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BITUMINOUS COAL STORAGE PRACTICE

BY

H. H. STOEK

C. W. HIPPARD

W. D. LANGTRY

BULLETIN No. 116

ENGINEERING EXPERIMENT STATION

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UNIVERSITY OF ILLINOIS
ENGINEERING EXPERIMENT STATION

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BY

H. H. STOEK
PROFESSOR OF MINING ENGINEERING

C. W. HIPPARD
RESEARCH GRADUATE ASSISTANT

W. D. LANGTRY
PRESIDENT, COMMERCIAL TESTING AND ENGINEERING COMPANY

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THE STORAGE OF BITUMINOUS COAL

I. Introduction

1. *Interest in Storage of Coal.*—One result of the coal shortage during the winter of 1917-1918 was to impress upon the general public, and particularly upon the Fuel Administration, the necessity of having a coal pile on which to draw in time of stress such as occurred during the winter of 1918.

Upon the recommendation of the Illinois Fuel Administration, a systematic campaign was instituted by the United States Fuel Administration in Washington, urging people to store coal. The conclusions and recommendations of the Engineering Experiment Station Circular No. 6* were reprinted in condensed form and given wide publicity by several State Fuel Administrations, by the Retail Coal Dealers Association of Illinois and Wisconsin, and by the National Board of Fire Underwriters. As a result of this campaign, it is safe to say that never before had so much attention been paid to the storage of coal as was the case in the spring and summer of 1918.

During the past year unusual attention has also been given to the subject of coal storage in England and in Canada and the conclusions which were reached in these countries, and which will be referred to later in fuller detail, agree very closely with the experience in the United States.

Details as to the amounts of coal in storage at different periods and the methods used to stimulate storage will be found in the reports of the Fuel Administration.

2. *Conditions under which Coal Was Stored.*—The present bulletin aims to supplement Circular No. 6 by presenting information secured in a further study of the shortage of coal under conditions somewhat different from those that existed prior to the publication of Circular No. 6 in the early part of 1918. These new conditions were:

(1) On account of the pooling of coals from a number of different districts and the zoning system of distribution

* "The Storage of Bituminous Coal," by H. H. Stoek. Univ. of Ill., Eng. Exp. Sta. Circular No. 6, 1918.

under the United States Fuel Administration during 1918, many were compelled to buy a different coal from that to which they had been accustomed in the past.

(2) It was often impossible to secure continuous shipments of the same coal; therefore it was frequently necessary to store a mixture of coals.

(3) Owing to the great demand for a maximum output under war conditions, less care was given to the preparation of the coal, with regard both to its sizing and to the separation of impurities; consequently much coal was stored that was not suitable for the purpose.

(4) Owing to the campaign for storing coal carried on mainly by government agencies, undoubtedly much more coal was stored than under ordinary conditions, and much of this was stored by people without any previous experience in the storing of coal.

In some cases, therefore, the results of storage during 1918 were discouraging to those who had no previous experience in storing coal. One purpose of this further study of the subject was to find out the experience of those who stored under these unusual conditions and, if necessary, to modify the conclusions and suggestions contained in Circular No. 6.

3. *Sources of Information.*—The data for the present bulletin were obtained:

(1) From a questionnaire sent to the same individuals or companies upon whose experience the conclusions published in Circular No. 6 were based. These included about two hundred individuals, manufacturing concerns, railroads, coke plants, etc., that had stored coal under widely differing conditions.

(2) From a similar questionnaire which, through the cordial coöperation of JOSEPH HARRINGTON, Administrative Engineer of the Illinois Fuel Administration, was sent to about eighteen thousand power plants in Illinois. From this questionnaire about three hundred answers were received.

(3) From a careful study of fires in coal piles in Chicago. This study was made by W. D. LANGTRY in con-

nection with work begun under the Conservation Department of the United States Fuel Administration in Illinois. J. C. McDONALD, chief of the Bureau of Fire Prevention and Public Safety of Chicago, for a period of six months beginning about May 1, 1918, reported daily all fires in coal piles in Chicago and either MR. LANGTRY or MR. HIPPARD, Research Assistant in Mining Engineering of the Engineering Experiment Station, investigated most of these fires and, in many cases, took photographs of them.

(4) From investigations made by the authors of this bulletin of fires which occurred in Mattoon, Decatur, Rock Island, Moline, Davenport, Aurora, Champaign, Urbana, St. Louis, and Milwaukee. The fires in these cities had been reported either to the local fire departments or to the County Fuel Administrators who were most helpful by notifying the authors of coal in storage and of fires. The conditions under which fires occurred in these cities were similar to those under which fires occurred in Chicago.

(5) From information furnished through the cordial coöperation of E. A. MCAULIFFE and the following supervisors of the Fuel Conservation Section of the United States Railroad Administration: E. P. ROESCH, ROBERT COLLETT, B. R. FEENY, H. C. WOODBRIDGE, N. CLEWER, J. W. HARDY, and L. R. PYLE.* S. W. PARR, Professor of Industrial Chemistry, University of Illinois, whose bulletins on spontaneous combustion are well known, has been most helpful through suggestions and criticisms of the manuscripts. MR. HIPPARD not only coöperated with MR. LANGTRY in studying Chicago fires, but also compiled the data secured in connection with these fires and the replies to the several questionnaires. So many have coöperated in gathering information that it is impossible to give adequate credit to all by name.

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* See "Storage of Coal by Railroads during 1918," by H. H. Stoek. Inter. Ry. Fuel Assoc. Proc., 1919.

II. Summary of Conclusions

It is believed that the following conclusions will be helpful to any one who expects to store coal. These conclusions and the evidence upon which they are based are discussed in detail in the subsequent pages of this bulletin.

4. *Preliminary Considerations.*—

(1) Storage of coal insures the consumer a regular supply of coal, assists in equalizing freight traffic on the railroads, and helps to stabilize the operation of coal mines.

(2) The storage of coal should not be undertaken without a careful consideration of the practice of those who have stored coal successfully.

(3) Before it is time to begin the actual storing a suitable place should be prepared and a policy outlined far enough in advance so that every one who will have to do with the storing can receive definite instructions and not mere suggestions. It is unwise to wait until the coal to be stored is on the track and then to dump it anywhere so as to release the cars promptly. When storing begins, the instructions should be carried out to the letter. Many failures in storing coal have been due, not to faulty instructions, but to the fact that the instructions have not been followed.

5. *Preparation of Place of Storage.*—If possible a place should be chosen that is dry and well drained; if not drained naturally, drains should be provided about the storage pile, not underneath it, as a drain beneath a pile may produce an air current up through the pile and thus assist spontaneous combustion.

Coal should not be dumped on ground covered with ashes or refuse of any kind, because often in addition to furnishing flues for the admission of air, such refuse contains combustible material; furthermore, the presence of such refuse will depreciate the value of the coal when it is reclaimed from storage. If possible, the ground should be cleared of vegetation and leveled off, so that the reclaiming of the coal will be made as easy as possible and that, in reclaiming, dirt and refuse will not be taken up by the shovel or by other devices used. There is some justification for the objection of firemen to using coal that has been stored, because of the dirt and other refuse that has been mixed with the coal in taking it from the storage pile. A hard clay bottom thoroughly drained is desirable, if a concrete is too expensive.

If possible, adequate space should be provided so that the coal can be moved, if heating occurs. Coal should not be piled around hot pipes, against a boiler, against hot walls, around a chimney, or in any place where it will be subjected to outside heat, because the liability to spontaneous combustion increases rapidly with a rise in temperature. Coal should not be stored above flues that will permit a current of air to enter the coal pile; hot air such as that from a sewer is particularly to be avoided.

6. *Time of Year for Storage.*—In order best to equalize transportation facilities, to help stabilize mine operation, and sometimes to take advantage of lower prices, coal should be stored between the first of May and the first of September. However, as these are the hottest months of the year, special precautions should be taken both in storing and in watching the coal after it is placed in storage. Coal is a poor conductor of heat and if coal that is already at a high temperature is covered by other coal, it retains the heat and is much more liable to spontaneous combustion than coal that is stored at a lower temperature.

7. *Kinds of Coal which May Be Safely Stored.*—It is probably true that all varieties of bituminous coal have been stored without fire resulting, and equally true that all varieties of coal have fired when stored. These facts do not mean that all coals store equally well, as there is undoubtedly a difference in coals in this respect. The kind of coal that is to be stored should be specified. Coals that are known to be particularly liable to spontaneous combustion should not be selected for storage if it is possible to avoid doing so. If there is no choice of coal to be had, greater precautions in piling and in watching storage piles will be necessary.

The spontaneous combustion of coal is due largely to the oxidation of fine coal; consequently, the liability to spontaneous combustion in stored coal is greatly reduced and in many cases eliminated if dust and fine coal can be kept out of the pile.

Hence, if possible, cleaned, screened coal of a uniform size should be chosen, the larger the lumps the better, so as to give the greater number of voids in the pile. Coal of one size is better than a mixture of sizes.

Sized coal should not be stored upon a foundation of fine coal.

The coal should be handled in such a way as to prevent breakage as much as possible. If there is a choice of coals for storage, the least friable should be chosen and the one in which there is the least fine material.

While many varieties of mine-run coal cannot be stored safely under ordinary conditions because of the presence of fine coal and dust, such coal has been successfully stored in small, low piles. In storing mine-run coal, it should be piled uniformly so as to prevent segregation of the sizes.

As fine coal or slack is more liable to spontaneous combustion than clean sized coal, it should be very carefully watched in storage to detect evidence of heating.

8. *Sulphur in Coal.*—Although experimentation has shown that the sulphur contained in coal in the form of pyrites is not the chief cause of spontaneous combustion as was formerly supposed, yet the oxidation of the sulphur in the coal not only produces heat but also assists in breaking up the lumps and thus increasing the amount of fine coal in the pile. Any considerable rise in temperature from either external or internal sources promotes the oxidation of the iron pyrites. This oxidation produces heat and thus increases the liability of the coal to spontaneous combustion. It is wise to select low sulphur coals for storage if obtainable, but it must not be taken for granted that a low sulphur coal will necessarily store well.

9. *Method of Piling.*—

(1) Coal should be so piled for storage that any part of the pile can be moved promptly if necessary.

(2) Coal should be so piled that air may circulate freely through it and thus carry off any heat generated, or else so closely packed that air cannot enter the pile; i.e., under

water storage conditions should be approximated as nearly as possible.

(3) Stratification or segregation of fine and lump coal should be avoided, since an open stratum of coarse lumps provides passage for air to reach the fine coal but not in sufficient quantity to keep down the temperature of the pile. Coal should be spread in horizontal layers and not dumped in conical piles, for in the latter case the fine coal stays in the center at the top of the pile and the lumps roll to the bottom.

(4) The depth and area of storage piles will be determined largely by the storage space available and the mechanical appliances to be used. Other conditions being equal, the deeper the pile and the greater its area the greater the difficulty in inspecting it, and in moving it quickly if necessary. Hence, a number of small piles, if practicable, are better than one large pile. Lack of space, however, usually prevents such spreading out of the coal. It is impossible to specify exact heights as so much depends upon the kind of coal and upon local conditions.*

(5) The hazard of spontaneous combustion seems to be independent of whether the coal is piled in the open or under cover.

10. *Moisture.*— The exact effect of moisture in connection with spontaneous combustion is not known, and, as shown in later pages, the evidence of laboratory experiments is contradictory.

The repeated wetting and drying of coal seems to increase the tendency to spontaneous combustion. This may be due to the breaking up of the coal which such alternate wetting and drying occasions, even if there is no chemical reaction between the water and the coal. It is not wise to put wet coal into a pile, or to store coal on a damp base if it can be avoided. After a rain or snowstorm a coal pile should be carefully inspected and watched.

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* The Railroad Administration has suggested piling coal for railroad storage not over twelve to fifteen feet in height when the track is placed on top of the coal pile, and not over twenty feet when a locomotive crane is used.

The Home Insurance Company advises against piling in excess of twelve feet, or more than one thousand five hundred tons in any pile, and suggests trimming the piles so that no point in the interior is more than ten feet from an air cooled surface. These are wise precautions, but frequently impossible of application on account of lack of storage space.

Water is an effective agent in quenching fire in a coal pile only if it can be applied in sufficient quantities to extinguish the fire and to cool the mass. The water must be applied at the source of the fire, for it can do little good if the stream is only played on the surface. To be sure that the water reaches the fire it is usually necessary to turn over the coal.

It is advisable to have water and hose available for use in case of necessity, but water should be used carefully and only as a last resort after other means, such as moving the coal, have been tried to lower the temperature. An effort should be made to determine the seat of the heating and to remove the coal affected, which should be spread out on the ground and allowed to cool off in the air, if possible. Only in case of necessity should water be used to cool it. If coal is ablaze it is necessary to add water, which very often will so control the fire that the danger to surrounding buildings is reduced, and more time is allowed to move the coal. Coal that has once heated should preferably be used at once and not be returned to the pile.

11. *Inspection and Precautions.*—There should be an inspector at each storage pile who not only is competent to inspect the coal furnished but who also has authority to reject it if not according to specifications and to see that the storage instructions are carried out.

Coal in storage should be inspected regularly and if the temperature reaches 140 degrees, the pile should be very carefully watched. If the temperature continues to rise rapidly and reaches 150 to 160 degrees, the coal should be moved as promptly as possible and the coal thus moved should be thoroughly cooled before being replaced in storage, or still better, it should be used at once. If the temperature rises slowly the pile should be carefully watched, but it is not necessary to begin moving the coal at as low a temperature as when the rise is rapid, for the temperature may recede and the danger be past.

Coal should be moved before it actually smokes. Such smoking is reported to begin at 180 degrees Fahr., though there is no very definite information on this point. Steaming should not be confused with smoking, for steam is frequently seen coming from a pile and this does not necessarily indicate a danger point. Temperature tests of coal in storage should be made, if possible, and one should not depend on such indications of fire as odor or smoke coming from the coal.

for when the coal reaches this stage it is well along in the process of combustion. Every storage plan should give special attention to loading out the coal quickly and promptly, if necessary.

Inflammable material, such as waste, paper, rags, wood, rosin, oil, and tar in a coal pile often form the starting point for a fire, and every effort should be made to keep such material from the coal as it is being placed in storage. Irregular admission of air into the coal pile around the legs of a trestle, through a porous bottom such as coarse cinders, or through cracks between boards, etc., should be avoided.

It is very important that coal in storage should not be subject to such external sources of heat as steam pipes, because the susceptibility of coal to spontaneous combustion increases rapidly as the temperature rises.

The effect of ventilating of coal piles is a disputed point, but the weight of evidence in the United States seems to be against the practice. This may possibly be due to the fact that ventilation has been inadequately done. The imperfect ventilation generally attempted in the United States is certainly disadvantageous, though reports from Canadian practice favor ventilation.

About 75 per cent of the coal pile fires studied have occurred within ninety days after the coal was placed in storage; hence particular attention should be given to the pile during the first three months that it is in storage. The greater the area of the pile exposed to the air the more quickly will the danger be passed.

Coal stored during the summer should, if possible, not be drawn on in the early fall, as is so often done, but kept for the time of congestion in railroad traffic, which usually occurs from December to March.

Finally, safety in the storage of coal depends upon careful attention to the details given in the foregoing conclusions, which represent the experience of a large number of those who have stored coal in amounts varying from a few tons up to hundreds of thousands of tons, and under widely different conditions.

A storage plan must consider all of the conditions, and not only a part; for instance, clean, lump coal of a certain kind may be stored with perfect safety in high piles; while the same coal, run-of-mine or unscreened, may not be safely stored at all, or at least only in small piles. Lack of attention to details in storage or failure systematically to inspect storage piles and to be ready for any emergency that may occur, may result in losses from fires.

For such amounts as are required by the ordinary householder, namely, ten to twenty tons a year, it can be positively stated (a) that there is little or no danger of spontaneous combustion if the foregoing suggestions are followed and (b) that there is no appreciable deterioration in the heating value.

As the amount of coal stored increases, increased care must be taken in the method of storing and in watching the coal after storage.

III. Experience in the Storage of Coal during 1918-1919

Data Secured by Questionnaires

12. *Introduction.*—As was previously mentioned, an effort has been made by means of questionnaires to secure information that would confirm, modify, or refute the conclusions upon the storage of coal as given in Circular No. 6.

Questionnaire *A* (see Appendix I) was sent to those from whom the information was obtained that was used in the preparation of Circular No. 6. This list included about one hundred and seventy-five individuals and companies who stored coal under widely different conditions and in greatly differing amounts, varying from the ordinary householder storing from ten to twenty tons, to such industries as the by-product coke companies, wholesale distributors of coal, large utilities companies, railroads, etc., storing as high as hundreds of thousands of tons. An effort was also made to include all varieties of storage; i. e., at the mines, by railroads, by large and small power plants, etc.

Questionnaire *B* (see Appendix I) was sent to the power plants of the State through the courtesy of Joseph Harrington, Administrative Engineer, United States Fuel Administration, Chicago.

It is realized that data obtained by questionnaires are somewhat uncertain, because of the difficulty of having those who fill out the questionnaires understand fully just what is desired in answer to the questions, and also because the data furnished may be interpreted in a sense different from that intended by the one filling out the questionnaire. However, it is probable that these difficulties are more than balanced by the much larger amount of material that can be gathered by the questionnaire method; by averaging a large number of answers these inaccuracies are minimized. As far as possible any ambiguity in the answers was cleared up by additional correspondence.

The data for the fires in Chicago were secured in person by either Mr. Langtry or Mr. Hippard who had unusual opportunity for obtaining first-hand information concerning these fires.

In tabulating and studying these data many variables must be considered, which are so interrelated that great care must be taken to avoid drawing erroneous conclusions from any one set of figures by failing to consider them in their proper relation to the other factors, even when these related factors cannot be expressed in the tabulated material. Therefore, general conclusions should not be drawn from isolated statements and tables.

13. *Kinds of Coal that Can Be Stored.*—Table 1, giving a statement of fires by districts from which the coal was obtained, not only substantiates the conclusions published in Circular No. 6 that

TABLE No. 1

GEOGRAPHICAL SOURCES OF SUPPLY OF STORED COAL

District	Questionnaire *A*						Questionnaire *B*					
	Fired		Not Fired		Total		Fired		Not Fired		Total	
	Not Mixed	Mixed	Not Mixed	Mixed	Not Mixed	Mixed	Not Mixed	Mixed	Not Mixed	Mixed	Not Mixed	Mixed
Arkansas		1				1						
Cape Breton	1				1							
Colorado		1	1		1	1						
Eastern Pool	1				1							
Illinois:												
Christian-Macon Co.							12	2	30	1	42	3
Danville	1				1		1		1		2	
Franklin Co.	4	4	8	2	12	6	15	5	88	4	103	9
Longwall		1				1	5		21		26	
Peoria	2				2		7	1	9		16	1
Saline	1		1		2		2	1	7	1	9	2
Springfield	4	3			4	3	11	2	26	1	37	3
Standard	1	1	3		4	1	7	1	10	1	17	2
District not known	2	2			2	2	3		19		22	
Illinois and Indiana							1		2		3	
Indiana:												
Clinton			3		3		1				1	
Mercer Co.							1		1		2	
Northern				1		1						
Pike							1				1	
Terre Haute								1	1	2	1	3
No. 4 Vein	1		2		3							
District not known		2				2	1				1	
Iowa		1				1						
Kentucky	2	2		2	2	4			2	2	2	2
Lake Ports Pool	3				3							
Michigan, Bay Co.	1				1							
Ohio	1	1	1	1	2	2			1		1	
Oklahoma		1	1		1	1						
Pennsylvania												
Anthracite			1		1							
Bituminous	4		4		8			1				1
Red Lodge (Montana) sub-bit.			1		1							
Virginia									1		1	
West Virginia	2	3	2	4	4	7			3	1	3	1
Totals	31	23	28	10	59	33	68	14	222	13	290	27

"most varieties of bituminous coal may be safely stored if of proper size and free from fine coal and dust," but also suggests the even more general conclusions: *that although practically every kind of bituminous coal has been stored without spontaneous combustion occurring, yet under certain conditions spontaneous combustion has occurred with practically every kind of coal stored.*

Table 1 also shows that the percentage of fires in piles of mixed coals is considerably greater than in piles of the same coals unmixed. Although no satisfactory explanation of the phenomenon has been offered, the opinion is very generally held that a mixture of two coals is more liable to spontaneous combustion than either one separately, and all the evidence gathered seems to support this opinion.

The Commonwealth Edison Company of Chicago, which has been very successful in storing large amounts of coal, reports that between February 26 and April 14, 1918, it stored at the Fisk Street plant about 3000 tons of central Illinois coal, principally egg and lump from one particular mine and a small amount of coal of the same size from two other mines, one located in central and the other in southern Illinois, together with six cars of run-of-mine coal from the same mines. The ground was cleared of old coal before the new coal was stored. During the early part of August, 1919, the pile was found to be heating and a part was removed and used at once.

Another phase of the question concerns the placing of fresh coal upon coal that has been in storage for some time, and a number of fires have been cited as taking place at the junction of the fresh and the old coal soon after the fresh coal had been placed in storage. For several fires investigated by the writers there was no other apparent cause. No explanation of this has been offered, and it is a subject requiring further investigation.

14. *Sizes of Coal that Can Be Stored.*—Tables 2 and 3 show that the fire hazard for piles of clean, sized coal is relatively small, compared with that for piles of screenings or mine-run, and that the size is an important factor in connection with storage. Table 2 shows that 56 per cent of all the piles of mine-run fired, and that 85 per cent of the piles of screenings fired. Table 3 shows that 88 per cent of the fires occurred in mine-run or screenings. Of the 98 storage piles of mine-run about 23 per cent fired, while of the 86 storage piles of screenings, 51 per cent fired. Of the 132 storage piles of sized coal less than 7 per cent fired.

These results appear conclusive enough to support the recommendation that screenings or mine-run should not be stored in large quantities excepting under water, but if it is necessary to store these sizes in any other way, they should be very carefully watched for evidences of heating and means provided for rapidly and promptly moving the coal if heating is detected. A mixture of sizes gives a pile much less void space and hence the heated air is less readily carried off.

TABLE 2

EFFECT ON SPONTANEOUS COMBUSTION OF SIZE OF COAL

QUESTIONNAIRE *A*

Size of Coal	Fired			Not Fired			Total
	No.	Per Cent of Total	Per Cent of Given Size	No.	Per Cent of Total	Per Cent of Given Size	
Lump (over 1¼ in.)	2	4.44	33.33	4	12.12	66.67	6
Lump (¾ in. to 1¼ in.)	3	6.67	42.86	4	12.12	57.14	7
Egg	0	....	....	1	3.03	100.00	1
Mine-run	*22	48.89	56.41	17	51.51	43.59	39
Screenings	18	40.00	85.72	3	9.10	14.28	21
Buck (anthracite)	0	....	....	1	3.03	100.00	1
Nut	0	....	....	1	3.03	100.00	1
No. 1 nut	0	....	....	1	3.03	100.00	1
No. 4 nut	0	....	....	1	3.03	100.00	1
Totals	45	100.00	....	33	100.00	....	78

* Three of these piles were a mixture of mine-run and screenings in about equal proportions.

TABLE 3

EFFECT ON SPONTANEOUS COMBUSTION OF SIZE OF COAL

QUESTIONNAIRE *B*

Size of Coal	Fired			Not Fired			Total
	No.	Per Cent of Total	Per Cent of Given Size	No.	Per Cent of Total	Per Cent of Given Size	
Lump (2 in. or over)	1	1.32	1.96	50	20.83	98.04	51
Lump (¾ in., 1 in., 1½ in.	0	....	....	5	2.08	100.00	5
Egg	2	2.63	6.25	30	12.50	93.75	32
Mine-run	23	30.26	23.45	75	31.25	76.55	98
Screenings	44	57.89	51.16	42	17.50	48.84	86
No. 1 and No. 2 nut	1	1.32	3.85	25	10.42	96.15	26
No. 3 and No. 4 nut	5	6.58	27.80	13	5.42	72.20	18
Totals	76	100.00	....	240	100.00	....	316

These results are confirmed by the experience in England and John H. Anderson of Purfleet, England, says†:

† Trans. Inst. of Marine Engineers, June, 1918.

"When the coal is at a low temperature this oxygen absorption is very little; therefore, there is not much heat generated, and in many cases this little heat escapes to the atmosphere just as fast as it is generated. This is generally the case with the larger coals or coals free from small dust when there is usually a path here and there sufficient to allow the heat to get through to the surface by natural means.

"On the other hand, heaps may be composed of small coal, which may be so dense that there will not be sufficient apertures or paths for the generated heat to escape; the consequence is that this heat gathers, thereby increasing the temperature of the coal, and incidentally, due to the increase of heat, it increases the rapidity and capacity for further oxygen absorption in a given time, thus giving off more heat in a given time than when the heap was cooler.

"It will be seen from this that if a heap has a tendency to rise in temperature steps must immediately be taken to arrest this, otherwise the increase of heat will be so rapid after a time that it will not be possible to cope with it unless drastic measures are taken, such as to turn over the heap, or as it has happened before, letting it burn itself out.

"The liability of small coal to create spontaneous combustion is very pronounced, both from its size and also from it closing up the paths whereby the heat generated would otherwise escape freely to the atmosphere. I suggest that most of the oxidation is superficial and, therefore, if the smalls absorb more oxygen, they generate more heat in a given time than the larger coal, and therefore, small coal is more liable to fire than large coal, particularly if steps are not taken to let this heat out. This means that there is one safe height that must not be exceeded, but as there are other factors that must be taken into consideration at the same time, it would be almost impossible to fix this height for every heap. The height of pile can be increased above this safe height, providing means are taken to vent it. The more it is vented the higher the heap can be piled. Generally speaking, 12 to 14 feet is about as high as one should deposit small sized coals; 9 to 12 feet for unwashed mixed coals; for slack a great deal depends upon the composition. Two heaps of slack were allowed to rise 120 degrees before moving. These heaps gave considerable trouble at a height of 10 feet, but even when the height was reduced to 6 feet, there was a tendency to increase in temperature. My opinion of the cause of the trouble was bad washing of the material; thus after a shower, the shale-like material formed a plastic mass with the coal practically preventing any escape of heat.

"As a rule, little trouble is experienced in the storage of large coal, but one must be careful even with this, for in event of fire great difficulty will be experienced in putting it out owing to the ready access of oxygen for supporting combustion. Care should be taken not to make any smalls when depositing this coal, and if possible the coal should be selected that will weather best, otherwise that on top will crumble up and fill up the interstices underneath.

"The geological age of coal is a fair guide to its liability to heat, anthracite being the safest to store and lignite the most dangerous. A good guide is the weathering effect on a sample rather prominently exposed and occasionally moistened with water by hand, that which readily crumbles up being the most dangerous but, of course, a great deal depends on the composition of the coal, considering the impurities and foreign material that may be mixed with it.''

The figures given in Table 4 indicate that a mixture of kinds and sizes increases the hazard; but these figures are by no means conclusive as to the effect of mixture of kinds of coal, for the questionnaires show that the mixtures which fired contained fine coal and this may have been the determining factor, rather that the mixture of different varieties of coal.

TABLE 4

RESULTS OF MIXTURE OF SIZES AND KINDS OF COAL

	Questionnaire *A*				Questionnaire *B*			
	Mixture of Sizes and Kinds		Same Size and Kind		Mixture of Sizes and Kinds		Same Size and Kind	
	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent
Fired	31	69	14	31	23	30	52	70
Not fired	12	36	21	64	39	17	185	83

15. *Effect of Depth of the Pile.*—There is a rather common opinion that heating is most likely to occur about five feet from the surface. The table given on page 187 of Circular No. 6 of temperature observed by the Cleveland, Cincinnati, Chicago, and St. Louis Railroad at Hillary, Illinois, shows the highest temperature to occur at points five to ten feet from the top of the pile and that, in general, there is a gradual decrease in temperature below this maximum point.

J. H. Anderson says*:

''From previous experience we found the warmest place to be between 6 and 8 feet deep from the surface; so from this we established a depth of 7 feet as the standard depth to record temperatures.''

John Morison says†:

''It is usual to find that heating commences at a depth of about 5 feet, and if left alone it will spread downward until the coal fires.''

If coal is so piled that the fine portion stays on top of the pile and the lumps roll to the bottom, a point will occur in the pile where the

* Trans. Inst. of Marine Engineers, Vol. 30, p. 83, June, 1918.

† North of England Institute, Feb. 9, 1918.

air supply will be just sufficient to cause combustion of the fine coal but not sufficient to carry away the heated gases. Just where this point will be depends on the height of the pile, kind of coal, and method of storage. The replies to Questionnaires *A* and *B* as given

TABLE 5

EFFECT ON SPONTANEOUS COMBUSTION OF DEPTH OF COAL PILE

Depth of Pile	Questionnaire *A*					Questionnaire *B*				
	Fired		Not Fired			Fired		Not Fired		
	No.	Per Cent of Given Depth	No.	Per Cent of Given Depth	Total No.	No.	Per Cent of Given Depth	No.	Per Cent of Given Depth	Total No.
8 ft. or less......	2	33.33	4	66.67	6	26	18.44	115	81.56	141
8 ft. to 20 ft......	21	52.50	19	47.50	40	37	32.17	78	67.83	115
Over 20 ft........	21	67.74	10	32.26	31	5	41.67	7	58.33	12
Not stated.......	1	....	.....	....	1	7	....	.....	....	35
Totals.......	45	....	33	....	78	75	....	228	....	303

in Table 5 indicate that the percentage of fires increases as the depth of pile increases. While the evidence seems to show that fires are more common in deep than in shallow piles, the reason for this is by no means certain, but any one of the following conditions may contribute to the result:

(1) There is less opportunity for the air to circulate through the pile and to carry off the surplus heat.

(2) The air and gases gradually rising through the pile and increasing in temperature as they do so, may finally reach the temperature of spontaneous combustion of the coal. This opinion is held by many, but if it is true, the greater number of fires should be found near the top of the pile.

(3) There will usually be increased breakage and an increased amount of fine coal which is the portion of the coal most liable to spontaneous combustion.

(4) There is greater difficulty in watching the pile and in detecting incipient heating. Consequently, fires develop in deep piles without detection more readily than in low piles.

16. *Effect of Quantity of Coal in Storage.*—Table 6 indicates that the liability to fires increases with the size of the pile, but the

TABLE 6

EFFECT ON SPONTANEOUS COMBUSTION OF QUANTITY OF COAL IN STORAGE

	Questionnaire *A*					Questionnaire *B*				
	Fired		Not Fired		Total	Fired		Not Fired		Total
QUANTITY	No.	Per cent of given size of pile	No.	Per cent of Size	Total No.	No.	Per cent of Size	No.	Per cent of Size	Total Size
Less than 500 tons	2	50	2	50	4	35	18.61	153	81.39	188
500 to 1000 tons	5	50	5	50	10	11	24.44	34	75.56	45
1000 to 10 000 tons	18	66.67	9	33.33	27	26	40.62	38	59.38	64
10 000 to 100 000 tons	11	47.83	12	52.17	23	0	......	3	......	3
100 000 to 1 000 000	8	66.67	4	33.33	12	....	......	....	......	......
Over 1 000 000 tons	....	......	1	100.00	1	....	......	....	......	......
Not stated	1	......	....	......	1	3	......	0	......	3
Totals	45	......	33	......	78	75	......	228	......	303

same considerations that make the evidence inconclusive for increased hazard with increased depth, apply here; also the term, *Quantity in Storage,* is often indefinite. Ten thousand tons stored in one pile thirty feet high is probably more of a fire hazard than the same amount spread out in a pile only five feet high; but this and other conditions of piling are not evidenced by the statements in the replies received under the heading, *Amount in Storage.* The difficulties of storing and watching a large quantity may increase the fire hazard, but a large quantity is not *per se* more dangerous than a small amount.

17. *Effect of Methods of Piling.*—A study of the effect of the methods of piling indicates that the lowest percentage of fires occurs where the coal is stored by hand. It is, however, only the small low piles which are piled by hand, and as pointed out previously, the depth of the pile and to some extent the quantity of the coal piled are factors in the liability to spontaneous combustion. Any mechanical method of piling should be so devised that there will be the least possible segregation of the sizes of coal and the least possible breakage in handling. The coal should be distributed in layers over the whole

or a considerable part of the pile and not dropped at one point so as to produce a conical pile. In a conical pile the fine material is generally found at the center and the lumps at the outside and toward the bottom of the slope; this arrangement gives a passageway for air to enter the pile and to reach the fine coal near the center, which is the most liable to spontaneous combustion. A number of fires have started at a point within the pile where the flow of the air current was obstructed by the fine coal, thus establishing a condition in which the material most liable to spontaneous combustion was in contact with an excessive amount of oxygen. On account of the rapid oxidation of fine coal, the air current passing through such coal should be greater than that passing through larger sizes, while if the coal segregates in piling just the opposite condition is set up. To prevent breakage the clam-shell or other bucket should be lowered near to the surface of the pile before being dumped.

TABLE 7

EFFECT ON SPONTANEOUS COMBUSTION OF METHOD OF PILING COAL

METHOD	Questionnaire *A*			Questionnaire *B*		
	Total	Fired	Not Fired	Total	Fired	Not Fired
Shoveled by hand	11½	5½	6	201	35	166
Dumped from wagon	1	1	......	......	......	......
Wheelbarrow	1	......	1	4	2	2
Dumped from truck	......	......	......	4	......	4
Wheeled scraper	2	2	......	......	......	......
Dropped from car	......	......	......	9	3	6
Crane (locomotive)	......	......	......	13	7	6
Conveyor	......	......	......	5	4	1
Dropped from car on trestle	1	1	......	......	......	......
Elevator	......	......	......	7	3	4
Bridge	......	......	......	2	......	2
Hydraulic	½*	½	......	......	......	......
In hopper	1	1	......	......	......	......
Not stated	......	......	......	58	21	37
Clam shell	7½	7½	......	......	......	......
Crane	35½	17½	18	......	......	......
Dodge storage system	1	1	......	......	......	......
Belt conveyor	3	1	2	......	......	......
Elevator	1	......	1	......	......	......
Bridge	2	2	......	......	......	......
Raising track on coal	7	3	4	......	......	......
Underwater	1	......	1	......	......	......
Not stated	2	2	......	......	......	......
Totals	78	45	33	303	75	228

* ½ indicates that a storage pile was partly piled by one method and partly by another.

18. *Causes of Fires.*—The question, "What in your opinion was the cause of the fire?" brought forth a number of reasons which are listed in Table 8 for the purpose of expressing popular opinion on the subject.

TABLE 8

CAUSES OF FIRE

Causes of Fire	Questionnaire *A*	Questionnaire *B*
Outside source of heat or aid to combustion in contact with coal		
Ground saturated with oil	2	....
Wood in coal	....	7
Heat from boiler	....	3
Litter from stables	....	1
Rust from embedded steel rails	....	1
Moisture or weather conditions		
Rain	2	4
Blanket of snow	1	....
Wet coal	....	7
Contact wet and dry coal	....	1
Wet ground or water under pile	2	1
Weather condition when coal was unloaded	2	....
Sun	....	2
Sulphur	3	9
No reason evident except coal itself or method of piling		
Lack of ventilation	....	2
Air circulation	3	....
Segregation of sizes	8	1
Fine coal	....	1
Mixture of coal	4	2
New coal piled on old coal	1	....
Pile too deep	2	1
Quality of coal	....	1
No opinion	15	31
Totals	45	75

19. *Extent of Fires When Discovered.*—The extent to which the fire was allowed to progress before discovery has been tabulated, not because it tells anything about the cause of the fire, but because it serves as an indication of the attention given the storage pile:

TABLE 9

EXTENT TO WHICH HEATING HAD PROGRESSED

Condition of Fire	Questionnaire *A*	Questionnaire *B*
Odor only	0	3
Smoke	26	39
Ablaze when exposed	7	13
Ablaze	12	20
Totals	45	75

If precautions had been taken by the ordinary methods of watching for fires and by being prepared to handle them promptly, none of the fires should have reached the point of blazing. If thermometer readings are taken, the heating of the pile can be stopped before it reaches the point where smoke due to combustion is given off. Temperature readings are not taken nearly so often as they should be in watching a storage pile but the following reports are of interest, as showing very imperfectly some relation between observed temperature and the other evidence of firing in a coal pile. The indefinite use of the term, *fire*, renders any generalization from these figures impossible as *fire* and *heating* are too often used synonymously.

TABLE 10

TEMPERATURE OBSERVED IN STORAGE PILES

No Fires Observed		Fires Observed	
		132° Fahr.	Short time before fire
145° Fahr.	Coal moved	180°	Smoking
69°–82°		160°	Smoking
120°	Coal moved	140°	Before smoke seen
		180°	After smoke seen
		185°	Smoking

Temperature readings were not taken in any one of the 75 piles where fires occurred as noted in Questionnaire *B* and in only one case of the 303 reports of storage was there a temperature reading taken. This was 125 degrees Fahr., in the center of a storage pile. When the coal was removed from above this point, the pile cooled off.

20. *Danger Temperatures in Coal Piles.*—One railroad advises loading out the coal if the temperature reaches 100 degrees, but as the temperature in the sun in summer over a large part of the United States is frequently above 100 degrees, this regulation would be impracticable. Moreover, summer is the best time to store much of the coal on account of production and transportation conditions.

J. H. Anderson* says: "Ninety degrees Fahr. was made a warning temperature. One hundred degrees Fahr. was adopted as a danger reading at which point a trench was dug in the pile."†

* Trans. Inst. of Marine Engineers, Vol. XXX, June, 1918.

† See page 36 for method adopted by Mr. Anderson to arrest rise in temperature.

In Circular No. 6, 140 degrees was given as a warning temperature; later studies indicate that if the temperature reaches 140 degrees the pile should be carefully watched and if the temperature continues to rise rapidly to 150 or 160 degrees, the coal should be moved as promptly as possible and the coal thus moved should be thoroughly cooled before being replaced in storage. If the temperature rises slowly, although the pile should be carefully watched, it is not necessary to begin moving the coal at so low a temperature as when the rise is rapid, for the temperature may recede and the danger be passed.

21. *Detection of Coal Pile Fires.*—The common methods of detecting the heating of a coal pile are:

(1) By watching for evidences of steaming in the pile.

(2) By noting the odor given off; bituminous or sulphurous odors are evidences of heating.

(3) By noting places where snow on a pile has melted.

(4) By inserting an iron rod in the pile, and by noting its temperature with the hand after withdrawal.

(5) By inserting thermometers into the pile and reading directly.

(6) By using a pyrometer or plates connected with an automatic recording device.

The first three methods are so self-evident in their application that it is unnecessary to discuss them in detail, but with a large pile, and particularly one where the heating is distant from the surface, a fire may reach an advanced stage without being detected by surface indications.

Method No. 4, by which the temperature of an iron rod is noted with the hand, is a simple test, and one well-adapted to piles not over eighteen to twenty feet deep. By this means a janitor using a poker may keep informed as to the condition of the comparatively small amounts stored in house or apartment basements.

Temperature readings with a thermometer or pyrometer furnish by far the best and most reliable method for keeping informed on the exact condition of a coal pile.

To get the temperature of the inside of a coal pile it is necessary first to provide an opening into which a thermometer or a pyrometer

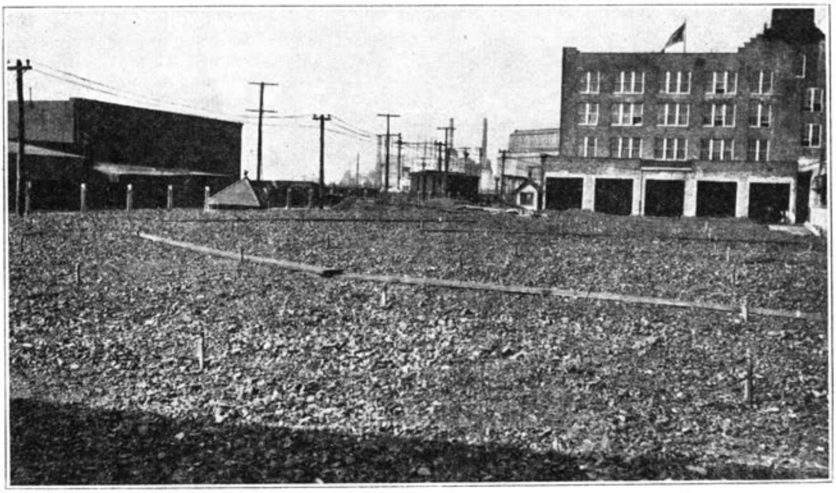

FIG. 1. PILE OF SCREENINGS WITH TEMPERATURE TUBES, CLOSED AT UPPER ENDS BY WOODEN PLUGS

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may be inserted. Such openings may be made after the coal is in storage by driving pipes into the pile, but it is easier to place these pipes when the coal is being stored. Pipes left permanently in a pile are a disadvantage as they interfere with the appliances used to remove the coal. Instead of leaving the pipe in the coal pile it is sometimes necessary only to drive it and then withdraw it, the hole remaining open sufficiently to permit the insertion of the thermometer. To prevent the hole from filling with coal, an inverted funnel of paper is used in Canada.

Such pipes as shown in Fig. 1 should be plugged at the upper end so as to exclude the outside air, for if ventilation is allowed through these pipes, a correct temperature reading of the interior of the coal pile is not obtained.

If an iron pipe of small diameter is forced into the coal pile and is then moved up and down, the small amount of coal which has entered the pipe is removed. To prevent the pipe from filling up with coal as it is driven into the pile, a pointed plug may be placed in the end of the pipe and when the pipe has been forced into the pile to the desired depth the plug may be driven out by means of a rod inside the pipe. Before inserting the thermometer the pipe should be pulled up a slight distance so that the thermometer reading may give the temperature of the coal and not that of the iron pipe.

One answer to the questionnaire described a method of making an observation hole by running a rod into the pile and then moving it around in a circle to form a hole sufficiently large and open for the insertion of a thermometer.

The Arthur D. Little Company, Incorporated, of Boston, makes the holes with a regular coal auger drill which is described as follows:

"These augers are regular mine auger drills and the total length of the auger can be extended indefinitely by sectional parts fitted with screw threads. It is preferable to have a handle for turning the drill, although this can be very easily accomplished by means of a Stillson wrench."

J. H. Anderson* describes a method that he used with success for watching and regulating the temperature of coal piles. A storage pile of about 16 000 tons composed of a variety of coals which would not be stored under ordinary circumstances was chosen for experimental purposes, the depth of the pile varying at different points. The coal was stored on marshy ground above a ditch which had been filled with ashes to the level of the surrounding marsh. Some of the

* Trans. Inst. of Marine Engineers, June, 1918.

coal was deposited during very hot weather and some during heavy rain. Some was dry when unloaded from the steamer and some soaking wet. The conditions thus seemed to be particularly unfavorable and extra care was exercised in watching the pile. Temperature readings were taken at fourteen different places in the pile nearly every day at a depth of seven feet from the surface, as previous experience had shown that the warmest place was between six and eight feet from the surface. This standard depth was also adopted for comparing the results obtained in piles in other parts of the county. Occasional check readings were taken at every foot depth in the pile. The temperature tubes ¾ inch to 1 inch in diameter were driven to the bottom of the coal and were long enough to project two or three feet above the pile. Each tube had a numbered metal label on it for purposes of easy identification. In addition to the temperature pipes about fifty "vent" pipes were placed in the pile, not to ventilate the whole pile, but to draw off hot gases from local points. These pipes were 3 inches to 4 inches in diameter and 8 feet long. About 8 inches along the length four holes were punched from the outside with a square tapered punch to about ¾ inch; thus leaving a burr which prevented the coal from going down inside the pipe. To facilitate driving into the coal pile, the ends of the pipes were flattened chisel-shaped with an aperture about one-half inch left to prevent an accumulation of water at the bottom of the pipe and to permit the escape of air and gases. The pipes were driven to a depth of seven feet in the coal, leaving one foot projecting above the surface. A distinctive number was painted on each so that temperature readings could be properly accredited.

By means of periodical temperature readings a close watch was kept on the pile. Ninety degrees Fahr. was made a warning temperature and when this temperature was observed at any place, four temperature pipes were driven north, south, east, and west about ten feet from the warm pipe. The next day readings of the four pipes were carefully noted and the one showing the highest temperature was made the center and other pipes were put down around it. When the warmest spot was found in this way, a vent pipe was put in at this point and the rise in temperature was generally arrested. The smaller temperature pipes were then removed. One hundred degrees Fahr. was adopted as a danger reading and if the vent pipe failed to arrest the temperature and it reached 100 degrees, a trench one foot deep was dug. If the daily readings were 100 degrees for, say three days, a spot would be trenched three feet deep. The danger temperature originally adopted was 95 degrees Fahr., and on four separate occasions trenching was done at one place, about 10 000 tons of material being removed. As the readings in this pile at no time reached 100 degrees Fahr., the trenching probably would have been unnecessary if additional vent pipes had been used. The coal was 16 feet deep at this point.

A somewhat similar method used by the Boston and Albany Railroad is described by S. Bisbee, Fuel Supervisor, as follows:*

"At one point 2-inch flues sharpened at the end were forced down to the bottom of the pile and worked around, then withdrawn, leaving a hole 3 to 4 inches in diameter, the holes being spaced 5 feet apart. If there is any tendency to heat, the number of holes is increased. Little trouble from spontaneous combustion. One fire started around a wooden pier, and another fire started in a high pile 10 feet from the bottom. Coal below this point found to be cool and no further trouble. Other fires occurred where piles had been placed on cinders. In no place did we have to dig out the coal for a distance of more than 40 feet, showing the spontaneous combustion was due to some local cause and that being removed there was no further trouble."

22. *Appliances for Reading Temperatures.—*

Thermometers

The simplest form of thermometer for obtaining the temperature inside such temperature holes is an armored maximum registering thermometer, as illustrated in Fig. 2.

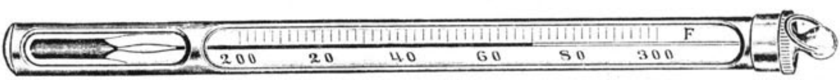

FIG. 2. MAXIMUM TEMPERATURE THERMOMETER — ARMORED TYPE

Thermostats

The Illinois Central Railroad has used at several coal chutes, thermostats which were placed on the bottom plates of the coal bins so that if the coal heated in the bottom of a bin an alarm would be rung. These were installed in connection with an automatic hot journal alarm system furnished by the Western Fire Appliance Company of Chicago.

* "Storage of Coal by Railroads during 1918," by H. H. Stoek. Inter. Ry. Fuel Assoc. Proc., 1919.

Recording Thermometers

A recording thermometer, made by the Foxboro Company, for obtaining the temperature of a coal pile, is illustrated in Fig. 3. It consists of a recording pen that is operated by the vapor tension from a volatile liquid placed in a bulb at the end of a long flexible armored tube. This capillary tube is usually about five feet long but practically any desired length may be used. To register accurately the temperature of the hub must be about that of the atmosphere. The instrument can be equipped with an electrical alarm so that a bell or other means of signal will be operated if the temperature rises to a predetermined danger point.

A cheaper installation consists of a dial thermometer as shown in Fig. 4, similarly connected to a bulb by a protected capillary tube. This form can also be arranged to give warning automatically when a given temperature is reached.

The Zeleny Thermometer

The Zeleny Thermometer system which is extensively used for observing the temperature of grain in storage tanks or bins has been adopted for observing the temperature of coal in storage in silos, pockets, or other storage bins.

The apparatus consists of a reading instrument and a switchboard as shown in Fig. 5. From the contact points of the switchboard, wires lead to the various points in the bins where the temperature is desired. The contact pins are properly labeled and when the switch lever is placed in contact with any one of these, the reading instrument indicates the temperature. In this way the temperature of many stations may be determined in a short time. The action of the instrument depends upon the thermo-electric properties of the metals used in the construction of the circuits. The wires leading into the coal are enclosed in heavy steel conduits so as to withstand the pull of the coal when the bins are being emptied. These steel conduits are supported at the top but are free to swing at the bottom. Naturally when there is coal in a bin the conduit is held stationary by the coal. When the bin is empty the lower end of the conduit may be tied by a small rope to the bottom of the bin so as to keep it from swinging when the bin is being filled. In coal silos or bins of small diameter it may be sufficient to know the temperature of the coal along the walls or other supports in the bins; in this case the swinging steel conduits could be eliminated, and stations fixed at several points along walls or supports.

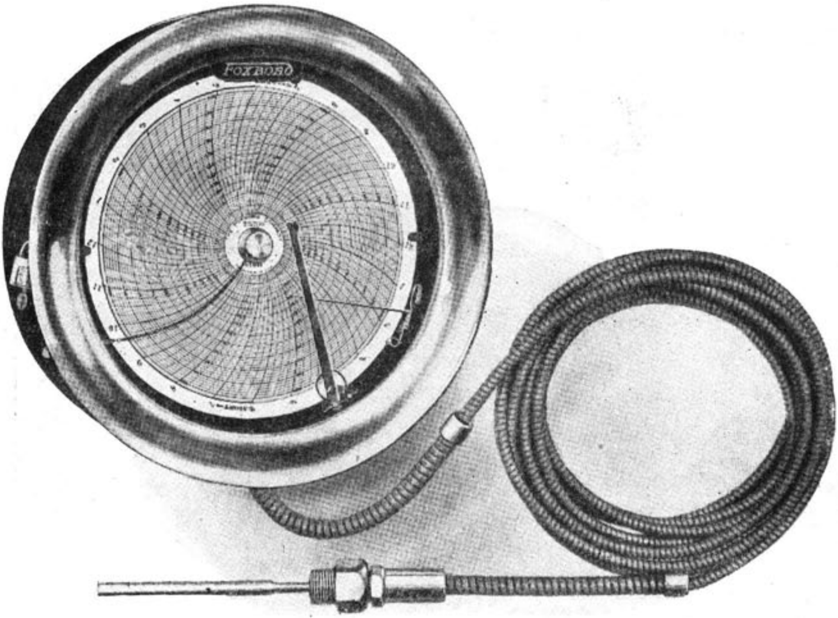

FIG. 3. RECORDING THERMOMETER — LONG DISTANCE TYPE

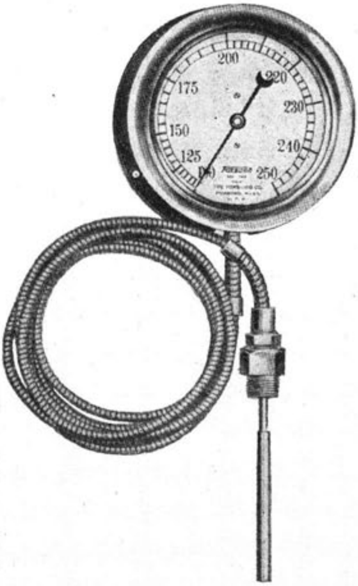

FIG. 4. INDICATING THERMOMETER — LONG DISTANCE TYPE

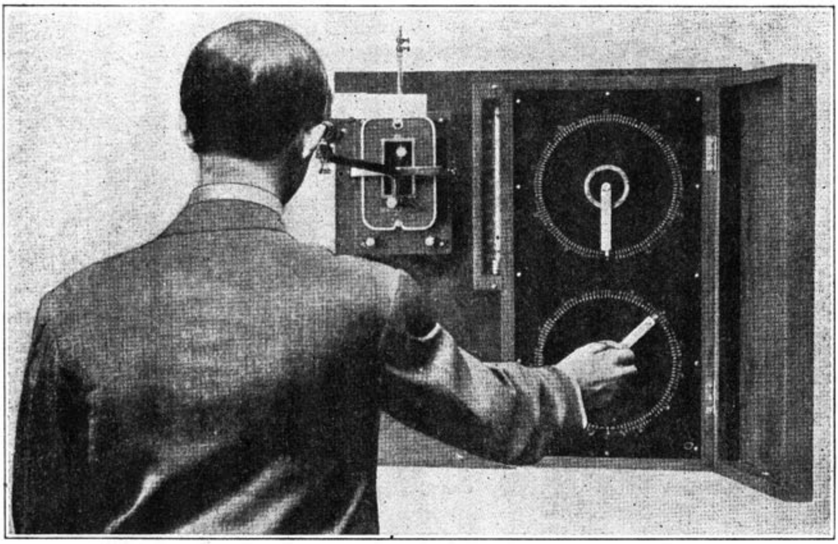

FIG. 5. ZELENY THERMOMETER SYSTEM — READING INSTRUMENT AND SWITCH BOARD

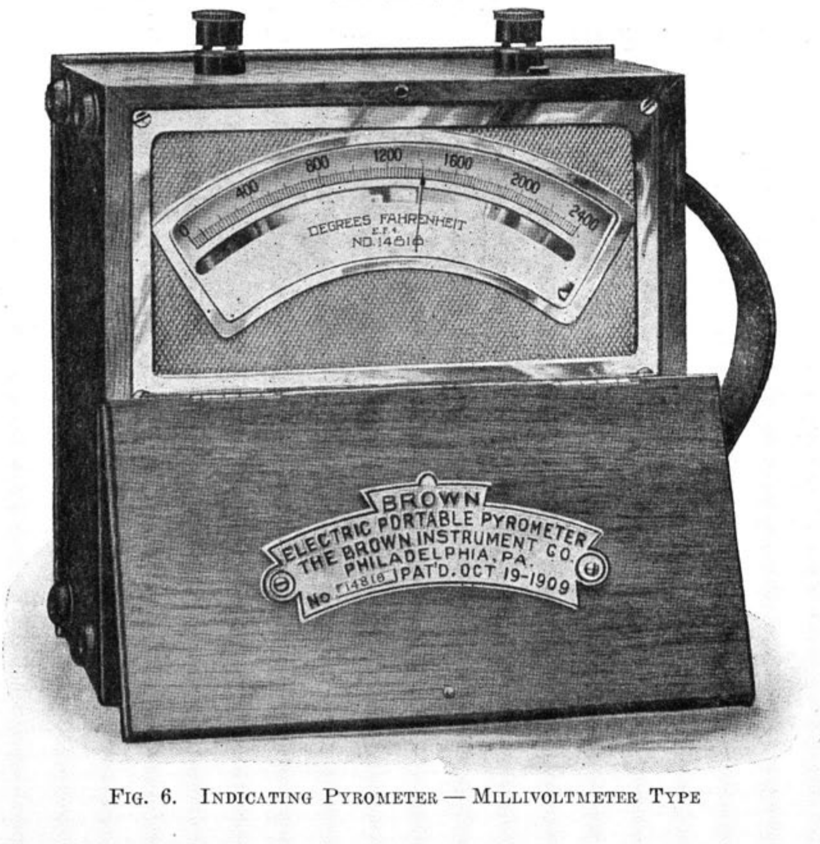

FIG. 6. INDICATING PYROMETER — MILLIVOLTMETER TYPE

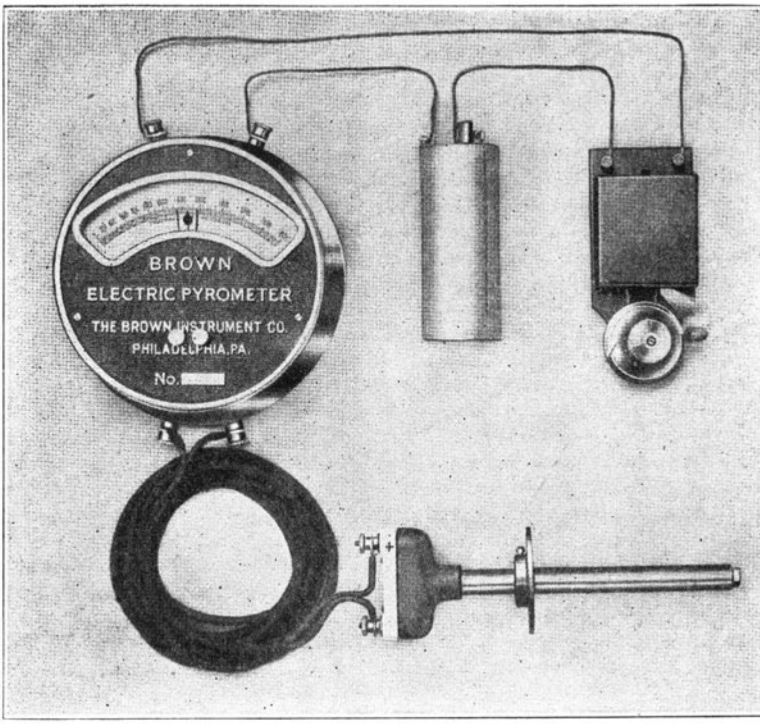

FIG. 7. INDICATING PYROMETER WITH ALARM ATTACHMENT

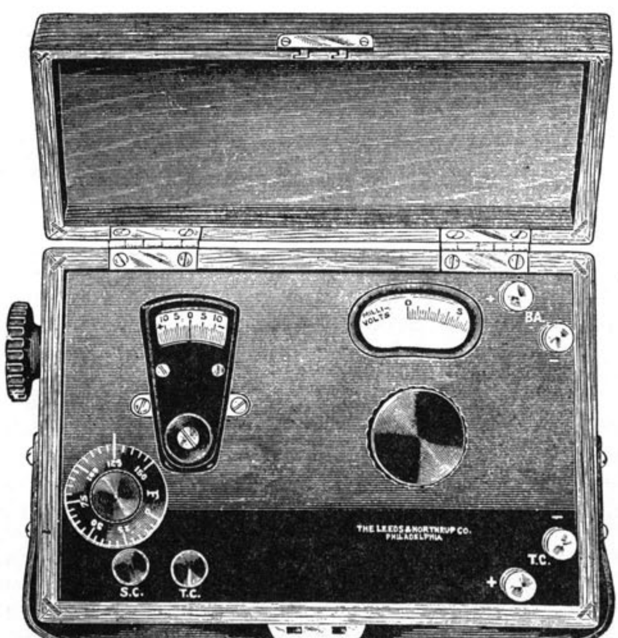

FIG. 8. INDICATING PYROMETER — POTENTIOMETER TYPE

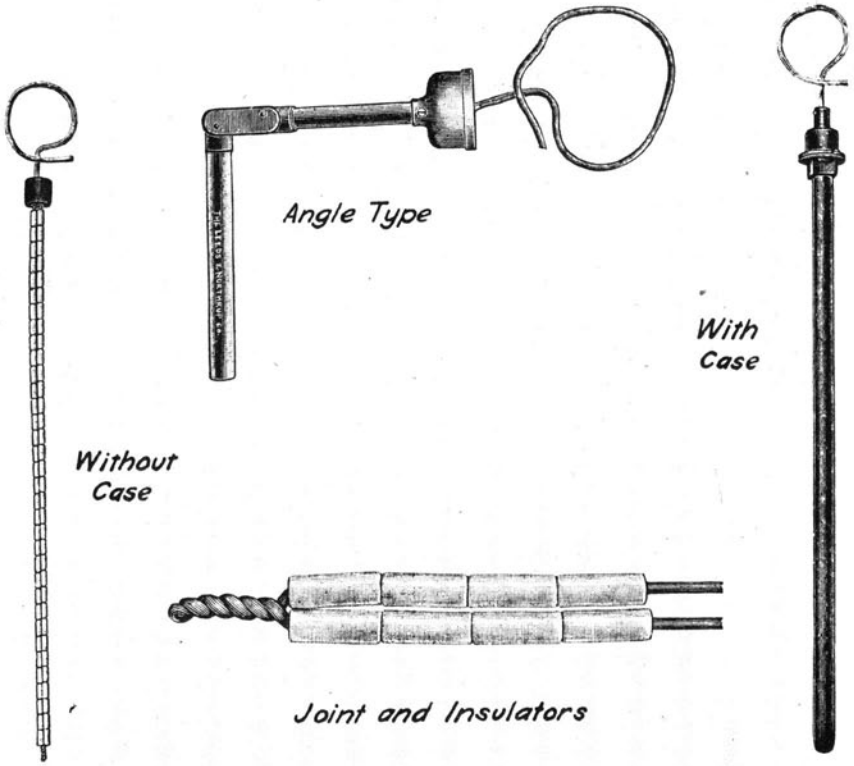

Fig. 9. Base Metal Thermocouples for Pyrometers

Pyrometers

Fig. 6 shows a portable electric pyrometer that has been used for obtaining the temperature of coal piles and Fig. 7 a similar alarm pyrometer.

A recording pyrometer may be connected with a rotary switch having any desired number of points, each point suitably connected with a separate thermocouple that may be placed in any part of the coal pile.

An indicating pyrometer of the potentiometer type for use with thermocouples is shown in Fig. 8. This reads in millivolts and it may be used with most types of thermocouples. The cold junction compensator on the instrument is also calibrated in millivolts. With this instrument it is necessary to use a transfer table of millivolts and temperature for the particular thermocouples used. The instrument will cover a range of approximately zero degrees to 340 degrees Fahr. Fig. 9 illustrates the type of base metal couple for use with this instrument.

Thermocouples and Potentiometers

Fig. 10 shows a method of observing temperatures in a coal pile of 10 000 tons described by T. W. Poppe.* Observations were taken at points noted in the plan inside of one-inch wrought iron pipes welded to a point at the ends which were driven into the pile. The exposed ends were fitted with self-closing caps to prevent the entrance into the pipes of anything that might interfere with the introduction of thermocouples. Fifteen portable thermocouples were used and the wiring from these extended to a pole centrally located in the coal pile from which a permanent wire extended to the engineer's office. The switches in the office were numbered and lettered to correspond with the pipes in the coal pile. An attendant placed the thermocouples in the pipes 1 to 15 row *A* and the readings were taken at the switchboard. As soon as the last couple had been placed in 15 *A*, the attendant began to move thermocouple 1 *A* to 1 *B*, etc., in numerical sequence, the time elapsing between the placing of 1 and 15 being sufficient to allow the couples to become heated to the temperatures in the several pipes. A recording pyrometer can also be used with the arrangement outlined. If a temperature of 250 degrees was indicated at any point, the nearby coal was at once moved to a point

* Power. Nov. 5. 1918.

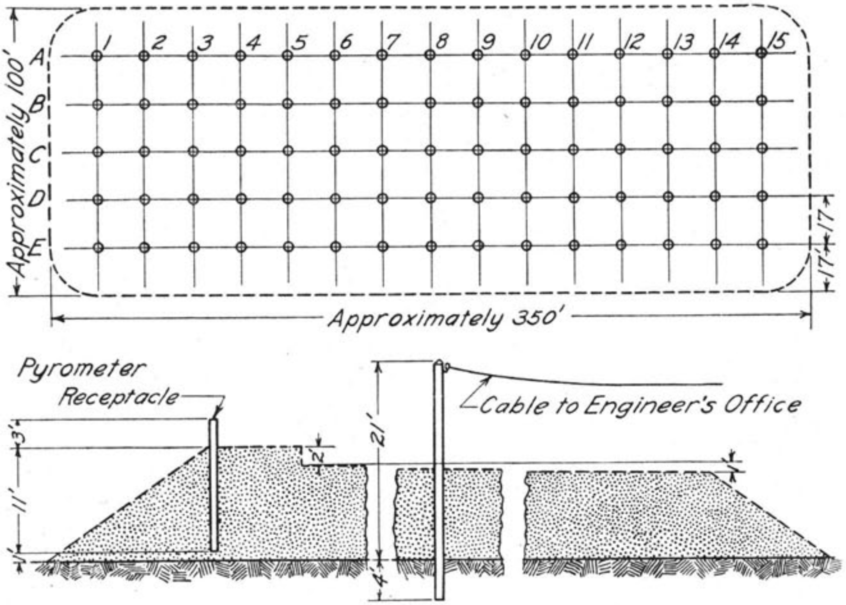

FIG. 10. PLAN AND SECTION OF COAL PILE SHOWING ARRANGEMENT OF RECEPTACLES FOR PYROMETERS

near the place of consumption. In removing the coal from this pile to the boiler plant it was taken off in layers two feet thick over the whole pile, a gradual slope being maintained as shown to facilitate the use of a wheelbarrow.

Mr. G. J. Congdon, Supervisor of Fuel of the Chicago Great Western Railroad, has described the use of a thermocouple and potentiometer by his road as follows:

"The machine was purchased after the coal was on the ground and in order to get the thermocouple down into the coal it was necessary to drive old flues into the piles about 15 feet apart and in addition we have a portable, jointed pipe which can be driven into the piles at any place desired where the temperature may be thought to be rising. These pipes are perforated at the bottom and covered at the top in order to keep the circulation down as low as possible.

"By means of the blank form (Fig. 11) which is filled out on the ground, a careful check is kept to see whether the temperature is rising or falling. It is a very simple matter to see how the coal is storing as the temperature can be compared from week to week and where there is an inclination to rise consistently we proposed to dig out that particular spot and use the coal at once in order that

Pyrometer Test Record ———— Storage Coal

Date	Pile Numbers																										

Fig. 11. Temperature Record Blank Used by Chicago Great Western Railroad

it may not spread to the rest of the pile, but we have never had to remove any of our coal on account of heating.

"The cables we use have five couples but it was never necessary to use but three of the couples as we had our coal piles only 10 to 12 feet high. The temperatures were taken by inserting this cable into the flue driven to the bottom of the coal or nearly so and leaving it to adjust itself to the temperature in the pipe, taking care meanwhile to keep the top of the pipe covered as much as possible. This takes only a few seconds. By changing the terminals on the cable to the potentiometer we could ascertain the temperature at the bottom, five feet from the bottom and ten feet from the bottom or by graduating the cable you could insert the same to any depth desired although on the whole I think but one temperature is about all you could get from the flue and that would be the highest one.

"One of the bad features of the machine is the fact that it is very hard to get it even on top of a coal pile and unless it is level there is liable to be quite a difference in two readings even taken on the same day. I used a small spirit level for this purpose satisfactorily."

23. *Time when Fire Was Noted.*—The length of time the coal was in storage before fire was discovered is shown by the graphs, Figs. 12 and 13 where the number of fires and the time in weeks are

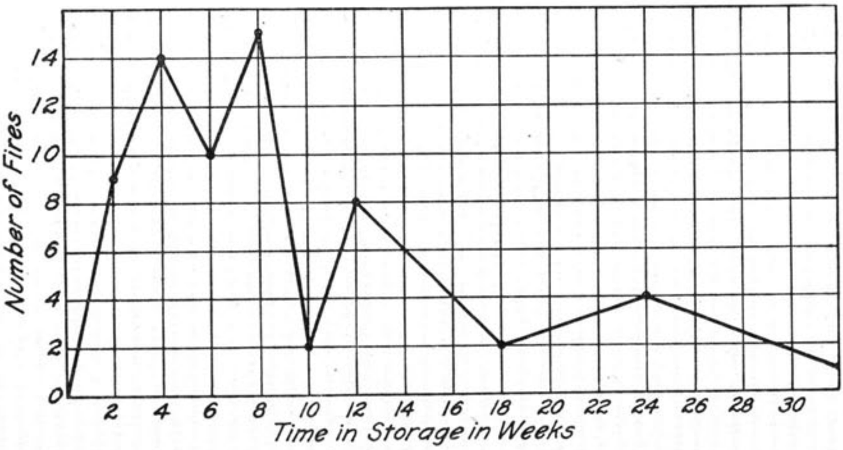

FIG. 12. GRAPH SHOWING LENGTH OF TIME COAL WAS IN STORAGE WHEN FIRE WAS DISCOVERED (QUESTIONNAIRE *A*)

the coördinates. These graphs show that most of the fires occurred in the first three months of storage. After that the hazard decreased as the time increased. This result is in agreement with the Chicago fire observations (see page 63), except that the peak of the graph

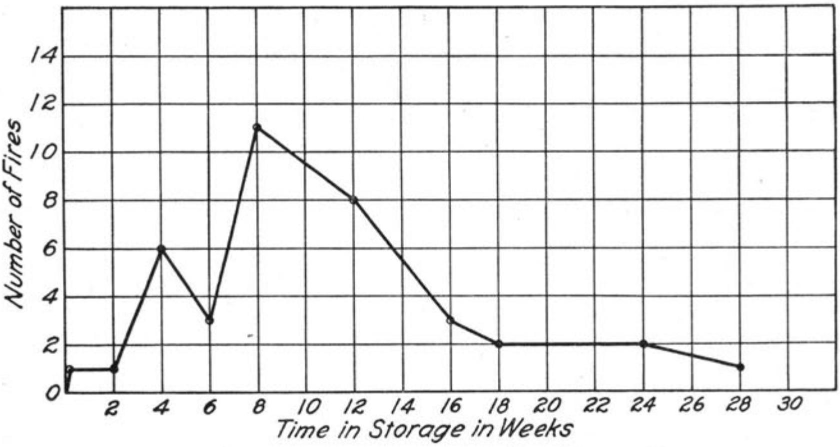

FIG. 13. GRAPH SHOWING LENGTH OF TIME COAL WAS IN STORAGE WHEN FIRE WAS DISCOVERED (QUESTIONNAIRE *B*)

occurs at eight weeks for cases reported in answers to Questionnaires *A* and *B*, while for the Chicago fires it occurs at twelve weeks.

These results confirm the opinion expressed in Circular No. 6 that, during the first three months after storage, particular attention should be given to watching a coal pile, and while the danger is by no means past after three months, the liability to fire seems to decrease rapidly. In this connection it should be noted that much of the coal involved in the answers to Questionnaires *A* and *B* was stored during the hot summer months so that the initial temperature was often high, which fact would tend to hasten spontaneous combustion. Some of those who store large quantities of coal do not feel that a pile is entirely safe until it has been in storage through one summer, but the experience of the Commonwealth Company quoted on page 23 shows that fires may occur after a pile has passed one summer.

J. H. Anderson says:*

"As a rule the greatest danger is up to about three months from the time of taking the coal from the pit."

24. *Reducing Temperature and Extinguishing Fires in Coal Piles.*—The following methods are employed for reducing the temperature in a coal pile.

* Trans. Inst. of Marine Engineers, Vol. XXX, p. 92, June, 1918.

Moving the Coal

The most effective method of combating a tendency to fire in a coal pile is by turning over the coal and exposing it to the air so that it may be thoroughly cooled. Care must be taken in exposing hot coal to the air, for, if the temperature is too high, as soon as the hot spot is opened out the mass will burst into flame and the fire spread very rapidly. Therefore, if there is evidence of a high temperature the spot should not be opened out unless there are ample appliances at hand immediately to move the hot coal or water sufficient to put out any fire that may start and thoroughly to cool off the mass.

Whenever the fire has reached the stage where the coal is actually ablaze, it may be necessary to use water but, in general, water should not be used if it can be avoided.

The smoke and fumes given off by the burning coal make the work of moving a coal pile very unpleasant, especially in a confined space, and the workmen may become dizzy. This difficulty was overcome at a fire in the basement of the Manual Arts Building of the public schools of Charles City, Iowa, during the spring of 1916,* by installing an electrically driven fan in such a way as to draw the smoke out of the basement so that the workmen could shovel the coal. The fan also drew fresh air over the shovelers, kept the space clear of smoke, and prevented the smoke from entering the building. When the fire was reached the smoldering coal was removed. The use of water on a previous occasion is said to have added to the trouble, but the reason is not stated.

Use of Water

The opinion is very commonly held that although fire in a coal pile is apparently extinguished by water, another fire is apt to break out in the same place. One reason for this was seen in at least one of the Chicago fires which were visited during the summer and fall of 1918. It was noted that as a result of the heating of the coal, a coating of tar had sealed the coal together in such a way that the seat of the fire at the center of the mass could not be reached by water. A coal pile also may have so much fine coal in it that the water can not penetrate to the point of the fire.

The ineffectiveness of a continued wetting of the surface of a coal pile in keeping down a fire was demonstrated by the Aurora,

* Power, Vol. 44, p. 567.

Elgin, and Chicago Railroad at Batavia, Illinois, in connection with a storage pile of 12 000 tons of Warrick County, Indiana, mine-run which gave trouble from heating during the summer of 1918. A pipe (see Fig. 14) was suspended over the pile of coal and to this pipe were attached nozzles or sprinklers with which the coal was sprinkled continuously for six or eight weeks.

The chief engineer of the plant reports that as soon as the water was turned off the fire started up again. He also states that in his opinion the fires were never thoroughly quenched throughout the piles,—that is, the water reached only the surface. The system was discontinued late in November to prevent freezing, and a number of fires were reported in the piles during the winter, so that it became necessary to reclaim a great deal of the coal during February and March.

A number of instances have been cited where perforated pipes were said to have been driven into heating piles and water injected into the pile at some depth through these pipes. There have been no personal observations of such an appliance upon which to base any conclusions as to the results of this method, but of six companies said by a manufacturer to be using the method successfully, one says that it was a complete failure, two have not tried such an appliance, one has not given it a sufficient trial to express an opinion, one said the appliance failed because tar clogged the nozzle, but thinks the apparatus would operate on certain kinds of coal, and one only had found it successful.

In England those who store coal have reached the same conclusion in regard to the use of water and J. H. Anderson says:*

> "In case of a fire in a heap of coal, although plenty of water should be available to quench out a fire if flames are seen issuing, still common sense must be used before we do even this, it being better to dig all round the fire; then, if possible, remove the hot coals away from the heap; then quench the material there.
>
> "Plenty of warning will be given and the spot localized before there is any actual danger if a systematic method of temperature readings is carried out. In case of overheating, the seat of heating would be dug out. Great difficulty would be experienced to get water to a fire in the middle of a heap, as the fire would cause a certain amount of the coal to melt and form a coked mass.
>
> "Of course, if the fire was in a receptacle that could be flooded out, such as a storage bin or a vessel's hold, it may be the best plan to flood; but I certainly should not do this except when there was an actual fire that could not be treated otherwise."

* Trans. Inst. of Marine Engineers, p. 92, June, 1918.

It is evident that the exact effect of moistening coal requires further examination as the results of experiments thus far performed and the opinions expressed by different experimenters are not in agreement.

In Technical Paper No. 16 the authors say:*

"The effect of moisture and the effect of sulphur on the spontaneous heating of coal are questions on which there has been a great deal of discussion and much difference of opinion. Very little experimental evidence has been brought to bear on either of the questions, and certainly neither is as yet settled. Richters has shown that in the laboratory dry coal oxidizes more rapidly than moist; but the weight of opinion among practical users of coal is that moisture promotes spontaneous heating. In not one of the many cases of spontaneous combustion observed by the authors, as representatives of the Bureau of Mines, could it be proved that moisture had been a factor. Still the physical effects of moisture on fine coal, such as closer packing together of dust or small pieces, may in many cases aid spontaneous heating."

In Technical Paper 113† the authors conclude:

"Heat is produced by wetting dry coal or a partly dried coal containing less than its normal percentage of inherent water. The relative quantity of heat generated depends upon the kind of coal and its deficiency in inherent water as referred to its maximum normal content. In other words the thermal effect of wetting varies directly as some function of the relative vapor pressure deficiency in the coal. The results of calorimetric determinations of the heat of wetting for different coals and for various percentage of water content are tabulated and illustrated by diagrams in the paper. Sub-bituminous coal from Wyoming that had been dried produced, by complete wetting, 19.2 calories of heat per gram of dry coal; brown lignite from North Dakota, 25.5 calories; bituminous coal from Franklin County, Illinois, 6.8 calories; and bituminous coal from the Pittsburgh bed, one calorie.

"On the basis of known specific heats of these coals, if the values of the saturated coals are taken and it is assumed that no heat is lost to the containing vessel or to excess water, or by radiation, the heat developed would raise the temperature of the different coals as follows:

	Degr. C.
Wyoming coal	43
Brown lignite from North Dakota	64
Franklin County, Illinois	20
Pittsburgh bituminous	4"

* U. S. Bureau of Mines, 1912, "Deterioration and Spontaneous Heating of Coal in Storage," by H. C. Porter and F. K. Ovitz.

† U. S. Bureau of Mines, 1915. "Some properties of the Water in Coal," by H. C. Porter and O. C. Ralston.

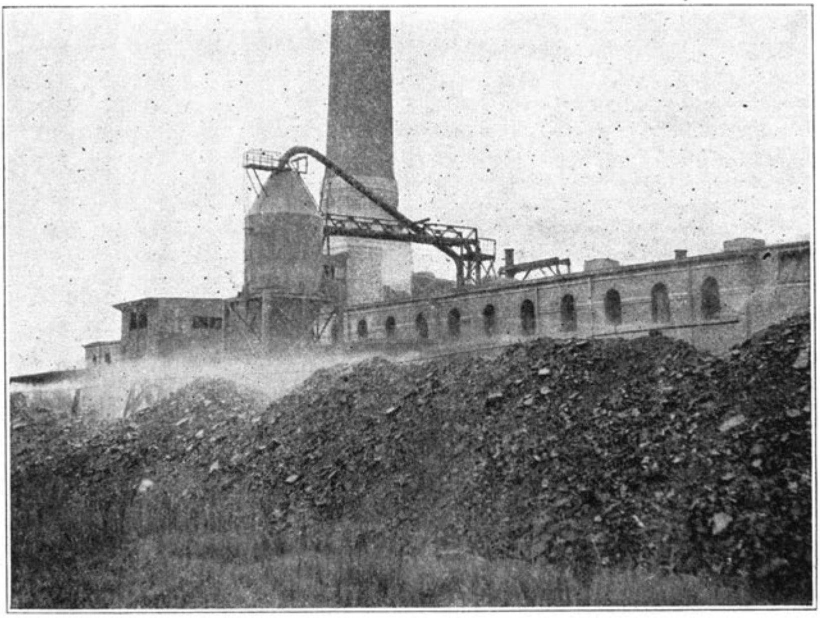

Fig. 14. Sprinkler System Used by Aurora, Elgin, and Chicago Railroad Company, Batavia, Illinois

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In Technical Paper No. 172* the authors conclude:

"The experiments showed that with Illinois coal thoroughly dried the rate of oxidation at ordinary temperatures was greater than with a comparative sample of moist coal. On the other hand a thoroughly dried sample of Pittsburgh coal oxidized at a slower rate than a comparatively moist sample of the same coal. This difference between the two coals probably explains the discrepancies in the observations of different experimenters. Richters found that a German coal absorbed more oxygen when dry than when moist. Mahler, investigating a French coal, and Graham, investigating an English coal, found that moist coal absorbed more oxygen than dry. Evidently the rates of oxidation of different coals are not affected uniformly by moisture."

The investigators named worked with small quantities of coal in the laboratory and used extreme conditions. Under actual conditions of storage both the coal and the air always contain moisture. Hence it seems doubtful whether water, other than the excess that actually wets the coal plays an important part in the rate at which coal oxidizes at the lower temperature, with consequent increase in the danger of spontaneous combustion. The experiments conducted on a working scale by Fayol, who could find no influence of wet weather on spontaneous combustion, and by the New South Wales Commission, which found that actual wetting of the coal produced a cooling effect during storage, tend to confirm this idea.

The authors of Technical Paper 172 summarize their conclusions as follows:

"However, the opinion among coal shippers and consumers that there is more danger of spontaneous combustion during warm, wet weather than during dry weather may have another basis, the physical changes brought about by wetting the coal on the surface of the pile. Such wetting reduces the proportion of voids or open spaces in the mass. If the coal is divided into particles fine enough, the water will fill the voids completely and be held there by capillary attraction. Such a mass of coal and water on any part of a pile would block the passage of air at that place. As a result the conditions of ventilation in the pile before the wetting would be changed, so that, is some instances, the heat generated by the gradual oxidation of the coal would be retained until the temperature of ignition was reached.

"For instance in a pile of coal formed in the usual manner with the fines at the top because of the rolling down of larger particles there would be a mass overlain with an impervious cover through the wetting of the outside surface. This cover would prevent air circulating by convection. Under such conditions oxygen would diffuse, as the coal absorbed it, from the lower parts of the pile to

* U. S. Bureau of Mines, 1917, "Effect of Moisture on the Specific Heating of Stored Coal," by S. H. Katz and H. C. Porter.

the covered part. The heat produced would be retained in the pile, and the temperature of the coal would increase at a rate dependent on the rate of oxidation alone; ignition temperature would readily be reached, and a spontaneous fire produced. The conditions described have been approximated to a degree in many storage piles of coal. In those piles moisture had a decided influence in the production of spontaneous fire.''

J. B. Porter* summarizes the effect of moisture as follows:

''From the Reports of the Royal Commission on Coal Cargoes in England (1876) and in New South Wales (1897) one might conclude that coal containing much moisture would be likely to heat badly; yet out of 26 persons, who in 1876 testified to the injurious effects of moisture, 25 admitted on cross-examination that they were simply repeating hearsay, and the other remaining witness was not available for cross-examination; furthermore, although the bulk of the testimony in 1897 was apparently to the same effect, the conclusions of the Commission did not give it much weight.

''One would naturally expect that a coal containing moisture would be retarded in its heating because, until all the moisture has been evaporated, the temperature cannot rise above 100 degrees C. Yet, on the other hand, the steam percolating through the surrounding mass, and condensing in the cooler parts, will heat as well as moisten them, and may thus tend to hasten oxidation in those parts.

''It would seem that the experiments (of Richters) definitely prove that moisture hindered the absorption of oxygen of the coal in question, but this is not in accordance with the results of recent experiments by Porter and Cameron, and furthermore, there is no doubt that moisture will increase the rate of oxidation of pyrite; and whether the net results will be an increase or decrease in the final temperature must depend on the amount of pyrite present and on the amount of moisture.''

Fayol experimented with:

1. Fresh fine coal.
2. The same coal dried in ovens at a temperature not exceeding 40 degrees.
3. The same coal dried but sprinkled to make it damp but not wet.

A number of piles of each kind were placed under similar conditions and temperature observations were made every day for several months. The temperature changes were found to be practically the same in all the piles and in no case did the temperature rise above 50 degrees.

* "An Investigation of the Coals of Canada," Extra Vol., Canadian Dept. of Mines.

Parr and Kressmann* studied dry and wet coals at temperatures of 40, 60, 80, and 150 degrees C. Without exception in these tests wetting the coal increased the activity as shown by the ultimate temperature. It must be remembered, however, that these coals were stored at high temperatures which were raised by external heat.

J. B. Porter says:

"A study of their results would seem to show that the wet coals did not heat on their own account until this externally applied heat raised them above 80 degree C., which is fatal to many coals."

J. B. Porter concludes his study as follows:

"In conclusion it may be said that in all probability the temperatures of ordinary coals under ordinary conditions of storage are not raised to any appreciable extent by moisture. The question naturally arises, what was the basis of the once prevalent belief that moisture was an important factor in spontaneous heating?

"This belief is, no doubt, chiefly due to the confusion of cause and effect on the part of persons who have discovered fires in coal storage. It is commonly observed that fires or hot spots in the pile are discovered shortly after rain storms, and that nearly always a hot spot is surrounded by damp or wet coal even if the main part of the pile is dry. The first case is easily explained by the fact that dry coal is so poor a conductor that the surface of a pile may show no indication of a hot spot or even an incipient fire in the interior. A rain storm would, however, provide moisture enough to soak into the pile, and this moisture on approaching the hot spot would be turned into steam which would work its way back to the surface and be observed, thus attracting attention to the hitherto unsuspected heating. The second explanation is equally simple. Air dry coal always contains some moisture, and in lignitic coals there is also a very considerable amount of combined water. In the case of a hot spot in the interior of a pile this moisture is driven off, either escaping at the surface as steam, or condensing on the cooler coal in the neighborhood. Added to this there is, of course, an actual formation of water when the hydrogen constituents of coal are oxidized.

"As an illustration of the second case it may be noted that during the experiments of the author at Outremont and Glace Bay vapor or condensed moisture was always noticed in the observation tubes in the neighborhood of hot spots even when the temperature was far below the boiling point."

The following extract from Circular No. 6 has a direct bearing on the same point. In a private communication Dr. J. B. Porter says:

"I fully appreciate the fact that nearly everybody experienced in the storage of coal objects to the use of water for quenching fires in storage piles. I ex-

* Univ. of Ill., Eng. Exp. Sta. Bull. No. 46.

press scepticism as to the harmfulness of water quenching. Recent information strengthens this scepticism, and I have come across several cases of successful fire fighting by the intelligent use of water. The fuel agent of the Canadian Pacific Railway states that he always recommends the use of water if the fire is a small one, and particularly if it is detected in an incipient stage. His practice is to locate the hot spot by driving test rods into the pile and then to dig a pit one or two feet deep right over the center of trouble; to drive and pull pointed rods or open pipes from it down into the heating mass and then to fill the pit with water, thus quenching the fire at the very center. At the same time if the fire is a large one he surrounds the whole heated part with a water curtain made by digging a ring ditch one or two feet deep and perforating its bottom with a row of holes as in ventilation. This ditch like the central hole is kept full of water from the hose, and if there is a tendency for the fire to be driven outward from the center, it is quenched by the water curtain.

"This method of putting out a fire is, of course, costly, but it is enormously quicker and less costly than that of digging out and results in far less loss of material. Personally, I am confident that it will prove successful in any ordinary case."

Use of Carbon Dioxide and Bicarbonate of Soda

A number of attempts have been made to utilize the smothering effect of carbon dioxide gas and solutions of bicarbonate of soda in ways somewhat similar to those used in the ordinary hand grenade or fire extinguishers of the Babcock and of similar types. The effect of CO_2 on fire is certain if it can be localized and applied where needed. The difficulty in a large coal pile is to confine the gases. The evidence as to the effectiveness of these agents in fighting fires in coal piles is by no means conclusive either for or against the method.

Parr and Kressmann* have shown that the saturation of coal with a 3 per cent solution of bicarbonate of soda exerted very little, if any, retarding influence on the oxidation of the coal, although the saturation of the coal with a 10 per cent solution had quite a retarding influence. The experiments were carried on not for the purpose of finding methods which would extinguish a fire but which would prevent spontaneous combustion.

In a report upon the Thomas Automatic Fire Extinguishing System, which uses a solution of bicarbonate of soda, the Pittsburgh Testing Laboratory has reported as follows:

"In this method of fire extinguishing there are the following important factors:

* "The Spontaneous Combustion of Coal," Bull. No. 46, p. 45, Univ. of Ill., Eng. Exp. Sta.

1. Quenching effect of water alone.

2. Smothering effect of carbon dioxide gas which is liberated at the surface of the burning material.

3. Smothering effect of the water vapor liberated by the chemical force.

4. Sealing and fire-proofing effect of the solid, non-volatile chemical.

5. Chilling effect caused by the heat absorption when the bicarbonate of soda is broken up by the heat.

"We have examined carefully the photographs and data concerning fire tests made with large quantities of combustible materials in box-cars and open piles. We note that these tests bear out all that is to be expected; namely, that water charged with bicarbonate of soda and applied under high pressure extinguishes large fires almost immediately.

"A saturated solution of bicarbonate of soda contains about 10 per cent or 13 ounces per gallon of water. Our practice has been to use from 2 to 4 ounces per gallon."

In response to Questionnaire *A*, the following information concerning the use of carbonated water was received from Robert Smith, Engineer of the Michigan Alkali Company, Wyandotte, Michigan:

"The method used consisted of a tank in which the chemical was mixed and fed into the suction of a force pump which used the plant pressure of 65 pounds on the suction and boosted the same to 140 pounds. The nozzle was 10 feet long made of 1-inch pipe and it was forced into the pile, but I believe the best results were obtained by casting over the pile.

"Our fire burned nearly two months, and towards the end seemed to increase. We used a solution of bicarbonate of soda and water and also turned over the pile and limited the pile to 25 feet."

In connection with the fire of the Cleveland, Cincinnati, Chicago, and St. Louis Railroad, bicarbonate of soda was used and J. L. Hampson, Fuel Inspector of the railroad says:

"Water is mixed with soda in proper proportions by a patented apparatus, controlled by J. A. Thomas of Columbus, Ohio. It is necessary to first put out the fire on the surface of the pile, then with a ditcher, steam shovel, or clamshell, to throw this coal over to a depth of 4 or 5 feet and then extinguish the fire thus uncovered. This is necessary for the reason that this chemicalized water will not penetrate more than 4 or 5 feet in some places.

"We did not use the method until we had given up the idea of saving the coal remaining on the ground at Bellefontaine and cannot, therefore, say what might have been the result if we had tried it earlier, for I am inclined to think that we would have saved much more of the coal."

J. C. Dougherty, Coal Inspector for the New York Central Railroad, says:

"In one particular place where the pile was not over 10 feet in depth, a barrel of bicarbonate of soda was used. The entire barrel was scattered over a length not to exceed 30 feet. Water was turned in onto it and men drove bars into the coal and worked in the solution. Explosions were heard and several days later the fire was as bad as ever."

Reports vary as to the effectiveness of the use of bicarbonate of soda in connection with fires on the Lake docks, and while it is undoubtedly true that if CO_2 can be confined, it will extinguish a fire, yet the advantage of carbonized water over plain water, in connection with the digging out of hot spots has not been thoroughly demonstrated.

Ventilation of Storage Piles

Of the forty-five fires reported in connection with Questionnaire *A*, six piles had some sort of ventilating device, three having vertical pipes, and in one case the method was not stated. Of the thirty-three piles in which no fires occurred one was ventilated by means of vertical boiler tubes.

In sixteen of three hundred and three storage piles reported on in answers to Questionnaire *B*, an attempt had been made to ventilate by means of iron or wooden pipes. In eleven of these sixteen piles fire occurred. These results do not suggest that ventilation as carried on is an efficient means of preventing spontaneous combustion and they agree very well with the results secured in the study of the fires in Chicago (see pages 73, 77).

The subject of the ventilation of coal piles is one upon which there is a great difference of opinion, and the evidence is very conflicting. It seems to be quite a common practice of Canadian railroads to ventilate their coal piles with a great deal of care, and it is the opinion of Professor J. B. Porter of McGill University and of S. H. Pudney, Fuel Inspector of the Canadian Pacific Railroad, that by means of proper ventilation spontaneous combustion can be prevented and the temperature of coal piles regulated to a very great extent. Other correspondents in Canada do not fully agree with this opinion. The experience of the railroads in the United States seems to differ widely upon this point, to judge from the replies to the questionnaires.

Attention should be called to the fact that many pipes placed in coal piles are intended merely for observing temperatures with no thought of ventilating the piles. Coal is a poor conductor of heat, and it is undoubtedly true that much of the so-called ventilation of coal piles has been inadequately done because only a few pipes have been placed irregularly throughout a pile. If ventilation is to be successful, it must be carefully done and pipes placed near together; but when so placed they interfere with rapid handling of the coal and increase the expense. The writers have not seen any of the Canadian coal piles that are reported to have been ventilated successfully, but a study of storage piles in the United States in connection with power plants has shown that the so-called ventilation is usually not well done and has been ineffective.

The Cleveland, Cincinnati, Chicago, and St. Louis Railroad, at its Mattoon, Illinois, storage yard found that large shaft-like openings in the coal pile were beneficial in lowering the temperature of the coal. These openings were dug with a steam shovel and were approximately 8 ft. by 8 ft. by 10 ft. deep.

At several Chicago storage piles it was noted that fires broke out near ventilation pipes, and at one place where the coal storage had been tiled horizontally with ordinary drain tile, the fire traveled along this tiling, which acted as a flue.

The subject is worthy of more careful study and possibly of experiment, but it should be remembered that climatic conditions may have an important influence on the success of any ventilation method and what is successful in the cooler, drier climate of Canada may not be successful in the much warmer and moister climate of Illinois. Moreover, in Illinois there is not the same drop in temperature at night as there is farther north, or at a higher elevation as, for instance, in Colorado or New Mexico. Consequently there is much less opportunity for a pile to cool off over night.

Mr. S. H. Pudney in an address* before the Canadian Railway Club of Montreal, gives the cost of ventilating coal as five cents per ton and states that in the case of Dominion coals, the holes are placed two feet apart, and in the case of United States coals three feet apart. In this same connection attention is called to the use of trenches dug through the coal pile at intervals. This practice is used by a number of railroads and has an effect similar to cutting a long pile up into a number of short ones by cross alley-ways.

* Jour. of the Canadian Railway Club, Feb., 1919.

Summary of Methods of Fighting Fires

The methods of handling the fires as indicated by the questionnaires is shown in Table 11.

TABLE 11

METHODS OF FIGHTING FIRES

How Handled	Questionnaire *A*	Questionnaire *B*
Water only	5	11
Coal moved—no water	32	43
Coal moved and water used	7	19
Sodium carbonate solution	1	....
Not stated	....	2
Totals	45	75

25. *Damage to Property and Loss of Coal from Fires.*—In connection with the replies to Questionnaire *A*, it appeared that three out of forty-five fires involved a loss of property, but no statement as to the value was made. The following amounts of coal were reported lost as the result of such fires:

TABLE 12

LOSSES OF COAL DUE TO FIRES

Coal Stored	Lost
4700 tons	200 tons
800 "	75 "
35000 "	200 "
6000 "	10 "
8000 "	50 "

In connection with nine of the fires reported in the answers to Questionnaire *B*, there was damage to the adjacent property, but in eight of the nine reported cases the loss was less than $100.00, while in one case the loss was something over $1000.00.

The coal lost as the result of the fires was variously estimated at from less than one per cent to thirty per cent, but these figures are open to considerable question and at the best are only estimates. The average estimated loss by the fire varied from five to ten per cent of the coal in storage where the fires took place.

26. *A Study of Fires in Coal Piles in Chicago during* 1918.—An excellent opportunity to study fires in coal piles was offered in Chicago during the summer and fall of 1918. Probably no better time or place could have been chosen for such a study, because, during that time the Fuel Administration was urging consumers to store coal, and, owing to the great variety of the industries in the Chicago district and the large amounts of coal brought in for coke and gas making purposes, practically all kinds of coal were stored, in spite of the zoning system for the distribution of coal. It is impossible to state with any degree of accuracy the total amount stored, but practically every dwelling had some coal in its cellar, manufacturers were storing all they could, and the railroads and public service corporations were storing to the full capacity of their yards. The Commonwealth-Edison Company alone at its different plants in the city had about 500 000 tons. The fires studied therefore occurred with amounts of coal varying from that found in an ordinary house cellar up to piles containing thousands of tons.

The Commercial Testing and Engineering Company, 1785 Old Colony Building, of which Mr. Langtry is president, kindly placed its office at the disposal of the authors, and through the courtesy of J. C. Donnell, Chief of the Bureau of Fire Prevention and Public Safety, each morning a list of all the coal fires that had been reported the previous day was furnished. An attempt was made to visit all fires thus reported and to collect such information as would be of value in studying the problem. One hundred and twenty-one fires were visited and reported on, the Data Sheet (see Appendix I) being used to facilitate the gathering of uniform information. The fires visited have been classified under the following heads, depending on the cause of the fire:

Class 1. Fires due partially, if not wholly, to outside sources of heat.

Class 2. Combustion aided by foreign material in the coal.

Class. 3. Fires due to no apparent cause except the kind of coal or the method of piling.

Table 13 gives in tabular form a list of the fires studied, classified according to the place in which the coal was stored, and to the cause of the fire, with the approximate amount in storage in each case.

TABLE 13

CLASSIFICATION OF FIRES IN CHICAGO COAL PILES

PLACES WHERE COAL WAS STORED	Class I	Class II	Class III	Total	Range of Tonnage in Storage
Residences	....	....	1	1	10
Apartments and flats	9	2	16	27	20 to 500
Hotels, saloons, schools, churches, business buildings	3	4	12	19	40 to 8000
Fraternal homes	1	....	....	1	150
Manufacturing plants	2	13	18	33	30 to 50000
Coal yards	....	20	15	35	40 to 8000
Grain elevators	....	....	2	2	150 to 4400
Railway	....	....	1	1	12000
Public service corporations	....	....	1	1	10000
Totals	15	39	66	120	10 to 5000 0

A number of typical fires have been selected from those studied and detailed descriptions of these follow, arranged according to causes.

Class 1. Fires Due Partially, if not Wholly, to Outside Sources of Heat

In fifteen of the fires visited an outside source of heat seemed to be directly responsible for the spontaneous combustion of the coal. These sources of heat can be classified as follows:

Hot Water Tanks	1
Hot Pipes	6
Hot Furnace	4
Hot Chimney or Breeching	3
Hot Ashes	1
Total	15

The following is a summary of the information collected with reference to these fires.

Thirteen of the piles contained mine-run and two screenings. Thirteen were under cover and two in the open. None was ventilated. In four piles there was a segregation of the larger from the smaller sizes.

The length of time which elapsed between placing the coal in storage and the discovery of fire is shown graphically in Fig. 15, in which the number of fires is plotted against the length of time as given in the following tabulation:

Time in Storage	Number of Fires
3 weeks	1
8 weeks	3
12 weeks	6
15 weeks	1
16 weeks	1
No time stated	3

The peak of the graph is at twelve weeks; after that time the susceptibility of the coal to spontaneous combustion seemed to be less.

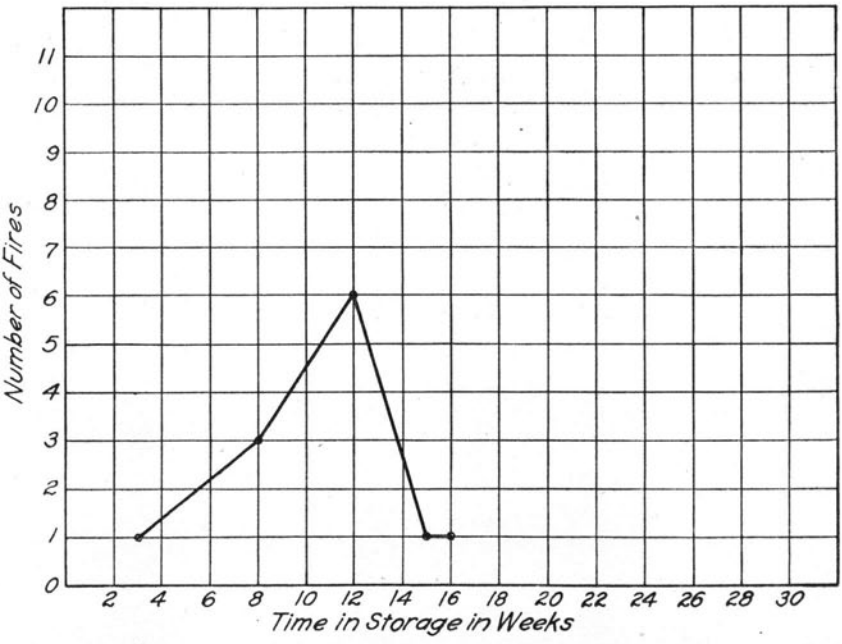

FIG. 15. GRAPH SHOWING LENGTH OF TIME COAL WAS IN STORAGE WHEN FIRE WAS DISCOVERED (CHICAGO COAL PILE FIRES, CLASS 1)

The cases hereafter discussed illustrate a too common practice that indicates ignorance or disregard of the fact that should be well known by all who attempt to store coal; i. e., that liability to spontaneous combustion increases very rapidly with increase in temperature, and therefore a coal pile should be kept away from all external sources of heat.

Because of the urgent necessity for laying in a larger amount of coal than in ordinary times, in many cases more coal was bought for storage purposes than could safely be stored in the usual space provided. Consequently any available space was used without regard to its adaptability and this fact explains some of the fires of this class. It is probable, too, that the proper method of storing coal had not been brought to the notice of all concerned.

A case where about seventy tons of Franklin County mine-run coal was stored in contact with a hot-water tank in the basement of a building is illustrated in Fig. 16. Heating of the coal started two or three weeks after the coal was placed in storage, and the center of the trouble was but a few feet from the tank. The janitor tried to keep the coal cool by wetting it with water two or three times per day, but finally called the fire department as the fire got beyond control. After the pile was flooded with water and the coal removed from around the hot-water tank, there was no more trouble.

Six fires were noted where the coal was stored in contact with or in close proximity to hot pipes. These storage piles ranged in size from forty tons to a few thousand tons and in all cases the coal was either mine-run or screenings.

A case where an uncovered sheet-iron smoke pipe leading from a furnace to the chimney was partially covered by coal is shown in Fig. 17. This pipe had several holes in it and at times became so hot that it could not be touched by the hand. After the fire, which resulted, was extinguished with water and the coal removed from the neighborhood of the hot pipe, there was no further trouble. Fig. 18 shows hot steam pipes placed in an uncovered trench about which coal was piled; fire resulted.

In four cases the heating was due to the coal being in contact with a hot furnace. All of these were in dwellings, and in every case the coal was mine-run. In two cases where the same kind of coal was stored in another part of the basement there was no trouble. Figs. 19 and 20 are views showing coal piled against furnace walls in basements. Fire occurred in both cases. Fig. 21 shows a chimney around which coal was piled; fire started in close proximity to the chimney. In another case a fire occurred in the basement of a flat in a coal pile at a point where hot ashes from the furnace had been piled against the coal.

Fig. 16. Coal Piled around Hot Water Tank

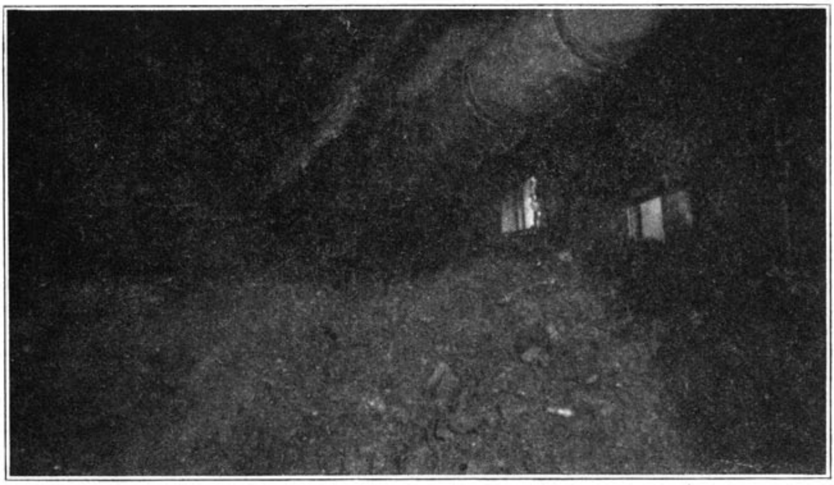

Fig. 17. Coal Piled about Sheet Iron Smoke Pipe

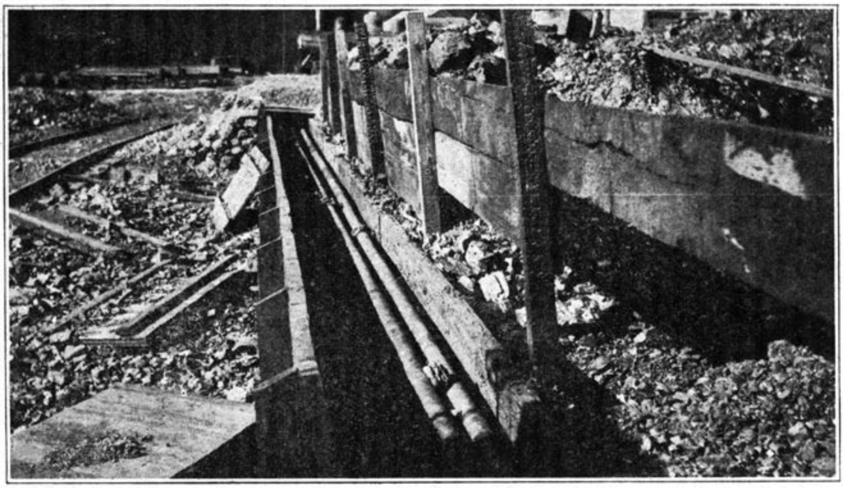

Fig. 18. Hot Steam Pipes about which Coal Was Piled, Causing Fire

Fig. 19. Coal Piled in Contact with Brick Wall of Furnace
(Coal Has Been Partially Removed)

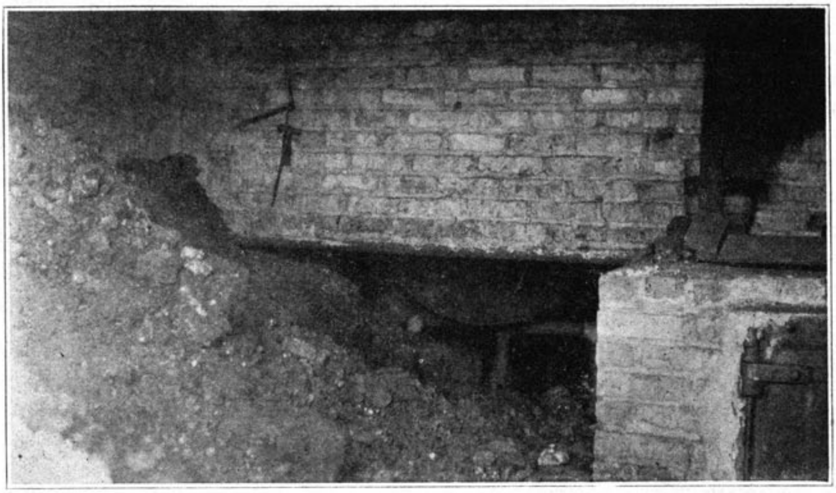

Fig. 20. Coal Piled in Contact with Brick Wall of Furnace
(Coal Has Been Partially Removed)

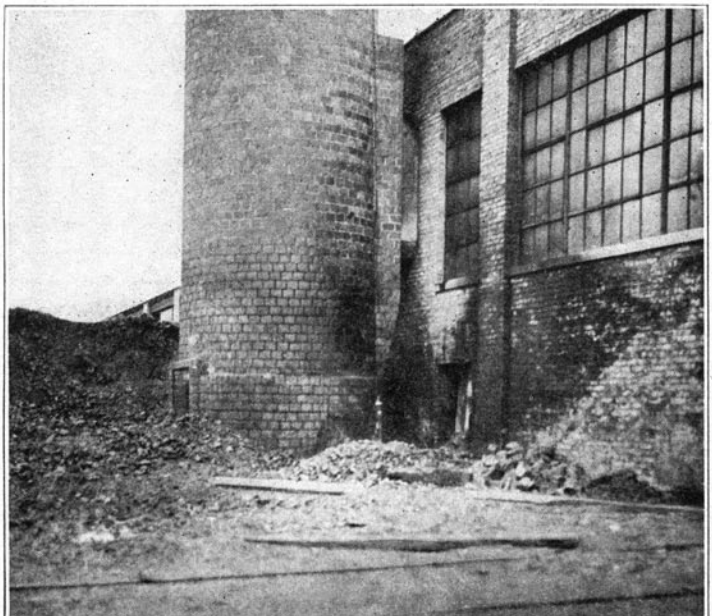

Fig. 21. Coal Piled around Base of Chimney
(Coal Has Been Partially Removed)

Fig. 23. Fire Starting in Coal Pile around Embedded Wooden Beam

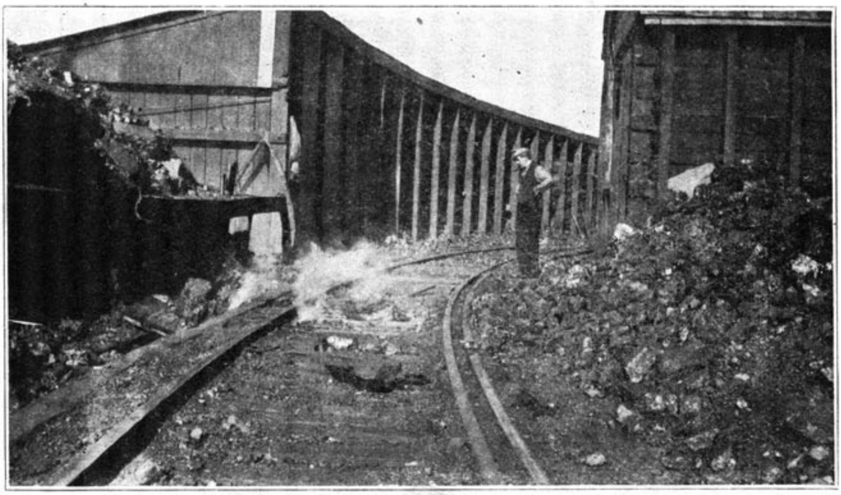

Fig. 24. Fire Starting in Coal Pile around Timbers of Trestle

Class 2. Combustion Aided by Foreign Material in the Coal

In thirty-nine of the fires visited the evidence indicated strongly that some foreign material such as wood, paper, rags, rosin, or sewer gas was responsible for starting the combustion as shown in Table 14.

TABLE 14

FIRES APPARENTLY DUE TO FOREIGN MATERIAL IN COAL PILES

Foreign Material	No.	Per Cent of Class II	Per Cent of Total Chicago Fires
Wood	31	79.5	25.8
Mixture wood, paper, rags, etc.	5	12.8	4.1
Rosin	1	2.6	.8
Sewer gases	2	5.1	1.6
Totals	39	100.0	32.3

Additional information concerning these fires may be summarized as follows: Of the thirty-nine piles in question, eighteen were mine-run, sixteen were screenings, four were No. 5, and one was No. 3, No. 4, and No. 5 mixed. Thirteen of the piles were under cover and twenty-six in the open; two were ventilated and thirty-seven not; in twenty-seven there was a segregation of sizes, and in twelve no evidence of segregation.

Fig. 22 is a graph showing the relation between the number of fires and the length of time in storage for Class 2 corresponding to the following tabulation:

No. Weeks in Storage	No. of Fires
2	1
6	3
8	7
12	9
14	4
20	2
24	1
28	1
No time stated	11

As in Class 1, the most dangerous period was during the first twelve weeks.

In view of the fact that 25.8 per cent of the total number of fires visited in Chicago were apparently caused by wood being mixed

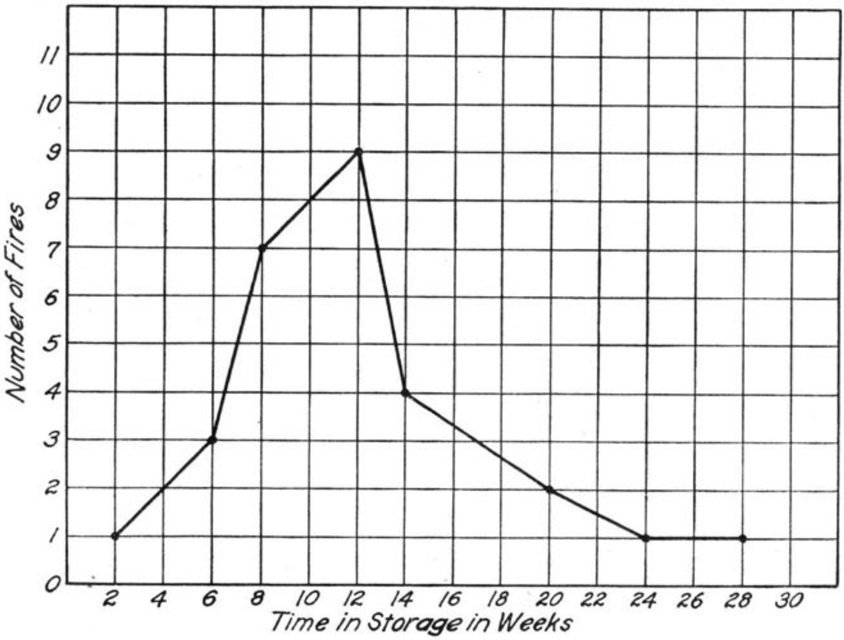

FIG. 22. GRAPH SHOWING LENGTH OF TIME COAL WAS IN STORAGE WHEN FIRE WAS DISCOVERED (CHICAGO COAL PILE FIRES, CLASS 2)

with or in contact with the coal, it is very important that those who store coal bear this in mind. Very often coal is stored around a wooden structure so that the wood is embedded in the coal. This is particularly the case where coal is placed in storage from a railroad track on a trestle.

There are two distinct ways in which such embedded wood may assist in starting combustion: first, by providing a flue along the timber for the circulation of an air current; second, by acting as a match in starting combustion at a lower temperature than that required for coal alone. It has not been definitely proved that wood acts in the latter way and the theory to that effect is by no means universally accepted as being true.

Figs. 23 to 30 illustrate cases where fires started alongside of or very near wood embedded in the coal piles in the form of supports to trestles or other structures, partition walls between piles, or enclosing walls for piles.

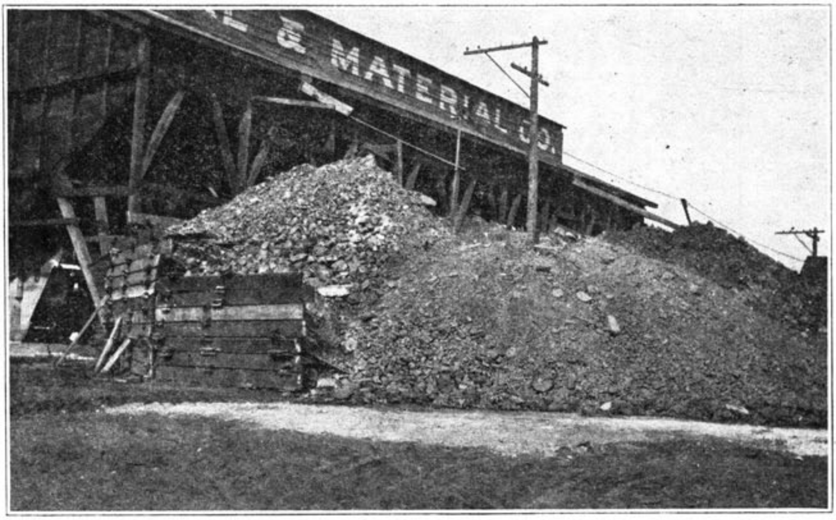

Fig. 25. View of Coal Pile Showing Timber Retaining Wall Anchored into Coal Pile by Wooden Supports

Fig. 26. Partially Burned Wooden Horse Removed from Coal Pile

FIG. 27. BRACING TIMBERS EMBEDDED IN COAL PILE AROUND WHICH FIRE STARTED

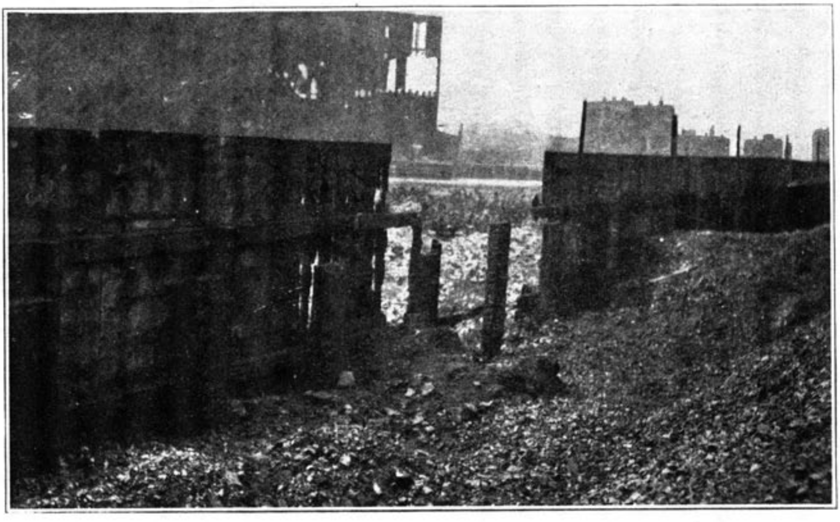

FIG. 28. WOODEN FENCE PARTIALLY DESTROYED BY FIRE IN COAL PILE, APPARENTLY DUE TO CONTACT OF COAL WITH TIMBERS OF FENCE

Fig. 23 shows a fire that was detected by smoke coming out along a beam embedded in the coal. Upon digging down into the pile the seat of the fire was found near the end of the beam. In a somewhat similar case fire started about an old coal retarder that had been surrounded by mine-run coal to a depth of twenty-five feet at the place where the fire occurred. Fig. 24 shows a very common condition. Smoke coming out along a track laid on top of a trestle indicates that a fire has started down in the pile. Such fires are usually found next to the leg of the trestle when the pile is dug into. In one case a fire was found at every leg of the trestle about which the coal had been dumped. Fig. 25 shows a common way of anchoring a timber retaining wall by means of timbers placed in the coal pile. Fire occurred in this pile but it was impossible to locate exactly the point of origin. A number of fires could be traced to no other cause than to similar wood anchors in the coal. Fig. 26 shows a wooden horse which formed part of a wheelbarrow runway that had been covered up with coal. Two of the legs are burned off at the end. Fig. 27 shows braces for a timber partition wall embedded in coal; a fire started around these braces. In another case a fire started about a plank carelessly left in a coal pile. Fig. 28 shows an enclosing wooden fence along which a fire started in a pile of Saline County screenings. A plank embedded in the pile, but projecting from it, thus furnishing a flue for air to enter the pile, was the apparent cause of fire in another case investigated. A pile of Pana No. 5 coal about some old partitions caught fire apparently near one of these partitions. In many coal yards the flooring under the coal piles is of wood and at a number of fires the origin was traced directly to this wooden floor. At other places where pieces of wood were embedded in the coal it was found when the coal was removed from the pile, that the hottest places were about these pieces of wood.

Fig. 29 shows a case where an attempt was made to ventilate a pile of screenings by placing horizontal wooden tubes about six inches square (indicated by arrows) in the pile as it was put in storage. A fire developed very close to one of these ventilating tubes. Fig. 30 shows an attempt to ventilate screenings by means of vertical wooden tubes (indicated by arrows). Fire developed very near these tubes.

Five of the fires visited were apparently caused by an accumulation of wood, paper, rags, etc, mixed in with the coal. At a service station visited, 180 tons of mine-run coal were placed in storage in the basement; spontaneous combustion occurred near the center of the pile and on removing the coal it was found that at this place there was a considerable amount of wood and rubbish mixed with the coal.

At a cold storage warehouse a fire developed in the storage pile at a point where there was a large amount of rubbish mixed with the coal (See Fig. 31). From this point the fire traveled toward a false bottom of wood which served as a flue.

A most interesting case of fire was noted at a yard where about 2500 tons of three-inch screenings from Murphysboro, Illinois, was placed in storage. Rosin had formerly been stored in this yard, and before it was used for coal storage a flooring of boards was laid on the ground over small quantities of accumulated waste rosin. The coal was piled on these boards, and within two months spontaneous combustion developed. When the coal was dug out with a crane, it was noticed that as the crane approached the bottom of the pile, the heat became more intense, and at the bottom there was a layer of coke about one foot thick on the boards which were burned to charcoal. A large quantity of molten rosin was mixed with the mass; the same condition was noticed at three different places in the pile. It is believed that the pressure and a slight heating of the coal caused the rosin to flow up through the space between the pine boards. Here it became mixed with the coal, and the kindling temperature of the mass was lowered to such an extent that it readily took fire. The kindling temperature of samples collected was so low that they could very easily be lighted by the flame from a match.

Two fires which occurred in basements of buildings started immediately over sewer outlets. There is no direct evidence that the gases from these sewer outlets caused the fires, but sewer gases are apt to be moist and hot and the proximity of the point where the fires started to the sewer outlets suggests that such gases raised the temperature sufficiently to cause, or at least materially to aid combustion.

One fire occurred in Chicago in clean sized No. 3 coal and the only explanation was that the coal had become heated by hot air entering the pile through a flue which led directly from the top of an adjoining boiler house.

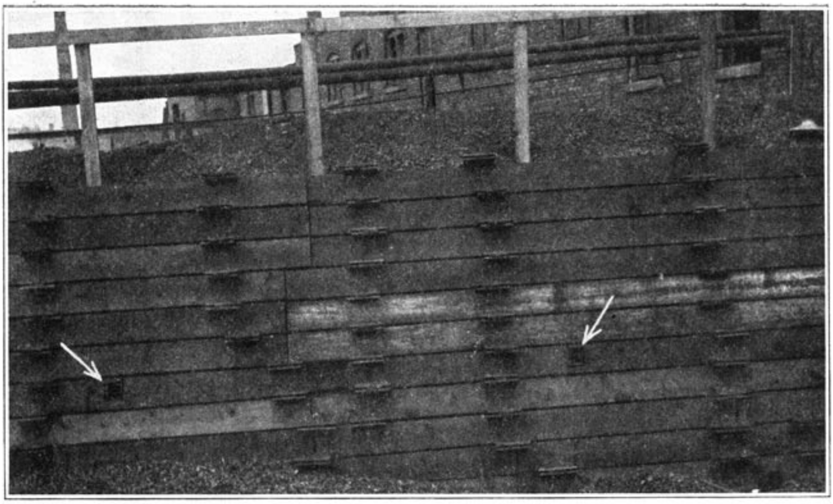

Fig. 29. View of Pile of Screenings with Horizontal Wooden Vents (Indicated by Arrows) near which Fire Developed

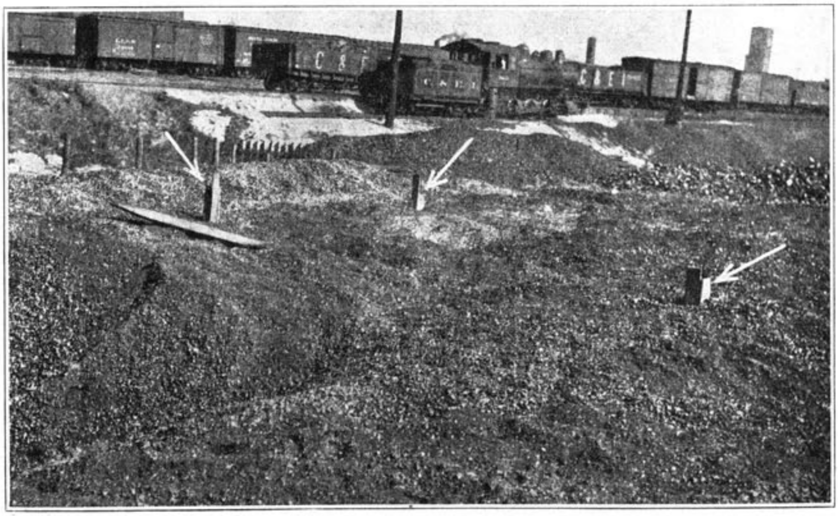

Fig. 30. View of Coal Pile, with Vertical Wooden Vents (Indicated by Arrows) near which Fire Developed

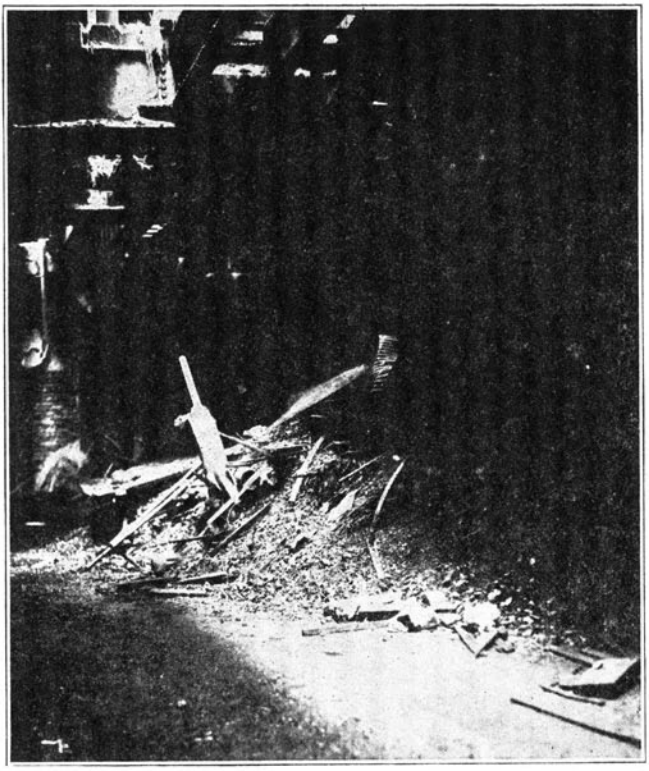

Fig. 31. Wood and Rubbish in Coal Pile around which Fire Started

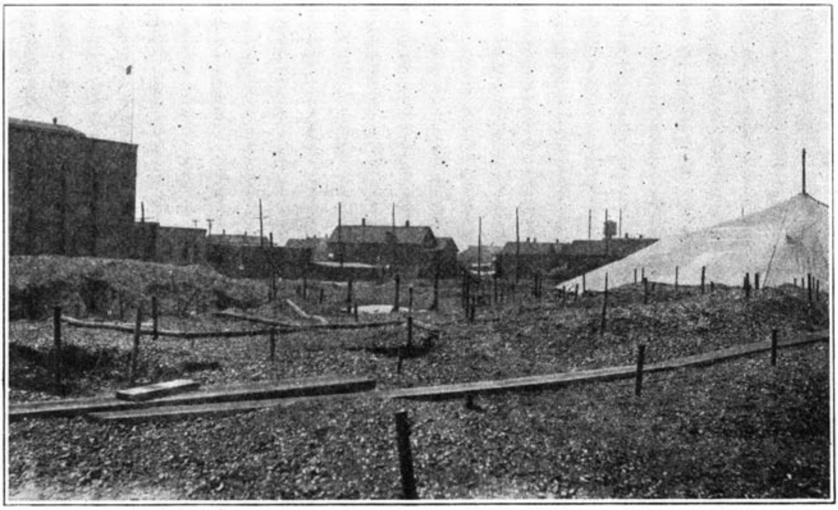

Fig. 32. View of Coal Pile Ventilated with Iron Pipes which Acted as Flues; Fire Occurred

Class 3. Fires Due to No Apparent Cause except the Kind of Coal, or the Method of Piling

In the case of sixty-six fires visited there was no apparent cause for the heating except in the kind of coal or in the method of piling. In a number of instances it was extremely difficult, if not impossible, to ascertain the exact conditions which caused the heating.

The most striking factor appeared to be the size of the coal stored. Eighty-six per cent of these fires occurred in mine-run or screenings, and in the case of those few fires which occurred in sized coal it was noted that there was a considerable amount of fine coal present, due to breakage in handling, weathering of coal, and improper screenings. The following table shows the number and percentage of fires occurring with each size of coal.

TABLE 15

RELATION BETWEEN SIZE OF COAL AND NUMBER OF FIRES

SIZE OF COAL	No. of Fires	Percentage
Mine run	35	53.0
Screenings and No. 5	22	33.3
Lump, 50 per cent, No. 5, 50 per cent	3	4.5
Nut	3	4.5
Lump	2	3.1
No. 4 Washed nut	1	1.6
Totals	66	100.00

Many believe that coal is safer if stored under cover, rather than in the open. A study of these Chicago fires would indicate that there is little difference whether the coal has a cover over it or not, for of the sixty-six fires in Class 3, thirty-four were under cover and thirty-two were stored in the open.

At four of the storage piles where fires were investigated an attempt had been made to ventilate the piles by using perforated iron tubes. Fires started very close to some of these tubes which apparently furnished the air needed for combustion. It was noticed that the smoke of a cigar was drawn down into one pipe which thus acted as an intake, while the smoke was blown outward at another pipe which served as a chimney; thus the pipes were producing a circulation of air through the pile.

Fig. 32 shows an attempt to ventilate with iron pipes, which was not effective, as fire resulted.

Special attention was paid to the results of segregation or *pyramiding* of the coal, as it is sometimes called, when unloaded into the storage piles. Coal will naturally segregate into different sizes if it is continually dumped on one spot as the pile is built up, the fine coal remaining at the center of the pile and the larger sizes rolling to the bottom; thus flues are formed that carry the air to the fine coal which oxidizes easily. This segregation of sizes was apparently the cause of many fires, as it was noted frequently that fires started near the place where coal was shoveled into a basement through a window. At this point there would be a natural segregation of sizes. The fire was usually found in the fine coal. Table 16 shows the importance of this item:

TABLE 16

RELATION BETWEEN SEGREGATION OF SIZES IN PILING AND NUMBER OF FIRES

	No. of Fires	Percentage
Sizes segregated	57	86.3
Piled uniformly	1	1.6
No information	8	12.1
Totals	66	100.00

The relation between time in storage and number of fires was as follows:

No. Weeks in Storage	No. of Fires
3	3
4	2
5	7
6	4
8	6
10	7
12	11
14	3
16	4
22	3
26	2
No time stated	14
Total	66

Fig. 33 is a graphical presentation of the information contained in the above table, and shows that as in the other classes of fires considered (see Figs. 15 and 22) the most dangerous period is during the first twelve weeks.

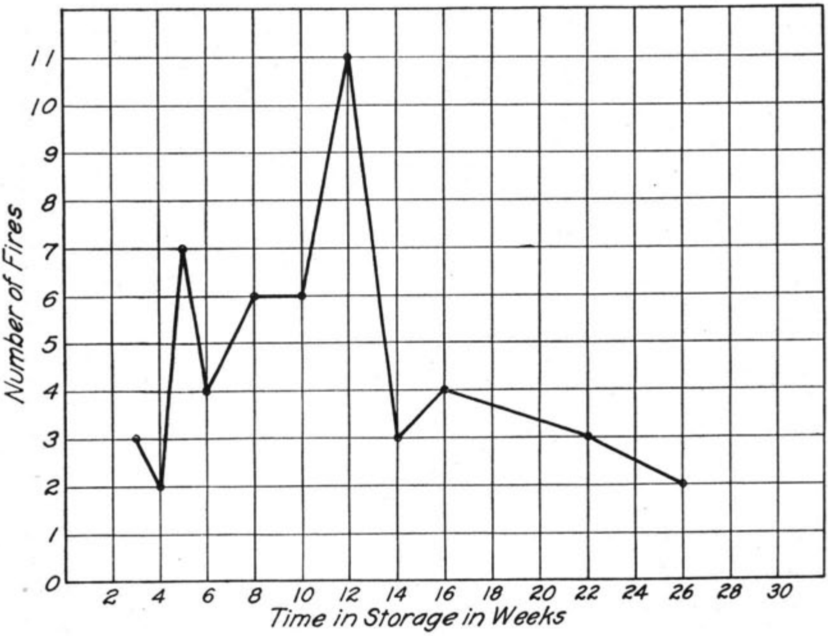

FIG. 33. GRAPH SHOWING LENGTH OF TIME COAL WAS IN STORAGE WHEN FIRE WAS DISCOVERED (CHICAGO COAL PILE FIRES, CLASS 3)

27. *Summary of Data from All Types of Chicago Fires.*—

Classification according to General Causes	No.	Per Cent
Class 1. Outside source of heat	15	12.5
Class 2. Foreign material in pile	39	32.5
Class 3. No apparent cause except kind of coal or method of piling	66	55.0
Total number of fires	120	100.0

Size of Coal		
Mine-run	66	55.0
Screenings	40	33.3
No. 5	4	3.4
No. 3, No. 4, and No. 5 mixed	1	.8
Lump 50 per cent, Screenings 50 per cent	3	2.5
Nut	3	2.5
Lump	2	1.7
No. 4 Washed Nut	1	.8
Total number of fires	120	100.0

Place of Storage	No.	Per Cent
Under cover	60	50.0
In the open	60	50.0
Total number of fires	120	100.0

Methods of Piling	No.	Per Cent
Sizes segregated	89	74.2
Piled uniformly	1	.8
No evidence of segregation	30	25.0
Total number of fires	120	100.0

The relation between length of time in storage and number of fires was as follows:

Length of Time in Storage (Weeks)	No. of Fires	No. of Fires (Cumulative Total)
2	1	1
3	4	5
4	2	7
5	7	14
6	7	21
8	16	37
10	7	44
12	26	70
14	7	77
16	6	83
20	2	85
22	3	88
24	1	89
26	2	91
28	1	92
No time stated	28	..
Total	120	

Fig. 34 shows graphically the relation between the length of time in storage and the number of fires occurring for all Chicago fires studied.

Fig. 35 is a cumulative curve which shows the total number of fires occurring plotted against the time in storage.

These data seem to show clearly that the following considerations should be taken into account in storing coal under the conditions prevailing in connection with the Chicago fires.

1. Coal should never be subjected to heat from outside sources, such as hot pipes, boilers, etc.

2. Foreign combustible material should be kept out of the pile.

3. The coal should be piled in uniform sizes and segregation prevented.

4. Sized coal only should be stored, if possible.

5. It is immaterial whether the storage is under cover or in the open.

6. The greatest liability to fires seems to be within the first three or four months and during that time special care should be taken to watch the pile for evidences of combustion.

The illustrations given are selected from a great number of photographs taken at more than one hundred fires visited in Chicago and in other cities, where the conditions were found to be similar in most respects to those found in Chicago with the exception that usually smaller amounts were stored.

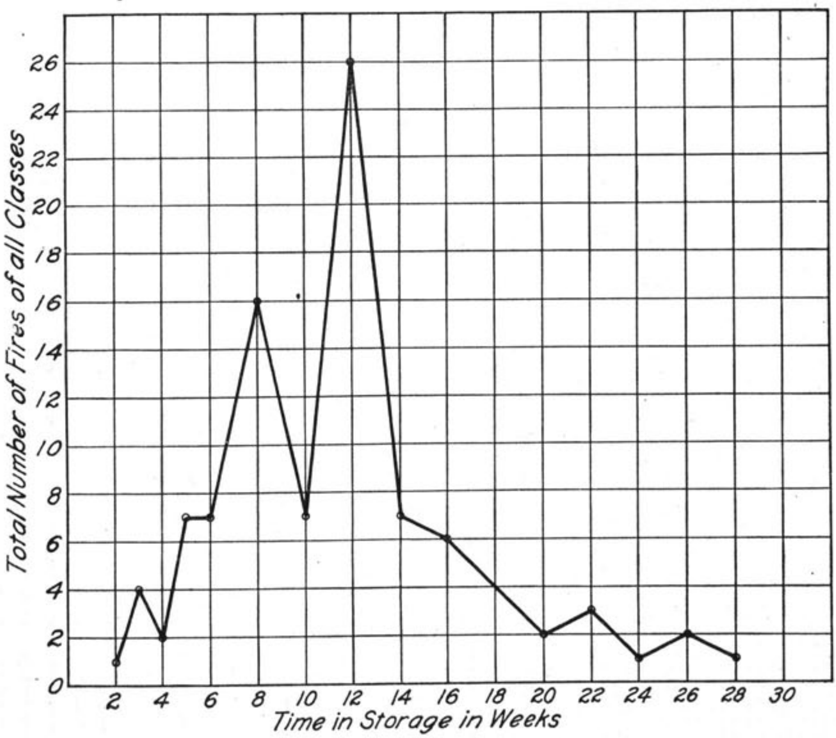

FIG. 34. GRAPH SHOWING LENGTH OF TIME COAL WAS IN STORAGE WHEN FIRE WAS DISCOVERED (ALL CLASSES OF CHICAGO COAL PILE FIRES)

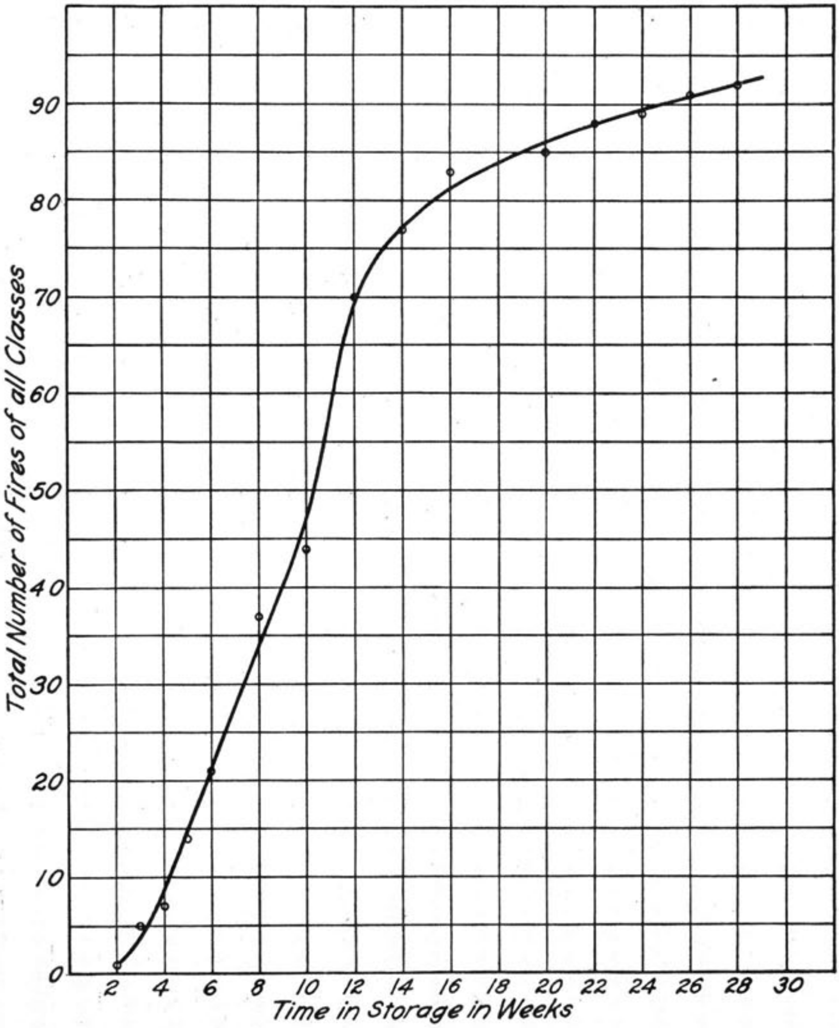

FIG. 35. GRAPH SHOWING RELATION BETWEEN LENGTH OF TIME IN STORAGE AND TOTAL NUMBER OF FIRES (ALL CLASSES OF CHICAGO COAL PILE FIRES)

IV. Effects of Storage upon the Properties of Coal

In Circular No. 6 the effects of storage upon the properties of coal were considered under the following heads:

1. Appearance.
2. Loss of heating value.
3. Firing qualities.
4. Spontaneous combustion.
5. Coking and gas-making properties.
6. Degradation or the increase in the amount of fine coal and dust due to breakage from handling and to slacking or weathering.
7. Loss in weight.

The conclusions in Circular No. 6 were as follows:

(a) The heating value of coal as expressed in B.t.u. is decreased very little by storage, but the opinion is widespread that storage coal burns less freely than fresh coal. Experiments indicate that much of this deficiency may be overcome by keeping a thinner bed on the grate and by regulating the draft.

(b) The coking properties of most coals seem to decrease as a result of storage, but coals vary greatly in this respect.

(c) The deterioration of coal stored under water is negligible, and such coal absorbs very little extra moisture. If only part of a coal pile is submerged, the part exposed to the air is still liable to spontaneous combustion.

Although a study of the data gathered in connection with railroad storage shows that a few consider that stored coal burns better than fresh and although similar opinions have also been given by those reporting on stationary power plants, yet the conclusion seems scarcely tenable. As pointed out by Parr in his bulletins, there may be a slight increase in B.t.u. value due to the washing out of the sulphur contents, thus giving a greater carbon content per ton in the resultant coal. This difference, however, is so slight as not to be appreciable in ordinary firing.

It should be remembered that very often the apparent deterioration in the coal taken out of storage is due not to any change in the coal but to the fact that the clam-shell or other device used for reclaiming, digs into the ground under the pile and mixes soil or refuse with the coal. It should also be remembered that the experiments at the University of Illinois, which indicated that storage coal can be burned as readily as fresh coal if a thinner bed is kept on the grate and if the draft is properly regulated, applied particularly to stationary plants and that the draft cannot be so well regulated in locomotive practice.

The following analyses furnished by W. D. Langtry confirm the conclusion that the decrease in heating value in B.t.u. of stored coal is very slight.

Coal stored by the Indianapolis Abattoir Company for two years showed a decrease in B.t.u. of only 5.85 per cent, as indicated by the following analyses:

	Coal Stored during 1918	Same Kind of Coal in Storage for Two Years
Moisture	13.66	17.19
Dry Ash	14.33	14.17
Dry B.t.u.	12 393	11 668

Indiana fourth vein coal showed a falling off of B.t.u. of only about one per cent, as indicated by the following analyses:

	Average of 472 cars Fuel Coal	Coal from Same Mine in Storage for one year
Moisture	13.66	17.96
Dry Ash	14.33	14.52
Dry B.t.u.	12 393	12 200

Variation in heating value in coal from Murphysboro, Illinois, was very slight after fifty-one days in storage, as is shown by the following figures, and the slight difference could be easily attributed to variation in sampling and analyses:

	About Dec. 1, 1918	Jan. 24, 1919
Moisture	10.08	10.65
Ash	15.41	14.90
Volatile	31.28	31.56
Fixed Carbon	43.23	43.89
B.t.u. (Moisture, ash, and sulphur free)	14 848	14 822

Another test of Murphysboro screenings placed in storage on the West Side in Chicago gave the following results:

	Coal from Boiler Room (or Fresh Coal)	Coal in Storage 4 Months	Coal in Storage 18 Months
	Per Cent Commercial	Per Cent Commercial	Per Cent Commercial
Moisture	10.25	12.44	11.89
Ash	9.08	9.16	7.98
Volatile	33.18	33.12	33.28
Fixed carbon	47.49	45.28	46.85
B.t.u. (moisture, ash, and sulphur free)	14 816	14 761	14 713

The coal in storage 18 months was piled 10 or 12 feet high and the pile was about 150 feet long and 25 feet wide, bulkheaded with wooden anchors running into the pile. It was reported that the temperature was at no time more than a few degrees over 100 degrees Fahr.

The Engineering Supplement of the London Times for July 27, 1917, in discussing the storage of coal, says:

"The loss due to weathering need not cause much concern since it would not be large from the pecuniary point of view. Colliery owners could in many cases select for storage the coals which, owing to their physical properties and chemical composition, are most immune from the effects of weathering or storage. Some tests on the effect of exposure on certain coals yielded the following results:

Description of Coal	Storage Condition	Effect on Calorific Power
Bengal coal, India	Large stocks exposed for 12 months in the open	Depth of stock 4 ft., aver. loss 7.6 per cent
Scotch anthracite cobbles*	Samples exposed to all weathers in England for 2¼ years	Loss 3.3 per cent
Scotch house coal*	Sample exposed as above for 2¼ years	Loss 8.4 per cent

* These coals, if stored in large quantities, would not show such a loss, as the total coal which is covered by the overlying layers would be protected from the effects of the weather."

V. Storage Systems

In Circular No. 6, Chapter V, the points to be considered in choosing a storage system and the requirements of an ideal storage plant were discussed. The following types of storage were described in considerable detail:

Hand-operated storage systems.
Storage by motor truck.
Pile storage from cars without a trestle.
Trestle storage.
Storage with side dump cars.
Side-hill storage.
Use of mast and gaff arrangement in storage.
Locomotive crane storage.
Parallel track storage.
The trestle and crane system.
Circular storage.
Steeple towers.
The Hunt system.
Bridge storage.
Deep reinforced concrete storage bins.
Underwater storage.

Since the publication of Circular No. 6, a large number of storage plants have been investigated and the following descriptions include a number of new systems and also additional information about some types that were described in Circular No. 6.

28. *Hand and Truck Storage.*—There are no developments to report in connection with hand storage systems since the publication of Circular No. 6.

The pile of coal stored by motor truck at the University of Illinois, as described in Circular No. 6, is still in storage and there have been no evidences of fire. The coal was screened 1½ nut in size when stored during 1918 and though the outside of the pile is now finely pulverized, the coal exposed by digging into the pile to the depth of a foot has the same appearance as when stored.

29. *Pile Storage.*—Pile storage from cars which run on a track laid on the coal pile and raised from time to time is probably the method most widely used by railroads. It is also adopted to some extent by commercial plants because it is the easiest in application, and requires only a small expenditure of money for permanent equipment and because the track can be moved from place to place as desired.

The objections to the method are:

(a) The pyramiding effect; that is, the segregation of fine coal at the center and top of the pile is intensified as the locomotive and loaded train crush the coal under the track.

(b) It is not practicable to divide the coal by cross-passageways so as to make a number of small piles and thus render each pile easy of access for reclaiming.

(c) When coal is piled in this way adequate track provision for moving the coal quickly is apt to be neglected until it is time to move the coal and a track cannot then be put in place quickly enough to save the pile. Where this method is used the track should be moved from the top of the pile to the surface alongside the pile so as to provide for the rapid loading out of the coal, if necessary. The use of a standard railroad ballast spreader to spread the coal on the pile is to be preferred to the ordinary method of dragging a tie through the coal.

Mr. J. F. Hanson, Fuel Supervisor of the Cleveland, Cincinnati, Chicago, and St. Louis Railroad, says:

"Our experience this year (1918) has certainly demonstrated that coal cannot be stored successfully by dumping cars over the track and then raising the track through the coal."

On the other hand during 1917 the Illinois Central Railroad successfully stored run-of-mine in this way at two mines near Duquoin, Illinois. Although the method has been successfully used in a number of instances, it is the least desirable of all methods and is to be avoided if possible.

Pile storage with the tracks placed alongside of the pile rather than on top is extensively used, and has not the same disadvantages as pile storage with the tracks raised on top of the pile. Fig. 36, shows long piles of the Missouri, Kansas, and Texas Railroad, Enid, Oklahoma.

The track should be kept in place, so that the coal can be loaded out promptly, if necessary, and should not be moved as soon as the coal has been stored, as is sometimes done. Two tracks between piles give greater flexibility in switching cars than one, though, if necessary, one track will suffice as the locomotive crane can be used for switching the cars. When two tracks are used the crane runs on the track next the pile and unloads from cars on the parallel track. The height of such piles should preferably be limited to 16 to 20 feet and, to prevent pyramiding and breakage, the coal should be laid down in layers as thin as practicable, usually not over three feet thick and spread over the full width and length of the pile. It should not be piled up to the full height at one spot in the pile. The clam-shell bucket should also preferably be lowered to a point just above the surface of the pile before being dumped so as to minimize breakage.

Fig. 37 shows the standard system of the Missouri Pacific Railroad. For coals that are liable to spontaneous combustion, the alleyways across the piles are used; otherwise the piles are continuous.

Locomotive cranes or ditcher appliances (see Figs. 38 and 39) afford great flexibility in placing coal in storage and in reclaiming it; they utilize equipment with which railroads and many industrial plants are usually already supplied. Piles can be made of any length that the available space permits and the width is limited only by the reach of the crane. They are also particularly well adapted for storing coal in circular piles.

With respect to usefulness for reclaiming, there is probably little difference between a revolving shovel and a locomotive crane or ditcher, but a shovel cannot be used for unloading from the cars. Any equipment of this kind requires a permanent investment in track for which, however, a rental may be charged to the storage account.

30. *Trestle Storage.*—Trestle storage requires an initial permanent investment in a structure which is used for only a short time. The legs of a trestle embedded in a coal pile are apt to be starting points for fires. In dumping from a trestle it is impossible to avoid pyramiding and the breakage is often excessive. The bents of a trestle interfere with the loading out of the coal and cleaning out of the bin. The combination of a trestle for unloading and a crane for reloading is satisfactorily used.

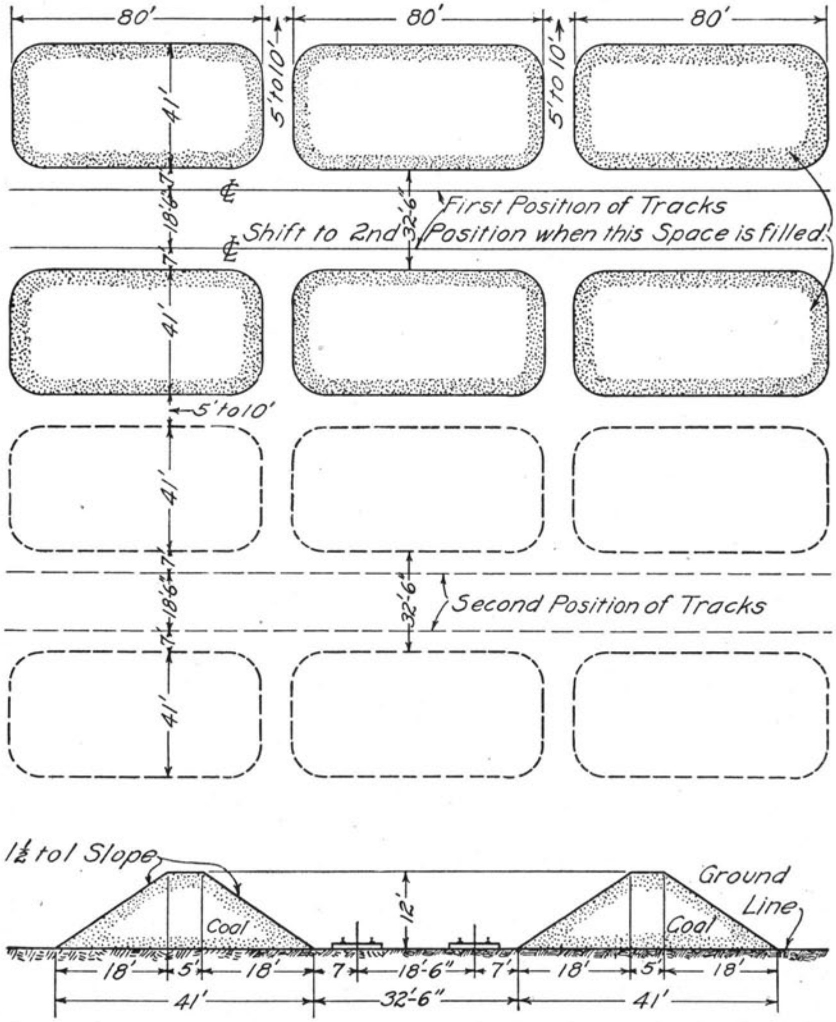

FIG. 37. PLAN AND SECTION ILLUSTRATING STANDARD COAL STORAGE SYSTEM OF MISSOURI PACIFIC RAILROAD

An innovation in storage trestles is claimed by the Seaboard Air Line Railroad in connection with its trestle storage at Jackson and Savannah, Georgia. Trestles are constructed as shown in Fig. 40 and the ground is covered with plank. The *A* section extends the entire length of the pile and is made air-tight, except at the ends. The pur-

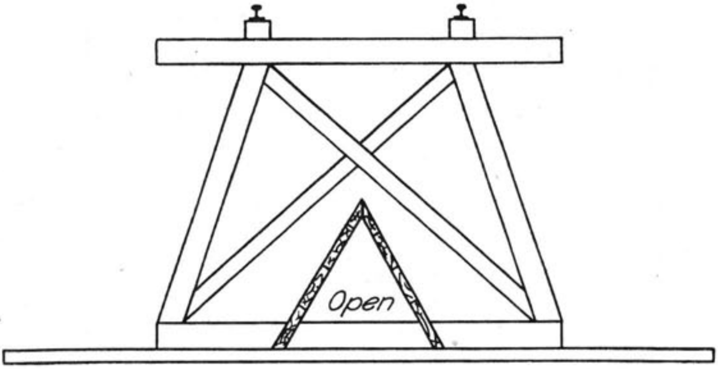

FIG. 40. COOLING DUCT UNDER PILE

pose of this flue is two-fold: to help in shifting the coal from under the trestle and thus facilitate loading by crane, and also to act as a cooling agent by conveying cool air the entire length of the trestle without having it come in direct contact with the coal. Run-of-mine coal containing a large amount of slack was stored. An effort was made to store low sulphur coals, because the action of water on sulphur in coal forms sulphuric acid, which breaks up the lumps into slack. At no time was a temperature above 70 degrees noted in pipes placed in the piles.

Fig. 41 shows the Standard Storage System adopted by the New

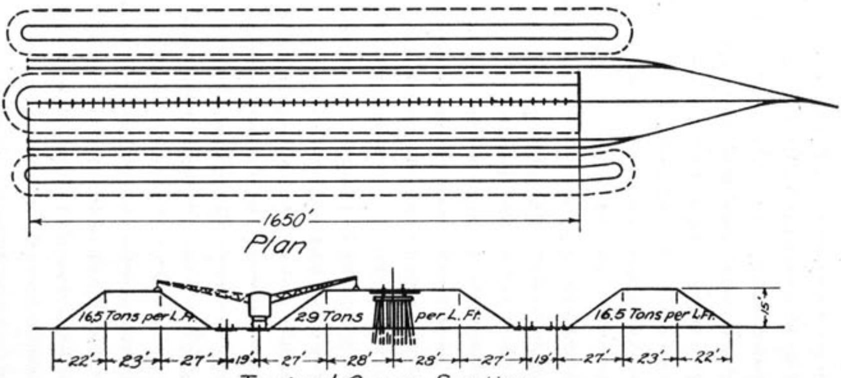

FIG. 41. PLAN AND SECTION ILLUSTRATING STANDARD COAL STORAGE SYSTEM OF THE NEW YORK, NEW HAVEN, AND HARTFORD RAILROAD (TONNAGE GIVEN PER LINEAR FOOT)

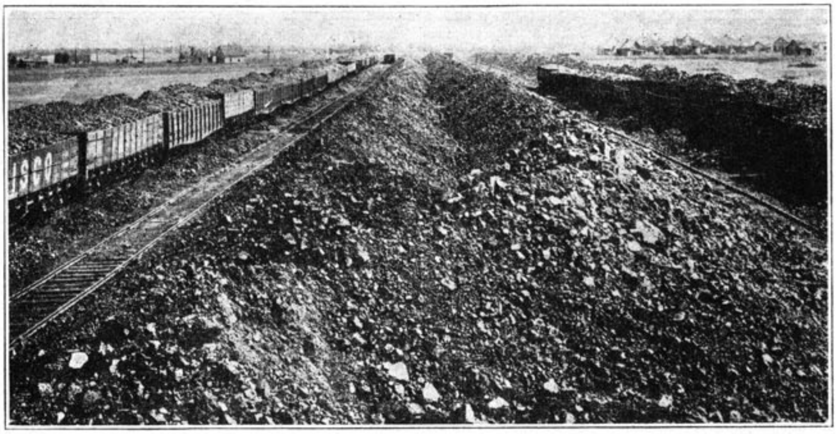

Fig. 36. Railroad Coal Storage Pile at Enid, Oklahoma

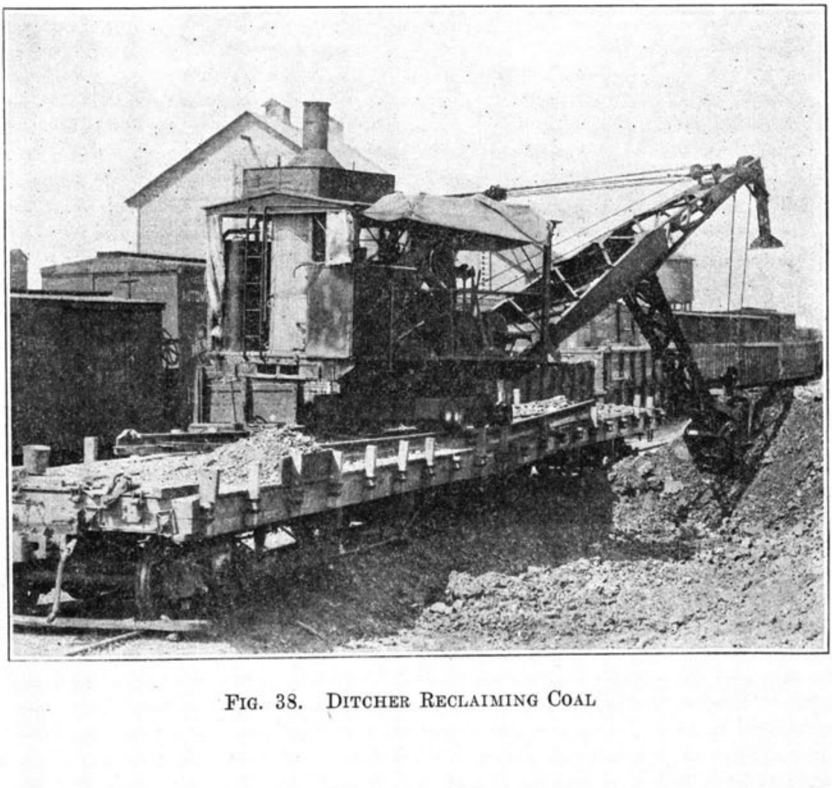

Fig. 38. Ditcher Reclaiming Coal

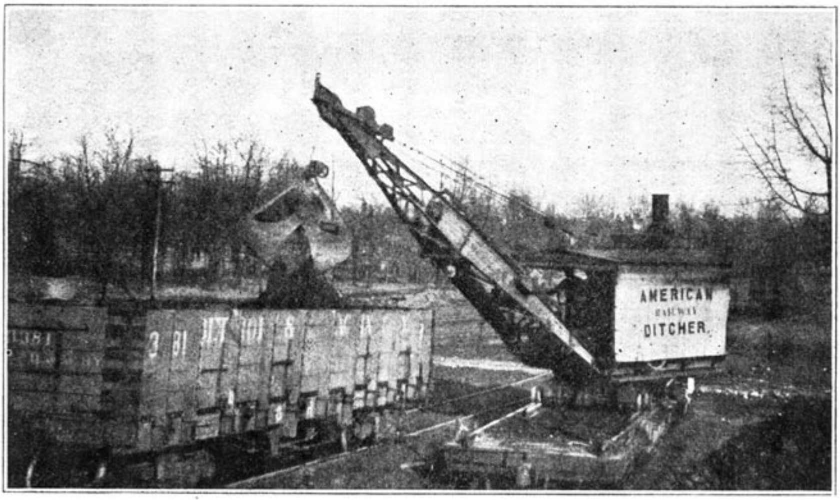

FIG. 39. DITCHER RECLAIMING COAL

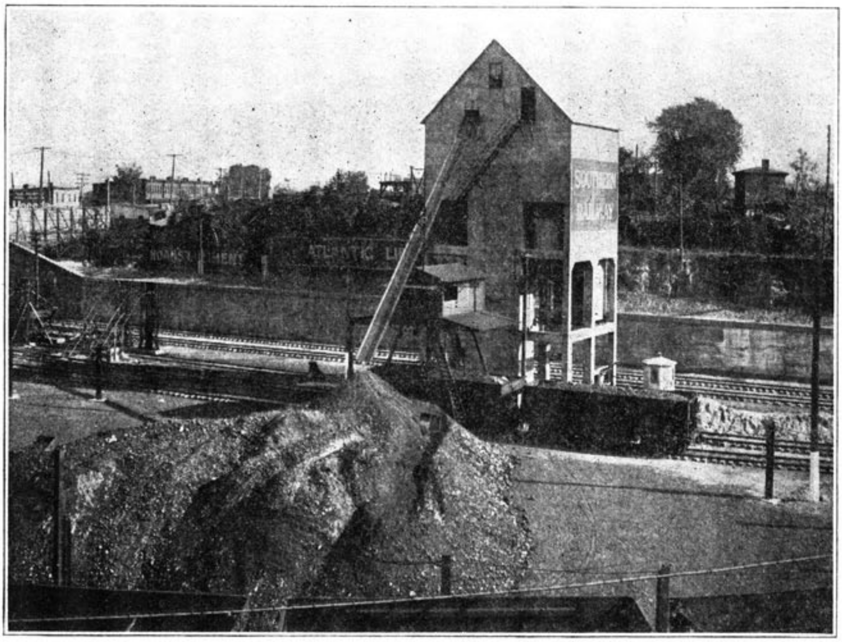

FIG. 42. DRAG-LINE COAL STORAGE AND COAL HANDLING PLANT OF SOUTHERN RAILWAY AT AIR LINE JUNCTION, VIRGINIA

York, New Haven, and Hartford Railroad at three coal storage yards recently installed. A trestle 1600 to 1700 feet long and 16 to 17 feet high runs through the center of each yard and on either side is a pair of parallel tracks. The trestle supports are wooden piling and the tracks on top of the trestle rest on steel girders. The two pairs of parallel tracks approach at the yard entrance. On one of the parallel tracks on either side of the center trestle a locomotive crane operates with a swinging boom which transfers the coal dumped from hopper bottom cars running on top of the trestle to piles built up about the trestle and also outside of the parallel tracks. The average height of the coal pile is 20 feet. The coal is trenched to a depth of 8 to 10 feet regularly throughout the pile and in addition ventilation pipes are put down to the bottom of the pile 40 to 50 feet apart. Temperature tubes are inserted in these pipes and readings are taken regularly for indications of heating.

Side hill storage is applicable only in certain districts and with it the pyramiding effect is exaggerated.

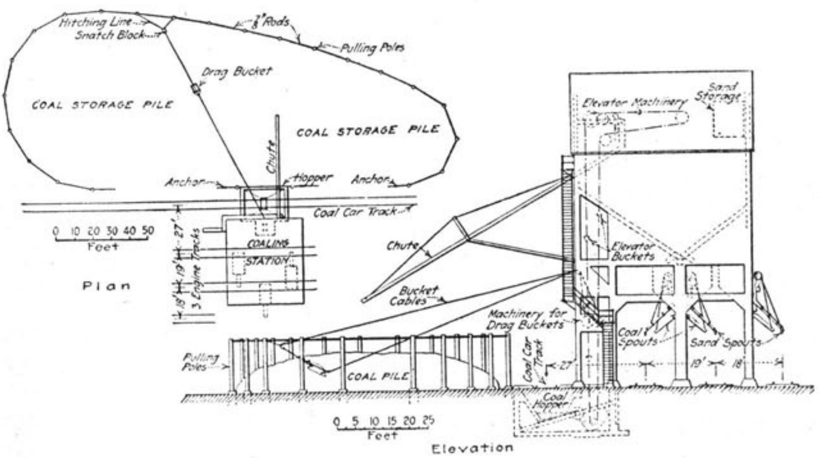

FIG. 43. PLAN AND SECTION OF COAL STORAGE AND COAL HANDLING PLANT OF SOUTHERN RAILWAY AT AIR LINE JUNCTION, VIRGINIA

31. *Drag-Line Bucket Storage.*—Figs. 42 and 43 show in perspective, in plan, and in section the drag-line type of storage used by the Southern Railway. The storage piles contain from 3000 to 10 000 tons each, with a depth of not more than 10 feet. The railway cars

dump the coal into a track hopper, from which it is fed by a loading device to a bucket elevator. This delivers it either to the storage bin of the coaling station or to a gravity chute which discharges at about the center of the storage pile and from this point it is distributed over the area of the pile by the drag scraper.

This scraper also returns coal from the storage pile to the track hopper and elevator for the supply of the locomotive coaling bin. The storage pile is of irregular form and is surrounded by poles, placed about 20 feet apart, to which is attached the cable line for operating the bucket. It has been found that the best height for these piles is about 12 feet. They are made of steel H-beams, each set in a concrete base and are connected at the top by a row of ⅞-inch rods.

The scraper bucket is operated by means of a double drum friction hoist driven by a 25 hp. motor geared directly to a countershaft. With this equipment the operator can take the coal delivered from the chute and distribute it between this point and the post to which the snatch-block is attached. To reach the space between two posts, lines may be fastened to them and the snatch-block attached to the lines. By shifting the block from pole to pole any point within the coal storage area can be reached. When it is necessary to supply the bin of the coaling station, the position of the bucket or scoop is reversed, its open end being turned toward the coaling station, the backhaul cable then becoming the hauling line.

Drag-line storage systems are somewhat less flexible than the locomotive crane type but they require less initial investment, for the motor, ropes, bucket, and posts are probably less costly than a crane, and no track investment is required.

32. *Silo Type of Storage Pockets.*—The silo type of coal storage pocket has been used by a number of industrial plants for strictly storage purposes and by retail dealers and railroads for temporary storage and current supply. The silos are constructed of reinforced concrete, of steel plates, or of wooden staves and are often built in batteries of two or more with a capacity of 100 to 1000 tons. They vary in diameter from 14 to 30 feet and in height from 24 to 75 feet. Old steel tanks have been remodeled in some cases to serve as coal pockets. The silos are filled from hopper bottom cars which are un-

loaded through a track grating into the boot of an elevator which delivers the coal at the top into a conveyor line running over the top of the silos and arranged for automatic dumping into any desired silo. Silos are usually set high enough above the ground so that the coal can be loaded out by gravity through chutes either into a conveyor for transferring the coal to a power plant, or into wagons; a screening arrangement may be located at the discharge point. At the top of the silo, in order to prevent breakage, the coal may be dumped upon a zig-zag coal ladder consisting of a series of projections from the walls of the silo, the coal falling from one to the other so as to decrease the height of drop.

The advantages of the silo are: small ground space required, less labor required for loading and unloading, and the ease with which the coal can be transferred by means of elevators and conveyors from one silo to another in case of a rise in temperature.

The disadvantages are: high initial cost of installation and excessive breakage when the coal is dropped through any great height, and the necessity of moving the entire contents of the silo below the heating spot if heating occurs.

It is believed by some that the danger of the coal heating is reduced to a certain extent because every load that is taken out of the silo shifts the position of the remaining coal. Such movement of the coal may also act injuriously by causing the circulation of air in an insufficient quantity. If heating occurs, the bin may be flooded with water, provided it has been constructed to withstand the pressure of the coal with the interstices filled with water.

Fig. 44 illustrates a coal pocket of wooden stave construction, which consists of a battery of four silos 34 feet high, three of them being 20 feet in diameter and the fourth one only 16 feet in diameter. The storage capacity of the plant is about 1500 tons of anthracite.

The coal is dumped from the car into a steel-lined concrete hopper from which it slides into a steel boot. It is then elevated by continuous buckets to a point over the bins, from which it is distributed as desired through several chutes and valves. To avoid excessive breakage it is lowered to the level of the coal in the different bins by a zig-zag coal ladder. The power is furnished by a 10 hp. electric motor.

The cost of operating this plant is given by the H. M. Tuttle Company of Bennington, Vermont, as follows:

Plant Expenses for One Month

1.	Depreciation	$31.59
2.	Real Estate Expense	
	Tax apportionment	14.08
	Insurance	10.33
	Land and track rental	22.01
3.	Light and Power	8.70
4.	Degradation	
	Shortage in weight of cars and loss from screenings for 1259.04 net tons at $.39 per ton	491.09
5.	Wages	
	Unloading and yard employees	202.46
	Total	$780.26

Thus, since 1259.04 tons were handled during the month, the cost per net ton would be $0.62. The average cost per net ton for nine months was $0.554.

The cost of silos similar to those shown in Fig. 44 was given in February, 1919, as $2.20 for a 400-ton bin to $2.60 for a 200-ton bin per ton of coal capacity for the materials on board cars at Rutland, Vermont, at the plant of the Creamery Package Manufacturing Company, builders of such silos. Erection and freight are said to add not over fifty cents per ton.

Fig. 45 shows a stave silo plant elevated for bottom discharge to retail trucks.

Concrete or steel construction for silos has an advantage over wood construction as the repair bill is less, and the fire risk is greatly reduced. With reference to a concrete storage pocket, F. W. Stock & Sons,* Hillsdale, Michigan, under date of January 30, 1919, says:

> "The coal storage tanks erected about a year ago have proved a very successful investment for us as a manufacturing concern. To prevent spontaneous combustion the coal should be drawn in rotation from all the tanks and not from only one; otherwise, there is considerable chance of spontaneous combustion, particularly if the coal happened to be slightly damp when put into the tanks."

The Macdonald Engineering Company, Chicago, Illinois, builders of this plant, reports upon these silos after they have been operated two years, as follows:

* Illustrated and described in Univ. of Ill., Eng. Exp. Sta. Circular No. 6, p. 95.

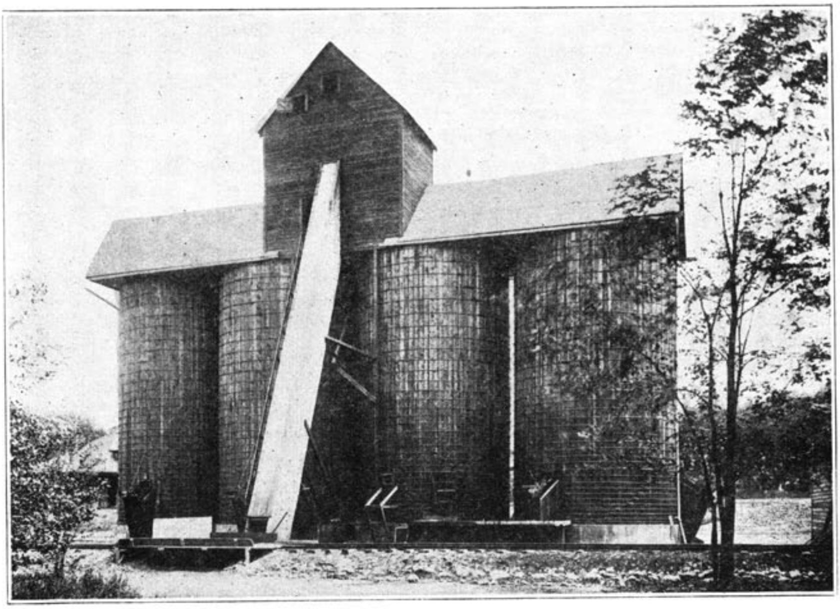

Fig. 44. Wooden Stave Silo Coal Storage Plant

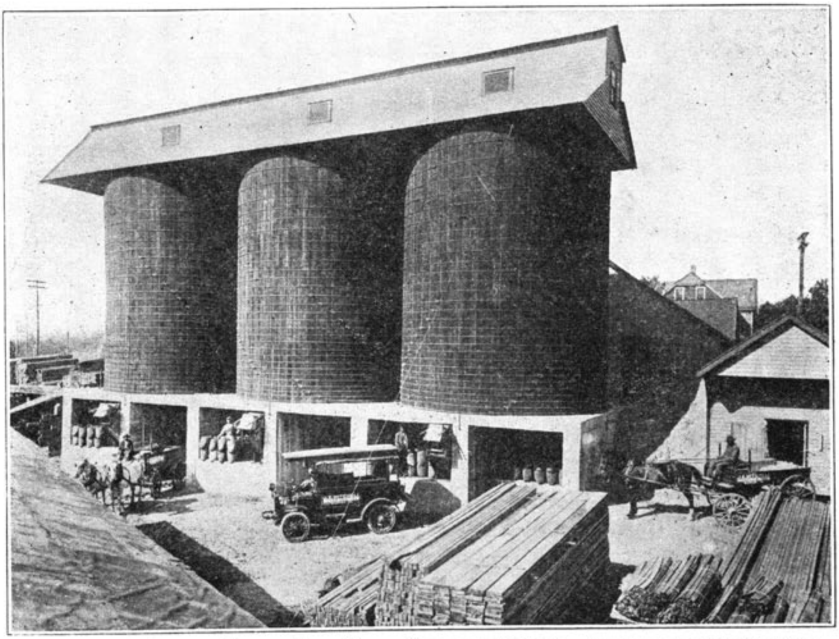

Fig. 45. Wooden Stave Silo Coal Storage Plant, Arranged for Bottom Discharge

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"One of the bins in this plant which is 28 feet in diameter and 70 feet deep was kept continuously filled with coal from sometime in October, 1917, to August, 1918. The contents in this time had not been disturbed to amount to anything. No perceptible rise of temperature was observed until sometime in August, 1918, when the moisture originally in the coal seemed to be pretty well evaporated and the temperature began to rise. We had equipped these bins with a means for flooding them with water. About the first of September when the temperature was at the ignition point we tried an experiment and turned on the water. This resulted in so much steam and gas that it was discontinued, as our man feared it might produce an explosion. Immediately after shutting off the water we drew out 10 tons of the hot coal through the bottom discharge spouts of the bin. This coal was smouldering and the amount drawn seemed to include all that was on fire. We then closed the valves and sealed them air-tight with a putty of clay. Two or three days later an inspection showed that the trouble was over and the temperature nearly normal, since which time there has been no further increase in temperature. At the date of the heating we had 65 feet of coal in the bin and we found that the fire was located on the hopper bottom of the bin and occupied the space between the outlet openings and the manhole which was built in the vertical outside wall of the bin. The indications were that there had been just enough air ventilation between the outlets and this valve to furnish the required amount of oxygen for combustion. From this experiment it would seem that if the opening were sealed perfectly air-tight there would be no rise in temperature. After using this plan for two years the only suggestion that the owners had to make is that they would use smaller bins for any future storage, so that if they had to change the coal from one to another there would not be so much to handle."

W. A. Joshel, wholesale and retail coal dealer of Geneva, Illinois, has two silos 60 feet in height and 18 feet in diameter. One of these is partitioned into four bins and the other into two bins by means of 2x4's laid flat. The silo walls are 6-inch reinforced concrete. There has been no trouble from heating; the coal is kept in motion by being constantly drawn out at the bottom. The breakage has been heavy and Mr. Joshel advises building silos much lower and either building more of them or increasing the diameter. He is able to unload a 42-ton car of anthracite, range size, from a hopper-bottom car in one and one-fourth hours with only one attendant, while a box car takes three times as long. Power is furnished by a 7½ hp. motor. The silos hold about 600 tons and the cost on the 1916 price basis was $7000, which is considered to be $700 too high, due to unusual foundation blasting and other difficulties.

Fig. 46 shows a storage plant of the American Hominy Company of Indianapolis, Indiana. It is built of concrete in silo type and has a basement conveyor tunnel running the full length of the building. Each of the five concrete bins is 28 feet in diameter and 75 feet in

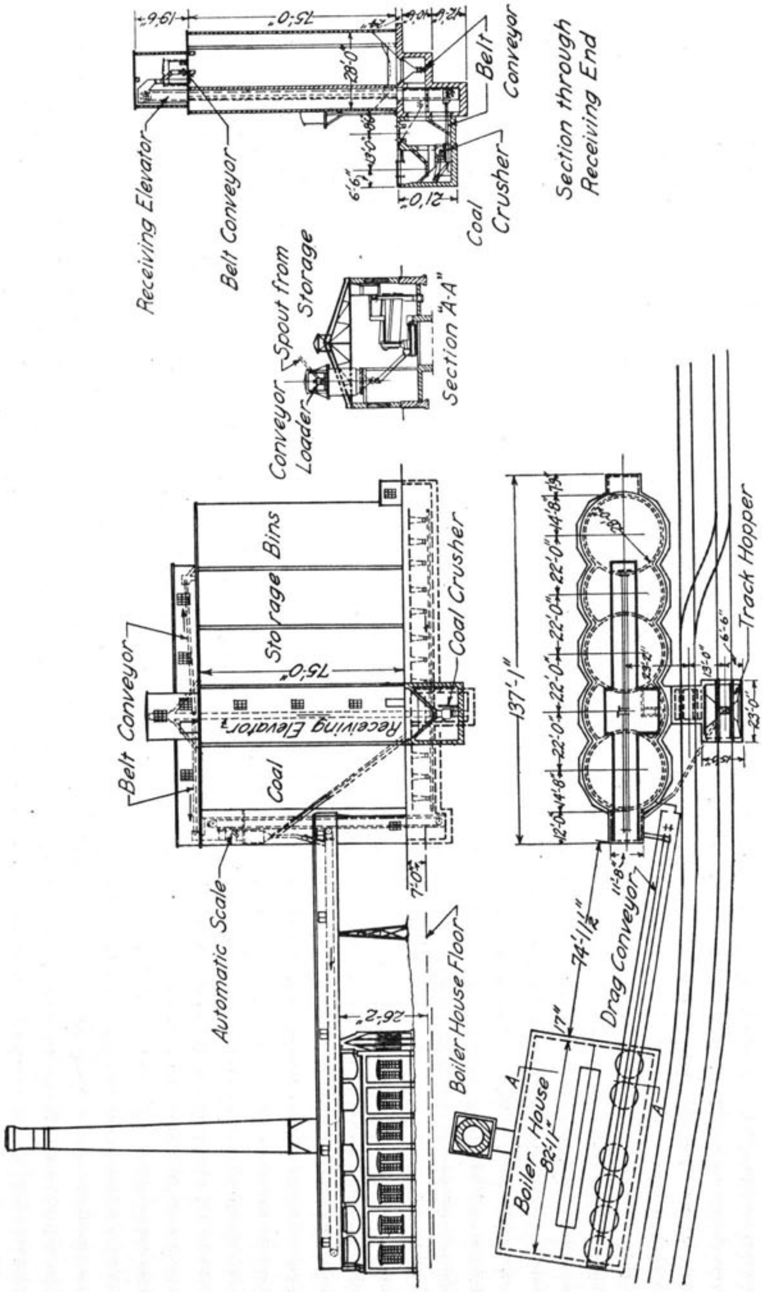

FIG. 46. SIDE ELEVATION, PLAN, AND SECTION OF COAL STORAGE PLANT OF AMERICAN HOMINY COMPANY, INDIANAPOLIS, INDIANA

height. The coal is received through a deep track hopper which will take the discharge from the longest coal car made and deliver it through a crusher to a vertical elevator which raises it to the top of the storage plant. The distributing arrangement is such that the coal may be delivered directly to the bunkers in the boiler-house or sent into the bins for storage. After being delivered into the bins it is transferred from these bins by means of a belt-conveyor located in the basement of the building, elevated by a vertical conveyor at the end, and discharged through an automatic scale to a conveyor which delivers the coal to the boiler room bunkers. The advantages claimed for this form of storage are reduction in ground space, as well as the reduction of labor cost due to automatic handling of material.

At this plant, during the summer of 1919, an explosion occurred in one of the silos while a small amount of coal that had heated badly was being drawn off at the bottom. The explosion had sufficient force to lift the roof slab a few inches and to carry away a small section of the side wall. The heating seems plainly traceable to an air leak around the outlet valves at the bottom which at first were not made air-tight. After the supply of air was shut off the heating ceased.

33. *Portable and Semi-Portable Conveyors.*—The portable or semi-portable type of elevator or conveyor has been developed by a number of firms to supply means for storing and handling coal in smaller quantities and with less expensive machinery than by the use of cranes of either the locomotive or gantry type.

These appliances consist essentially of a belt or bucket conveyor suitably supported and encased and moved about by means of wheels underneath or supported by a form of trolley overhead. Semi-portable conveyors have one end fixed or pivoted, while the discharge end can be rotated. These conveyors vary in size from the small wagon loader type to the long portable type intended distinctly for storage purposes, the conveyor arm varying in length from 6 feet to 60 feet and in width from 12 inches to 24 inches. According to the catalog of the Barber-Greene Company of Aurora, Illinois, the capacity of belt conveyors and power required for different materials is given in the following table:

TABLE 17

CAPACITY OF PORTABLE CONVEYORS

Width of Belt (Inches)	Capacity, Tons Per Hour					Horse Power Motors																
	Coke	Coal	Earth Clay	Cement	Sand or Stone	12′	15′	18′	21′	24′	27′	30′	33′	36′	39′	42′	45′	48′	51′	54′	57′	60′
12	10	17	29	30	34	1	1	1	1½	1½	1½	2	2	2	3	3	3	3	3	3	3	3
18	26	44	65	80	90	1	1½	1½	2	2	2	3	3	3	3	3	3	3	5	5	5	5
24	47	78	117	140	156	1½	2	2	3	3	3	3	3	5	5	5	5	5	7½	7½	7½	7½

It is claimed that, where material is delivered by gravity from the car directly to the conveyor, there is a saving of from 75 to 90 per cent in the handling cost and even where the material is shoveled to the conveyor half of the labor cost is saved. The power requirements are said to be from one to two kilowatts per hour for the short conveyors and from three to five kilowatts for the long conveyors. Several types of conveyors used in coal storage are shown in Figs. 47 to 61.

A typical method of using a combined fixed and portable system is shown in Figs. 47 and 48. The coal is delivered from the car into the boot of the fixed conveyor and at the delivery end builds up a conical pile, the height of which depends upon the height of the end of the conveyor and the amount of drop allowable. After the central

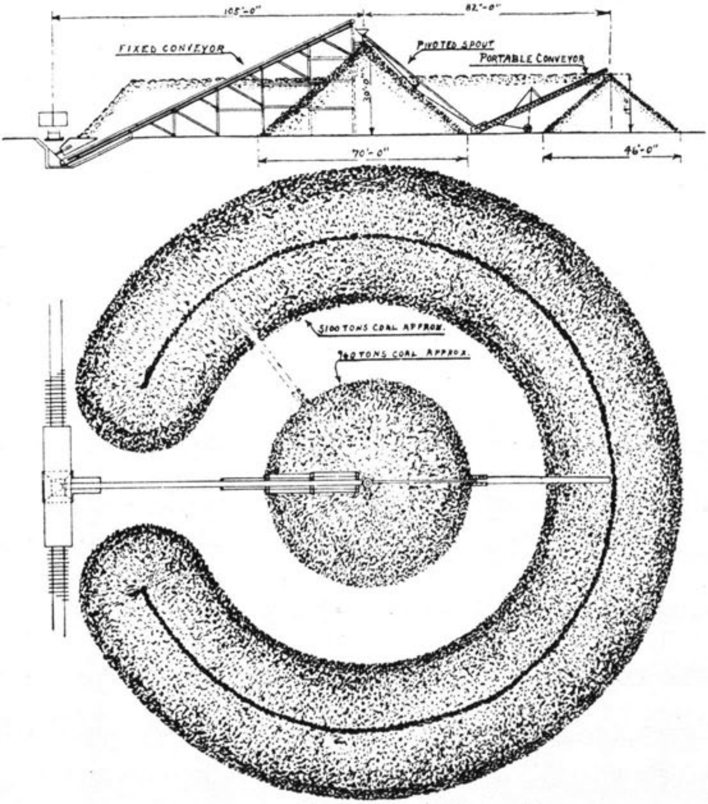

Fig. 48. Circular Method of Piling Coal, Using Both Portable and Semi-Portable Conveyors — Plan and Section

pile has been built a concentric pile is built up by delivering the coal into a chute which at the bottom feeds the boot of a portable conveyor. This conveyor in turn builds up either a series of conical piles concentric with the center pile as shown in Fig. 47 or a continuous, concentric, conical pile as shown in Fig. 48.

An application of this system built by the Barber-Greene Company at Mooseheart, Illinois, is illustrated in Figs. 49 to 51. In this plant the coal is delivered from a railroad track hopper shown at the left in Fig. 49 into the boot of a vertical bucket elevator which at the top delivers the coal either into a cross-conveyor which carries it into the boiler house bunkers, or else to conveyors which carry it to the storage piles.

In the original installation built in 1918, an inclined conveyor supported on trestles was used. This conveyor delivered the coal either upon a single conical pile or, by means of a long chute and a semi-portable conveyor, upon a concentric pile or several concentric piles as shown in Figs. 49 and 50.

To reclaim the coal the process was reversed, the coal being taken from the storage pile by a portable conveyor, which delivered it to a semi-portable conveyor which, in turn, delivered it to the elevator.

Experience showed that a large central conical pile at the end of the inclined conveyor was too high for safe storage; consequently this conveyor has been lowered so that it now runs horizontally and delivers to the belt of the portable conveyor.

Fig. 51 shows the new plant at Mooseheart with four conveyors in operation. On account of the railroad cut, through which incoming cars run, it was found advisable to divide the storage equipment into two units, one on each side of this railroad. The conveyors operate with reversible motors and the receiving hopper can be changed from end to end according to whether the coal is being stored or reclaimed. The initial cost of the plant was $4600 and the cost of the storing and reclaiming is estimated to be about twenty cents per ton.

Fig. 52 shows a portable conveyor used for storing directly from a railroad car and also for reclaiming directly into a railroad car. Fig. 53 shows a portable conveyor supported by cable, and if the ground permits, this system may be extended indefinitely.

Fig. 54 shows a view of a portable conveyor made by the Automatic Coal Conveyor Company of Chicago and operated by means of an

FIG. 47. CIRCULAR METHOD OF PILING COAL, USING BOTH PORTABLE AND SEMI-PORTABLE CONVEYORS

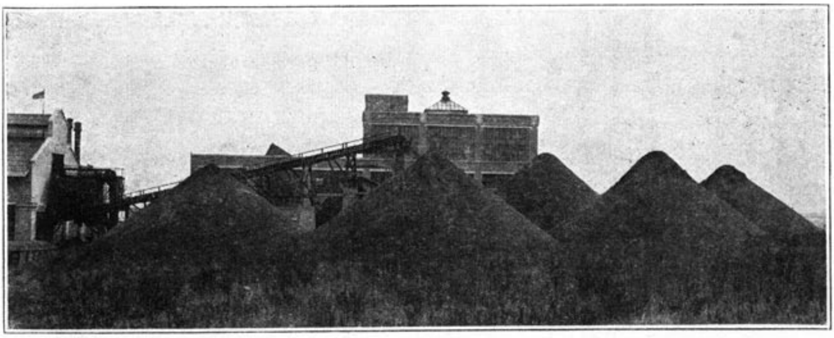

FIG. 49. COAL STORAGE PLANT USING FIXED AND PORTABLE CONVEYORS AT MOOSEHEART, ILLINOIS

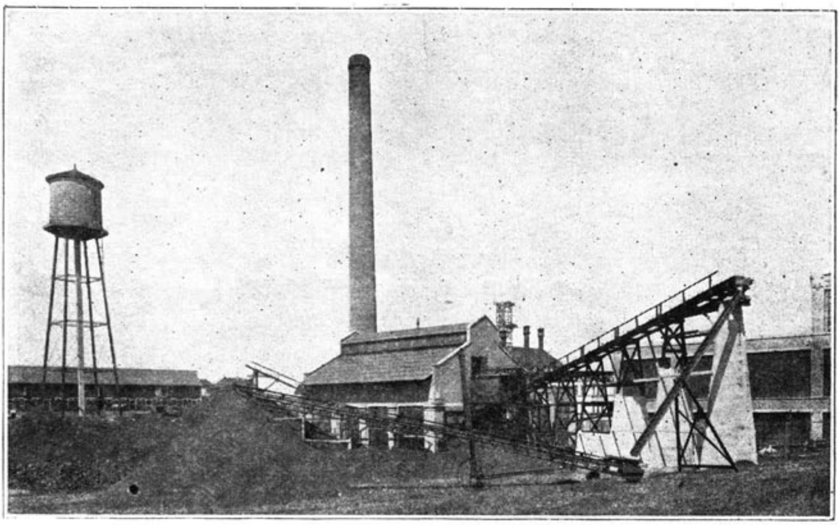

Fig. 50. Coal Storage Plant Using Fixed and Portable Conveyors at Mooseheart, Illinois

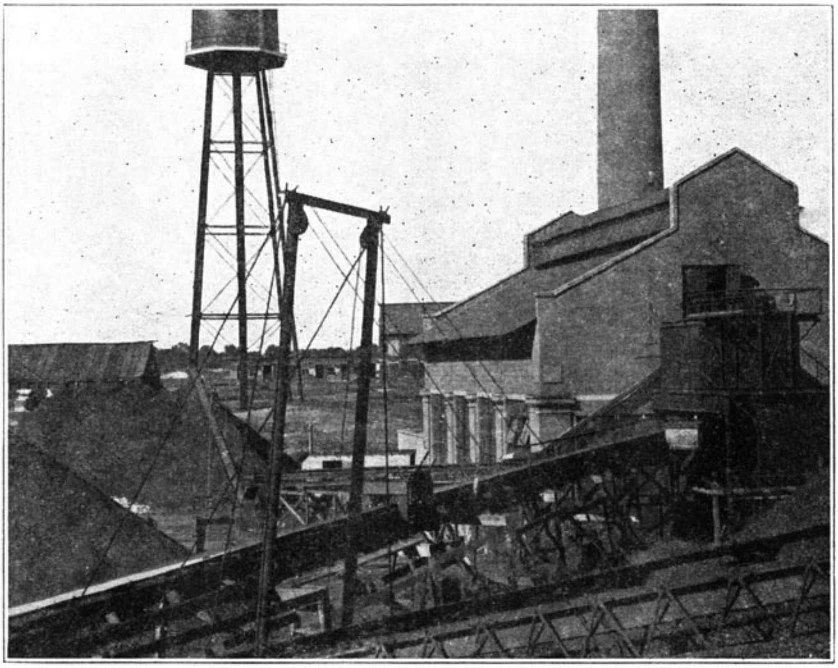

Fig. 51. View of Recent Addition to Mooseheart Plant, Showing Four Conveyors in Operation

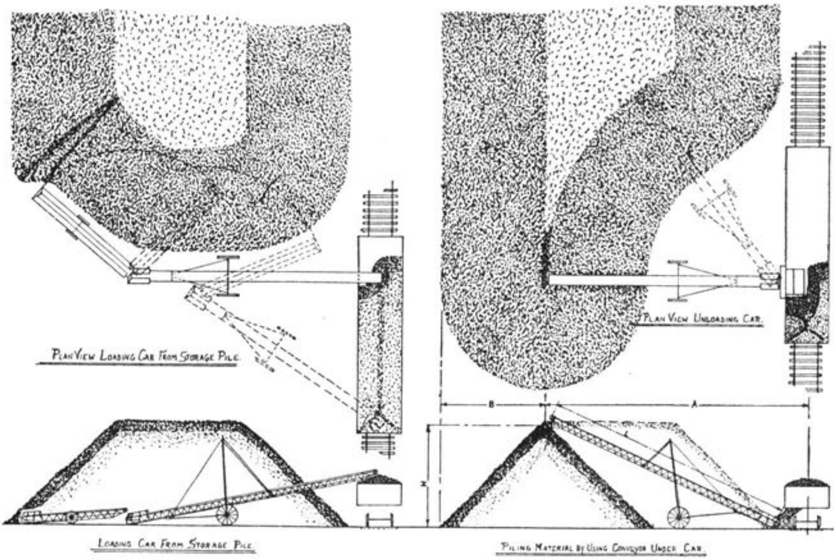

FIG. 52. PLAN AND SECTIONAL VIEWS ILLUSTRATING METHODS OF STORING FROM AND RECLAIMING INTO RAILROAD CARS WITH PORTABLE CONVEYORS

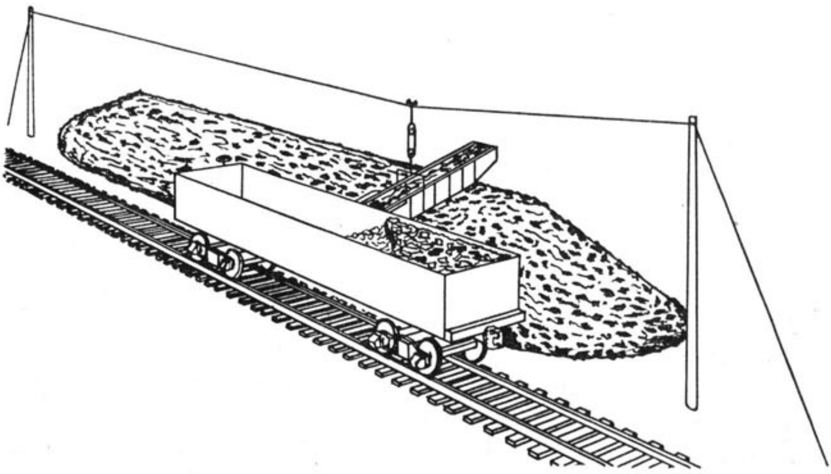

FIG. 53. PORTABLE CONVEYOR SUPPORTED BY CABLE

overhead trolley. This trolley can also be installed inside of a storage shed and used for placing coal under cover directly from the railroad car.

District of Columbia Storage Yard

The establishment of a Government coal storage yard in the District of Columbia marks a distinct epoch in coal storage. The reasons for this establishment and a description of the plant are as follows:

The Sundry Civil Act, carrying appropriations for the fiscal year from July 1, 1918, to June 30, 1919, inclusive, which was approved by the President on July 2, 1918, directed the Secretary of the Interior to establish under the Bureau of Mines a storage and distributing yard for the handling of fuel for the use of and delivery to all branches of the Federal service and the municipal government in the District of Columbia and immediately adjacent thereto, and authorized him to select, purchase, contract for, and distribute all fuel required by the said services.

This establishment was brought about as a result of the lack of adequate means for receiving and distributing coal for the use of the Government in Washington. On account of this lack of equipment, the Government was greatly handicapped in obtaining an adequate fuel supply for its buildings during the previous winter when coal production was at a low ebb and when transportation conditions, adversely affected by unprecedented weather conditions, made it impossible to get a daily supply into the city.

The annual requirements of the Departments supplied with fuel under the above legislation are approximately 400 000 tons of anthracite and bituminous coal per year. Most of the power and heating plants in which this coal is consumed do not have bunker capacity for more than a week or ten days' supply. Therefore the provision of sufficient storage space for coal to take care of all of the requirements of the Department for a period of a month seemed essential to the securing of a regular daily supply of fuel to the points of consumption.

There are periods in the middle of winter when the daily requirements for delivery of coal by trucks amount to from 2000 to 2500 tons. It seemed necessary, therefore, to provide some means of handling this large daily consumption in the middle of winter, with a minimum increase in the regular working force of the yard. The Stuart

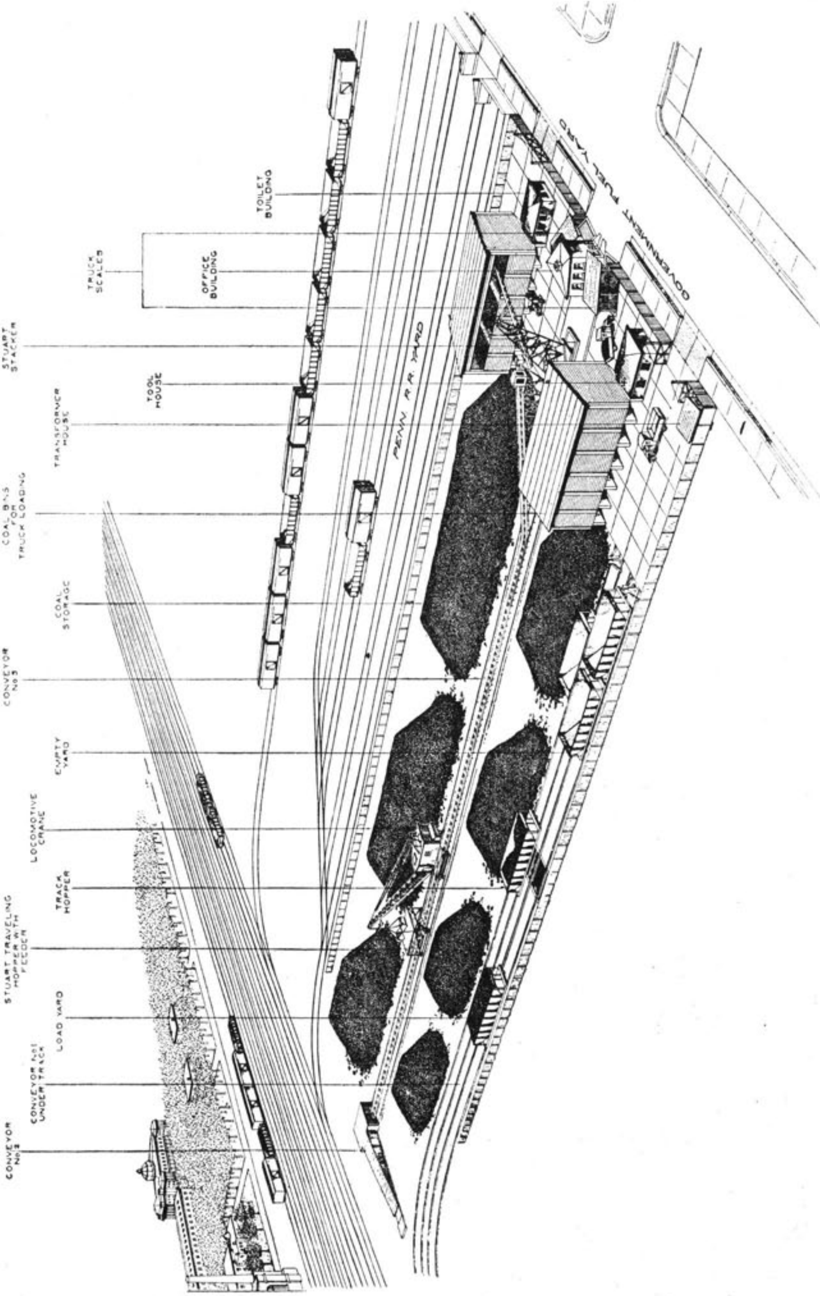

FIG. 55. GOVERNMENT COAL STORAGE PLANT, WASHINGTON, D. C. (STUART SYSTEM)

System of storage and distribution, with certain modifications to suit the conditions peculiar to the job, was selected.

Coal storage in this yard began about June 1, 1919. The storage capacity is about 30 000 tons with a capacity in the distributing bins of about 1200 tons; the plant is so arranged that the distributing equipment is not dependent for its continuous activity upon the amount of coal coming into the yard, and, on the other hand, the labor force in unloading incoming coal is not dependent upon the immediate ability of the distributing equipment to handle it.

The general arrangement and operation of the plant is shown in Fig. 55. The coal is received in self-clearing hopper-bottom cars which are dumped into a track hopper from which the coal is fed to conveyor No. 1, running in an underground tunnel, which has a capacity of 350 tons of coal per hour. The coal is weighed while in motion on the conveyor by means of a Messiter Conveyor Scale with a guaranteed accuracy of one-half of one per cent, so that the carloads of coal can be weighed separately. This conveyor delivers the coal to an inclined Conveyor No 2, shown at the left, which in turn delivers it to conveyor No. 3 (see also Fig. 56), running on the surface lengthwise of the yard. A stacker (see also Fig. 57) runs on the track and spans conveyor No. 3. It is of the portable conveyor type receiving the coal from conveyor No. 3 at any point and delivering it either to the coal bins for truck loading (See also Fig. 58) or to any storage pile alongside the conveyor. When the amount of coal received just equals the amount needed for distribution, the coal is conveyed directly to the distributing bins which are self-clearing and from which the coal flows without requiring any labor other than that of opening the valves directly into the trucks for distribution. If the amount of coal received in any one day is greater than can be placed in the distributing bins, the stacking machine which normally delivers to the bins can be withdrawn under its own power to any point in the storage yard where the surplus amount of coal received during the day can be put into storage. If, on the other hand, more fuel is required for distribution on any given day than is received in cars, the necessary amount of coal can be reclaimed from the storage space by means of a locomotive crane, which lifts the coal into a traveling hopper, whence it is fed to conveyor No. 3, and thence to the stacker and distributing bins as in normal operation.

Fig. 58 shows a general view of the office and bins from which the trucks used for distributing the coal are loaded. Mr. George S. Pope

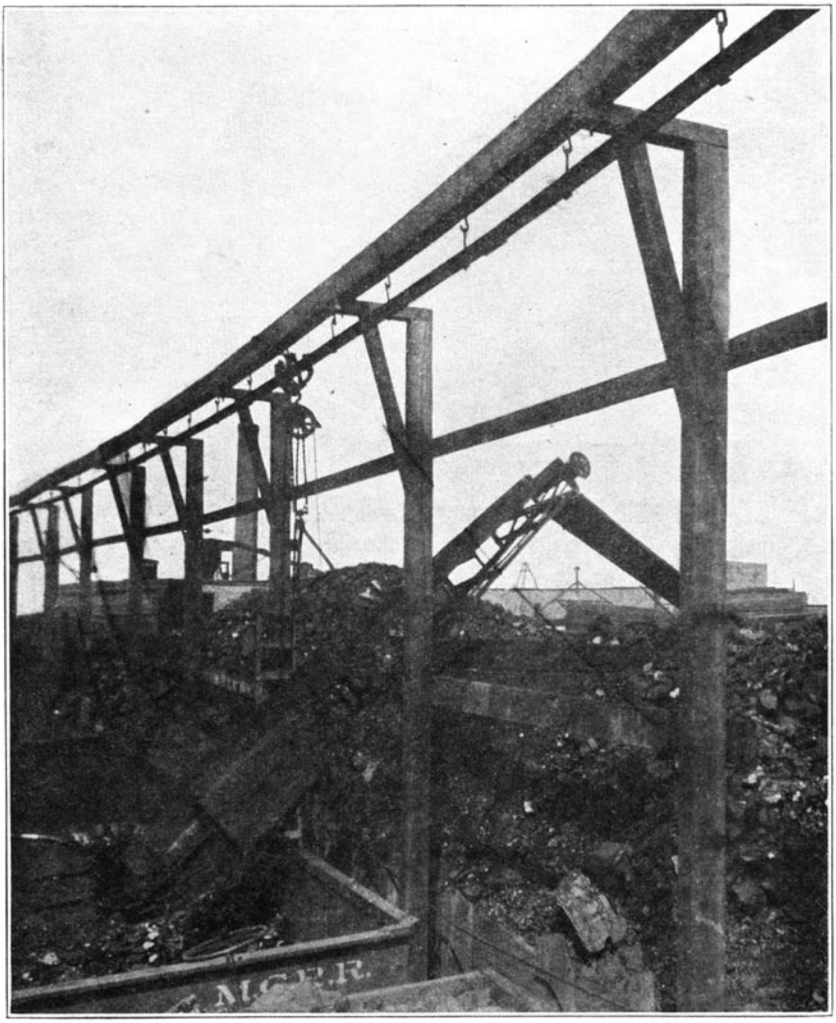

FIG. 54. PORTABLE CONVEYOR SUPPORTED BY OVERHEAD TROLLEY

FIG. 56. SURFACE CONVEYOR, GOVERNMENT COAL STORAGE PLANT, WASHINGTON, D. C.

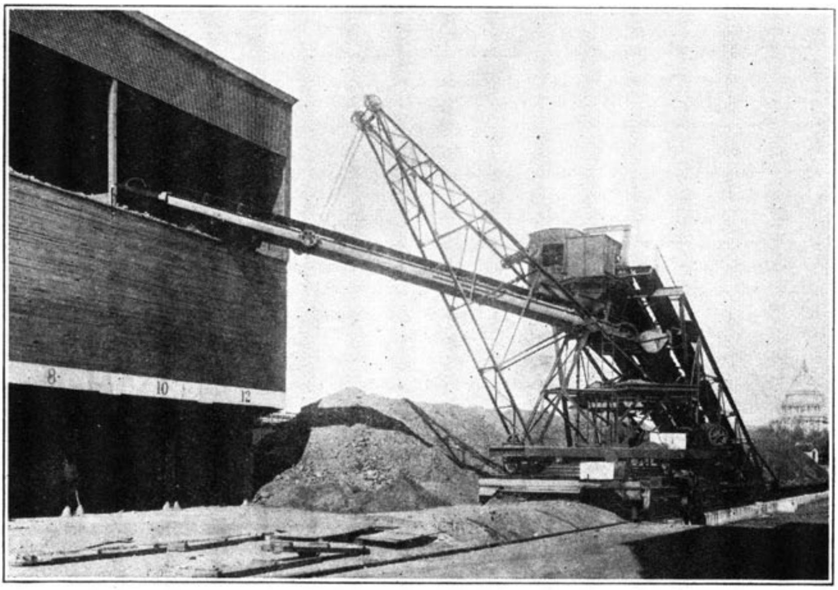

FIG. 57. STACKER, GOVERNMENT COAL STORAGE PLANT, WASHINGTON, D. C.

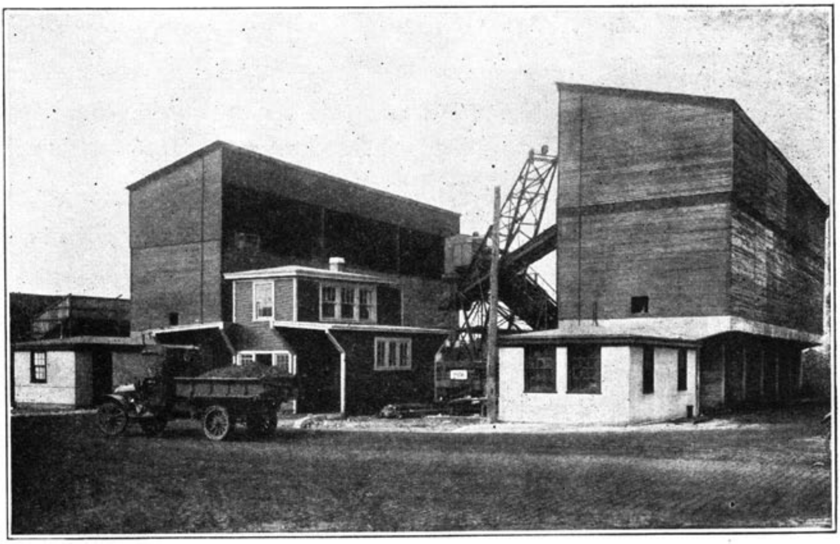

FIG. 58. DISTRIBUTING BINS AND OFFICE, GOVERNMENT COAL STORAGE PLANT, WASHINGTON, D. C.

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of the United States Bureau of Mines, who has charge of this storage plant, reports as follows in regard to the experiences at this plant.

Four kinds of coal were placed in storage as follows:

New River coal from various mines; coal from a mine operating the Upper Kittaning or C Prime bed, Somerset County, Pennsylvania; coal from a mine operating the B or Miller bed, Cambria County, Pennsylvania; and coal from several mines in Tucker County, West Virginia. The New River and Somerset County, Pennsylvania, coals were placed in storage in June and July, and the Cambria County, Pennsylvania, and Tucker County, West Virginia, coals in September and October.

With the New River coal three or four spots indicated heat by vapors being given off, but this was easily overcome by shoveling out the coal and in no case was it necessary to dig down more than five feet. The warm coal was spread over the outside of the pile and the heat subsided. This heating took place within a month or six weeks after the coal was put in storage and since then there have been no further indications of heating in the New River coal. There have been no indications of heating in the Somerset County, Pennsylvania, coal. Within two or three weeks after it was put in storage the Cambria County, Pennsylvania, coal showed signs of heating as indicated by vapors rising from different points. Attempts were made to overcome this heating by having men shovel the hot spots out as was done with the New River coal, but as this superficial treatment was not effective, the pile was dug into with the locomotive crane and the coal used at once. In a pile containing about one thousand tons of this coal the heating became so serious that arrangements were made to put in several tractor cranes but these were not necessary. The heating seemed to be at different points throughout the pile and some coal on the verge of flaming was found within two or three feet of the surface at the top and sides as well as throughout the interior. One spot where the coal had actually burned and where ashes were found was next to the concrete floor.

The Tucker County, West Virginia, coals showed some indications of heating and were given the same superficial treatment as the New River coal, but this coal as well as all of the Cambria County, Pennsylvania, coal was moved out of storage during the coal strike. The Somerset County, Pennsylvania, coal pile was practically untouched and about one-half of the New River coal was removed.

Mr. Pope describes the several coals as follows:

"The Somerset County, Pennsylvania, coal is about the lumpiest we have, the New River being second, the Cambria County, Pennsylvania, third, and the Tucker County, West Virginia, fourth. The Cambria County, Pennsylvania, coal has a slightly higher sulphur content than the others, its content averaging about two per cent."

The following analyses of these coals are taken from Bulletin 119, United States Bureau of Mines.

	New River, Shipments on 28 Contracts	Somerset County, Pa., Shipments on 1 Contract	Tucker County, W. Va., Shipments on 5 Contracts	Cambria County, Pa., Shipments on 16 Contracts
Moisture	1.21– 3.49	3.52	2.77– 4.09	1.82– 2.89
Volatile	16.61–23.56	15.43	17.39–24.29	19.56–22.71
Fixed Carbon	70.03–78.82	75.89	66.52–72.47	69.81–73.75
Ash	4.55– 6.57	8.68	7.87–10.14	6.30– 9.11
Sulphur	0.65– 1.00	0.92	1.02– 1.18	1.77– 2.13

The New River and Somerset County, Pennsylvania, coals were piled to a height of sixteen to eighteen feet but, by moving the stacker, the coal was piled in layers in a number of small cones so as to avoid the segregation that would result if the coal was dumped at one point and a large cone thus allowed to build. The Cambria County, Pennsylvania, and the Tucker County, West Virginia, coals were similarly piled twenty-five feet high in places.

Erie Railroad Storage Plant

Fig. 59 shows a plan of an extensive storage plant of the Erie Railroad located at Buffalo, New York. It comprises a typical installation of the Stuart System of belt conveyors built by the International Conveyor Corporation.* The storage piles are at some distance from the coal pockets and across the railroad yard. Two tracks for incoming coal are parallel to the two storage piles, each of which is to hold 15 000 tons, the total of 30 000 tons representing a month's supply for the coal pockets. Of these two tracks, one is for loaded and the other for empty cars. The coal is dumped through a track hopper into the boot of conveyor No. 1 which delivers it to a hopper at the top of the conveyor from which it is delivered, in turn, to belt conveyor No. 2, which runs lengthwise of the storage yard. On each side of the trough in

* A detailed description of the plant will be found in the Railway Age, Vol. 65, No. 14, p. 615.

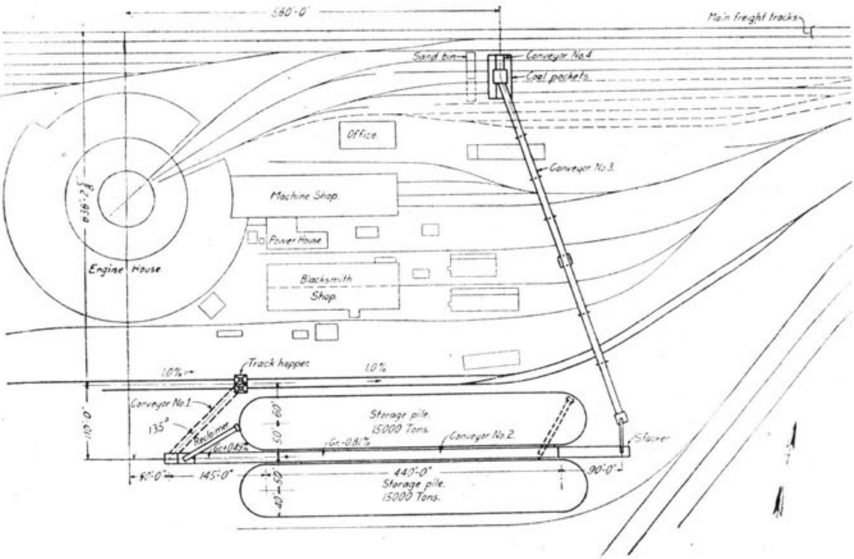

FIG. 59. PLAN OF COAL STORAGE PLANT OF THE ERIE RAILROAD, BUFFALO, NEW YORK

which conveyor No. 2 runs there is a rail; upon this rail runs a stacker which thus spans conveyor No. 2 (See Figs. 60 and 61). This stacker is essentially a movable tripper through which the conveyor belt runs and by means of it the coal can be delivered at any point along the travel of the conveyor belt. The stacker delivers to a loader running on the same track as the stacker which consists of a conveyor belt mounted on an arm that is pivoted so as to have a lateral swing of 180 degrees and a vertical movement so that the coal can be delivered with a minimum drop. The stacker in Figs. 59 and 60 is shown delivering to conveyor No. 3, which carries the coal to the coal pockets. For storing coal the stacker delivers into the storage piles.

To take coal from storage a reclaimer is used. This works on the same track as the stacker and loader, and is shown in Fig. 61. Like the loader, it is a belt conveyor operating on an arm that is pivoted on a platform and has a wide lateral swing. One end rests on the ground and a plow at the end of the arm is forced into the toe of the coal pile; the coal falling on the belt is then delivered through a hopper to conveyor No. 2 from which it is passed on to the coal pockets as previously described.

If the coal arrives at the yard faster than it is used for current coaling, it is placed in storage, but otherwise it goes directly from the track hopper through Conveyors 1, 2, and 3 to the pockets.

34. *Monorail System.*—The Godfrey Conveyor System for coal, ashes, etc., illustrated in Fig. 62, consists of a one-ton bucket or skip

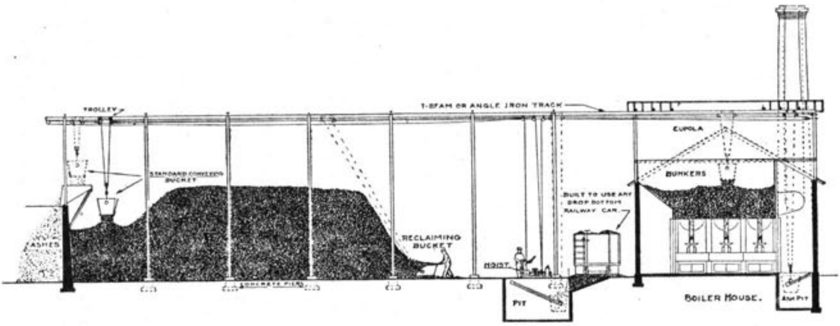

FIG. 62. GODFREY CONVEYOR SYSTEM FOR STORING AND HANDLING COAL

traveling on a suspended monorail or wire rope. The bucket is loaded by gravity at the side of the unloading railroad track. The full bucket is hoisted by means of a small electric hoist to the level of the suspended monorail or wire rope along which it is pulled by means of an endless rope operated by the electric hoist. When the dumping point is reached the bucket may be lowered to such a point that the breakage of coal in dumping will be small. The installation is designed to meet the needs of plants using from 15 to 150 tons per day and the manufacturers claim that one man can deliver about 30 tons of coal per hour either to storage or to the boiler plant. To reclaim the coal from storage, it may be shoveled into the bucket by hand, or a reclaiming bucket may be used.

A monorail system of storing and reclaiming coal as used by the American Spiral Pipe Works of Chicago is shown in Fig. 63. A steel structure supports a single rail upon which operates the support for a movable clam-shell bucket. The coal is both stored and reclaimed with the same device, but the capacity is limited by the fixed position of the monorail, and the coal piled with this device forms a conical pile with the resultant segregation of sizes and increased liability to spontaneous combustion.

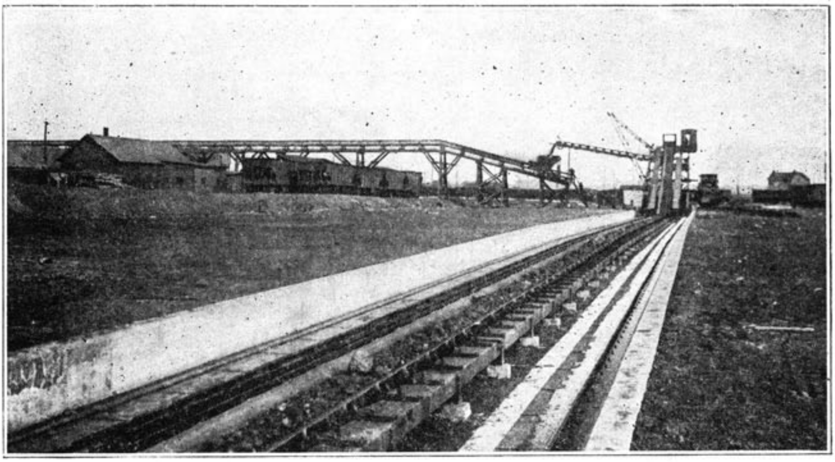

FIG. 60. VIEW OF COAL STORAGE PLANT OF THE ERIE RAILROAD, BUFFALO, NEW YORK, SHOWING CONVEYOR NO. 2 AND STACKER DELIVERING TO CONVEYOR NO. 3

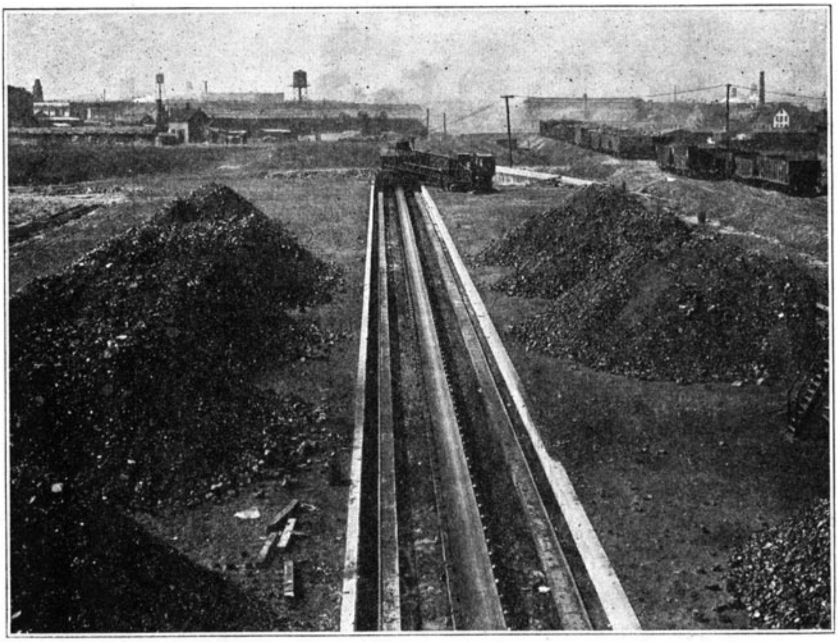

FIG. 61. VIEW OF COAL STORAGE PLANT OF THE ERIE RAILROAD, BUFFALO, NEW YORK, SHOWING LOADER AT END OF CONVEYOR NO. 2

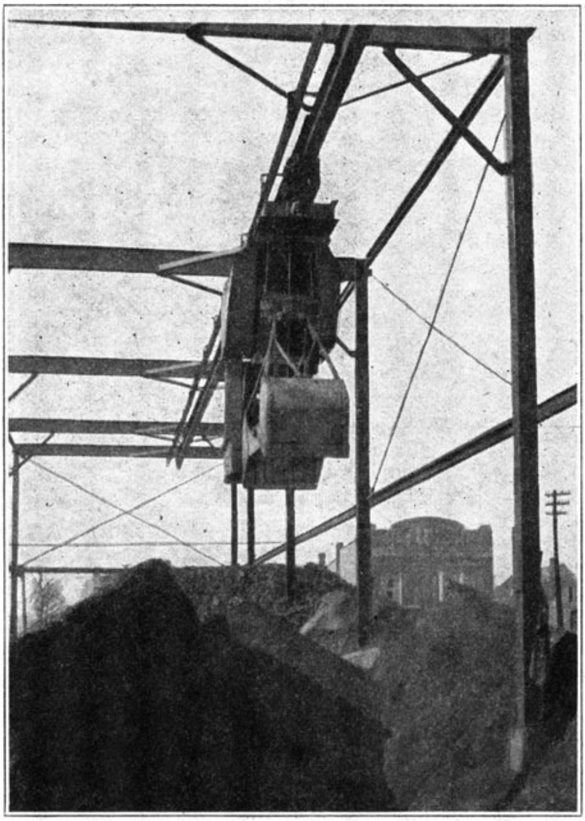

FIG. 63. MONORAIL SYSTEM FOR STORING AND RECLAIMING COAL

A similar bucket storage system has been built by the Lidgerwood Manufacturing Company, for the Galveston Coal Company, for unloading coal from steamers and conveying the coal to a storage pile. From the storage pile the coal is reclaimed and loaded into barges and railroad cars. The system consists of a self-filling bucket of the grab type which is moved along a fixed overhead track by means of rope haulage. The capacity of the Galveston installation is about 700 tons per day.

35. *Cableway System.*—The cableway system for storing and reclaiming coal consists of a hoisting and a conveying device, the latter operating over a single span cable supported by a tower at each end. The load may be taken from any point, conveyed in either direction, and deposited wherever desired along the line of the cableway.

The cableways are built in various types to meet different requirements, (a) with both towers fixed, as is Fig. 64; (b) with both towers

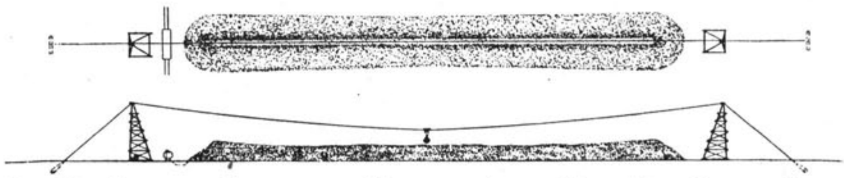

FIG. 64. CABLEWAY SYSTEM FOR HANDLING COAL — BOTH END TOWERS FIXED

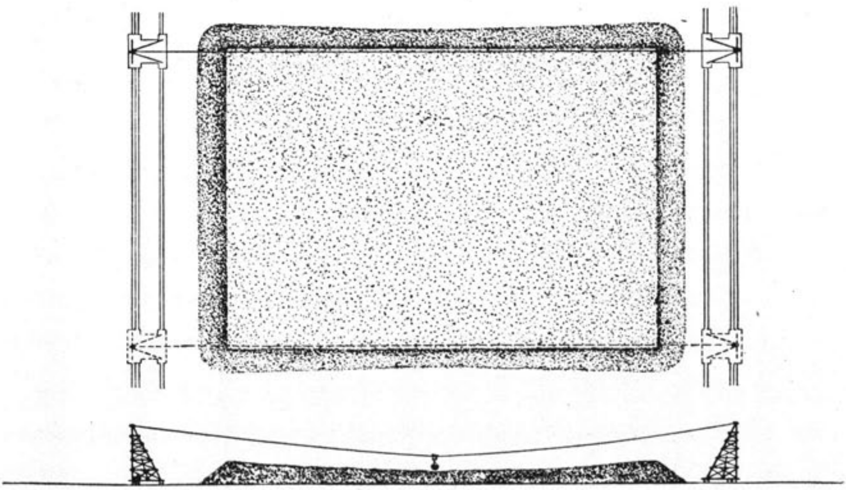

FIG. 65. CABLEWAY SYSTEM FOR HANDLING COAL — BOTH END TOWERS MOVABLE

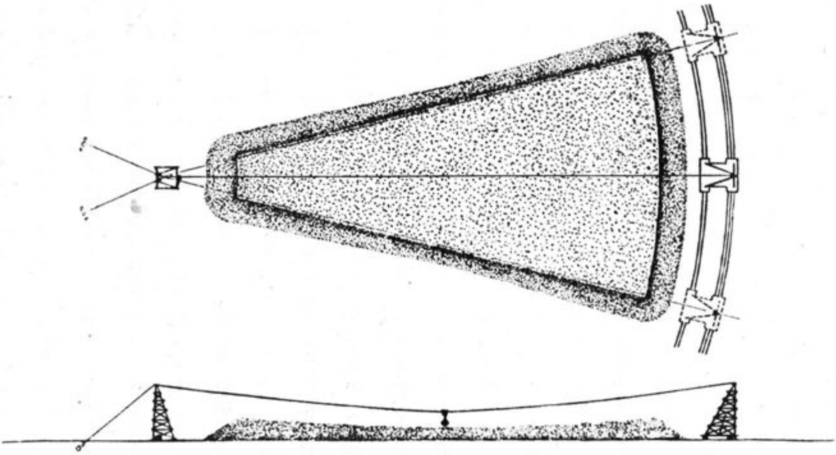

Fig. 66. Cableway System for Handling Coal — One End Tower Fixed, the Other Movable

traveling on parallel tracks, as in Fig. 65; (c) with one tower fixed the other traveling on a circular track about it as in Fig. 66.

36. *Automatic Dump Car Storage.*—The coal storage plant of the Karm Terminal Company at Bridgeport, Connecticut, installed by the Bergen Point Iron Works of Bayonne, New Jersey, is shown in Fig. 67. The coal is unloaded from barges by cranes as shown and dumped into automatically dumping electric cars which discharge either into a storage pile, into railroad cars, or into a coal pocket. Coal is reclaimed from the storage pile by another set of electric cars running through tunnels underneath the pile. These cars either take the coal to a loading pocket for loading automobile trucks or dump the coal into railroad cars, about twenty of which can stand underneath railroad viaducts. These railroad cars can all be loaded without being moved, as the small car can be made to dump automatically at any point.

37. *Cristobal and Balboa Coaling Stations.*—The coaling stations located at Cristobal and Balboa at the two ends of the Panama Canal are shown in Figs. 68 and 69. These were built by the Bergen Point Iron Works of Bayonne, New Jersey, and represent advanced practice for the handling of coal. The combined storage capacity of the two is 700 000 tons. At Cristobal Station 1200 tons per hour can be

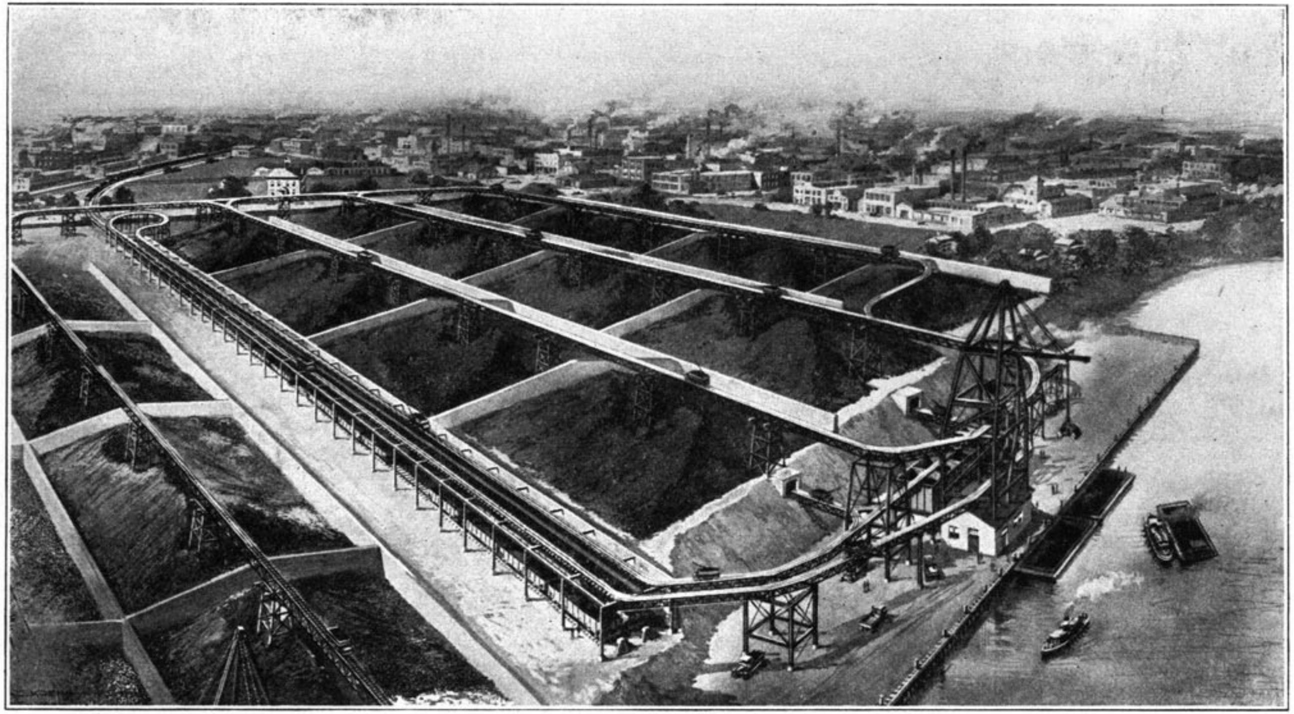

Fig. 67. Coal Storage Plant of the Karm Terminal Company, Bridgeport, Connecticut

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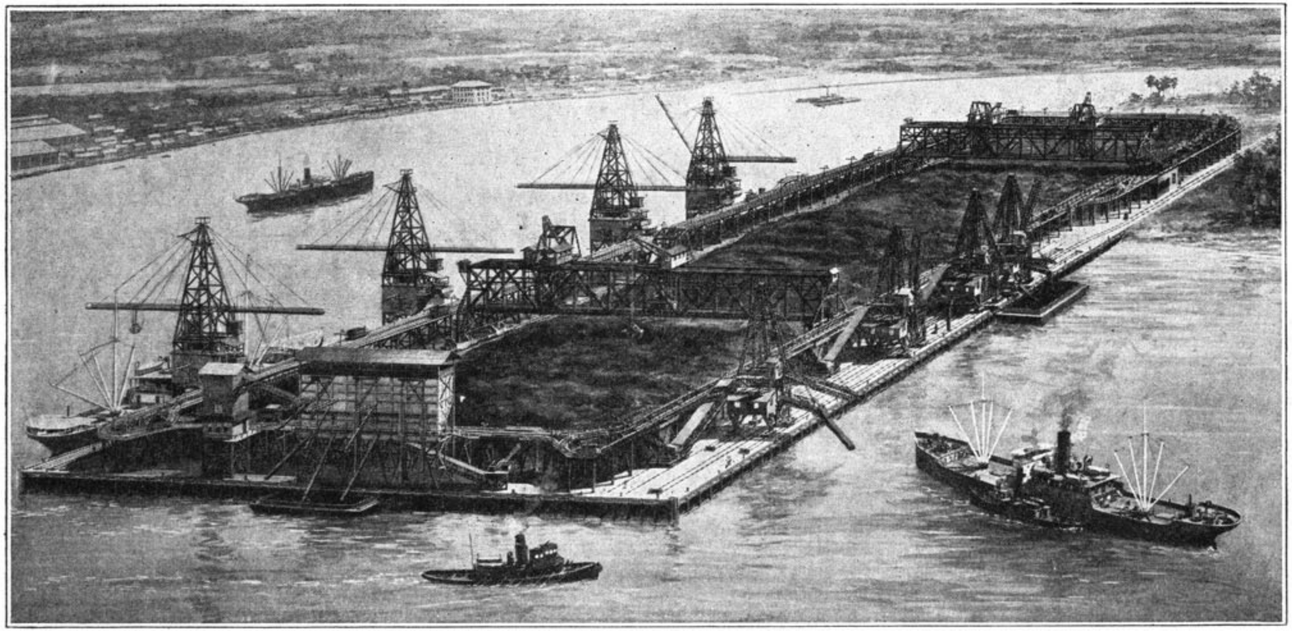

Fig. 68. The Cristobal Coaling Station, Panama Canal

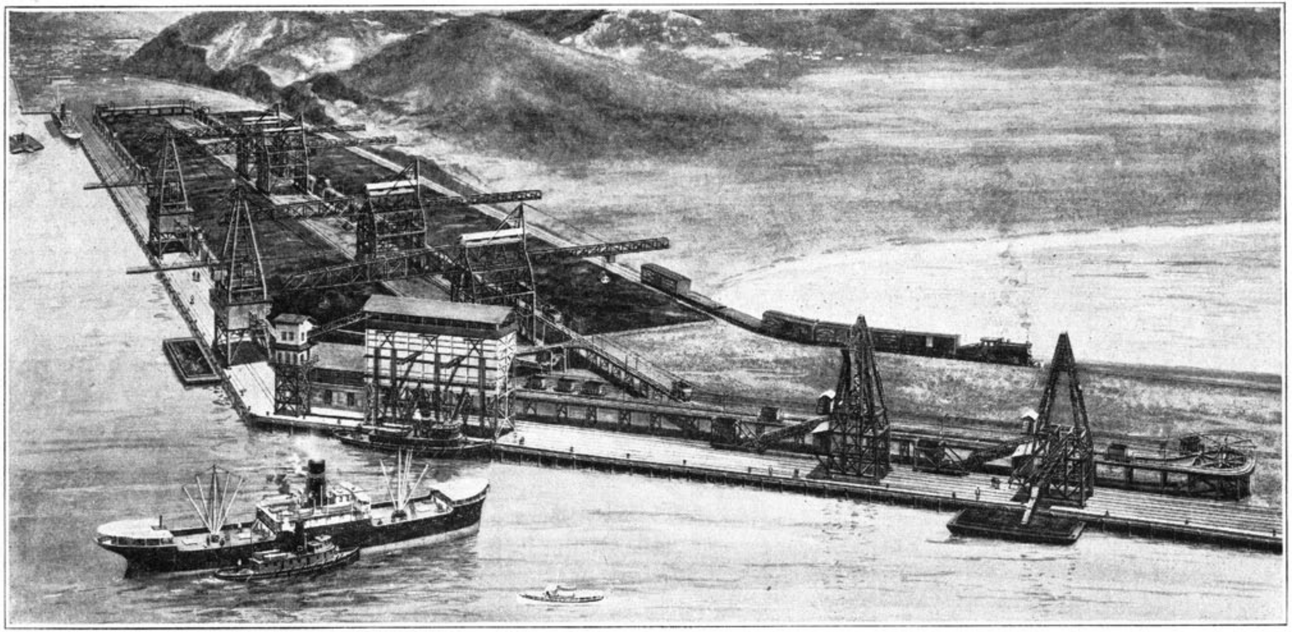

Fig. 69. Balboa Coaling Station, Panama Canal

unloaded and 2400 tons per hour reloaded. The storage plant includes both underwater and dry storage. The general layout of the plant is shown in the photographs; a number of articles descriptive of the detailed construction have been published.*

For the unloading and stocking, coal is taken from colliers or barges by unloaders equipped with 2½-ton buckets which have a rated capacity of 250 tons per hour. The coal is taken from the un-loaders to the dumping point by cars. It is reclaimed from storage by reclaiming bridges, each of which is equipped with a 5-ton bucket, having a rated capacity of 500 tons per hour. The total handling capacity at Balboa is only half that at Cristobal.

38. *Suction Conveyor.*—An application to coal storage purposes of the suction conveyor for handling coal and ashes at a power plant as used by the Pierce-Arrow Motor Car Company at Buffalo, New York, is shown in Fig. 70. Coal is taken from a track hopper by suction to a 100-ton coal tank from which it is delivered by motor-driven cars to the bunkers above the boilers. As is shown in Fig. 70 a reserve storage of 3000 tons is provided at one end of the plant by continuing the track and delivering coal from the coal tank in the motor driven cars to a storage pile instead of to the bunkers. Coal from the storage pile is reclaimed by permitting it to run into an underground reclaiming duct from which it is sucked into the 100-ton coal tank. At this plant bituminous screenings are used.

39. *Mine Storage.*—At Aldrich, Alabama, the Montevallo Mining Company operates a longwall mine with convict labor. In order that the mine might be operated six days a week with a variable supply of

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* "Coaling and Supply Depots at Panama." Black Diamond, Vol. 49, No. 25, p. 20, Dec. 21, 1912.

"Coaling Plants at Panama Canal." Coal Age, Vol. 3, p. 481, 1913.

"Panama Canal's Big Coaling Station." Coal Trade Bulletin, Vol. XXXV, p. 31, Oct. 2, 1916.

"Coaling at the Panama Canal—Cristobal," by F. J. Warden-Stevens. Colliery Guardian, Vol. CXII, p. 745, Oct. 20, 1916.

"Coal at the Panama Canal—Balboa," by F. J. Warden-Stevens. Colliery Guardian, Vol. CXII, p. 789, Oct. 20, 1916.

"Panama Canal Coaling Plants." Coal Trade Bulletin, Vol. XXXVI, p. 43, Apr. 2, 1917.

"Uncle Sam's Great Storage Docks." (Panama). Coal Trade Bulletin, Vol. 39, pp. 37-38, Oct. 15, 1918.

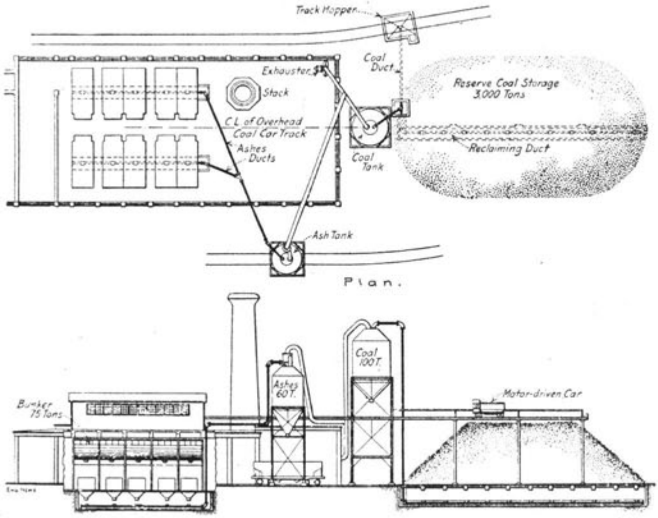

FIG. 70. SUCTION CONVEYOR COAL STORAGE PLANT OF THE PIERCE-ARROW MOTOR CAR COMPANY, BUFFALO, NEW YORK

railroad cars, a storage method was introduced. The general arrangement is shown in Fig. 71. Railroad cars loaded at the tipple are run by gravity several hundred feet to a suitable storage ground where the coal is shoveled out of the cars by hand labor or drawn from the bottom with hopper-bottom cars. When as much coal as possible has been stored in this way a wall is built of the larger lumps carefully piled along the railroad tracks. Planks placed on top of these walls and on top of the gondolas furnish a runway for the wheelbarrows which are loaded from the cars and dumped at the edge of the pile. The total capacity is about 20 000 tons and the cost of unloading approximately eleven cents per ton. The coal is reclaimed into one-ton mine cars running on a track at the foot of the storage pile as shown. These cars are pulled by a gasoline locomotive and hoisted three at a time up an incline into a revolving dump where the trip of three is emptied without uncoupling. The cost of reclaiming is ten cents per ton.

These costs will probably be decreased by the use of another rotary dump instead of so much hand-labor and if side-hill storage were used the cost of loading into the one-ton cars could be saved.

A belt conveyor has been built at Fairpoint, Ohio, by the Roberts and Schaefer Company of Chicago for the Clarkson Coal Mining Company of Cleveland, Ohio. This belt conveyor is supported on a trestle

FIG. 71. STORAGE SYSTEM USED BY THE MONTEVALLO MINING COMPANY, ALDRICH, ALABAMA

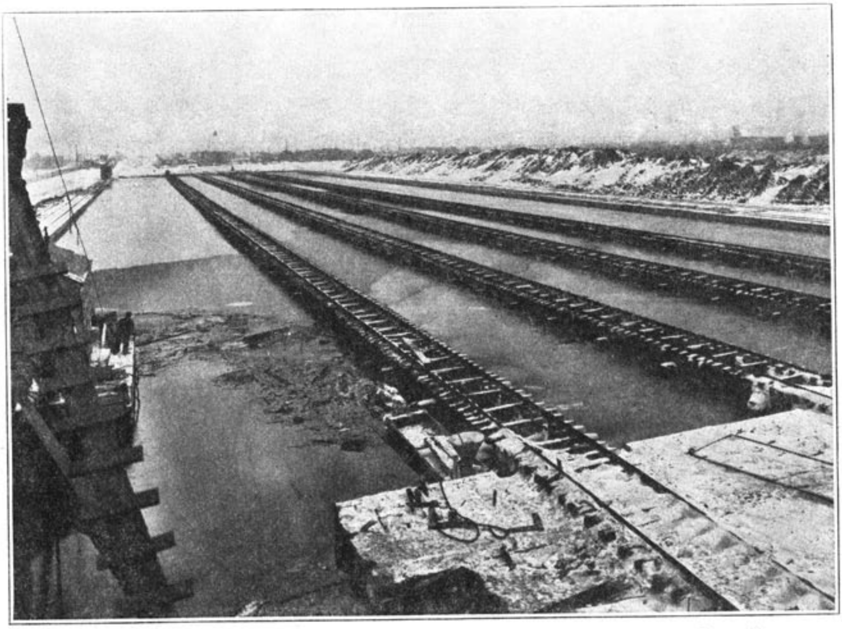

FIG. 72. UNDERWATER COAL STORAGE PLANT OF THE STANDARD OIL COMPANY, WHITING, INDIANA (100 000 TONS CAPACITY)

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for storing the slack, which is taken from beneath the screens, and by means of a tripper is dumped on the ground beneath the trestle. The coal is reclaimed with a locomotive crane. The plant has a capacity of 40 000 tons and 300 tons per hour can be handled. Lump, three-quarter, mine-run, and slack can be stored. The plant is intended for storage purposes when the car supply is low so that a full day can be run at the mine.

40. *Underwater Storage.*—

Duquesne Light Company Storage Plant

The Duquesne Light Company, Pittsburgh, Pennsylvania, completed during the fall of 1917 a large reinforced concrete storage basin at the Brunot Island power plant.*

The storage basin which is adjacent to the power plant, and between it and the main channel of the Ohio River, is 791 feet long, 153 feet wide, and 25 feet, 6 inches deep, the side and end walls sloping at an angle of 45 degrees. The basin has a capacity of 100 000 tons of submerged coal and 150 000 tons with the coal piled above the water-line. The side and end walls of the basin taper from 18 inches at the bottom to 8 inches at the top.

As the bottom of the basin is below the normal river level, special provision had to be made for the lifting pressure that would be exerted on the bottom of the basin at high water stages, the soil being coarse gravel and very porous. The bottom which is 18 inches thick is made of 30 main reinforced concrete slabs each 51 feet square. These slabs rest on reinforced concrete curbs the bases of which are 4 feet square and 12 inches thick; the bridge extending up from the base is 15¼ inches high and 6 inches wide. These curbs, besides supporting the bottom, also allow for expansion and contraction of the concrete slabs. All joints are filled with pitch. The plant condenser-water discharge duct which is constructed of concrete divides the basin into two sections. The fact that the top of the duct is 7½ feet above the concrete bottom permitted one-half of the basin to be used while the other half was being constructed.

Water for flooding the basin is admitted through 12-inch filling holes and is supplied by one of the plant condenser circulating pumps, equipped with a discharge pipe for this purpose. Four 18-inch

* Power, page 651, Nov. 13, 1917.

independent drain pipes which extend to the river are each equipped with a gate and a check valve, and with a by-pass around the latter. The basin can be drained by opening the gate valves. This arrangement permits the automatic flooding of the coal basin with river water to relieve the upward pressure on the concrete bottom. Should the river rise much above normal, water will flow into the basin to a height corresponding to that of the river. When the river subsides the water may be drained from the basin if desired. At the present time no figures with respect to the operating cost of the storage basin are available.

Underwater Pit of the Standard Oil Company, Whiting, Indiana*

Figs. 72 and 73 show an underwater storage pit built by the Great Lakes Dredge and Dock Company of Chicago, Illinois, for the Standard Oil Company about two miles south of the shore of Lake Michigan at Whiting, Indiana. This storage pit has a capacity of 100 000 tons.

The storage basin consists of a pit 1000 feet long, 202 feet wide, and 28½ feet deep below yard rail level and 24½ feet deep below ground water level. The pit is enclosed by a heavy wooden sheet-pile dock construction below water level, capped with concrete above water level. There are four lines of standard gauge railroad track trestle running longitudinally through the pit and four lines on each side of the pit.

The pit was excavated with a 15-inch hydraulic suction dredge, which was hauled overland a mile and a half to the site; advantage was taken of the marshy conditions to excavate a sufficiently large area in which to float the dredge. The excavated material was discharged through pipes at a point 1000 feet away from the pit and the run-off water carried back to the pit through trenches; thus a sufficient supply of water was insured to keep the dredge afloat. Wakefield sheet-piling and dock-piling were then driven by means of two floating pile drivers, built on the site, and the concrete mass surrounding the pit at the water line was placed, special concrete mixers being mounted on railroad flat cars. The bottom of the pit was leveled off with the hydraulic dredge by means of a special mouth-piece, so that no point was more than six inches above or below grade. After the dredge had leveled off

* See also Circular No. 6, p. 103.

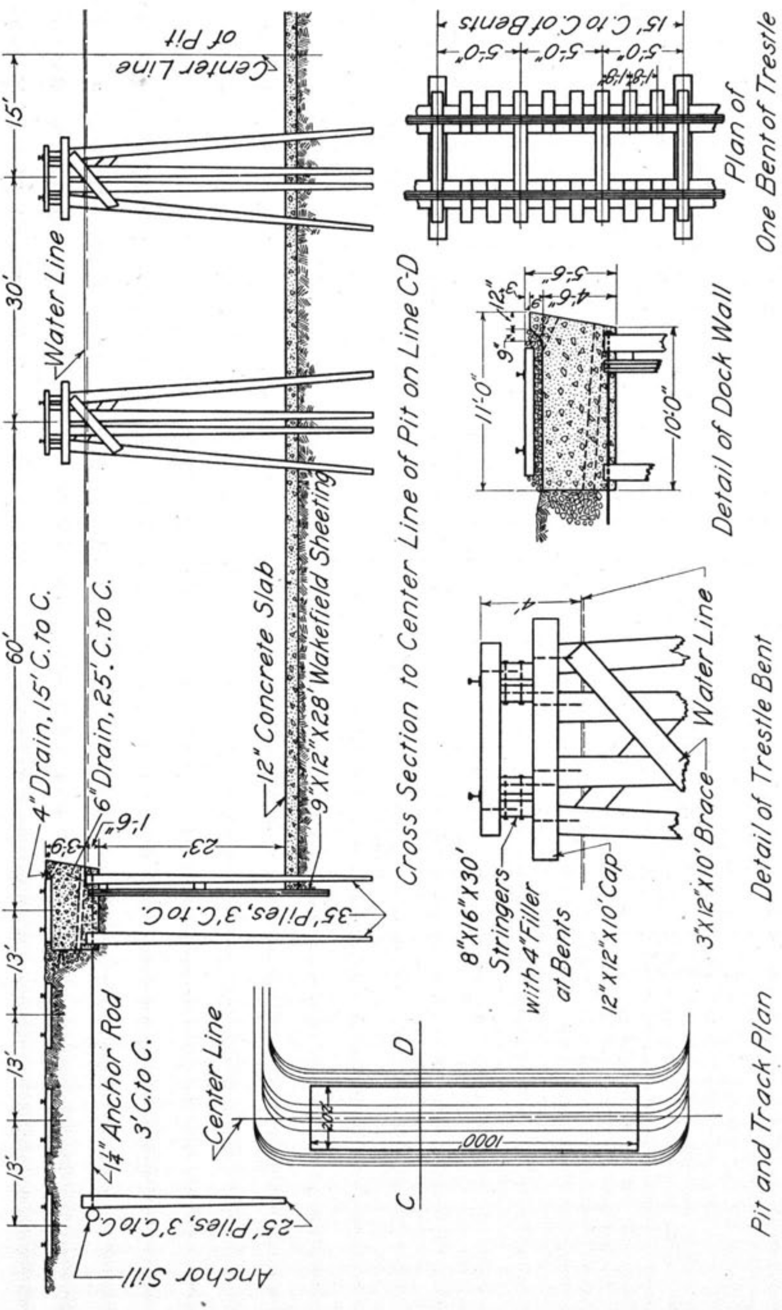

FIG. 73. UNDERWATER COAL STORAGE PLANT OF THE STANDARD OIL COMPANY, WHITING, INDIANA — SECTIONAL VIEW AND DETAILS

the bottom, a drag was used consisting of a heavy horizontal 12 feet by 1 foot timber fastened to a pile driver.

The concrete floor, one foot in thickness was placed in about 25 feet of water over the entire floor area of 1000 feet by 202 feet, by means of a special tremie device, patented by the Great Lakes Dredge and Dock Company. By using this device, it was possible to place the concrete under pressure and to spread it uniformly over the bottom, so that no point was more than three inches off grade.

The following advantages are claimed for this form of pit construction:

1. Lower cost than for all concrete or wood-and-concrete construction.

2. Lower cost of unloading coal by dumping from trestles and from tracks along the sides of the pit than by using grab-buckets operated by a bridge or crane. The bulk of the unloading cost consists in dumping the cars (either bottom or side dump) from the trestles or from the side of the pit, leaving a very small portion to be unloaded with yard cranes.

This method permits the use of different sizes of locomotive cranes where they are available around any plant.

By means of the four tracks running through the pit and those on each side, six trains, of at least twenty 50-ton coal cars can be unloaded or loaded simultaneously.

The four tracks in the pit and those along each side give a trackage length of practically two miles for rail storage purposes; in other words, little ground space is lost by installing one of these pits in this manner. In fact, any switch yard can have an underwater coal storage pit without the acquisition of more land.

APPENDIX I.

QUESTIONNAIRE *A*

1. What kind of coal was stored? ....
2. What size of coal was stored? ....
3. Was all of the coal stored of same size and kind? ....
4. What amount of coal was stored? ....
5. State from what mining district and if possible from what mine the coal came:..
6. Size of pile: Depth............; Length............; Breadth..........
7. Describe the method of unloading and storing:........................ ....
8. Was coal unloaded, by crane, drop bottom car, hand?....................
9. What trouble have you had from fires in your coal pile? ....
10. How much of the coal was destroyed by fire? ....
11. What in your opinion was the cause of the fire? ....
12. What evidence have you upon which to base this opinion? ....
13. How long had the coal been in storage when the fire was observed? ....
14. Was the coal actually ablaze or only smoking? ....
15. Was the temperature taken? .... What was it? ....
16. Where in the pile did the fire start? ....
17. How was the fire controlled or extinguished? ....
18. Was any attempt made to ventilate the pile; if so, how? ....
19. Was there any damage to adjacent structures? ....
20. Information furnished by:..

....
(Official title and Company)

....
(Address)

General Remarks:
....

Please use reverse side of this sheet for any general remarks and suggestions.

QUESTIONNAIRE *B*

Please answer the following questions and mail your answers direct and as soon as possible to Professor H. H. Stoek, Department of Mining Engineering, University of Illinois, Urbana, Illinois.

1. What kind of coal was stored? ....
2. What size of coal was stored? ....
3. What amount of coal was stored? ....
4. State from what mining district and
   if possible from what mine the coal came: ....
5. The size of pile: Depth..........; Length..........; Breadth..........
6. Describe the method of storing: ....
   ....
   ....
7. Have you had any difficulty
   from fires in your coal pile? ....
8. How much, if any, of the coal
   was destroyed by this fire? ....
9. What in your opinion was the cause of the fire? ....
   ....
10. What evidence have you upon
    which to base this opinion? ....
11. How long had the coal been in storage
    when the fire was observed? ....
12. Was the coal actually ablaze or only smoking? ....
13. Where in the pile did the fire start? ....
14. How was the fire controlled or extinguished? ....
15. Was any attempt made to ventilate the pile; if so, how? ....
16. Was there any damage to adjacent structures? ....

Information furnished by:

....
(Company)

....
(Address)

....
(City and State)

For general remarks use back of this sheet.

DATA SHEET

Date........................

NAME AND ADDRESS: ....
PARTY INTERVIEWED: ....
SIZE AND KIND OF COAL: ....
MINE OR DISTRICT: ....
NAME OF SHIPPER: ....
IS COAL CORRECT SIZE? ....
AMOUNT OF SULPHUR: ....
METHOD OF PILING: ....
TONNAGE AND DIMENSIONS OF PILE: ....
HOW LONG IN STORAGE? ....

VENTILATED:..

WHERE DID FIRE START? ....

WAS WATER USED? ....

PICTURE:...

HOW WAS FIRE HANDLED? ....

PROBABLE CAUSE OF FIRE:..

REMARKS:...

APPENDIX II

Railway Administration Storage Circular

The following circular of instructions for the storage of coal was sent by the government to all railroads in the United States. It is, undoubtedly, the most comprehensive effort to safeguard and stimulate the storage of coal ever made in an industry.

The Storage of Coal

To Operating Officers in Charge of Coal Storage:

The standing committee on the storage of coal, appointed by the International Railway Fuel Association, has made a number of recommendations which are contained in the transactions of the association for the year 1909 to 1917, inclusive.

An exhaustive study of the storage of bituminous coal was also made by H. H. Stoek, professor of mining engineering of the University of Illinois, Urbana, Ill., and published March 4, 1918, in Circular No. 6 of the Engineering Experiment Station of that university.

A further circular covering additional features in the storage of bituminous coal will be published and ready for general distribution within a few months. In the meantime Professor Stoek is preparing a paper on the storage of bituminous coal to be read at the eleventh annual meeting of the International Railway Fuel Association convening in Chicago in May next.

From this information, and that which has been furnished by the United States Railroad Administration, certain suggestions have been gathered covering the proper method of storing railroad coal which, if applied, will assist in keeping the cost of storage to the minimum, and will result in greatly reducing or entirely eliminating the hazard caused by spontaneous combustion.

From necessity no general rule can be made which will fit the various coals stored in the different sections of the country, and railroad officials in charge of this work will be compelled to exercise a reasonable measure of discretion in carrying out any recommendations of a general character that may be made.

Why Railroads and Other Consumers Should Store Coal

1. To insure an ample supply for locomotives and miscellaneous steam purposes during period of reduced delivery occasioned by cessation of water-borne traffic, mine strikes, extremely rigorous winter weather, periods of serious car shortages, etc.

2. So that a partial equalization of the coal-car supply may be made. The excess demand for railroad and commercial coal during the fall and winter season, accentuated by a decreased daily car mileage, invariably leads to a car shortage during that period, with a resulting surplus during the summer season, when coal is ordinarily stored.

3. The cost of transporting railroad coal during the summer season is estimated as not exceeding 60 to 65 per cent of the cost of such movement during the period of extreme winter weather, during which time if the carrier is relieved, if only in part, of the transportation of railroad coal, the locomotives, cars, and coal thus made available can be diverted to commercial consumers, with resulting revenue advantage.

How to Store Coal

The actual work incident to the storage of railroad coal should only be undertaken after a study of the subject has been made by some responsible official, who should, after conferring with the proper representatives in charge of purchase, transportation, and maintenance, formulate such definite plans as will insure the full co-ordination of every man responsible for any portion of the work to be done; to this end the following points should be given careful consideration:

(*a*) Determine the amount of coal which should be stored, beginning May 1, ending August 31, except in the case of water-borne coal, where the storage period will be governed by the navigation season. The rate of storage daily and weekly should be prescribed in order to prevent an under or over supply at the storage station. Storage points remote from the source of supply should be given preference.

(*b*) As far as possible, avoid purchasing coal for storage that bears the reputation of firing when stored.

(*c*) Store screened lump coal where such is obtainable, 4-inch or 6-inch lump preferably, the portion passing through the 4-inch or 6-inch screen openings to be used for current consumption during the storage period. Coal placed in individual storage piles should come from as few mines as possible. In no case mix coal from different districts or from different seams located within the same district.

(*d*) Before undertaking storage select a suitable location as near as possible to the point of consumption, avoiding hillsides, rough ground, and soft, wet, boggy ground in particular. The storage location should be thoroughly cleaned of all refuse matter, giving particular attention to the removal of vegetation, wood, discarded waste, old clothes, or other similar combustible matter which would assist in starting stock-pile fires or would depreciate the value of the coal when loaded out. Do not pile above a steam pipe, over a sewer trap, or against a hot wall. Positive provision should be made for draining the ground so that water may not accumulate under the pile.

(*e*) It is now well established that coal fires spontaneously by the oxidation of the fine particles, which present the maximum surface for the air to act upon, well-screened coal carefully piled seldom firing, for the reason that a minimum surface is subjected to oxidation, the openings between the lumps admitting of any heat engendered passing off. Fires usually start in piles where the coal is more or less separated in coarse and fine strata, the air entering through the coarser strata acting on the finer portion, which is too dense to admit of the heat created passing off with sufficient rapidity to prevent firing. Fine coal should be invariably stored by itself and in such a way as to exclude as far as possible the air from entering the pile.

Slack coal has been stored successfully to a height of 8 or 10 feet by packing it as hard as possible, covering the surface with the finer portion in such manner as to as nearly as possible exclude air and water.

Water entering the bottom of a storage pile is exceedingly dangerous from a firing standpoint.

Method of Unloading

(1) No plan covering the unloading of storage coal should be put into effect without due consideration to the work of reloading same, bearing in mind that in the event of spontaneous combustion the portion firing must be removed quickly.

Where locomotive cranes with clam-shell buckets are available, two parallel tracks, located at from 16 to 20 feet centers, should be laid down on high level ground cleared of all refuse and combustible matter. The loaded cars are placed on one track and unloaded by a crane operating on the parallel track, the coal being placed in a pile alongside the crane. The position of the cars and crane is reversed with the completion of the first pile. The width of the pile depends on the radius of the boom travel, and its maximum height is determined by the width of the base and the flow line of the coal, not exceeding, however, a total of 20 feet. The height should be decreased in the case of coals that have been known to fire easily. The tracks should remain in position for the quick removal of coal that may become overheated and for the subsequent reloading of the coal stored.

(2) Extensive investigation has shown that many fires have occurred in storage piles where a separation of the coarse and fine coal was made, by dumping the coal as unloaded, on the same spot, or along the center line of the pile, the coarse coal rolling down to the side, the fine coal accumulating at the center or axis of the pile; the air entering the pile through the coarser portion and acting on the centrally located mass of fine coal producing heat, which, on account of an insufficient air circulation, is not carried off with sufficient rapidity to prevent high temperatures and spontaneous combustion. This hazard will be very materially lessened if the clam-shell is lowered to a point just above the surface of the pile before the contents are dumped. A layer of coal 2 feet in height should be laid down to the full width of the base of the pile and over the entire length of same, the second and succeeding layers, each 2 feet in thickness, to be laid down in like

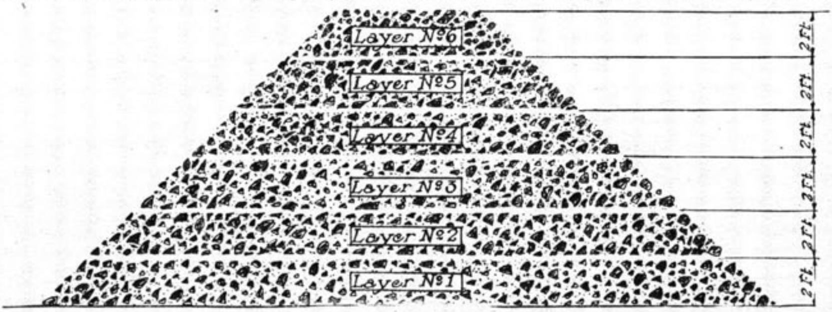

FIG. 74. METHOD OF BUILDING PYRAMIDAL PILE IN LAYERS*

* Level of storage pile raised two feet at a time the full length of pile, by lowering the clam-shell to a point just above the surface of the pile before discharging contents.

manner. This method of unloading will eliminate the accumulation of broken fine particles in the center of the pile, and in addition, give the coal a limited opportunity to season before being covered up by the succeeding layer. A sketch showing a cross section of a pile so laid down is shown herewith.

(3) Where locomotive cranes are not available, coal from necessity is frequently stored by unloading self-clearing cars placed on a track on the top of the pile, the track raised from time to time on the coal. This arrangement has the disadvantage of causing an accumulation of crushed coal in the center of the pile, with lumps on the outside as referred to in paragraph (2). Where it is necessary to employ this method of unloading and after the pile is completed, the track should be moved from the top of the pile to the surface level and parallel to the storage pile, thus making provision for the quick removal of any portion that may fire by using the standard railroad non-revolving steam shovel, the American type railroad ditcher, or locomotive crane, for reloading the coal either in case of emergency heating or for current use. Coal so stored should not be piled to a height exceeding 12 to 15 feet, and the reloading tracks should be maintained readily accessible for prompt use in event of spontaneous firing, and the shovel, crane, or ditcher kept readily accessible and always in condition to be used.

Where mechanical means are employed for spreading coal so unloaded, a standard railroad ballast spreader is preferable to the track tie dragged through the coal underneath a car truck as commonly done.

(4) Trestle storage should be restricted to the handling of coal of established reputation for safe-keeping. The fire hazard attendant on placing storage coal around the wooden trestle, plus the cost of construction of same, and the difficulty of handling, makes this method of storage inadvisable.

(5) Any attempt toward the storage of coal will prove, at best, only partially successful, unless some one responsible individual is placed in charge of same with full authority to co-ordinate the various branches of the purchasing and operating departments. A thoroughly competent foreman should be maintained at every storage pile to oversee the storage, to inspect the billing before cars are unloaded, to determine the source of supply and the grade of coal furnished, and to divert to current consumption cars received of grade or kind other than that prescribed.

(6) After the work of storage is completed the storage piles should be adequately policed to prevent wholesale loss by theft and to insure the detection of excessive temperature. It is generally agreed that any method of ventilating stock piles heretofore employed is insufficient to safeguard them. Excessive heating is easily detected by a careful examination of the pile, using the sense of smell; and in addition the inspector should be equipped with a few sharpened steel rods, which should be driven into the pile at frequent intervals. Any excess heat generated may be detected by feeling the rod immediately upon its removal. If a hot spot is found with the rods, the temperature should be carefully watched with a thermometer placed inside a pipe driven into the pile at the hot place.

(7) All coal stored should be picked up and consumed under an established schedule and during the period of car and coal shortage, when transportation is most expensive and the facilities of the carrier are in maximum demand.

EUGENE MCAULIFFE,
Manager Fuel Conservation Section.

APPENDIX III

Space Occupied by Coal

The question is frequently asked: "How many cubic feet are there in a ton of coal, or how many tons of coal will a railroad car, bin, etc., of a given size hold?"

Knowing the specific gravity of any coal, the weight of a solid cubic foot can be readily computed. While such values are useful in computing the tonnage of coal in the ground, they are not useful in determining the weight per cubic foot of coal broken into commercial sizes to be used for fuel or for storage. The weight of coal in commercial sizes depends upon the specific gravity, size, and condition of the coal, and the extent to which it has been shaken down or settled.

The following is a summary of the information available, compiled from the literature on the subject and from replies to a questionnaire sent to about seventy manufacturers of coal handling machinery, to engineers, and to various users of coal.

A tabulation of the weight of 177 samples of coal from many parts of the United States will be found in Technical Paper No. 184 of the United States Bureau of Mines. These tests were made on domestic sizes of coal received in barrels. The coal was shoveled loosely into a box measuring 2 ft. by 2 ft. by 2 ft. and leveled off with a straight edge. The results show a variation in bituminous coal from the several coal districts of the United States as follows:

Table 18

Weight of Bituminous Coal in Pounds per Cubic Foot by Districts

Region	Weight in Lb. per Cu. Ft.
Appalachian: Pa., W. Va., Md., Va., Ohio, Tenn., Ala., and Eastern Ky.	43 to 57.5
Eastern Interior Basin: Ill., Ind., and Western Ky.	44 to 55
Western Interior Basin	45.5 to 59
Rocky Mountain	44.5 to 52.5

An average of these same results by states is given in Table 19, but for exact information as to coal from any particular district and of any particular size, reference should be made to the original paper as the averages given include a variety of sizes.

TABLE 19

WEIGHT OF BITUMINOUS COAL IN POUNDS PER CUBIC FOOT BY STATES*

State	Number of Samples	Average Weight Per Cubic Foot	Extreme Values Per Cubic Foot
Alabama	5	51.3	45.5–54.0
Arkansas	4	53.3	49.5–59.0
Illinois	14	48.8	45.0–55.5
Indiana	9	46.1	44.0–49.0
Iowa	2	47.0	46.5–47.5
Kansas	2	52.8	50.0–55.5
Kentucky	11	47.2	43.0–54.5
Montana	2	52.3	52.0–52.5
Ohio	4	47.3	46.0–49.0
Oklahoma	4	48.5	45.5–50.0
Pennsylvania	41	51.2	46.5–55.0
Tennessee	9	57.3	45.0–51.0
West Virginia	9	53.3	41.0–57.5
Wyoming	4	48.9	45.5–52.5

*United States Bureau of Mines.

The conclusions reached by the author of the paper are:

"A study of the foregoing table indicates that heavier weights may be expected for coals of high fixed carbon content than for those of low. Increased ash content seems to lower the unit weight. It is also true, in general, that the coals high in moisture are lighter than those low in moisture and the younger coals are lighter than the older coals.

"These variables combine in so many ways, however, that it is difficult to determine from the data available anything more than a general trend and consequently little use can be made of the knowledge of a change of one or more of the variables."

The change in weight due to wetting and shaking down a sample are summarized in the same paper as follows:

"1. Of two samples of any coal that are composed of the same proportions of pieces of different sizes, the sample having the higher moisture content will usually weigh the more per cubic foot.

"2. A sample of higher moisture content will usually occupy more space for the same number of pounds of (dry) coal than will a sample of lower moisture content. However, the increase in volume for the wet coal is not as great proportionately as is the increase in weight per cubic foot.

"3. Coal shoveled loosely into a container will settle appreciably if the container is shaken, and the weight per cubic foot will be correspondingly increased.

"4. Slack coal composed of a mixture of the smaller pieces up to and including nut size weighs more than screened nut coal.

"This last statement coincides with the conclusions drawn from experiments with concrete mixtures, which have shown that a much denser mixture can be made by using certain proportions of various sized pieces. Pieces of nearly uniform size when piled leave about 45 per cent of voids. If these spaces are filled with still finer coal of uniform size the weight of the mass is increased and the interstices in the finer coal can again be filled with still finer pieces, resulting finally in a dense mass. It is evident, therefore, that the relative proportions of fine and coarse material have a considerable influence on the weight per cubic foot of the mass.''

Table 20 contains the results of a questionnaire which was sent to a number of coal handling machinery manufacturers, engineers, and coal users for the purpose of obtaining current practice upon the subject. It must be remembered in this connection, however, that these figures do not represent generally figures based upon tests of actual conditions but rather upon current practice, allowing an ample factor of safety, as most manufacturers desire to give the customer ample capacity so that they may be on the safe side in calculating tonnage or space.

TABLE 20

WEIGHT PER CUBIC FOOT OF COAL AS GIVEN BY MANUFACTURERS

Company	Kind and Size of Coal	Cu. Ft. per Ton*	Wt. per Cu. Ft. in Lbs.	Angle of Repose in Degrees	Remarks
Harriman, F., Mach. Co.	....	37	....	....	Mine car design.
Hyatt Roller Bearing Co.	Bituminous.	....	52½	....	"
Sanford Day Iron Works	Bituminous Mine-run.	40	....	....	"
Hockensmith Wheel & Mine Car Co.	Bituminous Mine-run.	....	50	....	"
Atlas Car & Mfg. Co.	Bituminous Mine-run. Anthracite.	40	....	40–45 30–33	"
Cherry Tree Mach. Co.	....	37½	....	....	"
Lakewood Engineering Co.	Loose Bituminous. Anthracite.	....	50 54–56	30 30	Mine and industrial car design.
Helmick, F., Mach. Co.	....	42	....	Varied with coal	Gross ton. Mine car design.
Jeffrey Mfg. Co.	Pocahontas. Pittsburgh Bituminous. Ind. and Ill. Anthracite. Bituminous. Anthracite.	40	50	35–37½ 40 40 30 40 37½	Practice in building chutes. " " " " " " " " " " " " Open piles. " "
Roberts & Schaefer Co.	Bituminous Mine-run. Anthracite. Lignite. Bituminous.	....	50 57 45	.... 30–35 35–40	....
Western Wheeled Scraper Co.	Bituminous Slack.	45	....	45	Ton of 2240 lb.

*2000 pounds.

TABLE 20—Continued

Company	Kind and Size of Coal	Cu. Ft. per Ton*	Wt. per Cu. Ft. in Lbs.	Angle of Repose in Degrees	Remarks
Robins Conveying Belt Co..	1¼ in.-¾ in. Nut.	38½	52	....	Loose.
	"	35½	56	....	Well shaken down.
Wood Equipment Co.......	Mine-run to Lump.	35-45	....	....	
	Large Lump.	55	....	....	
	Wet mine-run	30	....	....	
United Iron Works Co......	....	48	....	1½-1	Kansas Mine-run.
Bucyrus Co..............	....	40½	....	50	1½ cu. yd. per ton excavating machinery
Barber-Greene Co..........	....	40	....	45	
Macdonald Engineering Co..	....	45	45	38	Practice.
	....	....	40	45	Average as noted.
Brown Hoisting Mach. Co..	Bituminous.	40	....	1½ hor.	
	Anthracite.	35	....	to 1 ver.	
Wellman-Seaver-Morgan Co....................	Bituminous.	40	....	....	
	Bituminous Mine-run.	....	....	43-45	
R. H. Beaumont Co.....	Bituminous.	40	50	Max. Min.	
	Bituminous Mine-run.	....	....	45 35	
	Crushed Bituminous.	....	....	45 35	
	Anthracite.	....	....	30 27	
	Coke.	....	....	50 40	
McMyler-Interstate Co.....	Bituminous.	....	50	45	
	Anthracite.	....	56	30	
Webster Mfg. Co..........	Bituminous.	40	....	35	
	Anthracite.	....	....	27	
Morrow Mfg. Co...........	....	....	50	....	Bin design.
Great Lakes Dredge and Dock Co................	....	40	....	....	Dock and bin design.
Jacobsen & Schraeder......	Bituminous.	....	50	35	General practice.
	Anthracite.	....	52	27	"
	Coke.	....	30	35-45	"
	Bituminous.	....	50-55	....	More exact practice.
	Anthracite.	....	52-55	....	"
	Coke.	....	25-32	....	"
Watt Mining Car Wheel Co....................	....	40	....	....	Mine car design.
Heyl & Patterson Inc.......	Bituminous.	40	....	40	
	Anthracite.	36	....	30	
Link-Belt Co.............	Bituminous Mine-run, Lump, Egg, and Nut.	40	....	40	Design for bins and storage. This has been found to give ample capacity under approximately the extreme conditions.
	Bituminous ⅜ in. and under.	45	....	40	
	Anthracite.	37	....	27	
Phillips Mine and Mill Supply Co..............	Bituminous Mine-run.	....	52	45	Mine car and small storage bin design.

*2000 pounds.

The Peabody Coal Company uses the following figures in estimating storage for coal and coke in coal yard:

TABLE 21

CUBIC FEET PER TON OF COAL*

BITUMINOUS	CUBIC FEET PER TON	ANTHRACITE	CUBIC FEET PER TON
Pocahontas Lump and Egg	35.5	Chestnut	34
Pocahontas Mine-Run and Nut	36.	Range	35
Pocahontas Slack	35.	Small Egg	35
Hocking	41.	Large Egg	36
Screenings	40.	Pea	33
Indiana Lump	41.	Buckwheat	32
Mine-Run	36.	Dust	35
Smithing	43.		
Quaker Egg and Nut	40.	COKE	
Quaker Lump	38.	Petroleum	72
Acorn Lump	40.	Gas House	66
New Era	38.	Solvay Nut	55
No. 3 Washed Nut	42.		
Wasco Lump	40.		

*Peabody Coal Company.

Mr. J. A. Garcia of the Allen and Garcia Company, Chicago, has furnished the following results of actual tests on a large number of cars of coal loaded by the Dering Coal Company in 1907. The volume was calculated from measurements made on railroad carloads just after they left the mine tipple. The results are shown in Table 22. The work was scattered over a period of several months and the data were collected by three different division engineers acting under definite instructions from Mr. Garcia.

TABLE 22

WEIGHT PER CUBIC FOOT OF ILLINOIS AND INDIANA COAL†

COMPANY DERING COAL CO.	Cu. Ft. per Ton‡	Wt. per Cu. Ft.	Kind and Size of Coal	Specific Gravity	REMARKS
West Frankfort, Franklin County, Ill.			Vein 6	1.310	
	34.8	57.4	Mine-run		
	34.3	58.3	Mine-run		
	37.0	54.1	1½ in. (round) Screenings		
	40.8	48.9	1½ in. to 3 in. Nut		
	41.2	48.5	3 in. to 6 in. Egg		
	40.0	50.0	6 in. Lump		
			Vein 6		
Montgomery County, Ind., Vein 6	37.5	53.2	Mine-run	1.339	
	38.1	52.5	⅞ in. bar (Screenings)		
	40.5	49.4	6 in. (round) Screenings		
	38.6	51.8	1¼-3 in. Nut		
	41.8	47.8	6 in. Lump		
	42.1	47.5	1¼ in. Lump		
	40.1	49.8	⅞ in. (bar)		

†Estimates of Mr. J. A. Garcia.
‡2000 pounds

TABLE 22—Continued

COMPANY DERING COAL CO.	Cu. Ft. per Ton*	Wt. per Cu. Ft.	Kind and Size of Coal	Specific Gravity	REMARKS
			Vein 6	1.305	
Vermilion County, Ill.	40.5	49.3	Mine-run		
	45.2	44.1	1¼ in. (bar) Screenings		
	45.1	44.3	⅞ in. (round) Screenings		
	50.2	39.8	⅞-2 in. Nut		
	47.8	41.8	2 in. (round) Lump		
	43.8	45.6	1¼ in. (bar) Lump		
			Vein 3	1.372	
Vermilion County, Ind.	36.7	54.4	Mine-run		
	40.0	49.0	1¼ in. (bar) Lump		
			Vein 4	1.241	
Vermilion County, Ind.	38.1	52.5	Mine-run		
	40.8	49.0	1¼ in. (bar) Screenings		
	45.0	44.4	2½ to 4 in. Egg		
	42.6	46.9	4 in. Lump		
	43.5	45.9	1¼ in. (bar) Lump		
			Vein 5	1.368	
Vermilion County, Ind.	37.2	53.7	Mine-run		
and	39.3	50.9	Mine-run		
Sullivan County, Ind.	38.3	52.2	1¼ in. (bar) Screenings		
	40.6	49.2	1½ in. (bar) Lump		
	39.9	50.0	1¼ in. (bar) Lump		
			Vein 6		
Sullivan County, Ind.	40.7	49.1	1¼ in. (bar) Screenings		
	38.3	52.2	1¼ in. (bar) Screenings		
	41.0	48.7	1½ in. (round) Screenings		
	37.7	52.9	1 in. (round) Screenings		
	42.8	46.7	1¼-2½ in. Nut		
	42.8	46.7	1-2¼ in. Nut		
	41.3	48.3	2½-4 in. Egg		
	45.3	44.1	1½-4 in. Egg		
	40.1	49.8	2½-4 in. Egg		
	42.3	47.2	1¼ in. (bar) Lump		
	38.8	51.5	4 in. Lump		
	42.8	46.7	4 in. Lump		
	38.4	52.0	4 in. Lump		
	42.5	47.0	1½ in. Lump		

*2000 pounds.

Tables 23 and 24 give other results for bituminous coal and Table 25 gives results for anthracite coal.

TABLE 23

SPACE OCCUPIED BY BITUMINOUS COAL IN CUBIC FEET PER TON†

KINDS	CUBIC FEET PER TON‡
Cumberland	36.65
Clearfield	33.55
New River	40.15
Pocahontas	34.00
American Cannel	41.50
English Cannel	42.30

†Mines and Minerals, Nov., 1907.
‡2000 pounds.

TABLE 24

SPACE OCCUPIED BY BITUMINOUS COAL IN CUBIC FEET PER TON*

Kind	Cubic Feet per Ton†	Kind	Cubic Feet per Ton†
Pittsburgh	48.2	Cumberland, Max.	42.3
Erie	46.6	Cumberland, Min.	41.2
Hocking Valley	45.4	Blossburg, Pa.	42.2
Ohio Cannel	45.5	Clover Hill, Va.	49.0
Indiana Block	51.1	Richmond, Va. (Midlothian)	41.0
Illinois	47.4	Cannelton, Ind.	47.0
Pittsburgh	47.1	Pictou, N. S.	45.0
		Sydney, Cape Breton	47.0

*Trautwine's Engineer's Pocket Book.
†2240 pounds.

TABLE 25

SPACE OCCUPIED BY ANTHRACITE COAL IN CUBIC FEET PER TON‡

Kinds	Cubic Feet per Ton¶				
	Broken	Egg	Stove	Chestnut	Pea
Lackawanna	37.10	36.65	34.90	34.35	37.25
Garfield Red Ash	37.30	36.95	36.35	36.35	37.50
Lykens Valley	37.55	37.25	37.55	37.25	38.50
Shamokin	38.05	37.70	37.25	37.25	38.50
Plymouth Red Ash	34.90	34.85	34.75	34.70	36.90
Wilkes-Barre	34.95	34.35	33.75	34.00	36.90
Lehigh	33.30	33.80	33.55	32.55	33.05
Lorberry	34.65	34.20	33.80	33.55	35.20
Scranton	35.35	35.20	34.60	33.30	34.95
Pittston	35.45	34.95	34.35	33.70	35.50

‡Mines and Minerals.
¶2000 pounds.

The following formulas from which Table 26 was calculated are given in General Catalog 18 of the Gifford-Wood Company of New York (See Fig. 75).

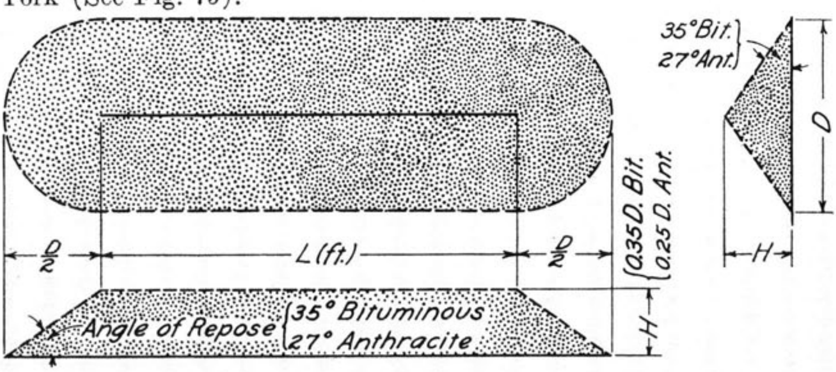

FIG. 75. DIMENSIONS FOR DETERMINING VOLUME AND WEIGHT OF COAL PILES

Formulas

For Bituminous Coal:

Vol. of each conical end $= 0.045815D^3$; vol. of cone $= 0.09163D^3$.

Vol. per foot of straight portion $= 0.175D^2$.

For Anthracite Coal:

Vol. of each conical end $= 0.0327D^3$; vol. of cone $= 0.0654D^3$.

Vol. per foot of straight portion $= 0.125D^2$.

Tons = Vol. in cu. ft. ÷ cu. ft. per ton, from table below. 40 cu. ft. per ton was used in calculating the following table.

TABLE 26

VOLUME AND TONNAGE OF BITUMINOUS COAL PILES

D Feet	Vol. in Cubic Feet		Short Tons	
	Conical Ends, Each	Per Ft. of Straight Portion	Conical Ends, Each	Per Ft. of Straight Portion
10	45.82	17.50	1.15	0.44
11	60.90	21.20	1.52	0.53
12	79.00	25.20	1.97	0.63
13	100.50	29.55	2.51	0.74
14	125.75	34.30	3.14	0.86
15	154.30	39.40	3.86	0.98
16	187.30	44.80	4.68	1.12
17	225.00	50.60	5.63	1.26
18	267.00	56.70	6.67	1.42
19	314.00	63.20	7.85	1.58
20	402.50	70.00	10.05	1.75
25	715.00	109.30	17.88	2.74
30	1236.00	157.50	30.85	3.94
35	1965.00	214.50	49.10	5.36
40	2930.00	280.00	73.20	6.99
45	4170.00	354.50	104.10	8.86
50	5720.00	437.50	143.00	10.93
55	7620.00	529.00	190.50	13.22
60	9900.00	630.00	247.50	15.76
65	12600.00	738.00	315.00	18.43
70	15700.00	857.00	392.00	21.40
75	19320.00	984.50	483.00	24.60
80	23450.00	1120.00	586.00	28.00
85	28100.00	1265.00	702.50	31.60
90	33400.00	1420.00	835.00	35.50
95	39250.00	1580.00	980.00	39.50
100	45815.00	1750.00	1145.00	43.75

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