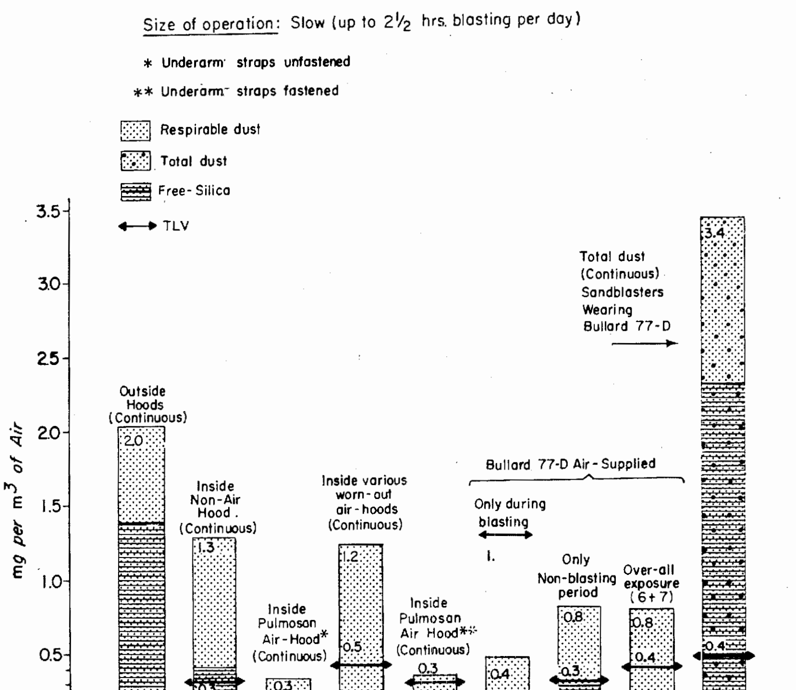

Figure 5. Comparison of mean concentration of dust in mg/m^3 of air, fraction of free-silica and TLV, in personal gravimetric samples collected at the breathing zone of sandblasters wearing various types of protective hoods.

It must be concluded that the majority of sandblasters, wearing various types of air-supplied hoods, were exposed to an average level of silica dust several times greater than the TLV. This was the result of wearing worn-out and defective hoods, faulty or careless operations and the presence of suspended silica dust transmitted from adjacent blasting sites during the non-blasting periods when sandblasters were unhooded.

Our observations demonstrate that the use of a modern air-supplied hood alone cannot adequately protect the sandblaster from the hazard of silica dust unless he learns the proper use and maintenance of his hood, avoids careless or faulty operations and wears a dust respirator at all times while he is not blasting. Regular supervision of the workers, maintenance and repair of protective devices and effective dust suppression measures are also required.

Efforts should be made to substitute silica sand with other abrasive materials, low in free silica. Such silica substitutes as Saf-T Blast and Stan-Blast are currently used in many shipyards. Further research for better and safer methods of blasting is necessary.

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Supplemental Documentation of Threshold Limit Values

The American Conference of Governmental Industrial Hygienists has announced that *Supplemental Documentation to the Third Edition of the Documentation of Threshold Limit Values (1971)* is now available. This supplement covers values adopted from the years 1971 through 1973. Copies, at a cost of $2.00 each, are available from the American Conference of Governmental Industrial Hygienists, P.O. Box 1937, Cincinnati, Ohio 45201.