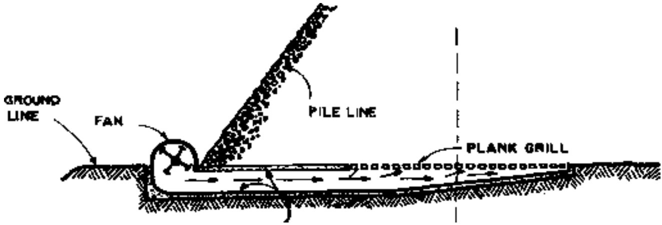
The Distribution of Air in Sugar Beet Stock Pile Ventilation Systems

C. M. HANSEN[1]

Sugar beet stock pile ventilation has brought a change to the harvest campaign in the eastern area. With the simple process of blowing cool night air into a pile of beets, the processor can receive beets on a larger scale through expanded facilities at an earlier date than was heretofore deemed wise. The insurance given by this system affords the processor an opportunity to speed up deliveries and thus cut the harvest period to a minimum, avoiding much of the usual inclement November weather.

LAKE SHORE SUGAR CO.

UNDER GROUND SYSTEM



CONCRETE CENTER LINE OF PILE

Figure 1.

Elimination of restricted delivery will give the farmer an opportunity to harvest his crop to the limit of his equipment. This means that the processor can be assured of fresh beets. With the advent of the mechanical harvester, which ironically made the delivery problem more acute, beets can be taken from the ground direct to the ventilated pile. This would cut the beet shrink loss to a minimum, assuring the farmer of maximum tonnage. However, the most important saving is the saving in sugar. From data taken by Fort and Stout (l)[2] we can see that with increasing beet temperature the sugar loss due to respiration alone is tremendous. On this factor alone, a properly installed stock pile ventilation system is a paying proposition.

Much basic information has been obtained on the storage of the sugar beet. The application of these data required a well organized research program. It was necessary to determine the most feasible method of ventilating the stock piles. It was also necessary to develop a technique to evaluate the

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[2] The numbers in parentheses refer to literature cited.

various proposed ventilation systems. The need for this information is emphasized forcefully by the data obtained during the 1947 M.S.C. sugar beet ventilation experiment (2) . These data indicate that beets which were treated at the rate of 10 cfm of night air per ton lost about 3 times as much sugar as the beets which received 20 cfm. Granted that these data are of only relative value, they do point out the fact that the air should be as evenly distributed as is economically feasible.

Our objective in stock pile ventilation should be to keep the beets as near 32° F. as possible. Even though a pile might keep from spoiling without ventilation (for every degree of temperature drop means a saving of sugar) , it is poor economy to treat a portion of a pile to twice as much air as another.

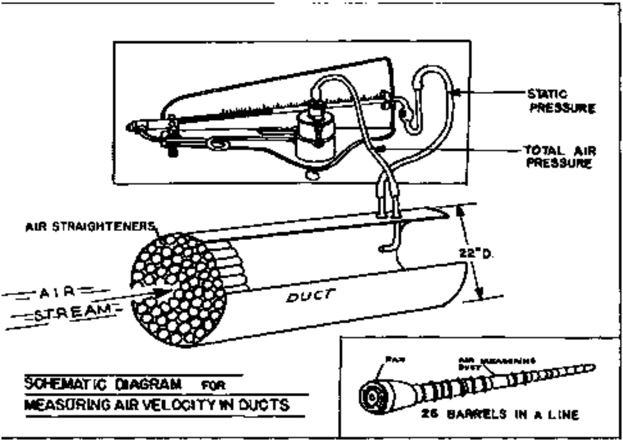

Figure 2.

By the same token no system should be powered beyond requirements. This fact is further emphasized by data obtained on two commercial stock piles this past fall. One pile had cross ducts placed on 20ft. centers and the other on 30-ft. centers. By captive sample analysis the pile which had ducts on 20-ft. centers showed 28% greater savings of sugar. Yet in spite of the limited experience with stock pile ventilation the processors of this area believe in it, for nearly 26% of Michigan's beets were piled over air ducts in 1949.

Systems Used

The two basic types of stock pile ventilation systems which were used in Michigan during the 1949 campaign are the surface and the underground. The surface systems were installed as the beets were piled. The ducts were spaced at regular intervals 20 feet apart the length of the pile and a place was provided for a fan on each duct. It is not necessary to provide a fan for every duct in this type of installation, for as soon as the beet temperature is down the fans can be placed on every other duct, or 40 feet apart. The fan or duct openings must be closed except during the blowing operation. Both steel barrels and steel road culvert tubes were used as ducts, and in one installation the ducts were steel fabricated sections. The performance of these ducts will be discussed further in this paper.

Two types of underground systems were also used. Michigan Sugar Co. forced air into the flumes at two of its plants. The flumes were 340 to 365 feet long. Two fans having a capacity of 16,000 cfm were installed at both

AIR DISTRIBUTION PATTERN-STOCK PILE VENTILATION
BARREL DUCTS
MICHIGAN SUGAR CO. PLANT
SEBEWAING, MICHIGAN

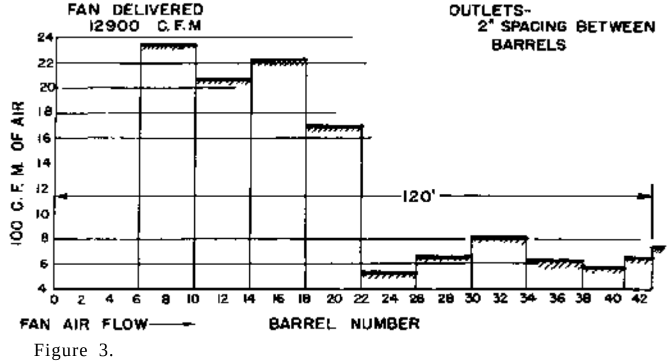

Figure 3.

ends of each flume, blowing the air toward the center of the flume. The fans should be placed on the ground or floor of the flume for two very definite reasons. First—if the fans are several feet above the flume it will cause an unnecessary bend in the header duct and restrict air flow. Second—during the still clear fall nights there is apt to be a differential of from 5 to 10 degrees in ambient temperature within a height six feet from the ground.

The management of Lake Shore Sugar Co. envisioned what stock pile ventilation could do for it and built 18 underground cross ducts on 30-ft. centers. Their managers turned to the men in their shops for the necessary steel fabrication. Ten-HP electric motors were used to power the fans, which were also made in their shops. The concrete underground duct side walls became a part of the lower fan housing and the air was forced directly through the 4x6 plank grill work and into the beet pile. (Figure **1)** .

Technique Used to Check Distribution

The basic tool used to check the distribution of air was a three-inch Ellison draft gage. This instrument registers inches of water at .001 graduations, and with it we can obtain the static pressure, which is the force exerted against the sidewalls of the duct, and the velocity-pressure from which can be obtained the velocity of air in feet per minute through mathematical formulation. A technique was developed in which pitot and static pressure tubes were installed 21/2 diameters down stream from the air straighteners (3) . The air straighteners assured us of the necessary smooth laminar flow. This appartus was built into a smooth steel pipe having a diameter equal to the steel barrels. After making a reading it was moved down the duct at given intervals for subsequent readings (Figure 2) . This technique had to be varied somewhat for the underground systems.

Results

Using the method described in the foregoing discussion we were able to obtain data which might be expressed in graph form for clarity. Three graphs of the data taken on various systems were selected at random. For this reason they are not necessarily indicative of the efficiency of that system. Our first research began on the steel barrel duct system (Figure 3) . Imagine, if you will, that you are looking at a cross section of a beet pile with a line drawn directly over the air duct. The steel barrels in this particular case were spaced with approximately two inches between them. A fan delivering 12,900 cfm is at the left. The information which we have on this graph shows that there is a definite need for spacing the first barrels closer. Static pressure was much greater the first 22 barrels—consequently there was a greater dispersal of air. Total length of this particular duct is 120 feet. This is about the maximum length at which barrel ducts will operate effectivly with this particular type axial flow fan.

Some experimental work was done with road culverts as ducts. Data were obtained on two sizes, 18" and 24" diameters (Figure 4) . Using the data obtained from the barrel ducts 111/2" holes were drilled, allowing for about 27 square inches of opening per foot of duct. This area was increased to 34 for the tubes between 48 and 72 feet, which tended to level off the curve. The sudden rise at the end of the duct is typical of much of the data which were obtained. Further study is needed on this type of duct to determine the best possible arrangement of holes.

The flume did not provide the most satisfactory air duct; nevertheless, the operation was successful (Figure 5) . The fans in this case were rated at 16,000 cfm at 3" static, yet due to the necessary restriction which the installation imposed on them they delivered something more than 10,000 at about 1.7 static. The left side of this graph is rather orderly with a sharp rise in the center area. The release of this large volume of air was corrected once the distribution pattern was known. All that was needed in this case was to space the duct covers closer and force the air into the area between the east 100 to 150 mark.

A somewhat different technique was used to check the Lake Shore Sugar Company's underground ducts. The shop-made fans were quite efficient and delivered approximately 17,000 cfm at .92 inches static. The duct as shown in the graph is 40 feet long (Figure 6) . It represents only the section which distributed the air into the beets. This distribution curve ranges between

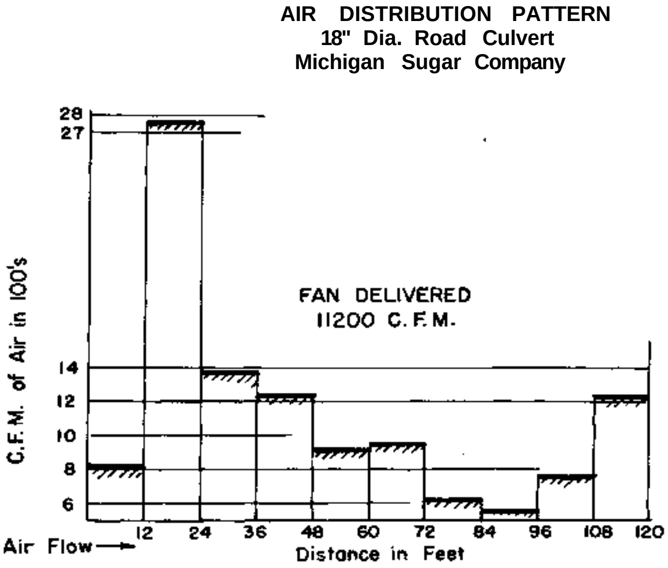

Figure 4.

700 and 1,200 cfm. This was not the most desirable pattern, and so an attempt was made to rectify it. Three 6x6 wood blocks were placed at given intervals in the ducts. The blocks did increase the volume release of air throughout the first ten feet, but they caused excessive turbulence and did not improve the pattern.

Rates of Air Per Ton of Beets

The various systems which have been discussed have different air capacities and as a result the cfm of air per ton of beets differs. The rates are as follows:

1. Portable system using axial flow fans with road culvert, or barrel ducts 16 cfm of air per ton of beets when beets are first piled, and 2 cfm to hold pile after initial cooling is accomplished.
2. Portable system using forward curved rotor fan or fabricated steel ducts, 9.3 cfm per ton.

3. Underground system, flume 15.6 cfm per ton.
4. Underground system, Lake Shore Sugar Co., 24.3 cfm per ton.

Smoke Check

It was felt that a visual check of the various distribution patterns would be interesting. For this reason smoke was injected into the air stream of the fan and forced through the pile. A word of caution as to the use of smoke for this purpose. It is necessary to use a compound which will not be toxic to either the beets or steel ducts. For example, we considered sky-writing smoke, but it leaves a heavy acid vapor. This method of checking gives one a very good idea of what is happening in the beet pile.

AIR DISTRIBUTION PATTERN STOCK PILE VENTILATION
No. II Flume
Michigan Sugar Co- Plant, Sebewaing, Mich.

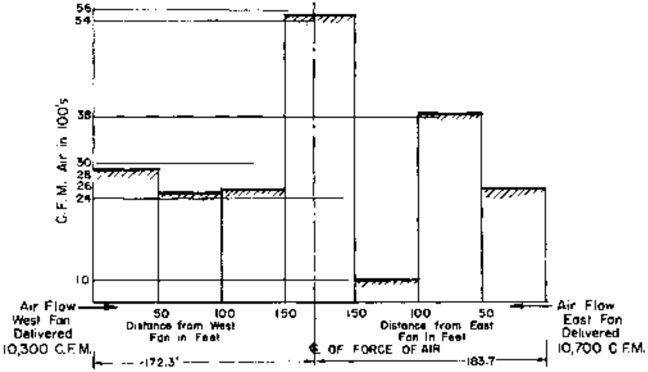

Figure 5.

Air Losses

As is true of much research one obtains other valuable information. Due to the fact that we must observe safety precautions, 1/4" wire mesh screen was placed over the intake side of the axial flow fan. A secondary purpose of this screen is to keep leaves and trash from being blown into the pile. A check was made to determine whether or not this screen restricted the fan operation appreciably. It was found that it cut the fan's output 24%, whereupon another screen made of chicken wire was substituted which met the requirements.

Barrel ducts which have been in service a year or more often sustain dents when they are reclaimed. Dents of any consequence restrict air flow markedly. A seven-inch dent, for instance, will retard flow 21%.

Temperatures

Temperatures of the ventilated beet piles were taken at various locations at about the 10ft. level. Standard mercury thermometers were suspended

AIR DISTRIBUTION PATTERN

LAKE SHORE SUGAR CO.

UNDER GROUND DUCTS

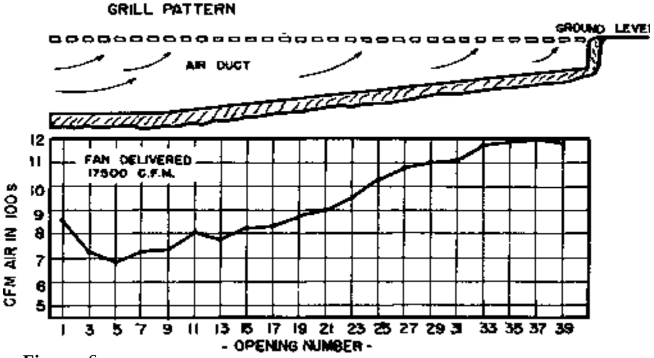

Figure 6.

on strings down 5/8″ pipe to be read at regular intervals. It would be superfluous to present all of the temperature data in graph form, so a comment or two on the subject will suffice. In general the fans were turned on only when the beets affected by that particular fan were 5° F. warmer than the ambient air. However, it was found beneficial in some cases if the fans were operated with only a degree differential. For this reason fan hours will vary from year to year. This past fall, for instance, on one 58,200 ton installation beets at one point were not ventilated more than 272 hours.

If we compare two rates of application of air on two different piles which were ventilated at the same time we notice that the beets which were treated with a lower rate of air, 9.3 cfm as against 24.3 cfm, were from 1 to 5 degrees warmer. These temperatures varied as the ambient air.

Costs

It is rather difficult to determine the cost of a stock pile ventilation system for one cannot set up a unit value. There are cases in which overhead is fixed such as in the cost of supervision. One man, for instance, can tend the fans, take readings, etc., on 50 to 70 thousand tons of beets with little more effort than is needed for 10 thousand. Also, many plants have fixed outside power rates which are imposed due to the nature of the seasonal operation. However, there are certain costs which can be considered (Table 1). There is some question as to whether or not the steel road culvert would not last longer than 10 years, in which case this system would be the least expensive.

The cost of placing portable ducts as the pils is formed and removing them when the beets are recovered was not computed with costs.

The supervision cost might be cut from $.012 per ton by the addition of automatic thermoswitches but there is no question that competent labor is much more satisfactory. Often it is possible to take advantage of evaporative cooling, lowering the temperature of beets by blowing in air which is the same temperature as the hottest spot in the pile.

Table 1.—Costs.

Type of System	Initial Cost /Ton	Total Equipment Cost/Ton for Given Period as Indicated	Power Cost /Ton at .08/k.w.hr.	Supervision /50,000 Tons	Duct Cost /Foot, 10-Yr. Period	Total Cost /Ton
Barrel Duct	.037	10 Years—.0058	.037	.012	2.00[1]	.0548
Road Culvert Duct	.058	10 Years—.0058	.037	.012	2.00[2]	.0548
Prefabricated Steel Duct	1.057	20 Years—.05	.05	.012	2.10	.112
Factory Flume	.10	20 Years—.005	.162	.012		.179
Lake Shore Co. Underground	1.078	20 Years—.054	.102	.012	9.80	.168

[1] Steel barrels replaced every three years.
[2] Road culvert replaced every ten years.

Conclusions and Summary

There are a few conclusions which might be drawn from the research work which was done during the 1919 harvest campaign.

1. Indications are that the least expensive surface portable air ducts can be fabricated from standard 16 to 18 gauge 18" diameter road culvert.
2. Stock pile ventilation can be accomplished at an annual cost of between 10 and 16 cents per ton of beets.
3. Stock pile ventilation is a paying proposition, for if the beet temperature is lowered 3 degrees, from 68° to 65° F., for 6 or 7 days, a processor can pay for the season's ventilation costs on the respiration factor alone.
4. Further research is needed to determine the best possible arrangements and sizes of openings in the road culvert ducts.
5. Static pressure in ducts should be held at a minimum.

Literature Cited

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(2) HANSEN, C. M.
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(3) 1948. Heating and Ventilating, Air Conditioning Guide.