RATE OF COMBUSTION AND DRAFT PRESSURE FOR A STOKER APPLIED TO 350 H. P. STERLING BOILER

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RELATION BETWEEN RATE OF COMBUSTION AND DRAFT PRESSURE FOR A CHAIN-GRATE STOKER APPLIED TO A 350 H. P. STERLING BOILER

A THESIS

PRESENTED BY

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INTRODUCTION

There has been but little or not attempt made to discover just what the relation between the rate of combustion and draft pressure in a furnace really is, and no authentic data has as yet been compiled.

It was with the above idea in mind that this thesis was started. No attempt was to have been made to accumulate data wherefrom an accurate heat balance might have been constructed, but simply to find what infulence the draft and thickness of fire really had upon the rate of combustion.

However, after all apparatus had been installed, the coal was of such a mixed variety of sizes and kinds, and there being no call for steam, the attempt was abandoned.

The enclosed report is then only an expression of what was really done in inetallation of apparatus and a proposed method of procedure for some one to follow for the actual determination.

INTRODUCTION

DESCRIPTION OF BOILER AND SETTING

The tests were to have been made upon one of a battery of five located at the Armour Institute of Technology, at Chicago, Illinois. The boiler is of a Sterling type and consists mainly of three upper, or steam drums, and a large lower mud drum. These sets of drums are connected by 3-1/4" inch, lap welded, mild steel tubes. The tubes are bent at the ends in such a way that they enter the drums radially. The drums are constructed of the best quality of flange steel, and are 3 feet 6 inches in diameter by 12 feet in length. Two hundred-fifty water tubes, and twenty nine tubes afford a heating surface of approximately 3500 square feet. Baffles, suitably placed, on the tubes direct the flow of the heated gases so that they pass up the first pass, down the second, and across the third pass.

Water for the boiler is fed into the upper rear drum, which is the coolest part of the boiler and flows to the bottom mud drum. The steam is taken from the middle upper drum.

DESCRIPTION OF BOILER AND SETTING

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Water for the boiler is fed into the upper rear drum, which is the coolest part of the steam. It is taken from the middle upper drum. The boiler and flows to the bottom mud drum. The

Two safety valves are also placed on the drum and are set to release at 150 pounds gauge pressure. The valves are piped to the atmosphere. The blow off valve is located at the bottom of the mud drum. A manhole placed in the ends of the three drums for the purpose of permitting inspection and cleaning.

The whole combination is enclosed by a brick setting. For the dimensions of setting see "dimensions and proportions." The upper drums rest upon wrought iron beams. These beams are in turn supported by wrought iron columns whose bases are set in cast iron foundations. The weight of the lower drum is carried by the tubes connecting it to the steam drums. This arrangement allows the entire mass to move with the contraction and expansion of the metal due to the heat.

Two fire doors are cut through the brick work to permit inspection of the fire in the furnace and over the bridge wall.

in the entrance hall over the bridge wall.

Two tube locks are cut through the brick work to permit inspection of the tube portion of the valve to the vent.

Two tube locks are cut through the casing to permit inspection and removal of the valve parts. The valves are placed to have and can be reached at the bottom of the tube.

The safety valves are also placed on the

A fire brick arch projects to within one foot of the front row of tubes. This arch becomes incadescent from the heat that it has absorbed, and ignites the green fuel, as the fuel comes into this region.

The grate employed, is the one manufactured by the Green Chain Grate Company. For dimensions of grate, see "dimensions and proportions".

Coal is shoveled into the hopper which extends across the full width of the grate. The depth of the fire on the grate is regulated by means of an adjustable sheet iron gate. Raising or lower this allows more or less coal to pass into this ignition zone, and also serves to keep a constant depth of coal on the grate.

Draft is produced by means of a one hundred-seventy five foot brick chimney. The chimney is connected to the furnace by a sheet metal breeching. A damper placed in this breeching serves to regulate the draft in the furnace. It may be opened

the dirt in the fissure. It may be cleaned
by a small metal scraping. A fissure in
glass is treated with plastic cement.
The cavity is compared to the fissure
mixed-cavity like lost plaster cement.
Paint is produced by mixing of a one
or two pints.

Glass sealer to keep a constant depth of coat
coat to pass into the imitation zone, and
Heating of lower this allows more or less
by means of an adjustable sheet iron mate.
The depth of the line on the crumbs is regulated
automatic moves the tilt depth of the plate.

Dust is absorbed into the hopper which
procedures".

The dimensions of plate, see "dimensions and
featured by the Green Tooth Plate Company.

The plate employed, is the one mentioned by the Green Tooth Company.

Special, and in the green test, in the course impossible from the fact that it has lost of the finest ice of types. This step be-

A life Point upon brushes to finish one

or closed from the boiler room floor by releasing the wires that hold the damper in position.

The feed water from the returns of the heating system is piped to a surge tank. From this tank the water is pumped through a venturi meter, constructed by The Builders Iron & Foundry Co., to the rear drum of the boiler. The height of the water in the boiler is determined by the use of the ordinary water column.

The chain grate stoker is operated by a three horse power vertical steam engine belted to a jack shaft. This shaft is connected to a rocker arm by means of an eccentric rod and a slip connection. The rocker arm is furnished with a ratchet working on a ratchet wheel. The ratchet wheel is connected to the axis of rotation of the grate through the ordinary reduction gearing. The speed of the grate is regulated by throttling the engine, or by changing the effective length of the rocker arm.

Coal is unloaded from the cars into bins, and thence gravitates to the boiler room floor.

and thence horizontal to the boiler room floor.

Coal is unloaded from the cars into bins, overlying the entrance tunnel of the boiler room. regulated by throttling the engine, or by reduction gearing. The speed of the grate is notation of the grate through the ordinary ratchet wheel is connected to the axis of a ratchet working on a ratchet wheel. The slide connection. The boiler room is furnished with a ‘jack shaft’. This shaft is connected to a three horse power vertical steam engine situated

The chain grate stoker is operated by a mixed by the use of the ordinary water column. The height of the water in the boiler is determined by the test cock on the front of the boiler. ronmity of the fire room of the boiler. tural water, constructed by The Phillips Iron & this tank the water is pumped through a vacheating system is piped to various tanks. From

The feed water from the tanks of the ing the water that feeds the boiler in question. or closed from the boiler room floor by mains-

It is shoveled into the hopper of the stoker by hand.

The ashes drop into a pit under the grate and are removed by hand.

It is accurately into the nozzle at the
stamer by hand.

The tapes grip into a bit under the
grate and are removed by hand.

DIMENSIONS AND PROPORTIONS.

BOILER.

Type of boiler,	Water tube.
Diameter of shell,	42.00 inches.
Length of shell,	12.00 feet.
Thickness of shell,	9/16 & 7/16 inches.
Thickness of head,	5/8 & 3/4 inches.
Number of tubes,	279
Diameter of tubes, (inside)	3.25 inches.
Diameter of tubes, (outside)	3.78 inches.
Length of tubes, (over beading)	18 feet 3 inches.

Steam taken directly from central drum.

Kind of grate,	Green Chain Grate Stoker.
Size of grate,	Width 9 ft, Length 9 ft. 2 in.
Area of grate surface,	82-1/2 Sq. ft.
Heating surface of boiler,	3500 sq. feet.
Ratio heating surface to grate surface	1 to 42.5

DIMENSIONS AND PROPORTIONS.

BOILER.

Type of boiler,	Water tube.
Diameter of shell,	42.00 inches.
Length of shell.	15.00 feet.
Thickness of shell,	9/16 & 7/16 inches.
Thickness of head,	9/16 & 9/16 inches.
Number of tubes,	275
Diameter of tubes,(inside)	3.25 inches.
Diameter of tubes,(outside)	3.75 inches.
Length of tubes,(over tube sheets)	9 feet 3 inches.
Style [illegible] direct from central dome.	
Type of grate,	Drum Chain Grate Stoker.
Size of grate, Width 9 ft, Length 9 ft. 5 in.	
Area of grate surface,	82-1/2 Sq. ft.
Heating surface of boiler,	33[illegible] sq. feet.
Ratio heating surface to grate surface	1 to 12.5

BRICK BOILER SETTING .

Height ,	18.5 feet.
Width ,	15 feet.
Length ,	22.75 feet .

BOILER PUMP .

Size,	7-1/2x4-1/2x10.

VENTURI METER .

Make ,	Builders Iron Fdy. Co.
Size ,	Indicating & recording.
Diameter ,(Inlet)	3" inches.
Diameter ,(Throat)	1 inch .

BRICK BOILER SETTING.

Height , 10.7 feet.

Width , 12 feet.

Length, 25.75 feet.

SIZE.

Size, 7-1/2x4-1/2x2in.

VERTICAL METAL.

Name , Smidgers Iron Mfg. Co.

Size , Unloading & reconfiging.

Diameter,(Inlet) 3"Inches.

Diameter,(Throat) 1 inch.

INSTALLATION OF APPARATUS AND PRECAUTIONS .

A rigid inspection of the boiler setting was made, and all of the air leaks stopped up as far as possible. The cracks in the brick settings, and small openings along the sides of the grate entrance and around all connections to the interior of the furnace, cemented over with fire clay. The doors to the bridge wall and grate were removed,and the opening covered with a sheet of 1/2 inch asbestos. Before putting the asbestos sheet in place, the surface exposed to the heat was covered with a thick layer of fire-proofing. This combination was then held in place over the door opening by small machine screws set into the metal frame work of the door. The edges around the asbestos sheet were then sealed with fire-proofing. The above precautions were taken to prevent air leakage as far as possible.

The asbestos covering for the door over the fire was fitted with two openings. One

INSTALLATION OF APPARATUS AND PREPARATIONS.

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The asbestos covering for the door over the fire was fitted with two openings. One

opening was made small enough to be fitted with a one-half inch pipe plug. Through this opening it was proposed to insert the connection to the CO_2 apparatus, to obtain the sample of gas over the fire for analysis. The second opening was about three inches, high, by four inches long, and was covered by a swinging screen of sheet mica. The sheet of mica was sufficient in area to completely cover the opening and permit no great air leakage around the edges. Through this apparatus it was proposed to take the temperature of the fire. A Fery pyrometer was set up, the mica screen swung to one side for an instant, and the pyrometer focused on the fire. The temperature resulting showed on the galvanometer. The reading of the temperature of the fire should take place after all other various readings have been recorded, in order to prevent air leakage.

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Any other cautions readings have been noted, such as the fire should the block after the deflagration. The reading of the temperature of the fire. The temperature reading showed on instrument, and the barometer focused on the mb, the mice access ammua to one side for an equal size of the fire. A hard rubber rat tubing was brought to take the displacement it was blocked to keep the displacement leakage around the edges. Though this cover the opening was permit no right air of mice was sufficient in size to completely a minimum access of about mice. The about mice," mice into the jar, and was covered pa The second opening was about three inches observation to the CO_2 apparatus, to obtain the sample of gas over the fire for analysis. with a one-hole rubber stopper. Through this opening the most small should to be little

A Hayes CO2 apparatus containing fresh solution was set up and connected to a five foot length of quarter inch pipe by the usual rubber tubing. The gas sample from over the fire was taken with this arrangement. A long piece of quarter inch pipe was installed permanently in theuptake. This length of pipe was fitted for proper connection to the gas analysis apparatus, and through it a sample of the gas in the uptake was obtained.

Two draft gauges were installed on the wall at a convenient height, and the proper connections to the interior of the furnace over the fire and in the uptake, were made. The connections were made with quarter inch cast iron pipe. All connections were burred out, and the pipes carefully cleaned before installation. This removed all obstacles for a true reading of the draft pressure, except that which arises from the friction in the pipes. This latter error may be neglected.

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The quality of the steam was obtained from the throttling calorimeter installed on main steam line leading from the central steam drum. A one-half inch pipe connection was already in place just abovethe drum, so the calorimeter was connected at this point. A half inch globe valve and a steam gauge with the customary "curl" for the gauge, were placed in the line leading to the calorimeter. The length of pipe between the calorimeter and the point of connection to the main steam line was made as short as possible. The thermometer cup was filled with a heavy cylinder oil, and a thermometer reading from zero to three hundred degrees put in place. The pressure of the steam as indicated by the gauge at the calorimeter was taken as the true boiler pressure.

Scales and baskets for the weight of coal fired were provided.

The water fed to the boiler per hour is measured by the venturi meter. A chart over the recorder keeps a record of the water evaporated.

Several small numbered baking powder cans were provided for samples of the coal and refuse. It was intended to take several samples of both at intervals during the run, and keep them in the cans for analysis at a convenient time.

All apparatus was carefully calibrated before its installation.

PROPOSED METHOD OF PROCEDURE .

OBJECT:-

The determination of the relation between rate of combustion and draft pressure for a chain-grate stoker.

APPARATUS:-

The test will involve the installation and use of the following instruments:

Draft gauges over the fire and in the uptake.

Throttling calorimeter and steam gauge.

CO2 Apparatus .

Smoke recorder .

Fery pyrometer.

Speed counter for grate.

Scales and baskets for weight of coal fired.

Venturi meter for measuring water evaporated.

METHOD OF PROCEDURE:

The boiler should be in operation as long as possible before the test is started. No runs should be attempted before the boiler and

and setting have had an opportunity to reach a uniform temperature.

When the above conditions have been satisfied, the hopper of the stoker should be filled full and then leveled off and the run started. Take the following readings every five minutes:

Average Draft, inches of water,
Over the fire.
In the uptake.

Average Gas Analysis,
Over the fire.
In the uptake.

Temperatures, degrees Fahrenheit,
External air) Average for test.
Boiler room)
Fire.
Steam.

Pressures,
Barometer.
True Boiler.

Weights, pounds per hour,
Water fed to boiler.(venturi meter)
Coal fired.
Sample of coal fired for later analysis.
Sample of ash for later analysis.
(Note in log sheet kind and size of coal)

Note Carefully:
Thickness of fire.(Constant for run)
Speed of grate, feed per minute.
Droppage of fuel through grate, if any.
Condition of fire (IMPORTANT).
Smoke observations (Smoke recorder).

Precaution must be taken to provide for an ample excess of air in the boiler room. The firing of the coal should be in such a manner that the conditions at the start of the run and at the finish are the same. That is, the water should be at the same level in the boiler, and the coal at the same level on the hopper at the finish as at the start.

The speed of the grate should be maintained as near uniform as possible, but every change in speed should be noted in the log sheet.

The observations as regards to the condition of fire should be watched very carefully. The swinging cover in the asbestos sheet provides a place where the fire may be carefully watched with blue glasses without opening cover. Notes as to whether the fire is short, even, contains holes, etc. should be made frequently.

The analyses of the gases should be carried on chiefly for the CO_2 content. If no CO_2 recorder is available, the analyses should be made at intervals not exceeding

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five minutes. The CO2 should not get below ten percent at any time.

Several runs should be made with different kinds of coal, varying the depth of fire, draft, and speed of grate for each kind of coal.

Have grate exactly level, and furnish photograph showing that the gate and arch are in satisfactory condition.

Too much stress cannot be put upon the importance of keeping accurate readings and conditions of fire. All air passages except those leading through the grate must be sealed off.

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DISCUSSION

The combustion rate curves printed in the various catalogues and magazines show the combustion rate decreasing about in proportion to the decrease in draft. This is probably true for a draft of more than two-tenths of an inch of water in the furnace, but it is doubtful if the combuetion rate decreases as rapidly at the lower pressures. A eet of tests of the aforementioned would give an accurate determination of this.

The great trouble with the chain-grate stoker is its small range of efficient operation. By varying the depth of coal on the grate, and the speed of the grate and then by means of the damper, regulating the draft pressure for each change in speed and depth of fire, the limit of efficient operation might be determined.

The lowest point of operation might be taken as that point at which the grate just begins to turn red, as it comes over the water back. The upper limit is held within the capacity of the grate.

DISCUSSION

The performance of the boiler and furnace may be expressed in terms of weight of water evaporated per hour per square foot of heating surface. The results should be plotted against the pounds of coal burned per square foot of grate surface.

Combining the tests would give the relation between rate of combustion and draft pressure for a chain-grate stoker.

The performance of the boiler and furnace may be measured in terms of weight of water evaporated per hour per square foot of heating surface. The results should be plotted showing the pounds of coal burned per square foot of grate surface.

Combining the tests would give the relation between rate of combustion and draft (see Fig. 2 for a chain-grate stoker).

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