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# EXPERIMENTAL PNEUMOCONIOSIS OF SANDBLASTING SUBSTITUTES

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16. Abstract (Limit: 200 words): A study was conducted to evaluate the pulmonary fibrogenic potential of STANBLAST. This substance is a sand substitute extensively used in the State of Louisiana. The study was conducted using both normal and silicotic rats. Analysis indicated that STANBLAST was a complex silicate with trace amounts of several elements. STANBLAST granules were milled in a ball mill to produced dust for animal exposures. Male rats were exposed by inhalation in a horizontal laminar flow whole body exposure chamber to 10.8 milligrams of the STANBLAST dust/cubic meter, 6 hours a day, 5 days a week for 1 year. Rats were killed 6 to 24 months after the start of exposure, and lungs were examined. Histologic examinations of the exposed lungs revealed the presence of microgranulomas throughout the lung fields, suggesting the release of certain cellular modifying agents. The absence of any obvious collagen deposition within the structures of the surrounding interstitium indicated a lack of fibrogenic potential for STANBLAST under the conditions of this experiment. The lack of significant difference in hydroxyproline content of the lungs of exposed and control rats corroborated the histologic conclusions.

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## I. INTRODUCTION

The use of sandblasting to clean steel structures before applying paint is associated with severe and rapidly progressive silicosis. High morbidity and mortality rates have been noted within a few years of exposure. The U.S. Department of Labor has estimated the number of workers engaged in sandblasting to be about 78,000. Recognition of these hazards led to the prohibition of sandblasting in Europe and Australia; in the U.S., sand substitutes are now increasingly being used. They are derived from coal ash residues and slag from smelting furnaces, and are comprised of amorphous silicates of Fe, Al, Ca, Mg, and Ti. The free silica content is only 0.03%. The substitutes most widely used in the southern part of the United States are marketed under the trade names BLACK BEAUTY and STANBLAST.

The objective of the investigation presented in this report was to evaluate, in a rat model, the pulmonary fibrogenic potential of STANBLAST, a sand substitute that is extensively used in the State of Louisiana. Both normal and silicotic rats were used together with appropriate non-exposed controls. Exposure of silicotic rats to STANBLAST may delineate and predict the potential occupational hazard for workers with and without pre-existing silicosis, who are involved in the use of sand and its substitutes for abrasive blasting operations.

## II. MATERIALS AND METHODS

### A. Comminution of STANBLAST granules

The appropriate parameters for ball milling of STANBLAST granules to produce adequate amounts of dust in the particle size range suitable for animal exposure by inhalation, i.e., milling time, amount of grinding medium and amount of STANBLAST granules. The consistency of the particle size of the milled material was determined by the Andreasen pipette technique. The finest possible particle size distribution of the milled material was reached after 48 hours of milling. Further milling did not reduce the particle size significantly. The mass median diameter of the comminuted dust was 9.5 um with a geometric standard deviation of 2.1.

### B. Elemental Composition of STANBLAST granules

The elemental composition of STANBLAST was determined by the Inductively Coupled Plasma technique (ICP) for both the ganules and the comminuted material (1). The latter analysis was performed to determine whether the comminution procedure (ball milling of STANBLAST granules) utilized in this project is affecting the elemental composition of the material. The results are presented in Table 1. These data indicate that STANBLAST is a

complex silicate of Al, Fe, Ca, K, and Mg, with trace amounts of Na, Ba, Zn, Cr, and Cu. The data also indicate that there is no significant difference between the elemental composition of the original granules and the milled material, that is, the milling process did not result in contamination of the sand substitute.

C. Animal Exposure System

The exposure system consists of a horizontal laminar flow exposure chamber, 2 x 3 x 4 feet with four shelves, a Wright dust feed, aerosol sampling ports, chamber air flow metering and control devices, a HEPA filter holder with a pre-filter, supporting duct work and a blower. The exposure chamber is shown in Figure 1. To ensure that the size distribution of the STANBLAST dust delivered to the exposure chamber is within the respirable range, a dust elutriator with a cut-off diameter of 10 um (aerodynamic equivalent diameter) is connected to the outlet of the Wright dust feed. The dust generator and elutriator are presented in Figure 2. Pressure gauges, compressed air regulator, air flow metering devices, electrical switches for control of flow rates of compressed air and aerosol sampling lines as well as a stop-watch are mounted on a control panel for ease of operation and control of the exposure procedures. The control panel is displayed in Figure 3. The HEPA filter holder is constructed from 3/4 inch thick plywood sealed with a polyurethane paint. All construction joints are sealed with a silicon sealing compound. Because of the high cost of the HEPA filters, a pre-filter constructed from two disposable vacuum cleaner filter bags is used to extend the survive life of the HEPA filters. Details of the filter holder are presented in Figure 4. Four special exposure cages were constructed from 1/2 inch stainless steal mesh. Each cage is divided by mesh partitions in 16 compartments. Each compartment is 4.5 x 7 inches. These cages, designed to separate the rats from each other and keep every rat in a straight position during exposure, are presented in Figure 5.

D. Evaluation of the Performance of the Exposure System

Several chamber air flow rates and Wright dust feed gear ratio combinations were explored to reach the target concentration of 10 mg/m3. The evenness of dust concentration in each shelf and also between shelves were evaluated by sampling a 16 point grid per shelf. The results indicated that the target concentration is consistently achieved and that there was no significant difference in dust concentration either within or between shelves. In fact the overall coefficient of variation in two consecutive tests were very low, i.e., 6.6% and 8.5%. The last set of results are displayed in Figure 6. The profile of weekly exposure over a period of 25 weeks, presented in Figure 7, shows the long-term consistency of dust concentrations. The size distribution of airborne dust in the chamber was continuously monitored using an

Andersen Cascade Impactor. The results showed that the mass median aerodynamic diameter was 2.6 um with a geometric standard deviation of 1.7. These results are presented in Figure 8.

E. Intratracheal instillation of Silica Dust

Experimental silicosis was induced in rats by intratracheal instillation. A comprehensive evaluation of the intratracheal instillation procedure of silica dust used in the study was performed to determine (1) the efficacy of the delivery of the injected dose, (2) the distribution of silica dust in the various lobes of the lungs, (3) the effect of the position of the animals, after injection on the amount of retained silica, and (4) compare the efficacy of administering silica dust by instillation to the efficacy obtained by inhalation in terms of dust distribution and dust retention in the various lobes of the lungs.

A group of six male rats received three intratracheal injection of 5 mg of silica dust (Minusil #5) suspended in 0.3 ml of 0.9% saline on Monday, Wednesday, and Friday. The rats were anesthetized with 35 mg/kg sodium Pentobarbital (50 mg/ml) and the silica suspensions were subsequently administered with a curved #18 gauge, 3 inch long, animal feeding needle. The animals were kept at an angle 30 degrees from vertical during injection and were placed on their backs for 15 minutes after injection. These rats were sacrificed the following Monday, i.e., on the third day after the last injection. Another group of 5 rats received one injection of 5 mg in 0.3 ml of 0.9% saline, and kept in the vertical position for 15 minutes before sacrifice. the purpose of this group was to evaluate the effect of position of the animal after injection. A third group, 5 rats, was exposed to silica dust by inhalation at a concentration of 26.7 $\pm$ 2.8 mg/m3 for six hours per day for 9 days, and were sacrificed three day after the last day of exposure. The lung lobes were digested in prefiltered commercial Clorax (5% sodium hypochlorite) and silica content was determined by x-ray diffraction as described below.

The results are presented in Tables 2 and 3. Briefly, the amount of silica retained in the lungs were 12.0 $\pm$ 1.62, 4.29 $\pm$ 1.05, and 1.66 + 0.162 mg in the three groups respectively. The retained silica as a percent of the injected amount were 80.0% and 85.85% in the first and second groups of the silica instilled rats. The amount of silica dust retained in the lungs by inhalation, third group, indicates that pulmonary deposition for the Minusil #5 dust used in the study is about 12%. The highest lobar burdens as a percent of total lung burden were 32.4 $\pm$ 8.44, 33.3 $\pm$ 9.14, and 39.1 $\pm$ 3.99 and they were all obtained in the left lobes in the three groups. The lowest lobar burdens 11.3 $\pm$ 3.09 and 9.10 $\pm$ 3.52 were obtained in the right middle lobes of the silica instilled rats and 9.42 $\pm$ 3.46 in the right upper lobe of the inhalation group. The evenness indices (EI for each lobe is defined as the amount of silica per gram lobe tissue divided by amount of silica per gram of whole lung tissue) ranged from 82.2 $\pm$

29.5 (right lower) to 178 ± 131 (right upper) in the first group, 83.3 ± 23.2 (left lung) to 181 ± 79.6 (right cardiac) in the second group, and 93.7 ± 12.9 (right upper) to 115 ± 5.56 ( right middle) in the third group.

These results indicate that the instillation procedure used in the experiment is efficient in terms of delivery and distribution of silica dust to the five lung lobes of the exposed animals. The same procedure was utilized afterwards for instillation of silica dust in 70 rats and saline in 20 control rats. Experimental silicosis in these 70 rats was induced by injecting 0.833 mg suspended in 0.3 ml of saline on Monday, Wednesday, and Friday of the same week for a total dose of 2.5 mg.

F. Animal Exposure to STANBLAST

Sixty four male rats were exposed by inhalation in the horizontal laminar flow whole body exposure chamber to ball-milled dust of the substitute (10.8 ± 3.5 mg/m3) for 6 hrs/day, 5 days/week for one year. Analysis of lung content of STANBLAST in ten rats sacrificed after six months of exposure showed a coefficient of variation of 21%, indicating that animal exposure was fairly uniform. It should be noted that this value reflects biological variability between animals and variability due to utilization of four elements for estimation of lung burden of STANBLAST, as well as the variability of the dust concentration in the exposure system described above in section D.

G. Determination of STANBLAST in lung Tissue

The same ICP technique described above was used to determine the amount of STANBLAST retained in the lungs of exposed rats after correction for elemental composition of the lungs of the unexposed controls. Estimates of lung burden were obtained from individual values of aluminum, calcium, iron, and silicon as well as the average of these four elements. The results are presented in Table 4. The lung burdens of STANBLAST dust after 6 and 12 months of exposure were 2.89 ± 0.61 and 5.38 ± 1.42 mg. The amounts of dust retained after 6 and 12 months from the last day of exposure were 3.13 ± 1.25 and 2.29 ± 1.48 mg, indicating that pulmonary clearance of STANBLAST is associated with a biological half-life of about 10 months.

H. Determination of Silica Dust in Lung Tissue

The determination of silica lung burden for rats receiving intratracheal instillation of Minusil #5 was performed using X-ray diffraction (XRD). A typical calibration curve is presented in Figure 9. Because these rats were subsequently exposed to STANBLAST dust, the effect of the presence of STANBLAST on silica determination was also evaluated. The amount of silica dust

recovered, i.e., measured by XRD compared to silica added is displayed in Figure 10, for 10, 25, 50, 75 and 90 ug of silica in 100 ug of mixture of STANBLAST and silica. The results show that the presence of STANBLAST dust in the sample does affect the analytical procedure. Conversely, the presence of equal amounts of STANBLAST dust and silica dust on determination of silica in samples containing 10, 20, 40, 60 80, 100, 150 and 200 ug of the mixture was also not significant (see Figure 11).

## I. Hydroxyproline Content, Wet and Dry Weights of Lung Tissue

Collagen is the major component of the connective tissue matrix in the lung and it represents 5% to 20% of the total lung protein depending on the species. It is found throughout the lung; in the interstitium and basement membrane. It is most prominently associated with epithelial and endothelial cells as well as in the cartilage of large and small bronchi. Consequently collagen plays a fundamental role in defining lung structure and function. Due to the disturbance in the turnover rate of collagen during the development of lung fibrosis, evaluation of lung collagen content is therefore essential in understanding fibrotic lung diseases. Our approach toward evaluation of lung collagen content is through the determination of hydroxyproline levels in the lungs of exposed and control rats. This is based on the assumption that essentially all the hydroxyproline in animal tissues is found in collagen or in degrative products of collagen, and that no significant amount of free or peptide hydroxyproline arise in the course of collagen biosynthesis. Hydroxyproline content in the acid hydrolysate of dry lung tissue was determined by the spectrophotometric method of Switzer and Summer (2).

Because pneumoconiosis is associated with significant changes in properties of lung tissue, wet and dry lung weights are usually used as response parameters of the disease process.

Wet lung and dry lung weights as well as hydroxyproline content in the lungs of controls and exposed rats during and after termination of exposure are presented in Table 5. With the exception of dry weights after 6 months of exposure and wet weights after 18 month from onset of exposure, all values for wet and dry lung weights as well as hydroxyproline content of the lungs were not significantly different from controls. These two exception can not be readily explained, however, they may or may not be due to chance specially when large number of comparisons are performed. The same parameter obtained from rats exposed to silica dust, in a different project in our laboratories, are presented in Table 6 for comparison. It can be seen that these parameters are altered significantly after brief exposure to relatively low dust concentrations.

J. Histopathological Evaluations of Lung Tissue

Rats were sacrificed 6, 12, 18 and 24 months after initiation of exposure with an overdose of sodium pentobarbitol (Nembutal). Blocks from sagital sections of right and left lung lobes were prepared in paraffin, sectioned at 5 um, stained by H & E, Gomoris' silver impregnation and Masson's trichrome stains and examined for histologic lesions by optical microscopy.

Histologic examination of lung tissue of exposed rats revealed a nonfibrogenic tissue reaction to the dust. Examination of lungs obtained from rats exposed to STANBLAST dust for 6 and 12 months displayed small, discrete, cellular accumulations profusely scattered throughout the parenchymal field. They were most often noted in peribronchiolar, perivascular and subpleural location. The majority of these cellular collections were composed of large alveolar macrophages and, less frequently, lymphocytes. Polymorphonuclear leukocytes were rarely seen. STANBLAST particles were readily apparent in these locations both intra- and extracellularly. In many instances, the particulates were especially numerous and appeared to completely obliterate the cellular components within the foci. Examination of the alveolar walls surrounding these nodules revealed individual interstitial macrophages containing granules of STANBLAST material. STANBLAST burdened cells were also frequently seen within the peribronchiolar lymphoid tissues. In addition to these benign appearing lesions, a very small proportion of the foci, observed in the 12 month exposed rats, were dominated by a lymphocytic infiltrate (rather than alveolar macrophages), and displayed an apparent increase in eosinophilic ground substance, suggestive of early granulomatous formation. Assessment of collagen deposition within these foci utilizing the Harrow Viche stain did not, however, reveal a significant increase in interstitial collagen. These variants of STANBLAST lymphocyte collections were noted in four of the ten animals exposed for 12 months. Examination of lung tissue obtained from animals sacrificed 6 and 12 months after the last day of exposure showed that epitheloid cells were much more neumerous in the discrete cellular nodules, but collagen deposition was not obvious histologically.

The only major problem that was encountered during this project was the development of a chronic respiratory disease, mycoplasmosis, among the rats exposed to both silica and STANBLAST during the final months of the project. This infection cannot be cleared by antibiotic treatment and the only effective way to eliminate the infection was to sacrifice that group of rats and appropriately disinfect the room used for their housing. It was not possible to repeat this part of the experiment because this problem occurred during the final months of the project.

## III. CONCLUSIONS

Histologic examinations of the lung tissue of rats exposed to STANBLAST revealed the presence of micro-granulomas throughout the lung fields, suggesting the release of certain cellular modifying agents. The absence of any obvious collagen deposition within these structures or the surrounding interstitium denotes a lack of fibrogenic potential for STANBLAST under the present experimental conditions. The lack of significant difference in hydroxyproline content of the lungs of exposed and control rats corroborate the histologic conclusions.

## REFERENCES


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TABLE 1

ELEMENTAL COMPOSITION (PERCENT) OF GRANULES AND BALL-MILLED STANBLAST AS DETERMINED BY ICP METHOD

| ELEMENT | STANBLAST GRANULES | STANBLAST DUST |
|---|---|---|
| Si as SiO2 | 58.9 | 58.9 |
| P as PO4 | <0.61 | <0.61 |
| Fe as Fe2O3 | 18.9 | 18.8 |
| Al as Al2O3 | 19.1 | 19.1 |
| Na as Na | 0.59 | 0.60 |
| K as K | 1.32 | 1.33 |
| Be as Be | <0.002 | <0.002 |
| Mg as MgO | 1.15 | 1.17 |
| Ca as CaO | 8.07 | 8.40 |
| Ba as Ba | 0.052 | 0.053 |
| Cd as Cd | <0.02 | <0.02 |
| Pb as Pb | <0.09 | <0.09 |
| Zn as Zn | 0.010 | 0.014 |
| Hg as Hg | <0.02 | <0.02 |
| Cr as Cr | 0.023 | 0.021 |
| Cu as Cu | 0.002 | 0.003 |
| Ag as Ag | <0.02 | <0.02 |
| Sb as Sb | <0.09 | <0.09 |
| Co as Co | <0.02 | <0.02 |
| Ni as Ni | <0.009 | <0.009 |
| As as As | <0.009 | <0.009 |
| S as SO4 | <0.06 | <0.06 |

TABLE II

Lobar Distribution of Silica (mg) and Lobar Burden
as a Percentage of Total Lung Burden

| Lobe | Inhalation | | Instillation | | Instillation V* | |
|---|---|---|---|---|---|---|
| Number of Rats | 5 | | 6 | | 5 | |
| Left Lung | 0.638 | 39.1 | 3.88 | 32.4 | 1.47 | 33.3 |
| Minimum | 0.491 | 33.0 | 2.50 | 21.7 | 0.77 | 25.9 |
| Maximum | 0.778 | 43.6 | 5.68 | 41.4 | 2.67 | 49.2 |
| S.D.** | 0.112 | 3.99 | 1.13 | 8.44 | 0.716 | 9.14 |
| C.V.%*** | 17.6 | 10.2 | 29.2 | 26.0 | 48.6 | 27.2 |
| Upper Right | 0.150 | 9.42 | 2.19 | 17.4 | 0.571 | 13.3 |
| Minimum | 0.0989 | 5.23 | 0.787 | 8.00 | 0.232 | 5.90 |
| Maximum | 0.228 | 14.7 | 5.83 | 41.4 | 1.03 | 21.5 |
| S.D. | 0.0501 | 3.46 | 1.85 | 12.5 | 0.339 | 6.62 |
| C.V.% | 33.2 | 36.7 | 84.5 | 72.0 | 59.3 | 49.9 |
| Middle Right | 0.227 | 14.0 | 1.35 | 11.3 | 0.408 | 9.10 |
| Minimum | 0.199 | 13.0 | 0.914 | 6.67 | 0.135 | 5.07 |
| Maximum | 0.270 | 16.5 | 2.08 | 14.8 | 0.709 | 14.8 |
| S.D. | 0.0303 | 1.45 | 0.425 | 3.09 | 0.208 | 3.52 |
| C.V.% | 13.4 | 10.3 | 31.5 | 27.3 | 50.9 | 38.7 |
| Lower Right | 0.486 | 30.0 | 2.88 | 24.6 | 1.25 | 29.5 |
| Minimum | 0.235 | 14.3 | 1.34 | 9.53 | 0.746 | 23.0 |
| Maximum | 0.649 | 36.0 | 3.98 | 30.5 | 1.49 | 37.9 |
| S.D. | 0.153 | 8.89 | 0.893 | 8.07 | 0.325 | 5.71 |
| C.V.% | 31.5 | 29.7 | 31.0 | 32.8 | 26.0 | 19.4 |
| Cardiac Right | 0.162 | 10.1 | 1.71 | 14.3 | 0.586 | 14.8 |
| Minimum | 0.100 | 6.33 | 1.25 | 11.2 | 0.456 | 8.40 |
| Maximum | 0.250 | 15.3 | 1.98 | 17.5 | 0.714 | 24.3 |
| S.D. | 0.0618 | 3.96 | 0.292 | 2.44 | 0.120 | 6.31 |
| C.V.% | 38.1 | 39.2 | 17.1 | 17.0 | 20.5 | 42.5 |
| Entire Lung | 1.66 | | 12.0 | | 4.29 | |
| Minimum | 1.49 | | 9.83 | | 2.66 | |
| Maximum | 1.89 | | 14.1 | | 5.43 | |
| S.D. | 0.162 | | 1.62 | | 1.05 | |
| C.V.% | 9.75 | | 13.5 | | 24.5 | |

*vertical position
**standard deviation
***coefficient of variation

TABLE III

Evenness Indices for Silica Distribution in Rat Lungs

| Lobe | Inhalation | Instillation | Instillation V* |
|---|---|---|---|
| Number of Rats | 5 | 6 | 5 |
| Left Lung | 97.6 | 86.8 | 83.3 |
| Minimum | 83.4 | 57.9 | 64.5 |
| Maximum | 108 | 107 | 123 |
| S.D.** | 9.30 | 20.4 | 23.2 |
| C.V.%*** | 9.52 | 23.5 | 27.8 |
| Upper Right | 93.7 | 178 | 141 |
| Minimum | 80.8 | 67.6 | 71.8 |
| Maximum | 115 | 423 | 266 |
| S.D. | 12.9 | 131 | 77.2 |
| C.V.% | 13.8 | 73.3 | 54.6 |
| Middle Right | 115 | 94.1 | 108 |
| Minimum | 109 | 58.9 | 84.3 |
| Maximum | 124 | 124 | 182 |
| S.D. | 5.65 | 23.1 | 41.2 |
| C.V.% | 4.89 | 24.5 | 38.0 |
| Lower Right | 102 | 82.2 | 88.6 |
| Minimum | 65.5 | 30.8 | 74.3 |
| Maximum | 121 | 109 | 116 |
| S.D. | 21.9 | 29.5 | 16.4 |
| C.V.% | 21.4 | 35.9 | 18.5 |
| Cardiac Right | 110 | 135 | 181 |
| Minimum | 74.1 | 102 | 92.9 |
| Maximum | 141 | 158 | 290 |
| S.D. | 27.0 | 19.3 | 79.6 |
| C.V.% | 24.5 | 14.3 | 44.0 |

*vertical position
**standard deviation
***coefficient of variation

TABLE IV

LUNG CONTENT OF SAND SUBSTITUTE AS DETERMINED
BY THE ICP METHOD (mg)
(MEAN ± STANDARD DEVIATION OF 10 RATS)

| DURATION | BASIS OF ESTIMATION OF DUST CONTENT OF THE LUNGS | | | | |
|---|---|---|---|---|---|
| | ALUMINIUM (Al) | CALCIUM (Ca) | IRON (Fe) | SILICON (Si) | AVERAGE (Al,Ca,Fe,Si) |
| 6 MONTHS | 2.80 ± 0.276 | 2.63 ± 0.715 | 3.31 ± 0.760 | 2.80 ± 0.400 | 2.89 ± 0.610 |
| 12 MONTHS | 6.71 ± 0.740 | 5.92 ± 1.45 | 4.68 ± 1.01 | 4.20 ± 0.863 | 5.38 ± 1.42 |
| 18 MONTHS | 2.89 ± 0.460 | 4.18 ± 1.47 | 3.56 ± 0.808 | 1.87 ± 0.703 | 3.13 ± 1.25 |
| 24 MONTHS | 2.10 ± 1.06 | --- | 2.33 ± 1.32 | 2.43 ± 2.02 | 2.29 ± 1.48 |

TABLE V

DRY AND WET WEIGHTS AND HYDROXYPROLINE CONTENT OF LUNGS FROM 10 EXPOSED AND 5 CONTROL RATS (MEAN ± STANDARD DEVIATION) DUST EXPOSURE AT 10.8 ± 3.5 MG/M3 FOR 12 MONTHS

| DURATION (MONTHS) | | DRY WEIGHT (gm) | WET WEIGHT (gm) | HYDROXYPROLINE (mg/rat) |
|---|---|---|---|---|
| EXPOSED | (6) | 0.411 ± 0.0454* | 2.53 ± 0.219 | 1.75 ± 0.195 |
| CONTROL | (6) | 0.340 ± 0.0275 | 2.35 ± 0.236 | 1.55 ± 0.253 |
| EXPOSED | (12) | 0.413 ± 0.0245 | 2.01 ± 0.178 | 2.75 ± 0.269 |
| CONTROL | (12) | 0.429 ± 0.0788 | 1.90 ± 0.363 | 2.87 ± 1.09 |
| EXPOSED | (18) | 0.408 ± 0.0929 | 2.71 ± 0.396* | 2.61 ± 0.973 |
| CONTROL | (18) | 0.359 ± 0.0265 | 2.06 + 0.175 | 2.97 ± 0.268 |
| EXPOSED | (24) | 0.466 ± 0.206 | 3.56 ± 1.55 | 4.84 ± 2.16 |
| CONTROL | (24) | 0.559 ± 0.239 | 3.48 ± 0.799 | 5.58 ± 1.36 |

* EXPOSED ARE SIGNIFICANTLY DIFFERENT FROM CONTROLS ($p < 0.01$)

TABLE VI

LUNG PARAMETERS MEASURED FOR CONTROLS AND RATS EXPOSED TO SILICA DUST FOR 3 MONTHS (MEAN ± STANDARD DEVIATION)

| Wet Lung Weight (gm) | Dry Lung Weight (gm) | Silica (mg) | Hydroxyproline (mg) |
|---|---|---|---|
| Controls: n = 5 | | | |
| 2.1 ± 0.43 | 0.32 ± 0.049 | N.D. | 1.5 ± 0.26 |
| Group I: Exposed to 20 mg/m3, n = 10 | | | |
| 4.1 ± 0.29* | 1.2 ± 0.14* | 4.6 ± 0.85 | 3.2 ± 0.33* |
| Group II: Exposed to 5 mg/m3, n = 10 | | | |
| 3.2 ± 0.25* | 0.71 ± 0.049* | 1.2 ± 0.59 | 2.3 ± 0.46* |
| Group III: Exposed to 4 mg/m3, n = 10 | | | |
| 2.6 ± 0.28* | 0.57 ± 0.041* | 0.63 ± 0.26 | 2.3 ± 0.36* |
| Group IV: Exposed to 2 mg/m3, n = 10 | | | |
| 2.3 ± 0.29 | 0.33 ± 0.021 | 0.42 ± 0.14 | 2.1 ± 0.24* |

N.D.: NONE DETECTED
* : SIGNIFICANTLY DIFFERENT FROM CONTROLS, $p<0.05$

List of Figures:

Figure 1

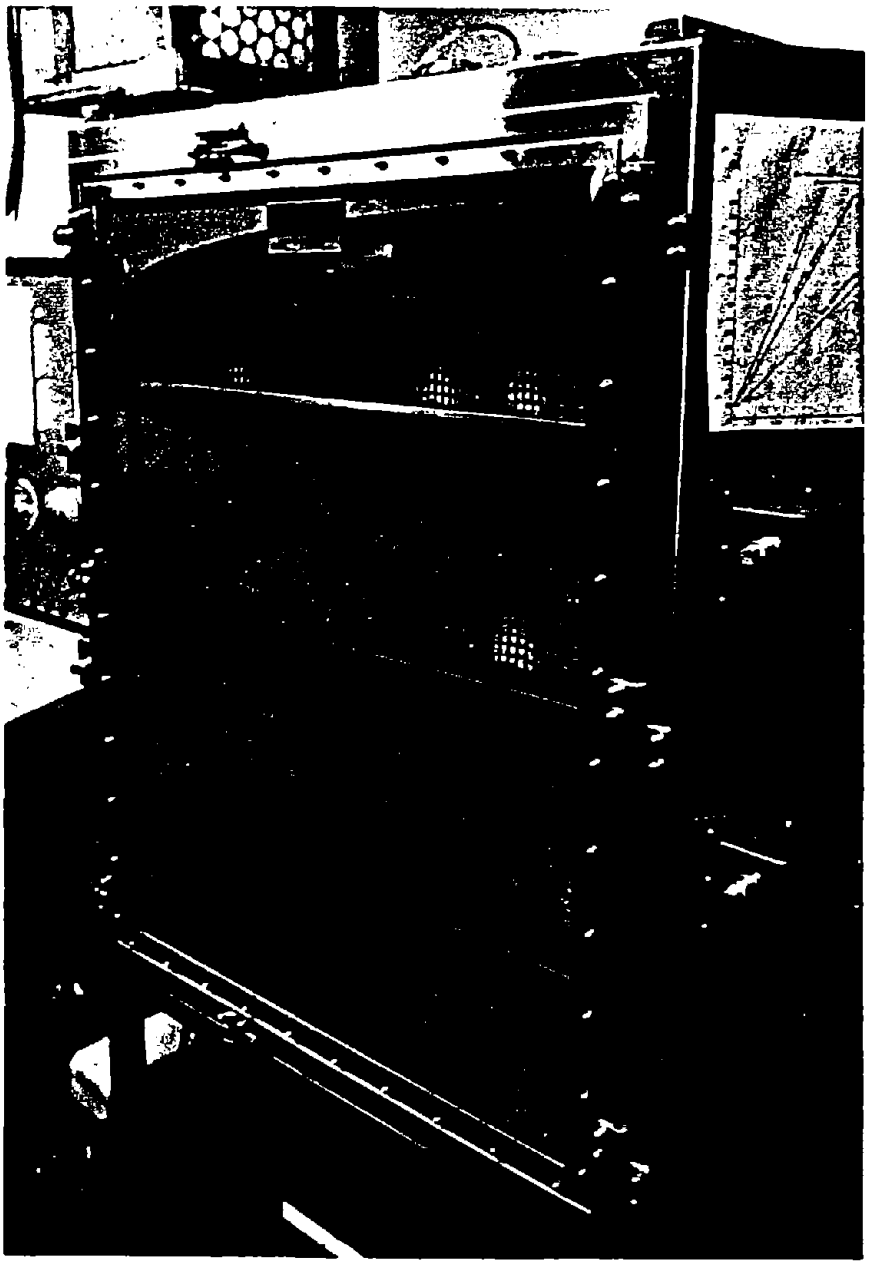


Figure 2

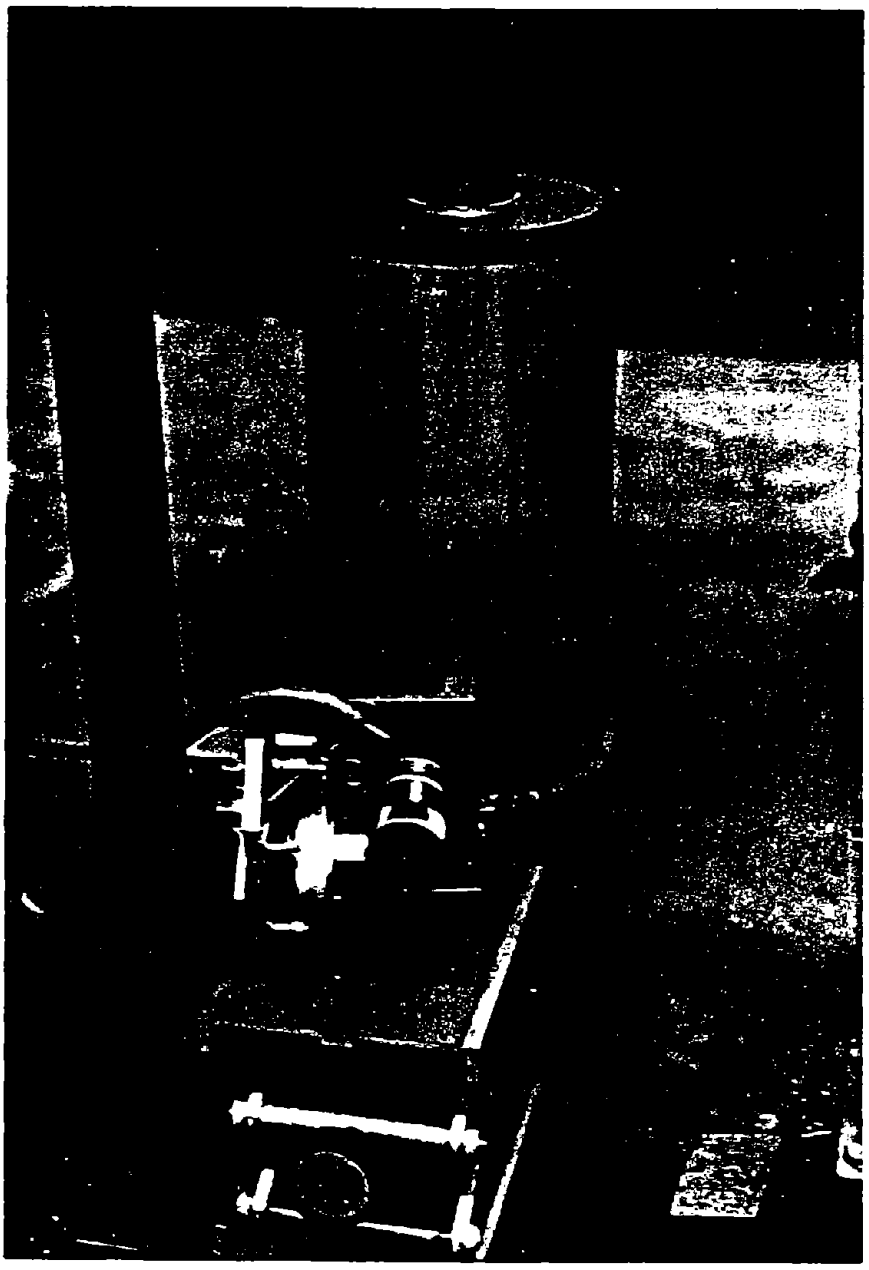


Figure 3

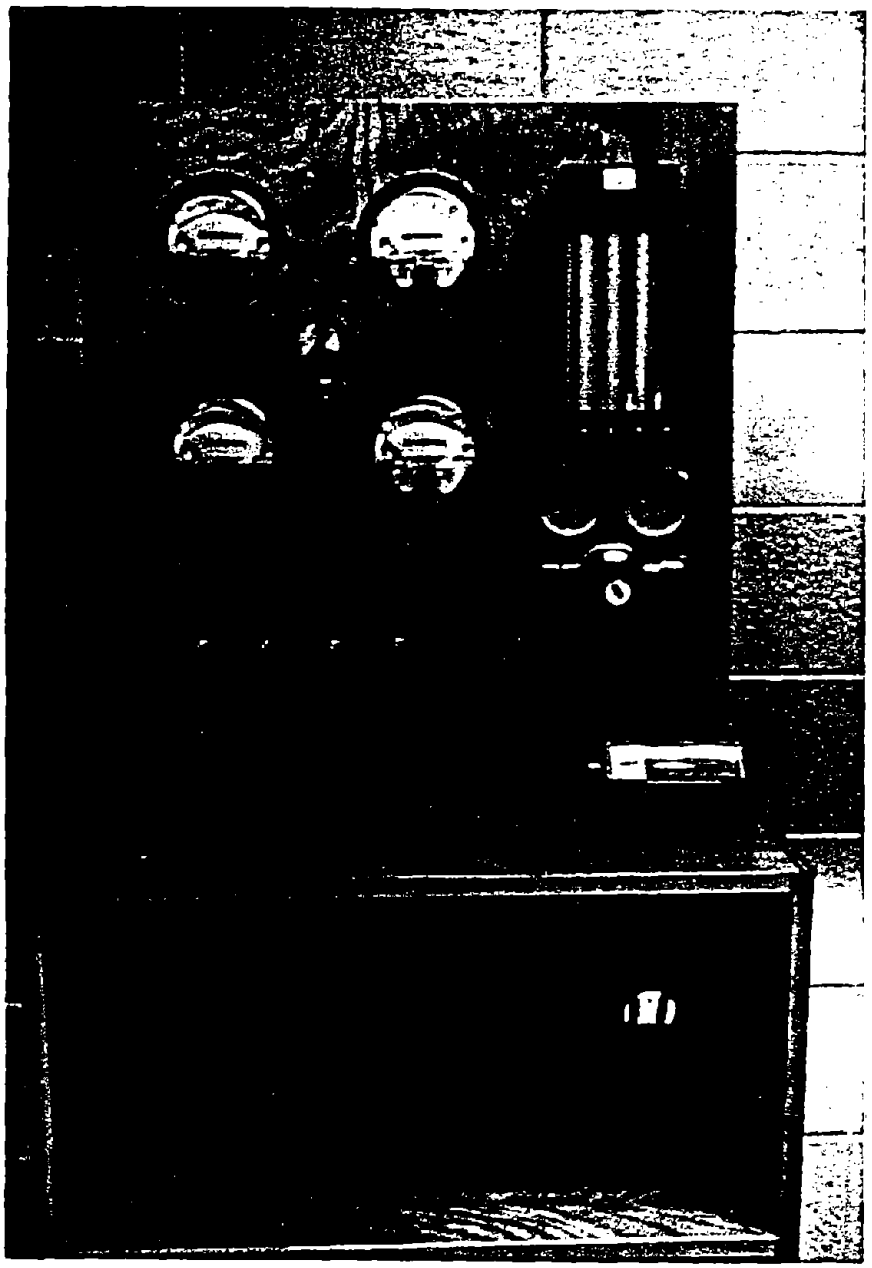


Figure 4

Figure 5

Figure 6

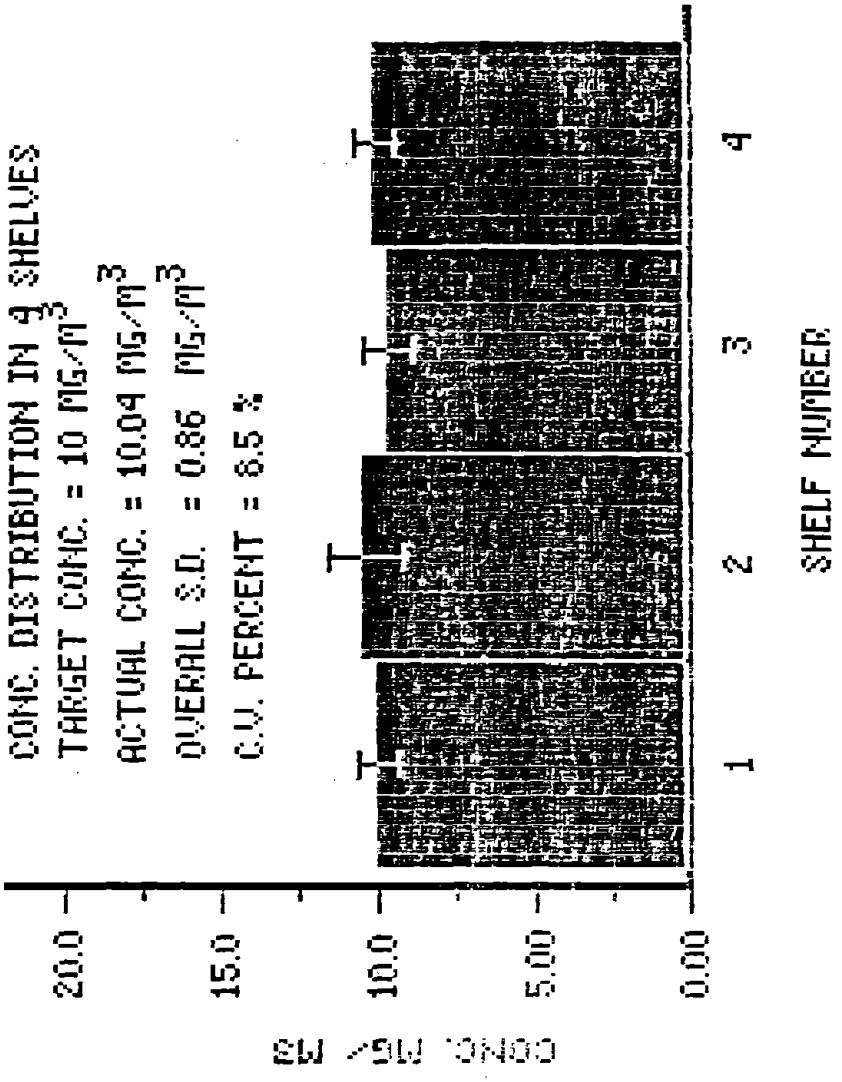

CONC. DISTRIBUTION IN 4 SHELVES
TARGET CONC. = 10 MG/M3
ACTUAL CONC. = 10.04 MG/M3
OVERALL S.D. = 0.86 MG/M3
C.V. PERCENT = 8.5 %
CONC. MG/M3
20.0
15.0
10.0
5.00
0.00
1
2
3
4
SHELF NUMBER

Figure 7

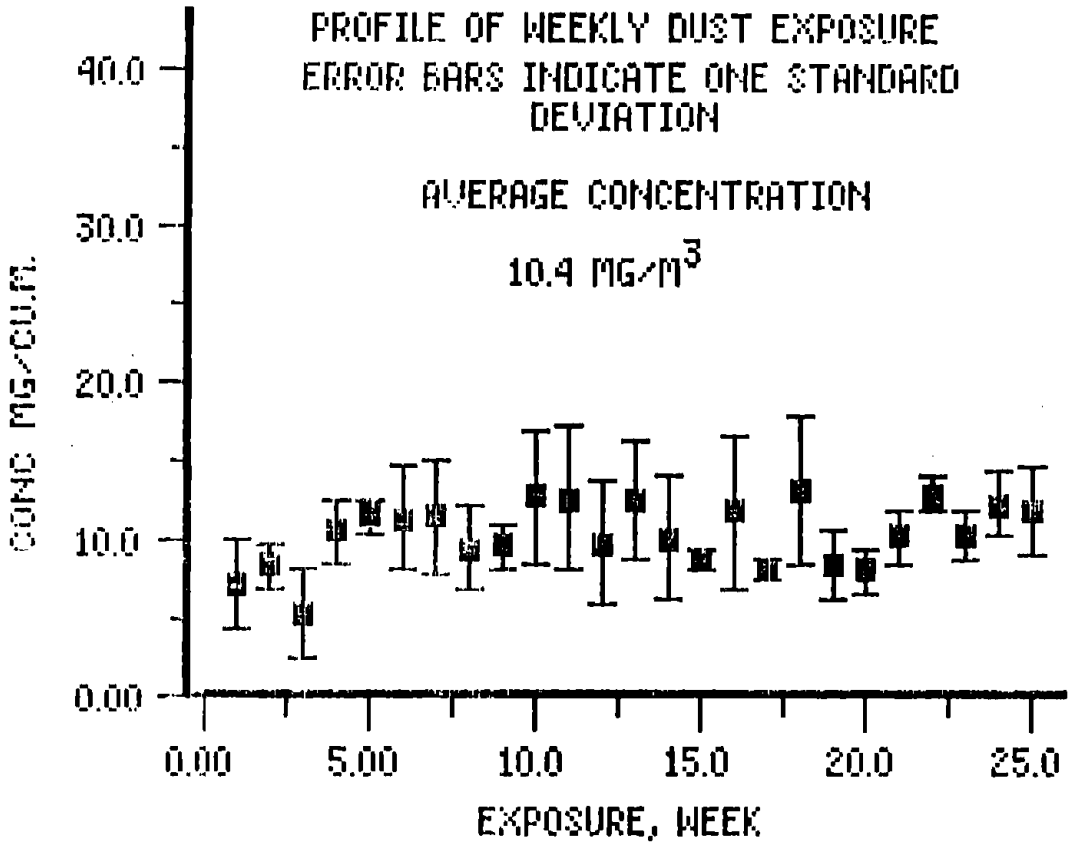

PROFILE OF WEEKLY DUST EXPOSURE
ERROR BARS INDICATE ONE STANDARD DEVIATION
AVERAGE CONCENTRATION
10.4 MG/M3
CONC MG/CU.M.
40.0
30.0
20.0
10.0
0.00
0.00
5.00
10.0
15.0
20.0
25.0
EXPOSURE, WEEK

Figure 8

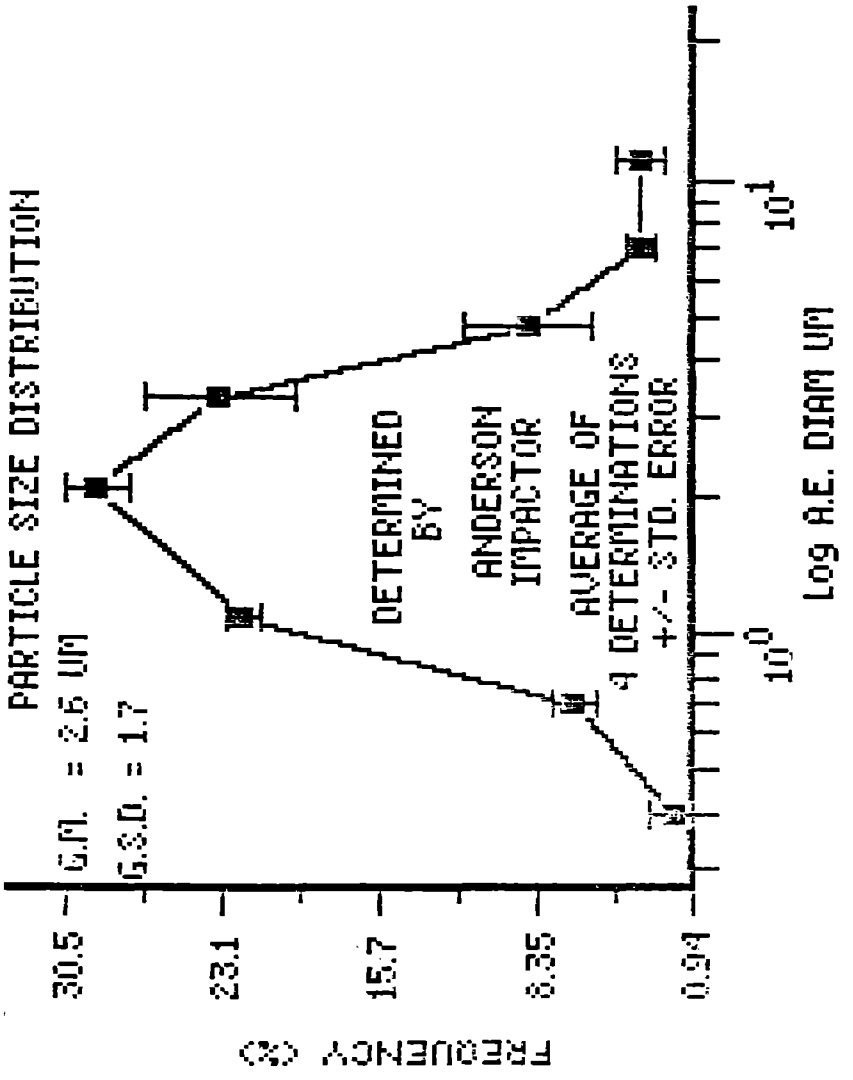

PARTICLE SIZE DISTRIBUTION
G.M. = 2.6 UM
G.S.D. = 1.7
DETERMINED BY ANDERSON IMPACTOR
AVERAGE OF 4 DETERMINATIONS +/- STD. ERROR
30.5
23.1
15.7
8.35
0.94
FREQUENCY (%)
$10^0$
$10^1$
Log A.E. DIAM UM

Figure 9

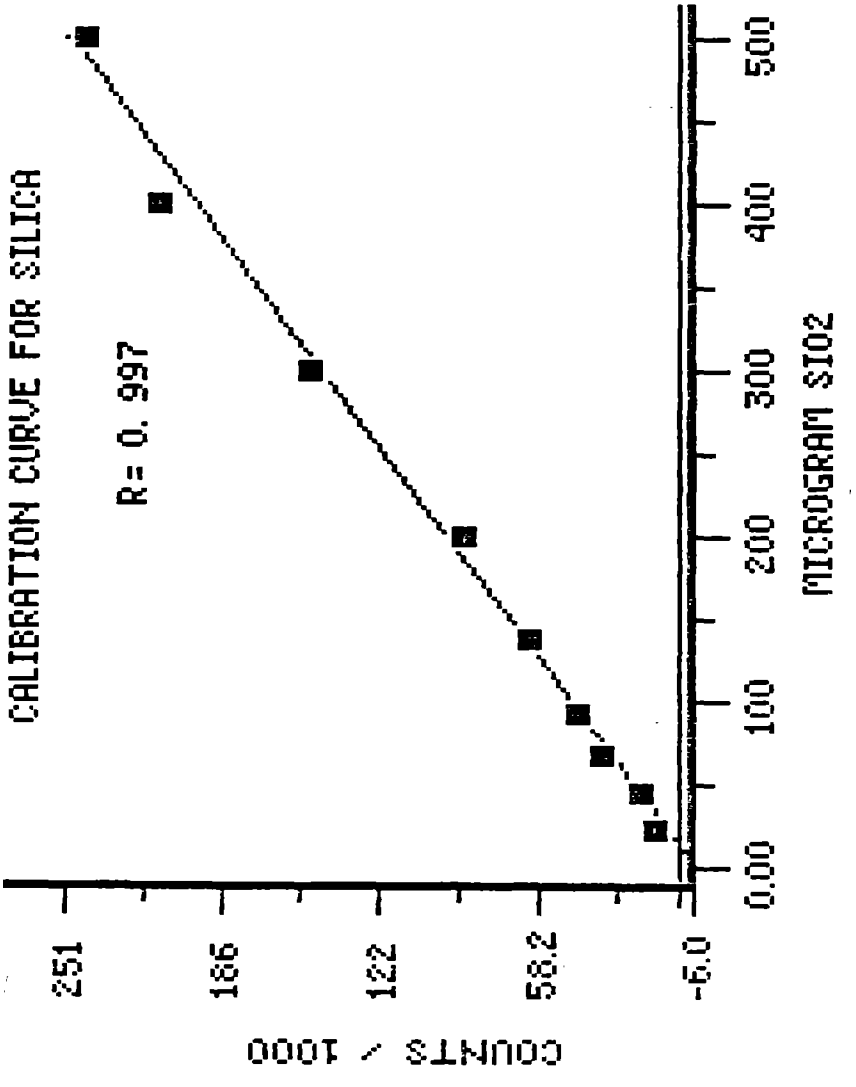

CALIBRATION CURVE FOR SILICA
R= 0. 997
COUNTS / 1000
251
186
122
58.2
-6.0
0.00
100
200
300
400
500
MICROGRAM SIO2

Figure 10

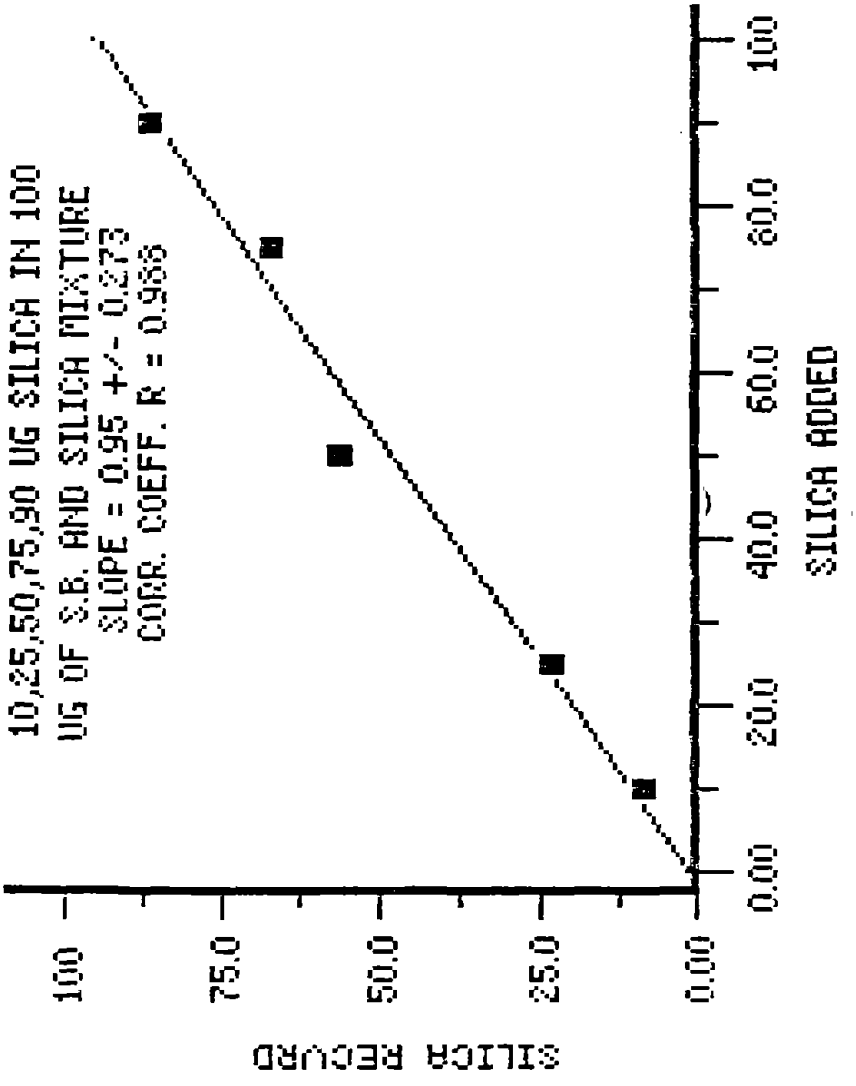
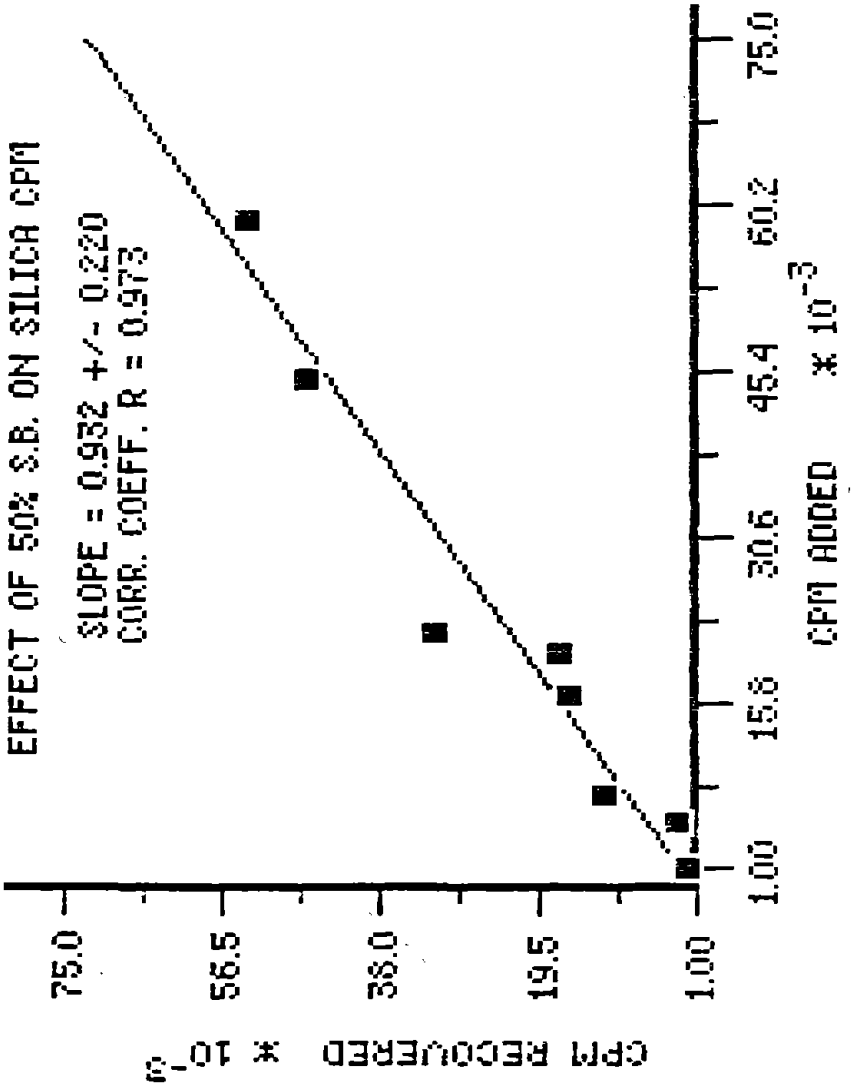

10,25,50,75,90 UG SILICA IN 100
UG OF S.B. AND SILICA MIXTURE
SLOPE = 0.95 +/- 0.273
CORR. COEFF. R = 0.988
SILICA RECVRD
100
75.0
50.0
25.0
0.00
0.00
20.0
40.0
60.0
80.0
100
SILICA ADDED

Figure 11


EFFECT OF 50% S.B. ON SILICA CPM
SLOPE = 0.932 +/- 0.220
CORR. COEFF. R = 0.973
CPM RECOVERED * 10^-3
75.0
56.5
38.0
19.5
1.00
1.00
15.8
30.6
45.4
60.2
75.0
CPM ADDED * 10^-3

**FINAL INVENTORY REPORT**

Grant Number: 5 R01 OH01970-03
Principal Investigator: Yehia Hammad, D.Sc.
Date: September 8, 1989

| ITEM NUMBER | DESCRIPTION OF ITEM | MANUFACTURER AND SERIAL NUMBER | ACQUISITION DATE | UNIT ACQUISITION COST | PERCENT OF FEDERAL FUNDS | CONDITION OF ITEM |
|---|---|---|---|---|---|---|
| *1. | Exposure Chamber: Horizontal laminar flow animal exposure chamber, 2 x 3 x 4 feet, with four shelves | The Baker Company Serial #: MS225 | 5/84 | $6,905.00 | 100% | Fair |
| *2. | Wright Dust Feed: Non-free-flowing powder dust generator | BGI, Inc. Serial #: 1217 | 5/84 | $4,440.00 | 100% | Poor; needs repairs |

*wish to retain for continued usage

Approved for use through 7
OMB No. 092

DEPARTMENT OF HEALTH AND HUMAN SERVICES

# FINAL INVENTION STATEMENT AND CERTIFICATION

(FOR GRANT OR AWARD)

DHHS GRANT OR AWARD NO

5 RO1 OH01970-03

A. We hereby certify that, to the best of our knowledge and belief, all inventions are listed below which were conceived and/or first actually reduced to practice during the course of work under the above-referenced DHHS grant or award for the period 4/1/84 (original effective date) through 3/31/87 (date of termination).

B. INVENTIONS (Note: If no inventions have been made under the grant or award, insert the word "NONE" under Title below.)

| NAME OF INVENTOR | TITLE OF INVENTION | DATE REPORTED TO DHHS |
|---|---|---|
| | NONE | |
| | | |
| | | |
| | | |
| (Use continuation sheet if necessary) | | |

C. FIRST SIGNATURE — The person responsible for the grant or award is required to sign (in ink). Sign in the block opposite the applicable type of grant or award.

| TYPE OF GRANT OR AWARD | WHO MUST SIGN (title) | SIGNATURE |
|---|---|---|
| Research Grant | Principal Investigator or Project Director | M Hammad |
| Health Services Grant | Director | |
| Research Career Program Award | Awardee | |
| All other types *(specify)* | Responsible Official | |

D. SECOND SIGNATURE — This block must be signed by an official authorized to sign on behalf of the institution.

TITLE

Dean, School of Medicine

TYPED NAME

Vincent Fulginiti, M.D.

SIGNATURE

DATE 9/11/89

NAME AND MAILING ADDRESS OF INSTITUTION

Tulane University Medical Center
1430 Tulane Avenue
New Orleans, Louisiana 70112