

**A GUIDE TO CLEAN AND EFFICIENT OPERATION
OF
COAL-STOKER-FIRED BOILERS**

2002

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FOREWORD

This document was prepared by the American Boiler Manufacturers Association (ABMA) to provide owners and operators of coal stoker fired boilers with information as to techniques and procedures to design and operate stoker-fired boilers economically and in an environmentally satisfactory manner.

The contents of this document are offered for guidance only. The American Boiler Manufacturers Association does not assume responsibility or liability for consequences arising from implementation or failure to implement the guidance contained herein. The contents of this guide should not be construed as an endorsement by ABMA of any product or manufacturer.

This guide is intended as a supplement to the manuals furnished by equipment manufacturers who should be consulted regarding design, operational or equipment problems.

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The ABMA has but one goal: to promote the welfare of the boiler and related products of the industry. It strives to improve services to the public, to cooperate with government in setting public policy, and to be both proactive and reactive in issues concerning its membership. The ABMA also provides a common forum for the industry to improve its technology, establish guidelines for codes and standards, develop safety programs, assure quality, and perform research.

Founded in 1888, the ABMA is a voluntary, non-profit corporation headquartered in Arlington, VA.

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DEFINITIONS

STOKER EQUIPMENT

AIR NOZZLE – An air port having direction and appreciable length for directing an air stream.

AIR PORT – An opening through which air passes.

BOTTOM AIR ADMISSION – A method of introducing air to a chain or traveling grate stoker under the stoker.

CHAIN GRATE STOKER – A stoker which has a moving endless chain as a grate surface, onto which coal is fed directly from a hopper.

CLINKER GRINDER STOKER – One in which the refuse is discharged into a pit containing at the bottom, one or more grinding rolls which are continuously or intermittently operated to produce a positive discharge of crushed refuse to the pit.

COKING PLATE – A plate adjacent to a grate through which no air passes and on which coal is placed for distilling the coal volatiles before the coal is moved onto the grate.

COMBUSTION CHAMBER – The space in which combustion takes place.

COMPARTMENT – One of two or more air chambers under the stoker from which air can be passed in controlled quantities.

DEAD PLATE – A grate or plate through which no air passes (see Coking Plate).

DEFLECTOR – A device for changing direction of a stream of air or a mixture of pulverized fuel and air.

DOUBLE INCLINED GRATE – A grate consisting of two parts, so placed and inclined to form a figure V.

DRAG PLATE – A plate beneath a traveling or chain grate stoker used to support the returning grates.

DRAG SEAL – In a chain grate stoker the hinged plate resting against the returning chain and used to seal the air compartments.

DUMP GRATE STOKER – One equipped with movable ash trays, or grates, by means of which the ash can be discharged at any desirable interval.

DUMP PLATE – An ash supporting plate from which ashes may be discharged by rotation from one side of the plate.

FEED PLATE – An element of a stoker having a reciprocating motion by means of which solid fuel, such as coal, is pushed into a fuel distributor. Fuel rate may be controlled by varying the frequency or amplitude of the reciprocating motion.

FIXED GRATE – A grate that does not have movement.

FORCED DRAFT STOKER – A stoker in which the flow of air through the grate is caused by a pressure produced by mechanical means.

FRONT DISCHARGE STOKER – A stoker so arranged that refuse is discharged from the grate surface at the same end as the coal feed.

FUEL FEED GATE – An element of a stoker, placed at the point of entrance of fuel into the furnace and by means of which the depth of fuel on the stoker grate may be controlled. It is generally used in connection with chain or traveling grate stokers and has the form of a guillotine.

GRATE – The surface on which fuel is supported and burned, and through which air is passed for combustion.

GRATE BARS - Those parts of the fuel-supporting surface arranged to admit air for combustion.

HAND FIRED GRATE – A grate on which fuel is placed manually, usually by means of a shovel.

LEDGE PLATE - A form of plate which is adjacent to, or overlaps, the edge of a stoker.

LINK – An element of the chain of a chain grate stoker.

MECHANICAL STOKER – a device consisting of a mechanically operated fuel feeding mechanism and a grate, and is used for the purpose of feeding solid fuel into a furnace, distributing it over a grate,

admitting air to the fuel for the purpose of combustion, and providing a means for removal or ash discharge of refuse.

OVERFEED STOKER – A stoker in which fuel is fed onto grates above the point of air admission to the fuel bed. Overfeed stokers include:

1. **FRONT FEED, INCLINED GRATE** – A stoker in which fuel is fed from the front onto a grate inclined downwards toward the rear of the stoker.
2. **SIDE FEED, DOUBLE INCLINED GRATE** - A stoker in which fuel is fed from both sides onto grates inclined downwards towards the centerline of the stoker.
3. **CHAIN OR TRAVELING GRATE** – A stoker having a moving endless grate which conveys fuel into and through the furnace where it is burned, after which it discharges the refuse.
4. **VIBRAGRATE** – An inclined vibrating stoker in which fuel is conveyed into and through the furnace where it is burned, after which it discharges the refuse.

SPREADER STOKER – A stoker that distributes fuel into the furnace from a location above the fuel bed with a portion of the fuel burning in suspension and a portion on the grates. Spreader stokers include:

1. **STATIONARY GRATE** – A stoker in which fuel is fed onto a fixed position grate.
2. **DUMP GRATE** – A stoker in which fuel is fed onto a nonmoving grate which is arranged to allow intermittent discharge of refuse through tilting action of the grate bars.
3. **CONTINUOUS ASH DISCHARGE OR TRAVELING GRATE** – A stoker in which fuel is fed onto a moving endless grate which conveys the fuel into and through the furnace where it is burned, after which it discharges the refuse.

UNDERFEED STOKER – A stoker in which fuel is introduced through retorts at a level below the location of air admission to the fuel bed. Underfeed stokers are divided into three general classes, as follows:

1. **SIDE ASH DISCHARGE** - underfeed stoker is a stoker having one or more retorts which feed and distribute fuel onto side tuyeres or a grate through which air is admitted for combustion and over which the ash is discharged at the side parallel to the retorts.
2. **REAR ASH DISCHARGE** – A rear ash discharge underfeed stoker is a stoker having a grate composed of transversely spaced underfeed retorts, which feed and distribute solid fuel to intermediate rows of tuyeres through which air is admitted for combustion. The ash is discharged from the stoker across the rear end.
3. **CONTINUOUS ASH DISCHARGE** – A continuous ash discharge underfeed stoker is one in which the refuse is discharged continuously from the normally stationary stoker ash tray to the ash pit, without the use of mechanical means other than the normal action of the coal feeding and agitating mechanism.

MULTIPLE RETORT STOKER – An underfeed stoker consisting of two or more retorts, parallel and adjacent to each other, but separated by a line of tuyeres, and arranged so that the refuse is discharged at the ends of the retorts.

NATURAL DRAFT STOKER – A stoker in which the flow of air through the grate is caused by the difference of pressure between the furnace and the atmosphere.

PROJECTED GRATE AREA – The horizontal projected area of the stoker grate.

PUSHER – A device for giving motion to the fuel bed by reciprocating motion, such as a moving block in the bottom of a retort.

RAM – A form of plunger used in connection with underfeed stokers to introduce fuel into retorts. Also a form of pusher.

REAR DISCHARGE STOKER – A stoker so arranged that refuse is discharged from the grate surface at the end opposite the fuel feed.

RECIPROCATING GRATE – A grate which has reciprocating motion, to convey ash to the discharge end of the grate.

RETORT – A trough or channel in an underfeed stoker, extending within the furnace, through which fuel is forced upward into the fuel bed.

SCREW FEED – A means of introducing fuel by rotation of a screw.

SHAKING GRATE – A grate from which refuse is removed by motion of the grate causing the refuse to sift through openings in or between the grate.

SIDE AIR ADMISSION – Admission of air to the underside of a grate from the sides of a chain or traveling grate stoker.

SIDE DUMP STOKER – A stoker so arranged that refuse is discharged from a dump plate at the side of the stoker.

SINGLE RETORT STOKER – An underfeed stoker using one retort only in the assembly of a complete stoker. A single furnace may contain one or more single retort stokers.

STATIONARY GRATE – A grate having no moving parts.

STOKER – See Mechanical Stoker.

STOKER GRATE – That part of the stoker within the space defined by the walls of the furnace at the fuel bed level which forms the bottom of the furnace and supports the fuel bed. On a chain or traveling grate stoker, the fuel bed is considered to be supported only to the centerline of the rear shaft or its equivalent.

TRAVELING GRATE STOKER – A stoker similar to a chain grate stoker with the exception that the grate is separate from but is supported on and driven by chains. Only enough chain strands are used as may be required to support and drive the grate.

TUYERES – Forms of grates, located adjacent to a retort, through which air is introduced.

V-TYPE STOKER – See Mechanical Stoker

WATER COOLED STOKER – A stoker having tubes in or near the grate surface through which water is passed for cooling the grates.

WINDBOX – A chamber below the grate (commonly called undergrate air plenum) or surrounding a burner, through which air under pressure is supplied for combustion of the fuel.

ZONE CONTROL – The control of airflow into individual zones of a stoker.

ZONES – Divisions of the stoker windbox in which air can be maintained at different and controllable pressures.

SECTION 1

INTRODUCTION

This manual has been written for boiler operators and is intended to be a concise, easily understood, and interesting guide to the clean and efficient operation of bituminous and sub-bituminous stoker coal-fired boilers. It should be made very clear that this manual neither replaces nor supercedes the manufacturer's operating manual. This manual will explain general principles of boiler operation and will suggest ways of reducing boiler emissions and increasing boiler efficiency. This manual will not show the operator exactly how to implement these suggestions. For this reason, the operator should consult the boiler manufacturer's operating instructions as well.

The first part of the manual includes a list of definitions used in discussing stoker equipment. The reader needs to understand terminology in order to properly address the technical and operational ramifications of a stoker-boiler installation.

The first section of the manual describes the types of stoker boilers in use today. Since stokers of different design have different operating characteristics, this part of the manual will explain each type of design to enable a better understanding of how to solve problems specific to the type of stoker in use. The next section of the manual explains the combustion process. Since both increased boiler efficiency and reduced boiler emissions can be achieved most inexpensively through combustion optimization, a basic understanding of the combustion process is essential to achieving improved boiler operation. The last two sections of the manual explain how the operator can control the combustion process in the coal stoker-fired boiler in such a way as to achieve increased boiler efficiency and reduced emissions. While it is frequently possible to achieve

increased efficiency and reduced emissions simultaneously, there is sometimes a tradeoff between the two. The nature of this tradeoff is explained in the last two sections of the manual.

SECTION 2

STOKERS IN USE TODAY

In the early days, a "stoker" was someone employed to tend a furnace. To stoke a fire meant to do whatever was necessary to keep it burning properly including poking, stirring, and supplying it with fuel. Eventually, these "stokers" were replaced with mechanical devices that automatically fed fuel to the furnaces and, in some cases, automatically disposed of the ash. These stokers became known as "mechanical stokers" and first appeared in the 1800's.

Today, there are a variety of mechanical stokers in use. They differ in the way in which solid fuel is fed onto the grate and in the way in which ash is removed from the grate. Each firing method has its own unique operating characteristics and its own best applications. This section will discuss the types of mechanical stokers that are commonly used today for firing coal.

Today's stokers can be classified into three categories based on the way in which fuel is fed onto the grate. These categories include:

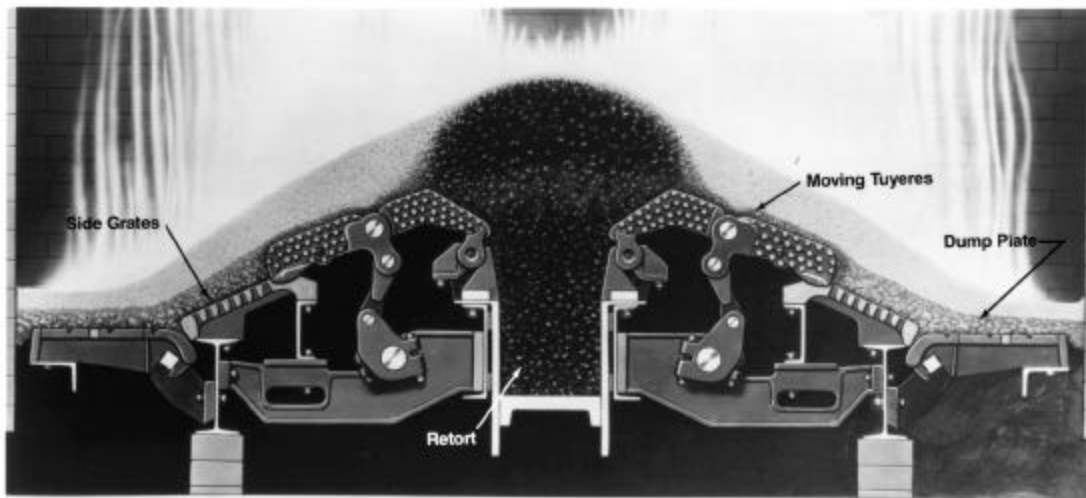
- 1) Underfeed Stokers
- 2) Overfeed Stokers
- 3) Spreader Stokers.

Within each category, the design differs according to the way in which the grate handles the ash. Each stoker category will be discussed and the most common stoker types will be illustrated.

UNDERFEED STOKERS

In an underfeed stoker, the fuel is introduced through long troughs called "retorts" at a level below the location of air admission to the fuel bed. The green coal (or raw coal) is at the bottom with the ash moving away from the retort. Combustion takes place in between constantly receiving a fresh supply of green coal from below and displacing the ash.

The smallest of the underfeed stokers has a single or double retort into which the coal is fed (Figure 1). The coal feed is by either a screw or a mechanical ram which forces the coal the length of the retort and upward. The ash on this type of stoker is normally discharged with side dumping grates. Some underfeed stokers have grate sections which have an undulating (wave-like) action to break up clinkers from high-coking coals so that manual poking is reduced. Most modern underfeed stokers are also equipped with overfire air jets to provide turbulence to mix the volatiles with the air for more complete combustion. These stokers will fire boilers in the size range of 3,000 to 30,000 pounds of steam per hour.



Sectional view of single retort stoker with moving tuyeres.

**Figure 1. Single Retort Underfeed Stoker with Side Dumping Grates.
(Reprinted with Permission of Detroit Stoker Company)**

OVERFEED STOKERS

In an overfeed stoker, the coal is fed onto the grate above the point of air admission. The two basic types of overfeed stokers are the chain, or traveling grate stoker, and the water-cooled vibrating grate stoker. Technically, a spreader stoker is also a type of overfeed stoker. However, because it is commonly considered in a class by itself due to its unique features, it will be classified separately in this text.

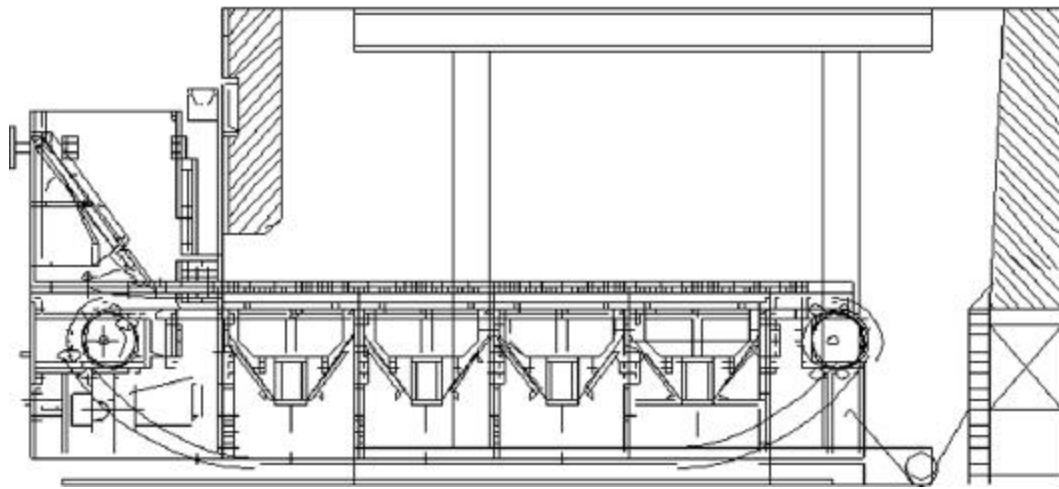


Figure 2. Side View of Chain Grate Overfeed Stoker.
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A typical chain grate overfeed stoker is illustrated in Figure 2. It consists of a continuously moving grate. Coal is deposited on one end of the grate by gravity feed from a coal hopper. The coal depth is adjusted by a guillotine-like movable coal gate to a thickness of about 4 to 12 inches. The coal is burned as it passes slowly through the furnace at grate speeds of less than 30 feet per hour. The ash is continuously discharged off the rear of the grate into an ash pit.

There are different types of grate construction in use. These are classified as either chain or traveling grates, although the chain grate also travels. The chain grate itself is a wide chain composed of close-fitting links. The air passes upward through the spaces between the links. In the traveling grate, grate sections called "bars" or "links" are

attached to a separate chain. Chain and traveling grate stokers have been built for boilers as large as 300,000 pounds of steam per hour.

The water-cooled vibrating grate stoker uses vibration and gravity to move the coal (Figure 3). This type of stoker originated in Europe and was introduced to the United States in the mid 1950's.

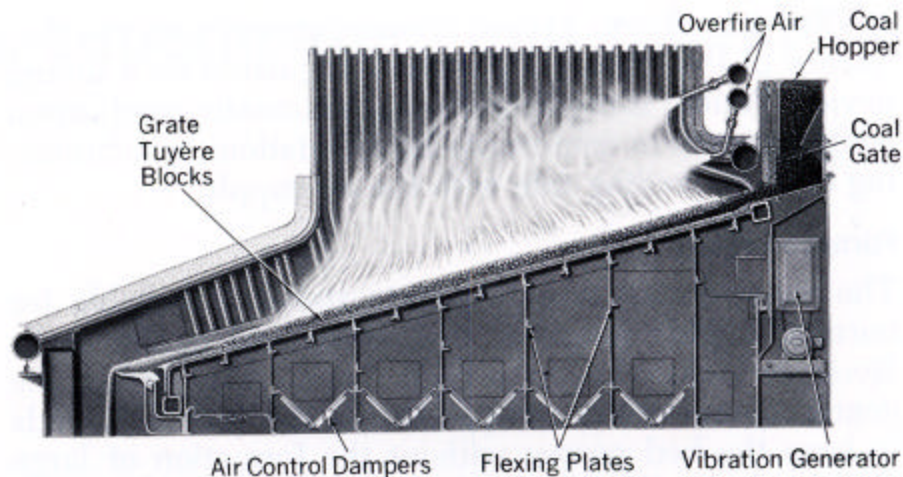


Figure 3. Side View of Water-Cooled Vibrating Grate Stoker.
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The water-cooled grate is supported by flexing plates and an incline at an angle of about 14° . As with the chain and traveling grate stokers, the coal is gravity fed at the top of the grate and has individually controlled air zones. The interval and duration of the vibrations is tied to the automatic controls and determines the rate at which the coal is moved through the active burning zone. Ash is discharged at the rear of the stoker.

SPREADER STOKERS

In a spreader stoker, coal is spread evenly over the entire grate surface by mechanical feeders located at the stoker front above the grate. Because the coal is thrown onto the

grate, there is suspension burning of the coal fines. This suspension burning coupled with a very thin fuel bed allows the spreader stoker to respond to rapid load changes.

There are many types of mechanical feeders in operation. They all utilize rotor speed and coal trajectory to adjust coal distribution on the grate. One type of mechanical feeder is illustrated in Figure 4. In this typical arrangement, coal is conveyed with a variable speed chain conveyor onto a rotating "underthrow rotor." The rotor has paddles on it and is spinning at several hundred revolutions per minute. As the coal moves onto the rotor, it is struck by the paddles and is thrown into the furnace. The paddles are designed to distribute the coal over a wide area. The rotor speed and conveyor discharge height can be adjusted to provide an even distribution of coal on the grate. The number of feeders used depends on the width of the stoker grate.

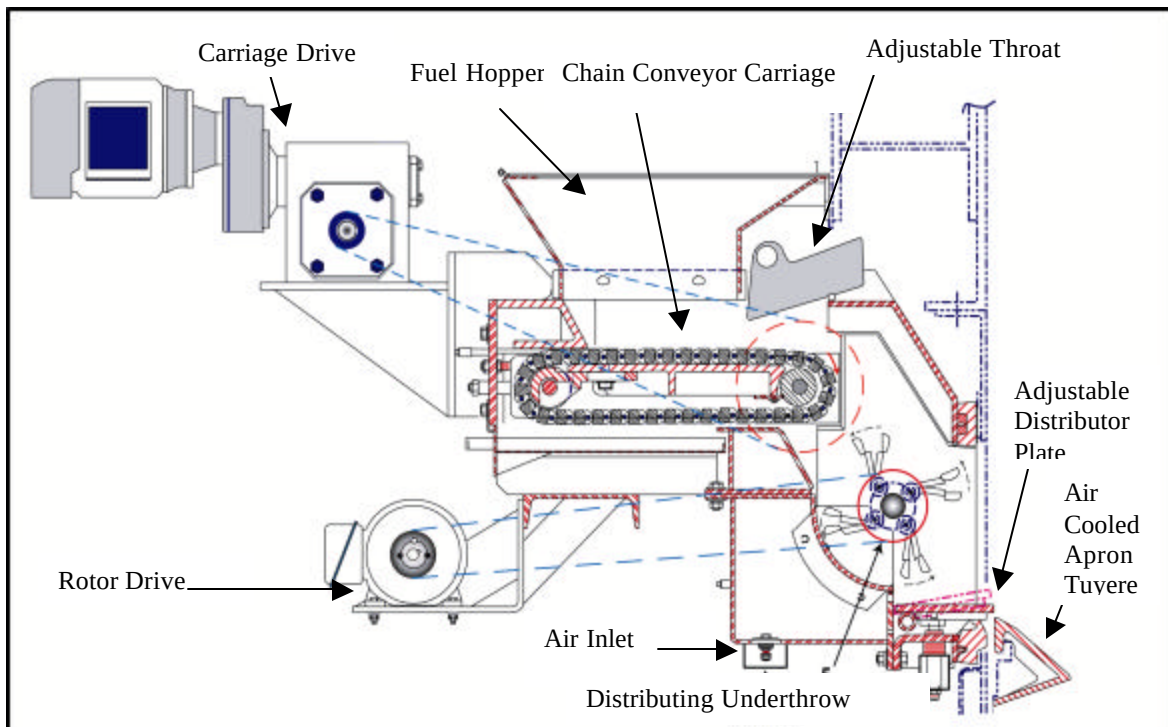


Figure 4. Side View of a Mechanical Coal Feeder Showing Components.
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Spreader stokers include a variety of grate types. One type is the dumping grate spreader stoker. The grate bars on a dumping grate stoker rotate open like Venetian blinds so that the ash will fall into an ash pit underneath the grate. Dumping grate stokers have been built for boilers in the size range of 15,000 to 75,000 pounds of steam per hour.

The larger coal-fired spreader stokers use continuous ash discharge grates. The most popular version of this type of grate is the traveling grate. Reciprocating grates and vibrating grates are also used but are less popular.

A typical arrangement of a spreader stoker with traveling grate is illustrated in Figure 5. Note that the ash is discharged at the front of the stoker rather than at the rear. The spreader stoker is usually equipped with overfire air jets front and rear to provide turbulence for mixing the volatile gases with the air and to hold the flames off the water walls and out of the feeder throat. Drying, burning, and burnout zones do not occur like an overfeed chain grate. The heat release rate is essentially constant over the grate area. The spreader stoker is characterized by a thin bed and partial suspension burning. As a result, it responds rapidly to changes in load. It is capable of firing a wide range of coal grades and types. The spreader stoker has high availability, simplicity of operation, and high operating efficiency but it has high flyash carryover and a high flyash combustible heat loss compared to mass fired grates. Cinder reinjection is used on spreader stokers to recover some of the carbon in the collected flyash. It has been found, however, that flyash reinjected along with cinders causes excessive erosion of boiler pressure part surfaces. Traveling grate spreader stokers have been built for boilers as large as 400,000 pounds of steam per hour.

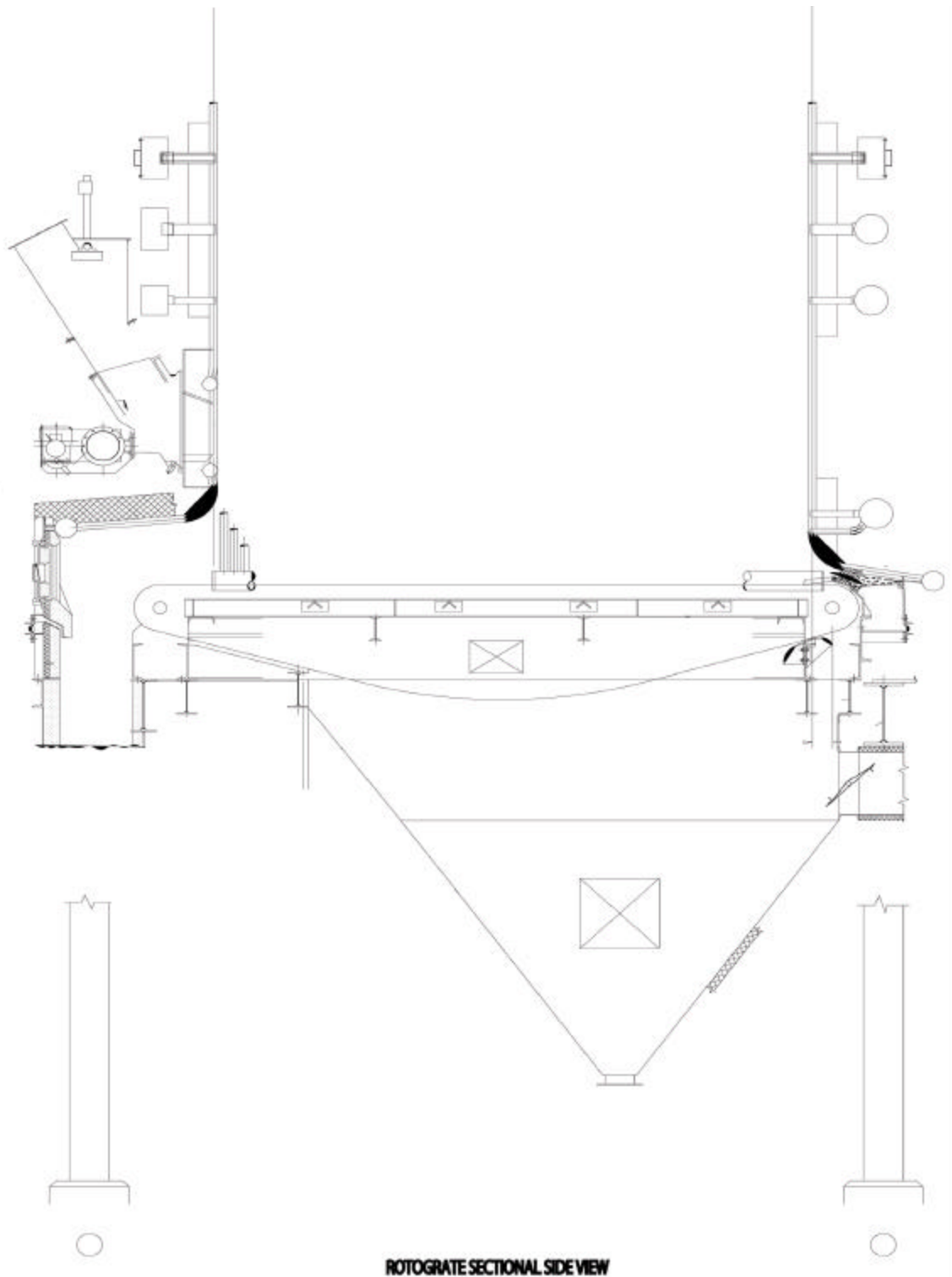


Figure 5. Side View of a Spreader Stoker with Traveling Grate.
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