INDEPTH SURVEY REPORT

MACAWBER ENGINEERING, Inc.

REPORT WRITTEN BY
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REPORT DATE

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Report # 144-21b

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PLANT SURVEYED: Macawber Engineering, Inc.
Clydesdale Street
Blount County Industrial Park
Maryville, Tennessee

SIC CODE: 3535 Conveyors and Conveying Equipment

SURVEY DATE: April 10-11, 1984

SURVEY CONDUCTED BY: William A. Heitbrink
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None

ANALYTICAL WORK PERFORMED BY:

Utah Biomedical Test Laboratory

Introduction

Background for Control Technology Studies

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services (formerly DHEW), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these complete studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of, an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

BACKGROUND FOR THIS STUDY

This facility was visited as part of a study of dust control during bag opening, dumping, and disposal. Significant dust exposures can occur during these operations. Although dust can be controlled during bag opening and dumping, bag disposal is a significant source of worker dust exposure. Ultimately this project will result in a concise 10-15 page report describing dust control techniques during bag opening, emptying, and disposal. This report should provide valuable information for those who are responsible for controlling workers' dust exposure.

Background for this Survey

Macawber Engineering Company markets an automatic bag opening machine which is called a JSK sack splitting machine.[1] This machine was located in a test facility for solids material handling equipment. This sack splitting machine was used to open bags of solid materials and discharge these materials into a dense phase pneumatic conveying system. The test facility is in a building which is 70 feet wide, 100 feet long, and has a ceiling 30 feet high.

Plant and Process Description

Macawber Engineering Inc. is a wholly owned subsidiary of a British company. This firm manufactures and sells equipment for handling solid materials. They believe their expertise is in the design and construction of pneumatic conveying systems for flowable solids.

Process Description

The automatic bag opener was operated to test its ability to prevent dust emissions into the workplace while bags of very fine limestone were opened. The properties of the limestone are shown in Appendix 1. This limestone has a mass median diameter based upon settling velocities of under 4.0 micrometers. Practically all of this limestone has a diameter smaller than 10 micrometers.

The bag opening machine was used to open 20 bags of limestone at a time. The bags, which were stacked on pallets, were set near the front of the bag opening (Figure 1.) The operator set the bags on the bag opening machine's conveyor at a rate of 4 bags per minute. This inlet conveyor feeds the the bags onto a second conveyor which grips the bags on the side. Then, a rotating blade cuts the side of the bag and the material falls out of the bag. A vibratory screen breaks-ups any large agglomerates and and helps feed the material into a discharge chute. The discharge chute was connected via a second hopper to a Macawber Densveyor Pneumatic conveying system. The empty bags are swept clean by a rotating brush and are fed into a bag disposal chute. The outlet of the bag disposal chute was covered with a garbage bag. (Figure 2.)

Figure 1. Picture of the Test Facility

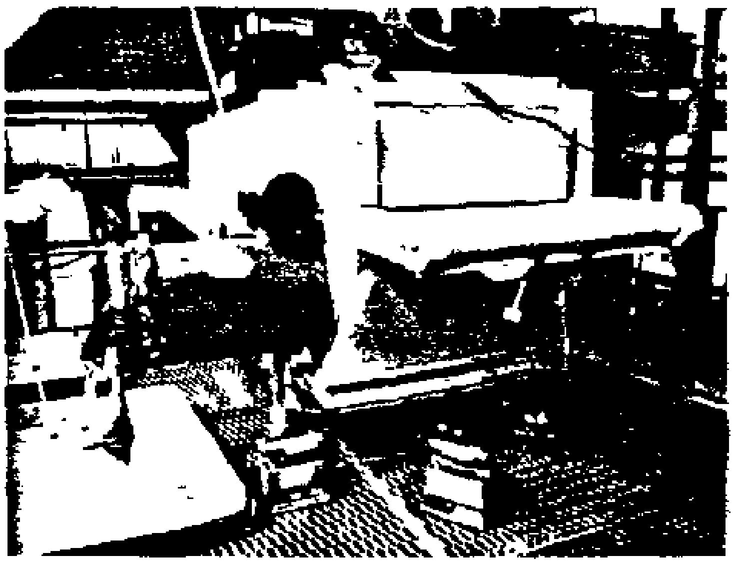


Figure 2. Picture of the bag disposal tube with garbage bag attached.

Control Technology

Principles of Control

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (material substitution, process/equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control both in terms of occupational and environmental concerns. Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment.

In general, a system comprised of the above control measures is required to provide worker protection under normal operating conditions as well as under conditions of process upset, failure and/or maintenance. Process and workplace monitoring devices, personal exposure monitoring, and medical monitoring are important mechanisms for providing feedback concerning effectiveness of the controls in use. Ongoing monitoring and maintenance of controls to insure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system.

These principles of control apply to all situations, but their optimum application varies from case-to-case. The application of these principles are discussed below.

Automatic bag opening machines, such as the JSK sack splitting machine, potentially isolate the worker from from dust generated by bag opening, emptying, and disposal. The air inside of the JSK sack splitting machine is heavily contaminated with dust. This air should be exhausted by the local exhaust ventilation system and/or by the pneumatic conveying system. As a result, inside of the bag opening machine should under negative pressure and and the bag opening machine should not be source of dust emissions into the workplace.

Study Methodology

The objective of this study was to determine whether the JSK sack splitting machine could be operated without becoming a dust emission source. This question was evaluated by using this machine to open bags of Franklin T-11 limestone. If this machine is not a source of dust emissions, then dust concentrations should not increase when this bag opening machine is in use. This premise was used to formulate the study hypothesis used to address the study objective. This hypothesis can be stated as null (H_o) and alternative (H_a) hypotheses:

H_o: Dust concentration (C) does not increase when the bag slitter is in use. Stated mathematically: $C_{initial} = C_{operational}$.

H_a: Dust concentration increases when the bag slitter is in use. Stated mathematically: $C_{operational} \cdot C_{initial}$

The study was conducted to choose between the above two alternatives at the locations listed in Tables 1 and 2. The first test was conducted at the locations listed in Table 1. Because the data from the first test suggested dust leakage, a second test was conducted using the sampling locations in Table 2.

First Test

The hypothesis was addressed by operating the JSK sack splitting machine and measuring the the total and respirable dust concentrations at the locations in Table 1. The sampling locations in Table 1 reflect either potential emission sources on the machine or a background measurement. The JSK sack splitting machine was used to open 20 bags of limestone during a test run. A total of four test runs were made. Before and during each run, the respirable and total dust concentrations were measured. The equipment used to make these concentration measurements is listed in Table 2. After the bag opening machine had finished emptying the 20th bag, the filled garbage bag was removed from the end of the bag disposal tube and empty bags were removed from the bag disposal tube. Then a fresh garbage bag was secured on the outlet of the bag disposal tube. All air sampling was terminated when empty bags were being handled.

Total dust concentrations were measure by drawing air through preweighed filters. A nominal sampling flow rate of 14 LPM was obtained by using carbon vane pumps and critical orifices. At each sampling location in Table 1, two air samples were collected on two filters. One sample, an "off" sample, was collected before the bag opener was in use and a second sample, an "on" sample, was collected while the bag opener was opening bags. Before the sack emptier was used, the off samples were mounted on the vacuum tubing, and air was drawn through the filters for 10 minutes. Then, the off samples were removed from the sampling train and the on samples were mounted on the sampling train. Air was drawn through these samples for the 5-6 minutes the bag opener needed to empty 20 bags. This was done four times, each time the same off and on samples were mounted at the same sampling location.

Respirable dust concentrations were taken with GCA Real Time Aerosol Monitors (RAMs) at the locations listed in Table 1. The RAMs at locations 0, 2, 3, and 4 were rotated through each of the sampling locations. This rotation was done when the empty bags were discarded from the bag disposal tube. The RAM concentrations were recorded electronically on an Apple II Plus Computer. The computer was equipped with an AI13 analog to digital conversion hardware and an internal clock. Two wire cable was used to attach the analog output of the RAMs to the Multiplexer of the the AI13. The settings on the RAM are listed in Table 3.

The program listed in Appendix II was used to obtain concentration data every 10 seconds. First the program records the analog voltage of the RAMs and then it converts the voltage to concentration using the conversion 2.0 mg/m^3 per volt. The program records concentration taken at ten second intervals as one large, Basic string variable. This string variable lists in order: the concentrations from channels 0 thru 4, the time the reading was taken, the run number, whether the bag opener was in use, and the respective identification numbers of the ram in channels 0 thru 4 respectively. The status of the bag opener was indicated by the reading a voltage in channel 5. Because RAM readings could vary from instrument to instrument, the four RAMS were rotated thru locations 0,2,3, and 4 in Table 1. The RAM in location 1 was not rotated through the other locations. Air samples at location 1 were taken to monitor the storage silo and associated equipment for dust leakage.

Second Test

Because the RAM concentrations indicated dust leakage from the sack emptying machine, additional RAM concentrations were measured with the RAM at the locations in Table 2. The operator fed 22 bags of limestone into the sack emptying machine. The concentration readings of the RAMs before, during and after the bags were emptied were recorded as described earlier. Because the sack emptying machine only operated about 6 minutes, sufficient material could not be collected on the filters to measure total dust concentrations.

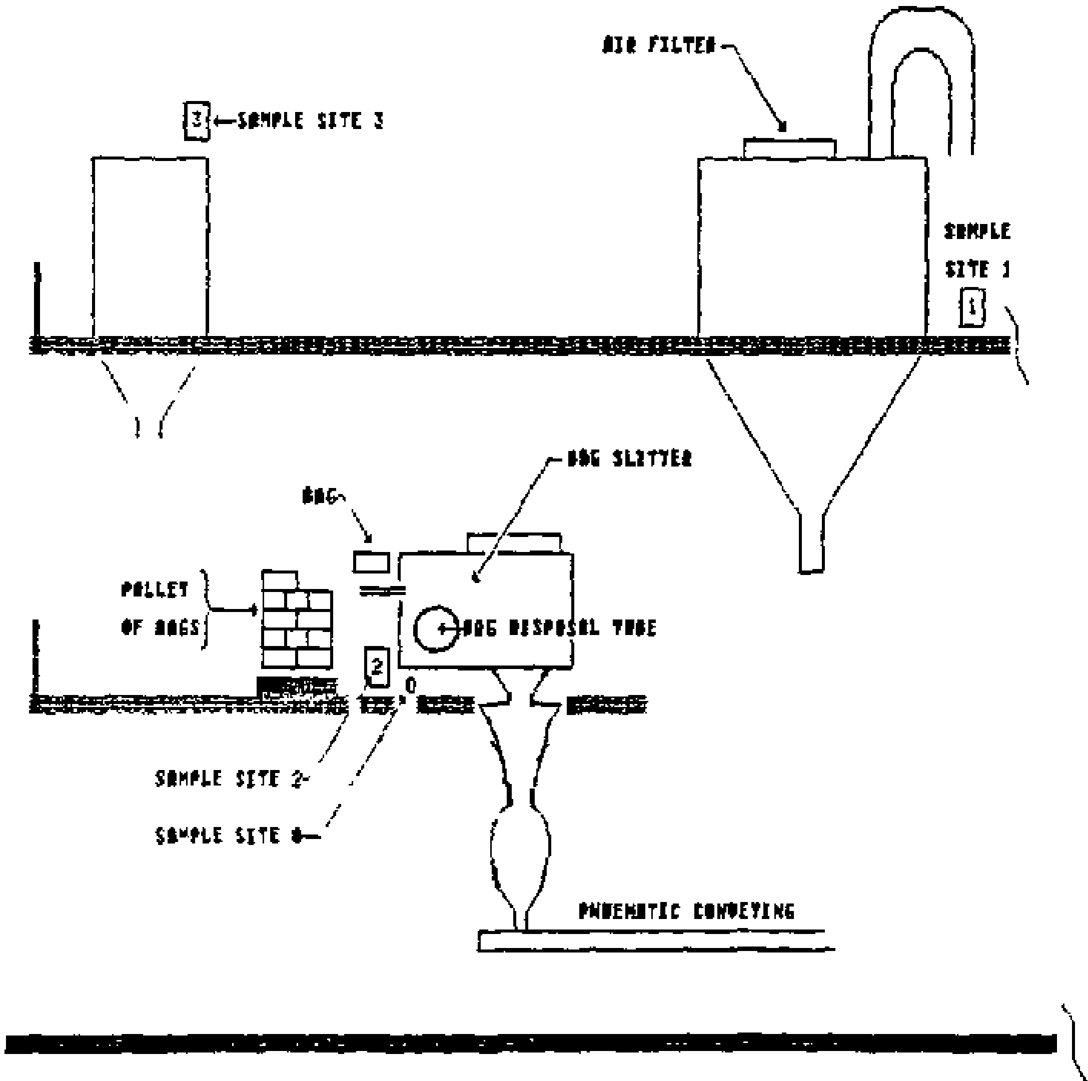


Figure 3. Schematic describing sampling locations

Table 1
Sampling Locations for Test

Channel Number	Location and description
0.	Bag disposal chute. At this location, RAM readings were taken below the chute and total dust measurements were taken above the chute as shown in Figure 2. An elevated dust concentration here would suggest that the seal on the bag disposal chute was inadequate.
1.	Near the storage silo on the third floor. Air samples at this location were taken to serve as an indication of dust leakage from the storage bin an associated equipment. If there is dust leakage here, background dust concentrations could increase.
2.	Under loading conveyor for the sack splitting machine. High dust concentrations here would be an indication of dust emissions either from the conveyor or dust on the exterior surfaces of the bags of limestone.
3	Top of silo, which is above pallets. There are no dust emission sources near this sampling location. Sampling results here reflect background air contamination
4	Operator's breathing zone. The total particulate samples were mounted on the worker while he was placing bags of limestone on the conveyor. The RAMs were held near the worker's breathing zone. This is shown in Figure 4.

Figure 3. Ram held in Worker's breathing zone

Table 2
Sampling Locations for Second Test On April 11

Channel Number	Sampling location and description
0.	Near bellows above vibratory screen on the same side of the machine as the bag disposal tube.
1.	At discharge chute for the bag opening machine. The discharge chute of the bag opening machine was connected to a bin which held material before it was to be fed into the dome valve.
2	Under bag disposal tube. See Table 1
3.	Near Storage Bin on Second level of platform. Because of bridging in the bin which holds material for the dome valve, no material was apparently being discharged into the storage bin. As a result, sampling results at this location reflect background air contamination.
4.	Next to bellows on the side of sack splitting machine opposite the bag disposal tube.

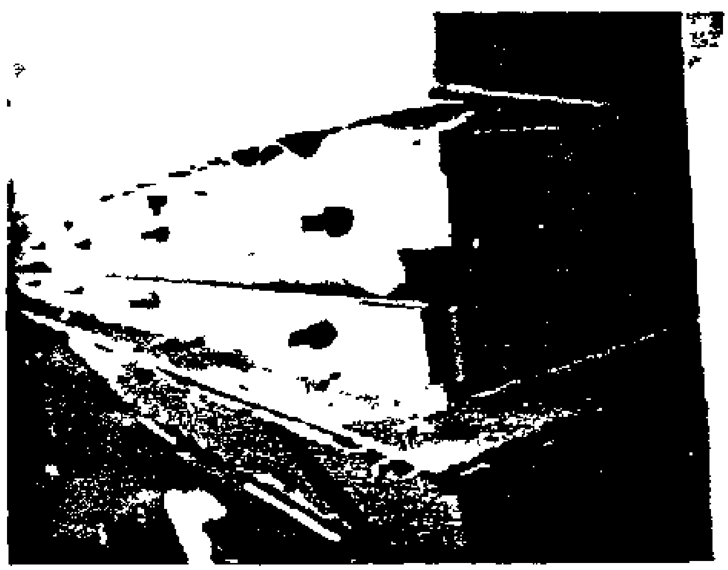


Figure 5. Picture of bellows

Instrument Variablity Test

The RAMS used at locations 0,2,3, and 4 were adjusted so that they all read the same. The RAMs were placed in a Marple Test Chamber which is similar to one described elsewhere.[2] A TSI 3400 Fluidized Bed Aerosol Generator was used to disperse a sample of Franklin T-11 limestone into the test chamber. The gain setting of the instruments was adjusted so that all four RAMS read the same concentration. The operating parameters for the test chamber and the aerosol generator were:

Test chamber settings
dilution air flow rate 500 ft^3/hr.
static pressure in chamber +0.05 inches of water

Settings on TSI 3400 Fluidized Bed Aerosol Generator:
chain speed 10
bed flow 40
Bead purge 50

Table 3.
Equipment Used During Survey

Equipment	Model Number	Use
Critical Flow Orifices		Control flow rate through filters
Gast Carbon Vane Pumps		Supply sufficient vacuum to draw air through filters and critical orifices and maintain a vacuum of 15 inches of mercury
GCA Real Time Aerosol Monitors	1	Monitor respirable dust concentrations
Apple Computer	II-plus	Record RAM concentrations
Interactive Structures A/D convertor	AI13	Convert the analog signal of the RAMs to digital signal
The Clock		Internal clock for Apple computer. This is manufactured by Mountain Computer.
Two wire cable		Transmit signal from the RAMs to the the multiplexer of the AI13

Results

Before the survey on April 10-11 was conducted, the four RAMs were adjusted to read identical concentrations in the Marple chamber. To document how well the four instruments agreed, the readings of all four instrument were recorded once a minute for 30 minutes. As shown in Table 4, the average RAM readings were within 0.02 mg/m^3.

Table 4
Calibration settings of four RAMs and average of 30 concentration readings

RAM NUMBER	Calibration Setting	Average Respirable Dust Concentration
92	8.42	0.74
91	6.89	0.73
90	5.81	0.75
89	6.56	0.73
	mean of four RAMS	0.74
	standard deviation	0.01
	number of readings per RAM	30

The concentration values obtained from the RAMs and the total dust and calcium concentrations are presented in Tables 5, 6, and 7. The output of the RAMs at the sampling locations during the second test on April 11 is presented graphically in Figures 6-10. In Figures 6-10, the bag opener was started at 0 seconds on the time axis. The data in these Tables and graphs show obvious increases in concentration when the bag opener is in use.

The air flow into the bag opener was not measured. The inlet to the bag opening machine was a swinging door which was open only when a bag was fed into the machine. The exhaust volume was not measured by taking a pitot tube traverse because the test facility manager did not want holes in the ducting. The ventilation ducting for the unbagger had 9 elbows. This is shown in Figures 10 and 11. These elbows appeared to be mitered joints. Such elbows have relatively high pressure losses. Fluid mechanics textbooks report pressure losses between one and two velocity heads for such elbows.[3,4] Assuming a pressure loss through the systems bag house of 4" of water, the estimate exhaust volume for the system would be below 400 cfm. This volumetric flow rate is divided between the automatic bag opener and at least 2 other bins. As a result, the air flow out of the automatic bag opening machine was probably under 200 CFM.

Table 5.
Summary of Ram Concentrations (mg/m^3) for First Test on April 11th

Sampling location	Respirable dust concentration when sack splitting machine is: off		on		significance
	mean	standard deviation	mean	standard deviation	
Under bag disposal tube	0.05	0.05	8.4	2.9	s
near storage bins	0.21	0.06	0.55	0.41	ns
under loading conveyor	0.09	0.03	0.16	0.06	ns
background, above worker	0.06	0.03	0.06	0.02	ns
operator	0.08	0.01	0.12	0.02	

Note:
1. s - significant difference at the 95% confidence level for a paired t-test
2. ns - difference not significant at the 95% confidence level for a paired t-test
3. The mean and standard deviation are computed from the average RAM concentration recorded for each of the four test runs.

Table 6

Total dust (TD) and Calcium (Ca) Concentrations (mg/m^3) Measured at Sack Splitting Machine

Sampling location	Date	On		off	
		TD	Ca	TD	Ca
above bag disposal tube	4/10	5.4	2.1	0.13	0.08
	4/11		0.68	0.17	0.06
near storage bin	4/10	0.25	0.05		
	4/11	0.48	0.14		
under loading conveyor	4/10	0.43	0.19	0.45	0.13
	4/11	0.77	0.21	0.09	0.03
on hopper above operator	4/10	0.03	0.04	below 0.01	0.008
	4/11	0.02	0.03	0.07	0.13
operator	4/10	1.61	0.29	0.01	0.01
	4/11	1.45	0.33	0.08	0.02

Note: Samples taken near the storage bin were taken during both on and off conditions.

Table 8

Summary of Respirable Dust Concentrations from the Second Test on April 11

Sampling Location	Respirable Dust Concentration (mg/m^3) Bag opener status on			off		
	x	s	n	x	s	n
Bellows above vibratory screens on same side as bag disposal tube	3.83	2.7	38	0.21	0.49	98
Under bag disposal chute	3.7	3.4	38	0.08	0.08	98
Discharge from sack splitting machine near dome valve	1.30	1.08	38	0.19	0.07	98
On third floor near storage bin	0.11	0.08	38	0.11	0.39	98
Bellows above the the vibratory screens on side opposite the bag disposal chute.	0.29	1.5	38	0.65	2.2	98

x = mean
s = standard deviation
n = number of times concentration was recorded.

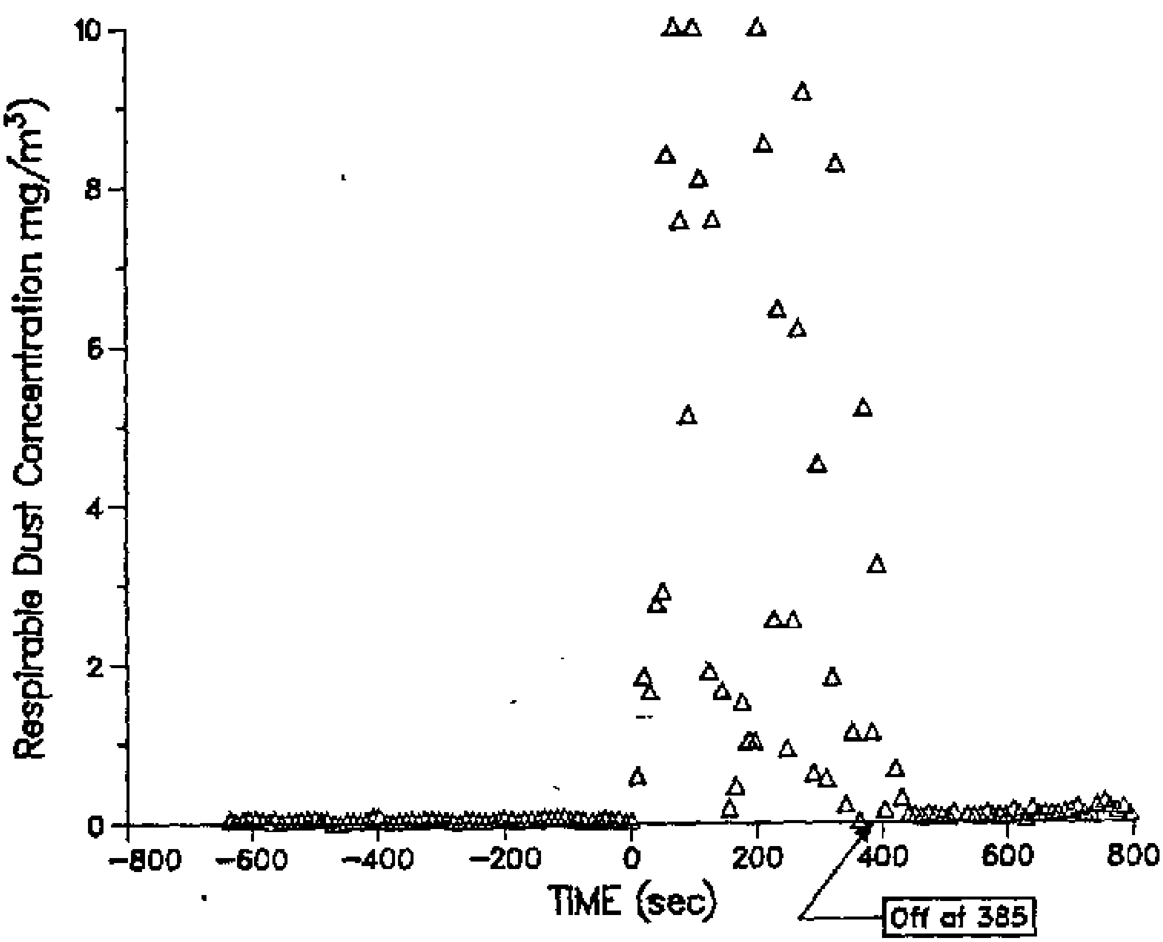


Figure 6. Dust Concentration Under Bag Disposal Chute.

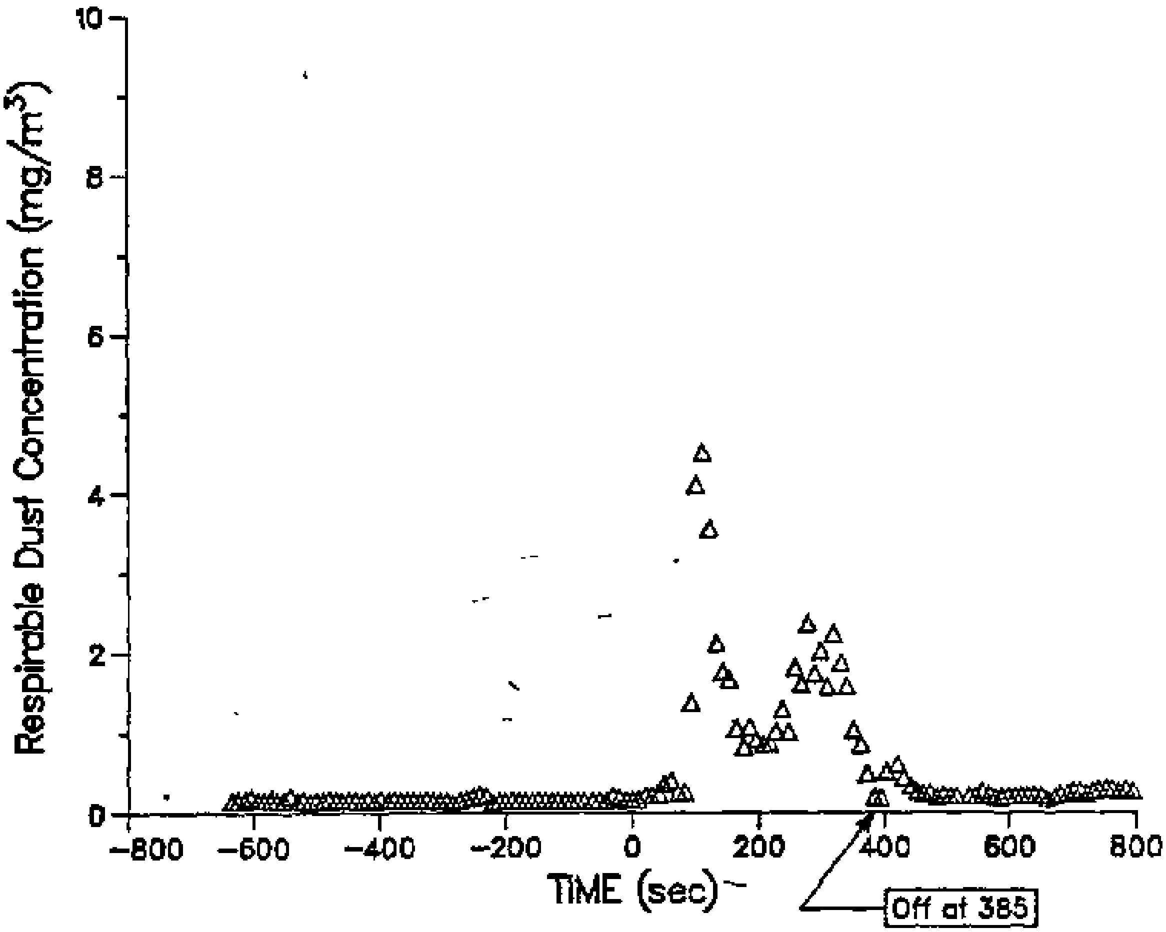


Figure 7. Dust Concentration at outlet of automatic unbagger.

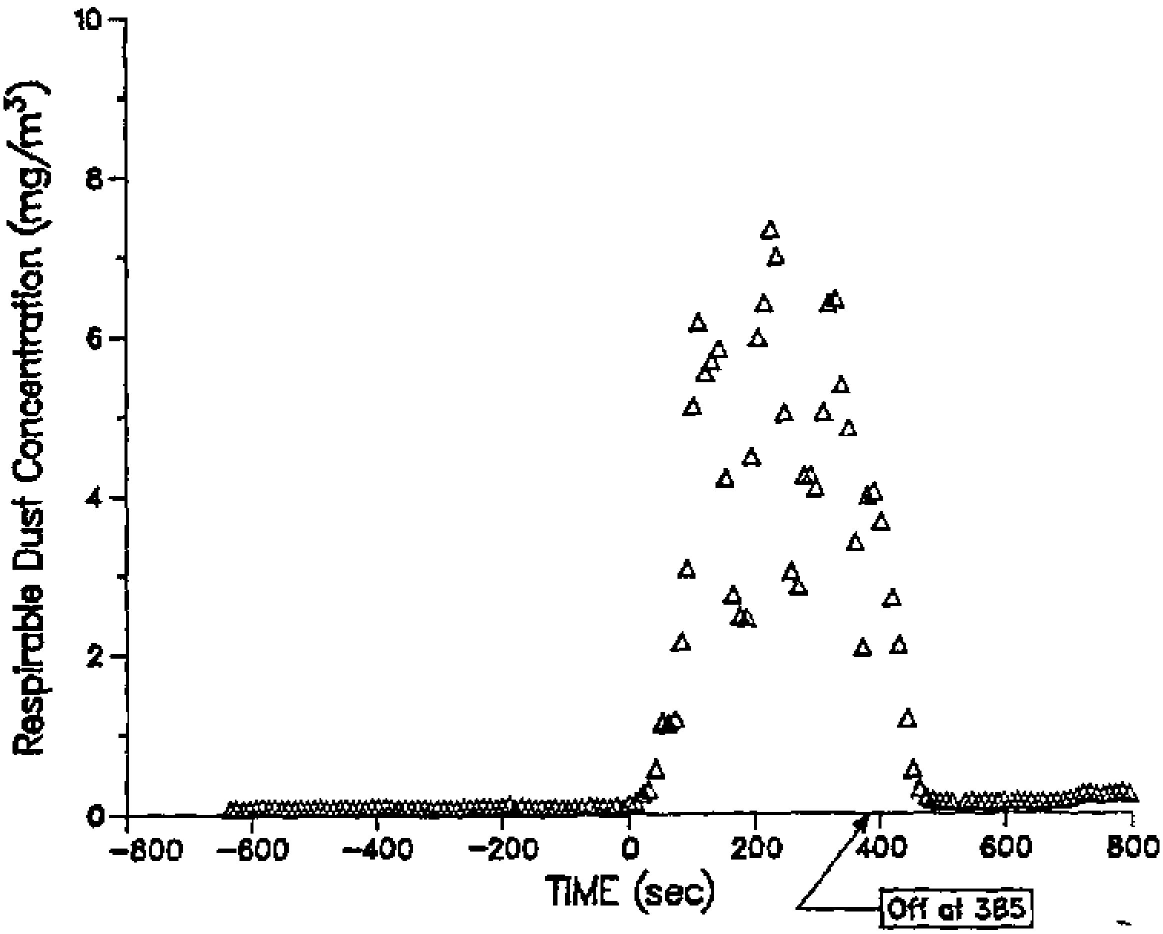


Figure 8. Dust Concentration Next to bellows on same side of automatic bag opening machine as the bag disposal tube.

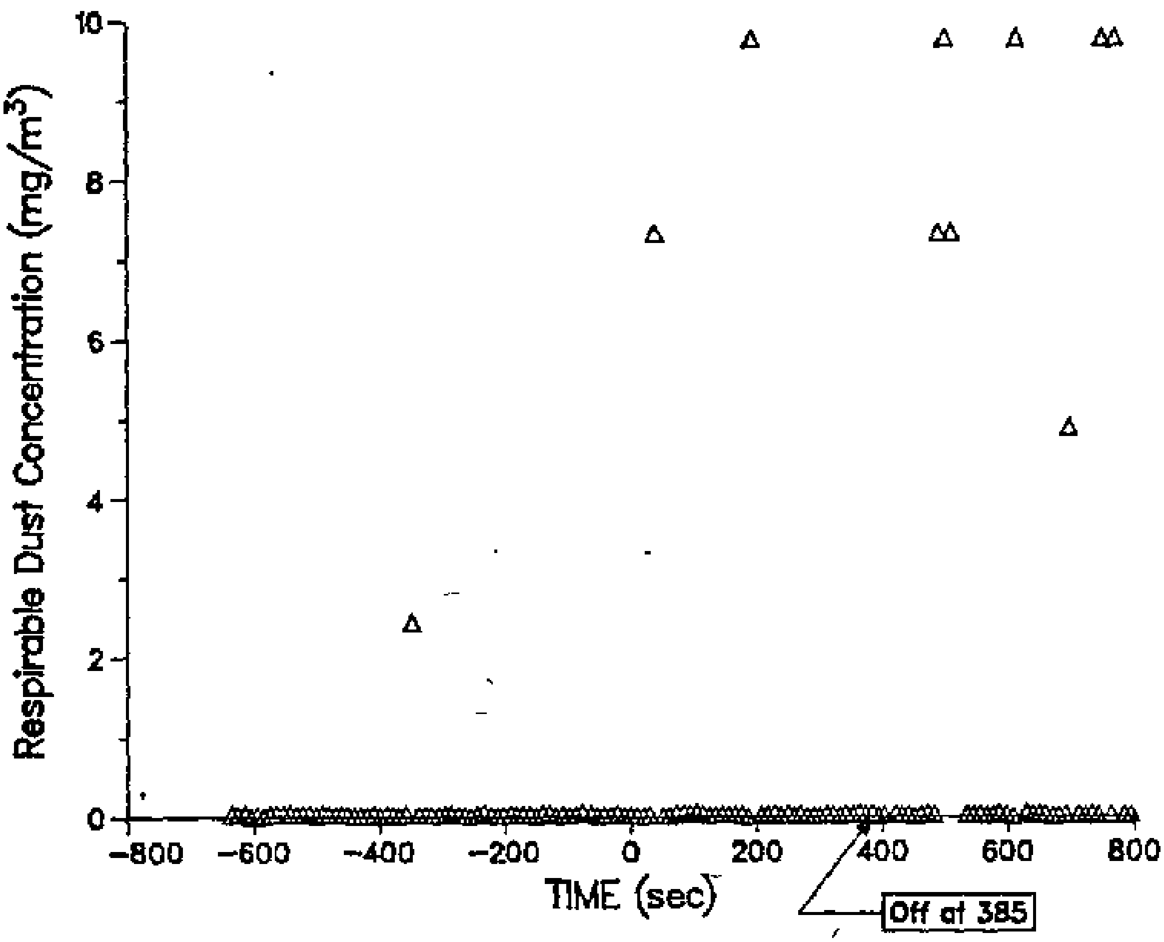


Figure 9. Dust concentration next to bellows on west side.

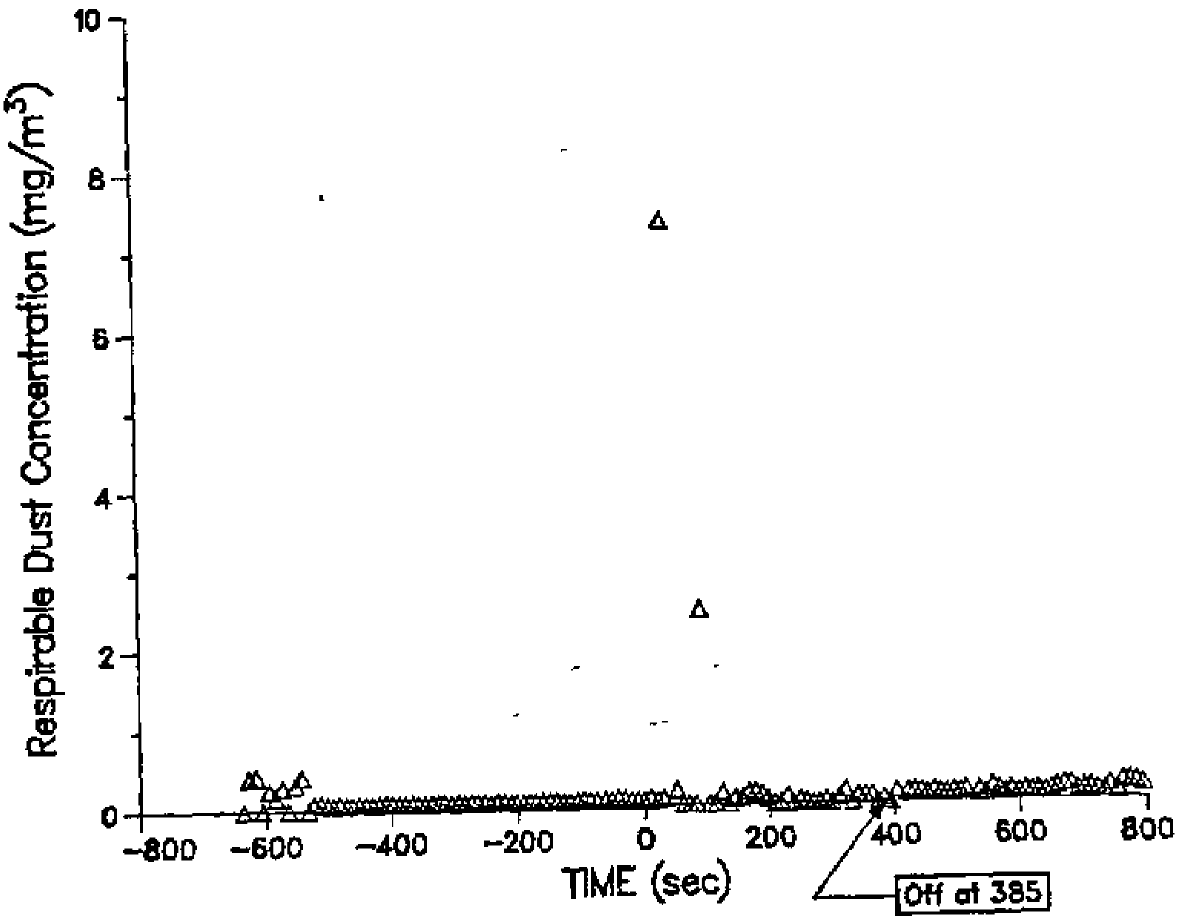


Figure 10. Dust Concentration next to storage bins.

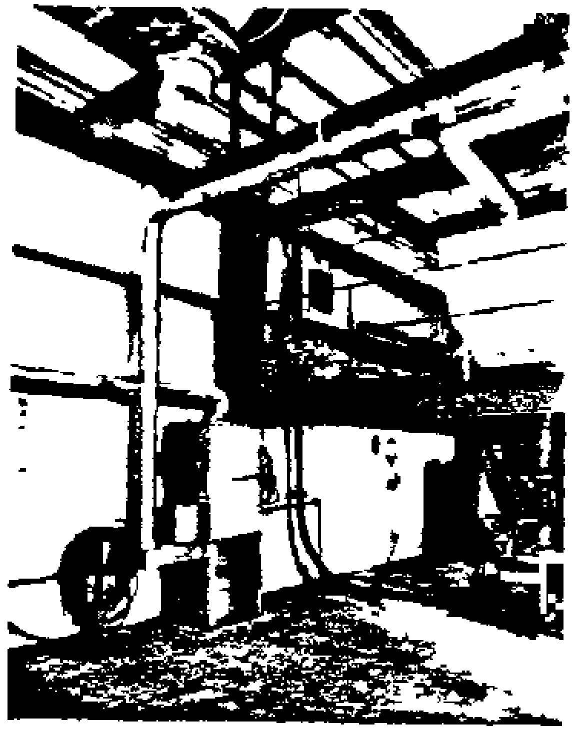


Figure 11. Picture of Duct Work from Baghouse to Sack Emptier

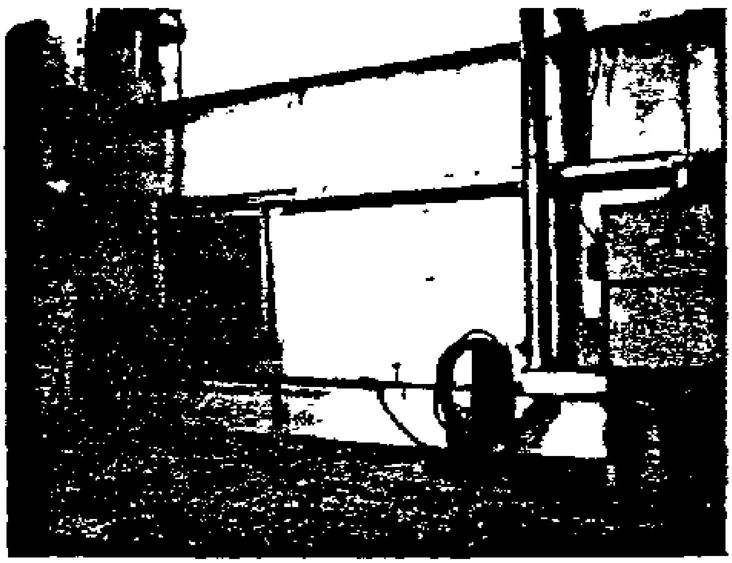


Figure 12. Picture of Duct Work from Baghouse to Outside of Test Facility.

Discussion

Dust Leakage

The concentration data obtained by using the RAMs' and by analyzing filters shows that the concentration of total and respirable dust was elevated at three sampling locations:

1. Under and above the bag disposal tube.

2. Near the bellows between the vibratory screen and the body of the sack splitting machine. This was on the same side of the sack splitting machine as the bag disposal tube.

3. At the point where material is discharged into hopper which is above the dome valve.

Increased dust concentrations at these locations suggests dust leakage. During this study, the flange of the bag disposal tube was not tightly sealed to the body of the bag opener. The motion of the bag disposal mechanism probably forces dust laden air between this flange and the body of the sack splitting machine. As a result, the dust concentration around the bag disposal tube would be elevated.

The limestone did not flow freely from the bin into the dome valve. The limestone formed a stable arch. This prevented the pneumatic conveying system from drawing air through the bin and the sack splitting machine. As a result, dust generated by limestone falling into the bin is not controlled and dust leakage would occur at this location.

The reason for the increased dust concentration next to the bellows is unclear. Perhaps, leakage occurring around the bag disposal tube was being blown towards the bellows. The cooling fan mounted just above the bag disposal tube was blowing air in the direction of the bellows. In addition, dust could be leaking through the bellows material. Mechanical motion in the sack splitting machine could be inducing more air flow into the sack splitting machine than the ventilation system is removing. Possibly, some of this air flows through the bellows and into the workplace.

Operator Dust Exposure

The total dust data indicates that the operator's dust exposure is elevated by putting bags of limestone on the conveyor. In contrast, the RAM's did not indicate such a marked increase in dust concentration. There are two possible reasons for this:

1. The RAMs' were not held close enough to the operator. The samples mounted on the worker would be much closer to the dust sources than the RAMs which were held near the worker's breathing zone.

2. The dust generated by handling the bags could be non-respirable. The RAMs are designed to respond only to respirable dust. As a result, the RAMs might not respond to the dust generated by handling the bags of limestone.

Increased dust exposures caused by placing bags of solid materials on to conveyors has been observed in other studies of automatic bag opening equipment. This simply indicates that the bags are dirty and handling these bags outside of the bag opening machine creates a dust exposure for the worker.

Concentrations Spikes

The data in Figure 9 shows concentration spikes after the sack splitting machine was turned off. Whether these spikes are real or artifacts is unclear. Near the sampling location, the operator was using a metal rod to break-up a stable arch in the bin which received limestone form the sack splitting machine. The operator simply used a metal rod to punch the arch. Such activity usually creates some dust. He also started and stopped equipment. The concentration spikes presented in Figure 9 could be due to dust generated by turning equipment on and off. Turning equipment on and off can generate voltages in the signal lines which transmit the output of the RAMs to the inlet port of the analog to digital convertor. When equipment is turned on and off, fluctuating magnetic fields could be generated. Such fields would generate a current and voltage in the signal wires. The extent to which this occurs is unclear. Other increases in concentration noted by the RAMs are not the result of this phenomena. The meter output of the RAMs was observed to increase and go off-scale when the sack splitting machine was used.

Conclusions

The data taken shows that the sack splitting machine leaked dust near the bag disposal tube, at the point where material is discharged from the unit, and possibly from the bellows between the vibratory screen and the top of the sack splitting machine. The dust concentrations at these locations all exceeded 1 mg/m^3. However, the occupational health standards for some solid materials are well below these levels. For example, OSHA permissible exposure limits for occupational exposure to lead and arsenic are 50 and 10 $micrograms/m^3$ respectively.[5,6] Such low health standards requires the control of dust leakage. As tested, the sack splitting machine is probably only suitable for handling relatively non-toxic dusts.

References

1. Pare, R.: Recent Advances in Sack-Emptying Technology. Bulk Solids Handling 1:531-534. (1981)

2. Rubow, K.L. and V. A. Marple: Instrument Evaluation Chamber: Calibration of Commercial Photometers. In: Aerosols in the Mining and Industrial Work Environments- Volume 3 Instrumentation. (1983)

3. Bird, R., W. Stewart, and E. Lightfoot: Transport Phenomena. Wiley New York. p217. (1960)

4. Morris H. and J. Wiggert: Applied Hydralics in Engineering. 2nd ed. Wiley. New York. p113. (1971)

5. 29CFR1910.1018

6. 29CFR1910.1025

Appendix 1

Properties of Franklin T-11 limestone

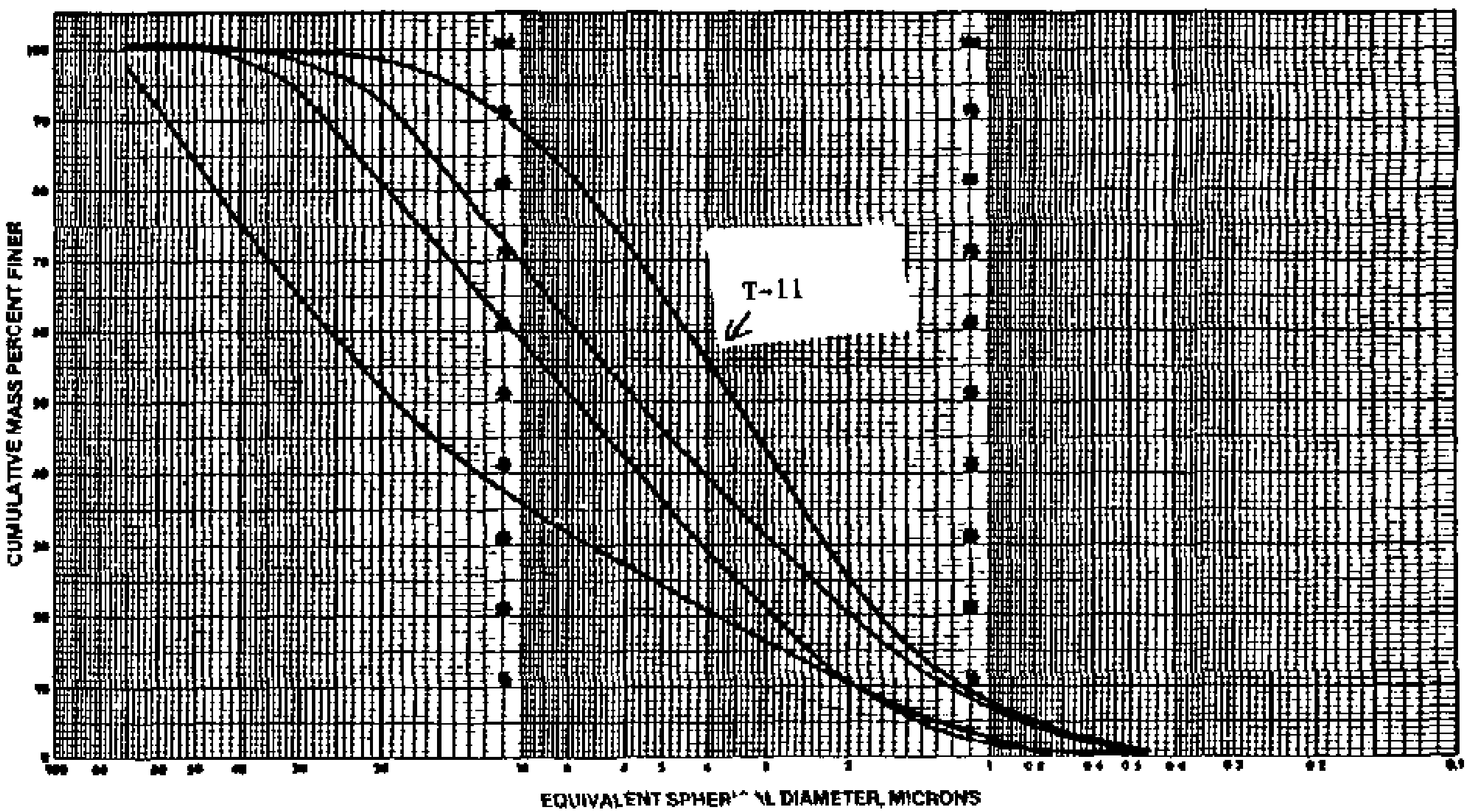
FRANKLIN LIMESTONE COMPANY

612 TENTH AVENUE NORTH
NASHVILLE, TENNESSEE 37203
(615) 259-4222

PRODUCTS

85-200 ________ 65-200 ________ 36-200 ________ T 11 ________ T 13 ________ T 325/T 14 ________

PARTICLE SIZE DISTRIBUTION—SEDIGRAPH CURVE



FRANKLIN LIMESTONE COMPANY
612 TENTH AVENUE NORTH
NASHVILLE, TENNESSEE 37203
(615) 259-4222

PEERLESS HIGH CALCIUM LIMESTONE
TYPICAL CHEMICAL ANALYSIS

CHEMICAL	REPORTED AS	Per Cent
CALCIUM CARBONATE	$CaCO_3$	97 64
CALCIUM OXIDE	CaO	54 51
MAGNESIUM CARBONATE	$MgCO_3$	1 26
MAGNESIUM OXIDE	MgO	60
IRON OXIDE	Fe_2O_3	095
SILICA	SiO_2	56
ALUMINA	Al_2O_3	23
PHOSPHORUS	P_2O_5	01
NICKEL	Ni	< 002
TITANIUM	TiO_2	02
CHROMIUM	Cr_2O_3	< 001
STRONTIUM OXIDE	SrO	03
MANGANESE OXIDE	MnO	< 01
SODIUM OXIDE	Na_2O	03
POTASSIUM OXIDE	K_2O	025
SULFUR	SO_3	08
BARIUM OXIDE	BaO	< .007
LOSS ON IGNITION	LOI	43 70

Appendix II

Program Listing Apple Computer.

```
50  TEXT   HOME   SPEED= 255
60  HIMEM  38144
70 D$ =  CHR$ (4)
80  DIM DRAM$(1000)
90  PRINT D$,"BLOAD DELAY
100 INP$ =    "  REM INPUTS
110 OP$ = D$ + "OPEN "
120 CL$ = D$ + "CLOSE "
130 RD$ = D$ +  READ
140 AP$ = D$ + "APPEND "
150 WR$ = D$ + "WRITE "
160 DE$ = D$ + "DELETE
170 RC$ =   "
180  HOME
190  INPUT "ENTER NUMBER OF CHANN
     ELS (0-15) ";IA
200  IF IA < 0 OR IA > 15 THEN  GOTO
     190
210  FOR I = 0 TO IA
220  PRINT "LOCATION ";I;"  ENTER
      THE RAM CODE ";

230  INPUT "-- ";RN$
240 RC$ = RC$ + RN$ +
250  NEXT I
260  REM PRINT RC$
270  PRINT
280  INPUT  FILENAME FOR RUN -->
     ;FL$
290  PRINT OP$,FL$
300  PRINT CL$ FL$
310  PRINT DE$ FL$
320  PRINT OP$ FL$
330  PRINT CL$ FL$
340 SLOT = 5 REC = 0
350  PRINT
360  GOSUB 1160  REM GET INPUT GA
     IN
370  PRINT
380  PRINT  DELAY
390  PRINT     1 --> 10 SEC
400  PRINT     2 --> 20 SEC
410  PRINT     3 --> 30 SEC
420  PRINT     4 --  40 SEC
430  PRINT     5 --> 50 SEC
440  PRINT     6 -->  1 MIN
450  PRINT
460  INPUT  AMOUNT OF DELAY (1-6)
     --> ;K
470  IF K < 1 OR K    6 THEN  GOTO
     460
480  PRINT
490  PRINT  NUMBER OF READINGS RE
     QUIRED
500  INPUT     (MAXIMUM 1000) -->
       ;N
510  IF N < 1 OR N > 1000 THEN  GOTO
     490
520  PRINT
530  HOME
540  INVERSE
550  FOR I = 1 TO 40  PRINT " ";
      NEXT
560  PRINT "  PRESS CONTROL-D TO
     SAVE DATA TO DISK   ";
570  PRINT                 BEFORE EN
     D OF RUN              "
580  FOR I = 1 TO 40  PRINT " ";
      NEXT
590  NORMAL
600  POKE 34,5  HOME
610  POKE  - 16368 0  REM  CLEAR
     KEYBOARD STROBE
620  FOR M = 1 TO N
630 REC = REC + 1
640  GOSUB 1020  REM -GO GET TIME
650  GOSUB 770  REM -GO GET AI13
     INPUT
660 DRAM$(REC) = INP$ + " " + T5$
      + RC$
670  IF M = N THEN  GOTO 710
680 PK =  PEEK ( - 16384)
690  IF PK = 145 THEN M = N N = R
     EC  GOTO 720
700  FOR DLY = 1 TO K  CALL 768: NEXT
     . REM DELAY
710  NEXT M
720  GOSUB 1020  REM WRITE TO DIS
     K
730  GOSUB 890. REM READ OUTPUT F
     ROM DISK
740  TEXT
750  END
760  REM
READ INPUTS

770 INP$ = " "  FOR I = 0 TO IA
780 AI13 =  - 16256 + SLOT * 16
790  POKE AI13,I
800 RESULT(I) =  PEEK  (AI13 + 1) *
      256 +  PEEK  (AI13)
810 RESULT(I) = RESULT(I) * GN /
     4095
820 RESULT(I) = RESULT(I) * 2
830 RE$ =  LEFT$ ( STR$ (RESULT(I
     )),5)
840 INP$ = INP$ + RE$ + " "
850  NEXT I
860  PRINT REC; "  ";INP$
870  RETURN
880  REM
READ OUTPUT FROM DISK

890  PRINT "READING OUTPUT FROM D
     ISK
900  PRINT OP$,FL$
910  PRINT RD$,FL$
920  FOR Q = 1 TO N
930 DRAM$ = ""
940  GET KEY$
950 DRAM$ = DRAM$ + KEY$
960  IF KEY$ <  >  CHR$ (13) THEN
      GOTO 940
970  PRINT DRAM$
980  NEXT Q
990  PRINT CL$ FL$
1000  RETURN
1010  REM
READ TIME

1020  PRINT   PRINT D$  IN#4
1030  INPUT   "";T$
1040  PRINT D$, IN#0
1050 T1 =  VAL ( MID$ (T$,7,2))
1060 T2 =  VAL ( MID$ (T$,10,2))
1070 T3 =  VAL ( MID$ (T$,13,2))
1080 T4 =  VAL ( MID$ (T$,16,1))
1090  IF T4 < 5 THEN  GOTO 1120
1100 T3 = T3 + 1  IF T3 < 60 THEN
      GOTO 1120
1110 T2 = T2 + 1  IF T2 = 60 THEN
     T2 = 0 T1 = T1 + 1
1120 T5$ = ""
1130 T5$ = T5$ +  RIGHT$ ("0  +  STR$
     (T1),2) + " "
1140 T5$ = T5$ +  RIGHT$ ( 0  +  STR$
     (T2),2) + "
1150 T5$ = T5$ +  RIGHT$ ( 0  +  STR$
     (T3),2) + " "
1160  RETURN
1170  REM
INPUT GAIN

1180  PRINT  GAIN CODES
```

```
1190  PRINT "  0 --> 0 TO 5 00 V"

1200  PRINT "  1 --> 0 TO 1 00 V"

1210  PRINT "  2 --> 0 TO 0 50 V"

1220  PRINT "  3 --> 0 TO 0 10 V"

1230  PRINT
1240  INPUT "PLEASE INPUT GAIN (O
    -3) -->";GC
1250  IF GC   0 OR GC > 3 THEN  GOTO
    1240
1260  IF GC = 0 THEN GN = 4.99878

1270  IF GC = 1 THEN GN = 0 99976

1280  IF GC = 2 THEN GN = 0 49988

1290  IF GC = 3 THEN GN = 0 09998

1300  RETURN
1310  REM
WRITE TO DISK

1320  PRINT
1330  PRINT OP$ FL$
1340  PRINT WR$;FL$
1350  FOR I = 1 TO REC
1360  PRINT DRAM%(I)
1370  NEXT
1380  PRINT CL$;FL$
1390  RETURN
```