JOURNAL

OF

THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXX SEPTEMBER, 1915 No. 3

MECHANICAL STOKING OF LOCOMOTIVES.*

BY

W. S. BARTHOLOMEW,

President, Locomotive Stoker Company, Schenectady, N. Y.

IT gives me more than ordinary pleasure to have this opportunity to speak upon the subject of "Mechanical Stoking of Locomotives" before this audience and under the auspices of The Franklin Institute of the State of Pennsylvania, because those of us in commercial and industrial activities are usually accused of having an ulterior motive when we speak upon the subjects in which we are personally interested, and the privilege of having an audience disinterested from the purely utilitarian standpoint is much appreciated, and I hope to make the subject of interest of itself. I am therefore more than happy to be permitted to speak plainly upon phases of the Locomotive Mechanical Stoker problems, which are ordinarily held in the background, especially so because The Franklin Institute stands committed to encourage the application of mechanical and scientific principles which, by their use in industrial pursuits, may in some measure relieve the stress of physical labor when arduous, conserve energy, or add to the wealth of the individual, community, or nation, by effecting economies in any direction.

I shall therefore try to approach the subject of the evening

* Presented at the stated meeting of the Institute held Wednesday, April 21, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

from the point of view of your honored institution, free even from what our legal friends would term " implied bias."

The firing of a steam locomotive with what in common railroad parlance is known as a " scoop " is about as crude a process as can be imagined, and has not changed very much in arrangement or method since locomotives were first used, and I shall take the liberty of assuming your entire familiarity with this hand-firing practice and also the continual increase in the size of locomotives during the past twenty or more years, and will refer mainly to locomotives in general service to-day, rather than to those in use when experiments with mechanical stokers first began.

There are something over three thousand patents on record covering mechanical stokers for locomotives, some of which were intended by the inventors to be suitable for use on stationary boilers as well. This does not include a still greater number of patents taken out on devices in connection with the firing of locomotives and stationary boilers with finely ground or pulverized fuel. This large number of patents will illustrate the difficulty of attempting to give any complete history of the development of the mechanical stoker for locomotives within the limits of this paper, and I shall therefore mention only some of the different angles from which inventors have approached the proposition.

Nearly all of the earlier inventors apparently had one object clearly in mind, and that was to fire a locomotive by machinery, not particularly for the purpose of reducing the fireman's labor, but to make it possible to use a helper, or common laborer, on the fireman's side of the locomotive in lieu of the regular fireman. This is well illustrated by the fact that with nearly all of the early stokers the operator was still required to actually shovel all of the coal into the stoking machine. The stoker was to do the work of putting the coal into the firebox and distributing it, the man was to be protected somewhat from the heat of the firebox, but the labor of shovelling the coal still remained.

It will readily be seen that such inventors were building their structure upon a false basis in assuming that stokers would be applied to any large number of locomotives for the simple purpose of reducing the grade or the class of labor and entirely overlooking the long-established practice of recruiting the engineers needed for the right-hand side of the locomotive from the firemen who have served their time and secured partially a locomotive engineer's experience through their years of service on the left-hand side of the locomotive.

Other inventors seemed to have in mind, as the main object for the use of a mechanical stoker on a locomotive, the preparation of the coal, and elaborate arrangements were made in the matter of crushing mechanism to handle lumps of coal twelve inches in diameter and over, so that the fireman would not be required to touch the coal in the coal-pit, and, having accomplished this, insufficient attention was given to the matter of putting the coal into the firebox and properly distributing it.

Several inventors brought out very elaborate devices for distributing the coal over the fire-bed, without making any arrangements whatever for the preparation of the coal or the conveying of the coal to the distributing mechanism.

Other inventors fully appreciated the arduous work of a locomotive fireman and the intense heat he is called upon to endure during the summer months under certain operating conditions, and were earnestly endeavoring to develop a locomotive stoker which would relieve the fireman from a large part of his physical labor and make it unnecessary for him to undergo the suffering due to the heat.

Some inventors confined their efforts exclusively to the proposition that the mechanical stoker would be a fuel-saving device. This was particularly true as to inventions in England and on the continent of Europe, where the cost of locomotive fuel is several times as much per ton as with us. Locomotives are being fired in Greece, for instance, with coal costing $12 per ton.

In the main, these experiments were along the conventional lines of hand-firing practice; that is to say, the delivery of the coal to the firebox in charges of fifteen to twenty pounds, as with a hand scoop, and the putting in of a "fire"; that is to say, a quantity sufficient for a period of more or less length, according to the way the locomotive was worked.

A few inventors, two in particular, whose inventions will be described later in this paper, were approaching the problem from an entirely different angle than the earlier history of the art disclosed, namely, to bring out machines which would assist the regular fireman in firing the locomotive in a better way and to a higher point of efficiency or to a greater horse-power output than was possible to do with hand firing, and at the same time do all that other inventors had done, or even go further in the matter of relieving him from physical labor and discomfort, or exhaustion.

It is only within the past three or four years, particularly the last three years, that mechanical stokers for locomotives have been brought out which included all necessary features to successfully meet the present operating conditions on large locomotives and be worthy of application in a large way.

Considering the mechanical stokers which have been applied and are still in use on locomotives, we may properly divide them into two general classes, namely, those which feed the coal to the firebox up through the fire-bed, and are commonly referred to as underfeed stokers, and those which feed the coal to the firebox over the top of the fire-bed, and are usually referred to as overfeed, or scatter type of stoker.

The underfeed stokers are of two types: those which feed the coal through the fuel troughs underneath the fire-bed with plungers, and those which distribute the fuel in the troughs with helicoid screws.

The overfeed stokers are more miscellaneous in character: There are those which distribute the coal over the fire-bed with plungers or other mechanical means, with steam jets without other directing means, and with steam jets with stationary directing means, and also with steam jets supplemented by movable mechanical directing means; also with steam jets having constant blast and with steam jets having intermittent blast; and both the underfeed and overfeed stokers might again be subdivided into those which supply the fuel intermittently to the firebox, putting in what the firemen call a fire or "slug" and then waiting for its consumption before another operation takes place, and those stokers which supply coal to the fire constantly in proportion to the rate of combustion.

There are conveyors for both the underfeed and overfeed stokers which have reciprocating action, supplying the fuel in separate charges to the stokers and those which carry the coal constantly to the stokers. Some of these conveyors are of the pusher type, which force the coal forward by pressure, and others carry the coal through its entire travel in a free and loose state.

Where preparation of the coal is attempted, it is usually done through the means of some part of the conveying mechanism, although in the early development of the stokers separate crushing machines were supplied, which, in turn, delivered the crushed coal to the conveying mechanism.

Counting all kinds of stokers which were applied to locomotives up to the year 1912, probably more than twenty-five different designs of stokers, widely variant in character, were put into service, and, strange as it may seem, *all of them fired the locomotives successfully, under certain conditions.* This peculiarity of the proposition led up to there being much misinformation circulated about the mechanical stoker for locomotives.

Some of this was also brought about by the promoters of the first stokers making unwarranted claims as to the machines being automatic, using this term even to the extent of certain companies being incorporated with the word "automatic" in their title.

This use of the word "automatic" brought immediate and very active opposition to the stoker on the part of the firemen, both individually and collectively, as they expected the "Iron Firemen" to supersede them, their wages to be reduced and their places taken by common laborers.

This fairly represents the locomotive stoker situation up to the end of the year 1911, as, notwithstanding the application of the many different kinds of stokers to locomotives in a comparatively short time, and the current reports that they were all wonderfully successful, no stokers of any consequence had been sold to the railroad companies in what could be considered a commercial way.

The American Railway Master Mechanics' Association had in the meantime appointed a Standing Committee on Mechanical Stokers for Locomotives, and several of the railroad companies also sent out committees to make investigations. The very intelligent and painstaking work of those committees contributed much to the development of stokers suitable to meet the conditions of operation obtaining on our larger locomotives of to-day, and the findings of the different stoker committees are of especial interest as an explanation of why large numbers of stokers were not applied prior to the middle of 1912, and also to forecast the characteristics of the present commercially successful locomotive stokers.

The summing up of the committees' reasons given for the non-application of stokers to locomotives in any great numbers is about as follows:

1. That most, if not all, of the locomotive stokers applied

up to the end of the year 1911 were not suited in one or more particulars to meet the variables in fuel, locomotives, and operating conditions, notwithstanding the fact that all the stokers applied up to that time actually had *bona fide* records of successful trips under certain conditions.

2. That practically all such stokers had been designed without due consideration having been given to the unusually severe requirements imposed upon strength of parts and correct mechanical design by the stress of operating conditions and the lower maintenance standards obtaining in railroad as compared with industrial service.

3. That the size of locomotives, particularly as to grate area and the tonnage hauled per train under the existing conditions of service up to the end of the year 1911, did not make mechanical stokers an absolute necessity.

4. That there was no evidence available to lead to the conclusion that a mechanical stoker would make it possible to fire a locomotive any more economically than with hand firing when the same amount of work was performed by the locomotive in each case.

5. That no advantage was being taken, to any appreciable extent, of the fact that, with mechanical stokers, large locomotives might be operated nearer to their maximum rated capacity than when hand-fired.

6. That nothing had developed up to that time to indicate that any less expensive fuel could be used for firing locomotives with a mechanical stoker than with hand-firing.

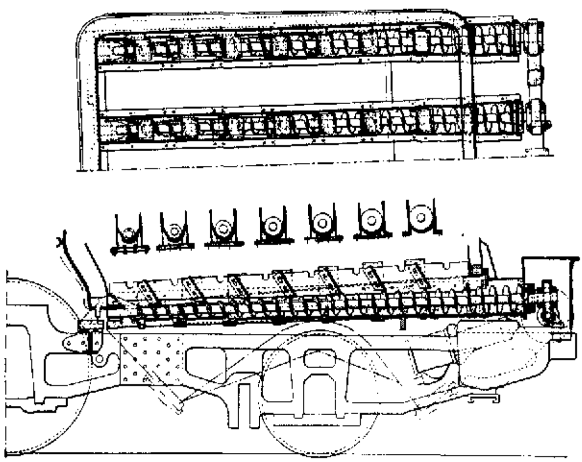
7. That it would not be possible, as claimed by some of the stoker inventors and promoters, to do away with the regular locomotive fireman and have the work done by a helper.

8. That labor-saving devices are not usually applied to any great extent simply to reduce the grade of or character of the labor—nor are they put into general use solely for the purpose of uplifting the grade and character of employment.

9. That therefore the only consideration left as an argument for the general application of mechanical stokers to modern locomotives was the possible reduction in the amount of physical labor and suffering of the regular fireman sufficiently to enable him to do the work without other relief.

A review of the history of the exploitation and introduction of a large number of labor-saving devices discloses the fact, regrettable as it may seem to have to admit it from a humanitarian standpoint, that most labor-saving devices are not applied generally unless there is some remunerative return to the purchaser, outside and apart from the ethical considerations; that is to say, there must be some increase in efficiency, some conservation of energy, some contribution to the wealth of the individual or the community at large, or the device must fail.

It is my intention to try to make it very plain that while the application of mechanical stokers to our large freight and pas-



Plan view of Barnum underfeed stoker.

senger locomotives will, in fact does, effect a very great relief to the firemen from the strenuous labor incident to shovelling coal at the rates required to fire locomotives, photographs of which will be shown upon the screen to-night, and that the firemen are almost entirely relieved from the suffering due to the heat effects of having the fire door open when hand firing, yet these benefits are only incidental to the main issues which contribute to the necessity for, or economy of, the application of stokers to locomotives.

Counting all stoking machines applied to locomotives up to April 1st of this year, there have been about 1200 put into service, of which about 1000 are now in use. This number is divided as follows:

1 Gee stoker—overfeed type.
20 Standard stokers—overfeed type.

20 Hanna stokers—overfeed type.
365 Crawford stokers—underfeed type.
600 Street stokers—overfeed type.

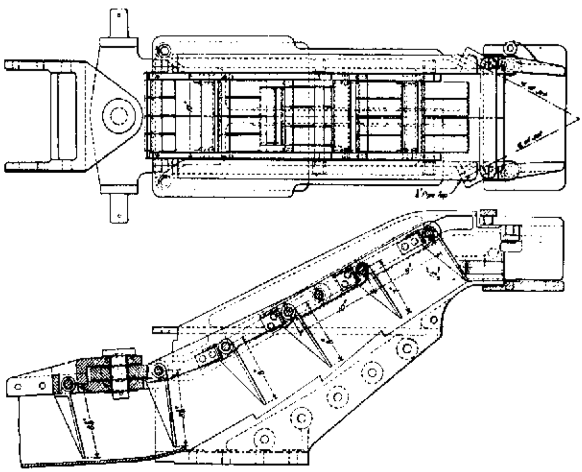
The 200 stokers applied at one time or another and later removed were not of these makes, with a few minor exceptions.

Before proceeding further with the general aspects of the subject, I should like to have you familiar with the details of these machines and some of the locomotives on which they are in use.

This is a plan view of the Barnum underfeed stoker. This was one of the stokers applied to locomotives experimentally and later on removed. One of the other slides will show the locomotive to which this stoker was applied. This stoker is of the underfeed type, having two or more stoking troughs placed longitudinally of the firebox. This drawing shows seven of the stoking troughs, but only three or four were used in the actual installations. The troughs were supplied with cast-steel helicoid screws, the flights of which were reduced in size at different points in their length, each diameter being about two feet long, and at the offset, where the reduction in flight took place, deflectors or partial partitions were provided, with an aperture equal only to the next reduced diameter of the flight of the screw. The effect of the use of these deflectors was to cause the coal to be lifted up out of the stoking troughs and forced over on to the grate areas at each side, and, of course, part of the coal was carried on through the reduced openings in the partitions until the next deflector was reached, where more coal was deducted from the quantity being forced along in troughs, and this continued until part of the coal had been carried to the extreme forward end of the firebox and forced up out of the trough by the bottom being slightly inclined upward. These stokers were operated by the use of two double-acting steam engines, one placed on each side of the locomotive at the end of the cross shaft. The screws were driven with worm drive, the worms being on the cross shaft and the worm wheels being at the back end of the cast-steel screws. Separate crushers of ample capacity were placed on the locomotive tender to prepare the coal.

Seven or eight of these stokers were applied and at least four or five of them saw considerable service with quite a number of different kinds of fuel and on locomotives of different types, at least one each being applied to a Switch, a Prairie, a Mikado, and a Decapod type of locomotive.

The results in service were quite satisfactory when the conditions existed which were favorable to the use of this kind of a stoking machine, and many successful trips were made with these stokers, taking the average of which it could probably be said that



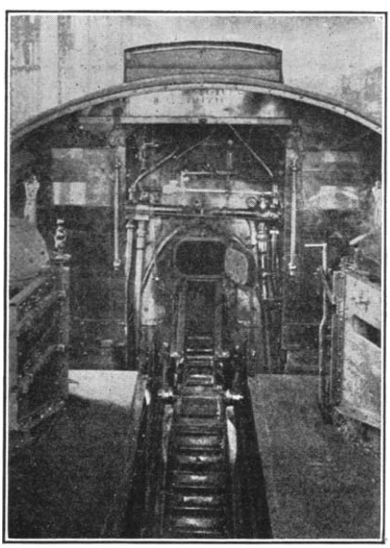
Plan view of Gee overfeed stoker.

75 per cent. of the coal burned on the trips made was fired by the stoker. The difficulty with this particular machine was probably more from mechanical shortcomings than from any inherent defects in the general scheme, although the results were not equally satisfactory with all kinds of coal used. It will be readily appreciated that, with the method used in firing with this stoker, there would not be the flexibility of control of the fire that will be noted with other stokers which will be shown and described.

This is a general plan view drawing showing the forward part of the conveying mechanism of the Gee overfeed scatter type of stoker and also the movable directing wings which are placed above the firing plate at the bottom part of the ordinary fire door. One of these stokers has been applied to a consolidation locomotive on the Pennsylvania Railroad, and is in operation in regular service to-day, firing the locomotive successfully. A crushing mechanism is placed at the back part of the conveyor of this stoker, which also serves as a measuring or feeding device to start the coal into the forwarding means of the conveyor.

This view also shows a cross-section of the forwarding vanes of the conveyor. These are not made all in one piece, but are practically fingers which drop back of the coal in the backward movement of the reciprocating conveyor and serve to push part, or all, of the coal in their vicinity forward, to be engaged by the next succeeding set of fingers in the following action of the conveyor. The reciprocating action of this type of conveyor accomplishes the purpose not only of forwarding the coal but of partially measuring it and serving it to the firing plate in separate charges, and the steam blasts are operated in timed relation to the forwarding of these separate charges of fuel, and serve as plungers to inject the coal into the firebox in very much the same manner as it would be fired with a scoop.

The direction of these separate charges of fuel to the different parts of the firebox is accomplished by the movement of the wings, in relation to which the jets are also controlled, so that when the wings are pointed toward the left-hand side of the firebox the jet on that side is shut off and the right-hand jet serves to force the charge of fuel in conjunction with the wings over to the left-hand side of the firebox, and so on.



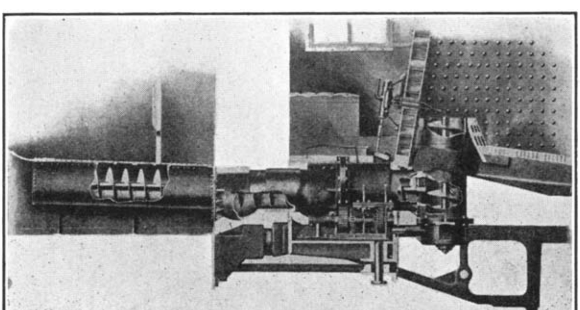
Photograph of general view of Gee stoker applied to locomotive and tender.

This is a photograph showing the general view of this stoker and with the deck of the tender and locomotive removed, so that the conveyor can be seen almost through its length. The crushing mechanism is just back of that part of the conveyor shown in the lower margin of the photograph. The position of the stoking mechanism itself, just below the fire door, can be readily observed in this view.

This stoker is operated by means of a steam cylinder placed at the side of the locomotive and attached to the frame just below the fireman's seat-box. The connection between this operating steam cylinder and stoker is by means of a cross shaft with the necessary arms and connections to give the conveyor and elevating mechanism the reciprocating action required by this particular design of forwarding means.

The individual characteristics of this particular stoker are *the firing of the coal over the fuel bed in separate charges,* representing very nearly the general scheme of hand firing and *the necessary intermittent action needed to permit each charge of fuel to be consumed before another is placed in the same location in the firebox.*

This stoker is firing a locomotive successfully, but has not been in service long enough to warrant any conclusions as to its commercial possibilities, only one of them having been put into service to date.



General view of Standard stoker.

This is a general view of the Standard stoker showing arrangement of conveyor, jets, and grates. This stoker is also of the overfeed scatter type, but it has the peculiarity of firing the locomotive by putting the coal into the firebox by conveying it to a point just below the back section of the grate area and elevating it by a vertical screw placed in a firing pot in the middle of the back part of the firebox. The distribution of the coal over the grate area is by steam jets, the nozzles for which are placed so as to come in the midst of the body of coal just as it reaches the top of the vertical screw, and the distribution is secured by having the jets pointed toward different parts of the grate area. There are no movable or stationary mechanical directing means to assist the steam jets in distributing the coal as with other stokers.

This stoker is one of those designed to supply fuel at a continuous rate over the entire grate area as compared with the intermittent action of the Gee stoker, which fires the coal in separate charges, as just described.

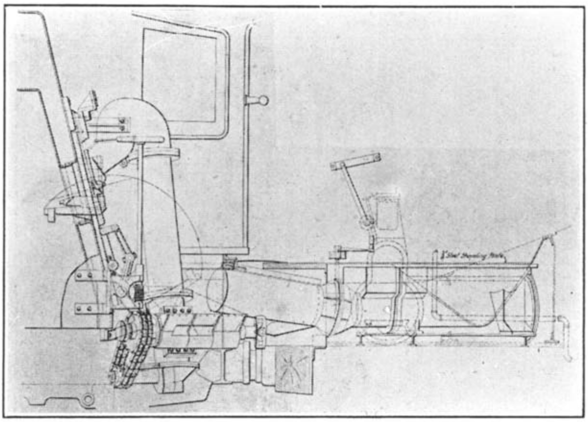
The Standard stoker also has arrangements for crushing or preparing the coal, this being accomplished by the use of a crushing zone at the forward end of the heavy cast-steel helicoid screw shown in the left-hand section of this general view. The necessary flexibility for the movement between locomotive and tender is secured by the ball joint actions, also plainly shown in the view.

The power motor which operates this stoker is a small, high-speed steam turbine on the left-hand side of the locomotive, and connection is made to the stoker through a train of gears with suitable reversing mechanism required for the clearing of the stoker from foreign matter or clogs of any description.

Suitable arrangements are provided for adjusting the jets to different degrees of force and also to shut one or more of them off when it is desired to stop the forcing of coal to any given part of the firebox. The general action of the jets is intermittent, being controlled by an operating valve moved mechanically by the arm and rod connection shown.

It might occur to you that the action of the jets being intermittent would result in firing separate charges of fuel to the grate area. This, however, is not actually the case, as the action of the jets is graduated so that the building up of the blast to maximum and decreasing in force to the minimum serves the purpose of waving the coal over the grate area by the use of the increasing and diminishing forces of the jets, and the valve controlling the jets begins to open almost immediately after each jet action, so that the result is a spreading of the coal continuously rather than firing it in separate charges.

Some fifteen or sixteen of these stokers have been applied to locomotives to date, and are firing the locomotives successfully.

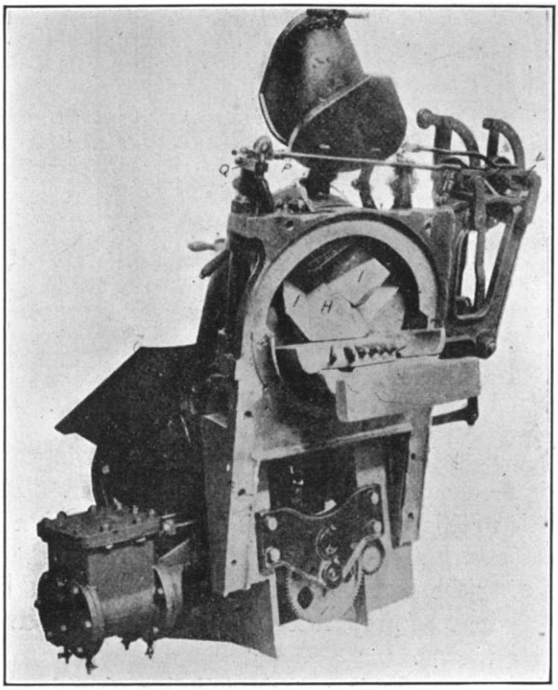


Drawing showing arrangement of Hanna stoker.

This is a drawing showing the general arrangement of the Hanna overfeed scatter type locomotive stoker. The peculiar characteristic of this stoker is the use of a combination of *movable mechanical directing means and continuously operating steam jets* for distributing the coal over the grate area. It also has means for crushing the coal preparatory to forwarding it to the elevating and firing means.

The driving motor is a twin-cylinder, double-acting steam engine placed on the locomotive tender, usually in one of the forward ends of the water space. The operating routine is to have the coal passed to the crusher through the opening in the deck of tender, and after being crushed the coal is forwarded by a cast-steel helicoid screw to a receptacle at the base of the elevating means, which is another cast-steel screw placed in the vertical casing just at the left of the ordinary fire door of a locomotive. At the top of the elevating means is a large elbow, or goose-neck, through which the coal is forced by the pressure of the vertical elevating screw and finally falls by gravity over the directing vanes, or wings, to the firing plate placed inside of the regular firing door of the locomotive.

This photographic view shows the firing plate, above which will be noted the main nozzles of the firing jets placed in fan-shaped arrangement, and above these jets will be seen the ridge plate and movable mechanical means or directing wings, which serve to assist the jets in distributing the coal over the grate area.

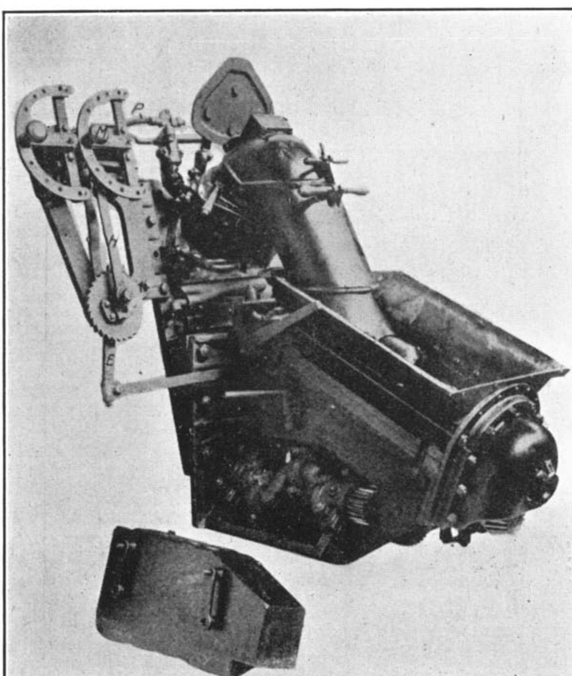


Photograph showing views of firing plate, steam jet nozzles, and stoking mechanism of the Hanna stoker.

Just below the main jets is a long slot in the casting at the level of the firing plate, and this can just be seen in the view.

The operation of the mechanism shown in this view is about as follows: The coal reaches the vanes at the upper part of the opening, coming by gravity from the goose-neck, and these vanes are in turn operated by the levers placed on backhead of locomotive, which will be shown in the next view, these levers keeping the vanes in constant motion while the stoker is in operation, which results in the coal being poured down over the jets, and the stream of coal is gradually directed from side to side, so that the jets pointed in any given direction intermittently force part of the coal, as it is directed over them, to some portion of the grate area; these jets being arranged in the segment of a circle, and the passing of the coal gradually from side to side in front of them has the effect of waving the coal over the grate area from one side of the firebox to the other. Steam also is forced against the coal through the long slot just below the main jets, but at a lower pressure, and this serves to force part of the coal just over the firing plate to the back of the grate area.

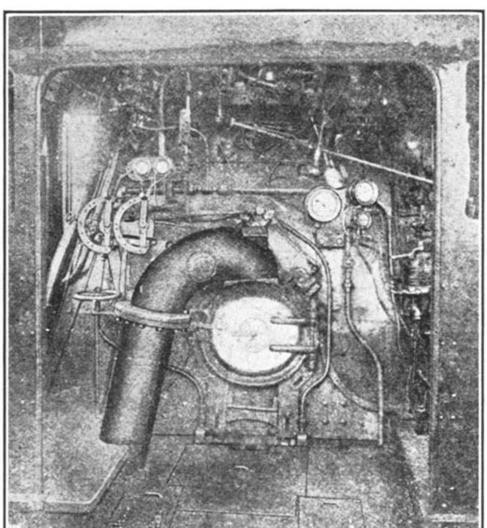
This delivery of the coal to one side of the firebox for a short time and the similar delivery in turn to the other side would make it proper to classify this stoker with those of the intermittent firing type, as a charge or " fire " is, in a partial sense at least, delivered to the different sides of the firebox and allowed to burn until the cycle of mechanical movement brings another delivery of fuel. The jets are constantly in action, the mechanical direct-



Photograph showing the adjustment levers for control of distributing wings of Hanna stoker ing means are also continually in motion, but the delivery of the fuel is intermittent—an arrangement just opposite from that of most stokers of the overfeed type.

The fan-shaped arrangement of main jets serves also as a fork, or set of fingers, to partially separate the coarser lumps of coal from the fine slack, which latter drops to the firing plate and is forced to the grate area by the low-pressure steam emitted from the long slot just mentioned; the larger particles are more violently forced by the steam jets to other parts of the grate area.

This is a photograph of one of the earlier forms of the Hanna stoker, but will serve in this connection to show the arrangement of control levers which operate the movable mechanical means which assist the steam jets in distributing the coal as just described, this lever arrangement being the same in the present installations of this stoker as shown in this view. The hopper shown was the receptacle into which the coal was shovelled manually. The moving of the small levers on the quadrants here shown has the effect of changing the range of movement of the directing wings so that the coal may be kept directed toward a limited part of the grate area, or by moving these levers on the

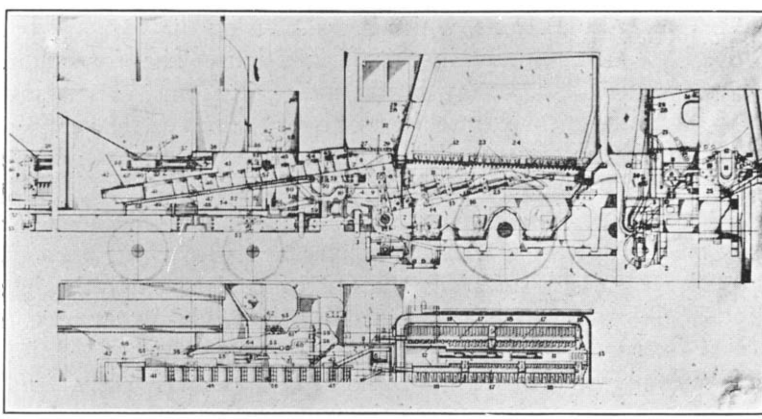


Photograph of backhead of locomotive showing Hanna stoker device lowered for hand firing.

quadrants the range may be changed so that the movement is over the entire grate area.

It will readily be appreciated that as this stoker is applied to the ordinary fire door of a locomotive it is essential that some means should be furnished for getting the stoking mechanism out of the way in the event of failure, or for the purpose of building the fire at the round-house by hand, and this view shows the upper part of the elevating means and the goose-neck, but the main stoking mechanism has been lowered below the deck of the locomotive cab. At the left of the goose-neck will also be seen the quadrants and operating levers shown in the other view.

Approximately forty of these stokers have been applied to locomotives to date, about twenty of which of the latest design are in daily service and firing locomotives successfully. About twenty of the earlier forms of this stoker, with which the fireman was required to shovel the coal into the hopper below the elevating means of the stoker proper, were applied to locomotives, but found to be either not practical or of sufficient advantage to warrant their continued use. Those at present in service, however, are giving good satisfaction.



Drawing showing general arrangement of Crawford underfeed stoker.

This is a drawing showing the general arrangement of the Crawford mechanical underfeed stoker as in use on a large number of Consolidation and Pacific type locomotives on the Pennsylvania Lines West.

This stoker was designed and developed by Mr. D. F. Crawford, General Superintendent Motive Power, Pennsylvania Lines West, and, as it was one of the first stokers to be applied to locomotives other than in an experimental way, it is of special interest in connection with the subject of the evening.

As explained earlier in this paper, the different stokers which have been developed have each individual characteristics as to mechanical design and method of handling the fire. This stoker is the foremost representative of the underfeed principle of firing; it has been in continual operation for the past four or five years, and well illustrates what can be done in the matter of successfully firing locomotives in that way.

The Crawford stoker is designed on the theory that the use, more or less completely, of the coking or gas producer process, during the progress of combustion, contributes toward economy and reduces the amount of black smoke usually made by a locomotive when working at or near its maximum output, and to secure this coking of the coal the fuel must be supplied to the fire from the bottom upwardly, hence the term underfeed stoker.

The mechanical arrangements of this stoker include preparatory means, or crusher, at or near the back part of the reciprocating forwarding means, which are shown on the forward part of the locomotive tender in this illustration. The forwarding means are placed generally horizontal, being only raised sufficiently at the front to elevate the coal over the top of the receiving hopper, in the bottom of which the main feed plungers operate. The crushing mechanism also serves the purpose of a measuring and feeding device to prevent the overloading of the conveyor. It is timed in operation with the reciprocating forwarding means, and only permits a sufficient amount of coal to enter the back part of the conveyor as can be readily and without congestion carried forward in the normal operation thereof.

The conveyor is made up of sets of fingers carried on a frame and hung from above the top of the trough; this frame is reciprocated forward and backward with considerable travel, so that the vanes or fingers, the bottom ends of which just clear the bottom of trough, serve to carry the coal forward and in the return stroke are lifted over the top of the coal which has just been moved toward the front end of the conveyor trough, and some of them in each set drop behind the coal below them, and in turn carry some more coal forward.

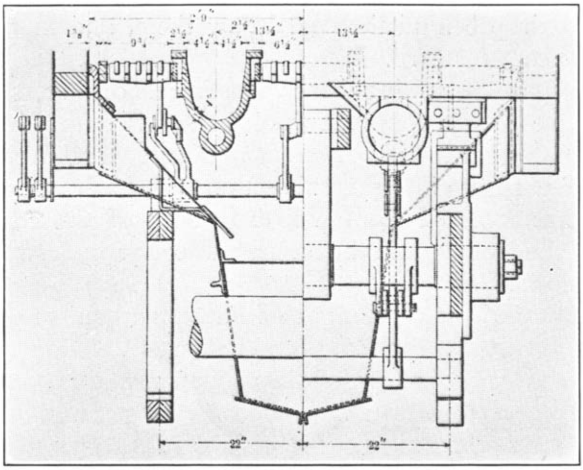
The purpose of making these vanes in sets of fingers is to prevent a lump of coal keeping the whole vane raised up, which would then move forward without carrying the coal with it, but by cutting the vanes up into several sections, or fingers it is found in practice that some of them will drop back of the coal in that section of the trough, and thus a general carrying forward of the coal is secured.

The action of the crushing, or feeding mechanism placed just below the opening in the coal pit of tender is timed in relation to the reciprocating movement of the conveyor, and is connected by substantial mechanical means to the operating steam cylinder on the locomotive, so that its action is powerful enough to crush any large lumps of coal which may drop into the crushing area in front of the piston and be broken up in the operation of being pushed through the feed opening into the back part of the conveyor, the lumps then being small enough to be readily taken up by the vanes or sets of fingers in the conveyor, as shown in this drawing, and forwarded, as just described.

The coal, on reaching the forward end of the conveyor, drops into a hopper in the bottom of which are the main feed plungers, which operate in a substantial casting placed just under the backhead of locomotive boiler.

In the firebox are placed two heavy cast-steel fuel troughs, into the back part of which the feed plungers force the coal. At points spaced throughout the bottom of the fuel troughs are auxiliary plungers which serve to assist in forwarding the coal still farther forward. Small castings in the shape of fingers or teeth are placed adjacent to the outward end of the auxiliary pistons to assist in enlarging the end thereof, and serve as agitators to keep the coal moving forward in the feed troughs as the auxiliary plungers are operated.

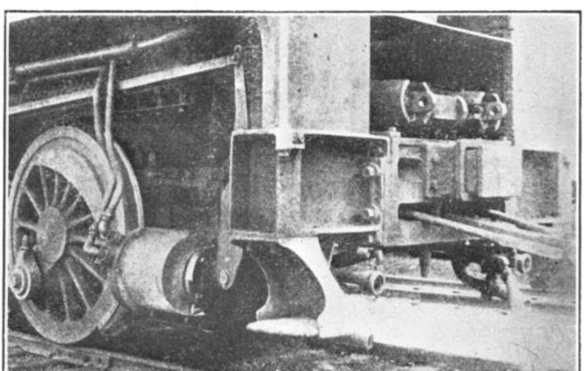
The grates of the firebox, of special form, are placed between the troughs and also between the extreme right and left troughs and the sides of firebox, and may be either level or at an angle of something like 42 degrees to represent the normal angle of the coal at rest as it is forced over the sides of the troughs by the feed and auxiliary plungers.



Section showing shape and size of main feed trough of the Crawford stoker.

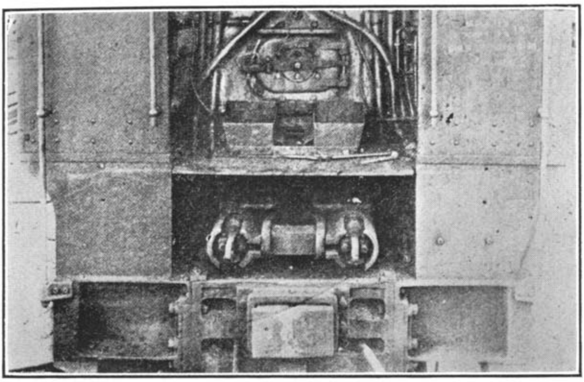
This view will show the troughs more in detail and the grates at each side. In this drawing the grates are of the level form.

The Crawford stoker is operated by means of a steam cylinder attached to back end of locomotive frame on left side of locomotive, and is connected to the stoker mechanism through means of cross shaft with arms thereon to attach to the steam cylinder, the conveyor, the crushing mechanism, and the main and auxiliary feed plungers.



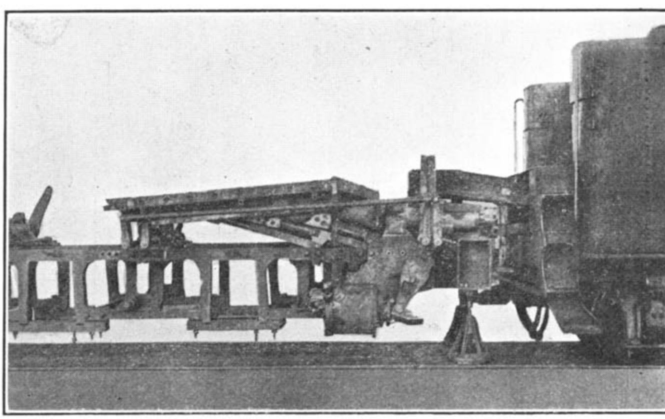
Photograph showing operating cylinder of Crawford stoker attached to locomotive frame.

This photograph shows the main operating cylinder of the Crawford stoker and the back part of main feed plungers.



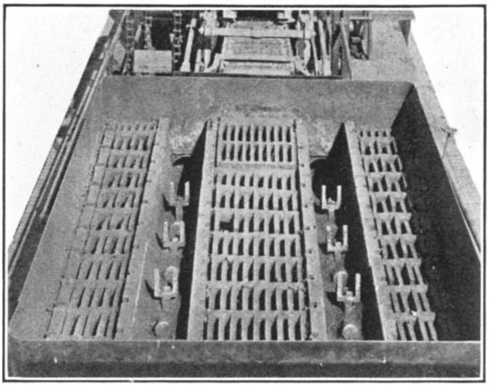
Photograph showing main feed plungers, Crawford stoker.

This photograph shows the back part of main feed plungers of the Crawford stoker and, rather indistinctly, the upper part of coal hopper in which the plungers operate.



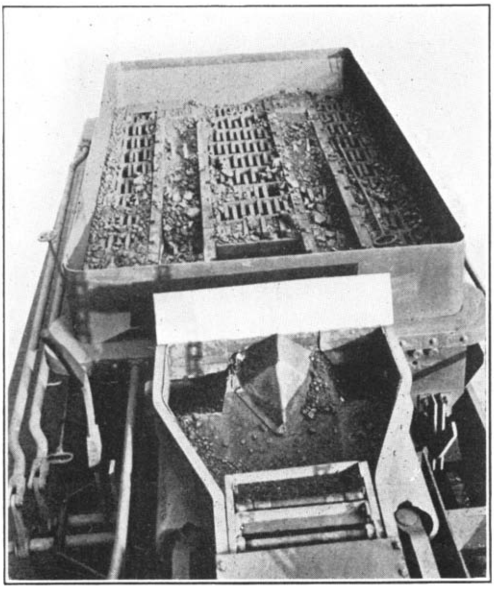
Photograph of general arrangement of Crawford stoking mechanism.

This photograph, while not very clear in its details, will serve to show the general arrangement of the stoking mechanism of the Crawford stoker and the forward end of the conveyor just above the feed hopper. The operating cylinder and lever attachment to cross shaft can also readily be observed.



Photograph of general plan of Crawford stoker, showing trough and grate arrangement.

These photographs will perhaps serve to give a better idea of the general arrangement, grates and stoking troughs of the Crawford stoker.



Photograph of general plan view of Crawford stoker, showing troughs, agitators, and main feed hopper.

The agitators on auxiliary plungers can be seen in this view and also the main feed hopper and feed piston positions.

The method of firing is about as follows:

The reciprocating action of the crushing and conveying means brings the coal to the main feed hopper, and it is directed toward each feed piston by a ridge plate therein. Each main feed piston forces its portion of these charges into the back part of the main feed troughs in the firebox through openings in the casting underneath the mud ring.

In this operation any lumps of coal which are larger than these openings will, of course, be additionally broken up by a similar action to that of the main crushing and measuring piston. These charges of fuel, forced into the trough in this way, serve as forcing means to push the coal, already in the troughs, still farther along, where it is taken up by the auxiliary feed pistons, and at the same time some of it is forced over the sides of the troughs as it travels toward the forward part of the firebox. The troughs are usually made with slight offsets in their widths which serve as abutments or partitions, similar to those described in the Barnum stoker, and these partially assist in lifting the coal up out of the troughs to the grate area. The forward end bottoms of the troughs are inclined upward, so that the small amount of coal which reaches the vicinity of the throat sheet is in turn lifted out of the trough on to the grate area in the front part of the firebox.

In firing a locomotive with this stoker, the fire is initially made in the round-house by hand firing in the ordinary manner. The stoker is usually not put into operation at all until the locomotive begins to do actual work in hauling the train.

The coking process is secured in the operation of this stoker by the filling of the feed troughs and supplying of sufficient coal to the grate area at each side thereof to make it possible for the fire to be maintained at a proper point without the stoker being operated continually.

The stoker is operated possibly ten strokes or so at a time; that is to say, a " fire " is put in and allowed to be undisturbed for a suitable period to permit the coking to occur.

During the time the fire is undisturbed by the operation of the main and auxiliary feed pistons of the stoker the green coal on the top of the feed troughs becomes ignited from the heat of the fire on the grates, and the fire is then well ignited over the entire firebox area. A casual observation of the fire at this time would not disclose the feed troughs at all. As no air is admitted up to the fire through these feed troughs, the ignited coal, on top of the troughs, together with the general heat of the firebox, serves to distil and break up the volatile matter, the hydrocarbons, from the next lower stratum of coal in the troughs. If the operation of the stoker is timed properly this stratum of coal becomes coke, and the next operation of the main feed and auxiliary plungers serves to force more green coal along the troughs, which in turn lifts the coked coal and turns it over on to the grate area.

Without going into the theory of combustion, it might be well to state that this gas-producing effect of the coking process undoubtedly contributes toward economy by breaking up these hydrocarbon contents very early in their travel as they pass through the ignited stratum as explained; the hydrogen combining with oxygen earlier than it might otherwise have done, and the carbon, requiring more time or raising to proper temperature, also starts to combine with oxygen nearer the fire-bed than with hand firing.

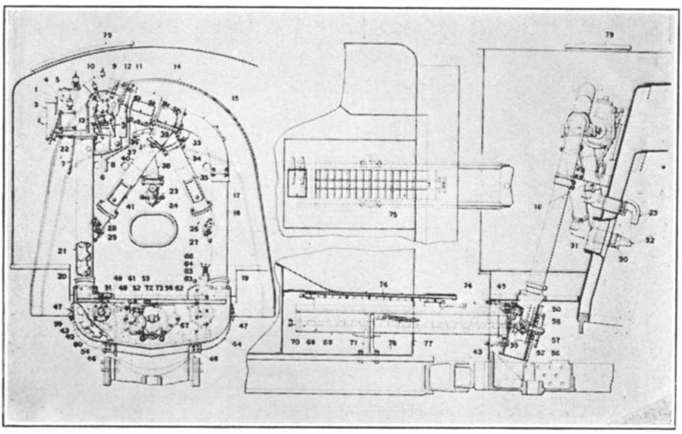
It will readily be observed that in order to secure this coking process there must be a proper time element introduced at intervals in the operation of the stoking mechanism, and the regularity of these intervals and the length of time the fire is at rest has much to do with the perfection of operation when firing a locomotive, or stationary boiler, for that matter, in this manner. If the demand upon the locomotive is such that the stoker pistons must be kept moving rapidly to supply a sufficient amount of coal to keep the engine hot, then, of course, the coking process is disturbed, more smoke is made, and probably less economy secured.

Any one who has observed the operation of firing a locomotive with this stoker in actual service will admit at once that this is a very excellent way of accomplishing the desired result, and it is no wonder, therefore, that this method has its earnest adherents.

There are nearly four hundred of these stokers in actual service, certain divisions of Pennsylvania Lines West being completely equipped, and they have been in service for the past three or four years with such success that this stoker may be considered very properly as one of the possibilities for general application.

Having thus described the underfeed stoker which has so successfully demonstrated the correctness of the theory of that method of firing a locomotive, you will no doubt be interested in the next description, which is that of the Street locomotive stoker, of which some six hundred are now in service on very large modern locomotives. It may very properly be considered as the principal representative of another method of firing; namely, that of supplying coal to the entire surface of the fire continuously at *the rate of combustion,* no coking periods being provided for as in the method just described.

The modern locomotive is called upon to operate at widely varying rates of horse-power output, often from maximum to zero within very short spaces of time, and this method of firing is based on the theory that there should be a given rate of combustion per square foot of grate area at any given time just sufficient to supply the steam output required of the locomotive boiler at that time; that is to say, there should be the same flexible control of the fire that there is of the throttle and cut-off.



Drawing showing general plan of Street locomotive stoker.

This drawing will give you an idea of the general arrangement of the Street locomotive stoker, which consists of a conveying, elevating, and stoking mechanism.

This stoker is designed to handle only coal which will pass through a screen having openings not to exceed three inches square. A screen of this character is placed just below the bottom of coal pit of locomotive tender, and above this screen are placed movable slides, so that a portion only of the screen is exposed at one time. Below the screen is placed a conveyor trough in which is operated the forwarding screw of helicoid form, which serves to carry the coal forward to the receiving hopper which constitutes the bottom part of the elevating mechanism.

In the left-hand section of the drawing is shown the general elevating and driving mechanism of the stoker. The endless chain of elevator buckets is driven by a single-acting, high-speed engine built into the upper left-hand part of the elevator, as will be plainly noted on the drawing. This high-speed engine drives the endless conveyor through means of worm, worm wheel, and the usual arrangements of sprocket wheels placed at different points. No sprocket is placed at the upper right-hand section of the elevator casing, however, as it is necessary to drop this part of the casing to clear the locomotive throttle connections which are at this point on backhead of locomotive.

In the centre of upper section of elevator casing is placed the mechanism which apportions the coal to the different firing points by first screening out the smaller particles and directing them toward the middle firing means, as will be later described, and then equally, or unequally, as may be desired, dividing the coarser particles of coal and directing them toward the side distributers.

On the right-hand side of the drawing will be seen a cross-section of the backhead of locomotive giving a better view of the hopper at bottom of elevator and showing the downwardly directive feature of the centre distributer; the purpose of this being to assist in directing the finer particles of coal or dust to a zone in the back part of the firebox, where these small particles will be less apt to be taken up by the draft and carried away before they can be properly consumed.

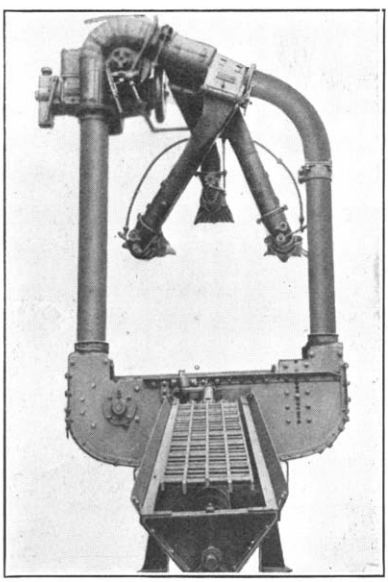
One of the side distributers will also be observed which serves to direct the coal generally forward, and on the bottom of which are placed directing ribs which assist in spreading the coal over a fan-shaped zone on each side of firebox. Each of the side distributers directing the coal over a fan-shaped zone in this way serves to cover the main part of the grate area, overlapping slightly in the centre of the firebox, leaving a small, triangular area at back of grate, which is covered by the finer coal directed there by the centre distributer as just mentioned.

The distributers at the side and centre are simply rough castings removable from the ends of the tubes which are placed in openings through backhead of locomotive boiler, and which permit their replacement when warped or destroyed by heat of firebox after their normal period of service.

At the point of connection between the delivery tubes and the distributers are placed elbows, and through the backhead are the removable tubes to which the distributers are attached on inside of firebox. In the elbows are placed firing nozzles, to which are made steam connections from the blast device, the latter operated by the stoker motor.

Photograph showing directive rib on stationary distributers—Street stoker.

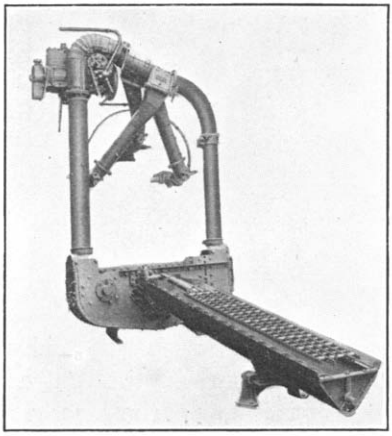
This photograph will give you a better idea of the directive ribs placed upon the lower part of the centre and side distributers for the purpose of assisting the blast device in distributing coal over the grate area to the different zones described.



Photograph of end view of assembled Street locomotive stoker.

This photograph of end view of Street stoker, assembled for exhibition purposes, will give you a better idea of the general arrangement, the view being directly toward the backhead of boiler.

This view will assist in showing the relation of the parts, especially the coal screen above the conveyor trough and the slid-

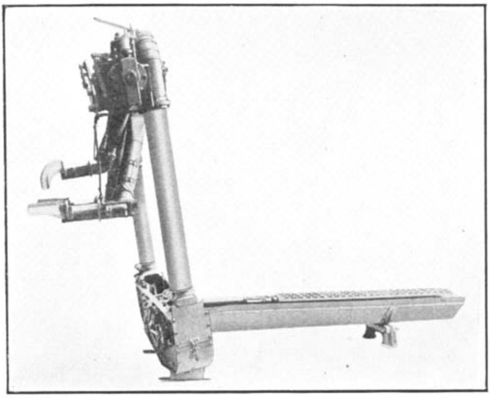


Photograph of quartering view of Street locomotive stoker.

able connection of the conveyor trough on the tender. The whole stoker being attached to the locomotive proper, the necessary flexibility between locomotive and tender is provided for by swivel connection at forward end of the conveyor trough at the point where it is attached to the elevator hopper, and the fore-and-aft movement incident to the usually loose coupling connection between locomotive and tender is provided for by simply having the conveyor trough slide upon the bracket placed below the trough, as can be readily observed in this photograph.

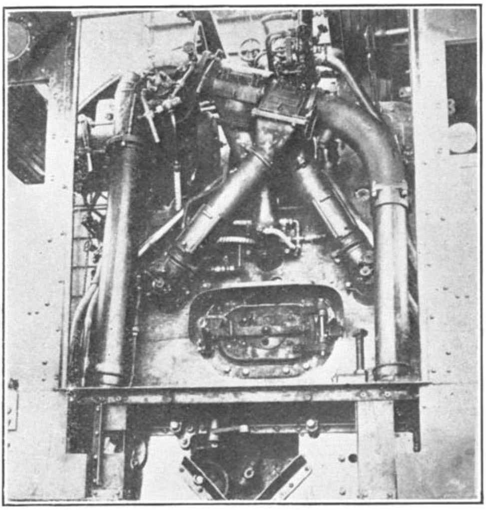
This photograph of the general side view of the stoker will give you a better idea of the driving means for operating the conveyor screw through sprocket connections on back of hopper, which are in turn operated by the endless elevator chain of buckets as they pass the main sprocket in lower left-hand part of elevator hopper, and also the elbows, tubes, and distributers which are placed on and through the backhead of the locomotive.

This view, showing the actual installation on a Mikado locomotive, will serve to show the general arrangements of an installation, and particularly the ordinary fire door, which is left available for such observation of the fire as is necessary, or hand firing to build the fire initially in the round-house and care for



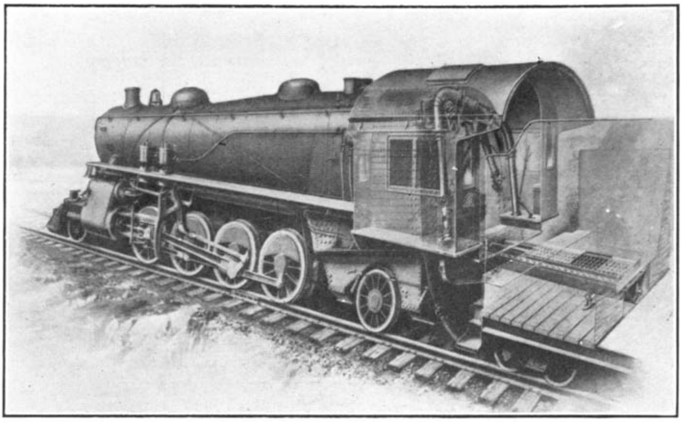
Photograph of general side view of Street locomotive stoker.

the fire when the locomotive is standing by at terminals or on sidings.



Photograph of view into locomotive cab of Mikado locomotive equipped with Street stoker.

This is a photograph of a pen-and-ink sketch of a large Mikado locomotive equipped with the Street stoker, and will serve to give a better conception of the general arrangement of the openings above coal screen and the availability of the ordinary fire door and the usual space in cab for locomotive engineer and fireman. This view also shows a sliding door provided in roof of cab for inspection of stoker motor.



Photograph of phantom view of Street locomotive stoker.

As I mentioned earlier in the paper, this stoker is particularly representative of that method of firing by which the coal is put into the firebox above the level of the fuel bed and dropped upon the surface of the fire continually, while the locomotive is being operated, and distributed over the entire grate area at the rate of combustion. Other stokers have been designed to partially carry out this method—the Hanna stoker, for instance, while putting coal into the firebox continually, does not spread it over the entire grate area at the rate of combustion, as it will have been observed that the movable mechanical directive means which assist the jets in the Hanna stoker in distributing the coal have the effect of putting coal to the different parts of the firebox in excess of the rate of combustion and then moving the directed stream of coal toward other parts of the firebox to permit the coal, just delivered, to be consumed in the meantime.

The routine of the process of firing a locomotive with the Street stoker is about as follows: The coal is assisted in passing down through the slide opening just in front of the main body of coal in the locomotive tender by the movement of the tender screen, this screen, by the way, being operated through a travel of three or four inches fore and aft by mechanical means and connections in the main elevator hopper. This movement of the screen materially assists a stream of coal being regularly delivered to the conveyor trough just below the opening, where it is carried forward and dropped into the main elevator hopper.

The endless chain of buckets, each bucket lifting about one pound of coal, then takes up the coal and carries it to the main discharge pipe in upper section of elevator casing, where it is again screened, divided, and directed toward the firing elbows. The coal drops by gravity to these elbows and is forced into the firebox by steam jets which are controlled by the blast-controlling device operated by main driving shaft of the elevating mechanism. The cams on this blast device are within the control of the fireman, so that the interval and duration of the jets may be adjusted to meet the conditions of operation. The jets are intermittent in action, but the coal is admitted to the firebox continually and is, in effect, scattered over the entire grate area all of the time while the stoker is in operation.

During the slight interval between the operation of the jets the coal is carried into the firebox from the firing elbows by the draft of air which enters the firebox at the stoker openings and is carried partially over the grate area, and, as the jets start, the coal is still further driven forward and, as the pressure of the jet increases, the wave of coal is projected farther and farther toward the throat sheet. As the pressure begins to die down the main wave of coal is then spread, with less force, toward the back part of the grate area.

The distributers, or stationary mechanical directing means, are placed above, rather than below, the tube openings just inside of the firebox, and on the bottom part of these distributers are the directing ribs which you have seen. The main purpose in placing these distributers above the openings is to direct the coal downwardly rather than forward. The steam jets, acting as plungers, force the coal forward, but at the same time the expansion of the steam as it leaves the nozzles would lift the smaller particles of coal to the upper part of the firebox and some of it might be carried on over the arch and through the tubes without being consumed. The distributers serve the double purpose, therefore, of keeping the coal downwardly directed toward the grate area and at the same time materially assist in spreading it.

The motor which operates the stoker has a variable speed governor—variable speed in the sense that it can be set to run at different rates of speed as may be required to drive the conveying, elevating, and stoking mechanisms at speeds suitable for supplying coal in proportion to the amount required for any given output of the locomotive.

The several constant speeds of the stoker motor make it possible for the fireman to set the stoker to run at the different rates for any interval of time that the locomotive may be operated with any particular setting of the reverse lever and throttle. The highest speed of the stoker motor represents the delivery of the proper amount of coal to fire the locomotive to its maximum capacity, and at the lower speeds at which the motor can be set the delivery of the coal will be in amounts proportioned properly to operate the locomotive at several different rates of output. The relation between the delivery of the coal by the conveyor and its elevation by the buckets of the elevator is arranged for in the initial application of the stoker to any particular locomotive.

If a delivery of coal is required of less quantity than the delivery at the slowest speed of the motor, the amount can be further reduced by partly closing, with the sliding plate, the opening over the tender screen or by disconnecting the stoker motor from the stoking mechanism through means of the friction clutch which is introduced between the motor and the stoker for the purpose of readily stopping and starting the stoker when desired.

Means are also provided to permit the fireman to control the supply of coal delivered to each of the three elbows. The increase and decrease of the supply to the centre elbow are adjusted by turning larger or smaller screen openings to register with the discharge opening for the middle distributer, so that in this way more or less of the fine coal is taken out of the main stream of coal as it passes over the upper screen.

The supply to each of the side elbows is regulated by a dividing rib which can be placed at different points in the opening so that the flowing stream of coal will be divided up in different proportions between the tubes going to the side elbows.

While there are means supplied, as described, for making different adjustments of regulation of the speed, as well as the dividing means for supplying the coal to the different zones in the firebox, the adjustable features generally of this stoker are designed with the idea of permitting a definite setting to be determined, and then permitting the stoker to operate at that setting of speed or coal delivery, so that, so long as the locomotive is worked at the point requiring that particular amount or distribution of the coal, the stoker will need no additional attention on the part of the fireman other than to see that the coal is being fed properly to the opening above the screen in the tender.

In designing the Street stoker the firing problem of itself was considered as of first importance; that is to say, the keeping of the fire in direct relation to all of the conditions of operation of a modern locomotive, especially that of securing the absolute maximum output and satisfactorily caring for the abrupt changes required of the power plant, yet it can be said that the general scheme of firing is in line with the best recommended practice and must contribute toward economy, although in a different manner from that of the underfeed method, and at the same time make it possible to burn fuel that could not be used for hand firing.

I beg leave to quote in this connection a few paragraphs from Technical Paper No. 80, issued by the Department of the Interior, Bureau of Mines, which particularly commends this method of firing, especially as to its possibilities for successfully burning slack coal:

"Soft or bituminous coal should be fired in small quantities at short intervals, the quantity that should be fired varying with the size of the grate and the intensity of the draft.

"Small and frequent firing makes the coal supply more nearly proportional to the air supply, which in most hand-fired furnaces is nearly constant. They also reduce the formation of crust on the fires and the chance of holes in the fuel bed. With small and frequent firings better combustion is obtained.

"When a fresh charge of bituminous coal is spread over an incandescent fuel bed, the coal is heated rapidly and twenty to forty per cent. of the combustible matter is distilled off in the form of gases and tar vapors. This distilled combustible matter requires for its combustion additional air. It can be readily understood that the heavier the charges, the larger amount of volatile combustible driven off two to five minutes after firing.

"To burn the volatile combustible, about fifteen times its weight of air needs to be supplied. Therefore, immediately after firing, a large quantity of air should be admitted over the fire, and this quantity should be gradually reduced as the distillation of the volatile combustible nears completion. The larger the quantity of fresh coal fired at a time, the larger the volume of air needed for the complete combustion of the volatile matter.

"*An ideal case is the one in which the coal is fed into the furnace constantly and at a uniform rate, as is done with some mechanical stokers.* The coal supply is then as uniform as the air supply.

"Small and frequent firings reduce the tendency of many coals to fuse and form a hard crust at the surface of the fuel bed. Most of the soft coals used for steaming purposes fuse in this way, and the crust in places prevents the free passage of air through the fuel bed. In these places the fuel burns slowly. At other places in the fuel bed where the crust has not formed or where it is cracked, a large quantity of air flows through and the coal burns quickly. On account of this uneven flow of air through the fuel bed the coal burns unevenly, and as a result the rate of combustion and the capacity of the boiler may be decidedly reduced. Such fusion of coal is particularly troublesome in case the coal contains a large percentage of slack and where large quantities of it are fired at a time, for then the crust must be broken and the fuel bed levelled frequently. In an extreme case this crust must be broken and levelling done after each firing. If, however, a little coal is thrown each time on the hot fuel bed, the thin layer of fresh coal burns through before a hard, tight crust can form. Often a coal gives trouble from the formation of crust when fired in large quantities and yet burns comparatively freely (without fusing into crust) when fired in small quantities, so that a good fire can be run two or three hours without the use of a rake. Therefore, to avoid or to reduce the formation of hard crust at the top of the fuel bed, the fresh coal should be fired in small quantities so that it will make a thin layer that will not fuse and interfere with the flow of air. If the flow of air is not hindered, the layer of fresh coal will burn through without fusing into crust. As this thin layer of fresh coal burns through in a short time, the small firings must be made at short intervals.

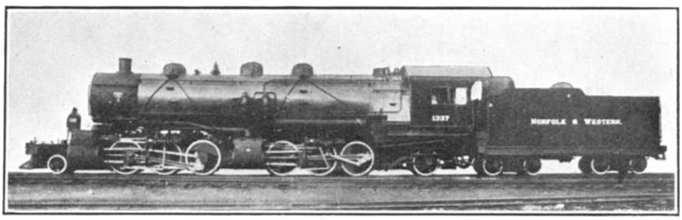
"With frequent firings there is much less danger of holes forming in the fuel bed. The thin spots are seen and covered with fresh coal before the holes actually form. In this way frequent firing reduces the losses from excess of air."

Slack was never used extensively for locomotive fuel until the advent of the Street stoker, and now something over 600 locomotives are being fired with coal that will pass through a screen having two-and-a-half or three-inch round holes.

If, by chance, a hand-fired locomotive should get a tank of this kind of fuel, the fireman would usually complain of "bad coal."

With the main points of the stoker story in our minds, as related thus far,—that is, the aims of the different inventors in the early state of the art, the findings of the stoker committees to the effect that not much of real value had been accomplished up to the end of the year 1911, and the descriptions given of the machines sold commercially since that time and now in service,—some information about the principal stoker-fired locomotives will be the best way of illustrating the progress made in the last three years.

In connection with the description of the locomotives, I shall also try to give information about the work the stokers are doing which will enable you to judge of their present economic value and draw conclusions as to the possibilities for the future.



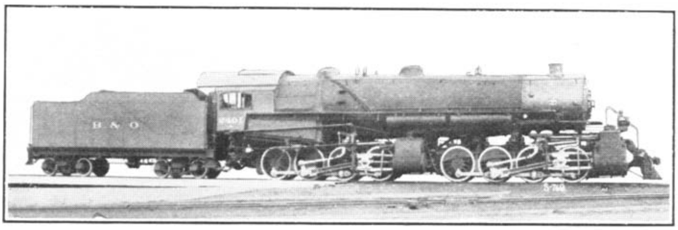
Photograph of Norfolk and Western Z-1 Mallet road locomotive.

This is a photograph of a Norfolk and Western Z-1 and Z-1-A road Mallet locomotive having 72,800 pounds tractive effort and 62.2 square feet grate area. Not a remarkably large locomotive, but well within what we have come to term the stoker class. There are 120 of them in service, all stoker-fired, and, from the stoker point of view, these locomotives are of somewhat unusual interest. They were practically the first locomotives to be bought new with mechanical stokers in the original specifications and the first ones to be commercially equipped. Forty of them were ordered to be furnished by the builders, complete with stokers, during the summer of 1912; forty during the summer of 1913, and forty during 1914. Of the 120, 105 have the Street stoker and 15 the Hanna.

Each of these locomotives hauls from one and one-half times to twice the tonnage of the consolidation locomotives displaced by them.

The fuel used is mine screenings or slack secured from the mines direct or screened by the railroad company from the coal used for hand-firing. Practically none of it could be used for hand-firing.

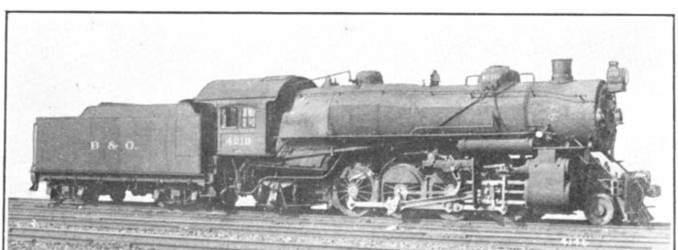
This locomotive was also built to be stoker-fired, is much larger than the one just shown, and, if size alone has anything to do with the need for mechanical stokers, this would be a shining example. The tractive power is 105,000 pounds and grate area 99.9 square feet. Thirty of this class are in pusher service on the Baltimore and Ohio, all having Street stokers.



Photograph of Baltimore and Ohio Mallet pusher.

The fuel used is mine screenings secured by passing run-of-mine coal over bar screens with bars placed one and five-eighths inches apart. Some of the thirty have been in service three years and all of them over eighteen months.

Using 100 pounds of coal per square foot of grate area per hour as a conservative figure for the amount of good quality coal required to fire these locomotives to their rated capacity, it will be admitted at once that this, then, would be a place for stokers, even if there were no other considerations.



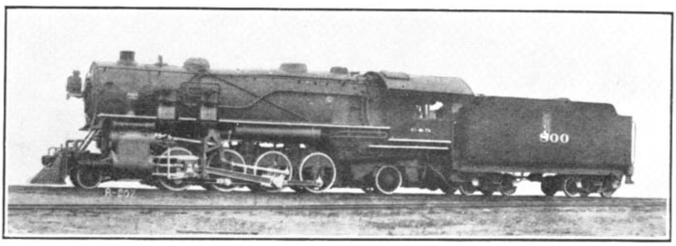
Photograph of Baltimore and Ohio Mikado.

This locomotive represents another phase of the stoker proposition. The locomotives just shown are unquestionably of the stoker class from their size alone, requiring more coal to fire them to their maximum capacity than could be put in manually, especially for any extended period. This locomotive has but 54,000 pounds tractive effort and 70 square feet of grate area, and can be fired by hand very satisfactorily in regular service. There are 320 of these locomotives on the Baltimore and Ohio, 160 of them stoker-fired with the Street stoker, 160 hand-fired. There are both saturated and superheated engines stoker- and hand-fired, so that ready comparisons can be made of the advantages, if any, of the use of the stoker on an engine of this size under various conditions of operation. Fifty of the stokers were applied during the summer of 1912, and the other 110 during the year 1913, so that all of the stokers have been in service long enough to permit these comparisons. There are two things which have been accomplished on the 160 stoker-fired engines which are of interest.

First, each locomotive stoker-fired is given more tonnage per train as its rating than the same engine hand-fired, and this increase in tonnage can be safely stated to be 500 tons for a superheated stoker-fired engine over a superheated hand-fired, and at least the same amount for a saturated stoker-fired over a saturated hand-fired, and this work is done on a stoker-fired locomotive with fuel that could not successfully be used for hand-firing in regular service. This fuel is secured by screening run-of-mine coal over bar screens with the bars one and five-eighths inches apart, or is purchased direct from the mines, this latter being the case when gas coal mine screenings are used.

A careful record kept for a considerable period of the hand-firing done on stoker-fired engines showed that at least 90 per cent. of the total fuel was fired with the stoker, counting everything, and in many cases no hand firing whatever was needed. This would illustrate the reduction in physical labor of the firemen, and, as the fire door is open very little, the heat in the cab is so reduced that the fireman can follow the locomotive trip after trip, almost, if not quite, as regularly as the engineer. Another rather interesting advantage came with the use of the stokers on these engines, in that since the tonnage rating has been raised for those that are stoker-fired there is great rivalry as between hand-fired and stoker-fired engines of the same class, and within the past year or eighteen months the rating of the hand-fired engines has been materially increased, but, as this has been raised, the tonnage rating on the stoker-fired has also been still further increased until on some divisions it is now one thousand tons per train more than was given the hand-fired engines before any stoker engines were received, and is still at least 500 tons higher than any hand-fired engine.

It was also found not practicable to run shovel-fired and stoker-fired locomotives on the same division, even with the less tonnage, as the speed of the hand-fired was so much less that they could not keep out of the way, and now all trains on the different divisions are generally either stoker-fired or hand-fired. In one case, on three divisions adjoining making a total distance of something like 450 miles, all of the freight power is stoker-fired.

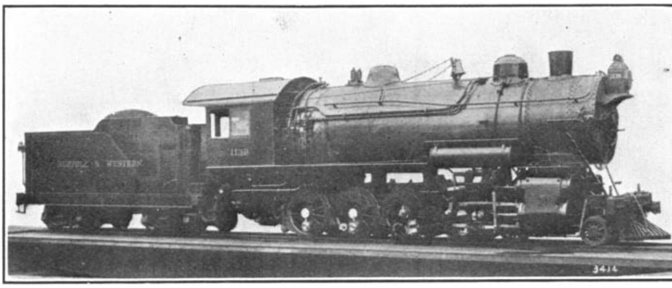


Chesapeake and Ohio Mikado.

This is one of the largest Mikado locomotives in service to-day, having a tractive effort of 60,000 pounds and a grate area of 66.7 square feet.

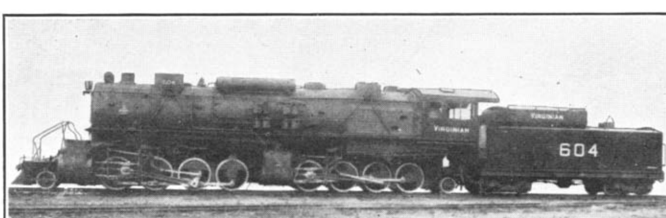
In answer to the question, "What size or class of locomotives should have stokers?" it can be said, first, that under average conditions any locomotive, freight or passenger, which has a maximum tractive effort of 50,000 pounds or burns 4000 pounds or over of coal per hour for an extended period, one hour or over, should be fired with the stoker.

This locomotive was designed on the basis of requiring approximately 120 pounds of coal per square foot per hour for its maximum capacity, or about 8000 pounds per hour. This, with a tractive effort of 60,000 pounds, would then theoretically bring this locomotive well within the stoker class. In practice this also proves correct, as on a certain division equipped with these locomotives the stoker-fired rating is 6000 tons, and if, for any reason, the stoker should be inoperative, the official rating is 4800 tons. Fifty of these locomotives were equipped with Street stokers during the summer of 1912, and they therefore have been in service long enough to secure records of mileage per mechanical failure, cost of maintenance, kind of coal suitable or available for stoker firing, and dynamometer car tests have been made which confirm the above statements as to comparative rating possible between stoker- and hand-firing.



Norfolk and Western Class M-2 locomotive.

This photograph is of interest as showing one of the smallest locomotives to which stokers have been applied. The tractive effort is 52,400 pounds and there are but 44.7 square feet of grate area. This is one of the locomotives on the Norfolk and Western that was used before the arrival of the Z-1 and Z-1-A Mallets, which are now hauling nearly twice the tonnage this locomotive was able to handle. The grate area of this locomotive is rather small for the boiler plant, and therefore it is a hard locomotive to fire as compared with others of similar size, and stokers have been applied to some fifteen or twenty of them—four or five Street stokers and twelve or thirteen Standard stokers. In this particular case the necessity for the application of the stokers might be questioned, although the engines can undoubtedly be worked harder and much relief is afforded the fireman from labor and heat.

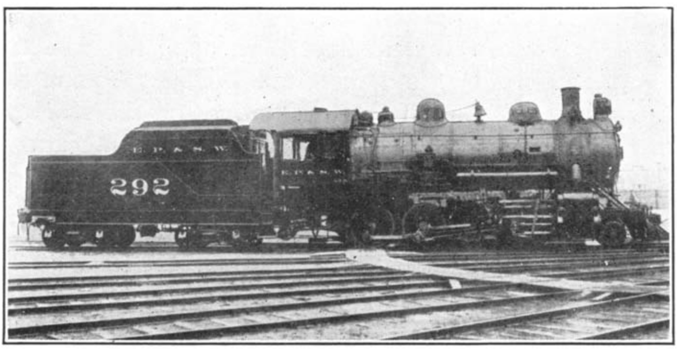


Photograph of Virginian Mallet.

This is the largest road Mallet engine ever built, having a tractive effort of 115,000 pounds and a grate area of 99.2 square feet—the latter about the same as the Baltimore and Ohio Mallets. Six of these locomotives are in service, all being fired with the Street stoker.

When these locomotives were built, some three years ago, the mechanical stoker was not enough of a certainty to warrant the use of a firebox longer than eleven feet, whereas it is, I think, a safe prediction that eventually locomotives of this size and larger will be designed to be stoker-fired and have fireboxes with grate area nine feet wide and fourteen or fifteen feet long, eleven feet being the admitted limit for hand-firing.

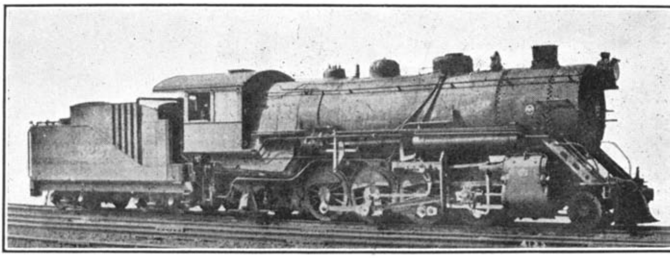
I am showing you practically all of the stoker-fired locomotives that there are, and all of them were designed to be both stoker- and hand-fired, which set limitations that will disappear later on.



Photograph of El Paso and Southwestern Consolidation.

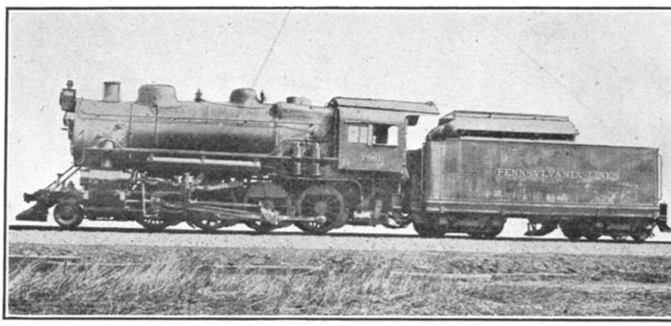
This locomotive is shown in this series particularly on account of size. It is just the opposite of the one last shown, and is about the smallest to which any number of stokers have been applied to date. The tractive power is 49,988 pounds and the grate area 49.5 square feet. Twenty-one of the locomotives are being fired with the Street stoker, mainly on account of the climatic conditions in the desert country of Southern Arizona, which makes it impossible for the firemen to, at all times, fire even this rather small locomotive to its maximum rating.

This is another very large Mikado locomotive. The first installation in the Western territory of mechanical stokers to handle the mine screenings from Illinois coal fields was made on thirty-five of them by the Chicago, Burlington and Quincy Railroad early last year.



Photograph of Chicago, Burlington and Quincy Mikado.

It was found possible to use screenings from nearly all of the mines, and at the same time secure the very satisfactory tonnage increase of from 500 to 700 tons per train over the same locomotive hand-fired.



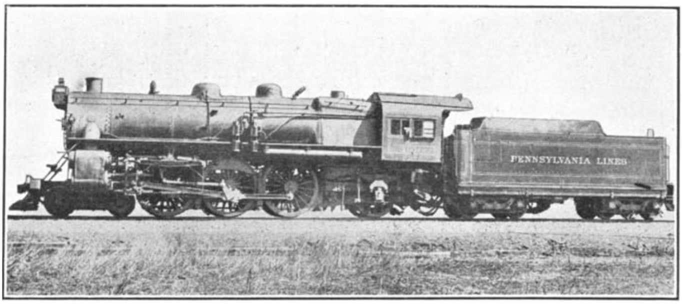
Photograph of Pennsylvania Lines H-10-S Consolidation.

This locomotive is of particular interest as having the Crawford underfeed stoker on over three hundred of them.

It is what might be called a medium-sized locomotive, having 55.12 square feet of grate area, 26 x 28 cylinders, 229,900 weight on drivers, and a rated tractive effort of 50,069 pounds. This latter is a low figure on account of the factor of adhesion used in determining it, being something like 4.95 or 5 as compared with 3.9 to 4.2 usually taken. As a matter of fact, this was taken advantage of by increasing the cylinders from 24 x 28 to 26 x 28 when it was found that the boiler plant could be forced enough harder with the stoker to supply steam for the increased cylinder volume.

The coal supplied for stoker-firing is the same as used on the hand-firing power, the stoker handling the large lumps by crushing as explained.

Three great advantages have accrued to the Pennsylvania Lines West from the application of this large number of stokers to this class of power. The locomotives have an increased tonnage rating, the firemen are relieved from a large part of their labor and suffering from the heat, and a considerable reduction is made in the amount of smoke.



Photograph of Pennsylvania Lines Pacific K-3-S.

This locomotive represents the largest installation of mechanical stokers on passenger power, nearly one hundred of them being equipped with the Crawford underfeed stoker.

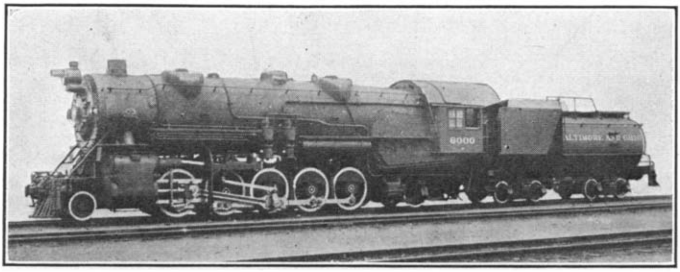
Only eight other passenger locomotives in this country besides these have mechanical stokers.

This locomotive is not a large one for stokers, having cylinders 26 x 26, weight on drivers 190,000 pounds, and grate area of 55.4 square feet, about the size of the Consolidation just shown.

So far as my observation has gone, it would lead me to say that this locomotive and the service in which it is used together make nearly ideal conditions for use of the underfeed stoker.

When a heavy through train leaves Union Station, Pittsburgh, going west, pulled by one of these locomotives, stoker-fired, the work is at a very uniform rate for 188 miles. A very satisfactory balance can be struck between the intervals required for the coking process and the total quantity of fuel required to keep the steam at proper point so that all the benefits of the underfeed scheme of firing are secured, such as capacity, economy, smoke elimination, and the improvement in the fireman's job.

We now come to a type of locomotive that is receiving marked attention by railroad companies, especially since the mechanical stoker became a commercial possibility.

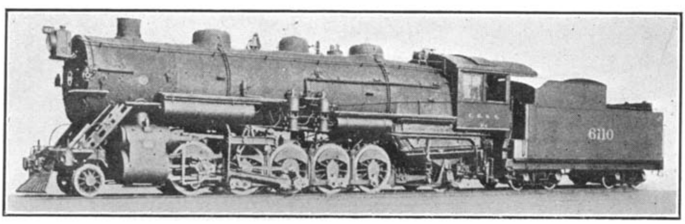


Photograph of Baltimore and Ohio Santa Fé type.

I do not believe it would be claiming too much for the mechanical stoker to say that thirty of these locomotives, on the Baltimore and Ohio, having a tractive power of about 80,000 pounds, cylinders 30 x 32, and grate area of 88 square feet, would not have been built to be hand-fired.

Street stokers were applied by the Baldwin Locomotive Works to the entire lot when built last year.

These are about the largest simple locomotives ever built.



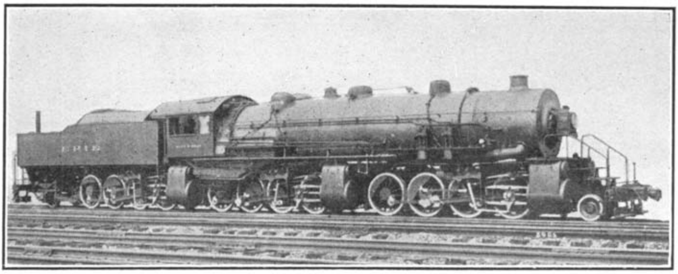
The Chicago, Burlington and Quincy M-2 Santa Fé type.

This locomotive is of special interest as being the very first designed, as to arrangement and dimensions, to be stoker-fired, and is of the same general dimensions as the one just shown, having cylinders 30 x 32, grate area 88 square feet, tractive power of 72,800, and weight on drivers of 301,800 pounds.

Designed in 1911, built in 1912, it was, even at that time, admittedly beyond the physical limits of hand-firing.

The first five of these locomotives were equipped with the Barnum stoker, the first stoker described in this paper. These were later removed, and the Street stokers are now on twenty-seven in service and being applied to fifteen more at the Baldwin Locomotive Works this month.

In daily service these locomotives burn an average of 5500 pounds of slack coal per hour, and for short periods each trip at the rate of 9000 to 11,000 pounds per hour, which well illustrates their being beyond the limits of hand-firing.



Erie Triplex locomotive.

This Erie locomotive, designed by Mr. G. R. Henderson, of the Baldwin Locomotive Works, has received a great deal of comment. It has such new and novel features that it is out of the ordinary.

It is commonly referred to as a Triplex locomotive on account of its having three sets of driving wheels—is three locomotives in one, in fact, and has a tractive power rating of about 160,000—the highest of any locomotive ever built.

The grate area is about the size of the Baltimore and Ohio and Virginian Mallets which we have seen.

Designed to take the place of at least two other locomotives in pusher service on the Susquehanna grade on the Erie Railroad, it requires about 10,000 pounds of mine screenings per hour to fire it to its maximum rating, possibly a little more under certain conditions. It is fired with a Street stoker and is in daily service, doing the work successfully.

In a published interview regarding this locomotive, Mr. S. M. Vauclain, vice-president of the Baldwin Locomotive Works, makes the following statement:

"This type of locomotive would never have been suggested, however, were it not for the fact that we are now able to feed a locomotive boiler any amount of coal up to its capacity to burn it. Thus the human equation heretofore preventing the use of large power units has been overcome, and it is my belief that we are just beginning to enter the field of large power units for freight service of the trunk lines of this country. If it can be proved that we can operate locomotives of 150,000 pounds tractive effort with the same engine crew as heretofore and with less physical exertion on the part of the fireman than with the locomotive of only 50,000 pounds tractive effort, it would appear reasonable that such units of power will be in demand, not only by the railroad companies but by the employees as well."

The fact that more than 1000 locomotives such as I have shown you are being fired with mechanical stokers ought to prove conclusively that the mechanical stoker is no longer an experiment and that it must have some economic value to warrant its application to so great a number of the largest modern locomotives.

What contributes to this economic value?

The use of slack coal or mine screenings for locomotive fuel, for one thing, has a share in it.

We now have enough information about the value of different kinds, grades, sizes, and physical characteristics of coal for locomotive fuel to state positively that the physical characteristics of coal are more important than the chemical analysis. Better results are often secured from coal of inferior quality, but of proper physical form than from that of a better grade in improper size; the variation of evaporation in pounds of water per pound of coal, due to such differences, being identical whether fired by hand or with a stoker.

If, therefore, by the use of a mechanical stoker, all kinds of coal that can be used for hand-firing can be used for stoker-firing with equal economy, and also other kinds and grades of coal become available for locomotive fuel that could not be used for that purpose, the stoker should be given credit for the economic value of a wider market being found for what is a by-product in many districts.

The stoker as a labor-saving device is also of great value not only in the reduction of physical labor and suffering of the firemen, but generally raising the grade of that class of employment, and, while this would not bring about, of itself, a general use of stokers on locomotives, it has its value in the general proposition.

The firemen themselves, as a rule, are favorable to the stoker.

The locomotive engineers, while ordinarily having no interest in the stoker, are just now very much in favor of it.

On one railroad employing nearly one thousand firemen the traffic conditions are such that it has been necessary to "set back" a large number of engineers; that is to say, they must temporarily take the fireman's side of the locomotive, the firemen either being laid off or put on the extra list. Engineers who have not fired a locomotive for several years have a hard time firing under such circumstances: first, because of their physical unfitness, and then, too, because when they served their time firing the locomotives were much smaller than at present. If there is a stoker-fired locomotive on their division and their "rights" entitle them to it, they surely see that arrangements are made for them to be called for the stoker.

The firemen can follow their runs with the same regularity as the engineers on stoker-fired locomotives, and this brings practically the only real criticism the men have against the stoker; that is, that less extra firemen are required in any given district than for hand-fired engines.

The firemen on stoker engines usually make more mileage per month than when hand-firing, with the consequent increase in size of pay check.

As for the need of a second fireman or helper on stoker-fired locomotives, it is now admitted by all, even the officers of the firemen's organization, that where stokers are in successful operation there is no need of—in fact, no demand will be made for—an additional man as asked for on large hand-fired power.

The stoker must eventually have the effect of inducing a better class of men to take up the locomotive firemen's trade. Certain railroad officials consider this tendency, already noted where large numbers of stokers are used, as of great importance.

In searching for all answers to the question, "What is to be gained by the use of mechanical stokers on locomotives?" the really important consideration is that a locomotive is the only thing on a railroad that earns money, and if the stoker can and does remove the limit which is set to the capacity of large locomotives by the inability of the fireman to fire them to their maximum capacity, especially for long periods, then something has been done of economic value not heretofore accomplished.

A brief explanation of why it is almost impossible to hand-fire a large locomotive to its absolute maximum capacity may be of interest here.

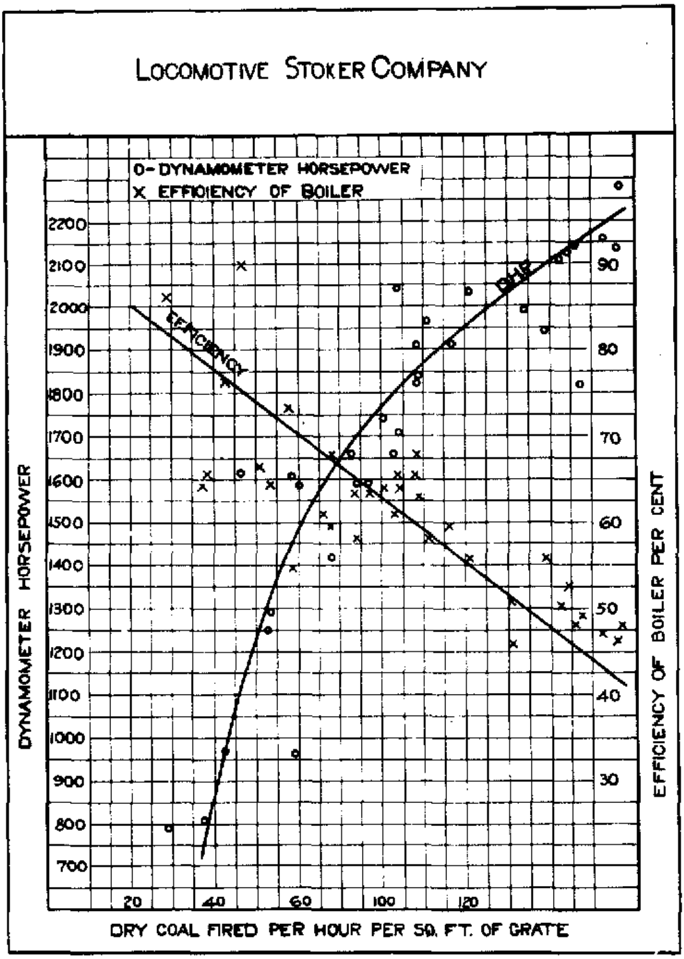


Diagram illustrating boiler efficiency and dynamometer horse-power at different rates of firing.

It is not generally appreciated that the boiler plant of a locomotive differs in many respects from that of a stationary power plant.

The over-all dimensions of a locomotive, which are largely governed by road clearances, centre of gravity, etc., make the firebox of such size, even the largest permissible, that the rate of combustion per square foot of grate area per hour is several times that of a stationary boiler.

This is a diagram illustrating the relation between the efficiency of a locomotive boiler and the dynamometer horse-power developed when burning coal at different rates per hour.

The drop in the efficiency curve is very marked as the horse-power increases. It will be noted at once that the per cent. of boiler efficiency drops off almost in a straight line as the locomotive is worked harder. This will illustrate why it is more difficult in proportion to fire a locomotive as the engineer opens the throttle and drops the reverse lever "over amongst the oil cans," as the enginemen term it.

The average fireman usually is at his limit when the firing rate reaches 75 pounds per square foot of grate area per hour.

The curvature of the dynamometer horse-power line is brought about by the decrease in the amount of water evaporated per pound of coal as the combustion rate increases.

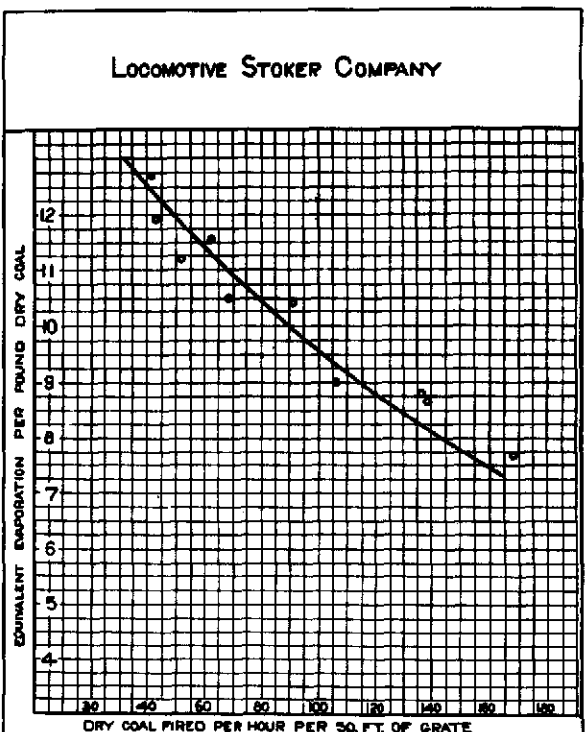


Diagram showing evaporation at different rates of combustion.

This diagram will illustrate the rates of evaporation as the coal fired per square foot per hour increases.

This will also explain why it is sometimes said that a stoker-fired locomotive burns more coal than hand-fired. It does, usually, because worked harder, and it takes more coal to evaporate a pound of water at the point where stoker-fired locomotives are worked.

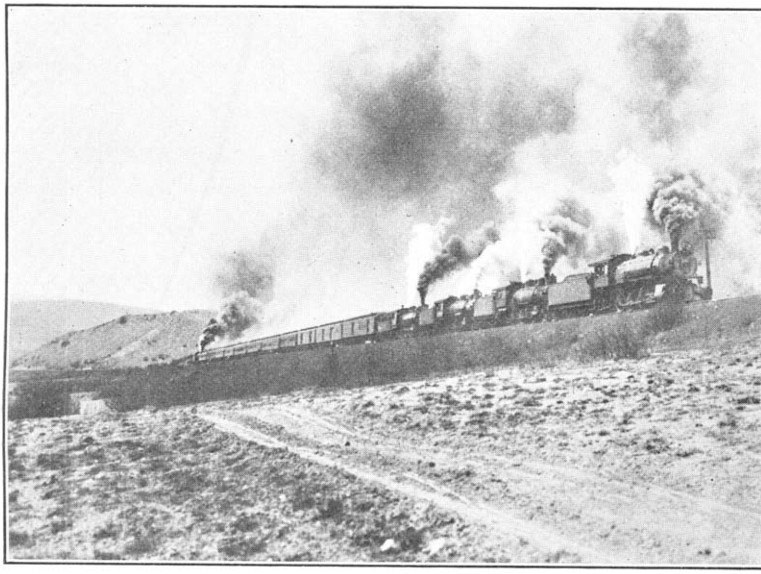


Illustration of stoker conditions in a mountain district.

All large locomotives are not now in a service requiring stokers. On the other hand, there are large numbers of rather small locomotives that are in use where larger locomotives, stoker-fired, could do the work more economically from every point of view. This is an illustration of such a condition: Five hand-fired locomotives on one train, worked hard and not well fired, either, if appearances count for anything.

Larger locomotives can and will be designed, two of which could handle this train.

Locomotive capacity then seems to be the real point in the stoker proposition, even at the expense of some economy in the amount of water evaporated per pound of coal, and what this means in increase of earning power of a locomotive as compared with any increase in cost of coal as the consumption increases per square foot of grate area per hour is illustrated on this diagram.

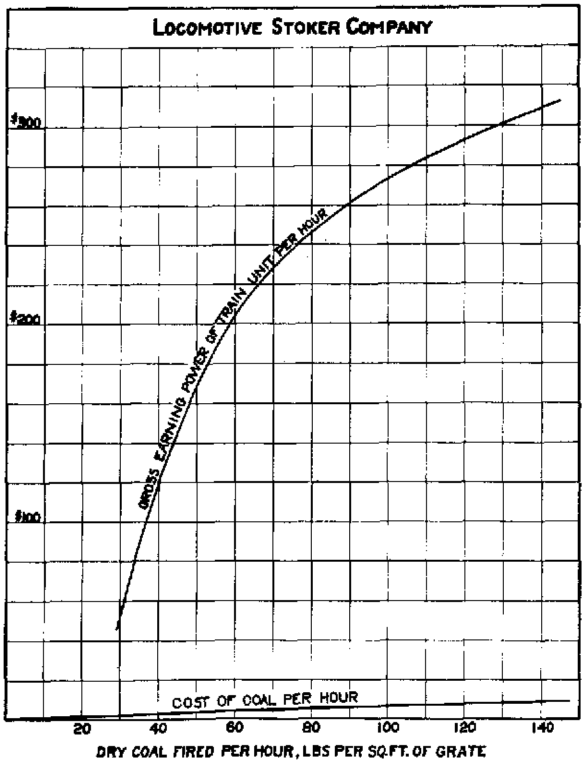


Diagram showing increase in earning power of locomotive as it is worked harder.

It will be seen at once that the increase in earning power is of vast importance as compared with the slight rise in the line showing the coal cost as the locomotive is worked harder.

These curves were plotted from statistics showing freight train earnings when handling such commodities as coal, ore, limestone, etc.—just such lading as is in heavy drag service where stoker-fired engines are used. The coal cost was figured at $1.50 per ton on locomotive tender.

So far as I know, there is not a single case where stokers have been applied by any railroad company that there has not been a material increase in tonnage rating, and in spite of the increase in tonnage there has usually been an improvement in the general smoothness with which the traffic has been moved on the stoker-fired divisions.

To sum up, therefore, mechanical stoking of locomotives raises the efficiency of the locomotive by increasing its earning power, raises the efficiency of labor by making it possible for one crew to handle more traffic per train unit or the same train unit with greater ease, lessens the arduous physical labor and suffering of the firemen, and lifts the grade of his employment; contributing in these and other ways such share of the improvement in the welfare of the individual and the community at large that any labor-saving device must do to be commercially successful.

DISCUSSION.

CHAIRMAN.—The mechanical stoker is the sort of device The Franklin Institute is always in sympathy with, a device that saves money and reduces human suffering to an extent that makes it possible for men to work with comfort to themselves and efficiency to their employers.

I will ask Mr. George R. Henderson to open the discussion.

MR. GEORGE R. HENDERSON (*The Baldwin Locomotive Works*).—Mr. President and Gentlemen of The Franklin Institute: I was very much interested in what Mr. Bartholomew has told us in regard to stokers, but when he says that stokers were not needed before 1912 I think he has gone a little bit too far. For several years before that there were a number of Mallet locomotives built and running in the northwestern part of this country, and when questions are raised as to the difficulty of firing, in keeping these engines hot, it was remarked that there was no trouble and the firemen took it very easy. When we examined these men at work we found it quite true that the firemen did take it easy, and that the engines took it easy. Instead of an engine of double the capacity, we had about the same horsepower delivered as with the smaller engines, simply because the firemen worked up to what they thought was the proper limit, and did not put any more coal in than they used to do on the smaller engines, thus showing the need for a stoker as early as 1907.

It is interesting to note that the stoker which Mr. Bartholomew said had disappeared—that is, of the plunger type—was operating, I think, on the Chesapeake and Ohio in 1904. In 1905 there was a company organized to exploit this stoker, and, in spite of my recommendations to get it out of the cab and bring the coal from the tender by a conveyor, they refused to do any more than sell what they had—it was take it or leave it, and therefore they *left* it, and the company went to pieces.

When you consider the method of blowing coal in by steam, which is the generally-accepted method, it is interesting to note that Mr. Kincaid, in one of his early patents (1909), covered that feature, but I do not think he made any application of it to a locomotive.

MR. A. N. WILLSIE (*Chairman, Fuel Economy Committee, C. B. & Q. Railroad, Chicago*).—Mr. Chairman and Members of The Franklin Institute; I appreciate the privilege of being present at this meeting.

I have had practical experience with but one kind of stoker, and that is the Street over-feed stoker. We have sixty-three of these in service on the Burlington road, and some twenty-five or thirty are being applied to new engines.

The time has come when it is necessary to have mechanical stokers on some of the heavy engines now in service and engines that are to be built. While it may be possible to fire these engines by hand, it is not possible to get the maximum amount of work out of the engines, but with the mechanical stoker this is possible.

I am told by men who have had experience with the different kinds of stokers mentioned and illustrated this evening that they are all giving satisfaction, and I have ridden on passenger engines on the Pennsylvania road that were equipped with the Crawford stoker and the work was done satisfactorily.

On the road which I am connected with we have been able to increase the tonnage considerably. This is so with the Mikado type engines, with a tractive power of 60,000 pounds.

The 2-10-2 type, with a tractive power of 71,500 pounds, were designed with the expectation that they be stoker-fired.

It would be very conservative to say that not over ten per cent. of the coal consumed is necessary to be handled by the scoop; in other words, a trip where twenty or twenty-five tons of coal are consumed, not over one ton would have to be shovelled by hand, and oftentimes a great deal less, depending upon the attention the fireman gives the fire and the feeding of the coal.

Some figures were made from actual service for the month of October, 1914, comparing stoker-fired Mikado engines with hand-fired Mikado engines for October, 1913. The average tons of the stoker-fired engines per train was 4326, of the hand-fired engines 3891, or an increase of 435 tons per train. Over a division of 136 miles thirty-one minutes less time was used with the stoker-fired engines, and these additional 435 tons were handled with a few cents less cost for coal; this saving made on account of the price of coal, the stoker engine using 85-cent screenings, while the hand-fired engines were using coal at about $1.20 per ton.

The 2-10-2 type of engines also showed in this same month as handling on an average of 5374 tons, or 1587 more than the hand-fired Mikado engines. The running time over the 136 miles was seven minutes longer than the hand-fired engine, but, as stated before, they handled 1587 additional gross tons, with an additional cost of but 71 cents for fuel.

With the stoker-fired engines it is possible to make better meeting points and get over the road so as not to be tied up on account of the sixteen-hour law. It also makes it possible for the fireman to follow the engine as close as the engineer, thereby making more money than he could possibly make if following one of these large engines hand-fired. This also gets the engine off the road, making room for other trains, and the engine is at a terminal where she can receive round-house attention. It is almost impossible to get over the road within the sixteen-hour limit with the largest type of engines hand-fired, and when the crew are tied up and take their rest wherever they can get it, the fireman especially is not fit to do as good a job of firing after that, and it is always very hard on the engine to be tied up on the road. This kind of work wears the men out, and the company cannot expect but to lose by it.

On one division of the Burlington road, where the heavy power is in service and the business drops off so that it is necessary for the young engineers to go back firing, they oftentimes take the stoker-fired freight engines in preference to hand-fired passenger engines. This results in the good of the service, for the reason that when a young engineer goes back to firing and accepts a passenger run for a few months he is not nearly so well prepared, when he again takes the engineer's position, as he would be had he put in his firing service on a freight engine, as by firing the freight engine he is kept familiar with freight conditions, such as handling long trains and keeping up to date on train orders, etc. This is bound to result in a benefit for the division.

We have also found in one piece of territory that with the mechanically-fired engine we are able to make what we term "turn-arounds," almost without exception, each trip; that is, the crew and engine are used 72 miles and then immediately turned around, returning the same distance. This not only gets the engine back into the terminal where she belongs, gets the crews home where they wish to be, but makes it possible to make this 72-mile turn-around (144 miles) within the sixteen-hour period, which saves over $10 in wages, and figures show a saving of over $7.50 in the cost of coal per trip. A great deal of this saving is caused by the engine not having to be herded around the clinker-pit tracks, fire knocked out, new fire built, and engine again delayed at terminal waiting for a train.

It is not claimed that a stoker engine will save coal over a hand-fired engine unless the engine is of such size as to make it impossible for a man to handle the coal if the engine is worked to her full capacity.

Another point in favor of the stoker engine: There may be conditions where the business has outgrown the present size of locomotive hand-fired, but in order to put in service the largest locomotives it would require many changes in the operating department, such as heavier rail, heavier bridges, larger turn-tables, addition to round-house, and numerous other items.

If the engines in this territory are of such a size as to be up to the limit of hand-firing, it may be possible that the same engine can be equipped with a stoker and get from 10 per cent. to 15 per cent. more efficiency from her. This might result in the engine being handled without any additional expense, as above mentioned. It might make it possible to handle the business over a single track, which would naturally require some double-tracking to handle the same volume if the engines were not equipped to do more work.

I feel quite confident that after the men become more familiar with the stoker-fired engines they will do a great deal better in the matter of fuel economy. On account of the engines being fired with the door closed, it is but natural that they should save coal.

With the stoker-fired engines, also, the fire, as a rule, is so much thinner than hand-fired engines that better combustion is bound to take place, for the reason that oxygen, which is very necessary, comes up through the fire and the air is heated before it comes in contact with the gases, which will naturally make much better combustion than cold air coming in volumes over the fire and through the door when the engine is hand-fired. This light fire will also save delay and expense at terminals, requiring less time to clean the fires.

As stated above, it requires a good fireman to handle the stoker economically, as well as hand-fired, and he is relieved of so much of the physical labor that the railroad company can well afford to insist that he do his stoker-firing properly.

With hand-firing, and with the largest type of engines, the men are inclined to put in too much coal at a time. The door being opened so much not only chills the firebox, but the amount of coal thrown in chills the fire, and it requires some time before the proper heat is again obtained; in other words, it takes about 1200 degrees of heat to distil the gases from the coal, and if the temperature is not up to 1800 degrees the gases cannot burn. Consequently they are taken out through the flues and out of the smokestack unconsumed, or, in other words, just that much heat is lost, and, as the volatile matter of most of the bituminous coal ranges from 25 per cent. to 35 per cent., this waste is enormous. By the door being kept closed and the air necessary for combustion coming through the fire, it seems to me, should result in a great saving.

DR. ANGUS SINCLAIR.—Mr. President and Gentlemen of The Franklin Institute: I am very glad to be here to-night and to have heard that very interesting paper on the mechanical stoker. I have had a great deal of railway experience, and much of my time has been devoted to improvements in firing locomotives.

I began railway service in 1856 with the locomotive superintendent who first applied a brick arch to a locomotive. I was brought into close contact with that invention shortly after it was brought out, and I have always paid particular attention to combustion, and especially to smoke prevention, which means proper firing and proper combustion.

During my time in connection with railways I have seen nearly all inventions of any consequence that have been brought out for improving the operation of the locomotive, and I have never seen anything yet brought out but what there was considerable opposition to its application. Any of you older members who can go back in your minds and follow the various inventions have seen how viciously the new things were opposed. Take the injector, for instance, and follow up other good inventions: they were bitterly opposed at the start. The locomotive men of all the companies that I am acquainted with are particularly conservative, and they object to putting something new on the engine, something that they are not accustomed to, and I think that is the secret—that there has been so much opposition to every improvement.

I have had some experience in running and firing locomotives. I ran locomotives for twelve years, and I always felt satisfied that some mechanical means of firing would be invented and perfected. It is some ten or twelve years, I think it must have been, since I first heard about the mechanical stoker, and I felt so much interested in it that I rode on the engines using them. My judgment of that first stoker was that it was rather imperfect and showed rather crude invention, but it seemed to be capable of improvements that would make it just as successful a device as the injector proved to be. However, the parties who had hold of that seemed to get discouraged at the first opposition. The enginemen were by no means enthusiastic about it. I heard that they expected ordinary laborers to be on the engines to do the work, and that the fireman's job would be at a finish, and my experience with the successful mechanical stokers has been that it requires a more intelligent man to operate the stoker as it should be operated than it does a man to shovel the coal, and I think that as the experience develops with the mechanical stoker it will be much more efficient than it is to-day, and the improvement that comes with practice will still add to this efficiency and therefore add to the economical operation of the mechanical stoker.

I have had quite a busy life. I have ridden on engines equipped with the stoker; I have been on several of them—on the

Street stoker particularly; and I do not think there is any mechanical device in use that works more successfully than it does.

When they talk about waiting for developments of the mechanical stoker, they are talking about something they do not understand. It is as well perfected as any ordinary device, and it will be successful when it is in the hands of its friends.

MR. W. L. ROBINSON (*Baltimore and Ohio Railroad*).—I came in a little too late to hear the entire paper read. We have 222 of these locomotives operating successfully in regular service, and, from what Mr. Bartholomew has read and shown you, there is not much left to say, due to a great deal of what has been stated applying to the operation of the Street stokers on the Baltimore and Ohio. However, I had the opportunity to read the paper carefully before coming to the meeting, and will say that, in so far as the experience of our road is concerned, Mr. Bartholomew has covered the matter very well.

Mr. Willsie has also spoken of the main advantages of mechanical stoking, and there are only one or two things I would care to mention in addition to what has been stated, and they are the question of increased train load and method of carrying the fire on the grates.

In regard to train load, it should be stated that this has increased from eight to fifteen per cent., and the stoker locomotives get over the road very much better and bring about a more uniform performance.

Regarding the method of carrying the fire on the grates, it has been necessary to carry a light, level, and bright fire to get the best results, and this has resulted in very little necessity for grate shaking, raking fires, or dumping ash pans; and I have ridden a great many engines during the past winter when trips were made with full tonnage trains and the fire not shaken or touched by rake or ash pan dumped from one end of the road to the other, and the fire in such condition that full steam pressure was maintained to completion of trip.

All these locomotives are operating in pool service, except on one division where they have recently been assigned to regular crews.

I think about all of the features have been well covered, and it is merely repetition to add to the remarks which have already been made, so far as Street stoker is concerned, and I have had no practical experience with any other type of over- or under-feed stoker.

CLOSURE BY AUTHOR.

From what has been stated in the paper and by those taking part in the discussion it is no doubt very plain that the mechanical stoker for locomotives does not come within either of two classes of labor-saving devices which were referred to earlier in the evening; *i.e.*, those which are applied entirely for the profit to be made on the investment or those which are applied entirely for humanitarian considerations.

It is evident that the railroad companies and the enginemen both profit by the application of mechanical stokers to locomotives.

Locomotive capacity is increased, while, strange as it may seem, the fireman's labor in shovelling coal and his suffering from the heat are materially reduced.

The railroads secure a return on their investment from the increased tonnage, less expensive fuel, and other economies effected, and the men, individually, make more money per month with less effort.

Small locomotives are made larger, and larger locomotives are made possible.

These and other results are being accomplished by stokers designed to be applied to existing power with the necessary limitations that come thereby, and much more may reasonably be expected in the future, now that the stoker has established itself for permanent use, as stokers will be taken seriously into account in the designing of new heavy power to be built in the future for capacity as well as economy.

The Franklin Institute deserves great credit and the hearty thanks of the railroads, the public, and the men who fire the locomotives for the interest taken in the development of devices of this kind which serve the double purpose of contributing to the uplift of the men who work and at the same time have economic advantages sufficient to warrant the necessary investment for their general application.