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

BY

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ARMOUR INSTITUTE OF TECHNOLOGY
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# RELATION BETWEEN RATE OF COM-BUSTION AND DRAFT PRESSURE FOR A CHAIN-GRATE STOKER APPLIED TO A 350 H. P. STERLING BOILER

## A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

#### ARMOUR INSTITUTE OF TECHNOLOGY

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MECHANICAL ENGINEERING

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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.

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It was with the spore identiculated that this thesis was started for thempt has to have been made in accurating the started and accurate heat balance might have been constructed, but sight to it is what infallence the draft and thickness of the really had upon its rate of accuration.

Forerer, after all apparatus had been installed, the coal and clay - : ived veriety of sizes and hirds, and there being no call for steam, the attempt was abardoned.

Tie enclosed repolt is them orly an expression of that is a really done in installiation of apparative and a projected network or procedure for some one to really actual desermination.

#### 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.

The tests mere to have been made ulor one or a pettacy of the located at the America Institute of Technology, at Chicago, Illinois. The loise is of a "terline type and consists mainly of three upper, or steen enums, and a large lover and dam . These sets of druns are connected by 2-1/4" inch, lap welled, mile steer tubes. The tubes are bort it the erds in such a say that they after the drug,s radiality. The inure are constructed of the hert quality of illance steel, and are ) rect 6 inches in temeter by 12 feet in isomth. Two hunused-lity water takes, and twenty mire tuber alocation surface of approximatile so , because the selilies spiring riaced, on the tubes direct the Lit of the heated ruses so that they have up the after pass, form the second, and across the tir case.

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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.

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Two firs doors are est thrown the bord work to practic inspection of the first in the Luceus and over the bridge wall.

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 showeled 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 1-placed in this breeching serves to regulate the draft in the furnace. It may be opened

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placed in this bresching sames to regalite the draft in the lineace. It has be duened

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 a 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 thense gravitates to the boiler room floor.

or slosed from the boiles now floor by released by the high the distantion.

The rest rater from the release of the heating system is piped to a sire tent. From this tank the mater is purped through a vectori meter, constructed by Tie Puiliars Iron & iouniry of, a the rest foundry of, the sater in the holler is easier.

The height of the water in the holler is deserbined by the use of the order of we're column.

The drain grade storer is overeine by a three horse power vertical steam evaine eated to a fack shaft. This shaft is commisted to a rocker and by means of an ecceptific not and a sai, sommution. The nocker and is familiated with a ratio t tourished with relation to the grade to the axis of a rotation of the grade family the ordinary requisited by the ordinary of the resting. The regulated by throttling the engine, or by regulated by throttling the engine, or by the grade of the rest is on agine, or by

goel is unloaded from the cars into bins, and they as recritates to the roller cool ilear.

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.

If is soorein into fin topper of the stoner by next.

ent abes dirp into a mit under the

#### 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 eq. feet .

Ratio heating surface to grate surface

1 to 42.5

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#### BDILER.

, relied to spor . ecut astaW 42. / inches. Dister of astal #10 . Jeef To.Si . 11ene is nimment Thickness of shell, 5/16 x 7/16 inches . FEE 13 SESMANI " Dec = 2/4 inches. esout to red yer 279 Pismitte of tures, (etteri), senut to resumain Disreter of tunes, (octatio) 2.70 inches . serioni c teel closings new level to dimens. There were directly area central drya. Villa of grate, Gr. m Chain fre's Stoker. Ties or grate, Width W It, Learth 9 Lt. 2 in. tras of grate surface , ecalinus eters lo sert Perting surface of holler, 99, sq. Lest. habic heating oldays tu 2.54 117 4 eugline ed. To

#### BRICK BOILER SETTING

Height, 18.5 feet.

Width, 13 feet.

Length, 22.75 feet.

BOILER PUMP .

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

VENTURI METER.

Make, Builders Iron Fdy. Co.

Size, Indicating & recording.

Diameter, (Inlet) 3"inches.

Diameter, (Throat) 1 inch.

# BRITH BOILDR STORING.

Heirst, 10.5 sest.

Width, 19et.

Temath, 22.70 1986.

, 9239 - 330E

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

#### . " THE LACT DA

lars , Puilders Iron Fity. Co.

Size, Indicating & reporting.

Timmetus, (Iniat) 2"incres.

Dianeter , (Taroat) linch .

#### 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

A rigid inapartion of the boiler setting THE PROPERTY OF THE PARTY OF THE PERMITTER UP wein' e't at a paro en' .eldiesog ea nei ee settings, and sanings along the siles -Joennoo Ile bouous for commatate etam ent lo ions to the interior or the purpage, cemented over with the clay. The doors to the bridge wall and grate were removed, and the chering comerced with a sheet of 1,2 inch ishastos. "ecalo mi deede aodaedes edd maidto stale" the suilide xposed to the heat was covered with a thick layer o. tire-proofing. This od tination ve then held in older over the door opening by shall laching sorers set into the metal irans rank of the door. The went siar feeds an impose ent fruot, an mis read with tire-propriet. The surer preemsk el ti dre terg of soked ew w emidise as L'ar as nossible.

The advantes overing for the Good over the life 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 CO2 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.

posming the note small around to be litted vill a one-talf inch pipe plur. Trough this openion it was proposed to ire; the commedian to the UO, ansarstra, to obtain the sample of gas over " a rice for an applied st The second op mior was about three inches id federes for the , most estend include the Mate a swinning sorner of sheat mile. "he elect or gios was entitioned in reacto coursetely pover the openior at paralle no read through leading around the earse. Through this injuration it was proposed to take the course ature of the life. A Fery parameter ve wet up, the lice server smarto one site lor an instant, and the pyroneter locused on the Lic. The talperature resulting and .- ii. the relyanoustir. The resider of the tempernthice of the line should the plant and .fahado-a r. of sysh shouther subjust andio ale in order to privert sir learene.

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.

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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.

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## 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

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energy and the second service of the service of the

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 uptaks.

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

Pressures,
Farometer.
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).

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The the above conditions have been attitied, the hopper of the etucer who he had the tells of the fill of the hill of the fello increedings

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Pressures Farometer. True Roller.

Weir in, gourns per hour,

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lot viiily:
Theres of fire (for short fir run)
Lord of wise, is of finite.
List, and the fire of it way.
Therefore of the fire of it way.
Lacke observations (indicate fire).

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 CO2 content. If no CO2 recorder is available, the analyses should be made at intervals not exceeding

Production must be taken to provide for an ample excess of the hollow root.

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The chaeser tions as repeats to the condition of line should be watched warp carefully.

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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.

Live rirutes. Include about the ret heapstern percent at any table.

Several note should be note with the levent lines of whit, verying the facts of the draft of the draft, and speed of restellor son with or open.

Fats of exectly level, and intring photograph showled that the site and intoher the terms of the condition.

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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 combustion rate decreases as rapidly at the lower pressures. A set 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.

The value catalorus and average printed in the value catalorus and average printed in the value of the course time of the decrease in draft. This is proportion to the deat of and a large that the form of the of an inch of art of in the furn os, but it is doubted if the original or the original or the original or the decreases as each by a time decrease as each of the action of the action of the action of the action of the decrease and the continuous of the action of the act

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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. 4 ...

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