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IMPROVED EFFICIENCY OF THE ST. LOUIS PUMPING STATIONS[1]

By Leonard A. Day

While hardly any one will dispute that the economical operation of pumping stations is deserving of much engineering thought and study, both from a theoretical as well as a practical standpoint, yet it is a fact that less attention has been given to this subject in the technical journals and in papers read before professional societies than to other branches of engineering connected with the supply of water to a municipality. When it is considered that large sums of money are spent annually in maintaining these pumping stations, and that the major portion of these expenditures are for pumping equipment, fuel and labor, the importance of close attention to economy becomes apparent.

Close attention to operating details connected with pumping stations will often result in quite a substantial saving, even without the necessity of changing existing equipment. For instance, cracks and air leaks in a boiler setting can, and frequently do, produce a heat loss of 10 per cent, and when coal bills amount to $150,000 or more annually, this 10 per cent means a saving or loss of $15,000 per year.

Probably one of the greatest drawbacks to obtaining maximum economy in a pumping station is a lack of coöperation between the so-called operating section and the engineering section. This condition of affairs is rapidly being eliminated, due to the fact that in many water works the operation as well as the design and installation

[1] Read before the Richmond Convention May 8, 1917.

of the equipment included in these stations is now under the supervision of but one engineer. It thus becomes possible to secure a thorough coöperation between the operating section and the engineering section, with a resultant economical improvement in the efficiency of operation.

Perhaps no means will serve better to present this subject than to dwell for a short time on what has been done in St. Louis during the past five years to improve the operating efficiency of its various pumping stations. St. Louis has one low-service pumping station and three high-service stations.

Six years ago the equipment at the low-service station included four Allis Chalmers crank-and-flywheel 30,000,000-gallon pumping engines and two direct-acting high-duty, Worthington 20,000,000-gallon pumping engines. Steam was supplied by eight water-tube boilers through four separate 8-inch headers. Six of these boilers were the National type of 365 horse power each, while two were 250-horse power Heine type, making a total of 2690 horse power based on 10 square feet per boiler horse power. All of the boilers were handfired and equipped with downdraft furnaces. The National boilers were installed in 1894 and were retubed in 1911. The Heine boilers were bought in 1907. All the boilers were originally provided with lapseam drums, a decidedly undesirable feature. The breeching areas were cramped, the stack capacity was not sufficient, the boiler supports and settings were badly in need of repair and the steam headers and fittings were poorly arranged and were giving constant trouble, due to lack of proper provision for expansion. In short, the plant was in need of a thorough overhauling, in order to bring it up to the standard of efficiency and service.

When it was decided to overhaul this station it became a question as to whether new boilers were to be installed or the old boilers rebuilt. The particular type of boiler in this station lent itself well to rebuilding and this course was adopted. New boilers at this time would have cost $12 per horse power, or a total of $32,280. The actual cost to overhaul and replace defective parts on the old boilers, including new drums with double-riveted butt-strap joint, thereby rendering them practically new, was $15,166. The resultant saving, therefore, due to reconstructing the old boilers amounted to $17,114.

It is not necessary to dwell at length on the possibilities resulting from the adoption of automatic stokers, coal and ash handling equipment and superheaters in a plant of this size. While the actual boiler efficiency may not be increased, the saving in labor pays well for the investment. Generally speaking, the efficiency of the boilers is also increased, in spite of the fact that a fuel of lower heat value and greater ash content is used.

Chain grate stokers were installed under each of the boilers. Overhead steel bunkers having a capacity of 600 tons of screenings were provided, as well as ash storage bunkers of 60 tons capacity. A bucket conveyor distributes the coal in the bunkers and also conveys the ashes to the ash hoppers from which they are dumped into railroad cars.

Superheaters have been installed in each boiler setting. In the National boilers, the superheaters were located between the top row of tubes and the drums. The space between the drums and the tubes in the Heine boilers being small, prohibited the location of superheaters at this point, and it was decided to place them in the combustion chambers behind the bridge wall. This is a comparatively new move in superheater construction. The temperatures here are as high as 2500°, but the superheaters apparently are not affected by these conditions.

Another decided step towards improved economy was the installation of a loop steam header. Originally there were four separate headers, one from each battery, running over the tops of the boilers and connected together by a manifold at the south end of the boiler room. It is readily understood that the maintenance of these headers, including the numerous valves and fittings, was high.

The scheme adopted was to provide a 10-inch header supported on the boiler columns, and running the entire length of the boiler room. This header was carried through into the engine room and extended full size to the middle of the house, where it was reduced to 8 inches and the return loop, being only for emergencies, was made 6 inches throughout both the engine and boiler rooms. In view of the fact that superheated steam was to be used, all fittings were made of steel, valves having steel bodies and monel metal trimmings were used, and the flanges were extra heavy, with male and female joints, and made up with asbestos superheat gaskets.

Iron galleries and platforms accessible by means of permanent stairs and ladders, were built around the conveyor, drums, and steam valves. This eliminates the need of temporary scaffolding when repairs have to be made, and is conducive to keeping the machinery in first class shape, which in turn promotes good economy. No condition in a plant is more destructive to good economy than an inconvenient arrangement of the boiler appurtenances. For instance, if the fireman has to walk around to the rear of his boiler to operate the dampers, the result generally is that the damper is not operated as it should be, or if the steam flow meter is located at a place where it is not easily seen or adjusted, it soon becomes worthless.

In arranging the various appurtenances for controlling the operation of the boilers at the station under discussion, care was taken to locate all apparatus as conveniently as possible. The damper levers are extended to the front of the boilers and a fireman in operating them can keep his eye directly on the draft gauge and observe the results. The steam flow meters are located on brackets about 7 feet above the floor where they can be seen and easily adjusted.

Due to the desirability of burning a lower grade of coal and the necessity of increasing the boiler capacity, a new stack became necessary. With proper alterations in the foundation of the old stack it was made amply strong to support the new one.

The new stack is of brick and reinforced concrete construction 225 feet high, with a fire-brick lining extending 80 feet above the base. The inside diameter at the base is 9 feet 6 inches and at the top it is 8 feet 8 inches. The stack will accommodate four 365 horse power boilers operating at 150 per cent rating, a total of 2200 horse power. It was designed on the assumption that screenings containing 10,000 B. t. u. per pound would be burned and is provided with approximately 22 square inches of sectional area per square foot of grate surface at normal rating, or practically 4 square inches per horse power.

It might be of interest to some to know that the fire-brick lining was laid up with a mortar composed of 3 parts cement, 5 parts fire clay, and 2 parts river sand. The remainder of the brick work was laid up with 2½ parts of sand and 1 part of cement, with 10 pounds of lime to every 100-pound sack of cement. The entire stack was laid up with standard square brick.

In order to keep a continuous and reasonably accurate record of the performance of the boilers and stokers, an automatic scale and weigh hopper was installed above each stoker. These scales weigh the coal in 100-pound lots before it is dumped into the stoker hopper, and also automatically record each dump. Tests conducted by allowing the scales to discharge into a box which could be actually weighed have shown that the automatic weighing device is accurate within 1 per cent. The boiler feed water is measured by means of a Venturi meter. From time to time the Department has tested the accuracy of these meters by actually weighing the water after it has been metered. It has been found that the meter is very reliable even when used with the reciprocating boiler feed pumps on the main pumping engines. In this station, however, turbine-driven centrifugal boiler feed pumps are used, which of course are ideal when for use with the Venturi meter.

The first pumping engines installed were the two 20,000,000-gallon high-duty compound direct-acting Worthington pumps previously mentioned, built in 1894. They were followed promptly with two 30,000,000-gallon compound crank-and-flywheel pumping engines built in 1895, and two more in 1899. The Worthington pumps, due to their small capacity and poor economy, were replaced during 1911–12 by two steam-turbine-driven centrifugal pumps, each having a normal capacity of 40,000,000 gallons daily. Thus a net increase in capacity of 40,000,000 gallons per day was secured.

In order to determine accurately the difference in cost between the repairs and maintenance for turbine-driven centrifugal pumps, as compared with crank-and-flywheel, cross-compound pumping engines, separate records have been kept of this cost for each since 1912. These records show that repairs and maintenance for the turbine pumps amount to an average of $413 each per annum, against $940 each for the compound pumps. This speaks well for the centrifugal pump. The fact is that for low-service work, especially when handling water containing sand and mud, and needle ice in cold weather, the centrifugal pump is far superior to the reciprocating pump.

An accumulation of sand occurs in the wet well between the suction pipes, due to a steady deposit in the quiet portion of the water in this location. Ice surging back and forth in the well is apt to throw these pyramids of sand into the suction pipes in such large quantities that the reciprocating pumps cannot handle it, with the result that a pump barrel bottom is pushed out or other injury done. This has happened on two occasions. Of course, the centrifugal pump is not subject to this defect.

As originally installed, the circulating water for the condensers on the reciprocating pumps was taken from a main carrying purified water. This amounted to about 20,000 gallons per hour for each pump, or 1,440,000 gallons per day for three pumps. To pump this amount of water cost $4.32 per day or $1575 per year. The proper location for condensers on pumps of the capacity of those under discussion is in the main suction or discharge pipe. Accordingly new condensers were bought and located in the discharge pipes of each engine. These condensers cost in the neighborhood of $3000 each and the actual saving, therefore, in water alone amounted to the price of one condenser in two years.

Feed-water heaters were installed in the exhaust pipes from the low-pressure cylinders, and by their use it was possible to secure an average increase in feed-water temperature of 25°. The average steam consumption on the compound pumping engines is 120,000 pounds per day. The total heat reclaimed per engine per day then is 120,000 × 25 = 3,000,000 B. t. u. This is equivalent to 2,705 pounds of steam per day, and with steam at 23.8 cents per thousand pounds amounts to an annual saving of some $564. Added to this is the advantage of having hotter feed water for the boilers. The heaters cost $290 each.

Sand in the water at the low-service station creates an excessive amount of wear on the pump plungers and packing. The difficulty has been largely overcome by adopting the following method of packing the plungers. A ring of flat tux packing is first inserted in the gland, on top of which a ring of soft marlin is placed, followed by one of hard marlin, then a second soft marlin ring and finally a ring of flat tux is inserted, on which the follower gland is brought down. To pack a complete pump requires 32 pounds of 1 × 2 inch flat tux, 140 pounds of hard marlin and 65 pounds of soft marlin.

Formerly the pumps were packed complete with flax and a ring of tux, top and bottom, requiring 180 pounds of flax per pump. At present prices, the marlin costs $76 per pump and a set of flax packing would cost $68. However, fully twice the service is obtained from the marlin as from the flax, and the service of the plungers before it becomes necessary to renew or turn them down is about twice what it formerly was.

Recent tests on one of the compound pumping engines shows that the efficiency of these units has not fallen off materially during their twenty-one years of service. The original official duty of the pump tested was 118,000,000 foot-pounds per 1000 pounds of steam, while the test in question showed a duty of 116,500,000 foot-pounds per 1000 pounds of steam. This test was conducted without any special preliminary tuning up, and indicates the average running conditions.

Each pumping unit is equipped with a Venturi meter which indicates, integrates and records the water pumped in gallons. The Venturi meter is especially desirable in low-service stations handling water containing grass and sticks, which are apt to tangle in the valves thereby increasing the slip. Before installing the meters in this station, the slip was assumed to be constant at 10 per cent and no means were available for telling when there was an excessive accumulation of débris under the valves, holding them open and seriously reducing the capacity of the pumps. It was the practice to open the valve chambers at regular intervals and thoroughly clean them out. They were invariably found choked up and a waste of energy was taking place. With the installation of the meters, however, any decrease in delivery can be detected at once and corrected. Thus the pumps are kept up to capacity and this source of waste eliminated.

Muddy, sandy water interferes seriously with the operation of the Venturi meter, and without some means for flushing out the pressure pipes connecting the meter proper with the Venturi tube, and maintaining clear water in these pipes, the instrument would soon become choked up and useless. To prevent this choking up, pipes carrying filtered water are connected to the pressure pipes just before they enter the meter, and by means of valves properly located it is possible to flush out the pressure pipes into the meter tube, thus keeping them clean and preventing their becoming choked up. When the meter is in service there is no circulation in the pressure pipes, and if once filled with clean water they remain full and dirty water does not enter. It is customary in starting up an engine to cut the meter out, turn on the clear water and keep it on until the pump is well under way, after which the clear water is shut off and the meter is put in service. Thus the pressure pipes are filled with clean water and remain so throughout the run.

These remarks, while referring specifically to reciprocating pumps, are equally true of centrifugal pumps. Sticks and floating material lodging in the passages in the impeller interfere seriously with the delivery and it is essential to have some means to indicate when the capacity falls off excessively. The Venturi meter serves this purpose thoroughly and is a desirable asset for the low-service plant.

At Bissell's Point, there are at present two stations, No. 1 and No. 2. Originally each station was supplied with steam from its own boiler house, which necessitated the up-keep of two complete steam plants, the unloading of coal in two coal sheds and two sets of ash handling equipment. It was perfectly possible by installing a steam pipe tunnel between the two stations, to operate No. 1 engine house from No. 2 boiler house. In order to accomplish this, the capacity of No. 2 boiler house was doubled, by installing four additional 350 horse power water-tube boilers. Chain grate stokers for all the boilers, a belt coal conveyor, a crusher and track hopper were installed, and a steam jet ash ejector and storage bin of 90 tons capacity were also provided. The entire load was thrown on No. 2 boiler house in June, 1916, and a saving in salaries alone of some $15,000 per year was effected at once. The essential difference between this station and the low-service plant just described, is that a separate belt conveyor handles the coal, and the ashes are handled by means of a steam jet ash ejector, which apparatus was selected owing to the necessary arrangement of the boilers in the station. There are four boilers on one side and four on the other, separated by a firing aisle through the center, and it was not practicable to arrange a bucket conveyor so that both coal and ashes could be handled by it. For this reason a belt conveyor was adopted leading from the crusher at the rear of the coal house up an incline to the overhead bunkers in front of the boilers. This belt is 18 inches wide, and has a capacity of 50 tons of coal per hour. A track hopper, cross conveyor and crusher were installed and the coal handling equipment made complete.

Plans have been made to utilize the belt conveyor for storing coal in the coal shed through which it passes. Scrapers will be provided for discharging coal from the belt into the shed and a secondary or reclaiming conveyor will be installed in a small tunnel under the coal house floor, which will convey this stored coal back onto the main belt when occasion demands. Thus a cheap and effective means for handling stored coal will be available, and the reliability of operation materially improved.

The steam jet ash ejector was installed in duplicate, a separate system being provided for each side of the house having sufficient capacity to handle six tons of ash per hour with 2,200 pounds of steam.

Venturi meters for boiler feed and automatic scales for coal permit keeping an accurate record of the performance of the station and detecting any decrease in efficiency due to improper firing conditions or any contigencies that may arise. Automatic stop and check valves were provided for each boiler and all fittings were made of steel, valves were made suitable for superheated steam and the same general construction was employed as that described in the low-service station.

The pumping equipment of the high service station consists of three 20,000,000-gallon Allis triple-expansion engines, two 20,000,000-gallon Holly triples and one 20,000,000 Cameron centrifugal pump driven by an Ingersoll-Rand steam turbine.

The two Holly pumps, No. 6 and No. 13, are the latest triple expansion engines installed by the Department and replace two old walking-beam engines of 18,000,000 gallons capacity each. These old pumps were of the single-cylinder walking beam type and showed a duty of only 65,000,000 foot-pounds per 1000 pounds of steam. They operated on saturated steam at 60 pounds pressure and their up-keep was expensive. The new engines develop a duty of 200,000,000 foot-pounds per 1000 pounds of steam at 160 pounds pressure and 100° superheat. The saving in steam realized in pumping 9,000,000,000 gallons of water per year with the Holly pumps over pumping the same amount with the old walking-beam engines is some $4,000.

In the acceptance test, No. 13 exceeded the duty of any existing pumping engine and no other builders have yet succeeded in equaling the duty developed. The guarantees were made on the work done per 1000 pounds of dry steam; however, sufficient data were taken to compute the duty on a thermal unit basis. The work done per 1,000,000 B. t. u. consumed as shown by the official test was 166,700,000 foot-pounds. The engine has since been equipped with feed-water heaters located in the exhaust pipes just before they enter the condensers. By increasing the temperature of the feed water an average of 20° the B. t. u. duty of the engine has been raised to 169,300,000 foot-pounds, effecting a saving of 1.45 per cent. For the two Holly pumps the saving per year amounts to $450. To equip both engines with heaters originally cost $1395, and allowing interest at 6 per cent, it will take three years and ten months for the saving to pay for the heaters, afterwhich the saving becomes clear profit, and in thirty years (the average life of such a pump) will amount to $12,000 in round figures.

High-duty station No. 3, at Baden, contains eight 275 horse power boilers which supply steam for four 15,000,000- and two 10,000,000-gallon triple-expansion pumping engines. Nothing has been done in this station as yet toward remodeling it. The boilers are handfired, with downdraft furnaces and coal and ashes are handled in trucks by hand. It is proposed to install coal and ash handling machinery, stokers, superheaters and a new stack.

In closing a few general remarks in regard to common practice at the several stations might be made.

It has become general practice throughout the country to buy coal on the thermal unit basis. The Department some ten years ago realized the importance and advantage of this, and it is its practice to draw up complete specifications covering each grade of coal required, and stating the normal B. t. u. value expected. A scale showing the bonus and forfeiture for exceeding or failing to meet the normal is included, and each contractor knows exactly the conditions he is required to meet. The system has been used with success and operating conditions in the boiler rooms have been materially improved, in addition to the saving in dollars resulting by paying only for value received.

All of the boilers in each station are provided with hand operated flue gas analysers, there being one single chamber or set for each battery. It is the duty of the operating engineers to make flue gas analyses at regular intervals throughout their watches and keep a record of the results obtained. The engineer is thus held responsible for the condition of the fires and furnaces, and being of a higher caliber than the average fireman is the proper person to be in authority.

The amount of boiler feed water evaporated per pound of coal fired is recorded on a blackboard at the end of each 8-hour shift. This creates a spirit of competition between the different crews of men, which has been found conducive of good results.

The boiler efficiency and station duty in foot pounds per 1000 B. t. u. is computed at the end of each week by the engineering office and the results for each station are posted in the engine and boiler rooms. This also creates a spirit of rivalry among the men which keeps them keyed up to their best effort.

All of the engine rooms are provided with an overhead central oiling system, thereby doing away with the necessity of an oiler filling individual sight feed oil cups on each important bearing. The scheme has resulted in reducing the force of oilers by one-half, as formerly one oiler was require to oil a single engine, whereas now one man can easily oil two engines.

The introduction of higher steam pressure and superheat has necessitated special care in the purchase of oil and grease. Too much attention cannot be paid to a study of the proper lubrication for each type of engine and condition of operation. Oil is not a universal product. That which is entirely suited to certain conditions may not be at all applicable to others. It is the practice of the Department to draw up rigid specifications, based on experience and advice from reliable manufacturers covering oil for every requirement and let yearly contracts. In this way a uniform price is secured and the most efficient oil for the purpose is used in each case.

Before this system was adopted each operating engineer in charge selected and ordered the grade of oil which he was in the habit of using. Two of the stations were paying 45 cents for cylinder oil while one was paying 33 cents and each station used a different engine oil paying from 22 to 25 cents per gallon. The cylinder oil used last year and bought under specifications cost 30½ cents per gallon and the engine oil cost 18⅛ cents per gallon. This is even less than the prices seven years ago, in spite of the fact that the cost of all material has advanced at least 25 per cent in the meantime.

The Department is now using superheaters in all but one of its pumping stations. Quite an appreciable gain in economy is effected by the use of superheated steam. It seems that no definite formula for computing this gain, for any engine, has been established. Probably receiver proportions, cylinder ratios, speed, vacuum, etc., influence the results in different cases. To contribute to the as yet rather meager information on this subject, the Department recently conducted a series of duty tests on one of its new 20,000,000-gallon triple-expansion pumping engines. The test was run at different degrees of superheat ranging from 25° to 100°, and sufficient data were obtained to plot a curve showing the relation between duty and superheat. The curve is not a straight line, the gain appearing to be most rapid at higher superheats. It was not possible to operate on saturated steam, due to the fact that the superheater dampers were not tight, but permitted a small amount of hot gases to circulate even when they were entirely shut. The gain in economy ranged from 2.3 per cent at 25° superheat to 14.25 per cent at 100°.

At the Baden station, as yet not remodeled, the Department has succeeded in reducing the cost by 17 per cent in the last five years, at Bissell's Point by 31 per cent and at the Chain of Rocks by 21 per cent.

DISCUSSION

John C. Trautwine, Jr.: The author mentions that, at St. Louis,

(1) Coal is bought on the B. t. u. basis; the specifications stating, for each grade of coal required, the normal B. t. u. value expected, and the bonus and forfeitures for exceeding this normal and for failure to reach it;

(2) The amount of boiler-feed water evaporated, per pound of coal fired, is recorded on a blackboard at the end of each eight hour shift.

It is certainly more rational and equitable to pay the coal contractor according to the value received from him, than to pay him according to the received quantity of a mixed material, made up of useful and useless ingredients in unknown proportions. And the question arises, why a similarly rational and equitable method of adjusting payments might not properly be applied to the men; basing their compensation, not upon the number of hours spent at the station, but upon their actual output of useful work, as inferred from the posted evaporation records. But then, by the same token, "the amount of boiler-feed water evaporated" by each crew should be registered, not "per pound of coal fired" but "per 1000 B. t. u."

It may safely be said that the "spirit of competition," which the posting of the evaporation record is designed to create between the men, would not be diminished by thus appealing, not only to their "spirit of rivalry," but also as in the case of the coal operators, to a baser motive. But, in Philadelphia, years ago, it was said that mechanical stokers could not be installed in the municipal pumping plants, because they were then "not old enough to vote;" and the speaker is ready to believe that, even in St. Louis, there may be "practical" reasons why a sane method, found useful in the case of coal operators, would never do in the case of boiler-house men

R. B. Howell: In Omaha bids were asked upon a B. t. u. basis for coal. When the bids were opened it was found that the proposals were much higher than the market. As a consequence the Department ceased to make contracts for coal at all. Now it goes into the market and buys coal when it can get it at a reasonable price. For instance, some time ago a mine operator offered 100 cars of coal, because the Department was able to handle it. However, the price did not suit, and the Department held off, finally buying it for one-half of the original offer. With this coal the Department filled its storage tank, and in addition had to pile some on the ground. The coal cost last year on an average, $2.54 per ton delivered. This coal, slack, averages about 10,500 B.t.u.

T. A. Liesen: Coal was bought at Louisville in three different ways during a period of three years. For several years it was purchased under a contract at the lowest market price for a given quality. For a year the purchasing was done on a B. t. u. basis. After that, owing to certain conditions in the coal market, purchasing was done in the open market in the manner suggested by a previous speaker, and this proved fairly satisfactory. During this time western Kentucky coal of about 12,000 B. t. u. was bought as low as $1.00 per ton delivered at the station. At the river station, where the boilers were fired by hand, western Kentucky coal did not give good results, and eastern Kentucky coal was used, at a cost of $1.25 or $1.50 delivered at the station.

In Detroit the bidders on coal are required to state the number of B. t. u. in the supply they will furnish, and preference is given to coal running over 14,000 B. t. u. In addition to stating the number of B. t. u. the bidder must guarantee the amount of moisture, ash, and other properties of the coal, and in the contract the right is reserved to make deductions in price providing these guarantees are not met. There is no bonus for any increase in quality above the guarantee. This method of purchasing has worked satisfactorily in buying West Virginia coal for several years. Until recently the price has been from $2.20 to $2.37 per ton, but in April of this year the Department bought 15,000 tons at $5.44 from the only bidder who submitted prices. The Department closed this contract after being assured by the Detroit Edison Company, one of the largest consumers of coal in the vicinity, that the price was a good one.

There are few pumping stations where considerable economies cannot be effected under careful supervision. Some results brought about in Louisville a few years ago are among the most remarkable the speaker has seen. In 1908 the annual operating cost at the river pumping station was $6.15 per million gallons. Two years later the operating cost was reduced to $2.59. A great part of this saving was due to larger use of the most efficient types of engines in the station. At the Crescent Hill re-pumping station, which had been in service for two years, the operating cost in 1908 was $3.72 per million gallons. Within two years, by continuous effort, the elimination of unnecessary help, and the installation of some auxiliaries, the cost was reduced to $2.59 per million gallons. Aside from the mechanical devices installed, the leading cause of this saving was a monthly statement sent to the station, giving the results for each month's operation, reduction or increase in the cost as the case might be, which was an incentive to the men in charge to improve their work so that there was in most cases a slight monthly decrease in the total cost of pumping. The statement made it possible to compare the work of different shifts and competition between the two stations was stimulated.

In studies of this subject it is desirable to have more pumping station records from plants of different sizes and types, giving the unit cost and the total cost per million gallons, so far as they can be obtained. The cost per million gallons should be divided into at least three items, the total cost of labor per million gallons, the total cost of fuel, and the sum of all other items of expense. Comparisons could be drawn readily from such records, which could be comprehended easily, and would not require computations. Such records would prove a decided stimulus to all station operators. The speaker has been endeavoring for a number of years to give such facts in his annual reports. On the basis of the prices for coal in Detroit there is no special reason why the total pumping costs should be less than at other large cities similarly situated. At Louisville, on the other hand, the low cost of coal should produce a low cost of pumping. With more data of this kind we should be able to ascertain readily where economies are possible and to encourage the station operators to bring them about.

L. A. DAY: The coal is bought at St. Louis on a B. t. u. basis and the determination is made by the testing laboratory, not by the firemen. In so far as B. t. u. value is concerned, the firemen know absolutely nothing about it, so it is difficult to see how the firemen can affect the price of the coal, so far as the contractor is concerned, because they do not know anything about the B. t. u. value.

The object of the CO_2 apparatus is to teach the firemen how to properly burn the coal. The station duties in B. t. u. are posted because conditions are not the same at all stations.

One station plant has certain features that the other has not, and therefore it did not seem right to post the duty per 1000 pounds of steam, which is the commonly known way of computing the duty at the station. In order to eliminate the differences that exist in the stations, the duty per 1000 B. t. u. was adopted.

The samples of coal for testing average about 25 pounds to the car. With some kinds of coal a pipe is driven through it at three different places, as a rule diagonally across from one end of the car to the other. The pipe used is similar to the pipe used in sampling wheat, except that it has not the sliding feature which closes over the opening. A 2½ inch extra heavy steel tube cutter, is used, somewhat similar to the cutters employed in stone work. A man on top of a car can drive the pipe right through to the bottom.

The oil for the engines is bought according to specifications prepared by experts. If the department tried to buy the same oil under its trade name it would pay much more for it.