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AIR POLLUTION CONTROL IN COTTONSEED OIL INDUSTRY

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Executive Summary

The purpose of the project of the first half of the forth year was modernizing of the experimental installation in Technion (Israel) and study of cottonseed packed bed filters in air cleaning processes. Experimental study of pressure drop and effectiveness of cottonseed bed filters continued in Architectural Building Institute of Tashkent. The parameters varied during the experiments were the kind and the layer thickness of the packed cottonseeds, the flow rate of the air and concentration of dust in the air. The measured data showed that pressure drop increases with increasing of dust concentration in the air, of airflow rate, and thickness of the bed layer.

Our experiments showed that granular bed filters filled by cottonseeds provide good possibilities for adjustment of dust particle removal and cleaning of air in local exhaust ventilation systems. The developed cottonseed filled bed filters support possibility for adjustment of resistance of the filter and maintenance of low dust concentration in the cleaned air. Inexpensive cottonseed fillers, which were return to the raw material after its filling with dust, made possible unnecessary of additional dust-removing devices. The cottonseed bed filters located in exhaust hoods made practicable development of principal new local exhaust ventilation systems.

Development of mathematical model of pressure drop in airflow through cottonseed filled bed filters was continued. The developed mathematical model compared favorably with most of the measured data. A joint paper with Uzbekistan collaborators "Airflow through Granular Beds packed with Cottonseeds" submitted for publication in scientific journal "Biosystem Engineering" have been corrected according to reviewers' remarks, and sent to the Editor.

Section I: Technical Progress

A) Research Objectives: The purpose of this study is to analyze the mechanism and obtain general expressions of pressure drop and catching of dust using cottonseed filled bed filters for cleaning of air at cottonseed oil mills.

B) Research Accomplishments:

Our experiments showed that granular bed filters, filled by particles of cottonseeds and placed in suction hoods solved many problems in aspiration systems, like carrying out of low particulate concentration in ducts and prevention of duct obstruction. It makes possible of regulating of air cleaning efficiency, the resistance of filter, dust-holding capacity and the like. It leads to unnecessary of additional dust-removing devices and provides of recovering dust particles in raw material. The cottonseed filter fillers are inexpensive, they were returned to the raw material after its filling with dust.

The functioning of granular bed filter may be qualified (ASHRAE, 2000; ASHRAE Standard 52-1) by the following minimum of parameters: effectiveness, pressure drop, dust holding capacity, etc. It is also important to take in account the effect of formation of compressible and incompressible deposits on incompressible partition.

Experimental study on experimental rigs equipped with cottonseed bed filters performed in Technion (Haifa, Israel) and Ventilation laboratory in Tashkent (Uzbekistan). The study included investigation of the next parameters:

1. Aerodynamical characteristics of the clean filters that included study of pressure drop across the filter (its resistance) as a function of airflow rate, type of bed filler, thickness of the bed layer.

2. Efficiency (or arrestance) of filter.

3. Pressure drop versus parameters of dust air mixture and duration of filter function (before the next cleaning and regeneration of fillers).

4. Dust holding capacity (integrated amount of dust held by the filter, will be presented in further Report).

5. The available duration of filter operating without regeneration in economically expedient conditions.

Methodologies

The methods of the investigation are based on the recommendations of (ACGIH, 1983; ASHRAE, 1999; ASHRAE, 2000; ASHRAE, 2001, ASHRAE, Standard 52-1; US EPA (40CFR-Chapter 1-Part 60, Appendix A, Method 5); EPA, ReportNo.EPA-600/4-77-27b, 1984; Tabak S, 1989; Tomany J P, 1975). The data obtained during the experiment was representative of the conditions of technological equipment operation and revealed the characteristics that will be important to the consumer. The experiment was carried out as near as possible to the operating conditions of filter employment.

Efficiency of an air cleaner measures their ability to remove particulate matter from an air stream. The degree to which particulate matter is separated from air stream is known as the efficiency of a collector and the fraction of material escaping collection is the penetration.

The efficiency of a collector is expressed (ASHRAE, 2000) as a percent of the mass flow rate of material entering and exiting the collector:

$$\eta = 100(w_i - w_0)/w_i = 100w_c/w_i,$$

where:

η -efficiency of collector, %;

w_i-mass flow rate of contamination in gases entering collector;

w_0 - mass flow rate of contamination in gases exiting collector;

w_c - mass flow rate of contamination captured by collector.

The efficiency of a collector can be expressed (6) in terms of the concentrations of particulate matter entering and exiting equipment.

Facilities. Development of an experimental installation for study the filter characteristics.

According to our experience in experimental investigations of granular bed filters and the recommendations of literature sources (ASHRAE, Standard 52-1; US EPA Electronic Code of Federal Regulations (40CFR-Chapter 1-Part 60, Appendix A, Method 5); EPA, Report No.EPA-600/4-77-27b, 1984; Tabak S, 1989; Tomany J P, 1975) the experimental installation included the following devices and elements: an intake contractor, ducts, dust feeder device for quispace distribution of experimental dust, diffuser, the studied granular bed filter, contractor, orifice meter for measuring of the air flow rate, choke, a fan, a dust scoop nozzle with chuck.

The investigated filler was placed between two grids of wires. The distance between the grids was able for arranging. The investigation was carried out with filters of 50 and 100 mm thickness bed fillers.

The method of collecting a sample of particulate matter from a gas stream involves collection train for a specific period of time. In order to insure particle size-representative sample (especially for particles larger than 1 micrometer as it is in case of cottonseed dust) from the primary stream, the flow into the probe must be isokinetic, i.e. the speed and direction of the air flow entering the prob must be equal to those of the primary stream. In addition, the leading edge of the prob must be knife-edged to minimize particle impaction losses.

"Apex Instruments" Isokinetic Method 5 Source Sampler, confirmed with the construction design criteria and specifications cited in US EPA Method 5, Code of Federal Regulations (40CFR Part 60) and APTD-0581 Document was used in our experiments.

To carry out the experiment as near as possible to the operating conditions of really filter employment the dust used in the experiment was collected from hulling separation operations at

cottonseed oil mill. The quantity of the dust that is going to the filter is determined by weighing the dust which is served by the feeder and is controlled by means of calculating the data received after measuring the concentration of the dust before the filter, the volume of the used air and the duration of the experiment.

The quantity of the dust caught by the filter was determined by calculating the data received after measuring the concentration of the dust in the air in front of and behind the filter and the corresponding volume of the used air and the duration of the experiment. The mass of dust that had not been caught by the filter was calculated as a difference between the served and the caught dust and calculated the residual concentration of the dust.

Results and discussion.

The values of the pressure drop and effectiveness of dust catching by cottonseed filled filters of different thickness of 50 and 100 mm, initial concentration of dust of 0.5, 1.0 and 2,0 g/m^3 are presented in Table 1 and 2. The initial filtration velocity was 0.2 m^3/s.

It is seen from the Table 1 and 2 as the time of filters using was increased, the pressure drop and effectiveness was found to increase for samples of all dust concentrations. Maximal pressure drop where using of the studied filters could be expedient were 1000-1200 Pa. That is the time when the cottonseed filler in the filter have to be cleaned or changed. These values were accepted basing on our experience of design of local exhaust ventilation systems. In Table 1 is shown that pressure drop of 1263 Pa was reached in 50 mm thickness filter by concentration of dust 0.5 g/m^3 during 55 h after beginning of testing. From Table 2 is seen that at the same conditions for filter of 100 mm thickness pressure drop of 1140 Pa was reached during 90 h of it functioning.

It is seen from the Table 1 and 2 that the pressure drop in air flow with initial concentration in the range 1.0- 2.0 g/m^3 considerably exceeds the pressure drop in air flow whose initial concentration was 0.5 g/m^3. In the Table 1 is shown that for filter of 50 mm thickness by dust concentration of 2 g/m^3 maximal expedient pressure drop of 1181 Pa and effectiveness of 99.9%

were reached during 35 h. During 35 h pressure drop reached of 814 Pa and effectiveness 99.2% in the same filter by dust concentrations of 0.5 g/m^3. Maximal expedient pressure drop of 1263 Pa and effectiveness of 99.7% were reached in filter of 50 mm thickness by concentrations of dust 0.5 g/m^3 during 55 h. After 35 h testing the pressure drop reached the maximal expedient value of 1133 Pa and effectiveness of 99.9 % in the 50 mm thickness filter by dust concentration 1.0 g/m^3.

In Table 2 is shown that in filter of 100 mm thickness the maximal expedient pressure drop were reached 1176 Pa during 35 h, 1112 Pa during 60 h, and 1140 Pa after 90 h by initial dust concentrations of 2.0 g/m^3, 1.0 and 0.5 g/m^{3}correspondingly. The effectiveness of the filters was there 99.90, 99.89 and 98.89 % accordingly.

Influence of the cottonseed filler bed thickness on the pressure drop and effectiveness of the filter was shown in Table 3. There was a comparison between bed 50 and 100 mm thickness. At the beginning of the experiment (0 h) pressure drop of 320 Pa in 100 mm thickness bed about two times larger then pressure drop in 50 mm bed that was 163 Pa. After 20 h running the pressure drops in air flow through the filters m became about equal: 489 Pa in 100 mm thickness bed and 485 Pa in 50 mm thickness bed. Thereupon there was an inverse phenomenon. During 40 h after filter running the pressure drop in 50 mm thickness bed became value of 892 Pa and after 55 h it was 1263 Pa. These values considerable exceeds the appropriate values of 682 Pa and 810 Pa measured at the same period of time at the filter of 100 mm thickness bed. This phenomenon may be explained in the following way. The process of filtration of cottonseed dust particles followed by the deposition of particles in a layer on the frontal surface of the filter and partially by settling of small particles in the pore channels of the cottonseed layer. Then pressure drop in air flow through the filter includes at least two components: pressure drop on cottonseed bed properly (including the resistance of the grid supports the cottonseed in the filtration layer) and the added component formed by layer of deposited particles on frontal surface of the

cottonseed bed. During the process of filtration the significance of each of the components permanently changed. At the time of beginning of the process of filtration (0 h) the pressure drop results of the resistance of cottonseed bed only (including the resistance of the grid supports the cottonseed in the filtration layer). So at the beginning of filtration process (0 h) the pressure drop in 100 mm thickness filters about two times larger in all samples then in filters of 50 mm thickness bed. In the process of growing of the deposited particles layer resistance of it became larger then the resistance of cottonseed bed layer.

If the dust concentration is higher and became 1.0 g/m^3, as it is shown in Table 4, there occurs the same phenomenon. But the equality of the pressure drop in case of 50 mm and 100 mm thickness bed happened earlier, during 15 h of running the filtration process. The value of pressure drop for case of 50 mm thickness bed was 504 Pa and for 100 mm thickness bed was 498 Pa. The effectiveness were 99.5% and 99.85% respectively.

By dust concentration of 1.0 g/m3 the maximal expedient pressure drop in case of 50 mm thickness bed had the value of 1133 Pa and the effectiveness of 99.9 % and took place after 35 h of the beginning of filter test. The values of maximal expedient pressure drop of 1112 Pa and effectiveness of 99.89% for 100 mm thickness bed were occurred during 60 h after beginning of the test.

In opposite to previous cases the filtration process by dust concentration of 2 g/m^3 as it is seen from Table 5 characterized by special properties. As usual, at the beginning of the process (0 h) the pressure drop at the cottonseed bed filter of 100 mm thickness was two times larger then in case of 50 mm thickness. After 20 h of filter performance the values of pressure drop both for 50 and 100 mm thickness beds became about equal. For 50 mm thickness bed the pressure drop was 729 Pa and for 100 mm thickness it was 732 Pa. The effectiveness were 99.8% and 99.58% respectively. Thereafter the pressure drops in both cases had grown approximately in equal manner. The values of maximal expedient pressure drop for 100 mm thickness bed filters was

1176 Pa and for 50 mm thickness bed was 1181 Pa and they took place during equal period of time, 35 h from beginning of the test. The reached effectiveness in both cases was 99.90%.

Conclusions

1. The main objective pursued in this research to develop methods and devices which control dust particle emissions was performed. Our experiments showed that granular bed filters filled by cotton seeds provide good possibilities for adjustment of particle removal and air cleaning in local exhaust ventilation systems. The developed cottonseed filled bed filters support maintenance of low dust concentration, possibility of adjustment of air cleaning efficiency up to 99.9%, and the required resistance of filters. It leads to unnecessary additional dust-removing devices. It makes able to return of dust particles to raw material, to obtain an inexpensive filter filler as cottonseed, which was returned to the raw material after its filling with dust. Suggested in this research cottonseed filled bed filters placed in exhaust hoods makes possible development of principal new local exhaust ventilation systems.

2. In our experiments were studied 50 mm and100 mm thickness bed filters filled by cottonseed. The cottonseed filled filter by the dust concentration of 0.5 g/m^3 in air flow before filtration can be used during 55 h without changing of the seed fillers for 50 mm thickness bed filters and for 90 h for 100 mm thickness bed filters. The changing of the fillers was performed by maximal expedient pressure drop of 1000-1200 Pa. If the initial concentration of dust was 1.0 g/m^3 the necessity for renovation or changing of the filler took place 35 h after it using for 50 mm thickness bed filters and after 60 h for 100 mm thickness bed filters. For concentration of dust of 2 g/m^3 the duration of filters functioning without changing the filler both for 50 mm thickness and for100 mm bed filters became equal of 35 h. The reached effectiveness in both cases was 99.90%.

Table 1. Pressure drop and effectiveness of filter with thickness 50 mm

Time, h	Pressure drop and effectiveness of filter with thickness 50 mm, initial filtration velocity 0.2 m3/s and different dust concentrations in air (included pressure drop of a grid ~105 Pa)					
	Concentration 0.5 g/m3		Concentration 1.0 g/m3		Concentration 2.0 g/m3	
	Pressure drop, Pa	Effective ness, %	Pressure drop, Pa	Effective ness, %	Pressure drop, Pa	Effective ness, %
0	189	96.6	190	98	190	98.8
5	223	96.8	262	99.1	286	99.2
10	294	97.7	376	99.3	395	99.6
15	406	98.2	504	99.5	542	99.8
20	485	98.4	686	99.6	729	99.8
25	592	98.5	831	99.7	855	99.9
30	674	99.1	984	99.8	1023	99.9
35	814	99.2	1133	99.9	1181	99.9
40	892	99.4				
45	1020	99.4				
50	1116	99.6				
55	1263	99.7				

Table 2. Pressure drop and effectiveness of filter with thickness 100 mm

Test duration, h	Pressure drop and effectiveness of filter with thickness 100 mm, initial filtration velocity 0.2 m3/s and different dust concentrations in air (included pressure drop of a grid ~105 Pa)					
	Concentration 0.5 g/m3		Concentration 1.0 g/m3		Concentration 2.0 g/m3	
	Pressure drop, Pa	Effective ness, %	Pressure drop, Pa	Effective ness, %	Pressure drop, Pa	Effective ness, %
0	320	96.21	322	97.78	322	98.71
5	352	96.31	379	98.09	418	98.84
10	396	97.56	432	98.32	510	98.92
15	448	97.89	498	98.85	621	99.32
20	489	98.35	575	99.16	732	99.58
25	546	98.41	596	99.34	891	99.78
30	586	98.64	721	99.46	1040	99.86
35	634	98.62	762	99.59	1176	99.90
40	682	98.79	798	99.69		
45	728	99.12	876	99.75		
50	764	99.23	954	99.76		
55	810	99.32	1036	99.89		
60	862	99.48	1112	99.89		
65	895	99.53				
70	943	99.72				
75	979	99.81				
80	1032	99.88				
85	1085	99.89				
90	1140	99.89				

Table 3. Pressure drop and effectiveness of filter with thickness 50 mm and 100 mm and initial dust concentration 0.5 g/m3

Test duration, h	Pressure drop and effectiveness of filters by initial filtration velocity 0.2 m3/s and dust concentration 0.5 g/m3 (included pressure drop of a grid ~105 Pa)			
	Filler thickness 50 mm		Filler thickness 100 mm	
	Pressure drop, Pa	Effective ness, %	Pressure drop, Pa	Effective ness, %
0	189	96.6	320	96.21
5	223	96.8	352	96.31
10	294	97.7	396	97.56
15	406	98.2	448	97.89
20	485	98.4	489	98.35
25	592	98.5	546	98.41
30	674	99.1	586	98.64
35	814	99.2	634	98.62
40	892	99.4	682	98.79
45	1020	99.4	728	99.12
50	1116	99.6	764	99.23
55	1263	99.7	810	99.32
60			862	99.48
65			895	99.53
70			943	99.72
75			979	99.81
80			1032	99.88
85			1085	99.89
90			1140	99.89

Table 4. Pressure drop and effectiveness of filter with thickness 50 mm and 100 mm and initial dust concentration 1.0 g/m3

Test duration, h	Pressure drop and effectiveness of filters by initial filtration velocity 0.2 m3/s and dust concentration 1.0 g/m3 (included pressure drop of a grid ~105 Pa)			
	Filler thickness 50 mm		Filler thickness 100 mm	
	Pressure drop, Pa	Effective ness, %	Pressure drop, Pa	Effective ness, %
0	190	98	322	97.78
5	262	99.1	379	98.09
10	376	99.3	432	98.32
15	504	99.5	498	98.85
20	686	99.6	575	99.16
25	831	99.7	596	99.34
30	984	99.8	721	99.46
35	1133	99.9	762	99.59
40			798	99.69
45			876	99.75
50			954	99.76
55			1036	99.89
60			1112	99.89
65				
70				

Table 5. Pressure drop and effectiveness of filter with thickness 50 mm and 100 mm and initial dust concentration 2.0 g/m3

Test duration, h	Pressure drop and effectiveness of filters by initial filtration velocity 0.2 m3/s and dust concentration 2.0 g/m3 (included pressure drop of a grid ~105 Pa)			
	Filler thickness 50 mm		Filler thickness 100 mm	
	Pressure drop, Pa	Effective ness, %	Pressure drop, Pa	Effective ness, %
0	190	98.8	322	98.71
5	286	99.2	418	98.84
10	395	99.6	510	98.92
15	542	99.8	621	99.32
20	729	99.8	732	99.58
25	855	99.9	891	99.78
30	1023	99.9	1040	99.86
35	1181	99.9	1176	99.90
40				
45				

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C) Scientific Impact of Collaboration: Joint scientific collaboration in solution of dust removing and air cleaning problems make the Uzbekistan researchers acquainted with modern methods and procedures of experimental and theoretical study of filters for cleaning of air. Uzbekistan collaborators used the purchased experience and knowledge in teaching and in scientist research work with students. Collaborating on the joint paper submitted for publication in scientific journal "Biosystem Engineering" added to the Uzbekistan researchers experience for publishing in international scientific journals.

D) Description of Project Impact: The results of experimental study and mathematical modelling of processes in air flow through cottonseed filled bed filters were used in design of ventilation systems for hulling-separation departments of Cottonseed oil mill. The obtained measurement data were used for estimating the potential occupational exposure to cotton dust of workers in the hulling–separation rooms of cottonseed oil mills. The results of the research were anticipated to use them in development of local exhaust ventilation systems. The acquired knowledge is expected to apply in development of aspiration and dilution ventilation systems for hulling-separation departments at Cottonseed Oil Mills.

An impact was rendered in methods of air contamination control in industrial workshops with scientific and practical aims. The acquired knowledge and experience will be very useful in implementation of air pollution control in industrial, civil and agricultural buildings in Uzbekistan.

The results of the project were used in teaching process, in training of students in methods of physical and mathematical modeling of dust catching processes in bed filters.

E) Strengthening of Developing Country Institutions: Researches of Tashkent Architectural Building Institute purchased an additional modern computer. It led to strengthening the scientist research and teaching processes. Acquisition and processing of experimental data, solution of

mathematical modelling problems, performing of drawings for experimental installations, etc. were accomplished using the purchased computer and accompanied tools.

Uzbekistan collaborators built an experimental set-up with bed filters packed by cottonseeds. The set-up is using in scientist research and teaching aims.

F) Future Work: During the second half of the forth year we will accomplish the experiments with the cottonseed bed filters, process of experimental and theoretical research results, perform the final report.

Section II: Management and Cooperation

A) Managerial Issues: The implementation of this Project became a fruitful and productive scientific collaboration between Israel and Uzbekistan researchers. The collaboration became useful for both sides, especially for Uzbekistan, which get acquainted with modern and state-of-the art scientific methods and equipment, using new technology for measurement, acquisition, preparation and presentation of scientific data.

B) Special Concerns: Not Applicable

C) Collaboration, Travel, Training and Publications:

1) List of participants in the Project: Principal Investigator I. Shmilovich, Dr. S. Tabak (Israel); Co-Principal Investigator B. Askarov, Y. Rashidov, E. Shernazarov (Uzbekistan).

2) Dr. S. Tabak visited Prof. Robert Pfeffer in New Jersey Institute of Technology and continued discussion and got consultations in mathematical modelling, analysing of the research data, and, especially, advises in preparing of a paper for scientific journal. The paper was submitted for publication in scientific journal "Biosystem Engineering". We wish to thank Prof. Robert Pfeffer of the New Jersey Institute of Technology, Newark, NJ for many insightful technical discussions during the progress of this research.

3) A joint paper named "Airflow through Granular Beds packed with Cottonseeds" of Israel and Uzbekistan collaborators B. Askarov, U. Rashidov as co-authors was submitted for publication in scientific journal "Biosystem Engineering".

4) In the next 6 month is anticipated: to accomplish experimental and mathematical modelling study of the processes in cottonseed filled filters, and to perform Final Report. To achieve the mentioned aims we have to meet with Uzbekistan collaborators.

D) Summary of Requests for CDR Program Actions. The both collaborating Israel and Uzbekistan sides ask assistance in continuation of this fruitful and productive scientific collaboration.