ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 4-1
File 724-31

10 September 1945

1. PROJECT NO. 4: Dust Exposure in Armored Vehicles. Final report on Sub-Project 4-1, Determination of Dust-Loads and Characteristics of Dusts Encountered in Operation of Armored Vehicles.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNCHD, dated September 24, 1942.

b. Purpose - To determine the characteristics and concentration of dust encountered by armored personnel, with particular reference to the silicosis problem.

2. DISCUSSION: Dust concentrations representing a wide variety of operating conditions and the free silica content of the respirable portions of dusts from operating areas have been determined. These findings are considered in relation to the possible silicosis hazard among armored personnel. Details are given in Appendix A.

3. CONCLUSIONS:

a. Owing to the low free silica content of the respirable dust, the flocculent nature of dust clouds and the limited duration of exposure, silicosis is unlikely in armored personnel as a result of their military operations.

b. Dust generated by armored vehicles under extreme conditions of operation causes temporary discomfort and interferes with effective operations.

4. RECOMMENDATIONS:

a. Every effort should be made to reduce the amount of dust generated by armored vehicles and development of a practical air cleaner for use with positive-pressure ventilation of the tank crew compartment should continue.

b. Dust protective goggles and expendable respirators should be provided for armored personnel when needed.

NOTE: The recommendations as set forth in this project have been concurred in by Hq. Armored Center and the President, AGF Board No. 2.

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Appendix w/table

APPENDIX

The dust concentrations to which armored personnel are exposed vary widely—from imperceptible levels to dense clouds which may reduce visibility to almost zero. Cloud concentration varies with type and dryness of the ground and with intensity of operation. The dust conditions at times constitute a great nuisance, cause temporary discomfort and interfere with operations; for these reasons every effort should be made to reduce the amount of dust generated by armored vehicles. Progress has been made in this connection through improvement in design and exhaust terminals and application of dust skirts and work is in progress by Ordnance on the development of practical air cleaners for crew-compartment ventilation systems of the positive-pressure type.

The purpose of the present report is to review the dust problem from the standpoint of the possible health hazard, with particular reference to silicosos as the dust disease of primary interest.

Silicosis is caused by the specific action of crystalline silicon dioxide (SiO_2) which has accumulated in the deep air spaces of the lungs as a result of prolonged exposure to dusty air containing fine particles of this material. The particles of SiO_2 in the air must be small enough to penetrate to the terminal air sacs of alveoli (less than 2 microns of 2/25000th inch in diameter, practically) and the rate of accumulation of SiO_2 in the lungs must exceed a certain minimum level in order to produce the disease. The period of exposure required to develop silicosis varies from months to years, depending upon the percentage of free silica, the fineness of the dust and the concentration to which the individual is exposed. Silicosis is an industrial disease, occurring chiefly among hard rock miners and stone cutters working in flint, granite and other rocks rich in quartz. Operations such as sand blasting, crushing, packaging and handling finely pulverized materials of high quartz content are also hazardous. Taking the granite cutting industry as a typical example, the conditions which lead to silicosis are: 35% free-silica in the stone, cutting processes which produced much extremely fine dust, dust concentrations generally above 50 million particles per cubic foot and, in many instances, well above 100 million, exposure of 10-20 years. A dust concentration of 10 million particles per cubic foot has been established as the maximum safe level for continuous exposure in this industry.

Not all industries in which quartz-containing dusts are produced have had serious silicosis problems. Foundry dust, for example, contains twice as much free silica as does granite dust but silicosis is relatively rare among foundry men. Silicosis has not been reported among farmers, tractor operators or earth excavators nor does it apparently occur among desert dwellers despite the high quartz content of most soils. One explanation for the apparent freedom from silicosis in these cases is that the free silica content of the dust is not uniformly distributed with respect to particle size, being concentrated in the larger particles. Thus, a total sample of foundry dust, for example, may contain 75% free silica whereas the portion of the sample smaller than 2 microns in diameter will contain as little as 5%. Since only the small particles penetrate to the alveoli it is evident that the hazard is not measured by the composition of the total sample. Another determining characteristic is the degree of dispersion, or its opposite, the degree of flocculation of the dust. Naturally occurring dusts

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(finely pulverized earth, natural sands, etc.) are not easily dispersed as separated particles. In the absence of fairly powerful disrupting forces, the finest particles remain attached to the larger ones in the dust cloud and the size of the flocculated material limits the depth of penetration into the lungs. Granite cutting processes evidently generate separate fine particles. Many foundry operations, on the other hand, merely throw material into the air without breaking up the flocculated masses. Similarly, earth excavation and the like do not really disperse separate particles.

The absence of specific lung damage in the cases cited is of significance in connection with the dust problem in armored vehicles since the nature of the dust and method of dispersion are probably similar. Further information on the nature and magnitude of dust exposures in armored vehicles is given below.

1. Dust Concentrations - Owing to the wide variety of conditions of operation of armored vehicles, a representative measure of dust concentration to which personnel are exposed can be given only in terms of the range of concentrations encountered—from low to high activity. Data covering such a representative cross-section of activities are presented in Table 1. Most of the samples were collected by the Desert Warfare Board in the California Desert Training Center area and sent to the Laboratory for analysis.* The findings, as presented in Table 1, are separated into groups according to activity. Concentrations range from a minimum of 9.0 million to an extreme of 1500.0 million particles per cubic foot. During halts, in base camps and the like, representing relatively inactive periods, the dust concentration is generally below 50 million particles per cubic foot. At the other extreme, when tanks are travelling over dry, pulverized soil in close formation, the concentrations will be found in the hundreds of million. Clearly, the average daily exposure will vary widely, depending upon the pattern of activity. For days of generally low activity, it will be below 100 million; on days involving considerable convoy driving, the average will be greater than 100 million particles per cubic foot with short periods of extreme exposure during the day.

2. Particle Size - The particle size of the airborne dust raised by armored vehicles may be expected to vary with the fineness of the soil and the degree of attrition. The fineness of soils in the California desert area was found in a series of 38 samples to differ widely, as seen in the following tabulation:

Percent of Samples	Average Number of Particles Less Than 2 μ Per Gram of Soil
15.8	3.3×10^7
26.3	7.6×10^7
42.2	7.7×10^8
15.8	1.2×10^{10}

* The Desert Warfare Board letter report, Study of Silicosis Hazard in the Desert, 15 February 1944.

For the same degree of ground disturbance, one would expect greater atmospheric dust concentrations with the finer materials. Roughly, this proved to be the case with the samples listed in Table 1, but a clear relation was lost owing to the widely different degrees of activity. Samples of airborne dust collected over well-worn driving ranges at Fort Knox had a median particle size of approximately 1.0 μ, with 90% of the particles less than 3.0 μ. Air floated material from Arizona desert was somewhat smaller, median 0.75 μ and 90% below 2.5 μ. By weight, however, 90% or more of the material was larger than 3.0 μ in both cases. No information was obtained on the degree of flocculation in the dust clouds. As compared with industrial dusts, however, the settling rate of the dust was high, indicative of a relatively high degree of flocculation.

3. Free Silica Content* - The free silica content of the total sample of airborne dust collected in the California desert was found to be 36%. A sample of air-floated dust from the Arizona desert contained 18% free silica and a soil sample (screened through 325 mesh) from the California area had only 12% of quartz. In the case of the Arizona sample, containing 18% in the total sample, a fraction having an average particle size of 11.0 μ contained 25% free silica whereas a finer fraction (average 3.5 μ) showed 12%, or less than half as much. The average free silica content of the <2 μ fraction of 30 soil samples from the California desert was found to be 4.0%, ranging from 0.5 to 7.2%. The bulk of the remaining material was muscovite (mica) with smaller portions of acid soluble substances—calcite and halite. By chemical analysis, the <2 μ fractions were found to contain an average of 45.9% total silica (free and combined) whereas the total soil samples contained 62%. Since the silica content of muscovite is approximately 45%, it is evident that there could be very little free silica in the fine fraction.

4. Discussion - That armored personnel are, at times, exposed to extremely high dust concentrations is evident from Table 1. It is also evident, however, that the average daily concentration will vary widely, depending upon activity. Analysis of the <2 micron fractions of soil samples and of airborne samples indicate that the free silica content of the inspired dust is considerably below the level generally associated with development of silicosis. The flocculation of naturally-occurring pulverized material further limits the hazardous nature of the dust. Finally, the intermittent exposure of armored personnel to extreme dust concentrations, and the limited duration of exposure as compared with the years of daily contact with dust which precedes the development of silicosis in the mining and stone cutting industries markedly reduces the potential hazard. Despite the intermittent high dust concentrations, the finding of low content in the inspired dust, the flocculent nature of natural dusts and the limited exposure of armored personnel coupled with the favorable past experience of workers in somewhat similar dust conditions, generally precludes the likelihood of silicosis among armored personnel. This does not lessen the dust problem from the standpoint of temporary discomfort, or interference with operations. Efforts to reduce the dust produced by armored vehicles should continue and personal protection in the form of goggles and throw-away type respirators should be provided for use where needed.

* All results were obtained by X-ray analysis.

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TABLE 1

SUMMARY OF DUST CONCENTRATIONS TO WHICH ARMORED PERSONNEL ARE EXPOSED

OPERATIONS	Dust Concentrations Millions per Cubic Feet
1. Minimum Activity	
Airborn dust from Infantry camp; some from a road grader	9.0
Motor pool of a Medical Battalion; slow traffic	12.0
Bivouac area, Sunday afternoon, fresh breeze	15.4
Div. Surg. Tent, Hdqrs., Camp area	21.0
Air Base; planes taking off clean runway	21.7
Motor pool; ambulance driving in loose sand	22.5
Infantry training on Regt. parade ground	25.0
Ordnance unloading depot. Only three vehicles moving	27.7
Army truck road. Dust raised by staff car	27.7
Regimental area of Camp; normal traffic	29.0
Gas dump; no vehicular movement. Light to no breeze	29.2
Repeated passage of ¼-ton truck on tank trail	29.2
Railhead with light traffic; no convoy movements	31.0
Railhead with little traffic	32.0
Hdqrs. Camp; light traffic, fresh breeze	32.2
Ordnance unloading depot; heavy wind storm; no traffic	34.5
2. Moderate Activity	
Infantry column; 4 companies ahead of sampler	41.0
In convoy behind half-track	41.2
Asst. driver's seat; light tank midway of column of tanks (Co)	42.7
Evacuation Hospital Area; sandy surface, fresh breeze	44.2
Corner Tank Battalion Motor Pool; 16 tanks and 1 truck moved	48.7
Entrance to railhead; almost continuous truck traffic	51.0
Troops drilling--no traffic	51.7
3. High Activity	
Maneuver road; dust raised by staff car	75.0
Convoy of cargo trucks spaced 100 yards	79.0
From ¼-ton truck and wind-blown dust	104.0
Deliberate dust disturbance by ¼-ton truck	113.0
Convoy of trucks and towed 75 mm guns	131.0
Repeated passage of ¼-ton through pulverized silt bed	160.0
Alongside moving tank column	187.0
Inside tank following another 150 yards	219.0
Convoy of trucks passing by	250.0
Following ¼-ton truck	472.0
Thirty feet behind half-track; loose sand	750.0

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TABLE 1 (Cont'd)

OPERATIONS	Dust Concentrations Millions per Cubic Feet	
4. Extreme Activity (conditions deliberately fixed for maximum dustiness)		
Medium tank operating alone on dry driving range, 10 mph	145.0	
Medium tank operating alone on dry driving range, 10 mph	350.0	
One tank trailing another, dry driving range, 10 mph	610.0	
One tank trailing another, dry driving range, 10 mph	700.0	
End of column of 5 light tanks, 10-15 mph	250.0	
Five tanks in wedge, sampled in 6th center tank	450.0	
Midway of column of 6 light tanks, driving into wind	1250.0	
Midway of column of 6 light tanks, driving into wind	1500.0	
5. Summary	Average	Range
Minimum activity	25.0	9.0 to 35.0
Moderate activity	46.0	41.0 to 52.0
High activity	231.0	75.0 to 750.0
Extreme activity	620.0	145.0 to 1500.0

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