THE MARSEILLES CONCRETE DAM.

A DIFFICULT ENGINEERING FEAT.

BY DR. J. H. GOODELL.

THE south end of Lake Michigan is in a large depression. From 20 to 40 miles in all directions from the shore of the lake there is a ridge, beyond which the drainage of the rivers flows into the Mississippi. The Kankakee River rises east of this ridge in southwestern Michigan and flows nearly south. Through northwestern Indiana it bends west, and in northwestern Illinois it runs in a northwesterly direction to join the Desplaines nine miles east of Morris, Ill. The latter river rises in southeast Wisconsin, west of the ridge spoken of above, and flows nearly south to join the Kankakee. The watershed of these rivers furnishes an approximate volume of 25,000 cubic feet per minute flowing past a given point, but the variation is so great that it can only be estimated by approximation. The Illinois River is formed by the junction of the Kankakee and Desplaines, that unite nine miles east of Morris, Ill. The Chicago Drainage Canal draws its water from Lake Michigan and discharges into the Desplaines River.

The large volume of water from the Drainage Canal with the watershed water from the Kankakee and Desplaines afford very desirable water powers down the Illinois where the fall is sufficient for an adequate head. There are very few rapids on this river, the one at Marseilles being perhaps the largest. The fall here, from Kickapoo Creek above the dam to Bell Island below, a distance of three miles, is 20 feet, the dam being nearly in the center. Ever since 1832 there has been some kind of improvement of the water power. The dam that went out in the winter of 1902-3 was constructed in 1868. Up to its time, it was the most pretentious affair of its kind. It was of cob-house form, the space between the logs being filled with stone.

At this point the river is 960 feet wide. The average depth of the water at the time of the erection of the present concrete dam was eight feet, with a velocity of from six to ten miles per hour. The average flow of water over the dam cannot be given with accuracy. In exceeding high water it is often 1,500,000 cubic feet a minute, or more. It is perhaps better to take the flow in a very dry season, when the river would naturally be very low. This occurs every eight or ten years. We have data to show the number of cubic feet from the Sanitary Canal as follows: From the Bridgeport pumps, 35,000 cubic feet; with the watershed water, about 25,000 cubic feet; and with the new pumps in Chicago, nearly ready for service, there will be not far from 500,000 cubic feet per minute going over the dam. To be acceptable to the Illinois Valley people, the law under which the Sanitary District of Chicago was established was made to provide for the passage down the canal of 600,000 cubic feet per minute to afford the requisite dilution to the sewage. Through the rock cut of the Sanitary District Canal, the channel is constructed to pass 720,000 cubic feet per minute with a velocity not to exceed three miles per hour. In former years, before the coming of the drainage water, a dry season would reduce the flow so much that the mills at Marseilles would often have to suspend operations, it being even possible to cross the river dry shod.

The old cob-house dam went out during the high water in the winter of 1902-3. Portions of it are shown in the photographs. The hardest part of the work in the new construction was the building of the coffer-dam. Cribbs of 6 x 12 timbers, 12 feet square, and when completed 12 feet high, were partially loaded with stone and launched upstream far enough to float down and land about 200 feet above the proposed site of the dam, where they were filled by boats with stone sufficient to weigh them down onto the bed of the river. Generally speaking, the bed of the river is clay-slate and quite smooth, but very slippery, as all clays are under water. These stay-cribs, as they were called, were located with some difficulty, owing to the strength of the current and the distance from the shore. Each crib was held by lines reaching to both shores of the river, and steered from a predetermined place. From these stay-cribs, the cribs of the coffer-dam were located, being constructed in the same manner as the others, except that the upper half of each crib was built up higher, to permit a railroad to be constructed at their lower end to transport the material of the dam to place. The same method of loading and launching was observed with the coffer-dam cribs as with the stay-cribs, only the lines ran from the stay-cribs instead of from the shore. The first crib of the coffer-dam was placed at the north shore, and another one ten feet from it. The railroad was then constructed

upon these, and as fast as a crib was located, it was filled with stone by the dump cars. On the upstream faces of the cribs, 12 x 12 timbers were put in, one at the bottom, the other at the top, across the space between the cribs, and two-inch plank put in vertically along the timbers on their upstream side. Cinders from the mills were used as filling, the swelling of the planks stopping most of the leaks; but one of the cribs moved from its position, which was due to a boulder in the river bed. No sheet piling could be used except as spoken of above, because of the rock bottom.

As before spoken of, the river bed is of soapstone or clay-slate, that overlies the coal measures in this part of Illinois. It is a soft, friable rock, easily breaking down on exposure, but reasonably firm under water. Two trenches, three feet wide and three feet deep, were cut in the soapstone transversely across the river, one at the downstream end of the concrete portion of the dam, the other at the upstream end. By this means there was raised up, so to speak, in the center of the concrete an anchor of rock, besides the lower edge down in the rock to hold the concrete from moving down stream. In other words, the concrete has two holds upon the rock bottom in place of one. The forms for the concrete were then erected over these trenches, and the fender dam, to be described presently, erected. When the cement was put in from the dump cars seen in the photographs, the fender dam was in place to receive its portion. All the concrete was machine-mixed in the north shore, and carried to place by the little railroad. A spur track from the Rock Island Railroad delivered all materials just at the place of mixing and using, to save handling. The specifications permitted 25 per cent of stone to be added to the cement while green. The dam was constructed in sections varying in length from 50 to 100 feet; each section dovetailed into its fellows on either side. The sections were also secured to each other by the timbers in the fender dam. In one of the views, the concreted portion and fender dam are shown partially in section, except the anchor trenches. While the excavation of the trenches was going on, the fender dam was being constructed, its downstream side forming a part of the form for the concrete. The timbers for this section were 4 x 6 hemlock, laid up in cob-house form, with an up-stream slope of 25 per cent from the rounded comb of the completed structure. Holes were drilled down through the two last courses of timbers at the upstream side when in place, and two-inch iron rods driven down into the rock for two feet, where they were cemented fast. As will be seen from the view, the spaces between the timbers were filled with limestone, carefully driven in to make it solid. Four-inch oak plank decking was spiked down onto the timbers, and 60-pound rails securely fastened to the decking. These rails were bent over to accommodate the rounded portion of the comb of the dam. The cement forms being then complete, the concrete was filled in. Necessarily, some of it ran between the stone and timbers, and joined the concrete to the fender dam. The timbers of the latter broke joints at the intersections, that is, they ran over into their fellows on either side, insuring the safety of the structure at the joints. The railroad rails were bedded down into the cement at the comb of the dam, and for 150 feet from the controlling works at the north end were five feet apart, the rest of the way ten feet apart. The object of these rails is to protect the dam from the ice and driftwood. The drawing of the water through the head gates makes a large amount of ice near the north shore; consequently the rails were placed closer together here than for the rest of the dam.

The old dam was protected on the downstream side by a 45-degree apron, but large holes were gouged out of the soapstone below the dam by the action of the water and ice. It was believed that this was very much greater than ordinary during the high water of 1902 and 1903, undermining the old dam so much that it went out. In the new structure the downstream end of the concrete portion is elevated in a graceful curve, the water in flowing over being thrown upward a little and broken up before it leaves the dam. This is well seen in the photograph of the completed dam. The white appearance of the water indicates its breaking up. This form of construction was used to prevent the gouging action of the water upon the soapstone. It has stood the action of the ice and water for four years, and practically seems to be as good as when put in. The experience of two winters of very severe ice has not impaired it, no gouging action be-

low the dam being apparent. It is also very efficient in breaking up the ice that goes over the dam.

The dam is 960 feet long, 12 feet high, 9 feet above the bed of the river, the concrete portion being 12 feet wide at the base. The fender dam reaches 20 feet upstream, the entire structure being from upstream to downstream side, 32 feet. There was of the concrete 2,850 cubic yards, which cost \$4.50 per cubic yard in place. The dam and its approaches cost \$30,000. When the cribs of the coffer-dam were taken away, the stone was left to protect the upper edge of the fender dam. The writer is indebted to W. D. Boyce, president of the Marseilles Land and Water Power Company, for information in the preparation of this article.

THE FIREMAN AT THE FURNACE.*

By D. T. RANDALL.

THE skill of the fireman is the most important element in connection with furnace equipment. As a matter of fact, the personal element is the greatest hindrance to progress in the abatement of smoke. Both the owner and the fireman must be interested to obtain the best results. Intelligent supervision in the boiler room to secure proper air admission and care in firing will result in the saving of the losses due to smoke or unconsumed gases and to heating an excessive amount of air. At many plants such supervision has reduced the coal bills by 5 to 20 per cent, depending on the coal and the methods formerly in use.

It is a generally conceded fact that intelligent men trained in boiler-room practice could save 10 per cent of the fuel used in 50 per cent of the plants of the United States, and that in another 25 per cent of the plants such men could save 5 per cent of the fuel. It is the practice of nearly all large power plants to employ a boiler-room expert, and many of them have chemists who make frequent tests and investigations to determine the conditions favorable to the best economy. The saving of only a small percentage of the coal consumed will make a handsome return for the cost of the experimental work. There are now in a few of our larger cities competent engineers who are making a specialty of supervising boiler plants for a number of firms.

A few examples of carelessness and indifference on the part of firemen will in a measure explain why many persons are skeptical regarding the value of mechanical stokers and other smoke-preventing devices.

At a plant which had a smoke-preventing device, but which was smoking, the fireman said a connecting chain had been broken for several days and he "didn't have time to bother with it." It would not have required more than ten minutes to join the two ends with wire for a temporary repair. In another plant the fireman said: "The thing takes too much steam, and I shut it off." Many other cases of willful neglect have been observed.

Very few firemen can be induced to fire regularly and frequently, because it is easier to put in enough coal to last twenty or thirty minutes at one time and have little or nothing to do in the interval between firings. In one instance the engineer took occasion to measure the draft between the grates before and after firing on a down-draft furnace which had a good draft. The draft before firing was 0.35 inch of water, but after the fireman had thrown on sixty-three shovels of coal the flow of air was so seriously retarded that the draft increased to 0.62 inch. Great volumes of smoke were given off, indicating this lack of air.

Prof. Benjamin, speaking of steam and air jets, expresses himself as follows: "It is a very effective method of smoke prevention, and is used very largely in Cleveland; but it depends so much upon the individuality of the engineer and fireman. I have found that men who use that means had to be watched so continually and reprimanded so much that I got out of patience with that sort of prevention."

Difficulties are also encountered with stokers. One of the greatest troubles is the tendency of the fireman to poke the fires unnecessarily instead of using or adjusting the attachments provided for feeding and handling the coal. In many plants where it is possible they will shovel green coal into the stokers, instead of feeding it through the hopper, and then take a bar and stir up the fresh coal with the coke and ashes, causing smoke and wasting the coal.

It is not an uncommon experience that on inspection the boiler tubes are found to be covered with scale on one side and soot on the other. One plant with

* Abstract from a Bulletin issued by the United States Geological Survey.

nearly 4,000 horse-power had soot hanging from the surfaces of the tubes, and on inquiry it developed that these tubes had not been cleaned for a period of four months, no cleaning having been done since the new master mechanic had taken charge.

These examples emphasize the facts that the management of the boiler room is a problem for properly

trained men and that as the coal burned is a considerable item of expense, averaging about 50 per cent of the cost of producing power, there is more opportunity to save in the boiler room than in the engine room with any given equipment. The average boiler room is a hot, dirty, and otherwise unattractive place. For these reasons but little attention has been paid to it

by superintendents and operating engineers in moderate-sized plants. The boiler rooms are managed for the most part by men hired not so much for what they know as for their ability to do hard work, and they get comparatively small wages. There are, however, some mechanical appliances, such as the chain grate, which leave but little to the skill of the fireman.

THE CAUSES OF "KNOCKING."

A GAS ENGINE PROBLEM AND ITS SOLUTION.

THERE is probably no trouble prone to develop in the engine which is so difficult to locate and remedy as a bad and persistent knock. Every motorist of experience knows that he can make the engine knock by advancing the ignition beyond the normal working point for a given number of revolutions, and he also knows that he can advance the ignition more when the engine is running fast than when it is running slow without knocking occurring. Advanced ignition, even a very slight advance with engine moving infinitely slow, as at starting, results in a back fire, and the knock is not so much heard as "felt." The effect may be illustrated in this way: Imagine a billiard ball supported by a cord and swinging like a pendulum from a support. The ball is allowed to reach the end of its swing, or very nearly so, and if at that instant one gives it a forward push or impulse with the closed fist so that the backward swing is *followed* up slightly the swing of the pendulum will be accelerated. Substitute for the pendulum ball the rising piston in the cylinder and for the closed fist the exploding charge, and we get a fairly close analogy of correctly timed ignition with no knocking. Suppose, now, one meets the oncoming pendulum half way, or nearly so, across the swing. The forward motion will be suddenly checked and the experimenter will get a smart rap on the knuckles; he will, in fact, feel the "knock." Apply the former analogy and we have the case of advancing the spark too much. To imitate a back-fire at starting one might substitute for the billiard ball a heavy weight, give it a good swing, and meet it less than half way with a sharp blow from the fist. The result would probably be either a badly sprained or broken wrist. Too advanced ignition is not quite the same thing as pre-ignition, which likewise can cause severe knocking; but this condition must also not be confused with self-ignition, although both may occur nearly simultaneously. Faulty carburetion or carbon deposit on the piston may cause pre-ignition as generally understood. Strictly, a pre-ignition is a too-advanced ignition occurring without the agency of the spark. On the other hand, self-ignition resulting from the same cause may, and often does, occur at approximately the correct time if the engine be running on about half-throttle. A not uncommon experience is to find that on switching off the spark and cutting off most of the gas the engine fires with perfect regularity for some hundreds of yards, but finally misfires and stops. If the throttle be opened full while the engine is thus running it generally results in a severe knock taking place. It is easy to follow why this is; more gas means higher compression, and the greater heat induced raises the ignition media to the critical point of incandescence earlier in the stroke. The trouble may still occur even after the combustion chamber and the top of the piston have been well scraped from carbon deposit. This is where the real difficulty begins, and one can only advance theories as against practical conclusion.

Suppose a pair of plugs are fitted in each cylinder and one is mounted over the exhaust valve and the other in the neighborhood of the inlet, it will follow that the electrodes—sparking points—of the former will be maintained at a higher temperature than the latter, and, furthermore, there will be a tendency for exhaust gas flame to lodge inside the bore of the plug, although the particular design of the plug may modify this. For instance, a plug with a deeply recessed insulator would be worse in this respect than one with a shallower insulator. The retention of a small quantity of the flaming gas would, it is reasonable to assume, cause a pre-ignition so soon as the compressed charge is urged into contact with it. In this case the result will be the same whichever plug is in action, and the only remedy is to change the plug over the exhaust valve for another pattern, preferably one with heavier electrodes and a solid insulator. In certain instances, however, the auxiliary plug over the exhaust had to be removed altogether and a twin plug used over the inlet. We have now to consider another source of the trouble, one which arises from a very small fault in the cylinder casting in the shape of a minute fin or projecting bit of metal, or a "wire edge" at one of the valve ports.

The result is that the bit of superfluous metal reaches the incandescent stage under certain conditions, on the principle that a piece of fine steel wire held in a gas flame will become white hot and melt, while a stouter piece of wire would only reach a dull red heat. This is about the normal condition of the valve heads, a temperature too low to ignite the charge. The combustion chamber and cylinder walls are at a still lower temperature, estimated at 250 to 300 deg. Centigrade. The valves are very rarely nowadays the cause of any pre-ignition trouble, but at one time a form of valve head was in vogue which was prone to overheat. This had a projection in the center of the head which was slotted to take a screw-driver for grinding-in purposes.

We now come to purely mechanical causes of the trouble. The gasoline engine, being of the intermittent torque class of prime mover, requires all moving parts to be as close a working fit as possible to insure smooth running. Any undue wear or backlash in the bearings, or any inaccuracy in the alignment between two moving parts, setting up intermittent stresses, will cause the trouble, but it is not generally so marked, or likely to have such serious consequences as the knock resulting from pre-ignition and faulty timing. It is quite easy for a practised ear to distinguish between the two kinds of knocks. An engine with loose bearings may, if need be, be run for a considerable time without anything serious resulting, but it can not be regarded as good practice to allow the bearings to get into a bad state of wear. These should be taken up or adjusted as soon as it is convenient to do so; this means, of course, when the car can be spared. The true alignment of engine shaft and clutch largely depends on the bearings being in good order. Special attention should be paid to the connecting rod bearings, as there is a greater tendency for these to wear oval, taking as they do the direct thrust from the explosion and with a tendency to wear on one side.

TESTS OF BRAKE SHOES.

THE wearing qualities of brake shoes have been the subject of experiment by a committee of the Master Car Builders' Association. Past tests have been confined to frictional qualities, and an attachment was fitted to the friction testing plant to permit the shoe to be brought into contact with the wheel for a predetermined interval, after which it would be automatically released, remaining in release position for another and much longer interval, during which time both wheel and shoe would return to their normal temperature. Accessory to the large machine there would be, of course, required a registering counter to show the number of applications, and a delicate balance for weighing the shoes before and after they are exposed to the action of the machine. The committee selected fifteen shoes on which frictional tests had been made in 1906 and used these shoes for the wearing tests. The machine was set under the control of

WEAR OF BRAKE SHOES ON CAST-IRON WHEELS—SPEED CONSTANT AT TWENTY MILES PER HOUR; PRESSURE OF SHOE ON WHEEL, 2,808 POUNDS; REVOLUTIONS OF WHEEL DURING APPLICATION, 190; EQUIVALENT DISTANCE RUN DURING APPLICATION, 1,641.5 FEET.

Number of Shoe.	Coefficient of Friction.	Weight of Shoe, Pounds.	Number of Applications.	Total Loss of Weight, Pounds.	Loss of Weight per Application, Pound.	1,000,000 Foot-Pounds of Work Absorbed per Application.	1,000,000 Foot-Pounds of Work Absorbed per Pound of Material Lost.
158	22.5	22.046	90	0.229	0.002544	1.036	407.2
161	21.8	21.208	94	0.644	0.006850	1.004	146.6
163	21.7	19.964	118	0.337	0.002856	1.000	350.1
172	22.8	17.180	90	0.366	0.004066	1.050	258.2
175	30.3	11.202	40	0.690	0.017250	1.395	80.8
178	20.0	18.662	90	0.364	0.004044	0.921	227.7
179	36.8	9.298	40	0.593	0.014825	1.635	114.3
183	38.7	7.846	60	0.615	0.010250	1.782	173.8
186	24.1	13.778	90	0.615	0.006833	1.110	162.5
194	26.5	22.730	90	0.198	0.002200	1.220	554.6
200	22.7	15.780	90	0.243	0.002700	1.045	387.0
205	23.5	17.610	90	1.058	0.011755	1.082	92.0
209	24.7	16.818	90	0.593	0.006588	1.137	172.0
215	20.9	16.354	90	0.320	0.003555	0.963	270.9
220	26.5	13.066	91	0.220	0.002417	1.220	504.7

a gear which required 800 revolutions for a complete cycle, during 190 of which the shoe was in contact with the wheel. It was found that by employing a speed of 20 miles per hour and a brake shoe pressure during application of 2,808 pounds the machine could be kept in continuous motion under the cycle without undue heating either of the wheel or shoe. The severity of test conditions may be judged from the fact that the work done by the brake shoe during each application is approximately the same as that which would be done by each of the eight shoes of a loaded 100,000 pounds capacity car in bringing the car to rest on a level track from a speed of 40 miles an hour. The accompanying table shows the results of these tests. In future tests the committee intends to measure the wear and tear on the wheel used in the testing, a factor not heretofore studied.

PHOTO-ELECTRIC FATIGUE.

PHOTO-ELECTRIC fatigue is considered by W. Hallwachs in a recent issue of Ann. der Physik. He concludes that the causes usually considered as producing the phenomena—such as oxidation, action of light, corrosion of the surfaces—have no influence; but that the principal fatigue phenomena in free air are due to the action of ozone. The author gives a summary of the experimental facts that lead him to the conclusion that photo-electric fatigue is not the result of the influence of light or of corrosion, and that it is not due to the formation of electric double-layers. In connection with the latter subject he discusses photo-electric fatigue and contact potential. In the last portion of the paper he describes the action of ozone in connection with the phenomenon. The feeble fatigue in closed vessels may be traced to the increase of electron absorption due to the increase of the gas charge of the plates. The strong fatigue in free space may be similarly explained as caused by the action of ozone in producing absorption of electrons in the gas charge of the plates, this being due to the influence of ozone on the motion of the electrons—strong absorption of slow electrons and eventual lessening of their energy of vibration in the metal.

In a recent paper on the same subject W. F. Holman describes his observation of the photo-electric current from zinc, carefully polished and cleaned. As source of illumination an electric arc between steel electrodes in hydrogen was used. The chamber in which the zinc was mounted was evacuated and left at an indefinitely low pressure in connection with a drying chamber for several hours. With a gas pressure of 0.001 millimeter the mean value of the photo-electric current was 6×10^{-10} amperes. After admitting hydrogen at a pressure of 1.5 millimeter, a glow current was then sent from the zinc as cathode for about 15 minutes, and the chamber again evacuated to a pressure less than 0.001 millimeter. Successive readings of the photo-electric current then gave a mean value of 3.8×10^{-10} amperes. After standing 12 hours the mean value observed was 4.1×10^{-10} amperes. Then hydrogen was again admitted, and the metal used as anode, during a period of about 7 minutes, after which the pressure in the chamber was reduced to less than 0.001 millimeter. The mean value of the photo-electric current in this case was 5.9×10^{-10} amperes. The results may be explained if it is assumed that hydrogen serves as carrier of negative electricity in the photo-electric current as in Skinner's experiments on the glow current through rarefied gases. A similar series of experiments, using electrodes of different metals, gave the following results:

	Photo-Electric Current (10^{-10} Amps.).				
	Zinc.	Copper.	Silver.	Aluminium.	Iron.
After using as cathode with glow current in hydrogen	16.0	11.6	6.4	0.6	0.6
After standing twelve hours in hydrogen	8.8	1.8	0.6	0.0	0.0
After again using as cathode	41.0	16.0	14.0	5.0	4.5
After using as anode in hydrogen	7.0	15.0	6.0	1.3	1.4
After using as cathode again	36.0	16.5	25.0	2.7	5.0
After standing in hydrogen several hours	28.0	9.3	16.0	2.5	3.2

* The Motor.