FLOUR MILL FUMIGATION

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PREFACE

The introduction of the Mediterranean Flour Moth and its rapid dissemination to most of the commercial flour mills of Ohio has made necessary that some simple method be devised for its control, and one that will, at the same time, be effective against other insect pests of the flour mill. With the idea of gaining an acquaintance with the insect depredators, and, also, with the hope of developing satisfactory means for their control, the study of the pests affecting stored products was begun by the writer several years ago. However, active work on a commercial scale to test the efficiency of measures, which had previously been tried in a smaller way, was not begun until 1910. As an introductory move, a paper was presented by the writer before the State Millers' Association of Ohio at their annual meeting at Columbus, Ohio, on May 11, 1911. At this meeting a number of millers signified their willingness to cooperate with the Experiment Station in developing methods for ridding their flour mills of insect pests. Differences in equipment and in the construction of the mills to be treated demanded that various means of control be tried out and compared. Cleaning thoroughly was tested, in connection with changes in construction of spouts and other parts; also fumigating with hydrocyanic acid gas, and the employment of high temperatures, were given a trial in large experiments. In this preliminary report, these tests are compared and the results given to assist others in controlling insect pests in their mills.

MEDITERRANEAN FLOUR MOTH

HISTORY OF THE SPECIES

The Mediterranean Flour Moth, *Ephestia kuehniella* Zell, was introduced into North America from Europe, appearing in destructive numbers in Canada in 1889. It was supposedly not introduced into Ohio until 1897 or 1898, but a few millers, in discussing its ravages, gave what appeared to be reliable records of its appearance and injuries in 1895 in several Ohio flour mills. Since that time it has been spread through the medium of second-hand machinery, and more often second-hand sacks, to many of the flour mills of this State.

DESCRIPTION, LIFE HISTORY AND HABITS

The moth is silver gray with a few darker, irregular markings across its fore-wings. The hind-wings are uniformly grayish with a narrow fringe of hairs around their rear edge. It is from two-fifths to two-thirds of an inch long, when at rest with wings folded, and from one-half to one inch across from tip to tip of its expanded wings. The moths fly towards evening and at night, remaining quiet during the day unless they are disturbed, when they seek other quarters with a rapid, irregular flight. The eggs are laid almost any place where there is a supply of food, but as most of the larvae pupate in the spouts, elevator legs and in other similar places, most of the moths issue here and consequently most of the eggs are laid in these places. Each female, after mating, lays from one hundred to three hundred eggs, which hatch normally in from three to eight days, depending upon the temperature. The larvae or worms begin feeding shortly after hatching, and spin fine, silken threads everywhere they go. The larval life is from four weeks to six months duration, depending upon temperature and kind of food. When full grown, the larvae are usually pinkish in color and about three-fourths to one inch in length. They are provided with three pairs of true legs near the head end of the body; four pairs of fleshy legs toward the posterior end, and at the extreme end is another pair of legs differing from the others, which are called caudal legs. There are from six to fifteen hairs on each segment, borne from little brownish spots. The head and cervical shield or plate just behind the head are brown. Wherever the Mediterranean Moth larvae go they spin a fine, silken thread; around these threads particles of bran, flour and middlings collect, and the mass of material grows larger and larger until it breaks loose of its own weight, or from a sudden jar or jerk, and clogs the spout or conveyor into which it is carried. These masses of webbed material collect in machines and make a great amount of trouble besides being, to a certain extent, a menace to the health of those who consume the products in which they occur. When full grown, the larvae construct silken cocoons, often surrounded or inclosed by particles of flour or middlings, and transform into pupae. In every case, the larvae seem to prefer the middlings or tailings for a breeding place. Very little trouble is experienced in the elevators or spouts at the head end of the mill, the trouble usually occuring in the tailings-elevators, spouts and conveyors. The composition of the middlings may have some influence on the development of the larvae, as it seems to be their favorite food.

After transforming to pupae the insects remain quiet five to eight days, when the adults emerge from the cocoons, providing the temperature is high enough, but it takes six to seven months before they emerge if exposed to normal winter temperatures. How long they would live in continued cold where the temperature is not extreme is an unanswered question.

The Mediterranean Moth does not seem to develop normally in the light. In glass breeding jars the larvae have failed to develop; not a single individual maturing in eight months from badly infested material. Infested material from the same mills, placed in metal breeding cans, has yielded thousands of specimens of adults under the same conditions of temperature and moisture.

METHODS OF CONTROL

A number of methods for the control of mill insects are practiced and are sometimes used in conjunction with fumigation. Among these are the following:

Cleanliness and fumigation. Constant watching of spouts, machines, conveyors and bolters, together with a thorough cleaning of the whole mill once or twice a year will almost keep the Mediterranean Moth in control. Fumoth, a paper saturated with a volatile compound and sold by F. A. Thomson & Co., Detroit, Mich., when used according to directions, is an excellent supplement to cleanliness, and will keep the moth in subjection fairly well. But the foregoing is much more expensive than many other methods of control, and, at best, is only fairly satisfactory. A great deal of trouble can be obviated when cleanliness alone is relied upon to hold the insect in check, if metal or metal-lined spouts, stiff brushes on elevator belts, metal conveyors, and leather elevator belts are employed. The Mediterranean Moth never webs together masses of flour on leather belts, especially on new belts. The tannin in the leather seems to be a repellent to the larvae, and they choose to live elsewhere. The metal spouts are so smooth that it is hard for the larvae to gain a foothold and these seldom clog if the elbows are carefully constructed.

Fumigation with hydrocyanic acid gas. Hydrocyanic acid gas has been considered one of our best fumigants, but it lacks penetration. It is a light gas, formed by dropping potassium cyanide or sodium cyanide into diluted sulphuric acid. It diffuses quite rapidly and condenses readily in a moist atmosphere; gives better results with high than with low temperatures; is deadly poisonous and should never be used by anyone not acquainted with its deadly character It is commonly used to fumigate greenhouses at mild strengths, as compared with the dosage used in flour mills. Greenhouse fumigation seldom allows the use of more than an ounce of potassium cyanide to 1000 cubic feet of space. In flour mill fumigation, eight, ten, and twelve ounces per 1000 cubic feet of space are commonly used.

Potassium cyanide is a white, crystalline substance, which is deadly poisonous, very soluble in water and takes up water very rapidly when exposed to the air. It should always be handled with care, and the operator should wear leather gloves, well oiled, in order to protect the hands, especially if there are any small cuts or abrasions of the skin. Rubber gloves are too apt to be cut by the sharp-edged crystals when the operator is compelled to break large pieces of potassium cyanide. Sufficient potassium cyanide might get into a wound to cause death, or, to say the least, serious trouble.

Sulphuric acid of 66 degree test, Beaumé, must also be handled with care. Ammonia should always be quickly available in case the acid splashes and reaches one of the operators. *The acid must always be poured into water, never water into the acid or an explosion will occur.* It weighs approximately 1.8 lbs. per pint measure, and is a little more than one and three-fourths times as heavy as water, which greatly simplifies the handling of this acid. Granite ware measures are very convenient for measuring it and are not affected by the acid if the granite glaze is not broken.

Preparing the mill for fumigation with hydrocyanic acid gas. In preparing a flour mill for fumigation, every part must be thoroughly cleaned if the fumigation is to be effective. Elevator belts should be removed and cleaned; elevators, spouts, machines, flour bins, floors and all corners should be thoroughly swept out so that no webbed material is left in or about them. All infested material should be burned.

The inside measurements of each story of the mill must be taken and the cubical contents obtained in order to estimate the amount of materials needed. Materials may be estimated at the following rates, the amount used depending entirely upon the construction of the mill, especially its openness.

Well built, tight mills—eight ounces per 1000 cubic feet of space.

Fairly tight mills—ten ounces per 1000 cubic feet of space.

Open mills—twelve ounces or more per 1000 cubic feet of space.

The amount of cyanide required for each floor may be readily estimated after finding the number of cubic feet of space enclosed. Then for each of the above rates, multiply by the factors in the table given below:

8	ounces	use	factor	.008
10	"	"	"	.01
12	"	"	"	.012
14	"	"	"	.014

Divide by 16 and the quotient is the number of pounds of potassium cyanide that will be necessary.

For each pound of potassium cyanide, one and one-half pound of 66 degree test, Beaume, sulphuric acid is needed, and twice as much water as acid is commonly used.

Generator jars of five-gallon capacity are used for each 3-pound charge of potassium cyanide, and small, 1-gallon jars for holding the acid are placed beside each generator jar. Heavy paper sacks for holding 3-pound charges of potassium cyanide, and sufficient, smooth, strong cord, and screw eyes to properly string the building are also necessary. A set of reliable scales and a measuring beaker complete the list of necessary apparatus.

The generator jars are placed in position, and the cords are carried to the various generators from some convenient point of exit. Heavy screw eyes, with about one-half inch diameter eyes, are used as pulleys, to guide the cords around obstructions. This permits the suspension of the charges of potassium cyanide, in paper sacks, directly over the generator jars. In each generator jar put in the necessary amount of water, then pour in the acid, and then from the point of exit lower the charges of cyanide by means of the strings. The next lower floor, which has previously been similarly prepared, should be set off at once in the same manner, and so on to each of the lower floors of the mill. In case of breakage or boiling over of a generator jar, serious injury to belts and machines on the lower floors may be prevented if each generator jar is set in a liberal amount of mill feed or shorts.

HYDROCYANIC ACID GAS FUMIGATION

MILL No. 1

This flour mill was fumigated with hydrocyanic acid gas, with only a partial cleaning beforehand, but the mill was run empty, and all machines, elevators and spouts were opened to allow free access of the gas to all parts of the mill. The cubic feet of space on each floor was ascertained and the generator jars placed according to the number of charges of cyanide required. The cyanide was distributed in approximately 3-pound charges, placed in heavy paper sacks and suspended over each generator jar by means of strong cords, the ends of the cords all coming to a common terminus on the stairway to the next lower floor. The following table gives the arrangement of the generators and the cubic feet of space on each floor:

Floor	Number of charges	Weight of charges	Cubic feet of space
Basement	12	1½ lbs.	20,000
First floor	4	3½ "	24,000
Second floor	4	3 "	24,000
Third floor	4	3 "	20,000
Fourth floor	4	3½ "	40,000

Total number of charges 28
Total weight of charges ....70 lbs. of potassium cyanide
Average weight of charges.............. 2.5 pounds
Rate per 1000 cubic feet.............. 8.75 ounces

This gave a fair test of hydrocyanic acid gas in a flour mill, without thoroughly cleaning the mill previous to using the gas. The mill was well built, and perfectly tight, and was kept closed from 1 P. M. Saturday, May 26th, until the following Monday morning, which allowed a 40-hour exposure. The windows were then opened from the outside by means of pulleys and ropes, and the doors were unfastened, allowing the building to be thoroughly aired before the men went to work. Inspection, June 12th, revealed a slight infestation. A second inspection on October 14th revealed no increase in numbers of the Mediterranean Moth, but rather a decrease, due, no doubt, to the persistent use of Fumoth. The mill was cleaned after the fumigation, yet enough Mediterranean Moth escaped, through a spout being clogged, to re-infest the mill. Some eggs, no doubt, escaped destruction, because most of the larvae found on June 12th were small.

Since fumigating a number of other flour mills, I have decided that the arrangement of the charges of potassium cyanide could have been changed advantageously. Because the gas is lighter than air and rises upwards, the bulk of the charges should be placed on the lower floors of the mill. A revision of the placing of generator jars, using 3-pound charges of potassium cyanide, distributed as they should be, is as follows:

Floor	Number of charges	Cubic feet of space
Basement	8	20,000
First floor	5	24,000
Second floor	4	24,000
Third floor	3	20,000
Fourth floor	2	40,000

Using 3 pounds of potassium cyanide, 2½ pints or 4½ lbs. of 66 degree test, Beaumé, sulphuric acid, and 9 pints of water for each charge.

Total potassium cyanide....66 lbs.
Rate per 1000 cubic feet of space....8.2 ounces

MILL No. 2*

This was a small, water-power flour mill of two stories and an attic, but having fourteen elevators, extending into a basement, and resting on a platform which was just above the water wheel. This mill had been thoroughly cleaned. Every spout, elevator, conveyor, bolter and machine had been thoroughly swept out, so that none of the Mediterranean Moth larvae, pupae, nor eggs could escape the hydrocyanic acid gas. The mill was open between floors so the entire charge was placed on the main floor and the mill treated as if it was one big room. The building was fairly tight and of the following dimensions:

Floor	Number of charges	Cubic feet of space
First floor	6	12,962
Second floor	None	12,962
Attic	"	5,185
Office	"	1,995

Weight of charges.... 3 pounds
Total potassium cyanide.... 18 pounds
Rate of potassium cyanide per 1000 cu. ft. of space.... 8.7 ounces

Small charges of hydrocyanic acid of about one-fourth pound each were set off in the basement in the boot of each of the fourteen elevators, and one charge was placed in the flour room, which is separate from the mill proper.

This mill was as clean as it was possible to get one with brooms and other implements, and under these conditions we would naturally expect perfect results with hydrocyanic acid gas. The mill was prepared for fumigation by placing the generator jars not directly under openings to the upper floors. The potassium cyanide was placed in paper sacks and suspended over the generator jars, each of which contained 5 pounds of sulphuric acid, diluted by pouring it into twice its weight of water. The strings supporting the charges all terminated at the exit door, so that the charges were easily and

*Fumigated Saturday, June 17, 1911.

conveniently set off. The temperature ranged between 85 and 94 degrees during the period of fumigation. Light rains fell Saturday and Sunday, and there was also a very light breeze.

Through an accident, one charge of cyanide in this mill was not generated, so the rate per 1000 cubic feet of space was 7.37 oz. instead of 8.7 oz. The results were very good and the mill would be called practically clean, yet enough Mediterranean Moth escaped to re-infest this mill. Their number will probably increase sufficiently to cause considerable trouble by the end of another summer, although they are giving no trouble at present. The inference must be that if fumigation with hydrocyanic gas is relied on, treatment must be given at least once every year; or two treatments given the same summer, with an interval of ten days to two weeks between them, might prove enough more effective to last through a period of two years.

MILL No. 3

This flour mill was fumigated with hydrocyanic acid gas without any cleaning beyond that normally given to the mill. The machinery and all elevators and spouts were opened up to allow a free circulation of the gas. The mill was prepared for fumigation in the same way as Mill No. 1. The temperature varied between 90 and 96 degrees Fahrenheit, with a fairly moist atmosphere and but very little wind. The charges were set off at 4 P. M., Saturday, June 24, 1911, and the mill was kept closed until the following Monday morning. There was a very heavy rain about 6 P. M., Saturday, with almost no wind.

The following table gives the distribution of the charges:

Floor	Number of charges	Cubic feet of space
Basement	3	5,616
First floor	9	16,979
Second floor	6	26,772
Third floor	5	44,712
Fourth floor	None	12,998
Total	23	107,077

Weight of each charge ... 3 pounds
Total weight of Potassium cyanide ... 69 pounds
Rate of dosage ... 10.3 ounces of potassium cyanide per 1000 cu ft. of space

This mill was much more open than most of the other mills which were treated, and most resembled Mill No. 4, although not nearly so open as No. 4. Inspection on Oct. 4, 1911, revealed a mild infestation, sufficient to cause considerable trouble before the end of another season. This mill is without a steam heating system, although steam is used for power.

TREATMENT WITH HIGH TEMPERATURE ON JUNE 10th AND 11th, 1911

MILL No. 4

This mill is equipped with radiators for heating by steam during the winter. Steam was turned into the radiators at 6 P. M., June 10th, and the temperature was taken, in most cases, every two hours. The initial temperature was 95 degrees Fahrenheit. Five standard, tested thermometers were located at various points on the lower floor, four on the second, four on the third floor, and one on the deck built in the third floor. The following tables give the details of the rise in temperature, the thermometers being designated by numbers.

FIRST FLOOR

Time of day	No. 1	No. 2	No. 3	No. 4	No. 5
	Degrees	Degrees	Degrees	Degrees	Degrees
7:30 P. M.	90	86	100	102	95
9:30 P. M.	94	91	102	124	101
11:30 P. M.	95	95	106	127	103
6.00 A. M.	96	103	108	131	108
8:00 A. M.	99	104	112	134	111
10:00 A. M.	104	107	113	141	115
12;00 M.	106	109	114	141	116
2:00 P. M.	106	110	115	141	116
3:00 P. M.	107	111	116	141	118

6:00 P. M.—Outdoor temperature 92 degrees.

Thermometer No. 1 near airshaft.
" No. 2 set 5 inches deep in flour.
" No. 3 in boot of elevator.
" No. 4 3 feet from floor
" No. 5 on inside of outer wall.

SECOND FLOOR

Time of day	No. 1	No. 2	No. 3	No. 4
	Degrees	Degrees	Degrees	Degrees
7:30 P. M.	107	102	101	107
9:30 P. M.	120	115	109	119
11:30 P. M.	122	117	116	122
6:00 A. M.	128	124	118	129
8:00 A. M,	130	127	120	131
10:00 A. M.	135	132	125	137
12:00 M.	137	133	126	137
2:00 P. M.	137	134	124	138

Thermometer No. 1 near the floor in elevator leg.
" No. 2 on support post.
" No. 3 on outside wall.
" No. 4 in a roll.

THIRD FLOOR AND DECK

Time of day	No. 1	No. 2	No. 3	No. 4	No. 5
	Degrees	Degrees	Degrees	Degrees	Degrees
7:30 P. M.	93	104	102	102	104
9:30 P. M.	104	113	113	116	113
11:30 P. M.	107	118	116	121	116
6:00 A. M.	118	125	125	129	129
8.00 A. M.	119	129	129	133	137
10.00 A. M.	122	134	138	138	140
12:00 M.	124	135	136	139	142
2.00 P. M.	127	136	136	139	142

Thermometer No. 2 in conveyor in 3 inches of flour.
" No. 2 in elevator leg.
" No. 3 near outside wall.
" No. 4 in bolter.
" No. 5 on a post on the deck built on third floor.

Average temperatures per floor were as follows:

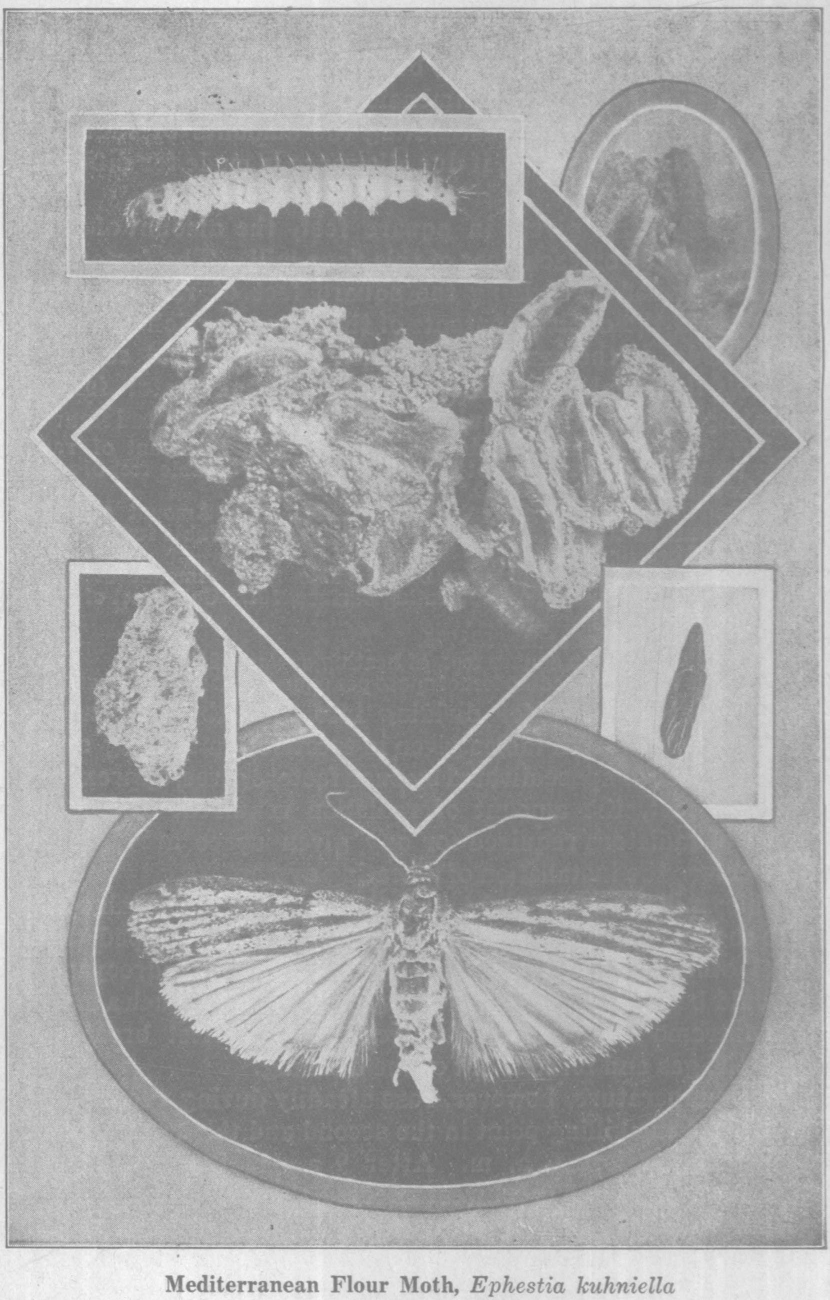
	First floor	Second floor	Third floor
	Degrees	Degrees	Degrees
Initial temperature	92	95	96
Time of day			
7:30 P. M	98	104	101
9.30 P. M	102	116	112
11:30 P. M	105	119	116
6:00 A. M	109	125	125
8:00 A. M	112	127	129
10.00 A. M.	115	132	131
12:00 M	117	133	134
2:00 P. M.	118	133	136
3:00 P. M.	119		

The thermometers were gathered up at 2 P. M. on the second and third floors, as the killing temperature had been reached by 6 A. M., and dead beetles and larvae could be found beneath 3 inches of flour, also in the bolters, in conveyors, in machines, and in the cracks of floors.

This experiment indicates that heat can be used successfully against insects affecting flour mills and stored products. The following insects were present or were brought into this mill from adjoining rooms, and all stages of them were killed, even by the temperature attained on the lower floor:

Calandra oryza Linn., Rice Weevil.
Calandra granaria Linn., Granary Weevil.
Silvanus surinamensis Linn., Saw-toothed Grain Beetle.
Tenebrio molitor Linn., Yellow Meal Worm.
Tenebrio obscurus Fab., Dark Meal Worm.
Tenebrioides mauritanicus Linn., Cadelle.
Tribolium confusum Duv., Confused Flour Beetle.
Platydema sp.
Ephestia kuehniella Zell, Mediterranean Flour Moth.

Several of these insects were represented by three stages—larval, pupal and adult, but all succumbed to the extreme temperatures.



Mediterranean Flour Moth, *Ephestia kuhniella*

Upper right and left figures, Larva
Upper center figure, cocoons and webbed mass of flour
Center right and left figures, cocoon and pupae
Lower figure, adult

This mill is equipped with an adequate heating system, as a temperature sufficiently high to be fatal to all insect life in it was readily attained, hence the dimensions and equipment of this building are used as a basis for estimating the amounts of radiation required in other flour mills, if due allowance is made for difference in construction.

The following gives, in square feet, the amount of radiation already installed on each floor of this flour mill. The factors in this case are obtained by dividing the square feet of radiation already present into the cubical contents of the floor on which the radiators are situated. In the final summation, the total cubical contents divided by the total radiation gives the average factor for use in estimating the radiation required in similarly constructed flour mills:

First floor—Cubical contents, 23,700 cubic feet Amount of radiation already present, in square feet, of heating surface, 484. Cubic feet of space per square foot of heating surface, 49.

Second floor—Cubical contents, 15,600 cubic feet. Amount of radiation already present, in square feet, of heating surface, 188 Cubic feet of space per square foot of heating surface, 83.

Third floor—Cubical contents, 20,475 cubic feet. Amount of radiation already present, in square feet, of heating surface, 161. Cubic feet of space per square foot of heating surface, 127.

Total cubic feet of space, 59, 775.

Total radiation, in square feet, of heating surface, 833.

Average number of cubic feet of space per square foot of heating surface, 72.

The factors used for dividing into the cubic contents are in practice obtained from tables given in treatises on heating systems. The cubic feet of space divided by such factors gives, approximately, in square feet, the amount of radiation required. The size and number of radiators required for any given space are thus ascertained before the installation of a heating system.

This mill was not tight and there were many small openings where the lap-siding boards had sprung apart or warped, besides several other small openings around the doors. Hydrocyanic acid gas would be entirely unsatisfactory for fumigating such a mill, even at the extreme strengths of dosage. The slightest breeze would diffuse the gas and force it out of the building.

The temperature, however, rose steadily during the night and had reached the killing point in the second and third stories on Sunday morning before 6 a. m. After 9 a. m., Sunday morning, a slight breeze from the southwest affected the temperature slightly, especially those thermometers located on that side of the building. They were more variable than the others and registered a much smaller rise in temperature until midday, when the breeze died down. Heat, or high temperature, has been used in this mill for killing insects since June, 1901, by one of the proprietors, Mr. R. A. Deed. The effects of high temperature were first noticed by him along the steam pipes which conducted steam to the corn dryer.

Because the insects along this pipe succumbed to the effects of heat, the rest of the mill was fitted up with radiators until sufficient radiation had been installed to accomplish the desired results. Where steam is used for power, the exhaust steam from the engine can be utilized for heating the mill. This means practically no additional expense, except for the installation of the heating system, and in many cases it will mean the utilizing of what, at present, is waste, in the form of exhaust steam. Enough radiation must be installed to heat the mill to 60 or 70 degrees Fahrenheit during cold weather. One square foot of heating surface is required to heat 60 to 90 cubic feet of space, depending upon the construction of the mill. The factor decided upon, when divided into the cubical contents of the mill gives the radiation required in square feet of heating surface. The factor varies, depending upon variations in the construction of the mill, according to whether it is old and open, or well built and tight; the larger factor, which means a smaller amount of radiating surface, should always be used for well built, tight mills. The rule commonly employed by plumbers may be used instead and is a little more exact, as it takes into account the exposed wall surface and windows.

Mill No. 1 has the following amounts of radiation already present. This mill is heated in winter with exhaust steam, and with some additions it could be used for heating the mill to 125 degrees Fahrenheit in summer:

Floor	Amount of radiating surface present	Amount of radiating surface required
	Sq ft	Sq ft
Basement	None	314
First floor	392	327
Second floor	280	351
Third floor	252	290
Fourth floor	196	617

Factor used	70
Total radiation present	1120 sq ft
Total amount of radiation required	1899 sq ft.

A factor as large as 80 could undoubtedly be used in this mill, which would reduce the amount of radiation required about one-eighth, or the total radiation would be only 1662 sq. ft. This would mean the addition of only 542 sq. ft. of radiation, of which considerably over half should be placed in the basement, which has no heat at present. Placing 342 sq. ft. in the basement, the remainder should be put on the first floor. The upper stories of the mill would become hot enough from the rising of the heated air from below. Some changes in the heating system would necessarily have to be made, but the time lost in cleaning and fumigating, and the cost of the fumigants, would more than pay for all the additions to the heating system in two years' time.

Heat or high temperature has been used successfully in European countries for destroying insect life for at least a quarter of a century. Prof. F. M. Webster performed some experiments in 1883, using heat to destroy the Angoumois Grain Moth, and several other authors refer to the use of heat for insect control, but do not give the results of any tests or experiments in which high temperature was utilized for controlling stored grain pests. Weed recommends its use for destroying weevils in beans and peas in the Seventh Annual Report of the Ohio Experimental Station, Article No. 7, 1888, pages 163-164, and also gives some experiments in which 140 degrees Fahrenheit was used to kill weevils in peas. More recently, Professor Dean, of the Kansas Experiment Station, has employed heat on a considerable scale as a means of mill treatment.*

The application of high temperatures for insect control is not new and the wonder is why this method did not come into general use long ago. It has many good features and very few bad ones. One hundred and twenty-five degrees Fahrenheit kills all stages of insects affecting stored products, if the heat is continued for any considerable period of time.

It is the most thorough method of treatment for the control of insects infesting flour mills; it requires but one treatment per year to completely rid the mill of insect pests and no preliminary cleaning is necessary.

In conclusion, the following reasons may be given for favoring the use of high temperature for controlling mill insects:

It is not dangerous to human life as are all of the other fumigants which are even fairly effective.

There is no possibility of injuring floors, belts, or machines, and practically no danger from fire.

The cost of a treatment, after the heating system is installed, is less than one-fiftieth of that of hydrocyanic acid gas fumigation.

No time is lost in getting ready to use heat. The mill does not need to be shut down a week beforehand, and as most of the Ohio flour mills use steam power, the cost of a heating system would not be prohibitive. High temperature, as compared with other methods of treatment, by saving time and extra expense, will pay for the average heating system required in a flour mill in less than five years.

ACKNOWLEDGEMENTS

To Prof. H. A. Gossard for his suggestions and to the millers who cooperated in these experiments, I desire to express my thanks.

* Journal of Economic Entomology, Vol. 4, No. 2, April, 1911.