KANSAS STATE AGRICULTURAL COLLEGE

Agricultural Experiment Station

Bulletin No. 189

MILL AND STORED-GRAIN INSECTS

MANHATTAN, KANSAS
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5 825

Announcement.

Since this manuscript was submitted the following important changes in the station staff have occurred: Ed. H. Webster, director of the experiment station, resigned December 31, 1912, to become associate editor of *Hoard's Dairyman*, and has been succeeded by W. M. Jardine. Prof. L. E. Call has succeeded W. M. Jardine as head of the agronomy department. Dr. T. J. Headlee resigned as heads of the departments of entomology and zoology, to become entomologist of the New Jersey Experiment Station, and has been succeeded by Prof. Geo. A. Dean, in the department of entomolgy, and by Dr. R. K. Nabours, in the department of zoology.

Contents.

Summary.

1. The most competent authorities believe that on an average five per cent of all stored grain products in the United States is lost through the attack of insects.

2. Preventive methods for the control of mill and stored-grain insects will eliminate a large proportion of the infestation and injury.

3. Since a large proportion of insect infestation in flour mills and warehouses is directly traceable to a disregard to cleanliness, it is very important to keep the entire plant scrupulously clean by sweeping up all accumulations of flour and meal on the floors, in the corners, under the machinery, and in all other places where it may find lodgment.

4. The only practical and efficient method at present known of completely controlling all classes of mill-infesting insects is by the application of high temperatures, and this method has been so developed within the last three years that it promises to revolutionize the present inadequate methods.

5. In Kansas the heating of several mills has absolutely proved that no stage of a mill insect, even in the most inaccessible places, could withstand the heat, and several mills in Ohio, Illinois, Nebraska, Iowa, Indiana, southern Canada, and elsewhere have corroborated the practicability and the efficiency of heat as a means of controlling mill insects.

6. In a mill, flour accumulates in recesses, and insects breed in places, inaccessible to the gas or vapor of any fumigating material, but heat passes through all these obstructions and penetrates the innermost recesses.

7. Many insects do not yield readily to hydrocyanic acid gas, but no mill insect can withstand for any length of time a temperature of from 118° to 122° F.

8. To fumigate with hydrocyanic acid gas requires from two to three days, and this long shut-down, with the additional cost of the material, is a large item of expense; there is, moreover, an element of danger to the operator. With the heat, since it can be applied from Saturday evening to Monday morning, there is no loss of time, very little expense, and no danger to the operator.

9. A mill that has sufficient radiation to heat it in winter to a temperature of 70° can readily be heated in summer to a temperature of from 118° to 122°.

10. With the heat method there is no possibility of injuring the floors, belts, or mill machinery, and there is practically no danger from fire.

11. The Mutual Fire Prevention Bureau, representing eight of the principal millers' insurance companies, recommends the heating system for effective fumigation against all mill and stored-grain infesting insects.

12. If a mill is infested with Mediterranean flour moth, hydrocyanic acid gas is a very effective treatment, but in no case where it is possible to use heat is the hydrocyanic acid gas treatment recommended.

13. The simplest, most effective, and least expensive remedy for all insects infesting the farmers' grain and grain products stored in tight bins is careful fumigation with carbon bisulphide.

14. If the building is reasonably air-tight and the temperature is above 70° four pounds of carbon bisulphide is sufficient for every one thousand cubic feet of space, or one pound for every thirty-five bushels of grain.

15. Carbon bisulphide is not an effective fumigation in flour mills, and since there is danger from fire in its use in large grain elevators, it is not recommended for this purpose.

Methods of Controlling Mill and Stored-grain Insects, Together with the Habits and Life Histories of the Common Infesting Species.[1]

By GEORGE A. DEAN.

INTRODUCTION.

SINCE the depredations of insects to stored grain and grain products amount each year to millions of dollars, and since these injuries are becoming more numerous and more destructive, a study of the methods of control of this class of insects is well worth the consideration of every miller and grain producer. The most competent authorities believe that on an average five per cent of all stored-grain products in the United States is lost through the attack of insects. This loss is usually so constant that few realize the enormous amount when considered in the aggregate, which annually in the United States amounts to more than one hundred million dollars. Just what this loss in dollars and cents is in Kansas can not be given, but with such a large representation of the insect pests which infest stored grains and mill products, an estimated injury of five per cent is a very reasonable and probable minimum figure. Mr. Coburn, in his biennial reports of the state of Kansas, gives in round numbers the average annual aggregate value of five of the leading cereal products in Kansas for the years of 1907 to 1911, inclusive, as $144,000,000. Computing the injury on the five per cent basis, we have had in this state for the last five years an average annual loss of more than seven million dollars. However, one must bear in

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1. The writer is very much indebted to Dr. T. J. Headlee, entomologist of the Kansas State Agricultural Experiment Station, and desires to express his gratitude for the timely suggestions and help received from him.

He also desires to acknowledge the valuable assistance rendered by R. M. Caldwell and W. B. Wood in carrying out laboratory experiments, and by R. M. Caldwell, F. B. Milliken, A. P. Davidson and J. W. McColloch in fumigating various mills with hydrocyanic acid gas and in making trials of heat as a method of destroying mill insects in the large mills where the practical tests were made.

He further desires to express his gratitude for the valuable help rendered by Mr. R. W. Lightburne, Jr., export agent of the Southwestern Millers' League, who made it possible for the writer to visit all the principal lake and seaport warehouses of the United States and Europe through which flour and grain are handled.

He also desires to acknowledge the valuable coöperation of the millers of Kansas who made it possible to carry out many experiments in their mills, and is very grateful to the editors of the various milling journals for the courtesies shown and the manner in which they have helped by giving publicity and interest to the work.

mind that these figures represent what the loss would be if all the grain raised in Kansas were stored and milled within the state. Placing the loss at a reasonable figure, one may say that Kansas has an annual loss of not less than two million dollars.

Preventive Methods for the Control of Mill and Stored-grain Insects.

On the Farm. In order that infestation in the stack may be avoided, the grain should be threshed as soon after harvesting as practicable. The writer has found on several occasions that where the grain was left in the stack until early fall it was seriously infested with the Angoumois grain moth and the grain weevil.

Fresh grain should not be exposed to attack by being placed in bins or granaries with that already infested.

Before storing, the old grain should be removed and the floors, walls and ceilings of the bins thoroughly cleaned.

If the granary has been badly infested, it should be fumigated before the new grain is stored.

Since cleanliness is very important in the prevention of injury by these insects, all dust, dirt, rubbish, refuse grain, flour, and meal, which serve only as breeding-places, should be removed.

If the grain is infested by the grain or meal moth, frequent agitation or handling of the grain will destroy many of them, because they are unable to free themselves from a mass of it and perish in the attempt.

A liberal use of air-slacked lime is recommended for dusting in corners and along the edges of bins. This lime should he dusted in the bins as soon as they are empty, but removed before storing the grain.

Granaries, as far as possible, should be constructed so as to be easily kept clean, and in such a manner as not to allow accumulations to collect and afford lurking places for insects.

Granaries should also be constructed so as to avoid dampness and heating. This dampness induces a condition in the grain termed "heating," and thus favors a rapid increase in insect life. It is also a fact that when insects are abundant in grain, they cause in some unexplained manner a rise in temperature.

If corn is showing infestation in the open crib, it should be shelled at once, and, after it is stored in tight bins or in the granary, should be fumigated with carbon bisulphide.

In Flour Mills and Warehouses. Since a large proportion of insect infestation in flour mills and warehouses is directly traceable to a disregard to cleanliness, it is very important to keep the entire plant scrupulously clean by sweeping up all accumulations of flour and meal on the floors, in the corners under machinery, and in all other places where it may find lodgment. This material should be removed from the mill and disposed of in such a manner as not to be brought back into the mill.

About every six weeks during the summer, all accumulations of flour or meal should be brushed out or removed from the elevator boots and flour conveyors, and destroyed by burning. Before removing these accumulations, it is well to go over the elevator legs with a spout maul and jar loose the infested accumulations.

In flour warehouses the floor should be thoroughly swept and all accumulations removed after each movement of flour.

All walls and ceilings of the mill or the warehouse should be smooth, so as not to afford hiding and breeding places for the insects. These walls and ceilings should either be painted or be kept whitewashed.

In order that infestation be avoided in the dark corners and other places in the basement, a liberal amount of air-slaked lime should be used. This lime not only will act as a repellant for the insects, but will tend to destroy some of the objectionable odors and sweeten the air.

Buildings should be constructed so as to avoid damp, dark places. Floors and walls should be joined so that accumulations along the edges and in the corners can be easily swept out. Floors of all basements should be cement, and all walls should be smooth.

All machinery should be placed high enough to allow thorough cleaning and brushing beneath it. As far as practicable, the bottoms of all flour conveyors should be metal, and should be rounded in such a manner as to allow the least amount of flour or meal to accumulate along the sides and at the ends. The hoppers of the rolls should be constructed of cement, and in such a manner as to allow no flour to accumulate in inaccessible places.

Sacks or bags should not be stored in packing rooms or in any part of the mill where flour or meal may collect on them and thus afford breeding places for insects. The sack room should be a separate room from any part of the mill.

Since the handling of second-hand sacks affords one of the best possible means of infesting a mill with several of the most serious mill pests, the sacks should be fumigated or treated before being brought into the mill, or the practice of handling them should be stopped at once.

In Grain Elevators. Since the dust, the dirt, the rubbish, and the refuse grain, allowed so many times to accumulate in grain elevators, serve only as breeding places for insects, there is nothing that will accomplish so much towards the prevention of injury as cleanliness and neatness.

Fresh grain should not be exposed to attack by being placed in bins that are already infested.

Before grain is stored, the floors and walls of the building, and the bottoms and sides of the bins, should be thoroughly cleaned. The dust and the refuse grain that collects on the tops of timbers and machinery should be removed. The refuse grain and the other material that accumulate in and about the dump, along the conveyor tunnel, and in the bottom of the elevator pits should be removed and burned, and a liberal amount of air-slaked lime should be kept scattered in these places.

All grain brought to the elevator, either in cars or in wagons, should be carefully examined for insect infestation, and if infested, should be stored in quarantine bins, where it can be fumigated.

The storage of grain in large bulk and in steel or concrete tanks or bins is strongly recommended.

If the grain is infested by the grain or the meal moth, frequent agitation or handling of the grain will destroy many of the insects.

Heat as a Means of Controlling Mill Insects.

Within the last hundred years a large number of very serious mill and stored-grain insects have been introduced into this country, and since they have been allowed to increase and steadily gain a foothold, we now have them to reckon with in nearly every flour mill and flour warehouse throughout the United States. After one has visited many mills throughout this country, and has made inspections of the principal ports along the Gulf, the Great Lakes, and the Atlantic seaboard, and of those in Europe, through which flour and grain are handled, he will soon be convinced that insect infestation is one of the important problems connected with the milling industry. He will also be convinced that the present methods of combating many of these pests are inadequate, and that something more effective must be done if we are to control this class of insects.

If a mill is infested with the several stages of the confused flour beetle and the other little rust-red flour beetles, the cadelle and the saw-toothed grain beetles, the treatment heretofore used is of little value, for these insects are found in cracks and in accumulations of fine stuffs inaccessible to any gas. The confused flour beetle and the cadelle, the larval stages of which are causing so much trouble in flour, are found in practically every flour mill in this country, in southern Canada, and in Europe. After inspecting the ports of this country and Europe, through which the flour from many of these mills is handled, either for domestic or for export trade, the writer is convinced not only that it is this class of insects that is causing the serious trouble, but that the large majority of the infestation originates at the mills.

The only practical and efficient method at present known of completely controlling all classes of mill-infesting insects is by the application of high temperatures, and this method has been so developed within the last three years that it promises to revolutionize the present inadequate methods. In Kansas the heating of several mills has absolutely proved that no stage of an insect, even in the most inaccessible places, could withstand the heat, and several flour mills in Ohio, Nebraska, Illinois, Indiana, Iowa, southern Canada, and elsewhere have corroborated the practicability and the efficiency of heat as a means of controlling mill insects.

Detailed Discussion of the Heat Method.

In connection with investigations relative to the inspection and fumigation of flour mills, the writer noticed on several occasions that the common mill insects were dead, although they were surrounded with an abundance of food. Upon further investigation it was observed that these insects were most frequently found dead in those parts of the mill where, owing to the surrounding conditions, they could easily have been subjected to a temperature varying from 105° to 120° F. for four or five hours a day for a period of several days.

First Use of Heat Against Insects in Stored Grain. On looking over available literature relative to the control of this class of insects, it was found that the French long ago knew the value of heat and devised contrivances, called insect mills, for the heating of infested grain. Experiments made by Prof, F. M. Webster in 1883 to ascertain the amount of heat required to destroy the Angoumois grain moth gave these results: A temperature of 140° F., continued for nine hours, literally cooks the larvae or pupae. A temperature of 130° F., for five hours, is fatal, as is also 120° for four hours, while 110° applied for six hours was only partially effective. It was also found in his experiments that wheat could be subjected to a temperature of 150° for eight hours without impairing its germinating properties. In the second report of the state entomologist of New York, Prof. J. A. Lintner, in speaking of the rust-red flour beetle *(Tribolium ferrugineum)* infesting grain and flour, says, "A moderate degree of heat, 120° to 130" F., continued for a few hours, would in all probability suffice to kill all the eggs, larvae, and pupae in the material, while a higher temperature, perhaps 150° or more, would be needed for the beetles." Prof. F. H. Chittenden in his article on "Insects Injurious to Stored Grain" says: "Prior to the adoption of carbon bisulphide as a fumigant, heat was relied upon in the destruction of these insects. A temperature of from 125° to 140° F., continued for a few hours, is fatal to grain insects, and wheat can be subjected to a temperature of 150° for a short time without destroying its germinating power."

Experiments to Determine the Heat Necessary to Destroy Mill Insects.

Nearly all the experiments of this nature were made relative to the discovery of a method to destroy Angoumois grain moth, and from the results of these experiments some of the experimenters and other writers have assumed that many of the grain insects could probably be destroyed in the same manner, but that it would require a higher temperature to destroy the adults than the larvae or pupae. Since this method of combating grain insects had not been developed and given a practical test in a flour mill, and since it was believed that the death of these insects in the Kansas mills was caused by a fatal maximum temperature, the next step was to determine this temperature and to ascertain not only whether it would be possible and practical to produce such a condition in a modern mill, but whether the temperature would prove fatal to the insects therein.

The First Series of Experiments. In the first experiment, about twenty-five individuals of both the adult and the larvae of the confused flour beetle *(Tribolum confusum)* were placed in a shell vial and covered with an inch of flour. A thermometer was placed in this vial with the bulb resting in the center of the flour. The vial containing the flour and various stages of the confused flour beetle *(Tribolium confusum)* was next suspended in a large bottle in such a manner as not to touch the sides of it. This bottle was then placed in a glass jar filled with water and the glass jar was placed in a vessel filled with water. The heat was applied beneath this vessel. This arrangement reduced to a minimum the unequal distribution of the heat in the shell vial containing the insects. In raising the temperature from 80° to 90° no change was noticed in the action of these insects. At a temperature of about 96" the adults became uneasy and began running around rather rapidly. At a temperature of 100° the larvae emerged and crawled over the flour, and the adults were running more rapidly than at 96°. At a temperature of 110° both larvae and adults were frantic and were making every effort to escape, and these actions were continued until a temperature of 115° was reached. At this temperature both the larvæ and adults were becoming passive, and at a temperature of 118° all adults were lying on their backs apparently dead, while four or five larvae showed very feeble movements. At a temperature of 119° there was no sign of life; however, the temperature was raised to 120°, and then the insects were removed and given a chance to recover, but none did. This experiment was repeated several times, and each time, as soon as a temperature of from 119° to 120° was reached, it proved fatal to all stages of the insects. It required from twelve to fifteen minutes to reach this fatal temperature.

Similar experiments were conducted and repeated with the larvæ, the pupae, and the adults of the saw-toothed grain beetle *(Silvanus surinamensis)*, the Mediterranean flour moth *(Ephestia kuehniella)*, the cadelle *(Tenebrioides mauritanicus)*, and the adults of the rice weevil *(Calandra oryza)*. As soon as a temperature of 116" was reached, it proved fatal to the adults of the Mediterranean flour moth, while it required a temperature of 118° to prove fatal to the larvae and pupae. A temperature of 118° was fatal to the adults of the rice weevil, and a temperature of 119° proved fatal to all stages of the saw-toothed grain beetle. At a temperature of 120° the majority of the cadelle perished, but it required a temperature of 120° for a period of three minutes to prove fatal to all.

Second Series of Experiments. In a second series of experiments a paraffin oven, or incubator, was used, and after the oven was heated to a required temperature, the insects were placed in it and the oven held to a constant temperature throughout the experiment. In this experiment about twenty-five specimens of eggs, larvæ, pupæ, and adults of the confused flour beetle *(Tribolium confusum)*, larvæ and pupae of the Mediterranean flour moth *(Ephestia kuehniella)*, and adults of the rice weevil *(Calandra oryza)*, and the cadelle *(Tenebrioides mauritanicus* were used. Experiments were made with these various stages of insects not only on top of the flour, but one and two inches below the surface. After a series of experiments it was found that a temperature of 115° for a period of twelve hours proved fatal to all the insects in their various stages.

Third Series of Experiments. Since in practical use it would be impossible actually to heat a mill in a few minutes, as in the first series of experiments, or to subject the insects to such a sudden change as was employed in the second series, a third set of experiments was conducted to determine the fatal temperature under conditions that could actually be produced in a mill. In these experiments the larvæ, the pupæ, and the adults of the confused flour beetle *(Tribolium confusum),* the adults of the saw-toothed grain beetle *(Silvanus surinamensis)*, and the adults of the Mediterranean flour moth *(Ephestia kuehniella)* were used, The various stages of the different insects were placed in shell vials, so that their actions under the slowly-rising temperature of the oven could be observed. The heat was applied at 8 o'clock in the morning and the temperature noted at intervals of every half hour. The temperature at the time the insects were placed in the incubator was 87°, or the same as the temperature of the place from which they were taken. The behavior of the various insects as the temperature gradually increased was most interesting. At 10:45 A. M., with a temperature of 95°, the larvæ and adults of the confused flour beetle began to appear uneasy, and their uneasiness increased rapidly with the rise of temperature. At 11:46 A. M., with a temperature of 99°, the adults of the Mediterranean flour moth began to move and fly about with the same uneasiness. At 2:15 P. M., with a temperature of 100° all stages of the different insects were most active and were making every effort to escape the heat. Even the pupæ were wriggling and struggling. At 3:45 P. M., with a temperature of116.5°, the first adult of the Mediterranean flour moth died, while at 4:30 P. M., with a temperature of 118.5°, all the moths were dead, and a few of the adults and larvæ of the confused flour beetle. At 5:15 P. M., with a temperature of 121° all of the saw-toothed grain beetles were dead, but two adults and five larvæ of the confused flour beetle were alive. At 5:30 P. M., with a temperature of 122°, two larvæ of the confused flour beetle were still alive, but these died eleven minutes later at a temperature of 122.5°. In this experiment fifteen insects of each stage were used.

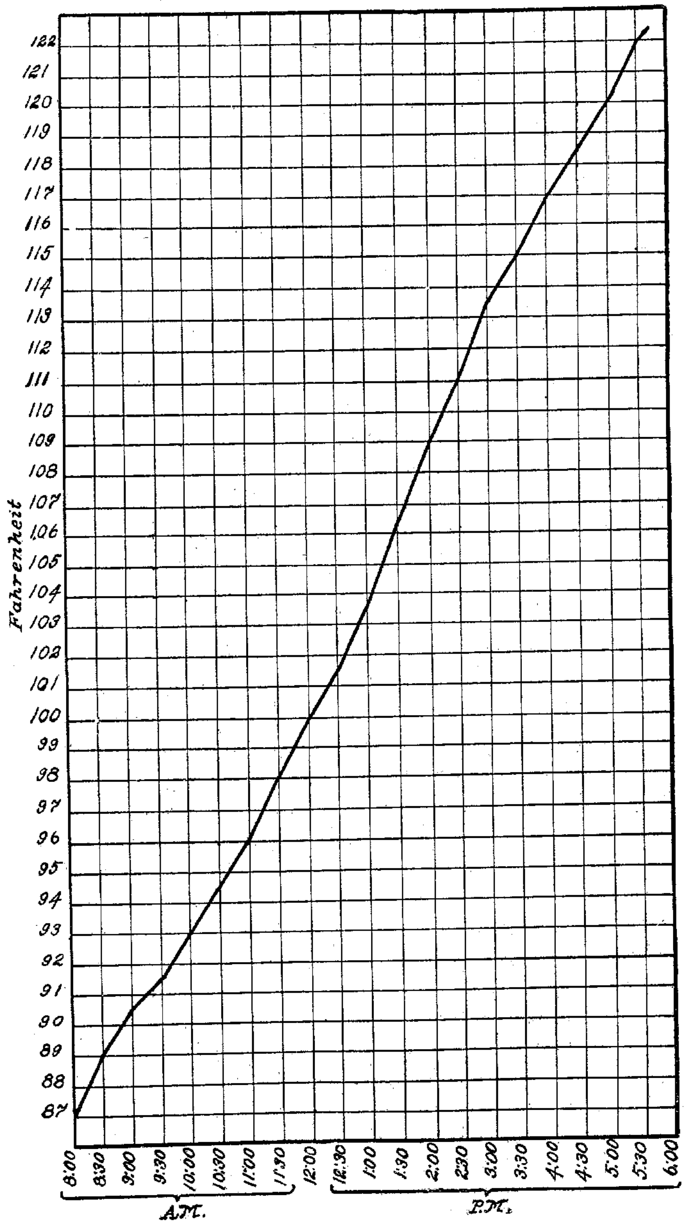

FIG. 1. Chart showing rise of temperature in paraffine oven.

The Heat Method Put to a Test in a Modern Mill.

Description of the Mill and of the Arrangement of the Steam Pipes. Since the laboratory experiments demonstrated that this class of insects could be destroyed at a temperature not beyond that which could actually be produced within a modern mill, a flour mill was selected for a practical test. This mill had heavy brick walls and tight wooden floors. It had no basement, and was four stories high; all stories were heated with steam, and were well filled with machinery. The packers, the elevator boots, and the pulley machinery were on the first floor; the rolls were on the second floor; the purifiers, the sifters, and the bolters were on the third and fourth floors. The mill had a daily capacity of six hundred barrels, and in its construction represented the average modern mill in the state of Kansas. The first floor, 38 feet wide, 63 feet long, and 12 feet high, with a capacity of 28,728 cubic feet, was heated by eight 1½-inch steam pipes, the radiating surface of which was 515 square feet. These pipes were arranged in eight coils near the ceiling along the two sides and across one end of the room. The pipes were placed near the ceiling in order not to obstruct the doorways. The second floor, the capacity of which was the same as that of the first, had one coil less of the steam pipes with a radiating surface of 450 square feet, but these seven coils were placed near the floor along the side walls and across one end. The third floor, which was 13 feet

TABLE SHOWING THE DIMENSIONS AND THE HEATING SYSTEM OF THE MILL.

Floor..........	Dimensions......	Capacity in cubic feet......	Number of coils of steam pipes..	Diam. of steam pipes (in.).....	Linear feet of steam pipes....	Radiating surface of steam pipes (sq. ft.).......	Location of steam pipes.	Remarks.
1	38x63x12	28,728	8	1½	1,250	525	Near ceiling.	Radiation should be near floor.
2	38x63x12	28,728	7	1½	1,120	560	Near floor.	There were no steam pipes across one end of each floor.
3	38x63x13	31,122	6	1½	920	460	Near floor.	
4	38x63x18	43,092	5	1½	800	400	Near floor.	
	Total....	131,670	26		4,090	2,045		

high and had a capacity of 31,122 cubic feet, had six coils with a radiating surface of 386 square feet, and these were placed the same as those on the second floor. The fourth floor, which was 18 feet high and had a capacity of 43,092 cubic feet, had only five coils with a radiating surface of 322 square feet. These pipes were arranged like those on the second and third floors.

First Heating of the Mill This mill was badly infested with all stages of the confused flour beetle *(Tribolium confusum),* and slightly infested with several of the other common mill insects. In the first experiment no change of any sort was made in the heating system. Four thermometers were distributed on each floor in such a manner as to get the temperature not only in the open, but in different depths of flour, and in accumulations in different parts of the room. At 10 o'clock in the morning of August 21, with the mill just as it had been shut down for Sunday, the steam was turned into the pipes, and since this mill was ordinarily heated with exhaust steam, the live steam had to be forced through the exhaust pipe, which fact prevented it from having more than two or three pounds pressure. The heat was applied from 10 A. M. to 5:30 P. M., and the temperature of all the thermometers was noted at intervals of every half hour. Although the day was very warm, reaching a maximum temperature of 95°, and the average temperature of the mill before the heat was applied was 89°, yet the mill did not heat rapidly, and by 5 o'clock there were only two or three places in the mill where a fatal temperature had been reached. On the first floor the highest temperature was 100.4°, while the thermometer in the bottom of an elevator boot registered only 94°. On the second floor the highest temperature, 123.8°, was registered by the thermometer hanging in the open, while the lowest temperature, 98.6°, was registered by a thermometer buried three and one-half inches deep in a sack of flour four feet above the floor. On the third floor the thermometer in the open registered 125.6°, and the lowest temperature, 114°, was registered in a flour conveyor six feet above the floor. On the fourth floor the thermometer in the open registered 118.4°, while the lowest temperature, 107.6°, was registered by the thermometer two inches deep in flour in a conveyor near the floor.

Moisture Content of the Mill During the Heating. A hydrograph was placed on the second floor in the middle of the room. The relative humidity of this floor at 10 A. M., or just as the heat was applied, was 93 per cent. From 10 A. M. to 12 M., there was a rapid decrease to 40 per cent, and from 12 M. to 5:30 P. M. there was a gradual decrease to 27 per cent.

Result of the First Heating. Although the temperatures reached were disappointing, and no insects were killed on the first floor, yet on the third floor fully one-third of the insects perished, and on the fourth floor about one-fourth succumbed to the heat. Even the second floor showed that many insects had perished. The experiment proved the following: More time must be taken to reach the desired temperature; this temperature should be held several hours to allow the heat to penetrate all of the infested parts ; there should be a water trap to draw off the water accumulated in the steam pipes; the steam should be turned on with some pressure so as to heat the mill more rapidly; the steam pipes should be near the floor in order to heat the room.

Second Heating of the Mill. In the second experiment, made three weeks later, two changes were made in the heating system. A water trap was attached, and arrangements were made to turn the steam on directly and with pressure. The arrangement of the pipes in the mill was not altered. At 6 o'clock in the morning of September 11 the mill was shut down, and, after the thermometers were distributed as in the first experiment, the steam was turned on with ten to twelve pounds pressure. The heat was applied from 6 A. M. until 6 A. M. of the day following, and the temperature of the sixteen thermometers noted at intervals of every half hour, save in a few cases, where the readings were made at intervals of one hour. The average temperature in the mill at the time the heat was applied was about 90°, while the mean temperature during the day outside of the mill was 77°.

In nearly all parts of the mill the temperature gradually increased, and at 3 o'clock P. M. fatal temperatures were reached in several parts. At 6 o'clock P. M. many of the insects had perished. At 9 o'clock P. M. fatal temperatures were indicated by nearly all the thermometers except those on the first floor. However, as the investigator realized that it required time to heat through heavy machinery and to penetrate into several inches of flour, the heat was continued until 6 A. M., by which time it had penetrated the innermost recesses of the mill, save on the first floor. On the first floor the highest temperature

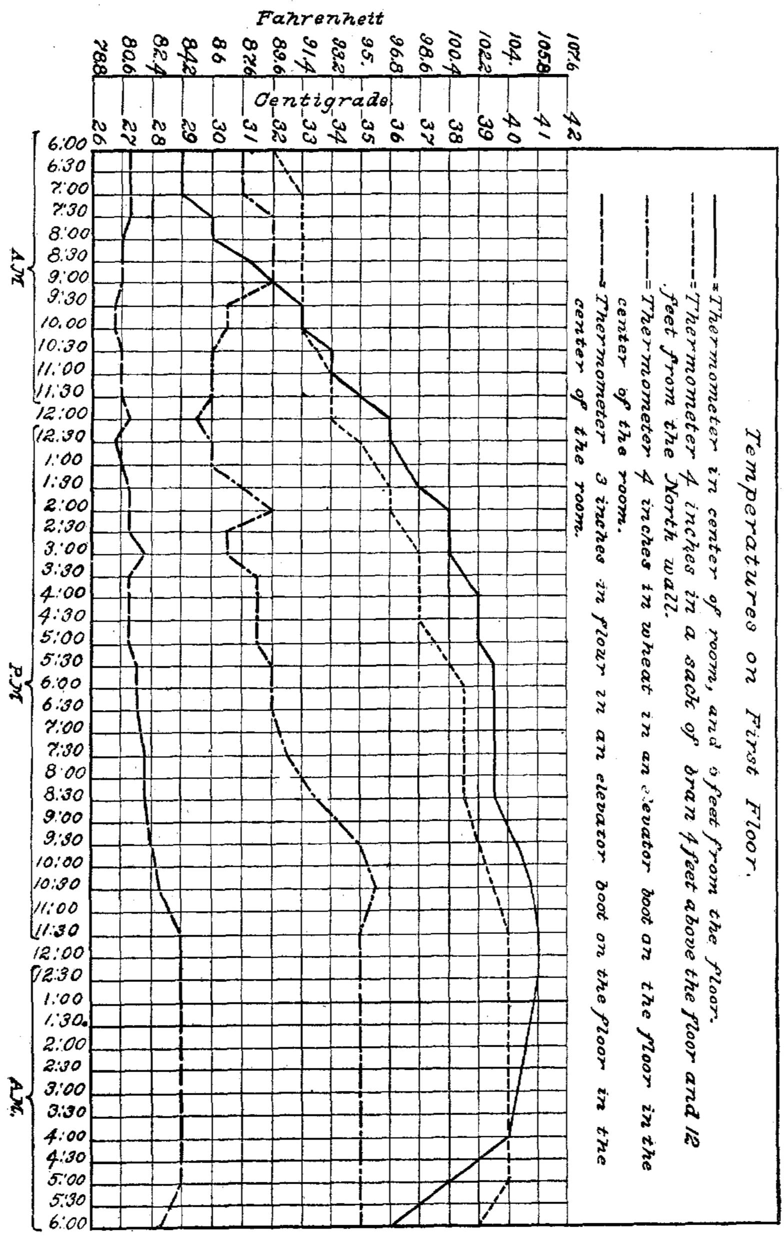

FIG. 2. Chart showing rise of temperatures on first floor.

was 105°, while one thermometer in four inches of wheat near the floor registered only 96°. (Fig. 2.) On the second floor the highest temperature, 133.5°, was registered by a thermometer hanging in the open, while the lowest temperature, 117.6°, was registered by a thermometer three inches deep in a sack of flour three feet above the floor, (Fig. 3.) On the third floor the thermometer in the open registered 141°, while the lowest temperature, 129°, was registered in a flour conveyor spout four feet above the floor. (Fig. 4.) On the fourth floor the thermometer in the open registered 128.6°, while the lowest temperature, 118°, was registered by a thermometer in flour in a conveyor six feet above the floor. (Fig. 5.)

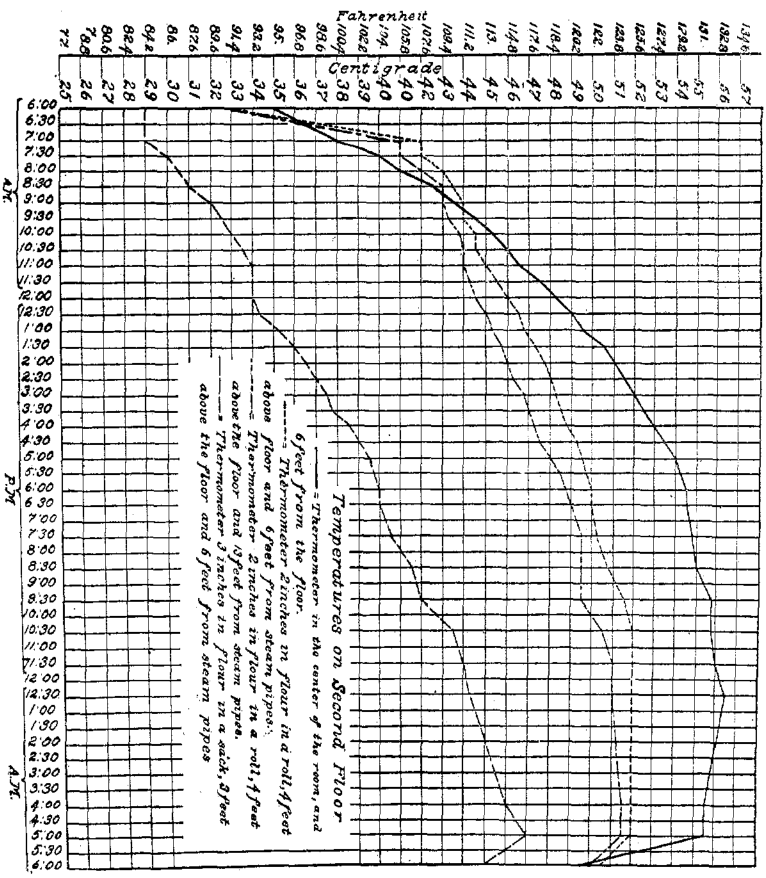

FIG. 3. Chart showing rise of temperatures on second floor.

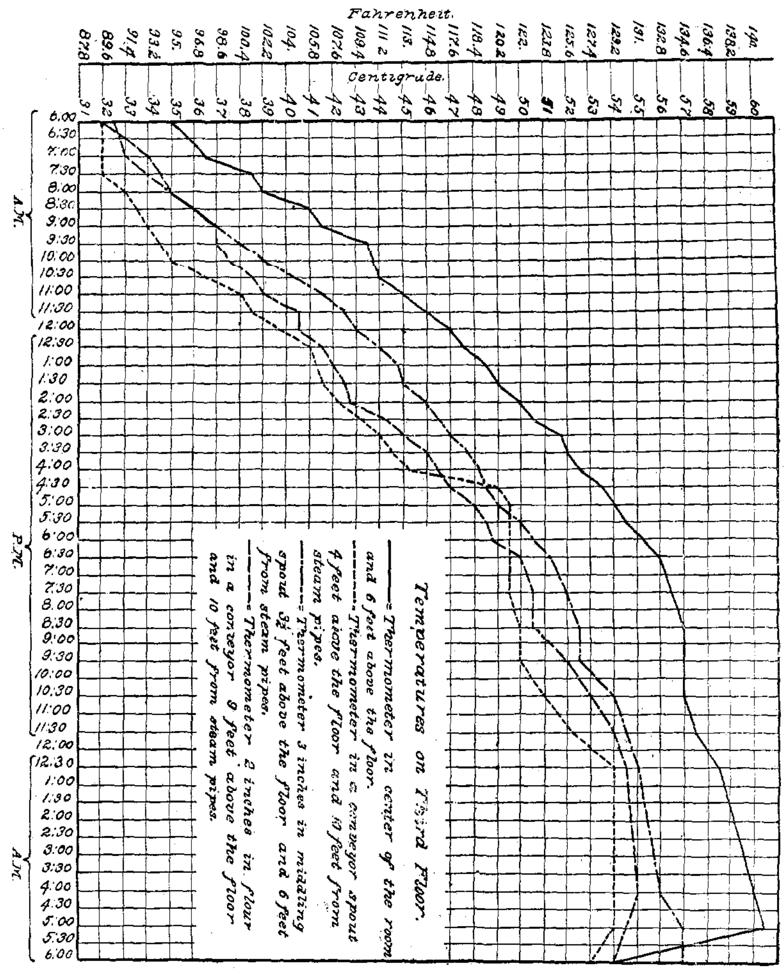

FIG. 4. Chart showing rise of temperatures on third floor.

Moisture Content of the Mill. The hydrograph was placed on the second floor in the middle of the room. The relative humidity of this floor at 6 A. M., or just as the heat was applied, was about 72 per cent. During the first few hours there was a rapid decrease to less than 40 per cent, and during the afternoon and through the entire night there was a very gradual decrease to 12 per cent.

Result of the Heating. After a very careful examination of the three upper floors, all parts of the mill, even the deepest accumulations in the most inaccessible parts, failed to show live insects, save one corner on the upper floor In several places where there were accumulations inaccessible to hydrocyanic acid gas, the conveyor or the bins were torn open, and after being carefully inspected did not reveal a live insect, but showed that thousands had perished. In a sample room on the third floor there were hundreds of samples of grain in

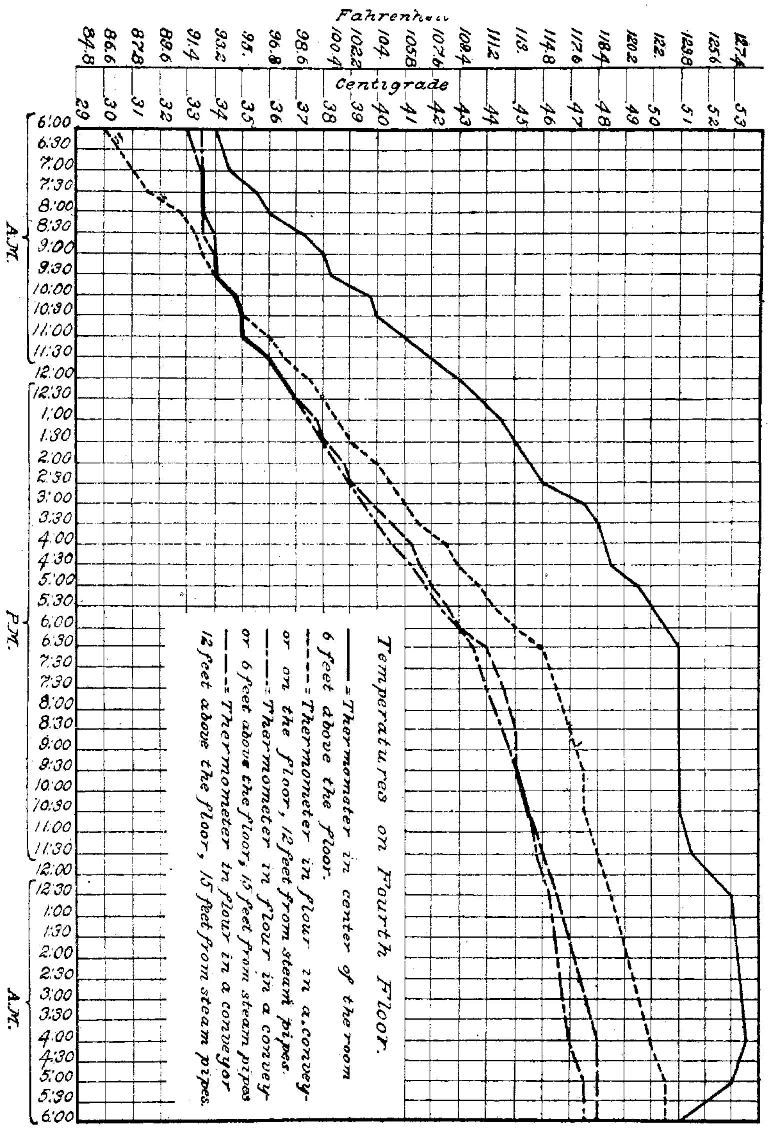

FIG. 5. Chart showing rise of temperatures on fourth floor.

paper and cloth bags, tin cans, and sealed glass jars. These were badly infested; but all of the insects were killed by the heat. On the fourth floor there was a large flour conveyor running the entire length of the mill, and in this conveyor the accumulation of flour, which was from three to five inches in depth, was badly infested, but after it was torn open from one end almost to the other it was found that all the insects had perished. Nearly three weeks later a second examination was made of the mill, and no live insects of any sort were found above the first story.

The Result of Heating: The Same Mill One Year Later The following summer the R. E. Kidder Flour Mill of Kansas City was again heated. A thorough examination of this mill, one and two months later, failed to reveal a live insect, save in one corner on the first floor where a few second-hand sacks had been piled after the mill had been heated. The examination also showed that no part of the mill had been injured during the heating process. The heating of this mill absolutely proved that no stage of an insect, even in the most inaccessible places, could withstand the heat.

Further Data as to the Practicability and Efficiency of Heat.

Several mills in Kansas, Ohio, Iowa, Illinois, Canada, and elsewhere have corroborated the practicability and the efficiency of heat as a means of controlling mill insects. The following brief summary will give the results of the heating of some of these mills.

Inter-Ocean Mill During the summer of 1910 the Inter-Ocean Mill, a thousand-barrel frame mill in Topeka, was given a thorough fumigation with hydrocyanic acid gas. No mill could have been given a better fumigation with the gas, yet a few months later this mill was showing evidence of serious insect infestation. The following spring this mill was given a second fumigation with hydrocyanic acid gas. One month later insects were in sufficient numbers to cause trouble. During the month of June, without any change or additional radiation in the heating system of the mill, the heat was turned on one Sunday morning and continued until nearly midnight. Examination the next day showed that far more insects were killed than in the gas fumigations, and, since the examination several months later failed to reveal a single live

Mediterranean flour moth in any stage, the manager of the mill was satisfied that it is a far more effective and practical method. Later, additional radiation was installed in this mill, which now has a most effective system.

The Hunter Milling Company. During the summer of 1910 the Hunter mill, a fifteen-hundred-barrel mill at Wellington, Kan., was fumigated with hydrocyanic acid gas. The expense of the fumigation was over $225, which does not include the shut-down of three days. Before the summer season had passed not only were the common mill insects again becoming abundant, but the Mediterranean flour moth was doing serious injury. The following summer, after installing additional radiation at an expense of not more than that of one fumigation, the mill was heated from Sunday morning until midnight of the same day. A careful examination the next day showed that no insect escaped death on the floors where the heat ranged from 115° to 130° F. No part of the mill was injured by the heat. Examination one year later showed that the Mediterranean flour moth was completely eradicated. The president of the Hunter Milling Company said of the heating method: "I am confident that the method is a great success. We find that after subjecting our mill to heat for eighteen hours not a creature which was exposed to the heat lived."

Heating of Mills in Ohio. Professor Gossard, entomologist of the Ohio Agriculture Experiment Station, in his annual report for the year 1911[2] recommends the heat as a practical and a most efficient method, and speaks of several mills in which the heat was used successfully. The millers in his state who have used heat are convinced that it is the cheapest and the most effectual method for the control of mill insects. In Bulletin No. 234 of the Ohio Agricultural Experiment Station, Mr. W. H. Goodwin, assistant entomologist, makes the following summary relative to the heat method:

"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.

"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.

2. Annual Report of the Entomologist, Ohio Agr. Exp. Sta., 1911.

"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."

Government Recommends the Heat Method. During the summer of 1911 the United States Department of Agriculture had one of the experts of the Bureau of Entomology stationed in the southeastern part of the United States to carry on experiments for the control of mill insects in rice and peanut mills. In a recent publication of the results of these experiments the government has approved of the heat method and recommends it as a most efficient method in the control of insects in this class of mills.

The Amount of Radiation Required.

The number of square feet of radiation surface required to heat a given number of cubic feet depends upon the condition and the construction of the building, the number of windows and doors on each floor, the character of the machinery, and the location of the steam pipes. Usually one square foot of radiation is sufficient to heat from fifty to one hundred cubic feet of space. A mill that has sufficient radiation to heat it in winter to a temperature of 70° without the heat of the running machinery can readily be heated in summer to a temperature of 120° to 125°.

If the mill is a five-story building, the writer would suggest for the first floor one square foot of radiation to 50 cubic feet of space; for the second floor one square foot to 60 cubic feet; for the third floor one square foot to 75 cubic feet; for the fourth floor one square foot to 90 cubic feet, and for the fifth floor one square foot to 110 cubic feet. If the building is of four stories, one square foot of radiation to 50, 60, 75, and 100 cubic feet of space for the first, second, third and fourth floors, respectively, is recommended.

3. Circular No. 142, Bur. of Ent., U. S. Dept. of Agr.

TABLE showing the radiating surface per linear foot, and the linear feet of pipe required to make one square foot of radiating surface.

Size of pipe in inches.	Radiating surface per linear foot.	Linear feet of pipe per sq. ft. of radiating surface.
1	0.346	2.9
1¼	0.434	2.3
1½	0.494	2.0
2	0.622	1.6
2½	0.753	1.3

In case steam pipe is used for the radiation, either 1%-inch or 1½-inch pipe is recommended as the most practical size.

Important Points to be Considered in the Successful Heating of a Mill.

1. The steam pipes should be located near the floor and so arranged as to give an equal distribution of heat.
2. There should be a water trap to draw off all water accumulating in the pipes.
3. The lower floors and the floors with heavy machinery should have more radiating surface in proportion to the cubic feet of space to be heated than the upper floors and the floors with light machinery.
4. The steam should be turned on with from twenty-five to fifty pounds pressure, so as to heat the mill more rapidly.
5. In order that advantage may be taken of the heat in the machinery, the heat should be turned on immediately after the mill is shut down.
6. Stairways and elevator shafts should be closed, so as to make each floor entirely separate.
7. Two or three thermometers should be placed at different points on each floor in order that the temperatures may be readily ascertained.
8. Time must be taken to reach the desired temperature.
9. A temperature of from 118° to 125° is sufficient for any part of the mill.
10. This temperature should be held several hours to allow the heat to penetrate all the infested parts.
11. Attempts to heat a mill should not be made on a windy, a cold, or a rainy day.

The Effect of Heat Fumigation Upon Flour.

In connection with heat fumigation, the question naturally arises as to whether the heat would have any deleterious effect upon the baking quality of the flour. To obtain data upon this subject, baking tests were made of a patent hard-wheat flour, a low grade hard-wheat flour and a pancake flour. These flours were subjected to a heat several degrees higher than that recommended for a mill. Not only was the low grade hard-wheat flour subjected to a temperature of 140° for nine hours, but the same samples were subjected to the same temperature two and six weeks later to ascertain whether a second and a third heating of the same flour would have any injurious effect. The pancake flour was subjected to a temperature of 130° for forty-eight hours. The baking tests of all these experiments showed conclusively that the heat had absolutely no deleterious effect upon the baking qualities of the flours.

Some Uncalled-for Criticisms.

The objection made by some that the insurance companies will not permit heat is without foundation. The only instance of an objection of this sort that has been brought to the attention of the writer was in case of a mill that may be equipped with the automatic sprinkling system. Mr. Wm. Reed, secretary of the Mutual Fire Prevention Bureau, representing eight of the principal millers' insurance companies, ina recent notice to all policyholders makes the following statement: "We propose to advocate the heating system for effective fumigation against the Mediterranean flour moth, weevil, and all other mill and grain infesting insects."

The objection that the system is not practical because of the impossibility of heating in winter is one scarcely worth considering. No one is advocating the heating of a mill in winter. Any one familiar with the insect infestation of a mill knows that if a mill is heated during the latter part of the summer and all the insects are killed, there will be no necessity for heating during winter months. The objection that heat will injure the belting and will check the elevator legs and the woodwork of the bolters and the purifiers is without a semblance of truth. In one experiment the mill was heated far above the required temperatures, some of the temperatures going as high as 150° F., for a period of nearly thirty hours, and the examination showed absolutely no injury to any part of the mill or of the mill machinery.

Summary of Results.

In a mill, flour accumulates in recesses, and insects breed in places inaccessible to the gas or vapor of any fumigating material, but heat passes through all of these obstructions and penetrates the innermost recesses. Many mill insects do not yield readily to hydrocyanic acid gas, but no mill insect can withstand for any length of time a temperature of from 118° to 122° F. The writer has fumigated many mills with hydrocyanic acid gas, but in no case has the fumigation with gas proved so successful as has heating in several mills. In the heating of these mills, it has been demonstrated that heat is the most practical, most efficient, most convenient, and least expensive method. To fumigate with hydrocyanic acid gas requires from two to three days, and this long shutdown, with the additional cost of material, is a large item of expense; there is, besides, an element of danger to the operator. With heat, since it can be applied from Saturday evening until Monday morning, there is no loss of time, very little expense, and no danger to the life of the operator.

Illustrations, Temperature Records and Other Data of Some Mills that Have Used Heat Successfully.

R. E. Kidder Flour Mills, Kansas City, Kan.

Capacity of mills, 600 barrels.
Building, brick.
Dates of heating, July 7, 8, 1912.
Character of days, calm and partly cloudy.
Outside maximum temperature, 91 degrees.
Outside minimum temperature, 73 degrees.
Heating system, steam pipes along the wall, except in space beneath the first floor, where radiators are used.
Steam pressure maintained during the heating, about 20 pounds.

FIRST FLOOR.

Capacity of floor, 28,728 cubic feet.
Amount of radiation, 525 square feet.

READING OF THERMOMETERS.

Time of day. July 7, 1912.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
10:30 A. M.	83	90	86
11:30 "	83	94	88
12:30 P. M.	84	98	91
2:30 "	88	104	96
3:30 "	90	106	100
4:30 "	93	107	102
5:30 "	94	110	103
7:00 "	95	110	107
8:30 "	97	113	108
9:30 "	98	115	108

Time of day. July 8, 1912.	Degrees. No. 1.	Degrees. No. 2.	Degrees. No. 3.
9:00 A. M.	100	122	116
11:00 "	106	124	117
12:00 M.	106	125	118
2:00 P. M.	106	128	118
4:00 "	107	129	120
5:30 "	108	129	121

LOCATION OF THERMOMETERS.

No. 1.—In two inches of flour in elevator boot on the floor, eight feet beneath steam pipes.

No. 2.—Hanging in the middle of the room, five feet high, fifteen feet from steam pipes.

No. 3.—In two inches of flour in elevator boot on floor, twelve feet from steam pipes.

Results: Although killing temperatures were reached in all parts of the rooms, only a few feet above the floor, killing temperatures were not reached in the elevator boots on the floor, except directly over the radiators in space beneath the floor.

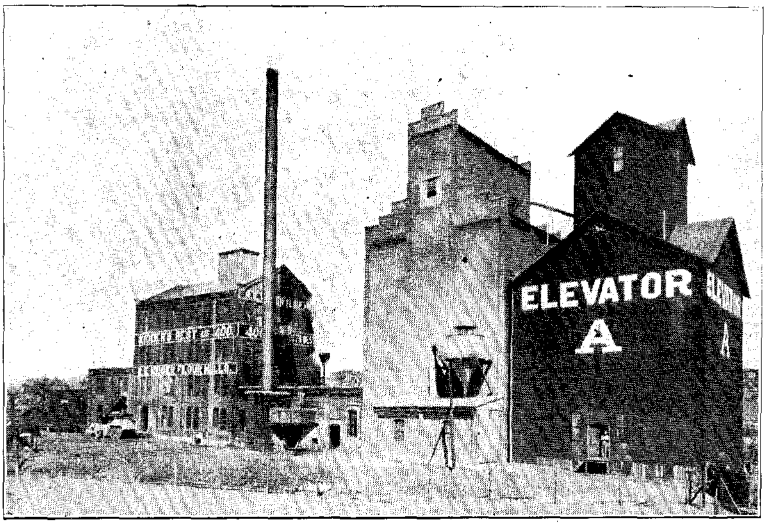

FIG. 6. R. E. Kidder Flour Mills, Kansas City, Kansas.

SECOND FLOOR.

Capacity of floor, 28,728 cubic feet.
Amount of radiation, 560 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 7, 1912.			
10:30 A. M.	98	97	99
11:30 "	105	97	106
12:30 P. M.	110	98	111
2:30 "	117	100	118
3:30 "	120	102	121
4:30 "	123	104	123
5:30 "	125	105	125
7:00 "	127	108	127
8:30 "	129	109	129
9:30 "	130	111	129
July 8, 1912.			
9:00 A. M.	140	122	140
11:00 "	142	125	142
12:00 M.	144	126	144
2:00 P. M.	144	127	144
4:00 "	147	129	147
5:30 "	146	131	145

--2

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open four feet high, fifteen feet from steam pipes.

No. 2.—Between the rolls in a roll, eleven feet from steam pipes.

No. 3.—Hanging in the open six feet high near roll machinery.

Result: One hundred per cent of the insects were killed.

THIRD FLOOR.

Capacity of floor, 31,122 cubic feet.
Amount of radiation, 460 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 7, 1912.			
10:30 A. M.	95	85	89
11:30 "	100	88	91
12:30 P. M.	105	91	95
2:30 "	114	100	102
3:30 "	116	102	103
4:30 "	119	105	107
5:30 "	122	107	108
7:00 "	124	111	111
8:30 "	126	113	113
9:30 "	127	114	114
July 8, 1912.			
9:00 A. M.	133	126	125
11:00 "	138	127	125
12:00 M.	139	127	126
2:00 P. M.	141	128	128
4:00 "	143	128	131
5:30 "	145	129	131

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open five feet high, fifteen feet from steam pipes.

No. 2.—In flour in a conveyor near the floor, twelve feet from steam pipes.

No. 3.—In flour in a conveyor six feet high, fifteen feet from steam pipes.

Result: One hundred per cent of the insects were killed.

FOURTH FLOOR.

Capacity of floor, 43,092 cubic feet.
Amount of radiation, 400 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 7, 1912.			
10:30 A. M.	96	88	88
11:30 "	100	90	90
12:30 P. M.	105	92	91
2:30 "	114	99	97
3:30 "	116	101	99
4:30 "	118	103	101
5:30 "	119	106	103
7:00 "	120	109	106
8:30 "	121	111	109
9:30 "	122	112	110

Time of day. July 8, 1912.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
9:00 A. M.	127	118	117
11:00 "	129	119	118
12:00 M.	132	120	119
2:00 P. M.	133	121	120
4:00 "	138	124	122
5:30 "	138	124	122

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open, five feet high, twelve feet from steam pipes.

No. 2.—In flour in a conveyor near the floor, twelve feet from steam pipes.

No. 3.—In flour in a conveyor near the floor, twelve feet from steam pipes.

Result: One hundred per cent of the insects were killed.

Hunter Milling Company, Wellington, Kan.

Building, brick.
Date of heating, July 21, 1912.
Character of day, partly cloudy and calm.
Outside maximum temperature, 97 degrees.
Outside minimum temperature, 74 degrees.
Heating system, steam pipes along the wall and a few radiators.
Steam pressure maintained during the heating, about 100 pounds.
Capacity of mill,[4] 1000 barrels.

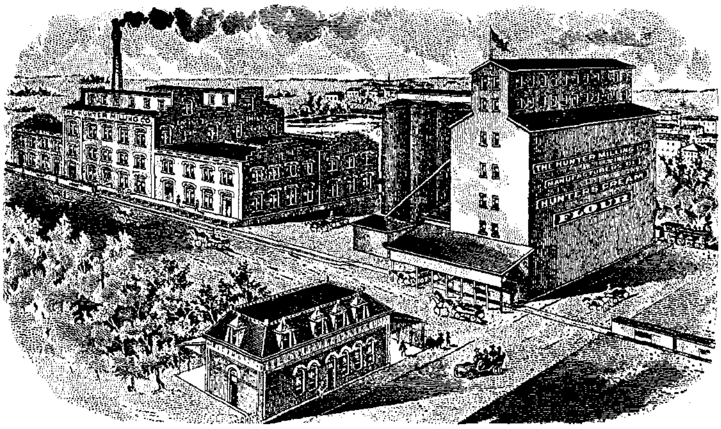

FIG. 7. Hunter Milling Co., Wellington, Kan.

BASEMENT.

Capacity of floor, 33,790 cubic feet.
Amount of radiation, 1020 square feet.

4. Only the new mill was heated.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.	No. 4. Degrees.
8:00 A. M.	96	128	98	98
10:00 "	97	134	104	98
12:00 M.	100	136	105	98
2:00 P. M.	102	136	107	102
4:00 "	104	138	108	106
6:00 "	103	140	109	109
8:00 "	103	143	109	109
10:30 "	102	145	113	109

LOCATION OF THERMOMETERS.

No. 1.—In flour in an elevator boot resting on the floor, five feet from steam pipes.

No. 2.—Hanging in the open, six feet high, ten feet from steam pipes.

No. 3.—In flour in an elevator boot resting on the floor, fifteen feet from steam pipes.

No. 4.—In flour in an elevator boot resting on the floor, ten feet from steam pipes.

Result: Killing temperatures were reached in all parts of the basement except in elevator boots resting on the concrete floor.

FIRST FLOOR

Capacity of floor, 40,040 cubic feet.
Amount of radiation, 780 square feet.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
8:00 A. M.	130	121	97
10:00 "	138	123	100
12:00 M.	140	123	102
2:00 P. M.	140	124	108
4:00 "	142	125	111
5:00 "	143	127	113
10:30 "	146	131	119

LOCATION OF THERMOMETERS

No. 1.—Hanging in the open, six feet high, fifteen feet from steam pipes.

No. 2.—In flour in a roll, twenty feet from steam pipes.

No. 3.—In flour in a roll in the cleaning room, five feet from a radiator.

Result: One hundred per cent of the insects were killed.

SECOND FLOOR

Capacity of floor, 43,120 cubic feet.
Amount of radiation, 800 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
8:00 A. M.	137	112	110
10:00 "	144	119	113
12:00 M.	147	122	115
2:00 P. M.	151	127	121
4:00 "	153	130	124
6:00 "	153	128	126
8:00 "	154	128	128
10:30 "	156	130	129

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open, six feet high, fifteen feet from steam pipes.

No. 2.—In flour in the bottom of an elevator boot, fifteen feet from steam pipes.

No. 3.—In flour on bolting cloth in a reel, twelve feet from radiation (cleaning room).

Result: One hundred per cent of the insects were killed.

THIRD FLOOR.

Capacity of floor, 43,120 cubic feet.
Amount of radiation, 900 square feet.

READING OF THERMOMETERS.

	Thermometers		
Time of day.	No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
8:00 A. M.	120	108	116
10:00 "	126	114	121
12:00 M.	131	116	125
2:00 P. M.	136	120	130
4:00 "	138	123	132
6:00 "	139	124	134
8:00 "	141	127	136
10:30 "	142	129	138

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open, five feet high, twelve feet from steam pipes.

No. 2.—In flour in a conveyor, fourteen feet from steam pipes.

No. 3.—Hanging in the open, five feet high, ten feet from radiator (cleaning room).

Result: One hundred per cent of the insects were killed.

TEXAS.

Capacity of floor, 5100 cubic feet.
Amount of radiation, none.

READING OF THERMOMETERS.

	Thermometers	
Time of day.	No. 1. Degrees.	No. 2. Degrees.
8:00 A. M.	121	109
10:00 "	129	113
12:00 M.	134	117
2:00 P. M.	138	121
4:00 "	141	124
6:00 "	141	126
8:00 "	141	128
10:30 "	141	130

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open, six feet high.

No. 2.—In flour in a conveyor near the floor.

Result: One hundred per cent of the insects were killed.

Wellington Milling and Elevator Company, Wellington, Kan.

Capacity of mill, 600 barrels.
Building, brick.
Dates of heating, July 27, 28, 1912.
Character of days, calm and partly cloudy.
Outside maximum temperature, 105 degrees.
Outside minimum temperature, 73 degrees.
Heating system, steam pipes along the wall.
Steam pressure maintained during the heating, about 100 pounds.

BASEMENT.

Capacity of floor, 23,199 cubic feet.
Amount of radiation, 260 square feet.

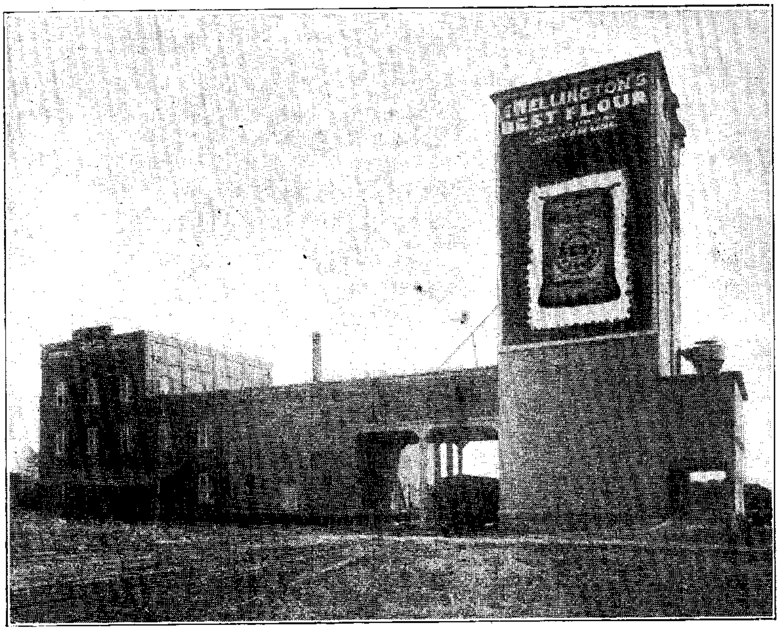

FIG. 8. Wellington Milling and Elevator Company, Wellington, Kansas.

READING OF THERMOMETERS

Time of day.	Thermometers No. 1. Degrees.	Thermometers No. 2. Degrees.	Thermometers No. 3. Degrees.
July 27, 1912.			
9:30 P. M.	113	104	102
11:30 "	112	102	102
July 28, 1912.			
6:30 A. M.	109	96	100
7:30 "	110	99	99
9:30 "	118	108	110

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 28, 1912.			
11:30 "	122	109	109
12:30 P. M.	122	110	110
2:30 "	124	113	113
4:30 "	128	114	115
5:30 "	129	115	115
7:30 "	130	119	118
9:30 "	130	117	117
11:00 "	130	118	118
July 29, 1812.			
1:00 A. M.	134	120	120
3:00 "	136	122	122
4:30 "	136	122	122

LOCATION OF THERMOMETERS

No. 1.—Hanging in the open 5 feet high.

No. 2.—In flour in an elevator boot resting on the floor.

No. 3.—In flour in an elevator boot resting on the floor.

Result: Ninety per cent of the insects were killed. The steam pipe exhaust opened into a pit beneath the basement floor, which allowed the steam to escape in the basement, thereby keeping the air moist.

FIRST FLOOR.

Capacity of floor, 29,526 cubic feet.

Amount of radiation, 210 square feet.

READING OF THERMOMETERS

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 27, 1912.			
9:30 P. M.	110	118	105
11:30 "	113	121	107
July 28, 1912.			
6:30 A. M.	116	123	110
7:30 "	118	124	110
9:30 "	120	128	113
11:30 "	122	129	114
12:30 P. M.	123	130	115
2:30 "	124	131	116
4:30 "	126	134	119
5:30 "	127	135	120
7:30 "	130	137	123
9:30 "	130	137	123

LOCATION OF THERMOMETERS.

No. 1.—In some bran in a roll, twelve feet from steam pipes.

No. 2.—Hanging in the open, five feet high, ten feet from steam pipes.

No. 3.—In flour in a packer near the floor, six feet from steam pipes.

Result: One hundred per cent of the insects were killed.

SECOND FLOOR.

Capacity of floor, 27,417 cubic feet.

Amount of radiation, 168 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 27, 1912.			
9:30 P. M.	117	108	109
11:30 "	120	111	112
July 28, 1912.			
6:30 A. M.	126	114	120
7:30 "	126	116	120
9:30 "	130	117	121
11:30 "	131	119	124
12:30 "	132	131	134
2:30 "	133	122	126
4:30 "	136	125	128
5:30 "	137	127	128
7:30 "	138	128	130
9:30 "	138	128	130

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open, five feet high, fifteen feet from steam pipes.

No. 2.—In flour in a conveyor, twenty feet from steam pipes.

No. 3.—In four inches of flour near the floor, eight feet from steam pipes.

Result: One hundred per cent of the insects were killed.

THIRD FLOOR.

Capacity of floor (including deck), 45,343 cubic feet.

Amount of radiation, 326 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 27, 1912.			
9:30 P. M.	111	120	111
11:30 "	113	122	113
July 28, 1912.			
6:30 A. M.	118	128	119
7:30 "	119	130	120
9:30 "	122	132	122
11:30 "	124	136	124
12:30 P. M	125	137	126
2:30 "	128	139	128
4:30 "	129	141	129
5:30 "	130	142	130
7:30 "	132	142	132
9:30 "	132	141	131

LOCATION OF THERMOMETERS.

No. 1.—In flour in a conveyor near the floor, twenty feet from steam pipes.

No. 2.—Hanging in the open five feet high, twelve feet from steam pipes.

No. 3.—In a pile of flour on the floor, ten feet from steam pipes.

Result: One hundred per cent of the insects were killed.

FOURTH FLOOR OR DECK.

Capacity included in third floor measurement.
Amount of radiation, none.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.
July 27, 1912.			
9:30 P. M.	123	113	115
11:30 "	124	115	116
July 28, 1912.			
6:30 A. M.	130	120	122
7:30 "	131	122	124
9:30 "	134	126	126
11:30 "	138	127	129
12:30 P. M.	138	128	130
2:30 "	141	133	134
4:30 "	143	133	136
5:30 "	144	134	137
7:30 "	144	136	138
9:30 "	143	136	138

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open five feet high.
No. 2.—In refuse flour on the base of a dust collector near the floor.
No. 3.—In flour three feet from the floor.
Result: One hundred per cent of the insects were killed.

Inter-Ocean Mills, Topeka, Kan.

Capacity of mill, 1000 barrels.
Building, frame.
Date of heating, July 28, 1912.
Character of day, partly cloudy, with a light breeze.
Outside maximum temperature, 95 degrees.
Outside minimum temperature, 72 degrees.
Heating system, steam pipes along the wall.
Steam pressure maintained during the heating, about 80 pounds.

FIRST FLOOR.

Capacity of floor, 34,790 cubic feet.
Amount of radiation, 262 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.	No. 4. Degrees.	No. 5. Degrees.	No. 6. Degrees.
8:00 A. M.	98	96	105	90	...	...
10:00 "	104	101	106	94	96	110
12:00 M.	110	106	108	97	104	113
2:00 P. M.	114	111	109	102	105	117
4:00 "	118	115	110	107	108	120
6:00 "	120	116	110	110	110	122
8:00 "	121	117	112	113	112	123
9:00 "	121	118	113	114	112	126
9:30 "	121	118	113	114	112	126

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open five feet high, fifteen feet from steam pipes.

No. 2.—Hanging in the open five feet high, eighteen feet from steam pipes.

No. 3.—Resting on a roll in a roller, twelve feet from steam pipes.

No. 4.—In two inches of flour near the floor, five feet from steam pipes.

No. 5.—In flour in a conveyor near the floor, twenty feet from steam pipes.

No. 6.—Hanging in the open six feet high, twenty feet from steam pipes.

Results: Ninety to ninety-five per cent of the insects were killed.

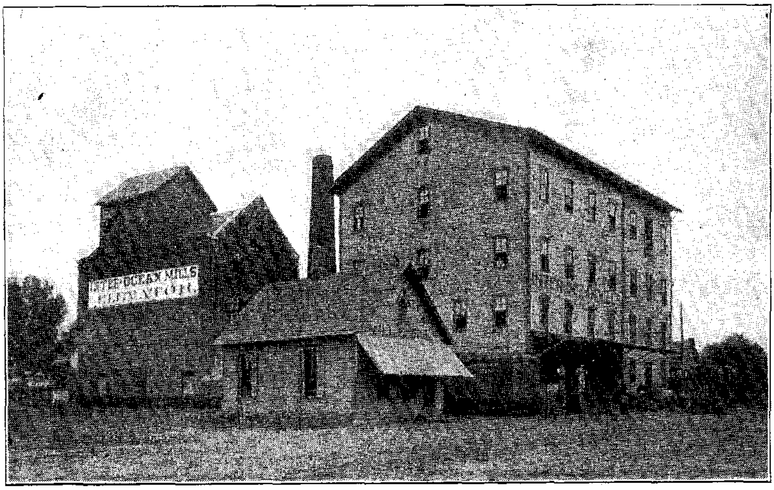

FIG. 9. Inter-Ocean Mills, Topeka, Kansas.

SECOND FLOOR.

Capacity of floor, 38,269 cubic feet.

Amount of radiation, 190 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.	No. 4. Degrees.	No. 5. Degrees.	No. 6. Degrees.
8:00 A. M.	98	94	93	92	...	...
10:00 "	102	100	93	94	120	94
12:00 M.	108	104	95	99	128	97
2:00 P. M.	114	112	99	104	134	100
4:00 "	118	115	103	107	139	106
6:00 "	120	118	106	108	142	106
8:00 "	122	118	110	110	143	108
9:30 "	122	119	110	112	144	110

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open, five feet high, twenty-two feet from steam pipes.

No. 2.—Hanging in the open, five feet high, eighteen feet from steam pipes.

No. 3.—In three inches of bran near the floor, five feet from steam pipes.

No. 4.—In flour in an elevator boot resting on the floor, seventeen feet from steam pipes.

No. 5.—In an oven in a laboratory, five feet high and three feet from steam pipes.

No. 6.—In flour in an elevator boot resting on the floor, thirty feet from steam pipes.

Result: Ninety-five to one hundred per cent of the insects were killed.

THIRD FLOOR.

Capacity of floor, 49,375 cubic feet.

Amount of radiation, 267 square feet.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.	No. 4. Degrees.	No. 5. Degrees.	No. 6. Degrees.
8:00 A. M.	98	95	94	96	...	...
10:00 "	104	101	100	98	96	102
12:00 M.	109	106	104	104	100	99
2:00 P. M.	115	112	108	108	104	103
4:00 "	120	117	112	112	108	108
6:00 "	124	121	116	116	112	112
8:00 "	126	123	119	118	114	115
9:30 "	127	124	120	122	116	114

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open, five feet high, twenty-two feet from steam pipes.

No. 2.—Hanging in the open, five feet high, twenty feet from steam pipes.

No. 3.—In flour in a conveyor, six feet high, eight feet from steam pipes.

No. 4.—In flour in a purifier, four feet high, thirteen feet from steam pipes.

No. 5.—In flour in an elevator boot resting on the floor, four feet from steam pipes.

No. 6.—In flour in a conveyor near the floor, eleven feet from steam pipes.

Result: One hundred per cent of the insects were killed.

FOURTH FLOOR.

Capacity of floor (including deck), 69,580 cubic feet.
Amount of radiation, 310 square feet.

READING OF THERMOMOTERS.

Time of day.	Thermometers No. 1. Degrees.	No. 2. Degrees.	No. 3. Degrees.	No. 4. Degrees.	No. 5. Degrees.	No. 6 Degrues.
9:00 A. M.	101	98	93	94	97	...
10:00 "	103	100	95	96	92	...
12:00 M.	110	107	102	100	98	...
2:00 P. M.	116	114	107	102	100	...
4:00 "	122	120	113	106	105	...
6:00 "	126	123	116	110	109	...
8:00 "	126	123	118	115	113	...
9:30 "	127	124	118	114	113	...

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open five feet high, twenty-six feet from steam pipes.

No. 2.—Hanging in the open five feet high, twenty-eight feet from steam pipes.

No. 3.—In flour in an elevator boot six inches from the floor, twenty-four feet from steam pipes.

No. 4.—In flour in a conveyor near floor, thirteen feet from steam pipes.

No. 5.—In flour in a conveyor near floor, twenty-two feet from steam pipes.

Result: One hundred per cent of the insects were killed.

DECK (OR FIFTH FLOOR).

Capacity included in measurement of fourth floor.

Amount of radiation, none.

READING OF THERMOMETERS.

Time of day.	Thermometers No. 1. Degrees.	Thermometers No. 2. Degrees.
9:00 A. M.	104	100
10:00 "	106	99
12:00 M.	114	112
2:00 P. M.	122	113
4:00 "	126	118
6:00 "	128	123
8:00 "	127	125
9:30 "	127	126

LOCATION OF THERMOMETERS.

No. 1.—Hanging in the open five feet from the floor.

No. 2.—In flour in a conveyor near the floor.

Result: One hundred per cent of the insects were killed.

Hydrocyanic Acid Gas Treatment for Mill Insects.

Up to the time of the discovery of the heat method, hydrocyanic acid gas fumigation was considered the most effective means for the control of mill insects. Experiments now show, however, that while some mill insects succumb very readily to the hydrocyanic acid gas, others, including some of the most serious ones, do not yield readily to this treatment. If a mill is infested with Mediterranean flour moth, hydrocyanic acid gas is a very effective treatment. All stages of this insect, including the eggs, if not covered with more than one inch of flour, succumb to the gas. On the other hand, if the mill is infested with the several species of flour beetles and of grain beetles, and with the cadelle, the gas treatment is of little value. In no case where it is possible to use the heat method does the writer recommend the use of the hydrocyanic acid gas treatment, but since it is effective for Mediterranean flour-moth infestation, and since there are flour mills where it may be impossible or impracticable to use the heat method, the hydrocyanic acid gas treatment is then recommended as the best method.

Detailed Discussion of the Hydrocyanic Acid Gas Treatment,

Necessary Chemicals and Articles for Fumigation. There are necessary for this treatment the potassium cyanide, sulphuric acid, water, stone jars, paper sacks, and vessels for the measuring and carrying of the acid and water.

POTASSIUM CYANIDE. This is a white or somewhat bluish-white crystalline salt, readily soluble in water, rapidly decomposing in a moist atmosphere, and soon deteriorating if left exposed to even a dry air. It is extremely poisonous. It may be had in air-tight screwed-top tin cans of five, ten and twenty-five pound lots, or in sealed tin drums of 112 pounds capacity. The cyanide should be not less than 98 per cent pure, and if in a can the crystals are found to be brownish or discolored, it should be rejected.

SULPHURIC ACID. Sulphuric acid, or oil of vitriol, is a dense, oily liquid, colorless if pure. The specific gravity is about 1.84, or nearly twice as great as that of water. The acid is very poisonous and corrosive. Great care must be exercised not to get any of it upon the skin, the clothing, or wooden floors. This acid is shipped in large bottles or carboys of twelve gallons each. The purchaser should insist on having the best commercial grade, with specific gravity of not less than 1.83.

STONE JARS. Four-gallon stone jars, such as are commonly handled by grocers, are the best and most convenient vessels in which to combine the chemicals and to generate the gas. To prevent the chemicals from boiling over, avoid the three-gallon size. The five-gallon size is permissible, but its inconvenience and the extra cost make it objectionable. One jar will be required for every three pounds of potassium cyanide. These jars, after being washed, are in no way injured for household or other purposes.

PAPER SACKS. Common manila sacks, sizes number 8 and 10, such as may be obtained from the grocer, are the best sacks in which to place the potassium cyanide to be dropped into the jars. Two sacks are used for every three pounds of cyanide. These sacks are doubled; that is, the smaller one is placed within the larger one. Do not use heavy paper sacks or sacks heavily glazed.

MEASURING AND CARRYING VESSELS. The best and most convenient vessels for measuring and carrying are the one-gallon or two-gallon graniteware cups or pitchers. Tin vessels must not be used. Graniteware buckets are very inconvenient, since the acid will run down the sides and thus drop on the floor or get on the person while carrying it. To avoid accident or injury to the floor, it is well to handle the acid in a carboy on the loading platform or outside the mill.

The Proportion of Chemicals Used to Generate the Gas. During the last two years the writer has used no other formula than what is known as the government formula, or the one resulting from the thorough investigation of the Bureau of Entomology in cooperation with the Bureau of Chemistry of the U. S. Department of Agriculture It is certainly the most economical, efficient and convenient one for the production of the gas.

5. Circular No. 112, Bur. of Ent., U. S. Dept. of Agr., 9.

Formula:

Potassium cyanide (98% pure), by weight, 3 pounds avoirdupois.

Sulphuric acid (best commercial grade), by measure, 3 pints.

Water, by measure, 9 pints.

The Amount of Material to be Used. Inside measurement of the length, width and height should be carefully taken to determine accurately the number of cubic feet in each story to be treated, no allowance being made for empty bins or machinery. It is advisable to prepare a plan for the guidance of the operator, indicating the exact number of jars and the required amount of chemicals for each floor.

The following plan will be found convenient:

Building .... Place ....

Name .... Date ....

Floor.	Dimensions.	Cubic feet.	Potassium cyanide.	Sulphuric acid.	Water.	Generators.	Remarks.
			lbs	pints.	pints.		
Basement.....							
First floor.....							
Second floor. ..							
Third floor.....							
Fourth floor....							
Fifth floor.....							
Total. ..							

If the building is well constructed and can be made reasonably tight, the following standard may be followed for mill fumigation: In the basement use one pound of potassium cyanide to every 1000 cubic feet; on the first floor one pound to every 1200 cubic feet of space; on the second floor one pound to every 1300 cubic feet of space; on the third floor one pound to every 1500 cubic feet of space; on the fourth and fifth floors one pound to every 1600 cubic feet of space.

If the building is practically air-tight, a smaller amount of cyanide to every 1000 cubic feet of space will probably give good results, but in view of the time and the labor it takes to get ready and to fumigate, it is not economy to risk the success of fumigation in endeavoring to save a few pounds of cyanide and acid. In case the floors can not be handled separately, the amount should be increased on the lower floors and lessened on the upper floors, for the gas is light and rises.

The Preparation of the Mill. The success of fumigation with hydrocyanic acid gas depends to a great extent upon the preparation of the mill for fumigation; that is, how thoroughly the mill has been cleaned and how nearly air-tight it has been made. Before stopping the mill, close the feed, and while the mill is running empty, go over the spouts, the elevator legs, etc., with a spout maul to jar the flour or the meal loose so it will run out. Open all hand holes, slide doors, etc., in the spouts, the elevator legs, the bolters, the purifiers, the rolls, the dust collectors, and the conveyors. These should all, with the exception of the elevator caps, be left open during the fumigation.

All accumulations of flour or meal should be brushed out or removed from the elevator boots, the conveyors, and other places in the machinery where flour has lodged. The entire plant should be as thoroughly cleaned as possible by sweeping up the flour and meal on the floors, under the machinery, and in the corners. This material should be removed from the mill and disposed of in such a manner as not to be brought back into the mill.

The building must be as nearly air-tight as possible. Windows may be wedged tight. If they are loose, either paper should be pasted over the cracks, or cotton batting should be inserted in the openings with a case knife. The batting should be packed tightly. Cracked panes should either be replaced or be pasted over with paper. A similar treatment should be given all doors, ventilators, and holes in the walls. Each floor should be made entirely separate from the other floors.

All belt holes should be stuffed with sacks, and all elevator shafts closed. Cracks should be closed by strips of paper pasted over them. All stairways should be closed, or covered by trap doors. These doors may be made of lumber closely fitted together, or of light frames with paper pasted over.

To provide for ventilation after the fumigation, arrange two opposite windows on each floor so that they may be opened by means of a stout cord or rope from the outside. This may be done by fastening a rope to a screw eye in the bottom of the lower sash of the upper window, and letting the rope hang so that it may be reached from the ground.

The Process of Fumigation. Measure the water and pour the correct amount into the four-gallon stone jars, and after the jars or generators containing the water have been placed so as to afford easy access in rows upon each floor of the building, add the correct quantity of sulphuric acid to the water in each of the jars. The acid should never be placed in the jars first. Since sudden heating of the water may crack the jars, the acid should always be slowly poured into the water to avoid sudden rise in temperature. When the acid is poured into the water, there usually arises a little vapor or steam. In arranging the generators throughout the mill, it is best to avoid placing them alongside of any belt, sacked material, or anything that might be injured from spattering or from leakage from the occasional cracking of a jar.

After the jars containing the water have been arranged, and the acid has been added, the cyanide should be broken into small lumps, none of which should be larger than a hen's egg, and made up into three-pound packages in the doubled manila sacks; that is, one sack placed inside the other. The cyanide should be handled with leather gloves, and out in the open air where the operator may avoid inhaling the dust. In breaking the large lumps, care should be taken to avoid any particles flying in the eyes or mouth. To prevent any particles flying in the eyes, it is well to protect them with goggles. The writer finds that the large lumps of cyanide can best be broken by striking the lump a solid blow with the hammer while holding it in the hand well protected by a leather glove. The cyanide should never be broken in a mill or in any place where pieces may fly or lodge in any feed or flour. The fine particles or dust of cyanide usually found in the bottom of the cans or drums should be distributed among several of the packages to avoid having an excess amount of fine cyanide in one package, which is apt to cause the boiling over of the liquid in the jar.

Two or three reliable men should now be sent through the mill to distribute the cyanide. A bag containing cyanide should be left at the side of each jar. Before dropping the bags of cyanide into the jars make an inspection of the entire building to see that all windows are closed and everything ready and in its place, so that after the first jar has received its cyanide it will be unnecessary to stop to adjust anything.

After all these preliminaries have been arranged, the operator should begin on the upper floor of the mill at the end opposite the stairway and place a bag of cyanide gently in each jar, passing quickly from one to the other. Pass quickly from one floor to the next one below, closing the trap door, where the process is repeated until the lower floor or basement is reached where exit is made. The outer doors should be locked and a watchman stationed to guard the building until the fumigation is completed. Every one connected with the fumigation should constantly bear in mind that hydrocyanic acid gas is extremely poisonous, and that if the fumes are inhaled, they are almost sure to prove fatal. (Plates I, II, III and IV.)

The Stringing Method. While it is not often necessary to use the stringing method in the fumigation of a mill, there may be a floor so crowded with machinery as to make easy access impossible, or a basement without outside exit, where the use of the stringing method will eliminate danger. This method consists in passing stout strings through convenient screw eyes, each string finally passing through a screw eye so as to hang from the ceiling to the floor at a point decided upon for the placing of a jar. The strings should be so arranged that all of the bags of cyanide may be gently lowered into the jars by the releasing of one main string. This may be done by carrying all of the strings through the screw eyes in the ceiling or woodwork to one stout cord at the door or stairway leading out of the room. The screw eyes should be firmly secured to the ceiling or woodwork and a good quality of smooth stout cord should be used and so arranged as to avoid friction with any of the machinery or woodwork. After the strings have all been arranged, the jars containing the water should next be placed and the acid poured into them. Each of these jars should be removed at least two feet from where the cyanide will be suspended. Men are now sent through the building with packages of cyanide, and a bag is firmly secured to each of the suspended strings. The string should be firmly tied around the neck of the sack, and since the string will stretch a few inches, the bag should hang at the time it is tied about eight inches above the top of the jar, After the bags have all been tied to the strings, the next step is to place each jar under one of the suspended bags. All the suspended bags should hang at least two or three inches above the tops of the

PLATE I. First floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanide for hydrocyanic acid gas fumigation where the bags are dropped in by hand.

jars. As soon as everything is ready for lowering the bags, they should be gently lowered into the jars by releasing the main string from the outside. In case they can not all be low-

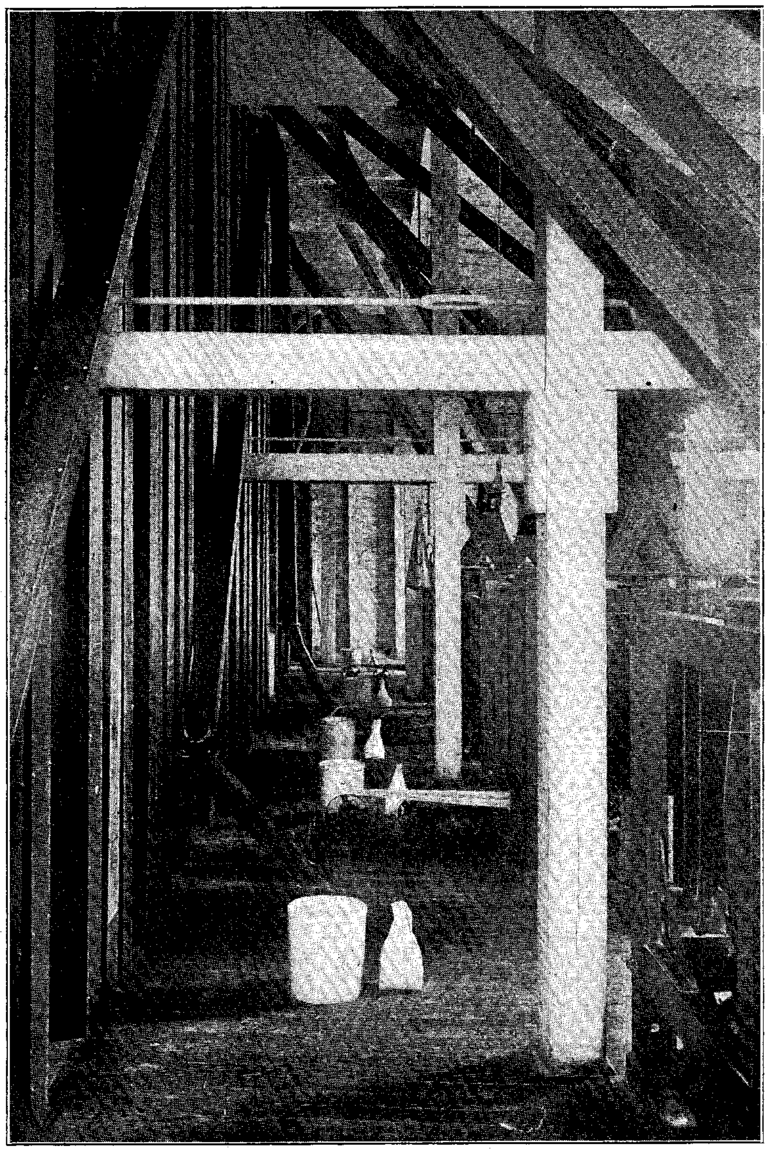

PLATE II. Second floor of a flour mill showing the proper arrangement of the generators and the bags of cyanide for hydrocyanic acid gas fumigation where the bags are dropped in by hand.

ered simultaneously from the outside, the operator should begin at the stairway at the top story and work downward. (Plates V and VI.)

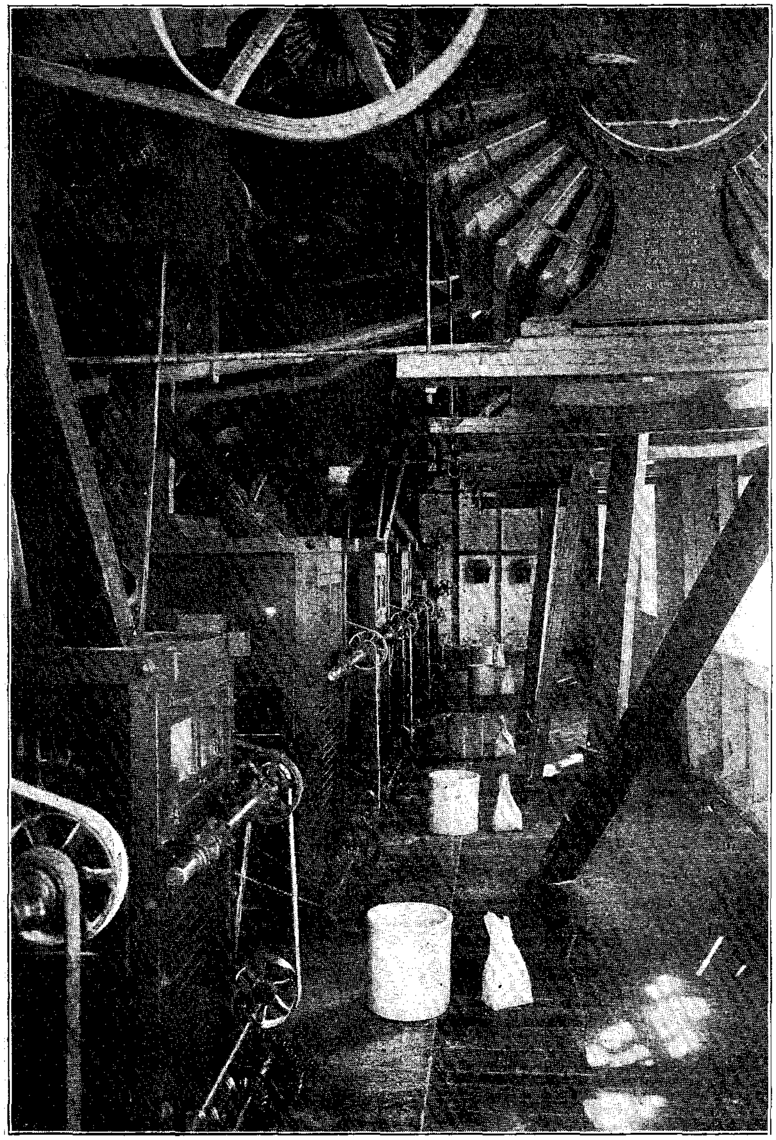

PLATE III. Third floor of a flour mill showing the proper arrangement of the generators and the bags of cyanide for hydrocyanic acid gas fumigation where the bags are to be dropped in by hand.

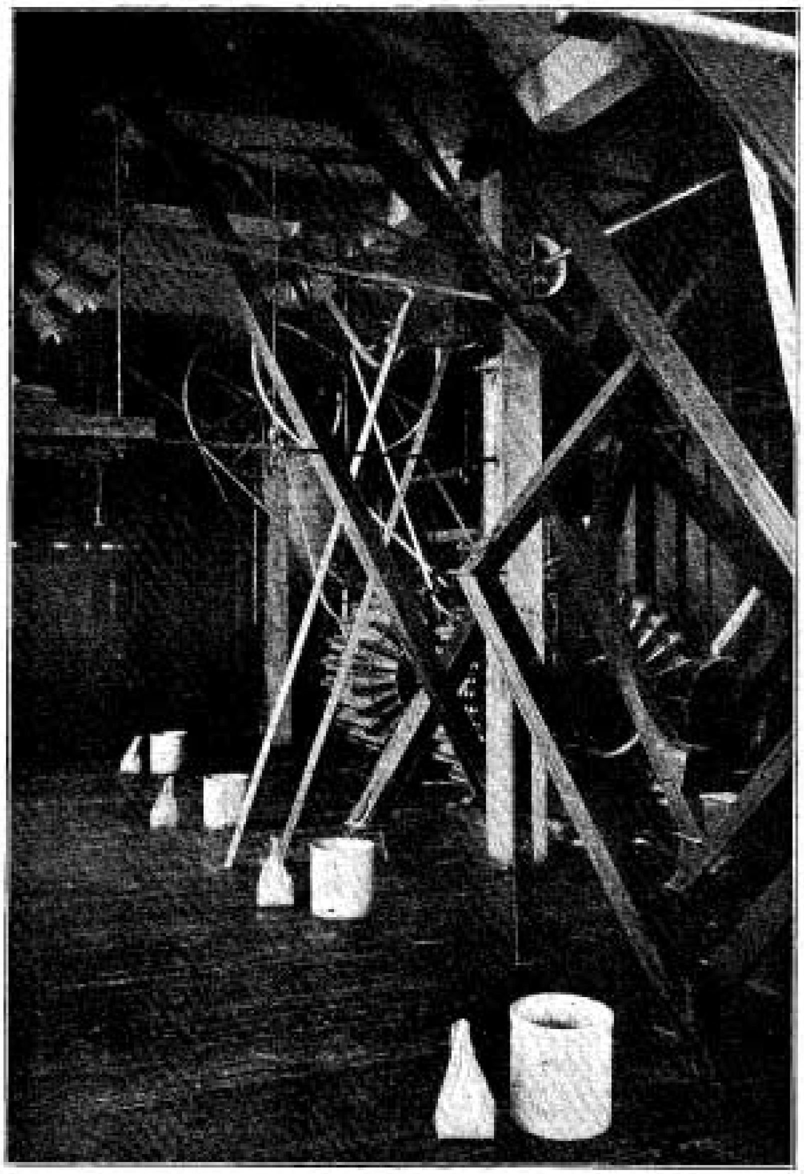

PLATE IV. Fourth floor of a flour mill showing the proper arrangement of the generators and the bags of cyanide for hydrocyanic acid gas fumigation where the bags are to be dropped in by hand.

PLATE V. First floor of a flour mill showing the proper arrangement of the generators and the bags of cyanide for hydrocyanic acid gas fumigation where the string system is to be used.

FIG. 1. GENERATOR TOO CLOSE TO BAGS OF FLOUR.

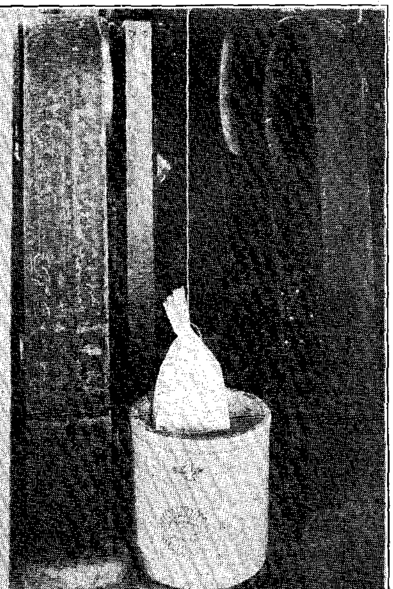

FIG. 2. GENERATOR TOO CLOSE TO BELTS AND BAG TOO LOW.

FIG. 3. GENERATOR TOO CLOSE TO BELTS AND BAG TOO HIGH.

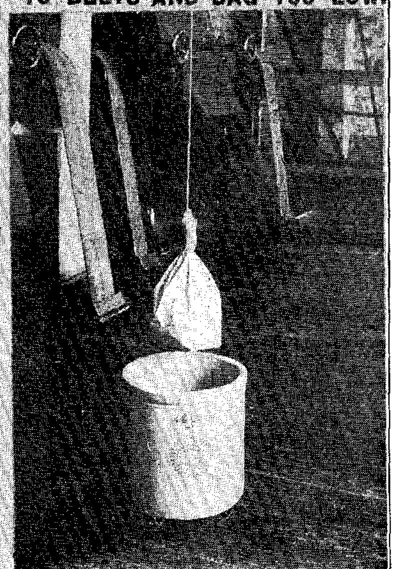

FIG. 4. CORRECT PLACING OF GENERATOR AND BAG.

PLATE VI. The correct and incorrect placing of generators and bags of cyanide for hydrocyanic acid gas fumigation.

The Time to Fumigate and the Length of Exposure. Since in case of a high wind the gas will be carried to one side of the room or may escape rapidly, a still day should be chosen for the fumigation. Inasmuch as experiments show that below a temperature of from 50° to 60° F. most mill insects are inactive and therefore not affected by the gas, a day should be selected for the fumigation when the temperature is 70°F. or above. Everything should be done during the day so that the charge can be set off in the evening before dark. Where circumstances will permit, the best time to fumigate is a Saturday afternoon, and the building should be left closed until the following Sunday evening or Monday morning. The building should be allowed to fumigate not less than eighteen hours, and, when time will permit, from twenty-four to thirty-six hours.

Ventilation. To ventilate, open from without the doors and windows that have been arranged for ventilation and air the building thoroughly for one or two hours before you enter. In opening windows and doors, open first those on the side of the building opposite to the direction of the wind. After the building has aired one or two hours, the operator should enter to open up the stair doors and more of the windows, but should not remain in the building until it has aired for fifteen or twenty minutes more.

The Procedure after Airing the Buildings. After the building has been thoroughly aired, the first thing to do is to go over the entire building, especially if the stringing system has been used, to ascertain if all the charges have "gone off," If through neglect or any other reason any bag has not been dropped or lowered into the jar, it should be carefully removed to a place of safety. The men should now begin on the lower floor to carry out the jars, and after the contents have been dumped into the sewer or a hole dug in the ground, the jars should be thoroughly washed. If the chemical action has been complete the residue in the jars after the operation may not be very poisonous, although it is still acid and will burn the skin or clothing. It is always best to consider this residue as an element of danger, and great care should be used in promptly disposing of it. No work of this sort should be entrusted to careless men. The men should be cautioned to avoid a jar that is bubbling and not to inhale any of the fumes that may arise from the pit or hole where the contents are dumped. After the contents of all the jars have been emptied, the hole should be covered with earth.

The entire plant should be carefully looked over for dead mice and rats, and all dead insects should be swept up before resuming work.

Precautions. Potassium cyanide is a most deadly poison. Do not handle it with bare hands. Do not break the lumps in the mill where particles may fly into any feed or flour. In breaking it prevent any particles from flying into the eyes or mouth, and do not inhale any of the dust. Do not use cyanide that has deteriorated or discolored. Always distribute the fine cyanide in several of the bags.

Sulphuric acid is poisonous and dangerous to handle. It is powerful in its action and very corrosive to both animal and vegetable matter. Avoid getting any of it on the skin, the clothing, or the floor of the mill. In pouring the heavy acid from the carboy, care must be taken to avoid spattering it on the hands or in the face. Always pour the sulphuric acid into the water; never pour water into sulphuric acid.

Hydrocyanic acid gas is the most energetic, powerful, and poisonous gas in common use. A single breath of the pure gas is almost certain to prove fatal to man.

The handling of these chemicals and the generating of gas should not be entrusted to men who are careless or ignorant of their deadly nature. Inasmuch as extreme care must be exercised it is always advisable to select three or four intelligent operators for the work.

Always provide for ventilation from without, and do not enter the mill until it is thoroughly aired. Do not fumigate on a windy day, or when the temperature is below 65° F. In dropping the bags of cyanide into the jars always begin on the top floor and work downward, and do not stop to adjust anything or return to any part of the building while it is fumigating.

The Efficiency of Fumigation. Our experiments show that in an air-tight chamber hydrocyanic acid gas will effectually penetrate flour to a depth of three inches. However, in mill fumigation it will not penetrate flour and mill products much beyond one inch, and in many places, particularly near the floor, not even one inch. Again, our experiments show that while some mill insects succumb very readily to hydrocyanic acid gas, others do not yield readily to the treatment. In a mill infested with Mediterranean flour moth, hydrocyanic acid gas is a very effectual treatment. All stages of the insect, including the egg, if not covered with more than one inch of flour, succumb to the gas. On the other hand, if the mill is infested with the several stages of the little rust-red flour beetles and the cadelle, this gas treatment is of little value. These insects are found in cracks and in accumulations of fine stuff inaccessible to the gas.

The Frequency of Fumigation. As a rule, most millers who use the hydrocyanic acid gas method fumigate once a year. However, in case of Mediterranean flour moth infestation, in order to guard against the infestation from eggs that may have escaped the gas, a second fumigation should follow at the end of the third or the fourth week. In a few mills where this method has been practiced, the Mediterranean flour moth has been eradicated. The miller who fumigates in the spring, following with a second fumigation in mid-summer and a third in early fall, will find that a fumigation in July, followed by a second fumigation within three to four weeks, will prove far more effectual.

The Effect of Hydrocyanic Acid Gas Fumigation Upon Flour. In connection with hydrocyanic acid gas fumigation, inquiries naturally arise as to whether the fumigation has any deleterious effect upon the flour. In order to have positive data upon this subject, the writer, in cooperation with Prof. C. O. Swanson, assistant chemist of the Kansas State Experiment Station, conducted a series of extensive baking tests, the detailed results of which are published in Bulletin No. 178 of the Kansas State Agricultural College Experiment Station. In these experiments, four grades of soft winter wheat flour, consisting of a patent, a straight, a clear, and a low grade, and three grades of hard winter wheat flour, consisting of a patent, a straight, and a low grade, were used. Twelve-pound samples of each of the grades of soft and hard winter wheat flours were treated with hydrocyanic acid gas at the maximum strength used in flour mills, viz., one pound of potassium cyanide to one thousand cubic feet of space. These treatments were given in an air-tight constant-temperature chamber for a period of twelve hours at a temperature of 90° F. From each of the samples baking tests were made immediately after the fumigation, and were repeated under the same conditions two or three days later, in order that any error that might have entered into the first baking might be checked up. Similar duplicate baking tests from the same samples were made at the end of thirty and at the end of sixty days. In every baking, under the same conditions and at the same time, one loaf was made from each grade of fumigated flour, and, as a check, one loaf was made from each grade of unfumigated flour. Very careful measurements, calculations, and observations were made during the entire baking process and of the finished loaves. Photographs were taken of all of the loaves baked, and examination of the measurement tables and photographs will show that the effects of the gas are so small as to be entirely negligible. It is only in the careful measurements employed in the tests that any difference between the fumigated and the unfumigated flour is apparent at all, and the only difference here appears in the maximum volume of the dough in the test made immediately after fumigation, but not in the test made after thirty days. The finished loaf showed absolutely no deleterious effect from fumigation in any of the tests.

Summary for the Fumigation of Mills with Hydrocyanic Gas.

Necessary Chemicals and Articles for Fumigation :

1. Obtain the chemicals, generating jars, and the articles for fumigation.

2. Do not neglect to order a few more pounds of the chemicals and a few extra jars in order not to run short at the last moment.

3. The potassium cyanide should be not less than a 98 per cent grade of fused potassium cyanide.

4. The sulphuric acid should be the best grade of commercial acid, having a specific gravity of not less than 1.83.

5. All generators should be four-gallon stone jars. Do not have three-gallon and five-gallon sizes.

6. Obtain from your grocer common manila sacks, numbers 8 and 10. Two sacks are used for every three pounds of cyanide. Do not get heavy paper sacks or sacks heavily glazed.

7. Have on hand, for the carrying of the acid, two graniteware pitchers. The pitchers should be of not less than one-gallon capacity.

The Preparation of the Building:

1. Before stopping the mill, close the feed and let the mill run empty. Go over the spouts, the elevator legs, etc., with a spout maul to jar the flour or the meal loose so that it will run out.

2. Open the hand holes, slide doors, etc., in the spouts, the elevator legs, the bolters, the purifiers, the rolls, the dust collectors, and the conveyors. These should all, with the exception of the elevator caps, be left open during the fumigation.

3. All accumulations of flour or meal should be brushed out or removed from the elevator boots, the conveyors, and other places in the machinery where flour has lodged. The entire plant should be cleaned as thoroughly as possible by the sweeping up of the flour and meal on the floors, under the machinery, and in the corners. This material should be removed from the milll and disposed of in such a manner as not to be brought back into the mill.

4. The building must be as nearly air-tight as possible. Windows may be wedged tight. If they are loose, either paper should be pasted over the cracks, or cotton batting should be inserted in the openings with a case knife. Cracked panes should either be replaced or pasted over with paper.

5. Each floor should be made entirely separate from other floors. All belt holes should be stuffed with sacks, and all elevator shafts should be closed. All stairways should be closed, or covered by trap doors.

6. To provide for ventilation after the fumigation, arrange two opposite windows on each floor so that they may be opened by means of a stout cord or rope from the outside.

7. Place danger signs of fumigation on all sides of the mill, and have a watchman guard the mill during fumigation.

8. Since the insurance companies require a watchman, and since he would not dare to pass through the mill during the fumigation, permission should be had from the insurance companies relative to the watchman clause.

The Process of Fumigation:

1. Measure into each jar the proper amount of water and distribute the jars so as to afford easy access to them upon each floor of the building.

2. Measure out the acid and add it to the water in the jars. Always pour the acid into the water.

3. Break up the cyanide into small lumps, and place it in three-pounds lots, using the double paper sacks.

4. Place a bag containing cyanide at the side of each jar.

5. Before dropping the bags of cyanide into the jars, make sure that all windows are closed and that everything is ready and in its place.

6. Begin operations on the upper floor and pass quickly downward, placing the cyanide in each jar.

7. Lock the doors, and station a watchman to guard the building until the fumigation is completed.

Procedure after Fumigation:

1. Open the windows and doors from without for ventilation.

2. Do not enter the mill until it has been aired for at least two hours.

3. Collect and dispose of the liquid left in the jars. This should be emptied into the sewer or into a pit. Avoid spilling any of the contents of the jars in the mill or on the person. One should be very careful of a jar with bubbles.

4. Clean or wash the jars before putting them away. They are easily washed with water.

5. Sweep up dead insects before resuming work.

Carbon Bisulphide Fumigation for Insects Destructive to Grain Stored in Granaries and Small Elevators.

Insects injurious to stored grains, when once started, work so vigorously that the farmer must kill them, dispose of his grain, or allow them seriously to damage it. The principal damage done by these pests occurs in bins, granaries, and small elevators, although in the South considerable injury results from infestation of corn and of small grains in the stack.

Of the several species of beetles and their larvae attacking stored grains, not more than five or six are commonly found in the farmers' bins, of which the two species of grain weevils (snout beetles or little "bill bugs"), the grain molitor, the cadelle, and the saw-toothed grain beetle are the most damaging. To these may be added three species of moths, the Angoumois grain moth, which is the most serious attacking corn, and the two meal moths, the serious ones in meal, bran, or any other ground grain products.

Fortunately, it matters little what species may be causing the trouble, for all succumb to the same treatment. The simplest, most effective, and least expensive remedy for all insects infesting the farmers' grain and grain products stored in tight bins is careful fumigation with carbon bisulphide.

While carbon bisulphide fumigation is effective and is strongly recommended for all insect infestations in the farmers' bins, it is not an effective fumigation in flour mills; and since there is such an element of danger from fire in its use in these mills and in large grain elevators, it is not recommended for this purpose. It is prohibited by mill and grain-elevator insurance companies, and the use of it voids the policies.

Detailed Discussion of Carbon Bisulphide Fumigation.

The Amount of Liquid to be Used. The amount of liquid to be used depends on the temperature, on the size and shape of the building, on its tightness, and on the nature of the attack. Since temperature is a very important factor in the success of fumigation, it should always be given careful consideration.

Our fumigation experiments conducted in practically an air-tight chamber with the larvæ, the pupæ, and the adults of the confused flour beetle *(Tribolium confusum)* and the adults of the rice weevil *(Calandra oryzæ)*, show that while at a temperature of 90° F. one pound of carbon bisulphide is sufficient for every 500 cubic feet of space, at a temperature of 80° F. one pound of the liquid is required for 400 cubic feet of space, and at a temperature of 70° F. one pound of the liquid is required for every 300 cubic feet of space. At a temperature below 60° F. the amount of carbon bisulphide required and the results obtained are so unsatisfactory that it is impracticable to attempt fumigation. If the building is reasonably tight and the temperature is above 70°, four pounds of carbon bisulphide is sufficient for every 1000 cubic feet of space, or one pound for every 35 bushels of grain. In case the building or bins are not sufficiently tight to allow thorough fumigation, the amount of the liquid should be doubled or even tripled. If the insects are very abundant, the liquid in every case should be doubled.

Preparation. The building and bins must be as nearly air-tight as possible in order that the vapor may remain in all parts of the space in full strength and for the required time. The vapor must enter all cracks and crevices by diffusion. Doors should be wedged tight. If they are loose, either paper should be pasted over them, or cotton batting should be inserted in the openings with a case knife. A similar treatment should be given all holes and cracks in the wall or floor. The batting should be packed tightly. The door and one or two windows should be so arranged that they can be opened from the outside when fumigation is completed. Care should be taken to have everything ready and in place, so that after the distribution of the liquid has begun it will be unnecessary to stop to adjust anything. Everything should be done to avoid unnecessary delays and to facilitate the rapid evaporation of the liquid.

Placing the Liquid. Since the vapor is heavier than air and settles to the lower parts, the liquid should be placed in shallow pans at the top of the bins or building. It should be well distributed, not more than a pound in a place, and even less than this amount where it is practical to have it distributed in small quantities. If larger amounts are used in one place, it should be placed in pans having considerable evaporating surface. In large bins, to hasten and to equalize the operation, it is well to put a quantity of the liquid in the center of the grain by thrusting into it a gas pipe, loosely plugged at one end, down which the carbon bisulphide may be poured, the plug being then loosened with a rod. The plug should be attached to the rod in order that it may be withdrawn. The liquid may be applied or sprinkled directly upon the grain. Unless used in excessive quantities the liquid will not injure the edible or germinative qualities of the grains or seeds.

If a building of more than one floor is to be fumigated, the operator should begin on the first floor and work upward, and after placing the liquid in the upper story, leave the building through a window that he can close after him. If it is impossible to get out from the upper story, the carbon bisulphide should first be distributed there, and the operator should work downward as rapidly as possible to avoid the settling vapor.

Length of Exposure. The bins or building should be allowed to fumigate 36 hours. If the grain is not to be used for germinating purposes, it is well to subject it to the fumigation for 48 hours. The best plan usually is to apply the liquid on a Saturday afternoon and leave the building closed until the following Monday.

Ventilation. Doors and windows should be opened wide and the building or bins aired thoroughly one or two hours before being entered. Slight traces of the odor will linger in corners and other places where the air does not circulate freely, but these will gradually disappear.

Precaution. The vapor of this liquid is highly inflammable and explosive. No fire or light of any sort should be allowed about the building while the fumigation is in progress. The application should always be made in daylight, for artificial light of any kind is dangerous. Electric lights must not be used, since when turning them on or off there is always danger of producing a spark. It is not safe to have heat of any kind in the building while the fumigation is in progress.

The Habits and Life History of the Common Stored-grain and Mill Insects.

Insects injurious to stored grain and grain products, when once started, work so vigorously that the farmer or elevator man must kill them, dispose of his grain or allow them seriously to damage it, and those injurious in flour mills and warehouses, when once they have gained a foothold, multiply so rapidly that the miller must either control them or allow them to cause serious damage and loss to his mill products. While the principal damage done by these pests occurs in granaries, elevators, flour mills, and warehouses, there is in the South considerable injury resulting from infestation of standing corn and of small grains in the stack. Within the last four or five years considerable damage of this sort has been done to stacked wheat and oats in Kansas.

Nearly all of the more than seventy species known in the United States have been introduced by commerce, and the more serious ones, numbering about twenty, are now commonly distributed over the greater part of the United States. All of these species are of small size, none of the beetles exceeding five-eighths of an inch in length, and most of them being less than one-fourth of an inch long. They are reddish, brown, or black in color, The moths are tiny "millers," and with the exception of the Angoumois grain moth, the work of their larva in bins, granaries and mills may be distinguished from that of the beetles by the presence of web or silk in the grain, bran, meal or flour. Only two of these insects are true weevils, although the farmer and the miller usually apply the term "weevil" to most of them.

The principal damage to whole grains is caused by the grain weevil, rice weevil, and the Angoumois grain moth. The most serious damage and loss in the flour mills is caused by the Mediterranean flour moth. The principal injury to flour is caused by the confused flour beetle and the cadelle, while the serious damage to meal, bran and breakfast foods is caused by the Indian meal moth, the meal snout-moth, and the saw-toothed grain beetle.

The Grain Weevils.

The term "weevil" is usually applied to all the various insects found in the granary and the elevator, but the granary weevil and the rice weevil are the only true grain weevils. These two species are very similar in both structure and habits, but the adults may be easily distinguished from all the other beetles found in grain by the fact that their heads are prolonged into a long snout or bill, at the tip of which are found the biting mouth parts. These weevils do not breed in flour unless it has become lumpy or caked from dampness.

THE GRAIN WEEVIL.
(*Calandra granaria* Linn.)

The adult is a small, cylindrical beetle, about one-sixth of an inch in length, with head prolonged into a snout; it is from shining chestnut-brown to nearly black in color and very firm and hard. The larva is footless, fleshy, maggot-like, and white in color, and works inside of the kernel.

DISTRIBUTION.

This insect has been a serious pest in stored grain since the earliest times, and in this country is a widely distributed granary pest.

HABITS AND LIFE HISTORY.

The adult beetle is very firm and hard, wingless, with body cylindrical, about one-sixth of an inch long. The head is prolonged into a snout or bill, and the thorax is pitted with a few longitudinal punctures. The female bores a minute hole into the kernel with her snout, and in this cavity deposits a very small white egg. In a few days the egg hatches and the larva at once begins to devour the interior of the kernel. The larva

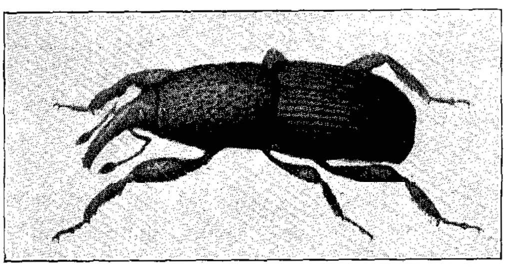

FIG. 10. Granary weevil (*Calandra granaria*), 22 times natural size. (After Girault.)

is a footless, short, robust, fleshy maggot, less than one-eighth of an inch long, and white in color. It changes to a white pupa within the kernel, which at this time is a mere hull. (Fig. 10.)

The female is very prolific, and her egg-laying period may last several weeks. Since during the warmer months the life cycle requires only from six to seven weeks, there are, in this latitude, four broods annually, and under very favorable conditions there may be five.

Inasmuch as the adult weevils live several weeks, gnawing into the kernels and devouring the inner contents, they do almost as much damage as the larvae. Both the adults and the larvae are serious pests on wheat stored in granaries and elevators. They are also injurious to oats, barley, corn, and kafir.

THE RICE WEEVIL.

(*Calandra oryza* Linn.)

The adult is a small, cylindrical, dull, dark, reddish-brown beetle, little less than one-sixth of an *inch long, with head prolonged into A snout. The larva is footless, fleshy, maggot-like, white in color, and works inside of the kernel.* (Fig. 11.)

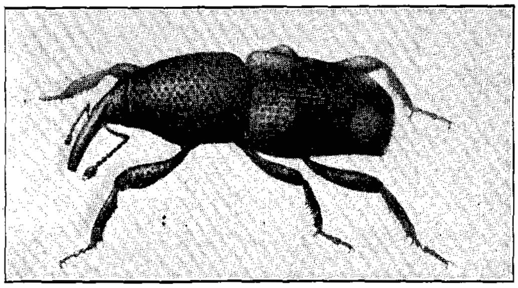

FIG. 11. Rice weevil (*Calandra oryza*), 22 times natural size. (After Girault.)

DISTRIBUTION.

Though this species is a native of India, it has become distributed throughout almost the entire world. It has been taken in every state and Alaska.

HABITS AND LIFE HISTORY.

In many respects the adult beetle is very similar to the granary weevil. However, it differs in having the thorax densely pitted with round punctures, and in having well-developed wings. Usually each wing-cover is marked with two more or less distinct reddish spots, one at the base and the other near the tip. The general color is a dull, dark reddish-brown, but there may be individuals varying from a light brown to nearly black. The larva and pupa resemble those of the granary weevil, and the life history is very similar, except that in the southern states the female may lay her eggs on the standing grain, and in the latitude of Kansas on shocked and stacked grain if it has been allowed to remain long before threshing. While this weevil is very serious in the central and northern states, it is far more serious in the southern states and in warmer countries. This species feeds upon wheat, corn, oats, barley, sorghum, kafir, buckwheat, rice, and sometimes flour and meal if they have become caked. (Figs. 12 and 13.)

FIG. 12. Rice weevil larva and pupa in situ in corn; both enlarged four times. (After R. I. Smith.)

The Grain Beetles.

While there are seven or eight very small reddish-brown grain beetles and one large, shining, black beetle attacking stored grain and mill products, only three or four are commonly found, of which the saw-toothed grain beetle and the cadelle are the serious ones, and are of common occurrence in granaries, elevators, flour mills, warehouses, and seed stores. Both the beetles and the larvæ of the little reddish-brown species are found infesting all sorts of stored grains, mill products, breakfast cereals, and seeds. The cadelle, though

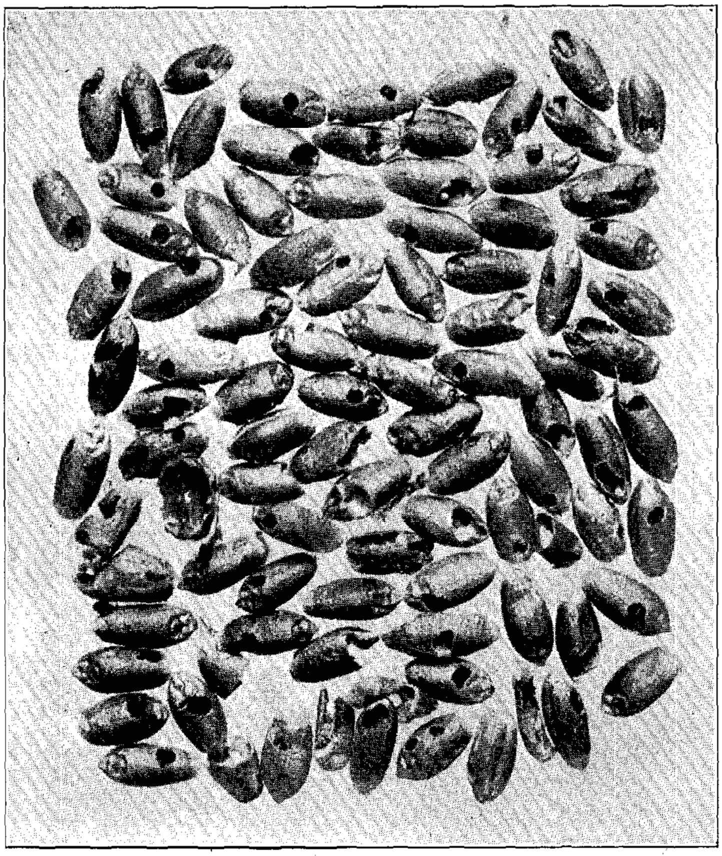

FIG. 13. Wheat infested with rice weevil, three times natural size.

grouped with the grain beetles, is more serious in flour mills, and the larva of it is very troublesome in flour while in transit and in storage.

THE SAW-TOOTHED GRAIN BEETLE.

(*Silvanus surinamensis* Linn.)

The adult is *a very small, slender, flattened dark-brown beetle, about one-tenth of an inch long, with thorax having six saw-like teeth oneach side. Larva ayellowish-white, slender, very active worm.*

DISTRIBUTION.

This insect is a common pest over the entire world, and is found almost everywhere infesting grains, grain products, and household edibles.

HABITS AND LIFE HISTORY.

Both the beetle and the larva infest all sorts of grains, flour, meal, bran, breakfast foods, dried fruits, rice, seeds of all sorts, nuts, starch, sugar, tobacco, dried meats, spices, and even salt. The larva is a very active, yellowish-white, slender worm with six legs. It hatches in a short time after the long, slender egg is deposited, and at once begins to feed upon the grain or grain products, but does not live altogether either upon or within a single grain or seed, but runs about here and there, nibbling and feeding upon several. After reaching its growth, the larva fastens itself to some convenient object or surface, constructs a case or covering by joining together particles of grain or small pieces of infested material by means of a sticky substance, which it secretes, and in this protective covering it passes the pupal stage. The larvae frequently pupate in cracks or crevices of the bin where they may be easily overlooked. In from six to twelve days the pupæ transform to the adult beetles. The beetles are very small, slender, flattened, dark-brown in color, and about one-tenth of an inch length, with the thorax armed on each side with six saw-like teeth. (Fig. 14.) The beetles are very active, and when disturbed run off in great haste. In the latitude of Kansas there are from four to six generations of this insect annually. During the spring the life cycle requires from six to ten weeks, but through the warm summer it may pass through its entire life cycle in from twenty-four to thirty days. The beetles and

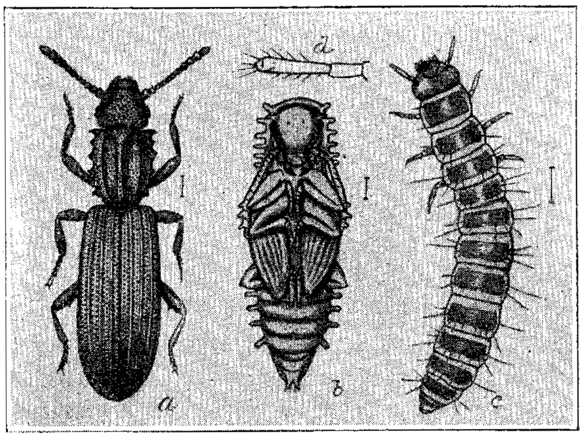

FIG. 14. Saw-toothed grain beetle (*Silvanus surinamensis*): *a*, beetle; *b*, pupa; *c*, larva, 16 times natural size; *d*, antenna of larva, much enlarged. (After Chittenden, U. S. Dept. Agr.)

their larvae will perforate paper bags and cardboard boxes in which flour, meal, dried fruits and breakfast foods are stored. These insects are usually very common in cereal and feed mills, and in warehouses and groceries where cereals and mill products are stored. In a flour mill they are always more abundant in the cereal or corn meal plant, especially the bins and places of accumulations. Corn bran is very likely to be infested, and should never be used for the bedding of cars. On several occasions, the writer has found this insect in cars both before loading and after unloading flour, and especially was this true if either wheat or corn bran had been used for the bedding of the car.

THE FOREIGN GRAIN BEETLE.
(*Cathartus advena* Waltl.)

A very small, reddish-brown beetle, not more than one-tenth of an inch long, and more robust and not so slender as the square-necked grain beetle.

While this insect is widely distributed and shows an extensive range in its food habits, it does not become a pest in grain stored in a dry, clean, well-aired place. It has been taken in wheat stored in granaries and small elevators. Both the beetles and the larvae are fond of grain, bran, shorts, and meal in a damp or moldy condition. It is reported by Dr. F. H. Chittenden as feeding in meal, flour, rice, shorts, dried fruits, beans, edible tubers, figs, and dates. (Fig. 15.)

THE SQUARE-NECKED GRAIN BEETLE.
(*Cathartus gemellatus* Duv.)

A very small, slender, flattened, reddish-brown beetle about one-tenth of an inch long; head and thorax nearly as broad as the abdomen, the thorax being nearly square and not toothed on the sides.

While this insect is more common in the southern states, where it breeds in corn and in the cotton bolls in the field, it is also a pest in the Middle West, where it is found feeding on stored corn, grains, and sometimes dried fruit. It is found principally infesting wheat and oats in the elevator and the granary, where it feeds usually upon the germ or embryo. During the warm summer months it may pass through its entire life cycle in less than twenty-four days. (Fig. 16.)

THE FLAT GRAIN BEETLE.

(*Læmophloeus minutus* Oliv.)

A very small flat, narrow, reddish-brown beetle, not more than one-tenth of an inch long. The antennæ very long and wide-spreading at the tip.

While this insect is called a grain beetle, and in Kansas has been taken in elevators and granaries, it is more often found in the flour mill. The favorite place of this beetle seems to be between the joinings of the doors and sides of the flour con-

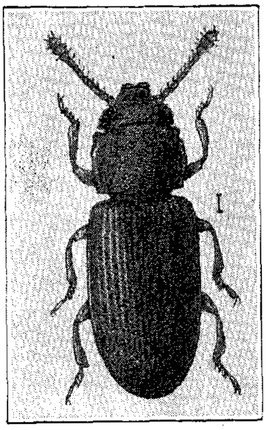

FIG. 15. Foreign grain beetle (*Cathartus advena*), 16 times natural size. After Chittenden, U. S. Dept. Agr.)

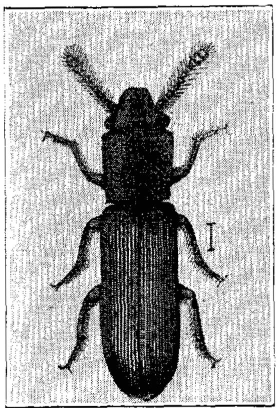

FIG. 16. Square-necked grain beetle (*Cathartus gemellatus*), 16 times natural size. (After Chittenden, U. S. Dept. Agr.)

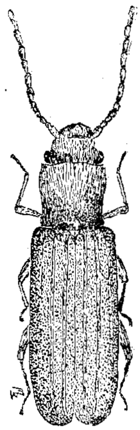

FIG. 17. Flat grain beetle (*Læmophlœus minutus*), 15 times natural size.

veyors of the purifiers and bolters. The beetles are often noticed along the edges just as the doors are lifted. Usually they do not appear in sufficient numbers to warrant alarm, (Fig. 17.)

THE CADELLE.

(*Tenebroides mauritanicus* Linn.)

The adult is a black or nearly black flattened beetle about one-third of an inch long, oblong in shape, with thorax and abdomen loosely joined together. The larva is a whitish, somewhat hairy worm, about three-fourths of an inch long, with head and tail dark brown, the tail ending in two horny points.

DISTRIBUTION.

This insect, probably of American origin, is widely distributed over the entire world, and, although it is partially predaceous and there is only one generation developed annually, it rivals many of the serious pests in the point of injuriousness.

HABITS AND LIFE HISTORY.

From the description given above, both the adult and the larva are easily distinguished from the other mill and stored-grain insects. In a flour mill, the adult may be found in nearly all parts, but is noticed more often in the elevator legs, the bolters, and the sifters. The writer has observed both the beetle and the larva of this insect cutting through sacks, and the beetle cutting through silk bolting cloth; in bolting reels and redressing machines standing idle part of the time, the silk cloth may be badly damaged. The larva is much larger and more fleshy than any of the other flour worms. In a flour mill they are found in the accumulations in the bottom of the elevator boots and the flour conveyors. They are a common pest in bags of flour in the warehouse. In one instance, upon careful examination of two 140-pound bags of a straight grade flour just previous to shipping, there were taken in one bag 1460 worms, and in the other 1001. During the blending process of flour in some of the blending plants, these larvæ sometimes are bolted out by the thousands. While examining flour at the various lake and sea ports of this country and Europe, the writer has on many occasions observed flour seriously infested with these larvæ. In a certain European flour warehouse, where the flour was being rebolted to remove the infestation, these worms were taken by the gallon. After one has made a study of flour while in transit and in storage, he is certainly convinced that this is one of the most serious of the mill insects. (Fig. 18.)

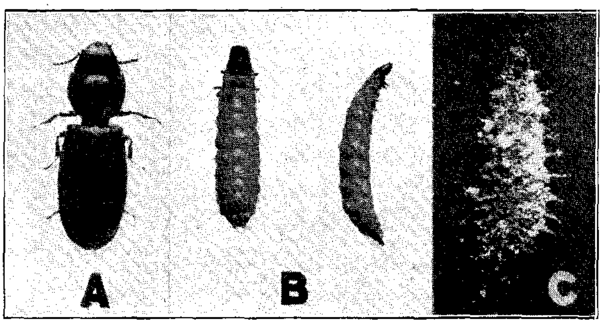

FIG. 18. The Cadelle (*Tenebroides mauritanicus*): A, adult beetle, 3 times natural size; B, larvæ; C, appearance of larva in flour, 1½ times natural size.

Both the larvae and the adults also feed upon grain, going from kernel to kernel, devouring the embryo, and thus destroying more seeds for germinating purposes than they consume. (Fig. 19.) In Kansas they are also often found in elevators, granaries and cereal mills. Both larvæ and adult beetles may be found devouring other grain insects. The pupa is white. This insect also differs from many of the other flour and grain-infesting insects in requiring an entire year for its life cycle, being most active, of course, throughout the summer season.

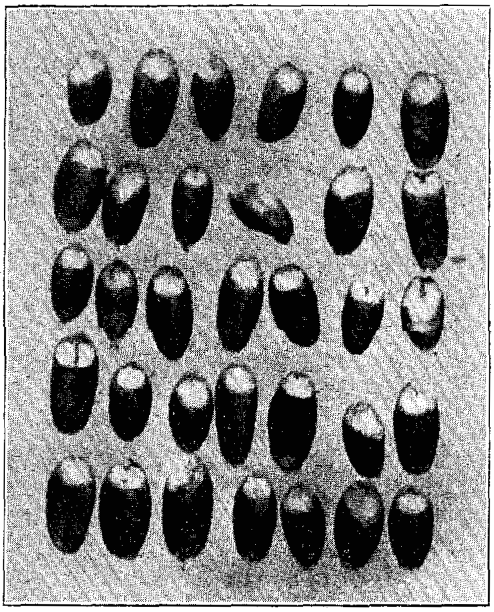

FIG. 19. Kernels of wheat showing the work of the larva and the adult of the cadelle, 2½ times natural size.

The Meal Worms.

Of the three or four species of meal worms infesting stored grain and mill products, only two are of common occurrence. In both the adults and the larval stage these two species are very similar in both structure and habits, and are about equally common. The adults are black, flattened beetles more than half an inch in length. The larvæ are hard, long, cylindrical worms, waxen in appearance, and resemble wire worms. These insects are particularly fond of grain and mill products in dark, damp, and undisturbed places in granaries, elevators, and flour mills.

THE YELLOW MEAL WORM.
(*Tenebrio obscurus* Linn.)

Species name should be molitor per photo below.

The larva is cylindrical, long, slender, more than an inch long when fully grown, waxen in appearance, and resembles a wireworm. The adult beetle is more than half an inch long, flattened, shining, and nearly black.

DISTRIBUTION.

This insect, a native of the Old World, is now common over the entire country, and is often abundant where grain is stored.

HABITS AND LIFE HISTORY.

The adult is more than half an inch in length, flattened and oblong in shape, shining and nearly black in color. While a few of the beetles appear all through the summer, the majority appear early in the spring, and in a short time the females deposit their white, bean-shaped eggs singly or in groups in the meal or grain which serves as food for the larvae. In from two to three weeks the eggs hatch, and the larvae, at first pure white, soon change to a waxen yellow, and are fully grown in from three to four months. They are now cylindrical, long, slender, waxen in appearance, and resemble wireworms. (Fig. 20.) They are yellow in color, shading to a yellowish brown

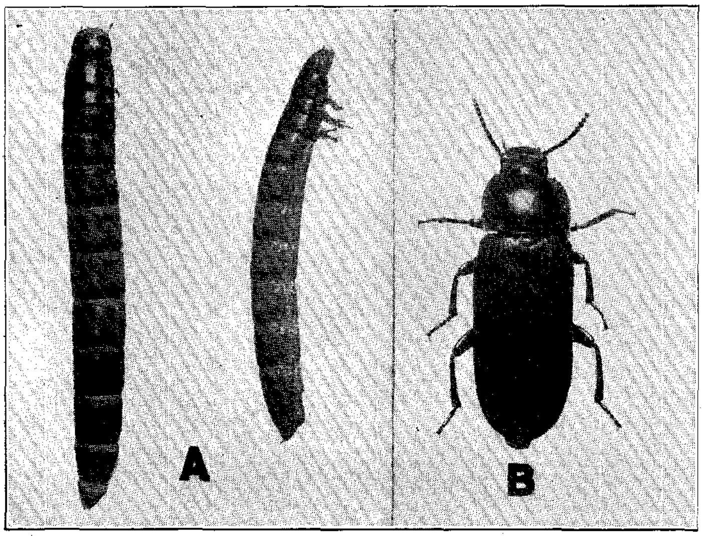

FIG. 20. Yellow meal worm (*Tenebrio molitor*): A, larvæ, 2¼ times natural size; B, female beetle, 3 times natural size.

toward each end and at the articulation of each joint. The tail terminates in two short spines. Although the majority of them are fully grown by the middle of the summer, they undergo no change until the following spring, when they change to white pupæ and remain in this condition from two to three weeks. The pupæ are naked, and may be lying exposed along the edges and in the corners of the bins or under sacks. Thus, as stated in the above life history, this insect requires one year for its life cycle. The beetles are noctural and are found breeding in dark corners, in cracks, and under sacks. This insect shows a great preference for refuse grain and for mill products that accumulate in corners and under machinery in basement and in undisturbed places. They are particularly fond of grain and mill products in these dark and undisturbed places if it is damp and slightly soured. The beetles are often seen running over the bags of flour in the warehouse and among the sacks in the sack room.

THE DARK MEAL WORM.
(*Tenebrio obscurus* Linn.)

The habits and life history of this meal worm are the same as those of the yellow meal worm, and the two species are usually found in the same places. The adult beetle is dull, pitchy black, and in size and shape very similar to the adult of

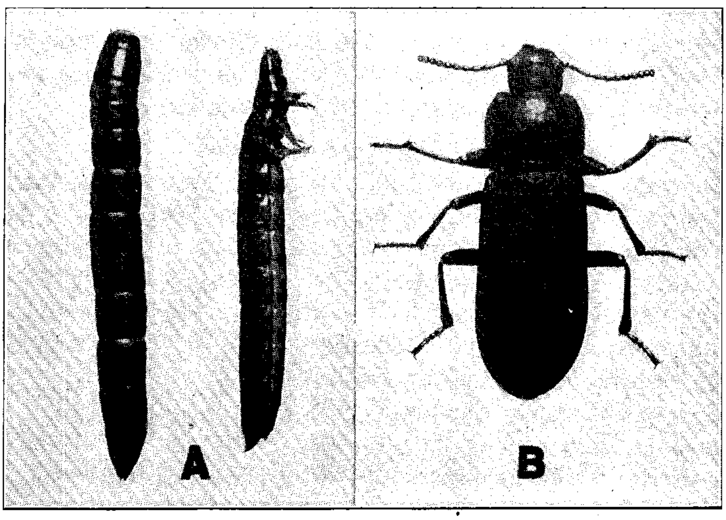

FIG. 21. Dark meal worm (*Tenebrio obscurus*): A, larvæ, 2¼ times natural size; B, female beetle. 3½ times natural size.

the yellow meal worm. The larva also resembles very closely that of the yellow meal worm. It is of the same size and shape, but differs in color, including much darker brownish markings. (Fig. 21.)

The Flour Beetles.

Of the eight or nine little flour beetles that may be found in flour mills only two or three are of common occurrence, and of these the confused flour beetle is the common and serious one. All of these beetles are very small, and with the exception of one black species, are all of a shining, reddish-brown color. The term "weevil" is often applied to these various insects, and flour infested by them and their larvæ is usually called "weevily flour." However, they are not true weevils, and flour infested by them should not be termed "weevily flour." The larvae are small, whitish or whitish yellow worms, and flour infested by them should be called "wormy flour.''

THE CONFUSED FLOUR BEETLE.
(*Tribolium confusum* Duv.)

The beetles are very small, flattened, rust-red in color, about one-sixth of an inch long, and very common in flour. The larvæ are little white worms, about one-fourth of an inch long. They are the most common of all flour worms.

DISTRIBUTION.

This insect is a native of the Old World, and though not noticed in this country until 1893, it is now a serious pest in the entire United States and southern Canada.

HABITS AND LIFE HISTORY.

The eggs are very small and in color clear white, and are laid in cracks and corners of bins, on seams and welts of sacks, in cracks and on the sides of barrels, boxes, or any receptacle containing flour, meal, or any other substance upon which the larvae may feed. (Fig. 22.) In the summer, when the temperature is from 85° to 90° the eggs hatch in five days, and the small, white worms, after feeding about twenty-four days, change to naked white pupae, in which stage they remain five or six days. Thus, during the summer, the life cycle requires only five weeks. With a temperature of 70°, the insect is from fourteen to fifteen weeks in passing through its life cycle. With favorable temperatures, such as we have in Kansas, there are

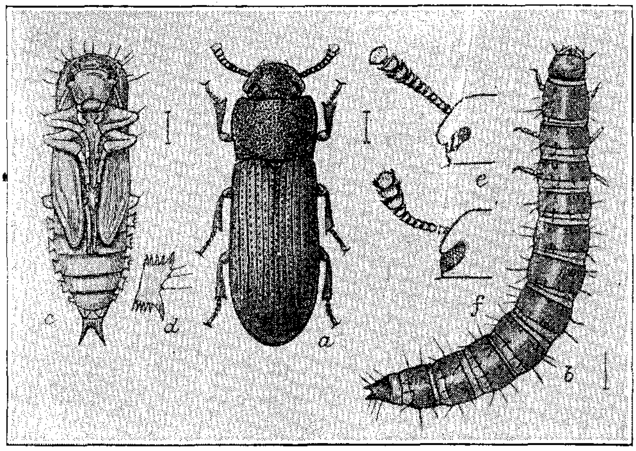

FIG. 22. Confused flour beetle (*Tribolium confusum*): *a*, beetle; *b*, larva; *c*, pupa—all 9 times natural size; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, (*T. ferrugineum*)—all greatly enlarged. (After Chittenden, U. S. Dept. Agr.)

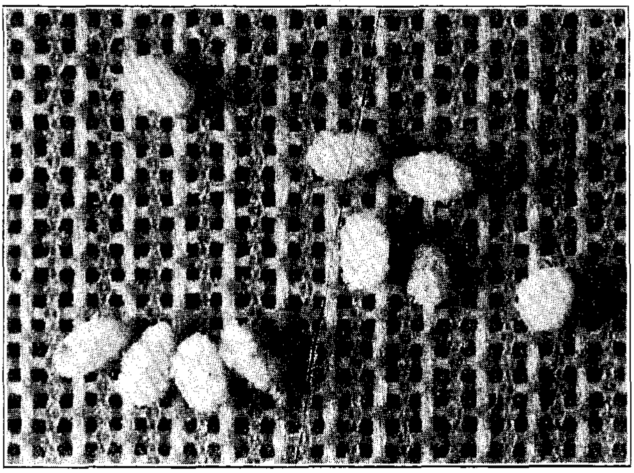

FIG. 23. Eggs of the confused flour beetle (*Tribolium confusum*) on No. 10 XX silk bolting cloth, 16 times natural size.

at least five broods annually, and, in mills that are heated during the winter months, there may be a sixth brood. This insect in all stages is found throughout the mill, but is particularly abundant in dead stock or in the accumulations of flour in elevator boots and flour conveyors. While it may show a preference for the sweet and more oily grades, such as the low-grade flours, yet it will often be found in great numbers in the best patent flours. In a flour mill it breeds in the cracks of the floor and mill machinery, and in accumulations in recesses inaccessible to any gas fumigation. (Fig. 23.) While this insect is primarily a flour pest, it also infests corn meal, cracked wheat, any dry, starchy material, stored peanuts, beans, and even baking powder, ginger, and cayenne pepper. On several occasions the writer has taken these beetles and the larvae in the accumulations of meal and flour in railroad cars.

THE SMALL-EYED FLOUR BEETLE.

(Palorus ratzeburgi Wissm.)

Tiny, flattened, shining, brownish-red beetles, scarcely one-twelfth of an inch long, smallest of the flour beetles known in this country.

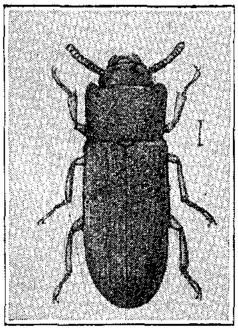

FIG. 24. Small-eyed flour beetle (*Palorus ratzeburgi*), 12 times natural size. (After Chittenden, U. S. Dept. Agr.)

This insect is a native of the Old World, and was first reported in this country in 1882, when it was found doing some damage in a mill near Detroit, Mich.[6] During the last three years specimens have been taken in Kansas in elevators, granaries, flour mills, and feed stores. While it has been found infesting stored wheat, it seems to show a preference for the ground products. (Fig. 24.)

6. Farmers' Bulletin No. 45, Div. of Ent., U. S. Dept. of Agr.

THE SLENDER-HORNED FLOUR BEETLE.
(Echocerus maxillosus Fab.)

AND

THE BROAD-HORNED FLOUR BEETLE.
(Echocerus cornutus Fab.)

Small, flattened, brownish beetles, about one-eighth of an inch long.

These two flour beetles are injurious in about the same manner as the small-eyed flour beetle, but are not widely distributed in this country and are seldom reported as doing any serious injury. In Europe they are serious pests in flour. They prefer flour and meal, but have been found in several ground cereals, and in wheat, corn, and rice. (Figs. 25 and 26.)

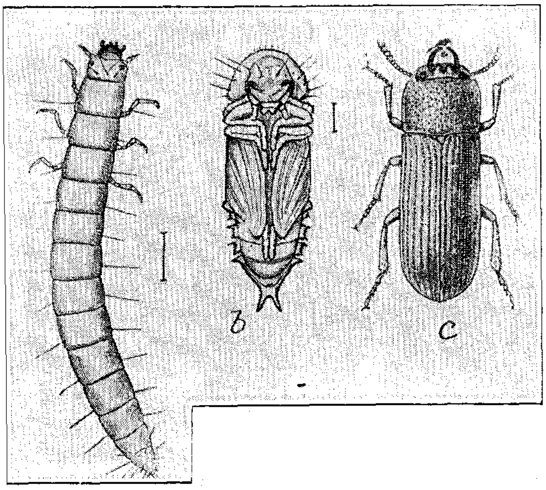

FIG. 25. Slender-horned flour beetle (*Echocerus maxillosus*), 7 times natural size. (After Chittenden, U. S. Dept. Agr.)

The Grain, Meal and Flour Moths.

Of the ten or twelve species of moths attacking stored grain and mill products, not more than four or five are commonly found. Of these the Angoumois grain moth is the most serious attacking corn and wheat; the Indian meal moth and the meal snout-moth are the most serious infesting meal and bran; while the Mediterranean flour moth is the most serious in flour. They are all small moths or tiny "millers," and, with the exception of the Angoumois grain moth, the work of their larvæ in bins, granaries and mills may be distinguished from that of the beetles by the presence of web or silk in the grain, bran, meal, or flour.

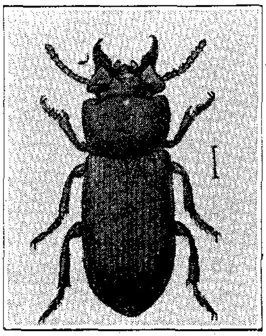

FIG. 26. Broad-horned flour-beetle (*Echocerus cornutus*), male; 7 times natural size. (After Chittenden, U. S. Dept. Agr.)

THE ANGOUMOIS GRAIN MOTH.

(*Sitoatroga cerealella* Oliv.)

Adult is a small, light grayish-brown moth, measuring across the expanded wings little over half an inch, with wings narrow, pointed, and bordered with long fringe. Larva, a little caterpillar one-fifth of an inch long, yellowish head, six pointed legs; it burrows into the kernel, and feeds upon the starchy material.

HISTORY AND DISTRIBUTION.

This insect is named from the province of Angoumois, France, where, as early as 1736, it was found in great numbers in granaries and in grain fields. Just when it was brought to America is not known, but probably with the first importation of wheat. It is now distributed over the greater part of the United States.

HABITS AND LIFE HISTORY.

The moths, or "millers," resemble the common little clothes-moths in size, shape, and manner of flight. In color they are light grayish-brown or buff, with a satiny luster, and more or less lined and spotted with black. The wings are narrow and pointed, the back pair and a portion of the back margin of the front pair being bordered with long, delicate fringe; when expanded, they measure a little over half an inch. (Fig. 27.)

The females, laying from sixty to ninety eggs, deposit them singly or in lots of about twenty upon both mature and immature standing corn; upon grain in the shock and the stack, and upon grain in the bin or the crib.

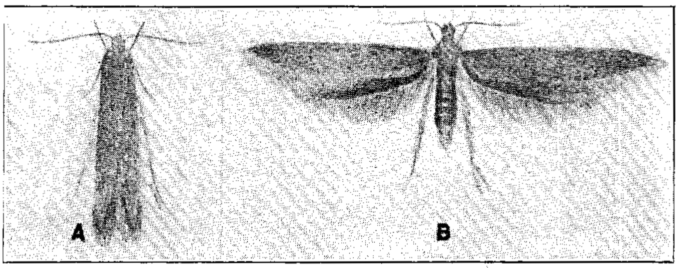

FIG. 27. Angoumois grain moth (*Sitotroga cerealella*): A, wings in natural position; B, wings expanded; 4 times natural size.

The little minute, oval-shaped eggs, white when first laid, but soon turning reddish, are placed in longitudinal channels on the side of the grain, and between the rows of kernels on ear corn. (Fig. 28.) They hatch in from four to ten days, depending upon the temperature, and the larvæ burrow into the kernels, leaving almost invisible openings, and feed upon the starchy material within. (Fig. 29.) In the smaller grains, usually a single larva infests a kernel, but in a kernel of corn two or three larvae may be found. (Fig. 30.) The little caterpillar, when fully grown, is about one-fifth of an inch long, white in color, with a yellowish head. It has six pointed legs in front, four pairs of fleshy prolegs along the middle, and one pair at the tip. In from twenty to twenty-four days it reaches maturity, and, spinning a thin silken cocoon within the kernel, transforms to a pupa. A few days later the moth emerges. During warm weather the entire life cycle embraces a period of about five weeks. In the latitude of Kansas this insect, so far as is known, hibernates or passes the winter in the larval stage in kernels of corn, wheat, barley, and rye, and there are four and probably five broods annually. In the South and in warm buildings six generations are possible. This insect is the most serious pest known upon ear corn in the crib.

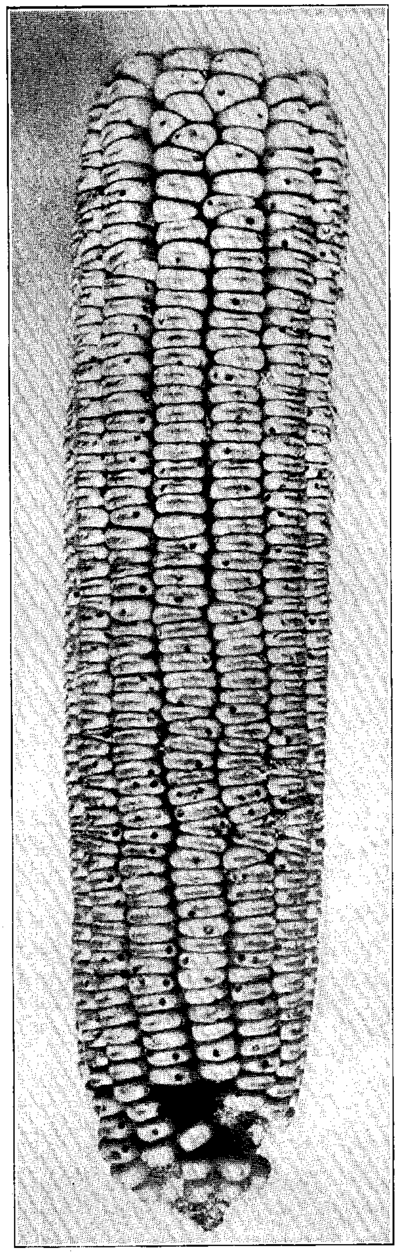

FIG. 28. Ear of corn showing the work of the Angoumois grain moth, reduced one-fourth.

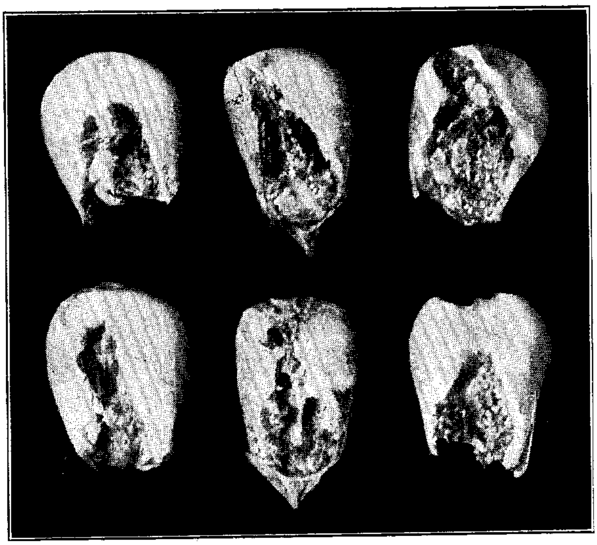

FIG. 29. Kernels of corn showing the work of the larva of the Angoumois grain moth, 1½ times natural size.

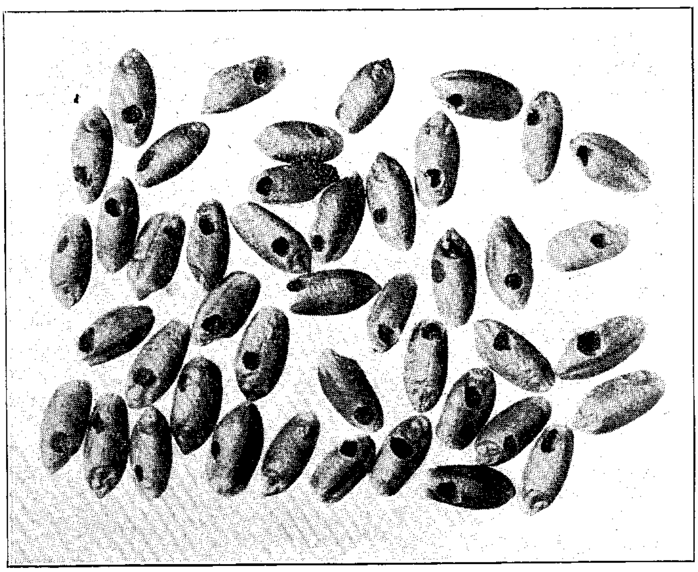

FIG. 30. Kernels of wheat showing the work of the Angoumois grain moth, 2½ times natural size.

THE INDIAN MEAL MOTH.

(*Plodia interpunctella* Huebn.)

The adult moth is in size and appearance about like a clothes-moth, with wing expanse almost three-fourths of an inch, the outer two-thirds of the fore wings being reddish brown, the inner third whitish gray: it is frequently seen flying about mills, stores, and houses. The caterpillar is whitish, greenish, or yellowish, slightly hairy, half an inch long; it spins silken tubes through the materials upon which it feeds, and fastens together seeds, grains, excrement, and particles of food.

DISTRIBUTION.

This insect is a native of the Old World, but is commonly distributed over this country.

HABITS AND LIFE HISTORY.

This insect feeds on edibles of almost every sort, such as meal, bran, flour, grain, breakfast foods, dried fruits, roots, seeds, nuts, etc. It will attack dried insects, herbariums and other museum specimens. It has even been taken in bee hives, where it was working upon the comb, or wax.

"The adult moth has a wing expanse of between a half and three-fourths of an inch. The outer two-thirds of the fore wings are reddish brown, with a coppery luster; the inner portion and the hind wings are light dirty grayish. (Fig. 31.)

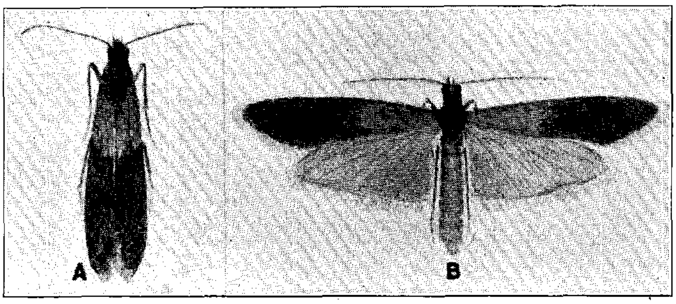

FIG. 31. Indian meal moth (*Plodia interpuctella*): A, wings natural position; B, wings expanded; 3 times natural size.

The larva, or caterpillar, measures when full grown about one-half inch, and varies in color, being whitish, with light rose, yellowish, or greenish tints. (Fig. 32.) The pupa is light brown in color.

"The eggs are minute and white, and are deposited, to the number of 350, singly or in groups of from three to a dozen or more, upon whatever substance the female may see fit to select for the sustenance of her offspring. In four or more days they hatch, and in four or more weeks another brood is produced. In this manner a succession of generations appear which will

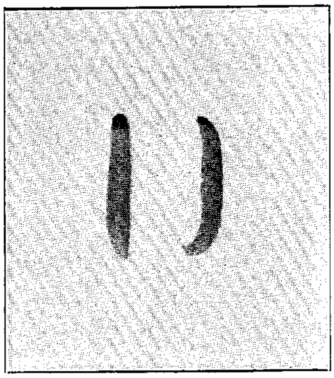

FIG. 32. Larvæ of Indian meal moth, 1½ times natural size.

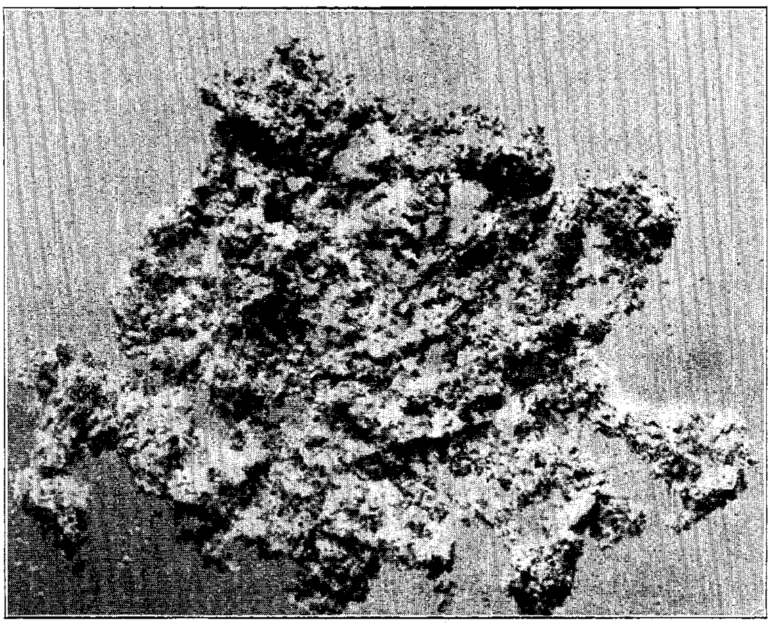

FIG. 33. Matted meal showing the work of the larva of the Indian meal moth.

vary, according to the temperature of the building that the insect inhabits, from four to possibly six or seven a year."[7]

The caterpillar spins thin silken tubes through the material upon which it feeds. It also fastens together seeds, grains, excrement, and particles of whatever material it happens to infest. (Fig. 33.) It has a special fondness for the embryo wheat, and, since it eats out the germ, one caterpillar will ruin dozens of kernels for seed or food purposes. Since the caterpillars deposit large quantities of excrement, which is attached to the silk, they injure much more than they actually consume. When full grown and searching for a suitable place to pupate, they leave large quantities of silken thread through the meal or grain, and this, with the silken cocoons, causes the meal or flour to be webbed together. In cereal and peanut mills this insect is a common pest. In flour mills it usually shows a preference for the middlings, and considerable pelted and webbed material may be found in the middlings purifiers.

THE MEAL SNOUT-MOTH.

(*Pyralis farinalis* Linn.)

The adult moth is light brown, with reddish reflections, having a wing expanse of nearly an inch, with fore wings crossed by two wavy, curved, white lines; when disturbed, it often curves its tail up over the back. The larva, a whitish caterpillar, shading to an orange-yellow color toward each end, and having a brownish-red head, constructs long tubes of silk and particles of meal and bran.

DISTRIBUTION.

It is also a native of the Old World, and is now commonly distributed over the grain-growing countries.

HABITS AND LIFE HISTORY.

The ground color of the moth varies from light to dark brown. The fore wings, when expanded, measure from three-fourths to one and one-eighth inches, are light brown in color, crossed by two wavy, white lines, and with dark chocolate-brown spots on the base and the tip of each. (Fig. 34.) The female is always larger than the male. The moth is commonly found near the food of the larva, but is often seen on the ceilings of rooms and on bags of flour or bran, and when disturbed will curve its tail up over its back. (Fig. 35.) The caterpillars

7. Bulletin No. 4, N. S., Div. of Ent., U. S. Dept. of Agr.

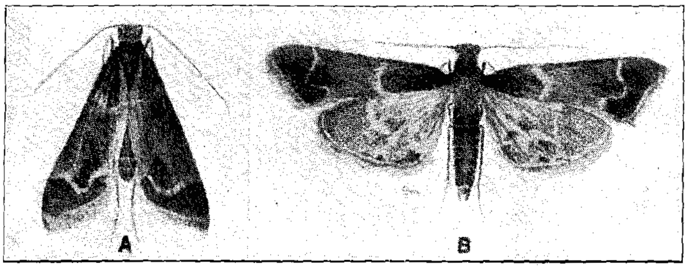

FIG. 34. Meal snout-moth (*Pyralis farinalis*): A, wings natural position; B, wings expanded; 2 times natural size.

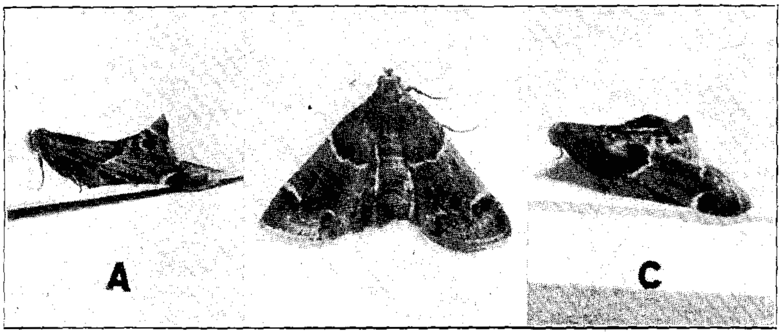

FIG. 35. Characteristic positions of the meal snout-moth when disturbed; A, lateral view showing abdomen curved up; B, dorsal view showing abdomen curved up; C, lateral view. All 1½ times natural size.

are rather-slender, measuring almost one inch in length, whitish in color, shading to an orange-yellow toward either end. The head is brownish red and rather shiny. The caterpillar constructs peculiar long tubes of silk and particles of meal, bran, or other food upon which it lives, and thus the meal or bran in which it is feeding may become stringy. (Fig. 36.) When mature, the caterpillars leave these silken tubes and construct tough, silken cocoons covered with particles of food, in which they transform to pupæ. (Figs, 37 and 38.)

While this caterpillar is peculiar and attacks almost all sorts of grains, ground products, straw, and dry vegetable material, it shows a choice for meal and bran, especially in places where it may become warm and slightly damp. The life cycle requires about eight weeks, and there are three or four generations annually.

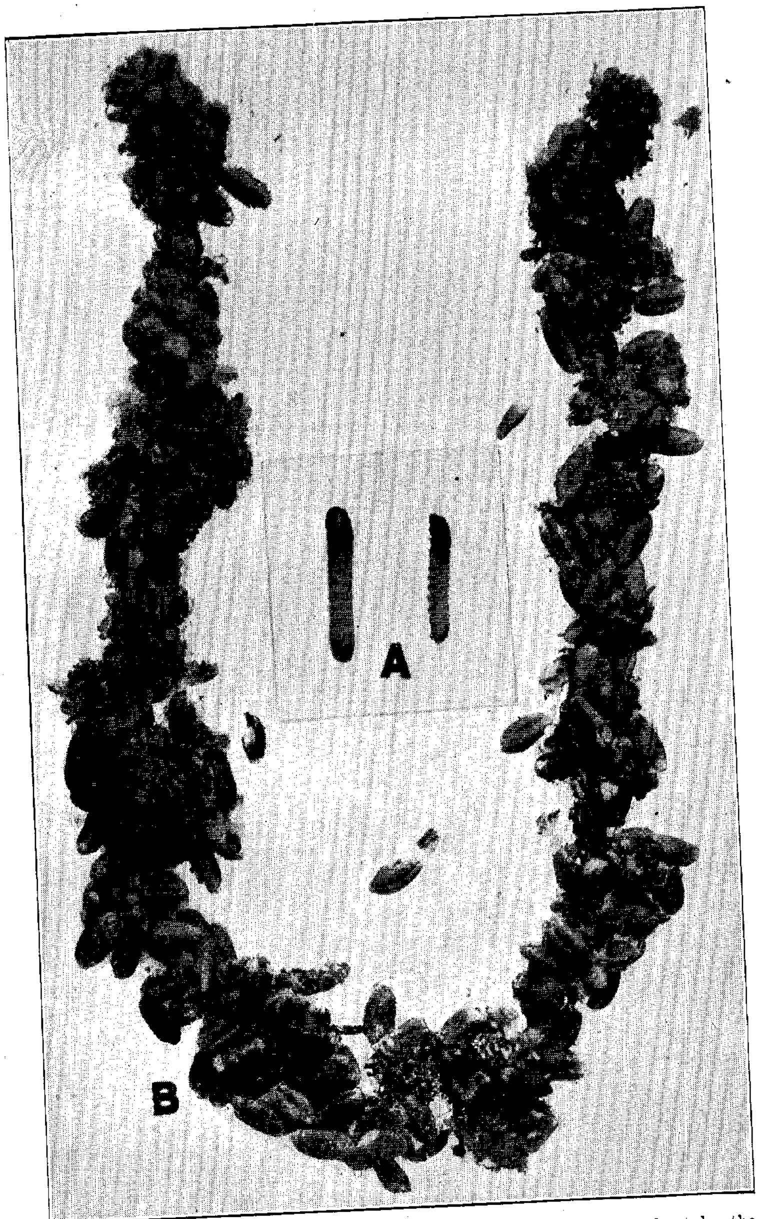

FIG. 36. Meal snout-moth: A, larvæ; B, feeding tube made in wheat by the larva; slightly enlarged.

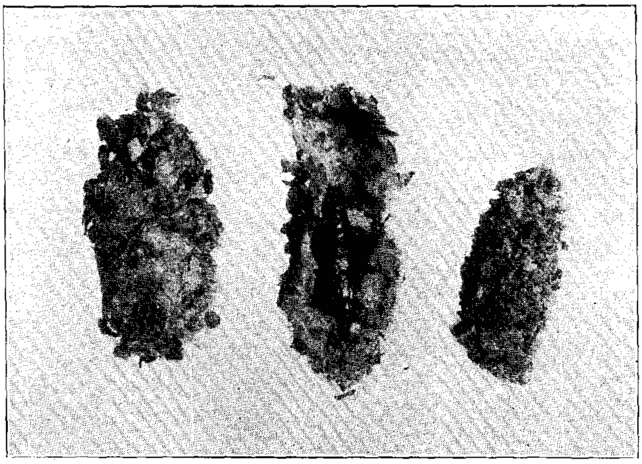

FIG. 37. Cocoons and pupa of the meal snout-moth; 1½ times natural size.

THE MEDITERRANEAN FLOUR MOTH.

(*Ephestia kuehniella* Zell.)

The adult is a small, tame, pale leaden-gray moth, measuring less than an inch across the expanded wings; the moth, when resting, assumes rather an elevated, position in front. The caterpillar is whitish or pinkish, slightly hairy, and about one-half inch in length; it spins silken tubes in the flour, causing it to become pelted and lumpy.

HISTORY AND DISTRIBUTION.

The first account of this insect was in the year 1877, when it was found in a mill in Germany. It now occurs throughout Europe. In 1889 it was taken in Canada, three years later it was a pest in California, and in 1895 it was reported injurious in several of the eastern states. It has been constantly spreading, and is now a pest in every milling state of this country and in the greater part of Mexico.

HABITS AND LIFE HISTORY.

While this insect, in the absence of its favorite food, such as flour, will attack grain and flourish on bran and cereals, it is primarily a flour pest, and as such it has no equal in destructiveness. It may well be called, as it commonly is, "the scourge of the flour mill." The little moth, measuring less than an inch across the expanded wings, is seldom seen flying.

It is very quiet and tame and may be seen resting on elevator legs, support posts, ceilings, walls, and mill machinery. When resting it assumes a characteristic slightly elevated position; that is, the head and thorax will be considerably higher than the tail end. (Fig. 39.) The fore wings are pale leaden-gray with transverse black markings, and when folded are wrapped about the body. The hind wings are dirty whitish in color. The caterpillar reaches a length of from one-half to five-eighths

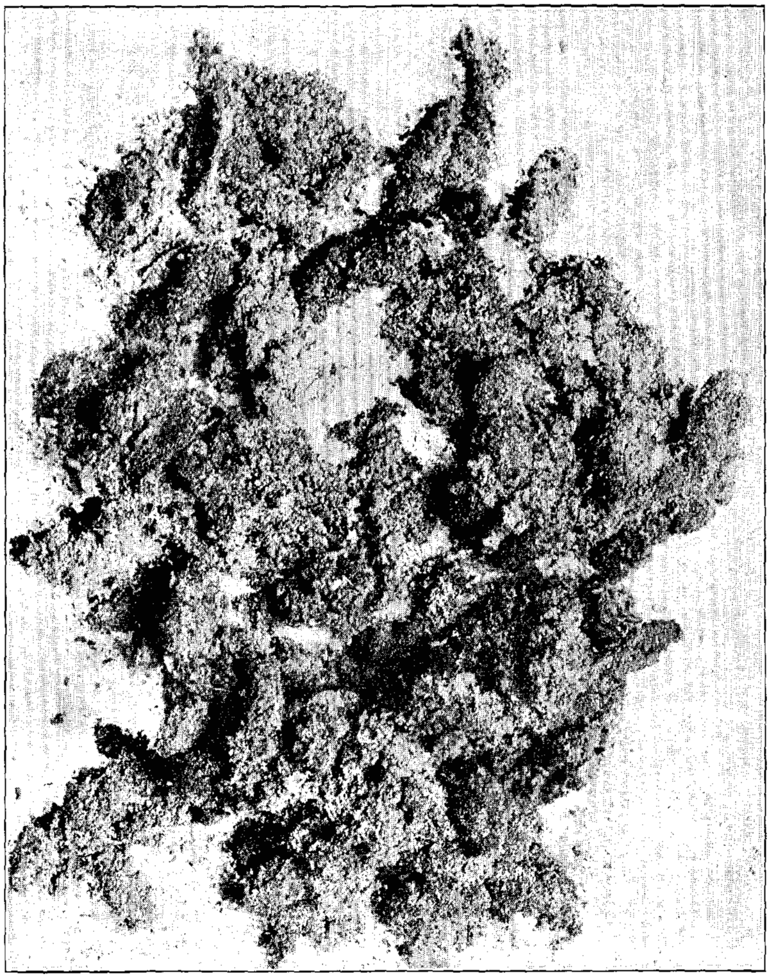

FIG. 38. Matted meal showing the work and the cocoons of the meal snout-moth.

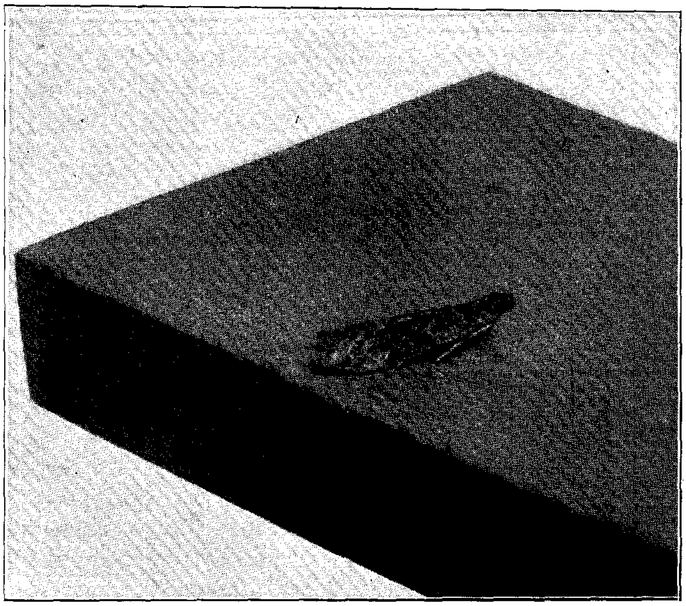

FIG. 39. Natural view of the Mediterranean flour moth while resting; two times natural size.

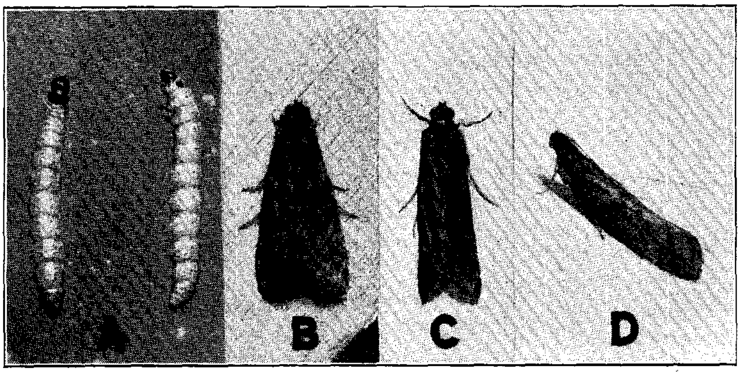

FIG. 40. Mediterranean flour moth (*Ephestia kuehniella*): A, larvæ; B and C, dorsal views of moth; D, lateral view of moth; two times natural size.

of an inch, is slightly hairy, and is whitish or pinkish in color, with a few minute black spots. (Fig. 40.)

The little white eggs are laid in cracks and accumulations of flour upon and down the elevator legs, throughout the spouts, around the dust collectors, and in the bolters and purifiers. (Fig. 41.) Experiments show that at a temperature

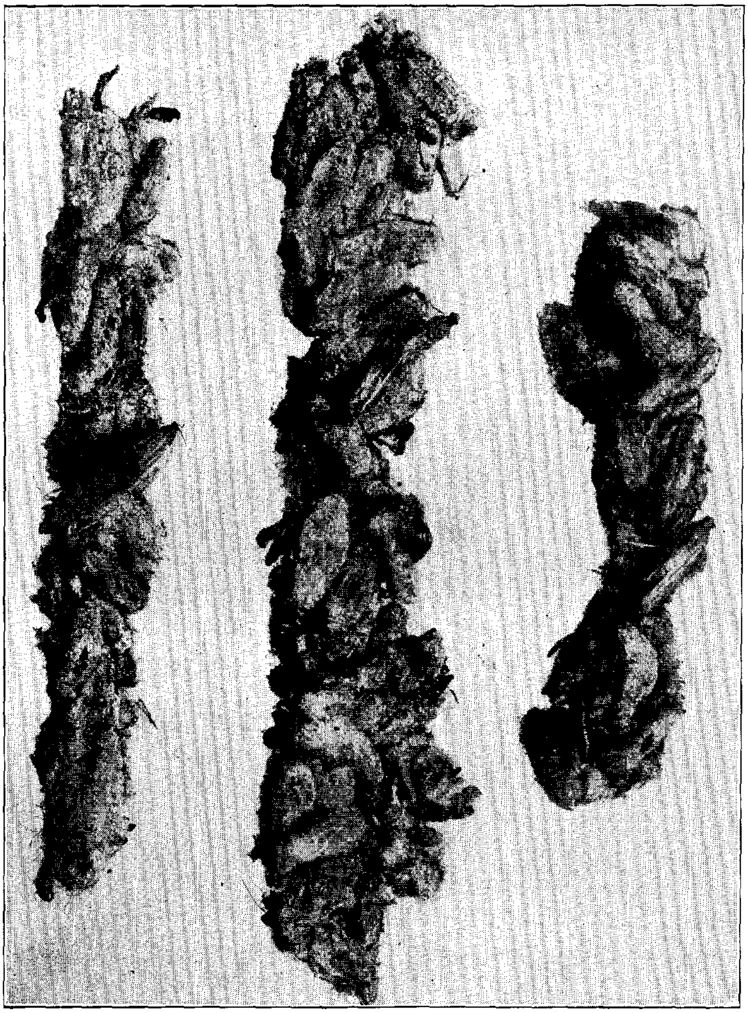

FIG. 41. Mediterranean flour moth and cocoons taken from the felt of a door on an elevator in a flour mill. Natural size.

of from 85 to 90 degrees they hatch in three days. The caterpillars begin at once to spin silken tubes wherever they travel and feed, and it is this web-spinning that renders them such a nuisance. In about forty days they are fully grown, and the caterpillars leave their silken tubes, and, while searching about for proper places to construct their silken cocoons, spin an immense amount of web. (Figs. 42 and 43.) This causes the flour and meal to become matted together, pelted, and lumpy, which clogs the machinery and spouts, and necessitates frequent shutting down of the mill for thorough cleaning. (Fig. 44.) The pupal stage lasts from eight to twelve days, and thus under ordinary conditions, such as are found in flour mills, the insect passes through its life cycle in nine weeks.

Usually in a mill just becoming infested, this insect will first be found in the elevators, the purifiers, and the machinery carrying and handling the warm, sweet stock or germ stock. During the cooler or the winter months it may often be found

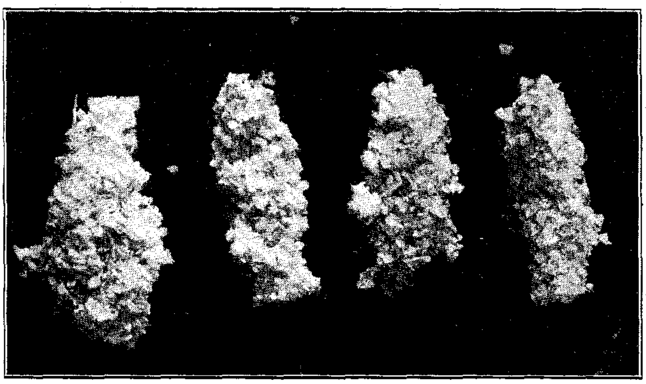

FIG. 42. Cocoons of the Mediterranean flour moth in meal, two times natural size.

FIG. 43. Cocoons of the Mediterranean flour moth in bran, two times natural size.

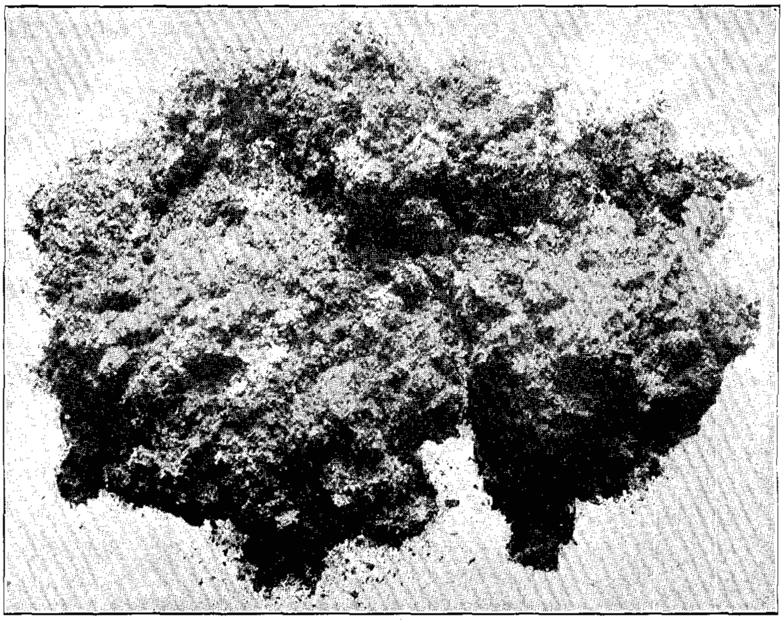

FIG. 44. Matted flour showing the work of the Mediterranean flour moth.

around and in the dust collectors, especially if they are warm or are taking the heat from the rolls.

Since the writer not only has observed Mediterranean flour-moth infestation in blending plants, but has seen the female moths laying their eggs on sacks and the larvæ hiding in the seams of sacks to be returned by the blending plant to the mill, he is convinced that in the large majority of cases the Mediterranean flour-moth infestation of flour mills has originated through practice of handling second or return sacks.

Other Mill Infesting Insects.

While carpet beetles, cockroaches, and fish moths are household pests and are not called mill-infesting insects, they are, however, so often found doing serious injury in flour mills that they deserve mention.

THE BLACK CARPET BEETLE.
(*Attagenus piceus* Oliv.)

The adult is a small, oval, black beetle, from two-sixteenths to three-sixteenths of an inch in length. The larva varies from light to dark brown, and is almost cylindrical, about three-eighths of an inch long, tapering toward the hinder end, where it is furnished with a brush of long hairs. It is active.

DISTRIBUTION.

This insect, which is widespread over Europe and Asia, and has been known for over half a century in this country, is commonly distributed over the greater part of the United States.

HABITS AND LIFE HISTORY.

The beetles are of common occurrence in a mill in the spring and early summer, and are noticed particularly running over the bags of flour in the warehouse, over bags in the sack rooms, and on the window sills of the warehouse and the bolting and

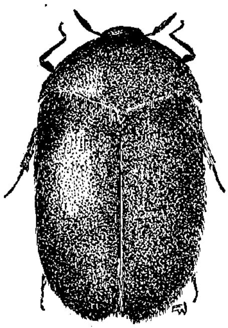

FIG. 45. Black carpet beetle (*Attagenus piceus*), 10 times natural size.

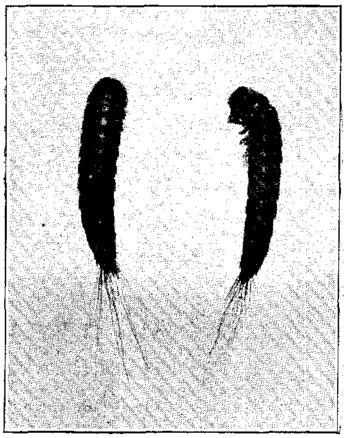

FIG. 46. Larvæ of black carpet beetle, 2½ times natural size.

purifying floors. It is a plump, oval, black beetle varying from two-sixteenths to three-sixteenths of an inch in length. The ventral surface is lighter in color, and the legs and the antennae are dark yellowish. (Fig. 45.) The larvae breed in the accumulations in the cracks of the floors and the corners of the rooms, and since the insect shows a preference for accumulations that are mixed with lint, fiber, or tow, it will be found more abundant in the warehouse, in the sack room and in corners around the bolters and the purifiers. (Fig. 46.) Both the adult and the larva cut cotton, jute, and paper bags, and silk bolting cloth. (Fig. 47.) Bolting cloth of redressing reels

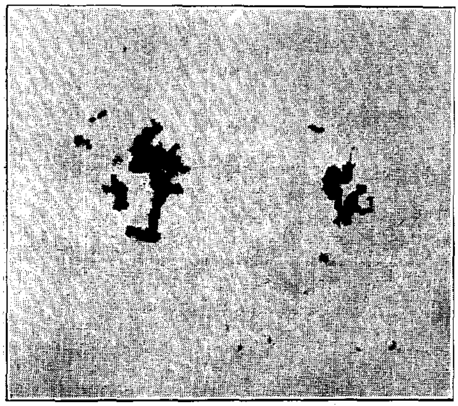

FIG. 47. Silk bolting cloth showing the work of the larva of the black carpet beetle; natural size.

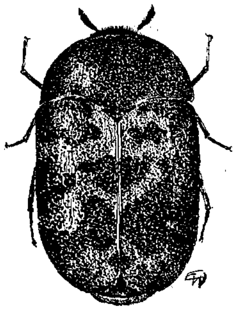

FIG. 48. Large cabinet beetle *Trogoderma tarsale*), 12 times natural size.

and of bolting machines that stand idle a part of the time are often badly injured or punctured with holes. Careful inspection should be made for this insect in cases where bolting cloth supplies are kept on hand. The pupa of this insect is white, rather soft, and covered with very fine, light brown or tawny hairs. The pupal stage varies from eight to fifteen days. The life cycle of this insect requires two years.

THE LARGE CABINET BEETLE.
(*Trogoderma tarsale* Melsh.)

The adult is a small, oval beetle about one-eighth of an inch long, with black body covered above with gray and light brown scales, and so arranged as to give the back a spotted appearance. The larva is nearly one-fourth of an inch long, reddish brown above and glassy white beneath, with its entire surface covered with short, soft, yellowish brown hairs, and having a short tuft of hair at the tail end. (Figs. 48, 49, 50 and 51.)

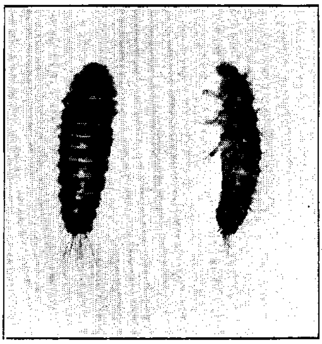

FIG. 49. Larvæ of large cabinet beetle, 3¼ times natural size.

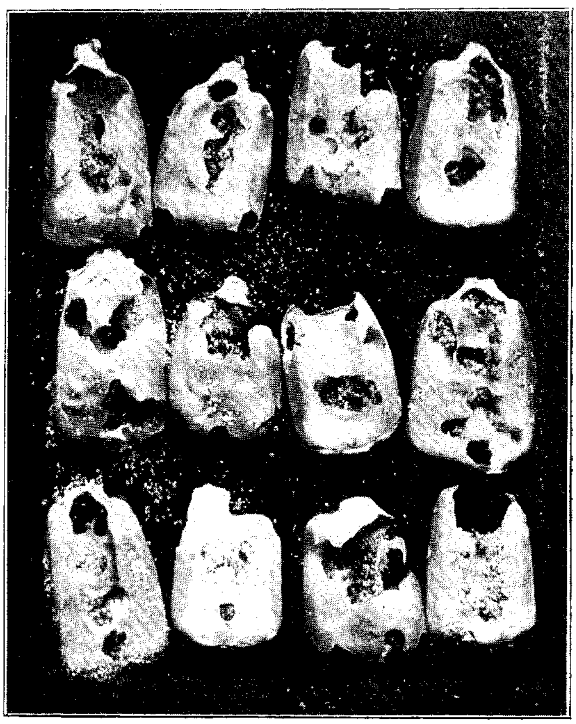

FIG. 50. Kernels of corn showing the work of the larva of the large cabinet beetle; 1½ times natural size.

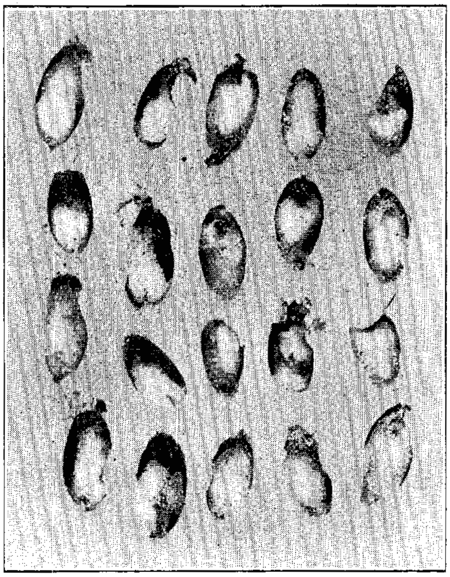

FIG. 51. Kernels of wheat showing the work of the larva of the large cabinet beetle; 2 times natural size.

THE SMALL CABINET BEETLE.
(*Authrenus verbasci* Linn.)

AND

THE MUSEUM BEETLE.
(*Authrenus museorum* Linn.)

The adult beetles are tiny very plump, broadly oval convex, with, body black, covered above with yellowish and whitish scales so arranged as to give the back a spotted or motley appearance, varying from one-sixteenth to two-sixteenths of an inch in length. The larvæ are active, small, plump, soft, hairy grubs.

The habits of these three insects are very similar to those of the black carpet beetle, and they are injurious in about the same manner. They do not seem to be so widely distributed or so common in the flour mills. They are also taken in grain elevators, and are known to infest both whole and ground cereals, flax seed, beans, peanuts, millet, and various seeds.

THE ORIENTAL COCKROACH.
(*Blatta orientalis* Linn.)

Soft, smooth, slippery, very dark brown, almost black, shining, broad, robust, varying from seven-eighths to over one and one-eighth inch in length; the females are nearly wingless, while the wings of the male are shortened, not reaching the extremity of the body; it is often gregarious in habits. (Fig. 52.)

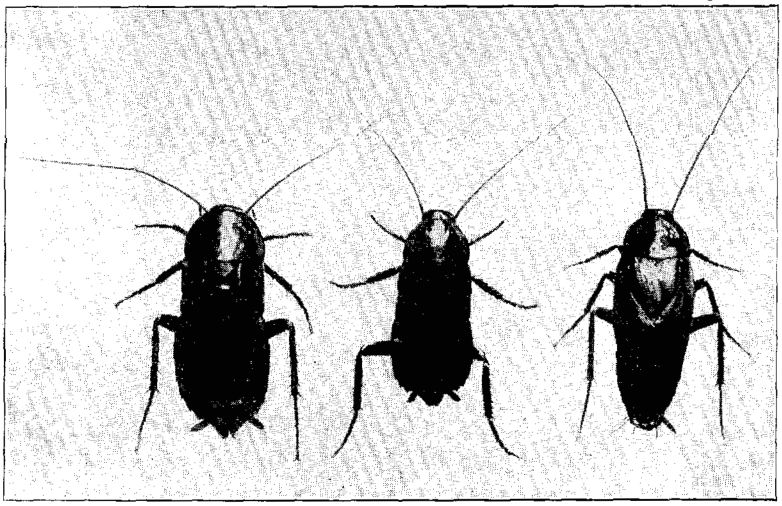

FIG. 52. Oriental cockroach (*Blatta orientalis*), natural size.

DISTRIBUTION.

This species, which has been a troublesome pest in Europe for nearly two centuries, is now commonly distributed over the greater part of the United States.

HABITS AND LIFE HISTORY.

In mills, roaches are particularly abundant in damp, dark places, especially under the floors of warehouses, in dark basements, and in the grain elevator pits. In these places, during the day, they will congregate in large numbers on the ceiling, on the walls, or in the corners, but during the night they will run around in the mill. In the flour warehouse, large numbers may be seen running on the bags of flour, and in these places the damage is not what they may consume, but in the soiling of the white bags. This soiling is due to a dark-colored fluid, exuded from the mouth, which stains the bags, and also from an oily liquid, which is secreted from glands on the abdomen, and which leaves a very disagreeable odor. The writer has observed bags of flour so badly soiled that one would think the. mill men were filthy in their habits, and had spit tobacco juice. upon the bags.

The eggs of this insect are not laid singly, but are brought together within the body of the mother into a hard, bean-shaped capsule. These dark brown, elongated, oval, bean-shaped capsules are deposited in the cracks and crevices in the walls and the places frequented by the insect. (Fig. 53.) The roaches, in

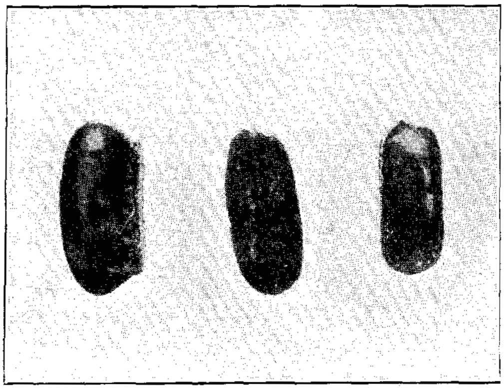

FIG. 53. Egg capsule of oriental cockroach, two times natural size.

their life from the egg to the adult, show comparatively little difference in habits and appearance. The young, except in that they are smaller and lack wings, are very much like the adults. Their development is slow, and probably under the most favorable conditions one year is required for the life cycle. The roaches are also found in kitchens, bakeries, and seaport warehouses, but in these places are not nearly so common as is the German cockroach.

THE GERMAN COCKROACH OR CROTON BUG.

(*Blattella germanica* Linn.)

Smooth, slippery, thin, very light brown or dirty yellowish in color, and marked on the thorax with two dark brown stripes; members of both sexes are winged and are about five-eighths of an inch long. (Fig. 54.)

DISTRIBUTION.

This insect, a native of the Old World, not only is abundant in Europe and America, but is probably widely distributed over the entire world.

HABITS AND LIFE HISTORY.

In flour mills this roach is not of so common occurrence as the Oriental, or black, roach, but in bakeries, seaport ware-

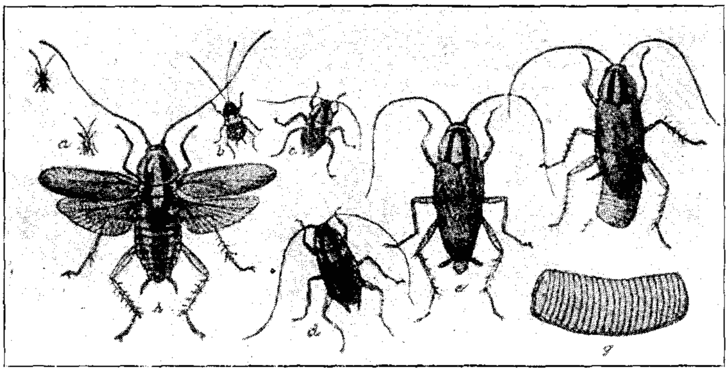

FIG. 54. German cockroach (*Blattella germanica*): *a*, first stage; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, adult; *f*, adult *female* with egg-case; *g*, egg-case; *h*, adult with wings spread. All natural size except *g*. (After Riley.)

houses, and pantries, and aboard ships, it is often very abundant and is of great economic importance. It is smaller and more active, and multiplies much more rapidly, than the other species of roach. Its favorable breeding places seem to be damp places adjoining water pipes.

THE SILVERFISH.
(*Lepisma saccharina* Linn.)
AND
THE FIRE BRAT.
(*Lepisma domestica* Pack.)

The Silverfish and the Fire Brat are characterized by very rapid movements; fish-like form; wingless, smooth, scaly, glistening bodies, nearly half an inch long, tapering from the head to the extremity of the body; long antennæ; and three long, bristle-shaped appendages at the tips of their bodies. (Figs. 55 and 56.)

In Kansas both of these species have often been observed in mills, and are probably commonly distributed over the greater part of the United States. In a flour mill they are of common occurrence in the flour warehouse, and in the sifters, the bolters, and the purifiers. They always avoid the light, and since they have the ability to run rapidly to places of concealment they are not often seen, although they may be very abundant. The writer has never observed these insects cutting or gnawing silk bolting cloth; but, knowing their habits as household pests, he feels safe in assuming that they may seriously damage bolting cloth in redressing machines or bolters and sifters that stand idle a part of the time. These insects feed upon books and papers in libraries, labels in museums, starched clothing in wardrobes and dressers, and stored substances in pantries and warehouses, and are troublesome in bakeries.

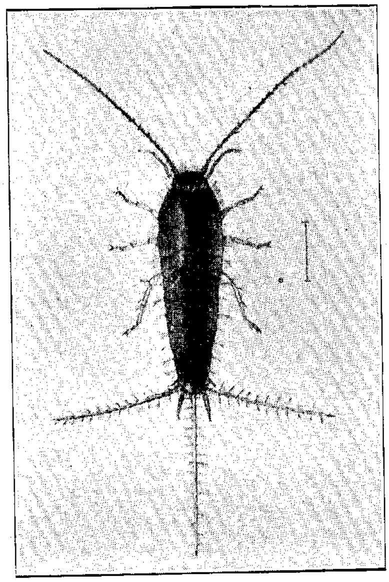

FIG. 55. Silverfish (*Lepisma saccharina*), 2¼ times natural size. (After Marlatt.)

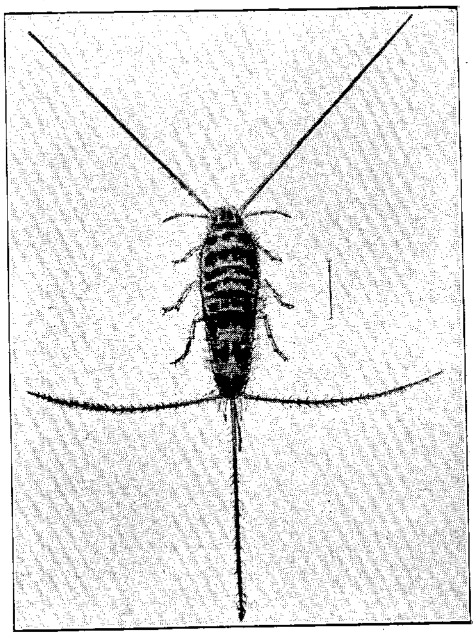

FIG. 56. Fire Brat (*Lepisma domestica*), two times natural size. (After Marlatt.)