

its governor, and moves the auxiliary slide-valve of engine No. 1 to admit steam to move its main slide-valve, thus keeping up a continuous plunger action and flow of water from the pumps. Each engine has an independent condenser and two air-pumps, the latter being operated from the rock shaft that gives motion to the governor or regulator cylinder.

The pumps are of the plunger variety, with packing-boxes in the middle, between the valve chambers, which admits of the packing being tightened up while the pumps are in motion. The pump-valves are easily accessible for inspection by the removal of a single cap at each end of the pump chambers. Ample air and vacuum vessels are provided, as are also shut-off valves for the suction and discharge pipes of each pump.

EXPLOSIVE AND DANGEROUS DUSTS.

By PROF. T. W. TOBIN, C.E., Ph.D.,
Of the Polytechnic Society, Kentucky.

[An address delivered before "The Fire Underwriters' Association of the Northwest," at the Thirteenth Regular Meeting, held at the Grand Pacific Hotel, Chicago, September 6, 1882.]

During the month of May last I was honored with an invitation to address the Kentucky Millers' Association on "Flour Explosions." Being a subject in which I had for many years been interested, I cheerfully undertook the preparation of a lecture, with illustrations. The experiments, although not new, for chemists well know the combustible nature of organic dust in a finely divided condition, yet so impressed my audience that I was more than repaid, on my part, in their interest and applause for the small amount of labor expended. In preparing that lecture there appeared to me certain conditions governing the combustible state of flour which hitherto had been passed by in investigating the appalling catastrophes that from time to time befall our national industries, in the form of mill fires and explosions. Many of my suggestions, the outgrowth of subsequent experiments, have been received with favor; and my theories, if such I may presume to term them, have had the endorsement of practical men before whom they have found their way. The desire to prosecute the

truth, which is implanted in every scientific mind, has led me further, and I am here to report progress and court your criticism.

DUST UNDER THE MICROSCOPE.—Let us together then retrace the narrative of these researches. I will first call into requisition that wonderful instrument that science plunges into the mysterious and opens out its inner secrets to the light of day—the microscope. As it would be difficult to show you individually the objects that I shall employ as illustrations, I made careful drawings and photographs of them, and by means of a powerful oxyhydrogen light will project magnified images of these upon the disk now before you. (*The lecture room was here darkened and the subsequent microscopic illustrations shown on a screen, magnified to many million times the size of their originals.*)

1. I take first some ordinary flour, commonly known as “*Graham meal*,” and we find that it consists of quite a miscellaneous gathering of various bodies. There are present: (1), the skins of the wheat-berry; (2), the hairs or “beard;” (3), cells of gluten, a waxlike substance, being the most nutritious portion of the grain; and lastly, (4), the starch in various sized granules. This body forms the bulk of ordinary flour and flour-dust. Now, in order to understand intelligently the natural placement of these parts of the wheat grain, I will bring magnified images of that body.

2. This shows: (1), the beard; (2), the skins, three in number, that enclose the internal starch or gluten; (3), at the bottom there will be noticed the germ, and contiguous with it the crease. Now, the first operation of the miller who has recourse to the newer processes of reduction, is to clean by brushing or agitation, the whole surface of the grain for subsequent operations, and 2d, to break open this crease and get rid of the germ and incidental impurities that are usually there. In so doing a small amount of flour is made, but being charged with impurities, is blown into the dust-room. There are then two classes of dust: 1st, wheat dust, obtained from cleaning the surface of the grain, and 2d, the refuse flour dust discarded, because being mixed with germ and other foreign matter. Although in my investigations I found two separate channels and outlets, the character and condition of both classes of dust therein were almost identical in physical properties.

3. This will show by a section of the grain the disposition of the parts already described.

4. Pure starch granules, as found in "arrowroot." This may be taken as the typical element in flour dust. We mark the compact spheroidal form of the granule. At a temperature of 140°F . in water it swells, bursts and is converted into the well-known pasty mass used in the arts. In common with most organic matter, starch is combustible, and contains normally about 18 per cent. of water.*

This amount varies, and exposed to a dry atmosphere, may be considerably reduced. I take it as a rational deduction that the most rapid combustion of flour, attended with explosive violence, would occur when freed from moisture. The individual granules burst simultaneously, and the disturbance thus produced bringing new supplies of oxygen, would instantly determine the rapid consumption by fire of the entire mass. This fact will be discussed further on.

5. Immediately following the starch granules we have a quantity of dust obtained from the club moss, called "lycopodium." It is the seed or spore of that plant. Notice the near resemblance in size and structure to the starch granule; but it differs in one respect in being of an oily nature, which (as our experiments will presently convince us), renders it very inflammable.

6. This is highly bolted flour, and as the microscope shows, freed from the husk, the beard, and even the gluten of the wheat, leaving nearly pure starch. We observe that there are three distinct qualities of the granule; (1), the giant; (2), the medium, and (3), the farina, or starch powder.

7. This view will give a fair idea of what change takes place in starch on submitting it to a heat of over 140° ; in other words, it is cooked flour. The granules have all disappeared, and in their place are irregular masses of amorphous "dough" or "paste."

8. Some dust collected from the "wheat dust room" shows starch, husk, fractured gluten cells, the beard, and other impurities; it also contains, generally, "fungi," or "smut." The dry and oily nature of this dust renders it more inflammable than starch.

9. Wood abrasions from an axe-handle factory, showing the fibrous and cellular texture of the minute particles of dust. This material is inflammable owing to its extreme dryness.

COMBUSTION.—I will now as briefly as possible lay down the principles that are generally acknowledged by chemists as underlying the phenomena of combustion in organic bodies and apply them to the

* Miller's Elements of Chemistry.

special instances under consideration. The substances which we will deal with to-night consist of three elements; oxygen, hydrogen and carbon. Although in variable quantities the oxygen and hydrogen are always in the ratio of water, *i. e.*, eight parts by weight of the former to every one part of the latter; heat is capable of determining their union and water is the result. Carbon or charcoal is thus left, and being incapable of existing in any but a solid condition, soon stifles further combustion. If, however, oxygen be added, either from the air or as a gas, perfect consumption of the body takes place. We know that a piece of wood, if an insufficient supply of air is present, can only become charred by the most intense heat known. This is the first principle that I will now endeavor to illustrate.

EXPERIMENTAL DEMONSTRATION.—Here is some hydrogen in a tube; it is very much the same as that burning from the lamps in the room. I plunge a lighted taper into it, and the taper is incapable of burning for lack of oxygen or air. Hydrogen, although a highly combustible body, will prevent combustion, and even suffocate this burning taper. I now add some air, neither in itself explosive nor combustible, and then heating the mixture, I get a deafening report. Beyond all question, I have generated an explosive body.

Then I will take some flour, and perhaps I should tell you that, like the hydrogen when free from free oxygen or air, it is incombustible. Flour thrown on the glowing furnace will retard and even, if sufficient in quantity, extinguish the fierce fire. Like hydrogen alone, it is a non-supporter of combustion. Observe, I plunge a burning taper in this measure of flour, and, as you would predict, the taper goes out. Here is a substance, chlorate of potash, which is very rich in oxygen, and I cannot alone make it burn, as you may see. Two harmless bodies I mix; the essentials of combustion are supplied and brilliant fire is the result. Oxygen gas, always present in the air, an exceedingly active and corrosive body, is then the one thing needed to render these inert bodies combustible, and even explosive.

MOISTURE.—Water, in all its forms, is opposed to combustion, and its presence modifies the rapidity with which the consumption takes place. It is, I think, hardly necessary to illustrate this as a general principle, although in the sequel we shall find in it an element of great importance.

Now, it is by these simple principles that combustion in its varied phases, from the slow decomposition and decay of the green vegetable

to the explosion of the modern flour mill, is governed. By the modification of them I think I can show you some interesting results.

WOOD DUST.—Here is some dust from an axe-factory. It was obtained and has been preserved in a dry state. By means of a simple piece of apparatus I cause it to be blown about and thoroughly mixed with air. A flame is near it, rapid combustion takes place, and a column of fire of intense heat leaps up in the air, six or seven feet high.

FLOUR DUST.—This sack contains ordinary flour. Previous to the lecture some of it was placed in a drying oven and submitted to gentle heat. By this time much of the moisture usually contained in flour has been expelled; one condition has been filled to make the substance combustible. I next comply with the other and mix it with air. See the result! Mark the violence attending the combustion.

You may seem astonished, and ask whether this is flour alone. Yes; from the same sack I use some more: this time not with the same and result, for it is damp and the air cannot mix sufficiently to render it even inflammable.

Then we arrive at a very important conclusion. The violence of combustion is the inverse of the moisture of the dust experimented upon.

OTHER DUST.—We will now put the testimony received so far to the torture of further investigation. I have some lycopodium. You remember its near resemblance to flour dust under the microscope. It is not necessary to dry this as we did the flour, for it is protected by an oily waterproof coat and moisture cannot enter it, but it requires air, for I plunge a lighted taper into its midst, and, as in other instances, neither will the powder burn nor will the taper. I urge some of it through the heated flame with this unexpected result: an all-devouring, an explosive column of fire.

EXPLOSION.—The results obtained so far convince us that dust is inflammable in degree according to its dryness. No actual explosion has yet been obtained in our experiments. Perhaps it will be well to define the term explosion since there has been objection raised to its use in connection with flour combustion by some writers whose opinion is worthy of respect. It almost seems ridiculous to imagine anyone looking at the disaster at Minneapolis, could so pervert the English language as to say that no "flour explosion" took place. Our dictionaries give us the definition of the word "to drive or burst out with a loud report or violence." Hitherto we have not then complied with

this definition and therefore had no explosion. Let us see if it is possible to obtain explosion, and by what means. When dry organic dust is heated to the point of ignition, the oxygen and hydrogen first combine to form water. Intense heat is thereby generated, and this heat acts in two ways: first, to char and finally convert the carbon into carbon dioxide gas; and, secondly, to expand the surrounding air. The gas and the heated air occupy considerably more space than in their first state, and the more rapidly these results are achieved the more nearly will the act approach the violence of explosion. The air then plays as important a part as the dust, and should the air space be confined, but insufficient to restrain its force of expansion, explosion in the full sense of the term takes place.

EXPLOSION, INTENSITY OF COMBUSTION.—We can trace the various degrees of combustion in the many mill and factory fires that have been placed on record. Notably amongst them I will call your attention to two—the terrible disaster of Minneapolis, which occurred May 2, 1878, and the Hecker mill fire in New York, July 31, 1882. In the former we may reasonably infer that the air was dry and the dust pretty generally diffused throughout its entire extent, owing to the long continued and busy period the mill had been taxed with work. The wheat of that year, we are told, was hard and dry, and at the time of the explosion, 7.20 P. M., the air was chilly and the windows and openings generally closed. Here are conditions for explosion. In the latter I will take the testimony of the superintendent, Mr. J. V. Hecker, as recently given before the fire marshal of New York. He says: “The fire originated in the ‘smutter’ on the seventh floor. ‘Smutters’ are considered the most dangerous parts of the machinery of a mill, on account of the friction which may be produced by any foreign substance getting in and striking fire between the revolving cylinder and the case surrounding it. These cylinders were of stone and the cases of chilled iron. The smutters make from 250 to 300 revolutions per minute. The dust is sucked from under the smutters and forced by a fan into the (wheat) dust room through a spout about ten inches square. I think the fire was caused by a spark struck by friction in the smutters, igniting the dust and passing through the spout into the dust room and igniting the dust therein.” That an explosion did not then occur, as in many other instances was, I take it, owing to the fact that while the air in the mill was charged with fine dust the dryness was sufficient to cause the flames to spread with

lightning-like rapidity through the entire building, making the 500 workmen run for their lives. There was insufficient moisture to allow the dust to burn with the violence characteristic of an explosion. From the meteorological record of that day I find the barometer stood at 30.42, temperature, 82° F., and there was 82 per cent. moisture in the air, with cloudy sky. Thirty per cent. of humidity that day, in all probability, saved the nation from a disaster far more terrible than happened in Minneapolis, or since the history of milling has been recorded.

Many other illustrations might be taken which would find an intermediate place in the degrees of intensity of combustion. You will call to mind the candy-works explosion in the same city some years ago that was an explosion of starch. The Ehret Brewery in August, 1881, experienced an explosion from the barley used in malting. Barley, in common with wheat and other cereals, consists principally of starch, and no difficulty is experienced in accounting for that phenomenon. The Pullman Car Works, at Detroit, 1880, had an explosion of dust in the spout used for conveying shavings from various portions of the factory to a place near the furnace. This spout is the counterpart of the dust room of the flour mill.

CONDITIONS OF EXPLOSION.—We will now proceed with our experiments and see if we can cause those substances which hitherto have shown themselves as highly combustible, to become explosive. We will confine the air space and see the result. For that purpose I have before you a simple piece of apparatus which, for a better name, we will call a dust or flour gun. It consists of a hollow shaft about seven feet high. At the top is a hopper, which by means of a paper cover I can close; at the bottom is a gas pipe to which is attached a Bunsen burner. By means of a trigger arranged near the top I can cause a fine shower of dust to descend and fill the shaft. When the first portion of it reaches the flame and the shaft is filled with dust, ignition takes place and the entire column burns. It is necessary that there should be a plentiful supply of air. This is provided for in numerous perforations about the walls of the machine. If the dust is now dry we have all the conditions for explosive combustion. Let us proceed:

I place some lycopodium and turn the trigger. The top is blown off and takes fire, so intense is the heat. Here is some wheat dust from the dust shaft of a flour mill. The result is much the same,

only less in degree, and yet sufficiently illustrates the principles we have discussed.

THE WET BULB HYGROMETER.—Before proceeding further in our subject it is necessary that we should understand the construction and use of an instrument that will play an important part in the subsequent line of thought I purpose now leading you. It is known by the modest title of “Wet Bulb Hygrometer,” and its mission is easily related.

Its indications tell us that the atmosphere about us on the clearest and brightest day or night contains a large amount of water dissolved in it; that this watery vapor or gas is very transient in its nature, but that very seldom is the air fully charged, and never is moisture entirely absent. When the air has as much water as it can possibly hold we call it saturated, and in that condition we say it has one hundred per cent. of humidity. Cold air requires less moisture to saturate it than warm air, hence elevation of temperature means increase of the saturating point.

It tells us that there is a constant variation going on—sometimes at short intervals, and at others in long periods; and it further shows, as we are ready to anticipate, that there is a constant change in the capacity of the air and amount of moisture in it during the twenty-four hours of each day. As I take it, this atmospheric property plays an important part in our investigation of dust combustion.

In various localities the average capacity of the air varies considerably. “In the North American Continent,” says Ganot in his admirable text-book on physics, “where the southwest winds blow over large tracts of land, the relative moisture is less than in Europe; evaporation is here far more rapid; clothes dry quickly, bread soon becomes hard; newly built houses can be at once inhabited; European pianos soon give way here, while American ones are very durable on the other side of the Atlantic. As regards the animal economy the liquids evaporate more rapidly, by which the circulation and the assimilation is accelerated and the whole character is more nervous. In some parts of East Africa, on the other hand, the air is so charged with humidity that paper becomes soft and sloppy from the loss of its glaze, and gunpowder, if not hermetically sealed, refuses to ignite.” As a suggestive thought incidentally to these statements—are not the greater number of mill explosions in districts over which a dry atmosphere is known generally to exist? By the indications of this instru-

ment we find regular changes during the day, there being maxima about 8 A.M. and 8 P.M., and minima about 3 A.M. and 3 P.M. The Signal Service record (Louisville) for a few days will suffice to show this fact:

	6.25 A.M.	10.25 A.M.	2.25 P.M.	6.25 P.M.	10.25 P.M.
Aug. 1,	90	79	59	72	88
Aug. 2,	82	62	51	61	85
Aug. 3,	90	67	57	90	93

CONSTRUCTION.—The instrument in construction is simple, consisting of two delicate thermometers, one of which is kept saturated by a reservoir of water. As the air loses or gains in capacity to dissolve moisture evaporation takes place from the wet instrument. Proportionate to the capacity of the air to contain water will be the degree of evaporation, and the extent of evaporation is indicated by the lowering of temperature. Thus, by a very easily constructed table, showing the difference of temperature readings of the two thermometers, a pretty accurate estimate may be made of the amount of water necessary to produce saturation and the amount already contained therein. The instrument may be easily constructed or purchased for a few dollars at any first-class optician's. It should, however, be accurately adjusted and the scales properly constructed. I will not occupy your time in explaining further how the readings are made, as that information may be obtained from any good text-book on meteorology, but will at once proceed to detail records arrived at by its aid in my subsequent description.

MILL FIRES.—The principles I have heretofore laid down, simple as they may appear, I felt convinced underlaid many of the fires and terrible explosions so disastrous to flour mills, and to their ignorance I conceived might be attributed at least some of the most awful catastrophes chronicled in our industries. Every year, to his sorrow, the mill-owner finds his risk of destruction of property and life growing greater, and I believe to-day there are insurance companies that would as soon grant a policy upon a gunpowder magazine or dynamite factory as to the proprietor of a flour mill. I determined to submit these principles to a rigid test. Accordingly, with hygrometer and note book in hand, and the valuable co-operation of Mr. Chas. Ballard, a

practical miller, I penetrated every crevice and chamber, from basement to roof, of one of the best-ordered mills in the country.*

I will not occupy your time in describing the various parts of an ordinary flour mill, but make use of the technical terms applied to the various localities. Suffice it to say that the mill in question has every modern improvement in milling machinery, is substantially constructed of brick, is run by steam power and well ventilated from all sides. The grain is received in the basement; the first floor is devoted to gradual reduction mills, and the second and third floors to bolting machinery and purifiers of the most approved description. It has a capacity of 180 barrels per day.

Mathematics cannot err; mark, now, the extraordinary records:

Record of Temperature and Humidity of the Atmosphere at the Flour Mill of Messrs. Jones, Ballard & Ballard, Louisville, Ky., August, 1882.

Date.		External.		Internal Humidity.			Weather.
Day.	Hour.	Temperature.	Humidity.	Grinding Floor.	Bolting Floor.	Dust Shaft.	
Aug. 10...	11 A.M.	70°	52 P. C.	67 P. C.	54 P. C.	Clear.
Aug. 11...	12 M.	80°	51 "	62 "	65 "	Fair.
Aug. 12...	3 P.M.	82°	45 "	60 "	53 "	Fair.
Aug. 14..	3 "	89°	53 "	54 "	53 "	43 P. C.	Fair.
Aug. 15...	1 "	81°	87 "	83 "	83 "	60 "	Rain.
Aug. 16...	1 "	82°	83 "	87 "	87 "	63 "	Rain.
Aug. 17...	3 "	79°	57 "	64 "	64 "	53 "	Clear.
Aug. 18...	3 "	83°	48 "	52 "	52 "	38 "	Clear.
Aug. 19...	2 "	78°	50 "	55 "	58 "	41 "	Fair.

The first unexpected result we notice in these records is that the atmosphere in both grinding and bolting rooms is moister than the air outside. On closer examination I soon discovered the cause of this.

* This mill is situated in Louisville, Ky., and owned by Messrs. Jones, Ballard & Ballard.

Each set of rollers used in reducing the grain, 22 in all, was heated, owing to the friction and resistance in crushing. By the heat thus generated the normal moisture of the wheat was continuously being evaporated, and escaped into the mill; the spouts near the rollers were bedewed with moisture and the flour doughed. Notwithstanding that the windows on all sides were open, and the ventilation as thorough as possible, the entire atmosphere of the mill was thus kept in a moist condition.

After carefully examining the purifiers, bolting chambers, wheat cleaners and other machinery for the dangerous element of dry air, I came lastly to the dust shafts. As I have already stated, in this mill there are two of these—one used for collecting the dust from the wheat cleaning, which is carried to the basement and there collected in a dust room; the other carries off the light refuse flour dust made in the first reduction of the grain. In making observations I found the amount of moisture in both these shafts, and the various parts of each one, differ so slightly that I did not deem it desirable to note the variation.

THE DUST SHAFT.—Could science speak plainer to us than in these facts? Recall the many mill fires and explosions that periodically visit us, and does not each narrative begin with the now easily interpreted incident, that destruction commenced at the dust shaft or in its vicinity? Here, month after month, streams of dry air, drier than the hot summer breezes, are urged with the velocity of a storm, depriving the wood and other combustible matter of its moisture, converting all that will burn into tinder-like fuel, dry air separating and buoying up the particles of drier dust until the fatal spark occurs and combustion ensues, with the explosive violence, alas! too well known now to need description.

I do not hold that mills are blown up by the dust alone in the shafts, but I do believe that the fires generally originate there, and the local explosion caused thereby is often sufficient to fill the entire atmosphere of a mill with lodged and loose dust. A second charge is thus prepared for combustion, and the grand explosion occurs.

Dust shafts are then danger centres. Can there be any longer doubt in your minds? Is it necessary for me to suggest that they should be well protected and solidly constructed? Dry air in a mill, I am inclined to think, is little less dangerous than coal gas escaping in the air. Why make these shafts of light match boarding? Will you longer, in face of these deductions, use gauze and canvas doors com-

municating with them and your mills? As I stood one day near by one of these doors my hygrometer showed the dangerous enemy stealing into the dust-charged atmosphere of the mill.

Having accepted the fact, which I take for granted is now settled in your minds, that the dust spouts and flour shafts are drier than the surrounding atmosphere, let us see if science can explain why this should be so. Nearly all dusts are well known to chemists to be hygroscopic in their character. Flour especially will divest moisture from the air. But we have seen also that in the process of grinding, by the heat generated in friction, a large amount of the normal moisture of the grain is driven off and the subsequent heated flour must necessarily be abnormally deficient in water. The percentage of moisture in the dust shafts would be, of course, governed by the humidity of the external atmosphere, as we find it shown in the table set forth.

THE BAROMETER.—There is another interesting relation between the dust and the atmosphere as its medium, which is at least worthy of a passing remark. Do you know that dust is sometimes lighter than at other times? More correctly, the atmosphere, in its variable density, causes the light particles of floating matter to become more or less buoyant. Let me illustrate the statement by a familiar incident: Have you not noticed at some times, generally on a dry day, how the smoke rising from the chimney will rise and be buoyed up in an almost vertical direction—how on those days the very dust in the roads hangs about and refuses to settle? The barometer on these occasions will be high, showing that the air is dense. Another day the air will be charged with moisture; the smoke hangs about the ground, no dust in the air now, for the air is too light to buoy it up; the barometer is low and rain is probable. Is it only reasonable to infer that during a high barometer the lighter particles of flour are reluctant to settle, and, floating in the air, add to the many dangers of a flour mill? I make this brief allusion to a probable cause conducive to fire and explosion. Time will permit me to do no more.

DEDUCTIONS.—Gentlemen, the accurate diagnosis of disease points to a line of remedy. Have we not enough information on the cause of dust explosion to suggest a mode of remedy? It may be that we have not yet gone to the bottom of the mysteries involved, but we have, I think, indications enough to adopt a line of treatment.

Let me, as I have presumed so far, in the interest of science suggest:

1. That dust rooms are dangerous centres, and should be built, if possible, of brick, as you would build a smoke stack, and all communicating shafts and doors be of sheet metal.

2. That, as in the long period of drought in summer nature moistens the dry forest with rain and dew, so our parching winds, constantly blown through shoots, shafts and dust rooms, should be daily, if practicable, charged with vapor or steam.

3. Keep the mill free from superfluous dust and flour.

4. As dry air is the miller's enemy, let him learn to use the hygrometer, and on its indications adopt methods, as he may think best, to drive it from the many lurking places in his mill.

5. In dry weather, when the air is dense and thick with floating particles, let him not overwork or strain the capacity of production. Overtaxing work has often preceded disaster.

6. Never use open lights in the mill if it is possible to avoid them, and get as much ventilation as possible.

CONCLUSION.—Before concluding the subject I have attempted to lay before you, the cause of events makes it necessary to add one more record. After I had formed the line of thought and made observations at Messrs. Ballard & Co.'s mill, an incident occurred that riveted my interest, as I think it will yours. After hunting nature to the utmost limits of investigation, I was rewarded beyond measure in an occurrence which took place unexpectedly to all, but unfortunately for my friends in labor, the Messrs. Ballard.

When lecturing before the Millers' Association of Kentucky I made the following remarks: "Could we have had a register of the state of the atmosphere in the unfortunate Washburn mill, Minneapolis, immediately preceding the explosion, I doubt not that it would have shown a marked absence of humidity." Science has permitted me to realize this, for on Aug. 22d my closing record at the mill reads:

Date.	Hour.	External.		Interior.	Weather.
		Temper- ature.	Humid- ity.		
Aug. 22.	11 A.M.	82°	60	Wheat dust shaft and adjoining bin on bolting floor now in flames. Fire confined to upper portion of shaft, but fierce and destructive.	Fair.

What originated the fire I pass uncommented upon. The fact that the dust shaft burned with rapidity, and that the entire mill was but a wreck from either the flames or explosion, I leave for your thoughtful consideration. On the spot where I had made my observation, in the wheat dust room, the last time I visited the building, there remained only the ruins of property estimated from eight to ten thousand dollars.

ECONOMICAL STEAM POWER.

By WILLIAM BARNET LE VAN.

[A paper read by title at the Stated Meeting of the Franklin Institute, Oct. 18, 1882.]

Up to this point I have spoken of the engine only, and now I propose to investigate boilers and their adjuncts. A few years ago fifty pounds per square inch was thought a high pressure of steam to use in mills, but of late years pressures of seventy-five and one hundred pounds, and even one hundred and twenty pounds per square inch have become common. I predict that the day is not far distant when one hundred and fifty and two hundred pounds per square inch will not be uncommon.

The efficiency of a steam boiler is measured by the number of pounds of water it will evaporate into dry steam by the combustion of one pound of coal, compared with its cost; that is to say, the quantity of steam produced for its first cost and the least total cost for running it.

The thirty years experience of the writer is to the effect that the deficiency of a large number of good boilers in producing steam economically is due solely to their imperfect brick settings, flue connections and improper proportioning of grate surface to heating surface. To make them good, economical steam generators a resetting of their brick work is all that is required.

To illustrate: Some years ago a large manufacturer in this city consulted the writer in regard to the great quantity of coal consumed under his boilers. On making an examination it was found that the chimney and main flue were all right, but about thirty square feet of the most effective heating surface of each boiler, immediately over the fire grate, were rendered practically useless from being enclosed in brick work.