water can be entirely dispensed with, and the summit level can be utilized for storage, its banks being high enough to contain the highest and its bottom low enough to give the desired draft at the lowest water, the variation being taken up at the lock. In most canals the heavy tonnage is one way, and down hill. In such cases the descending tonnage will not only operate the lock, but also lift water to the summit level. It will be seen that the first cost of canals and their demands on the water-supply are reduced to a minimum. Application of steel to the locks reduces their cost of installation, operation and maintenance as greatly as it has reduced such costs in other engineering structures. The State authorities estimate that the saving in wages at Lockport will exceed interest on the entire cost, and at Cohoes such saving will be double the interest on the cost of installation, so that building the Cohoes locks will save an actual profit. In ship canal locks the saving will be in ratio increasing with their size.

Mining and Metallurgical Section.

Special Meeting, held Wednesday, January 31, 1900.

FLUSHING OF CULM IN ANTHRACITE COAL MINES.

BY WM. GRIFFITH,
Mining Engineer.

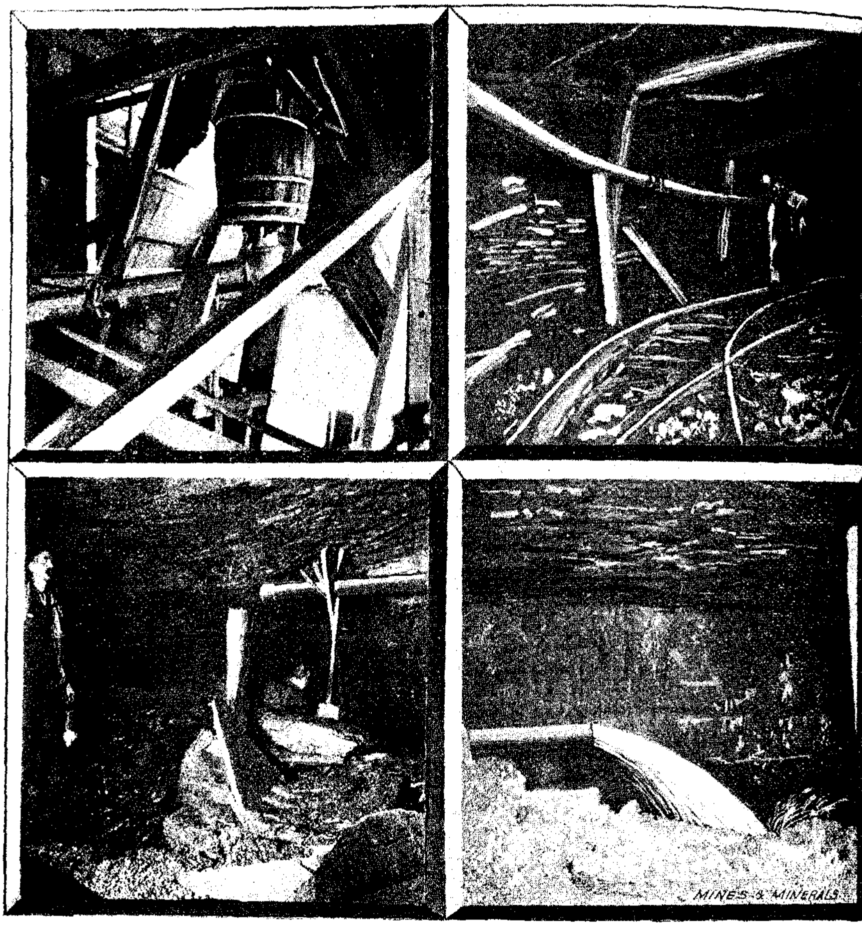
From 15 to 20 per cent. of the coal won from the anthracite coal mines according to the methods of the past was ground so fine in the course of preparation through the breaker that it could not be used or sold, and had to be piled away as refuse. The method of doing this, and which is still largely used, is to haul the culm, as it falls from the chute, to the foot of a plane. It is then hoisted up an incline to the top of a large pile and pulled to the dumping ground by a mule, all of which process costs in the neighborhood of a cent or more per ton for the total output of the mine. The result is that at every anthracite mine there are to be found immense piles of refuse which are not only unsightly, but occupy considerable areas of ground which it would often be very advantageous to use for other purposes. By the wet process of preparation, though the culm is flushed into streams with water, similar objections hold.

Of late years many of these culm piles are being re-worked and the coarser portions screened out and sold for use as steam sizes, leaving the finer culm still as a waste material. Furthermore, the improvement in methods of burning fine coal has been so marked that the culm or waste produced by present methods of preparation in modern coal breakers is not much larger than the printed letter of this page. Recently, however, a new process has been originated for disposing of the waste from the mines, which has been called "flushing." By this process the culm and waste material is carried back into the mines, with water, and allowed to fill part of the abandoned portions of the underground workings. This scheme was first resorted to in 1887, by the Philadelphia and Reading Coal and Iron Company, at their Kohinoor Colliery, near the city of Shenandoah, in the Schuylkill region. Here the Mammoth Vein is about 60 feet in thickness. An immense cavity about 100 yards square had been excavated by former operators, under valuable property in the city of Shenandoah, and it was feared that in case a cave should occur it might cause great damage. In order to prevent this, the cavity was filled with culm from an adjacent culm pile, flushed in with water, through a series of bore holes which were bored for the purpose. The success of this experiment excited considerable comment throughout the anthracite region, and resulted eventually in the repetition of the process at other collieries, for various purposes.

In the Northern coal field the process was first introduced in about the year 1892, at the Dodson and Black Diamond Collieries, operated by Mr. J. C. Haddock, under the superintendency of Mr. James B. Davis. Mr. Davis has since prepared a very careful and exhaustive paper upon the subject, which goes fully into the practical details of the operation. This paper was read on January 12, 1898, at a meeting of the Anthracite Coal Operators' Association, in New York, and was subsequently published in the monthly letter of this Association, issued in February, 1898. Also in March and April issues of *Mines and Minerals*, Scranton, Pa.

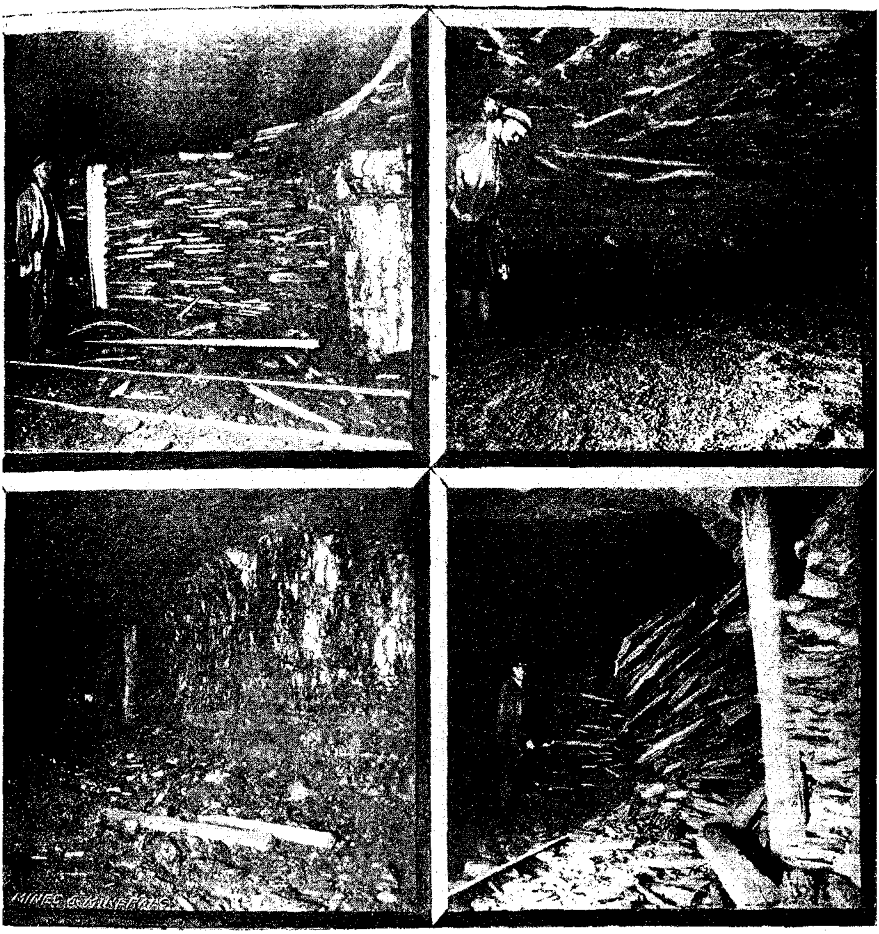
This process of flushing is now in operation at many other collieries throughout the anthracite coal region, although the great majority still cling to the older method of depositing the culm on the surface.

The process is a very simple one. The culm, as it accumulates in the breaker, is carried through a system of "telegraphs" or conveyors to a hopper—usually an oil barrel. A stream of water is also conducted into the same hopper by means of a 3-inch pipe, and the culm is carried by the water through a pipe usually 4 inches in diameter, passing out of the bottom of the hopper. This pipe passes down into the mines through the shaft, or by means of a bore hole, is conducted along the gangways and up the chambers through the cross-cuts to the point where it is desired to deposit the culm. The pipe used is ordinary black wrought-iron pipe. The joints are ordinary screw joints; or more commonly a piece of 4½-inch pipe, about 8 inches long, is split on one side and placed around the pipe, being held together by two clamps. This form of joint is very simple and easy to apply. It leaks for a short time after being put on, but the crevices are soon stopped by the culm and the joint becomes tight. This pipe may be carried from the foot of the shaft either up or down the pitch. Of course, if it is carried up the pitch, more water is required to deliver the same amount of culm than is the case where the pipe is carried down the pitch or level. The culm flows freely through these pipes for long distances, and may be deposited at almost any point in the ordinary anthracite mine. The water is usually turned on about fifteen minutes before the work starts at the breaker, and is allowed to run for about fifteen minutes after work stops in the evening, in order to thoroughly clean the pipe. Occasionally stoppages occur when the pipe becomes filled with culm from one end to the other, which of course requires considerable time and trouble to again clear. It is usually accomplished by breaking a joint near the foot of the shaft and allowing the pressure of the water to force the culm out of a section 100 or 200 feet in length. Connection is then made and again



broken several lengths farther on, and the water used to again clean the pipe. This process is continued until the pipe is all cleared.

The culm issuing from the pipe is discharged in the highest point of the chamber or portion of the mine desired to be flushed, and stoppings are placed at the outlets of the chambers, near the gangways. The culm, as it is deposited from the end of the pipe, takes a very flat slope, and is carried a long distance by the water, which ultimately sinks away and filters through the deposited culm to the lower



portion of the mine, where it is pumped to the surface by the mine pumps.

The stoppings which are used are often simply board partitions placed across the end of the chamber and fitted closely; or sometimes dry walls of slate or mine rubbish are used, a dike of culm being piled behind the wall, through which the water may filter.

When the chamber is filled to the roof the pipe is withdrawn and culm allowed to run into the next chamber, and so on the process continues until the desired area is completely filled with culm.

There are many details of the process which we do not care to enter into at this time. They will be found to be explained at length in the article previously referred to; as also the items of cost and the various advantages of the process from the cost point.

In general, it may be said that the net saving by flushing varies from $5 to $15 per day. In addition to this good showing in favor of the flushing process from the viewpoint of the expense, the advantages of the process are many, perhaps the greatest of which is the help that may be afforded the pillars by flushing culm at the time of a squeeze in a coal mine. During the past years, of course, the coal in the anthracite region has been mined largely from the upper seams, and from those from which coal could be won at the least expense, leaving the deep coals and expensive, dangerous mining for the future. During the mining of these shallow seams with thin overlying roof, the question of squeezes in the coal mines was a matter of comparatively small moment, but now that we are beginning to mine in the deeper portions of the measures, it becomes one of paramount importance. The squeezing and caving of our mines, owing to excessive weight on the pillars, has been the cause of many of the most serious and expensive mine accidents and awful disasters by which many lives have been lost, as well as much property, and will continue to be one of the great dangers of future mining in the deeper measures of the anthracite field. It has been customary in the past to leave about one-third of the coal in the ground, in the shape of pillars to support the roof, but experience now shows that it is necessary to leave a larger amount to support the roof in the deeper lying seams, because pillars composed of one-third the seam are not strong enough in all cases to sustain the weight. Besides this, in some coal seams the pillars, after long standing, are so affected by the action of the air, heat and pressure that they splinter and chip around the margin, and pieces keep continually falling off. This process, if long continued, will often so impair the pillars of an old working, that they become too weak to support the roof, and a cave or squeeze is started. It often happens, also, that in otherwise well-conducted coal mines a limited area of the workings may be so mined that the pillar area averages much less than is intended by the management, and a weak point is made which may start to squeezing. Whatever may be the cause, a squeeze usually starts at some weak point in a mine. And inasmuch as the crushing strength of anthracite coal is about twice the weight required to start it to squeezing or cracking, a considerable time elapses from the moment that the squeeze begins until a crush finally occurs, and, as a rule, ample warning of the impending danger is given by the snapping or grunting of the pillars. As the squeeze progresses at the point of weakness, the pillars become less able to support the overlying weight; consequently, the pressure is transferred to the surrounding pillars, and the result is that the squeeze gradually progresses from the weak point to the other or stronger parts of the mine, gradually squeezing the pillars as it progresses, due to the immense leverage on the adjacent pillars which are still intact.

The method of preventing such squeezes in the past has been to build cribs or "cogs," as they are called, of logs from the floor to the roof and fill them with rock and other refuse of the mines, until a sufficient number of these cogs have been built across the line or direction of the squeeze to take the weight from the adjoining pillars and cause a crack in the roof, which immediately relieves the strain on the adjacent pillars, and the squeeze will stop. Of course, considerable settlement of the roof will occur before the cogs will take the weight, and at best this system of stopping a squeeze in the mine is very imperfect, uncertain and dangerous; whereas, if the weak point of the mine can be filled full of culm by the flushing process, it forms a barrier which no squeeze can cross. The culm effectually fills up the cracks and crevices, all the interstices in the mine gob, and finds its way under the center of the affected parts where no man would dare to go, causing an effectual barrier capable of sustaining an immense weight; also protecting the pillars from further chipping, by excluding the air.

Now the question arises and is of considerable interest, as to how much the confined culm will be compressed by the weight of the roof, or how much it will settle. Mr. Davis ascertained by experiment that a cubic foot of anthracite coal ground to culm would be flushed into a space of nearly $1\frac{1}{2}$ cubic feet. Therefore it was impossible to compress the culm more than one-third, because it would then occupy the same space as the solid coal. In order to determine the compressibility of culm under these conditions, we have recently made a few experiments in this line. The first and second experiments were with wet culm; the third with dry culm. A section of 4-inch wrought-iron pipe $9\frac{1}{4}$ inches long was flushed full of culm and after the water had drained off, was placed in a hydraulic press and the pressure required to compress the culm noted. The same was done in the second experiment, using a pipe 3 inches internal diameter and $15\frac{1}{4}$ inches long. In the third test a cylinder of cast iron $3\frac{3}{8}$ inches diameter and $13\frac{7}{8}$ inches long was flushed full of culm and placed on top of a nest of boilers for about a week until it became thoroughly dry. The results of these tests are shown in the following tables, indicating tests Nos. 1, 2 and 3 in triple columns. It will be noted that, other things being equal, dry culm will withstand two or three times the weight of wet culm. It requires a long time for culm to dry after being flushed into the mine. It is not often, therefore, that dry culm could be depended upon to withstand the weight of a mine squeeze. However, when it does become dry it is so firmly compacted that gangways may be driven through it having vertical walls of culm on either side which show only a slight tendency to caving.

While these tests are very crude and the results are rather varied and altogether unsatisfactory, still, so far as our knowledge goes, they are the only tests ever made in this particular line and we trust are only the beginning of more extended ones to be carried forward under more exact methods and more favorable conditions. They are introduced here because they will serve to at least give a better idea of the extent to which culm may be depended upon to hold the roof of a caving mine, which has heretofore been a matter of mere conjecture by engineers of the coal fields.

Compression in Inches.	Weight in Tons.			Tons, Weight Per Square Inch.			Per Cent. of Compression.			Remarks.
	1	2	3	1	2	3	1	2	3	
½	—	2	6	—	·29	·67	—	3·28	3·7	
1	—	4	9	—	·57	1·0	—	6·56	7·44	
1½	7	6	14	0·56	·85	1·57	16·	9·83	11·16	
2	13	8	23	1·04	1·14	2·57	21·6	13·12	14·88	
2½	34	12	35	2·72	1·71	4·0	27·0	16·3	18·6	Test No. 1. Pipe began to expand.
2¾	34	—	48	—	—	5·4	—	—	20·46	Test No. 1. Pipe burst.
3	—	19	56	—	2·71	6·26	—	19·67	22·34	
3¼	—	—	61	—	—	6·82	—	—	24·18	
3⅜	—	26	—	—	3·71	—	—	22·14	—	
3½	—	—	70	—	—	7·83	—	—	26·04	
3⅞	—	38	—	—	5·43	—	—	25·42	—	Pipe burst.

Test No. 1. 4-inch gas pipe 9¼ inches deep, flushed full of culm and drained.
" " 2. 3 " " " 15¼ " " " " " " " "
" " 3. 3⅜ " cast cylinder 13 7/16 " " " " " " "thoroughly dried

We note by test No. 2 that to produce a compression of 10 per cent. would require about $\frac{9}{10}$ of a ton in weight per square inch. Therefore, in a 5-foot seam of coal, if we assume the superincumbent strata to weigh about 145 pounds to the cubic foot, a pressure of about $\frac{9}{10}$ of a ton per square inch would be produced by a column of sandstone 1,800 feet high. In a 5-foot seam which had been completely flushed with culm the compression caused by this weight would be about $\frac{1}{2}$ foot, an enormous resisting power.

From the experience of the past, as well as tests which we have recently made, we know that the pillars of a coal mine will begin to squeeze when the pressure upon them amounts to from 400 to 4,000 pounds per square inch, depending upon the thickness of the bed, quality and firmness of the coal and the conditions under which it is mined. Therefore, for example, to show the utility of flushing, if we assume mining at 500 feet depth in a bed in which we know by test that the weakest bench of coal will begin squeezing at 1,500 pounds per square inch, if two-thirds of the coal in such a mine be exhausted, we know we have a weight on the pillars which is liable to start a squeeze at any moment, particularly if in any part of the workings the pillars average less than one-third the whole, or the pillars of the seam are subject to much chipping. Therefore, by examination of the mine and the maps, the engineers may select the weak points and flush them with culm, knowing that if a squeeze should start, the roof could settle only about 3 to 8 per cent. of the thickness of the bed; or, if the culm were dry, only about 2 per cent., after which the culm would take the weight and stop the squeeze. From which it may readily be seen that culm flushed into the mines by this process becomes an ample and positive safeguard against the crushing of the mine, if properly done. Of course, in case of robbing or remining the pillars after flushing, the settlement would be much greater than above stated, unless the space formerly occupied by the pillars be reflushed.

The advantage also of culm as a preventive of mine fires must be conceded. It has been supposed that the culm thus deposited would be subject to spontaneous combustion, as is so often the case with culm piled on the surface. Experience, however, shows that spontaneous combustion is not liable to occur under these conditions. Many tests have been made by digging through the culm to the bottom rock, but in nearly all cases no sign of heat or fire has been discovered, and there is no case on record, so far as we are informed, of the culm thus deposited taking fire spontaneously.

We know of no attempt to use a mixture of culm with water for the purpose of drowning a mine fire, but it would seem that it might readily be used for this purpose, since by placing the proper stoppings around the fire, as is usually done, for excluding the air, that water and culm could be flushed in through borings from the surface until the space was completely filled with wet culm. This method would effectually exclude the air, and in all probability stop the fire, particularly if water was kept running in the bore hole, so that it could seep through the culm, in order to keep it wet.*

There are many other advantages which might be named in favor of this process, but we have not time to consider them here. There is one other point, however.

The question will of course arise as to how much additional coal may be mined by first flushing the old workings with culm and then extracting the pillars. This may be safely done and is a very advantageous way of robbing pillars where the surface contains valuable property which cannot be disturbed. The quantity of coal which may thus be recovered in addition to that obtained by the first mining over is a question which is entirely controlled by the thousand and one conditions which obtain at each colliery. In some cases little coal, in others much; perhaps 20 per cent. or more may be saved, providing the mine is worked and portions flushed with the view of remining it. This process has been considered so advantageous that at some particular mines in our Northern coal field they are now taking the culm from the old banks without rescreening to save the small sizes, passing it through rollers to grind up the large particles, and flushing it into the mine for the purpose of filling up, with the idea of remining the pillars or preventing a squeeze at particular parts of the mine, and so on.

It is quite likely that this process will become more and more used as the coal approaches exhaustion, and especially will this be the case in connection with the deep mines of the future. So that this question of the flushing of culm

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* Since above was written instances have been recorded where culm has been thus used successfully for stopping mine fires. See *Mines and Minerals*, February, 1900.

in the mines may eventually be expanded to the larger question as to whether or not it may be advantageous, when facilities warrant, to flush sand, loam and other material from the surface into the mines, for the same purpose. In our opinion it is quite likely that we may ere long see the time when this may be done to advantage in particular cases.

ELECTRICAL SECTION.

Read at the stated meeting held November 28, 1899, and discussed at the stated meeting held February 27, 1900.

INCANDESCENT LAMPS.

By Francis W. Willcox.

The commercial incandescent lamp is now in its twentieth year. In this short period it has grown from a weakling to a giant of industry. The value of the manufacturing lamp business of the United States alone aggregates over $2,000,000, with a total production of between 15,000,000 and 20,000,000 lamps per year, and European factories will swell this total output to over 25,000,000 per year.

Assuming the value of a lamp at 20 cents, we have an annual expenditure of between $4,500,000 and $5,000,000, paid for this one detail of electric lighting—certainly a significant index of the great value of the electric industry.

Although an apparently small detail of electric lighting, the incandescent lamp is the most important part of the system.

Some one has well said that the incandescent lamp is the very soul, the essence of electric lighting, and it is an evident fact that electric lighting cannot improve any faster than the art of lamp manufacture permits.

Electric lighting waited for the production by Edison of a successful incandescent lamp. The improvements in electric machinery and methods of distribution, the refined results obtainable to-day, have caused more dependence than ever to be placed upon the incandescent lamp, and have accentuated the need and the importance of the most superior quality of lamp to secure the best results.