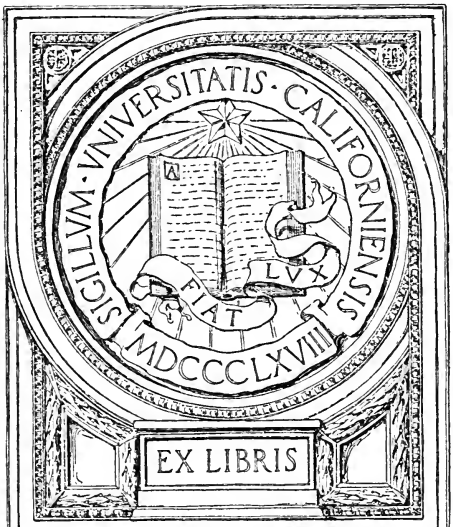
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Grain Dust Explosion Prevention

UNITED STATES GRAIN CORPORATION

In Co-operation with the
Bureau of Chemistry
UNITED STATES DEPARTMENT OF AGRICULTURE

DUST from grain will explode when mixed with air in proper proportions and ignited by sufficient heat or flame. The hazards of a dusty and dirty plant are very great. The only safe guaranty against a dust explosion is to practice "good housekeeping" and keep your plant clean at all times. It is your duty to protect not only your property but the health and lives of your employes

NEW YORK
June 1920

ORGANIZATION OF DUST EXPLOSION PREVENTION CAMPAIGN

In carrying on the dust explosion prevention campaign for the year 1919-20 the United States was sub-divided into four districts: Eastern, Northwestern, Central and Pacific Coast. The personnel of this campaign was as follows:

UNITED STATES GRAIN CORPORATION

Dr. J. W. T. Duvel, New York, in Charge

Mr. H. E. Roethe, Jr.....Washington, D. C.
Mr. J. O. Reed.....Washington, D. C.
Mr. H. R. Brown.....Washington, D. C.
Mr. G. D. Witmer.....Washington, D. C.
Mr. E. L. Riley.....Buffalo, N. Y.
Mr. P. L. Mann.....New Orleans, La.
Mr. Vernon Fitzimons.....Minneapolis, Minn.
Mr. Paul E. Brady.....Minneapolis, Minn.
Mr. W. B. Lind.....Minneapolis, Minn.
Mr. G. A. Hibbard.....Chicago, Ill.
Mr. G. H. Rice.....Chicago, Ill.
Mr. H. J. Helmkamp.....Kansas City, Mo.
Mr. M. E. McCollam.....San Francisco, Cal.
Mr. G. P. Bodnar.....Portland, Ore.

U. S. DEPARTMENT OF AGRICULTURE

Mr. D. J. Price,
Engineer in Charge of Dust Explosion Investigations.
U. S. Bureau of Chemistry,
Washington, D. C.

Dr. H. H. Brown,
Organic and Physical Chemist,
U. S. Bureau of Chemistry,
Washington, D. C.

GRAIN DUST EXPLOSION PREVENTION

CONTENTS

GRAIN DUST EXPLOSION PREVENTION

INTRODUCTION

The Government first gave consideration to the dangers from grain dust explosions and fires, as a result of a disastrous explosion in a feed grinding plant at Buffalo, New York, in 1913. As a result of this explosion, a series of investigations were conducted by the Bureau of Mines of the United States Department of the Interior, in cooperation with the milling and grain interests, with the view of determining the causes of such explosions and fires, and to devise methods for their prevention. Subsequently this project was turned over to the Bureau of Chemistry of the United States Department of Agriculture, and much valuable information brought together relative to explosions and fires in grain elevators, flour mills, threshing machines([a]) in the Pacific Northwest and in cotton gins([b]) of the South.

The importance of continuing and extending these investigations was fully realized at the beginning of the war, in order that the country's food supply might be fully protected against the hazards of dust explosions and fires. Accordingly the United States Department of Agriculture and the United States Food Administration inaugurated an extensive educational campaign, in the Fall of 1917, to provide the owners and operators of mills, elevators and threshing machines, with the information available, so that the losses resulting from dust explosions might be reduced to a minimum. The necessity for this undertaking was strongly emphasized by several disastrous dust explosions which occurred between March, 1916, and October, 1917, resulting in the destruction of four of the largest grain and cereal plants in the United States and Canada, together with the loss of twenty-four lives. The dust explosion, together with the fire which followed, in one of these plants (Brooklyn, New York), was of special significance at the time in that it resulted in the destruction of a quantity of grain equivalent to bread rations for an army of 200,000 men for an entire year, and at the same time most seriously crippled facilities badly needed for loading grain for overseas shipment.

(a) Department of Agriculture Bulletins 379 and 681, and Circular 98.
(b) Department of Agriculture Circular No. 28.

The workmen in this plant were not generally familiar with the causes of dust explosions and fires and methods that could be adopted for their prevention.

The United States Grain Corporation assumed financial control of the grain dust explosion campaign in July, 1919, to make sure that the Government's stocks of wheat were fully protected at all times; otherwise the work would have lapsed June 30, 1919, with the termination of the war emergency provision granted by Congress to carry on this work as a part of the food conservation program. Since this time, the United States Grain Corporation, in cooperation with the Bureau of Chemistry of the United States Department of Agriculture, has carried on an extensive campaign to assist in removing dangerous conditions in plants carrying Government grain and flour stocks, and also to familiarize the grain and milling interests with the true nature and means of prevention of dust explosions and fires. The aim has been to lessen the inherent hazards in the grain industry. Throughout this campaign active cooperation has been given by many agencies and commissions engaged in explosion and fire prevention activities, and this opportunity is taken to acknowledge our indebtedness to these organizations, as well as to the grain and milling interests, for the excellent assistance rendered.

EDUCATIONAL WORK

In addition to the regular inspection of plants carrying Government stocks, an effort was made to impart to the employes of elevators and mills special information on the subject of dust explosions and fires. In the war emergency campaign all mills with capacity of approximately 50 barrels or more, and elevators over 25,000 bushels capacity, were visited. In the campaign carried on by the Grain Corporation attention has been directed primarily to plants where Government stocks were stored. The work has been extended, however, to outside plants as time permitted.

The employes in the plants were acquainted with the causes by which explosions can be produced, with special reference to the simple causes within the control of the workmen, such as a lighted match, smoking, use of open flames, careless use of electric lights, etc. This was done in many cases by a direct "heart to heart" talk with the men either individually or in group meetings, on the working floors or in convenient parts of the plants. In order to familiarize the men with the extent of damage done by previous explosions, a series of specially prepared photographs showing views of damaged plants in which there had been extensive losses of life, grain and property were used.

Whenever it was possible to assemble a number of the employes, either at the noon hour, or by special arrangement with the management, illustrated lantern slide lectures, showing results of experimental work, and also effects of recent explosions, similar to photographs referred to

above, were given. In addition to the lecture, various demonstrations of dust explosions were produced to show the men how readily a violent explosion may result from an apparently simple cause. Two demonstrations in particular impressed the men effectively and aroused their interest. In one case a dust explosion was produced in a specially provided miniature grain elevator by blowing dust onto an open flame, as shown in Figure 1. In the other, various common dusts were readily

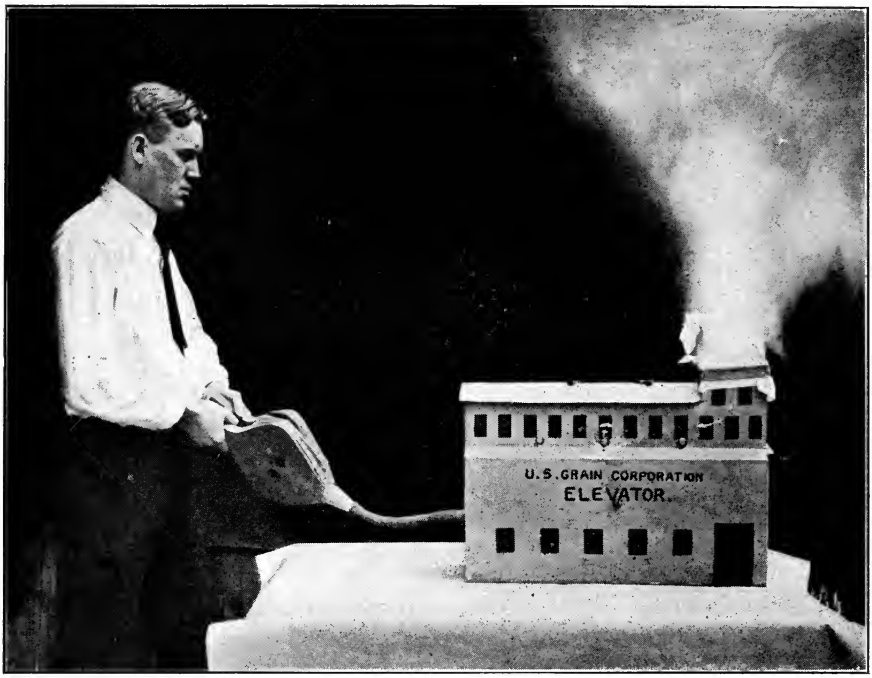


FIG. 1.—Dust Explosion Demonstration—produced by blowing dust into an open flame in a miniature elevator.

ignited by sifting through a piece of cheesecloth onto a burning match. In order to remove any doubt regarding the nature of the dust used in the demonstrations, the workmen were asked to collect dust from various parts of the plant. In many instances samples of the dust which the employe had to work with and handle daily were presented for testing. The effect of the explosion on the workmen in these cases was very marked. From expressions made by the men it could be seen that they would not forget the lesson and would do all they could to prevent dangerous conditions.

Pledge Cards

At the close of the lecture and demonstrations, or during the inspection trip through the plant, the moral support of the workmen was enlisted by having them sign pledge cards as shown in Figure 2.

a.

UNITED STATES DEPARTMENT OF AGRICULTURE
AND
UNITED STATES FOOD ADMINISTRATION
(IF YOU HAVE ALREADY SIGNED, PASS THIS CARD ON TO A FELLOW EMPLOYEE)

To prevent grain dust explosions and fires in the mills and elevators in which I am employed, I agree personally to observe preventive measures and to use every effort and influence to induce others to take all possible precautions. I make this promise in the realization that carelessness may result in loss of life, loss of food needed by the Nation, and destruction of factories needed to produce food.

Name .....

Firm or Company .....

City ..... State .....

8—4118

b.

TO PROTECT YOUR MILL AND ELEVATOR.

Failure to observe these reasonable rules may result in dust explosions or fires which may cause loss of life and will cause loss of food needed by the Nation:

1. Smoking and lighted matches have caused many of our greatest fires and explosions.

Do not smoke while in or near the mill or elevator.
Do not carry matches in or near the buildings.

2. An open flame will cause a dust explosion and fire in a dusty mill or elevator.

Do not carry any open flame, lantern, or torch into a dusty atmosphere.
Do not lower lanterns or open flames into dusty bins.
Do not lower unprotected electric light bulbs into dusty bins; the bulb may break, making a spark that will ignite the dust.

3. Dust and dirt invite dust explosions. The records show that there are six times as many fires in dirty mills and elevators as in clean ones.

See that no dust accumulates on beams, machines, pulleys, or floors in the department where you are working.

4. Elevator choke-ups are frequent causes of fires and explosions. In many cases choke-ups have led to fires which destroyed over a million dollars' worth of grain and property.

Examine all elevators and conveyors in your department frequently and at regular intervals. Make sure that they are running properly. Report immediately any slight rubbing, slippage, or other trouble.

A LITTLE CARE MAY AVERT A DISASTROUS EXPLOSION.

8—4118

FIG. 2.—Pledge card signed by workmen.
(a) Front of card.
(b) Back of card.

A ready response was always secured and large numbers of these cards were signed by the employes. By so doing they promised to observe the precautions designed for the prevention of these explosions. The cards were forwarded to the Washington office, and their receipt immediately acknowledged, with the name and address of the workmen inserted on the card, as shown in Figure 3. It is believed that the workmen adhered to their promises and were responsible in many instances for the removal of dangerous conditions which might have resulted in explosion and fire.

UNITED STATES DEPARTMENT OF AGRICULTURE
AND
UNITED STATES FOOD ADMINISTRATION
WASHINGTON, D. C.

Mr. Joe Taylor,
340 North Duncan St.,
Chicago, Ill.

Dear Sir:

This is to acknowledge receipt of the card, recently signed by you, in which you personally agree to observe preventive measures and to use every effort and influence to induce others to take all precautions to prevent grain-dust explosions and fires in mills and elevators in which you are employed. By signing this card and carefully observing the pledge made thereon, employees of mills and elevators are actively cooperating with the United States Department of Agriculture and the United States Food Administration in their effort to SAVE FOOD AND WIN THE WAR.

HERBERT HOOVER
Food Administrator

D. F. HOUSTON
Secretary of Agriculture

FIG. 3.—Card acknowledging pledge of workmen.

Meetings in Grain Centers

In addition to presenting the dust explosion prevention work to the employes in the plants, it was considered desirable to acquaint the owners and operators with the hazards. As it was impossible to stage large-scale demonstrations all over the country, specially arranged motion pictures showing the results of large scale dust explosion tests, as described on page 27, were shown to the grain men in various sections of the United States. While the small scale demonstrations of dust explosions served their purpose well, they did not show fully the rate at which an explosion might propagate through the plant. The motion picture reels also contained views of plants damaged by explosions and fire together with measures of prevention. The work was also presented at conventions of fire protection, conservation, and similar associations. These conventions in many instances included not only grain men but firemen and insurance representatives as well. Numerous requests for presentation of the work were received from associations of firemen, in order to obtain information to assist in the prevention of dust explosions during the progress of fire fighting.

Cooperation with Canadian Government

In connection with the series of meetings held in the larger grain centers of the United States, as a result of a request from the Dominion Fire Commissioner, a special dust explosion prevention meeting was held at Fort William, Ontario, in November, 1919. This meeting was attended by a large number of Government, provincial and city officials, as well as representatives of the Canadian grain and milling industries and insurance companies.

Interest in dust explosion prevention was aroused in Canada by an explosion in August, 1919, in a large grain elevator at Port Colborne, Ontario, operated by the Dominion Government. The explosion was investigated in cooperation with the Canadian Government officials and assistance rendered in the development of precautionary measures in the rebuilding of the plant.

INSPECTION OF PLANTS

As previously stated, this campaign was undertaken primarily for the protection of the Government grain and flour stocks against the hazards of dust explosions and fires. For this purpose, regular inspections were made of the mills and elevators where Grain Corporation stocks were stored. Other plants were likewise visited frequently in order that the country's food supply might be fully protected. If conditions seemed hazardous in any respect, definite suggestions for remedying them were

made to the official in charge of the plant. At the time of the first visit to each establishment, the inspector filled out a complete report on the following form provided for the purpose:

GRAIN DUST EXPLOSION CAMPAIGN
U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF CHEMISTRY AND BUREAU OF MARKETS

District.....Date.....Inspected by.....
Name of Company.....
Office Address: Street.....City.....State.....
Plant Address: Street.....City.....State.....
Kind of Plant.....Mgr.....
Supt.....Capacity.....No. Employees.....
Construction: Wood.....Brick or Stone.....Concrete.....Steel.....
Remarks .....
Bins: Open.....Covered.....Remarks.....
Elevators: Wood.....Steel.....Combination.....
Discharge to Bin: By Spout.....Belt.....Steel Conveyor.....
Remarks .....
Is Grain Cleaned before Storage? Yes.....No.....
Remarks .....
Dust Collectors: Location.....Cloth.....
Cyclone.....Dust Room.....
Remarks .....
Suction System: On Bins.....Elevator Heads.....Conveyors.....
Remarks .....
Grinding Mills: Type.....
Discharge to: Elevator.....Conveyor.....Bin.....
Misc. .....
Any Explosion Protection.....
Remarks .....
Power Plant: Steam.....Electric.....Gasoline.....Misc.....
Lighting: Type.....Method of Installation.....
Remarks .....
General Condition of Plant.....
Remarks .....
Are Sweepers Employed?.....
General Remarks .....

No. of Cards Signed.....No. of Circulars Desired.....
No. of Posters Desired.....
Suggested Recommendations for Explosion and Fire Prevention.....

.....

Copies of this report were then sent to the district office and also to Washington, where they were recorded. On all subsequent visits the inspector used a shorter form on which he noted only the rating for equip-

ment and maintenance and, when necessary, his recommendations to the company, as well as any changes in equipment since the preceding inspection.

GRAIN DUST EXPLOSION AND FIRE PREVENTION
U. S. GRAIN CORPORATION
U. S. DEPARTMENT OF AGRICULTURE

District.....Date..... Inspector.....
Name of Company.....
Address: City.....State.....
Manager..... Supt.....
Kind of Plant.....Capacity.....
Equipment.....Maintenance.....No. Employed.....
Recommendations Made to.....
Recent Changes, Recommendations, etc.....
.....
.....
.....
.....
.....
.....
.....

In making these reports the following series of letters was used to classify the equipment and maintenance of the plant:

Equipment	*Maintenance*
A. Modern, first-class, up-to-date appliances	A. Good
B. Fair, not new.	B. Fair
C. Old and not representative	C. Poor

A well-constructed plant, with modern mechanical appliances, would be given "A" for equipment. If precautionary measures were being carried out, and the explosion hazard recognized, the plant received "A" for maintenance. The classification for such a plant would then be "AA." If the maintenance was not up to the standard and the dust conditions looked after in only a "fair" manner, the classification would be "AB." If the plant was well equipped, but found in a dirty, dusty, or poor condition, it would receive a grade of "AC." In many cases, however, equipment which was not strictly modern but was rendering satisfactory service was put in the "B" class, to distinguish it from that of newer type or design. If the plant was well maintained it would be classed as "BA," while "BB" and "BC" represented the intermediate and poor classes, respectively. Old type plants, in which the equipment had been installed for some time fell in the "C" class. When it was well maintained and particular attention was paid to the removal of the dust conditions, the plant would be placed in the "CA" class. Similarly, "CB" and "CC" represented the other grades of upkeep and maintenance.

United States Department of Agriculture

SAVE LIVES

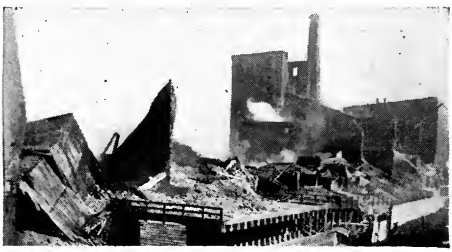
United States Food Administration

SAVE FOOD—SAVE PROPERTY

PREVENT DUST EXPLOSIONS

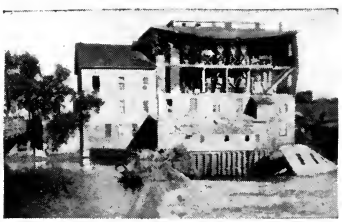
Six Recent Dust Explosions and Fires in Mills and Elevators Killed 39 Persons and Injured 60. They Destroyed 2,500,000 Bushels of Grain, and Property Worth $8,000,000

Keep Your Mill and Elevator Free from Dust and Dirt



Dust-free Mills and Elevators are Explosion-proof

Elevator explosions and fires sometimes destroy enough grain to feed a large army for a year



A flour-dust explosion wrecked this mill

This large cereal plant was completely destroyed by fire following a dust explosion

PROTECT YOUR MILL AND ELEVATOR

A little care may avert a disastrous explosion. Observe the following rules:

1. Do not smoke or carry matches in or near the buildings. Smoking and lighted matches cause explosions and fires.
2. Do not use open flames, torches, candles, lanterns and unprotected electric light bulbs in a dusty atmosphere or when examining bins and elevator legs.
3. Do not let dust accumulate on beams, machines, pulleys or floors. Dust-free Mills and Elevators are explosion-proof.
4. Examine elevators and conveyors often. Elevator choke-ups often cause explosions and fires. Report immediately any slight rubbing, slipping, or other trouble.

For further information regarding grain dust explosions write to the

U. S. Department of Agriculture, Bureau of Chemistry, Washington, D. C.

This Company and its Employees are Co-operating in the Control of Dust Explosions and Fires

FIG. 4.—Reproduction of first poster used in Grain Dust Explosion Prevention Campaign. (Original 16 x 24 inches.)

These reports also were sent immediately to district headquarters and then to Washington, so that the officials in charge could at all times keep in close contact with the general conditions of the mills and elevators throughout the country. By comparison with previous reports, it was possible to determine whether or not the condition of the elevator was improving and whether the precautionary measures previously recommended had been adopted.

Improvement in Condition of Plants

That conditions in the elevators and mills inspected were materially improved as a result of the recommendations made to the officials in charge is evident from the reports turned in by the field men. The following table gives a few typical cases of the results of this phase of the work.

Elevator	Visit	Date	Grade
1	1	September 4, 1919	A C
(Middle West)	2	September 26, 1919	A B
	3	February 18, 1920	A A
2	1	September 23, 1919	A C
(East)	2	November 29, 1919	A B
	3	March 5, 1920	A A
3	1	November 26, 1919	B C
(East)	2	March 1, 1920	B B
	3	March 20, 1920	B A
4	1	September 11, 1919	C C
(West)	2	October 17, 1919	C B
	3	February 4, 1920	C A
5	1	August 19, 1919	A A
(East)	2	December 17, 1919	A A
	3	January 28, 1920	A A
	4	April 13, 1920	A A

Elevators 1 and 2, although well constructed and equipped with modern machinery, were poorly maintained at the time of the first inspection. As a result of following the recommendations made by the inspector, conditions were so improved that when the last inspection was made the plants received the grade of "AA."

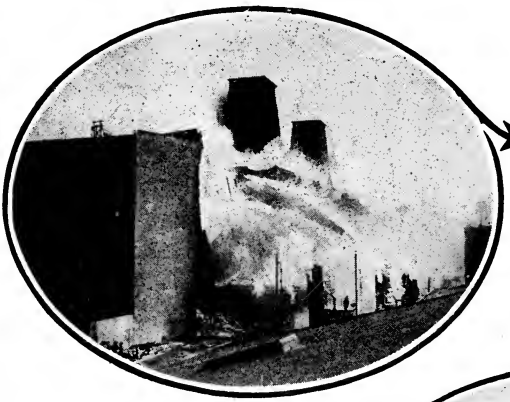
Although elevator 3 remained in class "B" (medium) for equipment, it improved sufficiently in condition to rise from "C" to "A" in maintenance.

Elevator 4 was poorly equipped and very poorly maintained at time of first inspection, showing evidence of but little precaution against fires and explosions. The information received by the officials, however, enabled them to bring their grade up to "B," and finally, after they had adopted additional methods of dust explosion and fire prevention, to "A," the equipment in this plant was not improved, remaining in the "C" grade.

Elevator 5, modern in construction and equipment, was found at the time of each visit to be in an excellent condition and provided with every device for minimizing the dangers from dust explosions.

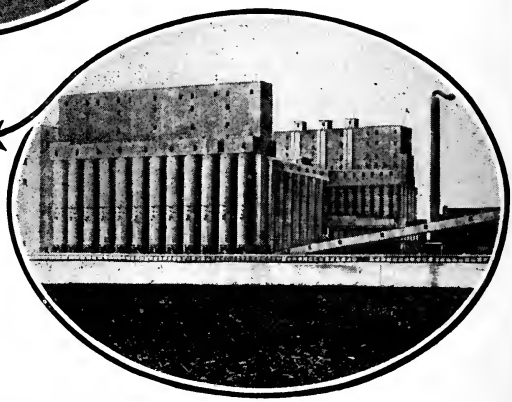
As this summary is representative of the large number of reports received from all over the country, it may be concluded that the recom-

DUST-FREE
Mills and Elevators *are* EXPLOSION-PROOF



Carelessness

a lighted match
dusty machinery
an uncovered candle
or lantern
friction in machinery



Cleanliness

means nothing to explode
protects workmens' lives
saves property
saves food

U.S. Grain Corporation~
U.S. Department of Agriculture

For further information about grain dust explosions write to the Bureau of Chemistry, ··· U. S. Department of Agriculture

FIG. 5.—Reproduction of second poster used in Grain Dust Explosion Prevention Campaign. (Original in colors, 14½ x 22 inches.)

mendations made in this campaign brought about an improvement in conditions and a decrease in dangers from explosion and fire in the elevators and mills of the United States.

LITERATURE

To keep the dangers from explosions and fires before the men at all times, two sriking posters (Figs. 4 and 5) were prepared. These posters were mailed to every licensed elevator and mill and also distributed through the conservation and fire prevention agencies. They were displayed in prominent parts of the plants and in the frequent visits to the elevators and mills it was found that the workmen were following the precautions outlined.

Several pamphlets were also provided for the workmen to read during their lunch hours or at any spare moments. In the circular entitled "Prevent Grain Dust Explosions and Fires" (Fig. 6) attention was directed to the great loss of life, property and foodstuffs due to dust explosions, and a brief description is given in simple language of how a dust explosion actually occurs. The employes were asked to help reduce this loss by observing the following rules:

FIG. 6.

1. Get the dust.
2. Prohibit smoking and carrying matches in or around the mill or elevator.
3. Use no open flames, as gaslights, torches, lanterns or candles for any purpose whatever in or around the mill or elevator.
4. See that all wires for electric lighting are placed in conduits, and use only well-protected globes.
5. Do not lower artificial lights into bins to determine the amount of grain, flour or feed they contain.
6. Keep all foreign material from entering the grinding machinery.
7. Eliminate static electricity.
8. Look out for elevator chokeups.
9. Do not let elevator or conveyor belts rub.
10. Sack the ground material immediately or convey it to bins of small capacity.

"Just a Word About Grain Dust Explosions" (Fig. 7) contains a summary of the dust explosion campaign preceding September, 1919, pointing out that for a period of 19 months there were no explosions in plants where the workmen had pledged their support to the work, while disastrous explosions had occurred in other industries. It includes eight short stories describing eight explosions, illustrated with attractive drawings, and gives the cause and method of prevention in each case. It further urges employes to adopt the following dozen rules for safety:

1. Keep the plant clean.
2. Inspect the plant frequently for hot bearings.
3. Keep constantly on the watch for elevator choke-ups.
4. Report immediately any slight rubbing, slipping or other trouble with belts or machines.
5. Keep all foreign material from entering the grinding machinery by installing a magnetic separator.
6. Do not smoke while in or near the elevator.
7. Do not carry matches in or near the buildings.
8. Do not allow an open flame, lantern or torch in the mill or elevator.
9. Do not lower artificial lights into bins to determine the amount of grain, flour or feed they contain.
10. Prevent the accumulation of static electricity on machines and belts by proper grounding methods.
11. See that all electrical equipment is properly installed, light bulbs well protected, switch and fuse boxes kept closed.
12. Sack the ground material immediately or convey it to bins of small capacity.

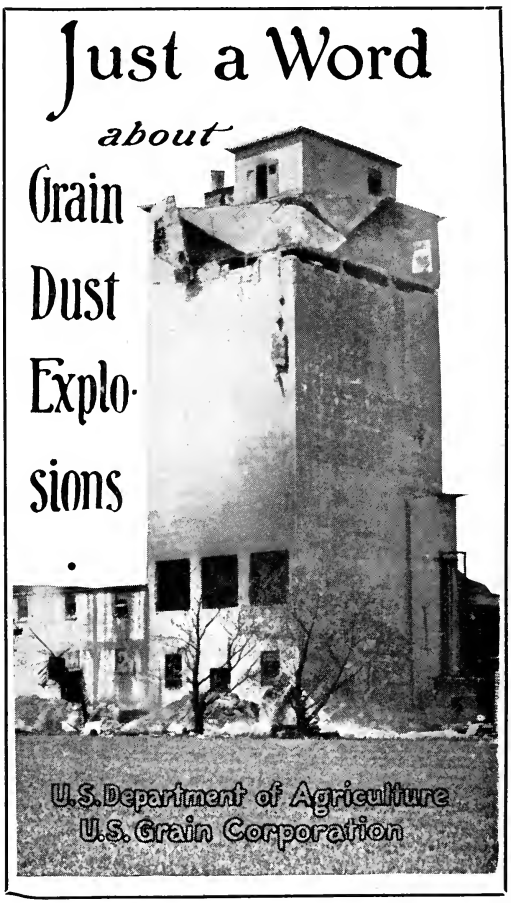


FIG. 7.—Upper portion of this plant destroyed by dust explosion. From cover-page of pamphlet used in educational campaign.

Two small folders were designed to call attention, in a few words and by means of pictures, to the dangers of dust explosions and to some of the simple preventive measures. The folder entitled "Four Reasons Why You Should Be Careful" (Fig. 8), urges the employee to follow a few important rules for the protection of life, property, food and his job. The other, commonly called the "Capitol Folder," emphasizes the cost of carelessness, and endeavors to impress upon the employee by a specially prepared story, the fact that one careful man in a plant is better than a whole fire department. It contains four rules for the protection of lives, food and property from the dangers of dust explosions.

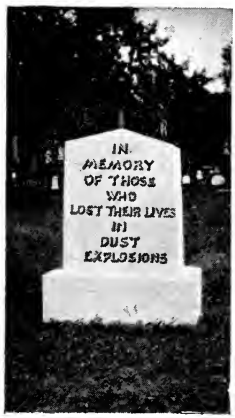
4

REASONS WHY YOU SHOULD BE CAREFUL

REASON No. 1

Loss of Property.

REASON No. 2



Loss of Life.

REASON No. 3

Loss of Food.

REASON No. 4

Loss of Job.

HOW TO BE CAREFUL

Look over the elevators and conveyors often, report at once any rubbing, slipping, friction, or other trouble, no matter how slight.

Also observe carefully these four important DON'TS:

Never smoke in or near the mill or elevator.

Never strike a match anywhere on the premises.

Never use open flames, torches, candles, lanterns, or unprotected light bulbs in dusty air or when examining bins or elevator legs.

Never let dust accumulate on beams, machines, pulleys, or floors.

UNITED STATES GRAIN CORPORATION
Cooperating with the
United States Department of Agriculture
Bureau of Chemistry

FIG. 8.—Reproduction of small folder used in educational campaign to prevent destruction of Government food supplies by dust explosions and fires.

RESULTS OF CAMPAIGN

The dust explosion and fire prevention work was well received in every section of the country. With the splendid cooperation of the American mills and elevators, as well as the various fire prevention agencies and commissions established to conserve our food supply, the campaign was most successful. During the entire period of its existence (about three years) the United States Grain Corporation suffered no extensive explosion or fire losses. The fact that practically at all times the value of the stocks in storage was $100,000,000 and at certain times approximately $500,000,000, shows the importance of the saving thus effected.

During the period of the campaign there has been only one disastrous explosion in a grain elevator where United States Grain Corporation stocks were stored. The actual loss to Government grain in this case,

FIG. 9.—Extensive damage resulting from explosion of starch dust.

however, was limited to about $25,000. Since this explosion in September, 1919, there has not been an explosion in the last nine months in a plant where Government grain was stored or handled, and where attention had been given to the removal of explosion and fire hazards.

While the explosion and fire losses in the grain industry appear to have decreased during this special campaign period, reports indicate that in other industries the fire losses were considerably increased. In May, 1919, a very disastrous explosion in a starch factory in the Middle West resulted in the loss of 43 lives and property damage estimated at $3,000,000. The wreckage of this explosion is shown in Figure 9. In August, 1919, a large grain elevator operated by the Canadian Govern-

ment was badly damaged by a dust explosion in which 10 lives were lost and 10 injured. An explosion of aluminum dust in a factory in Wisconsin caused the death of six girls and injuries to as many others. Explosions of minor proportions have occurred during the period in feed mills, flour mills and other industrial plants.

The effect of enlisting the aid of the workmen is shown by the fact that during a period of 19 months (October, 1917, to May, 1919) no dust explosions occurred in any of the plants where the employees had pledged their support to the campaign. In marked contrast to this are the five disastrous explosions in the United States and Canada of the preceding 20 months (March, 1916, to October, 1917).

EXPLOSIONS DURING CAMPAIGN

Buffalo, N. Y.

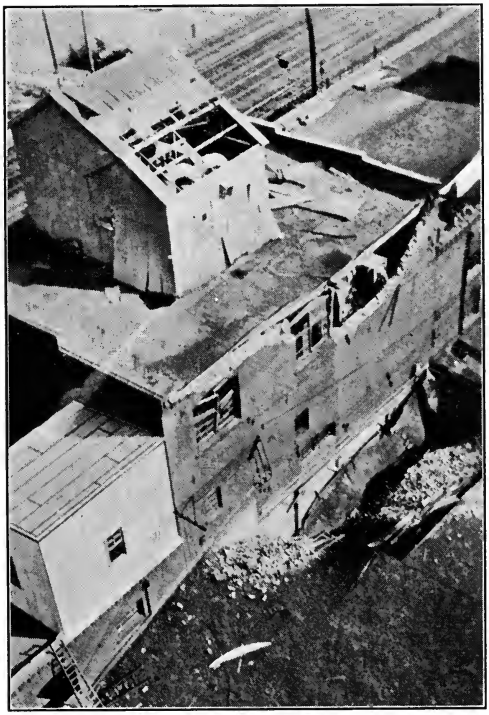


FIG. 10.—Damage to upper floors resulting from dust explosion in a feed mill.

On September 12, 1919, a dust explosion in a feed mill and elevator at Buffalo. New York, injured 3 men, 1 seriously, and damaged property to the extent of $20,000 (Fig. 10).

The investigation showed that the force of the explosion traveled upward, blowing out a part of the west wall of the fourth floor as well as part of the roof of the lofter room at the top of the building, and that a muslin cover used to keep one of the motors on an upper floor free from dust had been burned. At first it was thought that the explosion was caused by the ignition of this muslin cover by sparks from the motor. A detailed observation of the motor, however, showed that no sparks issued from its brushes while it was in operation, and that it worked satisfactorily, thus making it apparent that the motor cover was set on fire by the explosion. From the nature of the damage it seemed that the explosion originated from an unknown cause at some point on the first floor near an elevator leg, and propagated up to the fourth floor where a second and more disastrous explosion occurred.

Port Colborne, Ontario, Canada

On August 9, 1919, an explosion occurred in an elevator owned and operated by the Canadian government at Port Colborne, Ontario, Canada, as a result of which 10 men lost their lives and the same number were more or less seriously injured, while the loss of property was estimated at $750,000 (Fig. 11).

Fig. 11.—Upper portion of grain elevator badly damaged by dust explosion. Note "trough-like" construction of interior walls of bins.

The damage wrought by the explosion was confined to the area above the storage tanks, very little damage being done to the basement and storage section of the plant. The bin floor and the roof over the storage section were entirely blown off. Part of the side walls of the working tower was demolished, as well as a large portion of the roof of the working house. Both ends of the tower were badly damaged. In fact, the force of the explosion at these points was so great that heavy 8-inch steel "I" beams were carried some distance from the plant. In some cases large pieces of reinforced concrete were hurled for a distance of 150 feet. A barge which was being loaded with grain in the slip on the east side of the plant was sunk by the large quantity of debris which was thrown upon it.

From the evidence obtained in the investigation it would seem that the explosion was the direct result of a choke-up which occurred in an elevator leg. Before the choke-up was noticed and the motor stopped, so much friction had developed at the head of the elevator that the belt began to smolder and burn, until it parted and dropped down through the legs into the elevator boot and well. The dense dust cloud raised in the legs and well was ignited by the smoldering or burning ends of the belt. The explosion then propagated through a small opening in the well to all sections of the plant. On account of the peculiar trough plate construction of the sides of the bins a great deal of dust had accumulated on the bin walls. This dust, thrown into suspension by the force of the first explosion, was ignited by the flame which traveled through the opening between the tops of the bins and the bin floor. Since all the bins were connected, the explosion blew away the entire upper portion of the plant.

Kansas City, Mo.

In a very disastrous explosion which occurred September 13, 1919, in a large terminal elevator at Kansas City, Mo., 14 men lost their lives and 10 were seriously injured (Figs. 12 and 13). The elevator was par-

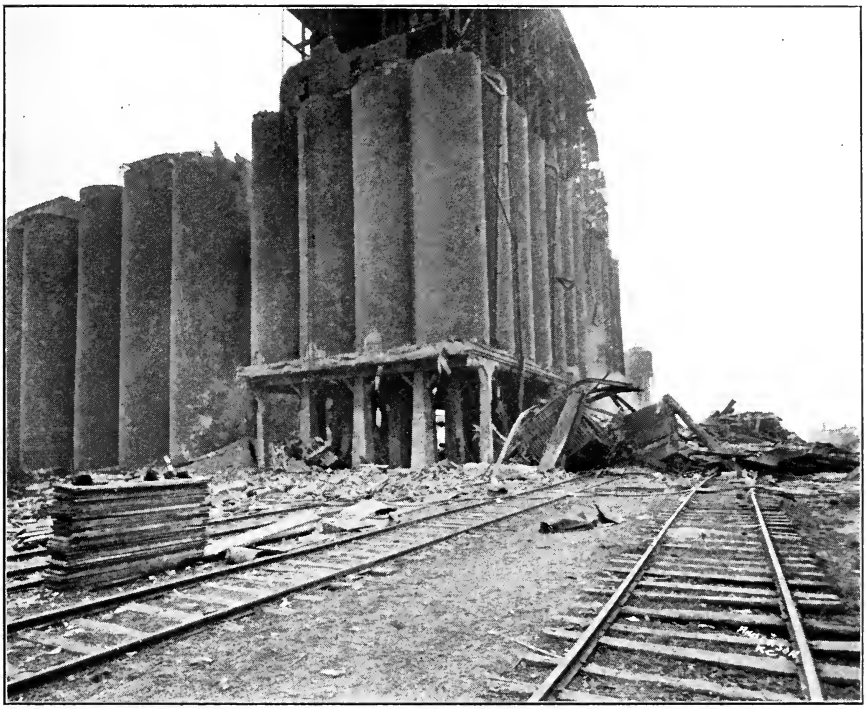


FIG. 12.—View showing violence of explosion and damage to working floor and shed. Explosion originated in basement.

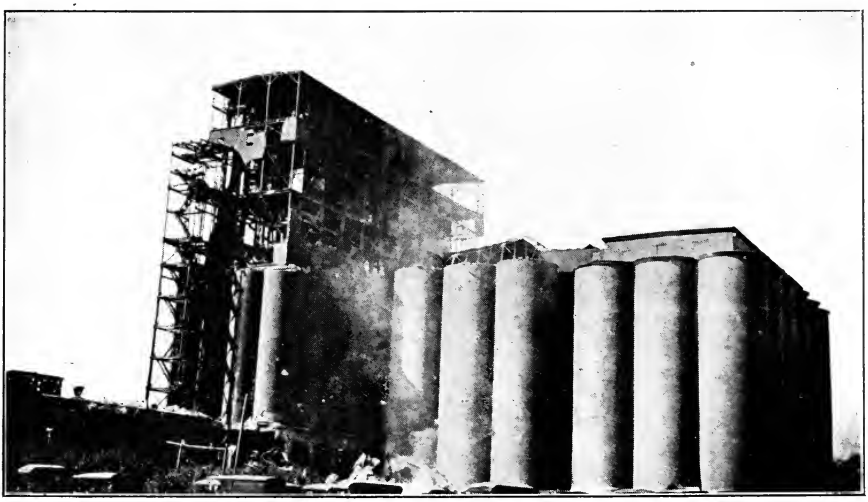


FIG. 13.—Explosion traveled from basement through man-lift tower to "texas" or top of elevator.

tially wrecked, the property loss being estimated at $650,000. This explosion was not confined to any one portion of the elevator, but propagated to all sections of the workhouse.

The evidence at hand indicates that the explosion originated in the basement, in the vicinity of one of the receiving legs, where workmen were cleaning up the plant. Great difficulty was encountered in determining the exact cause of the explosion, owing to the fact that all the evidence required to establish it had been destroyed on account of the force of the blast. Judging from the violence of the explosion, the dust in this plant must have been very inflammable.

The evidence secured from one of the workmen indicated that the source of ignition may have come from an electrical short circuit. This workman stated that he heard a sharp cracking noise shortly before the explosion, and thought that he had seen blue flashes of flame traveling along the electric light wires. The short circuit may have been caused by defective extension cords or the breaking of an unprotected lamp bulb in the dusty atmosphere present. Workmen in the basement were known to have been using extension cords at the time of the explosion, and it is possible that ignition came from such a source.

Spice Dust Explosion

On January 17, 1920, 4 firemen were killed and 13 injured, 3 of them very seriously, when an explosion in the burning mills of a spice company in Cincinnati, Ohio, blew out the east wall of the structure (Fig. 14).

FIG. 14.—At extreme right can be seen bridge from which firemen were fighting the fire when the wall was blown out by explosion of spice dust.

Since the early newspaper reports stated that the disaster was due to an explosion of tea and spice dust, an investigation was conducted to determine if possible the true cause of the explosion. From the evidence that was secured it seems that the walls of the building fell without any warning. Tests showed the spice dust to be very inflammable, and it is reasonable to conclude that the explosion or force which blew out the walls of the plant was probably due to the ignition of a cloud of spice dust which was formed when the floors in the building fell.

Aluminum Dust Explosion

On February 26, 1920, a disastrous dust explosion occurred in an aluminum goods manufacturing plant at Manitowoc, Wis., as a result of which 6 girls lost their lives and 5 were seriously injured (Fig. 15).

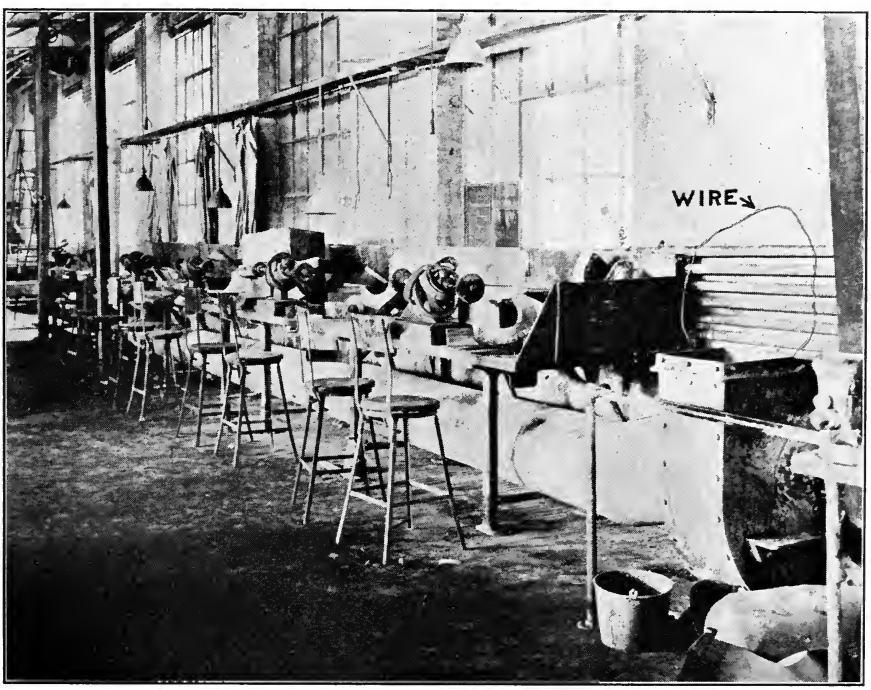


FIG. 15.—View of dust collecting system showing wire as found in fan following the explosion. Buffing brushes used can be seen on bench.

The explosion originated in a dust-collecting system used in collecting the fine particles of aluminum dust which are given off during the process of putting the satin finish on aluminum goods. This process consisted in holding the aluminum article against a rapidly revolving steel brush.

The cause of the explosion is attributed to a piece of No. 7 iron wire winding itself around the blades of a blower fan. This produced a spark which ignited the fine particles of aluminum dust in suspension in the fan and gave rise to the explosion.

These and other like disasters should lead the chiefs of the city fire departments to make an earnest effort to acquaint themselves and their men with the nature of dust explosions occurring in grain-handling and inflammable dust-producing plants.

Boissevain, Manitoba, Canada

On the evening of December 6, 1919, an explosion occurred in a flour mill at Boissevain, Manitoba, Canada (Fig. 16), resulting in a loss of about $15,000, and injury to one employee.

The explosion, caused by the striking of a match in a flour bin, propagated up the stairway and through other openings to the next floor above where a secondary explosion did extensive damage. The brick wall at one side of the mill was blown out and the warehouse was damaged. As the mill was quite clean, very little fire occurred.

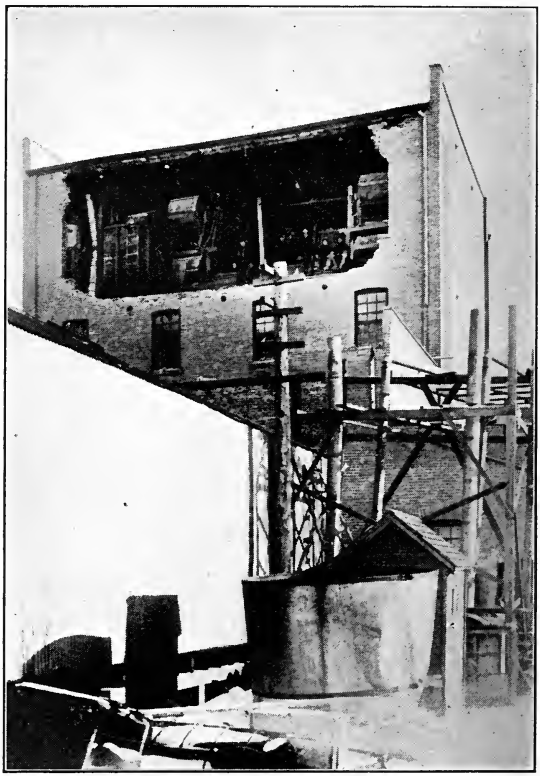


FIG. 16.—Explosion blew out wall of upper floor after propagating from floor below.

Buffalo, N. Y.

On November 21, 1919, an explosion occured in an elevator leg of a Buffalo feed-grinding plant.

At the time of the explosion workmen were using an oxy-acetylene torch to cut an opening in the boot of an elevator leg. A man at the top of the leg was changing a spout leading from the elevator head to a steel conveyor. After as much of the steel casing had been cut out as was necessary, and the torch had been extinguished the men began to hammer the plate out of the opening. At the same time the man at the top of the elevator leg started to hammer on the short spout leading from the head. It is not known whether the torch had ignited the dust in the boot, causing it to smolder, or whether the hot plate ignited the dust, which had been stirred up by the hammering. The explosion that followed traveled up the back leg and burst it open for a distance of about 30 feet, in spite of the fact that a portion of the leg was open and a vent provided. No fire followed the explosion but several employees were injured and the elevator leg was damaged.

Denver, Colo.

A dust explosion followed by fire caused a loss of over $125,000 in a large Denver flour mill on January 20, 1920.

At first the cause of the explosion was ascribed to the production of sparks by a suction fan used in connection with the dust-collecting system. In the investigation of the explosion it was noted that the fan blades from which the spark was said to have originated were fastened to an overhanging fan shaft by means of a feather key held in place by set screws, with a one-inch clearance between the fan blades and the right-hand side of the outer fan casing, but none on the left-hand side of the casing. The theory that the key became loose in the fan shaft and permitted the revolving fan blades to strike the sides of the fan casing, thus producing sparks which in turn ignited the fine flour dust coming from the roll suction, was then advanced. Since the damage resulting from the explosion indicated that the ignition of dust took place in the dust-collecting system, it was decided that ignition could be attributed to the presence of sparks either in the fan or from the rolls. On the strength of the evidence of a workman on the roll floor that one of the doors on the roll stands had been blown open, it seems reasonable to suppose that the explosion originated within the rolls rather than in the fan.

EXPERIMENTAL WORK

Theory of Dust Explosions

A misunderstanding seems to prevail among some as to what a dust explosion really is. These assume that dusts explode in the same manner as high explosives, that, for instance, a sack of flour or a package of starch in the kitchen cabinet might suddenly blow up as gunpowder might. This, however, is not the case, for dusts explode in the same way as gas does, not like gunpowder and other explosives. Just as gas and air must be intimately mixed, and in the proper proportions, in the cylinder of an internal combustion engine, so grain dust must be in suspension in the air as a cloud, intimately mixed with air, and in certain proportions. Neither the mixture of gas and air nor that of dust and air will explode until it comes in contact with a flame or some other source of heat of sufficient intensity to cause it to ignite.

Density of Dust Cloud.—The minimum quantity of grain dust which must be in suspension before an explosion can be initiated has not yet been determined. It is reasonable to assume, however, that, since most of the grain dusts are more inflammable than coal dust, the density of a cloud of grain dust need not be greater than that of a cloud of coal dust through which an explosion will just propagate. The Bureau of Mines, of the United States Department of the Interior, has found this density in case of coal dust to be 0.0253 ounce of dust per cubic foot, while the French Experiment Station has shown that it is 0.023 ounce per cubic foot.

Source of Ignition.—To ignite most dusts it is not always necessary to bring them in contact with a large source of heat, such as an open flame, nor a very high temperature, such as an electric arc. Indeed, a number of explosions have resulted from the ignition of the dust by sparks struck as foreign materials passed through the machinery. A spark formed by the discharge of static electricity will ignite many, if not all, of the dusts under certain conditions. Some of the dusts are ignited when they come in contact with bodies having a temperature of 540 degrees C. (1004° F,). which is well below dull red heat, and most of them will ignite when brought in contact with a body having a temperature slightly above 600 degrees C. (1112° F.).

Velocity of Propagation of Explosion.—The velocity of propagation of explosions through most gas mixtures is more rapid than through most dust clouds, although in a few cases it has been found that the velocity of flame propagation in coal dust explosions has exceeded the maximum for certain gases. In only two tests has any attempt been made to measure the velocity of propagation of the flame in clouds of materials other than coal dust. One indicated that the velocity through a cloud of wheat flour dust was practically the same as that through coal dust; the other that the propagation through a cloud of powdered starch was several times as rapid as through the coal dust. These results, however, cannot be considered to be conclusive.

Pressures Developed in Explosions.—As high pressures have been developed in coal dust explosions as in those of many of the gases. Higher pressures have resulted from the explosion of several of the grain dusts than from the explosion of coal dust. This indicates that certain grain dusts are more inflammable than coal dust, and quite as inflammable as many of the combustible gases, if not more so.

Conditions for Explosion.—Although it is true that not all dusts will explode, the dusts from any material which burns, or is readily oxidized ,will explode under certain conditions. The ease of ignition depends upon various factors, such as the composition and fineness of the material and the amount of moisture in the dust. The composition of each dust, of course, is fixed, but its fineness and moisture content may vary. Speaking broadly, the finer the dust and the lower its moisture content, the more readily ignition takes place, or the greater the possibility of an explosion. This, however, should not be taken to mean that a coarse or a moist dust will not ignite. As a matter of fact, if the dust is fine enough and dry enough to form a cloud or to be thrown into suspension in the air, it can be ignited, and may propagate an explosion.

Propogation of the Explosion.—When a plant is destroyed by an explosion a series of reports resembling a roll of thunder usually is heard. This is due to the fact that several explosions follow one another so rapidly that the report of one blends in with that of the next, making a continuous roar. For example, the original, or primary, explosion

may occur in a grinding machine where the dust cloud is confined within a small space. The pressure and percussion from this primary explosion throws into suspension the dust which has accumulated on beams, ledges, and floors. This dust is ignited by the flame of the primary explosion, giving rise to the second explosion, which, in turn, stirs up the dust in the surrounding portion of the plant. Thus the explosion is propagated throughout the plant, or as far as dust is held in suspension or capable of being thrown into suspension.

PREVENTION OF EXPLOSIONS.—To prevent explosions, therefore, it is essential not only that all possible sources of ignition, such as open flames, the presence of foreign material in the grinding machines, an accumulation of static electricity, improper installation of electrical equipment, and an inadequate protection for all electric lamps in a dusty atmosphere, be eliminated, but also that the plant be kept scrupulously clean, thus offering no medium of propagation of the primary explosion into the secondary, and more extensive, as well as more disastrous, explosion.

Large Scale Tests

Large scale tests on the explosions of grain dusts were conducted at the testing station of the Bureau of Mines at Bruceton, Pa., where a large steel gallery, 6 feet in diameter and 220 feet in length, with vents every few feet to relieve the pressures, is used in testing the inflammability of coal dusts. The grain dust tests were made under the same conditions as obtain in testing coal dust.

One pound of dust to each linear foot of the gallery was spread on four shelves on both sides of the interior of the gallery. The dust was thrown suddenly into suspension and ignited at the closed end of the gallery, thus propagating the explosion well out through the open end.

Ordinary wheat flour, corn starch, and a mixture of 60 per cent. flour and 40 per cent. shale dust (ash) were used, in addition to the coal dust.

Flour and coal dust behaved alike, the explosions produced in each case being propagated at about the same velocity and developing approximately the same pressure. The flame was propagated readily through the cloud produced from a mixture of flour and shale, but much less readily than in one from pure flour, and with but slight pressure.

The explosion from the starch dust was the most violent of all, and developed pressures several times greater than those from the coal dust or flour. The rate of propagation also exceeded that in any of the other tests. Indeed, the percussion was so great that windows and dishes in buildings two or three miles distant were shaken, and employees of the station stated that it was the most violent explosion they had ever seen at the gallery. In considering the relative violence of the explosions from starch and from flour, it should be borne in mind that the flour was coarser than the starch and that its particles had a tendency to adhere.

Electrical Equipment and Dust Explosions

Investigations of explosions in the various industries where inflammable dusts are created during the operating processes developed the relation of the electrical equipment and appliances to the cause of dust explosions. In some instances the explosions appeared to be due to the ignition of the dusts by electric sparks or the breaking of incandescent electric lamp bulbs in dust clouds. In the investigation of a very recent disastrous explosion resulting in large loss of life and extensive property damage, one of the probable causes suggested was the ignition of the dust in suspension by an electrical source.

The lamp manufacturing companies were naturally very much interested in this phase of the problem, and arrangements were made for cooperative experimental work relating to electric lighting equipment. Special tests are already in progress as a result of which it is hoped to determine the relation of electric lamp bulbs to explosion and fire and develop equipment which will afford extra protection. In the preliminary tests already conducted, explosions were readily produced when incandescent lamp bulbs of all types were broken in dust clouds.