Study of a Suction Gas Producer

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A STUDY OF A SUCTION GAS PRODUCER.

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I N D E X

A STUDY OF A SUCTION GAS PRODUCER.

In making this study it was desired to determine under what conditions of operation the gas made in a suction gas producer varies in power producing constituents, and in what manner the percentage of these constituents varies. It was not expected that the conditions could be investigated fully, but it was desired that at least, most of these conditions would be determined, so that they could be fully studied at a future time.

The plant studied is owned and operated by the Cole Manufacturing Company, at 32d Street and Western Avenue, Chicago, and was installed by the Otto Gas Engine Works of Philadelphia, Pennsylvania.

This study was made possible by the courtesy extended by the Cole Manufacturing Company in permitting the work to be carried on in their plant. To the superintendent, Mr. South, and to the engineer, Mr. Coleman, this work is indebted for their assistance in every way possible. To the Otto Gas Engine Works, credit is due for the use of a four inch gate valve.

A diagrammatic view of the plant is shown in blue print form. It consists of the generator, the vaporizer, scrubber, a small storage tank, and the engine. The gas producer is rated at ninety horse power, while the engine is rated at sixty horse power.

The generator is a plate iron vessel, four feet six inches at its greatest diameter, and seven feet high with a nine inch fire brick lining. The magazine and charging

A [illegible].

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A diagrammatic view of the plant is shown in blue print form. It consists of the generator, the vaporizer, scrubber, a small storage tank, and the engine. The gas producer is rated at eighty horse power, while the engine is rated at sixty horse power.

The generator is a plate iron vessel, four feet six inches at the greatest diameter, and eleven feet high with a nine inch fire brick lining. The magazine and charging door are shown on the top of the generator in the blue print. A grate is provided near the bottom, beneath which is the ash pit. A door is provided at either side on a level with the grate, and another just below the grate. This permits cleaning the grate from above and below. In cleaning the grate while in operation, it was customary to clean it from the bottom, but in the morning and evening it was cleaned at the top.

The vaporizer consists of an iron shell through which the hot gases must pass. A baffle plate in the middle makes the gas go first to the bottom of the vaporizer and then out at the top on the other side. On top of this shell is mounted an iron vessel, to which are attached iron tubes which extend down into the shell just described. These tubes are full of water. The vessel itself, contains about two inches of water. This vessel also has a pipe marked "Air Supply", which opens to the air and another, connecting it with the ash pit of the generator.

The scrubber consists merely of an iron shell filled with coke from the perforated plate near the bottom to the dotted line near the top. A pipe marked "Water Supply", is connected to the city mains and supplies the scrubbing water. The cylindrical vessel between the scrubber and the engine is a small storage and equalizing tank. It was at the elbow leading into this tank that a four inch pipe was connected in making the study of a draft equalizer.

The engine has a fourteen by sixteen inch cylinder, and is of the hit and miss type. It makes 210 revolutions per minute. It is started by means of compressed air.

The apparatus used for gas analysis, consisted of a complete set of the Moorehead burette and all its auxiliaries, door as shown on the top of the generator in the blue print. A grate is provided near the bottom, beneath which is the ash pit. A door is provided at either side on a level with the grate, and another just below the grate. This permits cleaning the grate from above and below. In cleaning the grate while in operation, it was customary to clean it from the bottom, but in the morning and evening it was cleaned at the top.

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The scrubber consists merely of an iron shell filled with coke from the perforated plate near the bottom to the dotted line near the top. A pipe marked "Water Supply", is connected to the city water and supplies the condensing water. The cylindrical vessel between the scrubber and the engine is a small storage and equalizing tank. It was at the elbow leading into this tank that a few [illegible] occurred in making the study of a draft equalizer.

The engine was a [illegible] by [illegible] inch cylinder, and is of the hit and miss type. It makes [illegible] revolutions per minute. It is started by means of compressed air.

The apparatus used for gas analysis, consisted of a complete set of the Hempel burettes and all its accessories, and the necessary chemicals; a transfer pump; acid bottles fitted with rubber stoppers, glass tubing, and rubber tubing so that a sample of the gas could be pumped into the bottles and stored there for sometime if necessary; a thermometer, and three manometers.

The plan at the outset was to study the manner of operation and determine the probable causes of variation of the gas, and finally determine whether the gas actually does vary as a result of these apparent causes

Whenever an event occurred which was to be studied, a sample of the gas was taken and its composition compared with that taken when conditions were normal.

Referring to the diagrammatic view, when the plant is in operation, the only inlet for air is through the "Air Supply" pipe, and the only outlet is through the engine. The entire draft is created by the suction of the engine and is periodic. When the engine takes gas a suction is created and air enters through the supply pipe.In the vaporizer it becomes somewhat preheated and picks up some water vapor. It then passes into the ash pit and up through the grate into the fuel bed. Here it unites with the hot coal causing combustion and producing carbondioxide gas (CO_2), at the same time generating heat. This burning takes place in the fuel bed, extending from six to ten inches above the grate, and is known as the "zone of combustion". The heat here generated heats the bed for some distance above to redness. This part of the fuel bed is known as the "zòne of reduction". In passing through this red hot bed of coal, most of the carbondioxide is reduced to carbon-monoxide, taking carbon from the hot coal.

and the necessary chemicals; a [illegible] with rubber stoppers, glass [illegible], [illegible] sample of the gas could be passed [illegible] there for analysis if necessary; a thermometer, and a manometer.

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The [illegible] as [illegible] sample of the gas was taken and its composition [illegible] that taken when conditions were normal.

Referring to the diagram [illegible]. When the [illegible] in operation, the [illegible] pipe, and the [illegible] draft is produced by the [illegible] then the [illegible] through the supply pipe. [illegible] preheated and [illegible] the ash pit and [illegible] through the [illegible] it unites with the hot coal [illegible] carbon dioxide gas (CO_2), or [illegible]. This burning takes place in the [illegible] to ten inches above the grate, and is known as the "zone of combustion". The [illegible] distance above [illegible] to the "zone of reduction". [illegible] bed of coal, most of the [illegible] carbon monoxide, [illegible] from the hot coal.

The hot gas from the generator passes on to the vaporizer. In passing through the vaporizer it gives up most of its heat to the water in the pipes, thus causing the water to vaporize and also topreheat the air going into the generator. From here, the gas passes into the bottom of the scrubber. In passing upward through the scrubber it is met by a spray of water from the"water supply", which cools the gas and washes out particles of ash and tar. This water is drained off at the bottom through a water seal. The gas then passes on to the engine.

There is also some water in the ash pit which forms a water seal. This water is heated by ash falling from the grate, and by the grate itself. The air which has picked up some moisture in the vaporizer, is here further preheated, and supplied with more moisture. The steam thus carried into the fuel bed is decomposed, forming hydrogen and carbondioxide, thus enrichingthe gas. This reaction takes place in the zone of combustion so that the carbondioxide is again reduced in the upper zone. The decomposition of steam absorbs heat and hence this reaction tends to reduce the temperature of the generator. For this reason there is a limit to the steam to be used. Too much hydrogen is bad for the engine, on account of preignition and too rapid explosion. If not enough steam is used, the fire becomes too hot and clinkers are formed. Addition of steam softens these clinkers and makes them brittle. The steam then cools the grate, cools the fire, thus preventing, or at least moderating clinkers, furnishes hydrogen, and furnishes oxygen for more carbon monoxide, but its use is limited on account of too much cooling, and on account of the

effect of too much hydrogen on the engine.

The action of steam on hot carbon also causes formation of marsh gas. At least a dozen tests were made for this gas, but never more than a trace could be found so that the record is not given at all. Some illuminants are present to the extent of a trace only, and were similarly omitted.

Fuel was fed into the feeder at regular intervals. Through a hole in the cover on the feeder the coal and ash and clinker were poked down from the top. The grate was also cleaned at regular intervals. These each seemed to have an effect on the gas.

The following studies finally resulted:-

Effect of scrubber.
Effect of tending furnace.
Effect of no load with blast on.
Effect of temperature of ingoing air.
Effect of accumulation of clinker.
Amount of carbon left in ash.
Study of draft equalizer.
Effect of increased load.

Referring to the "General Data", this is a tabulation of the data in the order it was taken, and explains itself generally. Under the column "Sample Taken B.S." and "A.S." refer to "Before Scrubber", and "After Scrubber", respectively. In calculating the heat units per cubic foot, 340 B.t.u. per cubic foot were used for both hydrogen and carbonmonoxide. Two values are given at 62° F. and 32° F. The first is the temperature at which gas is usually taken into the engine, and is practical, while the second is the one usually given as the standard. The difference is one due to density.

Effect of [illegible] much hydrogen on the engine.

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Fuel [illegible] the [illegible].

Through a [illegible] clinker were [illegible] from the [illegible]. The [illegible] cleaned [illegible]. None such seemed to have [illegible] effect on the gas.

The following studies finally resulted:-

Effect of [illegible].
Effect of [illegible] Furnace.
Effect of [illegible] with blast [illegible].
Effect of [illegible] of [illegible] size.
Effect of [illegible] of clinker.
[illegible] of [illegible] left in ash.
Study of [illegible].
Effect of [illegible].

Referring to the "General Data", this is a tabulation of the data in the [illegible] it [illegible] and [illegible] itself generally. Under the [illegible] "[illegible]" [illegible] and "[illegible]" refer to "[illegible]", [illegible] respectively. In calculating the heat units per cubic foot, [illegible] per cubic foot were used for both hydrogen and [illegible]. The values are [illegible] at [illegible] F. [illegible]. The first is the temperature at which gas [illegible] into the engine [illegible] is practical, while the second [illegible] the one usually given as the standard. The difference is not due to [illegible].

EFFECT OF SCRUBBER.

Object:- All gases are soluble in water to a greater or less degree.

CO_2,	one cubic foot in one cubic foot of water.	(From
O_2,	0.03 " " " " " " " "	(Newth's
CO,	0.03 " " " " " " " "	(Inorganic
H_2,	0.019 " " " " " " " "	(Chemistry.
N_2,	0.015 " " " " " " " "	(

A study was made of the change in the composition of the gas in passing through the scrubber, and whether or not it would be adviseable to use more water.

Method:- A sample of the gas was taken just before it entered the scrubber, and as soon as it had passed through the scrubber another sample of it was taken. The analysis of the two were compared for any difference that might exist.

Data:- See Table I.

Discussion:- From the above table it would appear as though it would be possible to dissolve out all the carbondioxide by the use of enough water, since this constituent is much more soluble than the others. Time, however, is also an element here. The time required for the gas to pass through the scrubber is very short and hence solution is small, the rate of solution of CO being the lowest. According to the laws of gas pressure, each constituent present in a mixture of gases is present at its own respective pressure, i.e., in the case of analysis #1, CO_2 forms 8.2 percent of the total volume of the gas and therefore is present at 8.2 percent of atmospheric pressure, and hence one cubic foot of water would dissolve only .082 x 1 cubic foot of CO_2 at atmospheric pressure. Nitrogen is present to the extent of 57 percent, and therefore, one cubic foot of water will dissolve 0.57 x.015

cubic feet or 0.0086 cubic foot of nitrogen. From the above, it will be seen that there ought to be a loss in the percentage of CO_2 present.

Referring to Table I, analysis #1 and #2 of gas taken at 10:15 and 10:20 A.M. respectively, there is a difference of 0.8 percent CO_2 in the gas, and this is a decrease in passing through the scrubber. Oxygen also decreased. CO increased. There is a decrease of 5 percent in hydrogen. This is abnormal for hydrogen and cannot be accounted for by absorption. Sample #2 stood in a bottle under pressure having rubber tube connections. Hydrogen will pass through rubber, so that this may account for some of the loss. It will be noticed also by referring to the general data, that the percentage of hydrogen varies more than the percentage of the other constituents present. These two facts will at least fairly well account for the loss in hydrogen. Analysis #19 and #20 show a similar condition, CO_2 and hydrogen decreasing and the balance increasing. The heat values in both cases decrease. This is due to the loss in hydrogen and should not be charged against the scrubber, but to the length of time the sample stood before analysis.

Much difficulty was experienced in taking the sample before scrubber, on account of the ash in the gas which clogged the valves of the pump so that this work had to be abandoned for others which could be carried out more satisfactorily.

Conclusions:- The data taken is not extensive. It does appear as though the gas is actually improved in heat giving constituents and as though the quantity of water in the scrubber should be as large as possible, with other conditions of the plant. The subject will bear further investigation and if such

an investigation is made, it is suggested that a siphon be used instead of a pump to take out the gas and also that it be analyzed as speedily as possible.

EFFECT OF TENDING FURNACE.

Object:- Prof. MacFarland suggested a study of the effect on the composition of the gas of cleaning the grate, poking the fire from the top of the furnace, and of filling the feeder. It appearedthat the gas was weakened by each of these events and this study was to determine, if possible, what the effect is.

Method:- The time of either event was noted, and as soon thereafter as it was believed that the effect would be perceptible at the engine, the sample of gas was taken. These analysis were compared with the analysis for the day, and results noted.

Data:- Table II.

Discussion:- Referring to the diagrammatic view of the plant, it will be seen that in order to fill the feeder it is necessary to open the top of the magazine. This means that air can enter the top of the generator and that the amount of air admitted will be inversely proportional to the resistance offered by the coal in the magazine. If the gases in the top of the producer are hot enough to ignite, this means an increase in CO_2, a decrease in CO, and a decrease in hydrogen. If the gases are not hot enough to ignite, then there should be an increase in oxygen and nitrogen.

Poking should cause an increase in CO_2 because the top of the fuel column becomes cooled, due to the settling of the coal and thus fails to so reduce the CO_2 to CO as it should. After sometime when the settled coal has had time to become ignited, the gas ought to be better, both on account of the

distillation of what volatile matter is present and on account of the increase of the hot fuel bed.

In cleaning the grate it is necessary to open the doors at the bottom. This practically cuts off the circulation of air through the vaporizer, and hence cuts off most of the supply of moisture, and ought to cause a reduction in the hydrogen content. Cleaning the grate also causes the fuel column to settle and this as already shown above, should cause an increase in CO_2 and a decrease in CO.

Conclusions: Referring to Table II, sample #6 is considered normal for the day. The feeder was filled and the fire poked at 9:30 and the sample taken at 9:35 A.M. There was less CO_2 in the sample taken five minutes after these events than was normal. Oxygen, however, increased, showing the cooling effect at the top of the furnace. Hydrogen is higher, showing that moisture was effected. In sample #7, all events were contrary to expectations except oxygen, which was higher. On Aug. 15th theory and practice agreed more closely. Sample #10 is taken as normal. Poking was started at 11:00 and cleaning the grate at 11:02. Four minutes were consumed in taking sample #11, starting at 11:01 and ending at 11:05. The analysis of this sample shows an increase in CO_2, increase in oxygen, decrease in CO, and a decrease in hydrogen. The heat value was also decreased. Sample #12, taken from 11:06 to 11:08 shows more CO_2, less oxygen, less CO, but more hydrogen, and a greater heat value. It will be seen that the hydrogen doubled itself. This is probably due to an accumulation of steam in the vaporizer while the grate door was open and which became effective distillation of most volatile matter is retarded on account of the increase of the [illegible].

In operating the retort it is necessary to open the doors at the bottom. This necessarily cuts off the circulation of air through the vaporizer, and hence cuts off most of the supply of moisture, and ought to cause a reduction in the hydrogen content. [illegible] the [illegible] causes the fire [illegible] to settle and this is already shown [illegible], which gives an increase in CO and a decrease in CO_2.

Conclusions: Referring to Table II, sample 81 is considered normal for the day. The fire was filled at [illegible] the gas passed at [illegible] and the sample taken at [illegible]. There was less CO in the sample taken five minutes after [illegible] was normal. Oxygen, however, increased, showing the cooling effect at the top of the furnace. Nitrogen is higher, showing that nitrogen was affected. In sample 82, all [illegible] except oxygen, which was higher. [illegible] theory and [illegible]. Sample 83 is taken as normal. [illegible] at 11:[illegible] and [illegible] at 11:[illegible]. Four minutes were allowed to [illegible] sample [illegible], starting at 11:[illegible] and ending at 11:[illegible]. The analysis of this sample showed an increase in CO, [illegible] in oxygen, decrease in CO_2, and a decrease in hydrogen. The heat value was also decreased. Sample 84, taken from 11:[illegible] to 11:[illegible], shows [illegible] CO_2, less oxygen, less CO, but more hydrogen, and a greater heat value. It will be seen that the hydrogen [illegible] itself. This is probably due to the [illegible] of steam in the vaporizer until the [illegible].

at once when the grate door was closed.

On August 17th sample #14 was taken as normal. Sample #15 was taken four minutes after the second event. Here expectations were borne out except hydrogen, which increased probably on account of the accumulation of steam in the vaporizer. In sample #16, taken four minutes after the second event, expectations were all fulfilled.

The predictions then in general are borne out, namely, that cleaning the grate, filling the feeder, and poking from the top effect the gas for a short period of time, and that that effect is a decided weakening of the gas.

EFFECT OF NO LOAD WITH BLAST ON.

Object:- It was necessary in this plant to throw off the load for a short period of time, about fifteen minutes during the noon hour so that certain bearings on the line shaft could be oiled. It was found that when the engine ran "light", the gas became so weak that the engine would not run on it even with no load. For that reason the fan was started, the air from the vaporizer shut off and the blast from the fan admitted to the generator. The object was to determine the effect of this blast on the gas.

Method:- On August 13th, a sample was taken while the air pressure was being applied, so that this sample is really a mixture of the gas already being produced, and that affected by the blast. This sample was compared with the normal. On August 14th a sample was taken just before the load was removed, and another just before the load was again applied. On August 20th, a sample was taken just before the load was again applied, and this compared with the normal sample.

Data: Table III.

Discussion:- When the load is removed from the engine, the number of explosions decreases and hence the number of intakes of gas also decreases, so that the amount of air drawn through the generator decreases in proportion to the decrease in load. The amount of heat generated in the zone of combustion of the generator decreases while the radiating surface of the generator and vaporizer remain constant. The result is a cooling of the reduction zone of the generator, and a cooling of the vaporizer. The first condition causes less reduction of CO_2 to CO, while the second causes less steam and hence less hydrogen.

By closing off the steam supply from the vaporizer and then turning on the blast after opening the escape pipe at the engine, the combustion in the generator was increased. This meant increased heat in the zone of reduction, and hence more reduction of the CO_2 to CO. Cutting off the vaporizer meant only the admission of the meager supply of steam generated in the ash pit of the generator and hence little hydrogen.

Conclusions:- Referring to Table III, under date of August 13th, the above predictions seemed to be realized. The increase in CO more than offset the decrease in hydrogen, so that the heat value of the gas actually rose. On August 14th, the samples were taken just before and just after the change respectively. CO increased slightly, but hydrogen dropped more than one-half. The reduction in heating value is very marked. On August 20th, the results as to hydrogen were anticipated. At this time the accumulation of clinker had advanced to an agrivating state, so that much of the CO_2 probably never passed through a hot carbon bed. There also was an excess of air which would have

Data:- Table [illegible].

Remarks:- When the load is removed from the engine, the number of explosions increases and hence the number of charges of gas also increases, so that the amount of air drawn through the generator decreases [illegible] to the increase in load. The amount of heat generated in the zone of combustion of the generator decreases while the [illegible] [illegible] of [illegible] and vaporizer [illegible] constant. The result is a reduction [illegible] of the generator, and a cooling of the vaporizer. The first condition causes less reduction of [illegible], while the second causes less steam and hence less hydrogen.

By closing off the steam supply from the vaporizer and then turning on the blast after running the engine [illegible] minutes, the [illegible] in the generator was increased. This result increased the [illegible] of combustion, and the reduction of the CO_2 to CO. Shutting off the vaporizer [illegible] only the admission of the [illegible] supply of steam generated in the [illegible] of the [illegible] and hence little hydrogen.

Conclusions:- Referring to Table [illegible], [illegible] August 13th, the above predictions seemed to be verified. The increase in [illegible] more than offset the decrease in hydrogen, so that the heat value of the gas actually [illegible]. On August 14th, the [illegible] were found that [illegible] part after the [illegible] respectively. [illegible] increased slightly, but hydrogen [illegible] than one-half. The reduction in heating value is very marked. [illegible] the results as to hydrogen were anticipated. At this time the accumulation of clinker had advanced to an alarming state, [illegible] that [illegible] of the [illegible] probably [illegible] carbon bed. [illegible] also [illegible] excess of [illegible] caused a burning of the hot CO in the top of the generator. There is no question about the reduction of hydrogen in this case. The amount of CO will increase unless a condition similar to that on August 20th, sets in. The heat value of the gas usually declines considerably. The gas remains rich enough to keep the engine running.

EFFECT OF TEMPERATURE OF INGOING AIR.

Object:- Referring to the early part of this study as shown in the general data, it will be noticed that the percentage of hydrogen fluctuated very much. At that time the temperature of the air was changing by jumps of ten to fifteen degrees from day to day. In trying to account for these fluctuations in the hydrogen values, it appeared that the temperature of the ingoing air determined, at least partly, the percentage of hydrogen present by its ability to carry moisture into the fuel bed. It was desired to record the temperature of the air entering the ash pit of the generator.

Method:- A hole was drilled through the movable plate shown at "A", in the diagrammatic view of the plant, and a rubber cork inserted. A thermometer was inserted through this cork so that the bulb of the thermometer was situated near the center of the pipe. From this thermometer the temperatures were recorded as indicated in the data. The temperatures of the outside air were not recorded, but these temperatures varied about the same amount as those recorded. A curve was plotted using temperature as abscissae and percentage of hydrogen as ordinates.

DATA.

Date	Time of Reading.	Temperature.	Time of Taking Sample.	Percent Hydrogen.
August 20th	10:20	135	10:10	11.9
" 20th	11:40	144	-----	----
" 23d	10:48	142	10:50	12.9
" 23d	11:50	144	11:50	12.7
" 24th	11:00	118	11:20	10.3
" 24th	11:50	126	11:55	10.5
" 28th	11:10	106	10:40	9.4
" 30th	10:30	127	10:40	12.4
September 1st	11:45	145	11:40	11.4

Discussion:- It will be noted that the air entering the generator must first pass through the top of the vaporizer. In doing so, the air becomes somewhat preheated in the vaporizer, while, at the same time, it takes up moisture. The amount of moisture taken up will depend both on the temperature of the air and on the temperature of the water. If the air is cold when entering the vaporizer, it will take up more heat from the water, thus tending to keep the water cool. It will leave the vaporizer at a lower temperature and hence carry less moisture. This means less hydrogen. The insertion of a thermometer at A, gave the temperature of the air as it entered the generator. By comparing this temperature with the percentage of hydrogen generated, the relation should be established.

Referring to the curve drawn, it will be seen that there is a rise in percent of hydrogen present with increase of temperature of ingoing air. The variation in temperature

is not great, but it does indicate that the higher temperatures of the ingoing air will cause the generating of more hydrogen. Subsequent commercial work of the writer in which the temperature of ingoing air was noted, confirms the above conclusions.

EFFECT OF ACCUMULATION OF CLINKER.

Object:- In this plant the fire was raked out of the generator at the end of every two weeks. It was stated that the gas became weak on account of the clinker which accumulated on the walls of the generator. It was determined to analyze one or more samples of the gas each day, in order to determine just what effect this clinker had on the gas from day to day, during one of these two week periods.

Method:- One or more samples were taken each day at a time when conditions were normal. If more than one sample was taken on any day for this purpose, then the mean value of those analysis was taken as the sample for that day. These were tabulated. Curves were plotted, using percentage of CO_2 and CO as ordinates and time as abscissae. During the following week a sample was taken every second day and treated as before. This second series was taken merely as a sort of check on the first series. After the fire had been raked out on August 25th, the walls of the generator were examined to ascertain approximately, (for the walls were hot), the form and thickness of the clinker.

Data: Table V.

The thickness of the clinker at the thickest point as shown in the diagrammatic view, was between four and five inches and extended completely around the walls of the generator. Its general vertical form along the walls of the generator is shown by the dotted line marked "clinker line" in the generator is not great, but it does indicate that the [illegible] of the [illegible] will cause the [illegible] of [illegible]. Subsequent [illegible] of the [illegible] in which the [illegible] of [illegible] was [illegible], confirms the above [illegible].

[illegible]

Object:- In this plant the fire was raked out of the [illegible] at the end of every two weeks. It was [illegible] that the [illegible] second week on account of the [illegible] which [illegible] the walls of the generator. It was [illegible] to analyze one or more samples of the gas each day in order to determine just what effect this clinker had on the gas from day to day, during one of these two week periods.

Method:- One or more samples were taken each day at a time when conditions were normal. If more than one were taken on one day for this purpose, then the mean value of these analysis was taken as the [illegible] for that day. These were tabulated. [illegible] and [illegible]. [illegible] were taken every [illegible]. This [illegible] as a [illegible] of [illegible] on the [illegible]. After the fire had been [illegible], the walls of the generator were [illegible] (the walls were hard), the [illegible] of the clinker.

Data: Table V.

The thickness of the clinker at the [illegible] point as shown in the diagrammatic view, was between four and five inches and extended completely around the walls of the generator. Its general vertical form along the walls of the generator is shown by the dotted line marked "clinker" [illegible] in the diagrammatic view. Nearly all of this clinker was very hard. In some instances small portions of the fire brick were broken off with pieces of clinker.

Discussion:- The accumulation of clinker in this form is bad because it affects the heating value of the gas, and because in knocking down this clinker portions of the fire brick lining are also broken off. Of the constituents in producer gas, carbon monoxide is the most valuable. When air enters the bottom of the generator into the zone of combustion carbondioxide is formed there. If this carbon dioxide passes through a bed of hot carbon it will be reduced to carbon monoxide according to the equation

$$CO_2 + C = 2\ CO$$

The extra carbon being furnished by the red hot coal in the zone of reduction. If, though, some of this carbondioxide does not pass through a bed of hot coal it will appear in the resulting gas as carbondioxide.

Referring to the diagrammatic view, it will be seen that there is a space extending a few inches above the grate which is free from clinker. This is because the engineer can easily reach all this space from the grate doors with a hook poker. During operation, this space is filled with burning coal. As air enters the grate and passes into this zone, carbondioxide is formed, just beneath the clinker as well as in the middle of the generator. The clinker is porous and offers about the same resistance as the hot coal in the inside of the clinker ring offers to the passage of the gases. The carbondioxide then formed under this clinker ring will pass through the clinker and never reach the hot coal in an [illegible]. Nearly all of this clinker was very hard. [illegible] some instances small portions of the fire brick were broken off with pieces of clinker.

Discussion :- The accumulation of clinker in this case is bad because it affects the working value of the gas, and because in knocking down this clinker portions of the fire brick lining are also knocked off. Of the constituents of producer gas, carbon monoxide is the most valuable. The air enters the bottom of the generator into the zone of combustion carbondioxide is formed there. If this carbon dioxide passes through a bed of hot carbon it will be reduced to carbon monoxide according to the equation

$$CO_2 + C = 2 CO$$

The extra carbon being furnished by the red hot coal in the zone of reduction. If, however, some of this carbondioxide does not pass through a bed of hot coal it will appear in the resulting gas as carbondioxide.

Referring to the diagrammatic view, it will be seen that there is a space extending a few inches above the grate which is free from clinker. This is because the engineer can easily reach all this space from the ash pit with a [illegible]. During operation, this space is filled with burning coal. The air enters the grate and passes through this coal, carbondioxide is formed, [illegible] the clinker as well as in the middle of the generator. The clinker is porous and offers about the same resistance as the hot coal in the inside of the clinker ring [illegible] the outside of the [illegible]. The carbondioxide then formed [illegible] will pass through the clinker and never reach the hot coal in the zone of reduction which is confined to the inner part of the generator. From this, it also follows, that if this clinker ring increases in thickness then the percentage of CO_2 remaining unreduced will increase and correspondingly of course, the percentage of carbon monoxide will decrease.

It does not appear as though the hydrogen could be similarly affected. The steam is decomposed upon entering the fuel bed at the bottom according to the equation

$$2\ H_2O + C = CO_2 + 2\ H_2$$

If the quantity of steam furnished remains constant, there should not be any change from this source. The carbondioxide thus formed is reduced or fails to be reduced in exactly the same manner as the carbon dioxide formed by combustion.

Conclusions:- Referring to the curves for the effect of the accumulation of clinker, rings indicate points on the curves for the two week series of analysis, while the short lines are points on the curves for the six day series.

The curves for carbondioxide shows a constant increase with time. The decrease in carbonmonoxide is slightly less the latter half of the period. The sum of the two increases very slightly with the time. For the second series in which there are only three points on each curve, the curves are drawn from point to point instead of taking the mean value as in the first series. They do, however, follow the same general direction as the first set.

Referring to Table V, it will be seen that the hydrogen remained fairly constant. During the first few days the values are low, but that could not have been due to the clinker, since the hydrogen is practically constant after the third day.

in the zone of reduction which is confined to the lower part of the generator. From this, it also follows, that if this clinker [illegible] increased in thickness [illegible] the percentage of the remainder produced will increase and correspondingly [illegible] the percentage of carbon monoxide will decrease.

It does not appear as though the hydrogen would be similarly affected. The steam is decomposed upon contact with the fuel bed at the bottom according to the equation:

$$C(H_2O) + H = CO + 2H_2$$

If the quantity of steam introduced remains constant, there should not be any change from this source. The carbon dioxide thus formed is reduced on falling to the [illegible] exactly the same manner as the carbon dioxide formed by combustion.

Conclusions.- Referring to the curves for the effect of the accumulation of clinker, [illegible] for the [illegible], while the [illegible] are [illegible] on the curves for the [illegible] series.

The curves for carbon dioxide show a constant increase with time. The increase is [illegible] in the latter half of the period. The [illegible] very slightly with the [illegible]. From the second series, in which there are only three points on each curve, the curves are drawn from point to point instead of taking the [illegible] as in the first series. They do, however, follow the same general direction as the others.

Referring to Table V, it will be seen that the [illegible] remained fairly constant. During the first [illegible] the [illegible] are low, but [illegible] could not have been [illegible]. Since the hydrogen is practically constant after the [illegible].

The effect of accumulating clinker is then to raise the carbondioxide constituent and lower the carbonmonoxide value. It does not effect the hydrogen.

In subsequent work of the writer in which similar conditions prevailed, the results were identical with the above.

AMOUNT OF CARBON LEFT IN ASH.

Object:- It was decided to determine the amount of fixed carbon left in the ash and its relation to the original amount of fixed carbon in the coal used.

Method:- In cleaning the grate, while the producer was in operation, the engineer raked the grate from underneath leaving the ash fall into the water in the ash pit. This was cleaned out each morning and a sample taken. Every morning and evening in cleaning the grate the ash and clinker were raked off the top of the grate until clean hot coal appeared. This ash was raked onto the cement floor, allowed to accumulate for several days, and then screened. The screenings were again used. A sample of the ash thrown away was taken. A sample of the clinker taken from the producer on the last day was also analyzed. To get the mean fixed carbon left, the mean of all the samples was taken. An analysis of the coal was made and its calorific value determined.

The percent of the original fixed carbon left in the ash was found as follows:

100 - 37.58 = 62.42 = percent of ash in ash.
62.42 ÷ 8.9 = 7 = number of pounds of coal represented by one pound of ash taken from producer.
7 x .8496 = 5.9472 = number of pounds of fixed carbon put into producer for each pound of ash taken from producer. But each pound of ash taken from the producer contains .3758 pounds of fixed carbon.
Therefore, .3758 ÷ 5.9472 = .063 = 6.3% = percent of original carbon in coal left in the ash.

The [illegible]

[illegible]

I [illegible] the [illegible].

It [illegible] of the [illegible] in which [illegible]

conditions prevailing, the [illegible] with the [illegible].

[illegible]

Object:- It was decided to determine the amount of [illegible] left in the ash and its relation to the [illegible] applied in the [illegible].

Method:- [illegible] the ash, [illegible] operation, the [illegible] the ash [illegible] into the [illegible] of the ash [illegible]. This was [illegible]

[illegible]

[illegible] the [illegible]

[illegible]

[illegible] of the ash [illegible]

[illegible]

[illegible]

[illegible]

The [illegible]

[illegible]:

[illegible]

DATA.

Date	Where Taken	Percent Carbon
August 13th	Ash Pit	37.92
14th	"	44.00
15th	"	40.20
16th	"	No Sample.
17th	"	38.20
18th)) 19th)	"	22.44
20th	"	45.36
21st	"	36.72
22d	"	42.40
23d	"	39.08
24th	"	39.24
August 13th to 17th incl.	Grate.	48.76
20th to 24th "	"	38.01
Clinker from sides of producer at end of run		39.24
Mean value		37.58

COAL.

Moisture - - - - - - - - - - 1.03

Volatile Matter - - - - - 4.01

Fixed Carbon - - - - - - - - 84.96

Ash - - - - - - - - - - - - 8.90

Calorific Value - - - - - 12,970 B.t.u. per pound.

Percent of original Fixed Carbon Left in Coal - 6.3

B.t.u. left In Ash (Calculated) - - - - - - - - 916

Percent of Original Heat Energy Left In Ash - - 7.06

The amount of fixed carbon in the coal at first seems excessive, but when calculated in terms of the original coal, it is not excessive.

The engineer stated that the average amount of coal used was 2600 pounds per week including stand-by losses. The plant delivers approximately, 25 horse power for six days of ten hours each week. This would be equivalent to 1.73 pounds of coal per horse power per hour. With coal at $4.00 per ton this would be equivalent to .346 cents per horse power per hour.

STUDY OF A DRAFT EQUALIZER.

Object:- Reference to the general table will show that the greatest manometer reading is 6 inches, and was at C, while that at B was 5 inches, and that at A was 2 inches. These were maximum readings and were only instantaneous. The draft varied from zero to a maximum and back to zero again in each case.

The engine made 210 revolutions per minute and therefore used less than one-seventh of a second in taking a charge of gas. If the engine were carrying full load it would make 105 explosions per minute so that the draft would exist one-fourth of the time in the producer and that it would come in 105 installments of one-seventh of a second each. Prof. MacFarland suggested a method by which this draft might be equalized so as to get a more nearly continuous draft. This study was not intended to perfect the idea, but merely to get data to demonstrate

whether or not the idea was a good one, and if so, along what lines to continue trials.

Description:- Referring to the diagrammatic view of the plant, a connection was made at the elbow of the pipe leading into the small storage tank between the scrubber and the engine. A four inch pipe was used and was led into theequalizer as shown in the equalizer diagram. The valve shown was a gate valve. The equalizer consisted of a wooden tank about ten inches deep and made by puttying up a shipping box. Then about seven inches of water were put into the tank. The four inch pipe extended about six inches above the surface of the water and opened upward. Over this was placed the top of a sterilizer, eleven inches in diameter, as shown in the diagram. The bottom of this cover rested on four bricks, thus leaving the entire bottom open.

Method:- The gate valve was opened and the effect on the manometers observed. Several trials were made using different depths of water. No record was made of the manometer readings, but it was observed that the manometer at B varied up to four inches only, instead of five, while the variation at A was one-half inch less than before. It was also observed that the action was less violent with the equalizer than without it, and that the draft lasted a longer period of time when the equalizer was used.

Discussion:- Most producers do not use equalizers. Manufacturers who install them claim that a continuous or nearly continuous draft is preferable to a periodic one, and that the gas is better. Leaks ought to be less frequent since the draft is not so great.

[illegible]

Description:- [illegible] tank, [illegible] small [illegible] tank [illegible] the equalizer [illegible] the equalizer [illegible] above in the equalizer [illegible]. The [illegible] valve. The equalizer consists of [illegible]

Design:- The [illegible] different [illegible] but it was [illegible] and that the [illegible] equalizer was used.

Operation:- [illegible]

In this equalizer when the engine takes gas in its forward stroke it creates a partial vacuum, or rather a pressure less than that of the atmosphere outside. This is communicated to the entire system and since the only opening to the outside air is through the vaporizer the air must pass through the fuel bed of the generator where it meets much resistance. The scrubber also offers some resistance. Now, with the equalizer connected, this partial vacuum was communicated to the chamber between the equalizer cover and the surface of the water. With the pressure on the surface of the water on the inside less than that on the water on the outside, the water was forced into the chamber until equilibrium was established. A part of the draft was thus taken up by the equalizer. When the piston reached the end of its stroke and no more partial vacuum was being created, the water gradually passed out at the bottom thus again creating that part of the draft it had absorbed.

The plan seemed to be a good one, but the water rushed out of the equalizer too fast. Some scheme was needed to make its action slower. A bottom having a number of openings controlled by valves was suggested. Owing to the lack of time and means it was necessary to discontinue the work. The matter was subsequently taken up by Mr. Singer and Dunmore of the Mechanical Department, and completed satisfactorily.

EFFECTS OF INCREASED LOAD.

Object: Reference to several trade catalogues and engineering magazines brought out the fact that the average composition of suction producer gas is considerably higher in combustible constituents than that which was being found here. The actual load carried by the plant was much less than the rated load, [illegible] suction, [illegible] which it creates a partial vacuum, [illegible] a pressure less than that of the atmosphere outside. This is characteristic of the suction system and since the only opening to the outside air is through the vaporizer the air must pass [illegible] the fuel [illegible] generator where it meets much resistance. The vaporizer also offers some resistance. [illegible] With this equalizing arrangement, [illegible] the chamber between the [illegible] and the surface of the water. [illegible] on the surface of the water [illegible] the water [illegible] the chamber until [illegible] established. [illegible] draft was [illegible] by the [illegible]. When the [illegible] reaches the amount [illegible] being created, the water [illegible] at the bottom thus again creating that part of the draft [illegible].

The [illegible], but the [illegible] out of the [illegible] to make its action [illegible]. A [illegible] controlled by valves and [illegible] air [illegible] it [illegible]. The outlet was subsequently [illegible] of the Mechanical [illegible].

[illegible]

Object: [illegible] the fact that the [illegible] suction producer gas is considerably higher [illegible] conditions [illegible]. The [illegible] which was nicely illustrated by the fact that the engine gave an average of 41 explosions per minute instead of 105, as it would at full load. Considerable discussion was provoked about the plant as to the advantages of an increased load. It was finally decided to try the effect of a greater load for a short period.

Method:- The method used for increasing the load was very crude, but it was the best that we had at that time and place. A piece of plained scantling about eight feet long was placed under one of the fly wheels of the engine. One end of this scantling rested on the floor while the other end rested on a wooden wedge. By driving this wedge back or forth the friction on the wheel could be adjusted. The increase in load itself could only be determined by the number of explosions in the engine per minute. This was crude regulation at best, but nothing better could be obtained. At 10:45 A.M. the engineer poked the fire and cleaned the grate so that the furnace would be in good order when all was in readiness for the test.

A sample of the gas was taken just before the load was increased so that any change could be noted. The number of explosions was counted at 10:57 A.M., and the loads then increased until at 11:10 the number of explosions was 64. The load was kept as nearly constant as was possible by the means employed. The number and time of the explosions were noted at irregular intervals. The run was continued until 11:28. Three samples of the gas were taken.

The actual load was determined by referring to a curve developed as a result of a test on this engine by Prof. MacFarland and published on page 677, #42 Engineer (U.S.) Oct. 16, 1905.

DATA. TABLE V.

Horse Power Determined From Diagram Referred to Above.

Time	Explosions per Minute.	H. P.	
10:57	45	25	
11:03	53	30	
11:09	59	33	Mean Explosions
11:10	64	37	per min. - 56.6
11:20	53	30	Average H.P. - 32
11:25	64	37	
11:28	60	34	

Discussion:- This producer had been running at about 25 H.P. for less than half load. If the design of a producer is proper, then at, or nearly at, its rated load, the radiation will be small enough so that the reduction zone of the generator will be hot enough and large enough to reduce nearly all the CO_2. If this same producer is running at less than half load the reduction zone will be smaller on account of the ratio of heat generated to the radiating surface. Now, if only a certain amount of CO_2 gas is turned into this reduction zone the reduction will be a certain percentage of the whole. But, if suddenly a greater volume of CO_2 is introduced there will be a decrease in the percentage of reduction. This is exactly what happened between sample #33 and sample #34. The number of explosions increased gradually from 45 to 64 between 10:57 and 11:10. This means that one-third more gas had to be reduced in the same zone at 11:10 as was reduced at 10:45. The result was an increased percentage of CO_2 and a decreased

percentage of CO.

In the vaporizer a similar condition exists. The rate of passage of air carrying away steam is suddenly increased while the heat imparted to it by the hot gases does not increase in the same ratio, much of the heat of the hot gases being taken up in warming the upper zone of the generator. This means a decrease in the supply of steam and hence less hydrogen.

After a short time, however, the generator became heated to what might be termed the normal temperature for that load and the reduction of CO_2 increases as well as the production of hydrogen. In sample #36 there is a slight increase in CO_2 and a corresponding decrease in CO. Hydrogen is higher. The change is only two-tenths of one percent. It may be due to the increased cooling effect of the increase in steam to produce the increase in hydrogen shown. The heat values increase.

The relation between changes of the gases is shown in the form of curves in blue print. Time is shown as abscissa and percent gas as ordinates. Acurve is shown for heat values. The ordinates should be multiplied by ten to get the respective B.t.u. per cubic foot. Attention is called to the decrease in the combustible constituents at first and then to their gradual increase. The same can be said for the heat curve while for the CO_2 curve, the reverse is true.

Conclusions:- The first tendency of an increased load, especially a suddenly increased one, is to reduce the heating constituents of the gas. The increased load will, in a few minutes, increase the strength of the gas due to the additional heat generated.

The duration and suddenness of load change of the above test was not great. The writer has since had part in a test (for which the data cannot be given here) in which the increase was sudden from one third to full load. Several other tests were made, not so great in suddenness. The result in each instance was similar to that here obtained.

S U M M A R Y .

Effect of Scrubber.- The scrubber was found to absorb CO_2 to a greater extent than it did the other constituents. An extended study of its effects with varying quantities of water on the composition of the gas and on the percent of ash and dust left in the gas should be made.

Effect of Tending Furnace:- The effect of tending the furnace is injurious for a short time, but usually improves the gas after a few minutes. No two manufacturers build their gas producers alike, and no two engineers will tend the same producer exactly alike, so that the field for investigation here is extensive.

Effect of No Load With Blast On:- The effect in this producer was to increase CO and decrease hydrogen. Most producers would be similarly affected. Some, owing to their construction, would produce different results. The object of the blast is to keep the zone of reduction hot when the engine is not using enough gas to do this. Hydrogen falls off because the steam is cut off from the generator.

Effect of Temperature of Ingoing Air:- Air of a high temperature passing through a vaporizer takes up more moisture than cold air, and hence causes more hydrogen to be formed. A curve shows an increase of hydrogen with an increase in temperature of ingoing air. Some producers preheat the ingoing air as high as four and five hundred degrees. This is a good field for more investigation.

Effect of Accumulation of Clinker:- The effect is nicely illustrated by the curves shown in blue print form. Work of this kind on different producers and producers operating under different conditions is adviseable. The effect of steam on the quantity and quality of the clinker should be noted. The temperature in various parts of the generator should also be noted.

Amount of Carbon Left in Ash: This is interesting from the standpoint of economy. Much carbon remains in the ash from suction producers. A study along this line with a view of determining the most economical method of firing is suggested.

Effect of [illegible]:- [illegible] this tendency

seem to increase [illegible]. [illegible]

would be [illegible] affected. [illegible] their constitution.

would produce different results. [illegible] of the blast is

[illegible]

enough [illegible]

is cut off from the [illegible].

Effect of [illegible]:- [illegible]

passing through a vaporizer [illegible]

[illegible] more hydrogen [illegible] formed. [illegible]

[illegible] increase in temperature

of igniting air. [illegible]

high as [illegible] hundred degrees. [illegible]

[illegible] introduction.

Effect of Accumulation of Clinker:- The effect is [illegible]

illustrated by the [illegible]

[illegible] producers and producing [illegible]

under different [illegible]. The effect of [illegible]

on the quantity and quality of the [illegible].

The [illegible] of the [illegible]

be noted.

Amount of carbon left in [illegible]: This is [illegible] from the

standpoint of economy. [illegible] in the ash [illegible]

ruction producers. [illegible] this line with [illegible]

[illegible] determine the [illegible]

ted.

Study of Draft Equalizer: This study was intended merely to determine whether or not a certain idea was practicable. It was found to be practical and was subsequently completed. Some makers claim that a draft equalizer is not beneficial to the gas. This could be determined by a series of tests similar to those here made.

Effect of Increased Load:- In this case the increase of load was injurious for a few minutes, but finally increased the value of the gas. This is true in general. In practice the load on an engine is often suddenly increased from a light load to full load. In such cases there is danger of stopping the engine on account of temporarily weakening the gas. There is an extensive field for investigation in this direction.

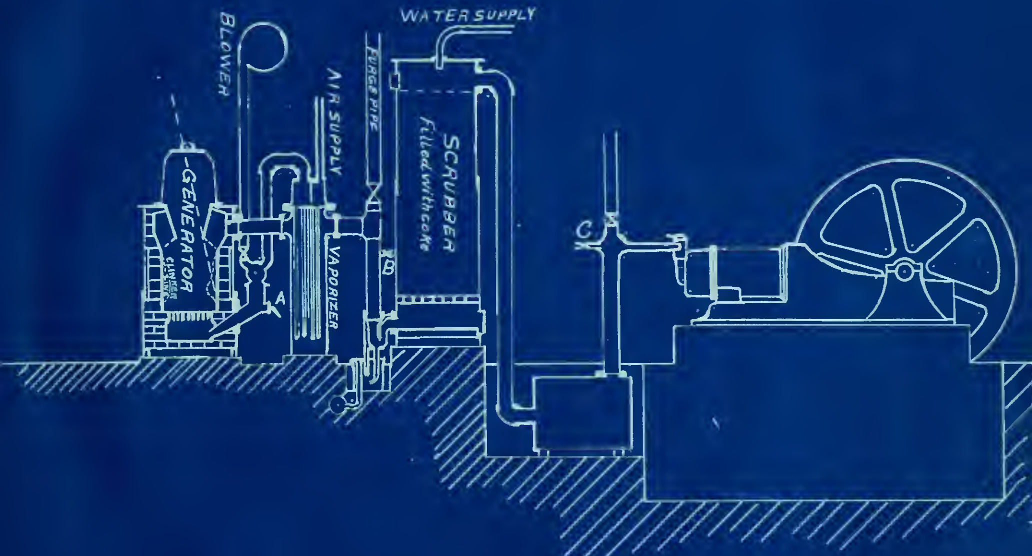
In conclusion, this work is indebted to Helon Brooks MacFarland, Associate Professor of Mechanics, Armour Institute of Technology, for many suggestions and much valuable information. To Benjamin Ball Freud, Assistant Professor of Analytical and Organic Chemistry, Armour Institute of Technology, this work is indebted as director.

[illegible]: This study was limited strictly to [illegible] [illegible] equipment possible. It was found to be practical and very economically possible. Some persons claim that a draft regulator is not beneficial to the user. This could be determined by a series of tests similar to those here made.

Effect of Increased Load: The tests show the increase of load and [illegible] from [illegible], but finally increased the value of the [illegible]. This is true in general. In operating the load on the engine is often suddenly increased from light load to full load. [illegible] the [illegible] temporarily [illegible] the [illegible]. There is an extensive field for investigation in this direction.

In conclusion, this writer is indebted to Helen [illegible] MacFarland, associate Professor of Mechanical [illegible], Armour Institute of Technology, for many suggestions and much valuable information. [illegible], Assistant Professor of Analytical and [illegible] Chemistry, Armour Institute of Technology, this work is gratefully dedicated.

DIAGRAMATIC VIEW OF PLANT STUDIED



ELEVATION OF DRAFT EQUALIZER

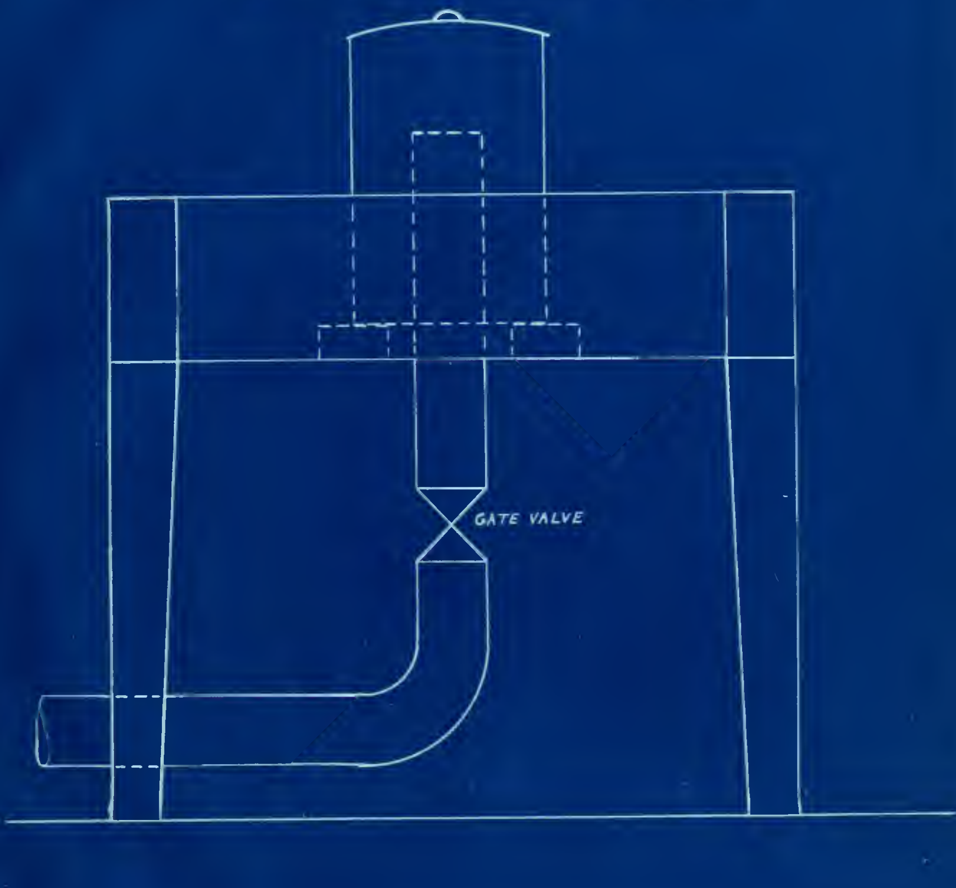


TABLE I

Effect of scrubber

NUMBER	1906 DATE	TIME OF CLEANING GRATE	TIME OF FILLING FEEDER	TIME OF POKING FROM TOP	TIME OF TAKING SAMPLE	TIME OF STARTING ANALYSIS	SAMPLE TAKEN	PERCENT COMPOSITION CO_2	O_2	CO	H_2	N_2	B.T.U. PER CUBIC FOOT STANDARD PRESSURE (CALCULATED) 62°F	32°F
1	Aug. 7				10:15	10:25	B S	8.2	1.0	18.0	15.6	57.0	110	116
2	" 7				10:20	11:25	A S	7.4	0.8	18.3	10.6	62.9	93	99
19	" 20	9:30	9:30		10:10	11:00	B S	8.4	0.6	18.2	11.9	60.9	98	103
20	" 20				10:25	11:40	A S	8.2	0.6	18.6	11.1	61.5	96	102

TABLE II

Effect of tending furnace

NUMBER	1906 DATE	TIME OF CLEANING GRATE	TIME OF FILLING FEEDER	TIME OF POKING FROM TOP	TIME OF TAKING SAMPLE	TIME OF STARTING ANALYSIS	SAMPLE TAKEN	PERCENT COMPOSITION CO_2	O_2	CO	H_2	N_2	B.T.U. PER CUBIC FOOT STANDARD PRESSURE (CALCULATED) 62°F	32°F
5	Aug. 14		9:30	9:30	9:35	9:40	as	6.2	1.2	20.4	8.7	63.5	94	100
6	" 14				10:20	10:25	as	7.6	0.6	20.6	6.6	64.6	89	93
7	" 14	11:02		11:00	11:04	11:05	as	6.8	1.0	21.9	12.5	57.8	112	118
10	" 15	9:30	9:30		10:50	11:20	as	6.0	1.0	21.4	5.8	65.8	88	93
11	" 15	11:02		11:00	11 $\frac{01}{05}$	11:55	as	6.4	1.4	20.0	3.6	68.6	75	80
12	" 15				11 $\frac{06}{08}$	12:25	as	7.6	0.7	19.7	11.6	60.4	101	107
14	" 17				9:25	9:40	as	7.5	0.9	18.7	12.6	60.3	101	107
15	" 17	9:33	9:32		9:37	10:20	as	7.8	1.2	18.6	13.5	58.9	104	110
16	" 17	11:02		11:00	11:06	11:10	as	8.4	1.2	17.4	11.2	61.8	92	98

TABLE III

Effect of no load with air blast on

	1906	TIME OF							PERCENT COMPOSITION					B.T.U. PER CUBIC FOOT STANDARD PRESSURE (CALCULATED)		
NUMBER	DATE	CLEANING GRATE	FILLING FEEDER	POKING FROM TOP	TAKING SAMPLE	STARTING ANALYSIS	SAMPLE TAKEN	CO_2	O_2	CO	H_2	N_2	62°F	32°F	
3	Aug. 13				7:30	10:30	a.s.	5.8	2.6	17.2	6.6	67.8	76	81	
4	" 13				12:00	12:05	a.s.	4.8	2.2	21.6	3.4	68.0	80	85	Blast on
8	" 14	11:02	9:30	11:00	11:50	11:55	a.s.	7.2	0.2	21.4	11.4	59.8	107	113	
9	" 14				12:12	12:25	a.s.	7.2	0.0	21.5	5.2	66.1	86	91	Load off at 11:55. Blast on till 12:10
20	" 20	9:30	9:30		10:25	11:40	a.s.	8.2	0.6	18.6	11.1	61.5	96	102	
21	" 20			11:00	12:12	12:30	a.s.	10.0	1.6	16.2	2.5	69.7	59	63	Load off at 12:00 Blast on till 12:12

TABLE IV

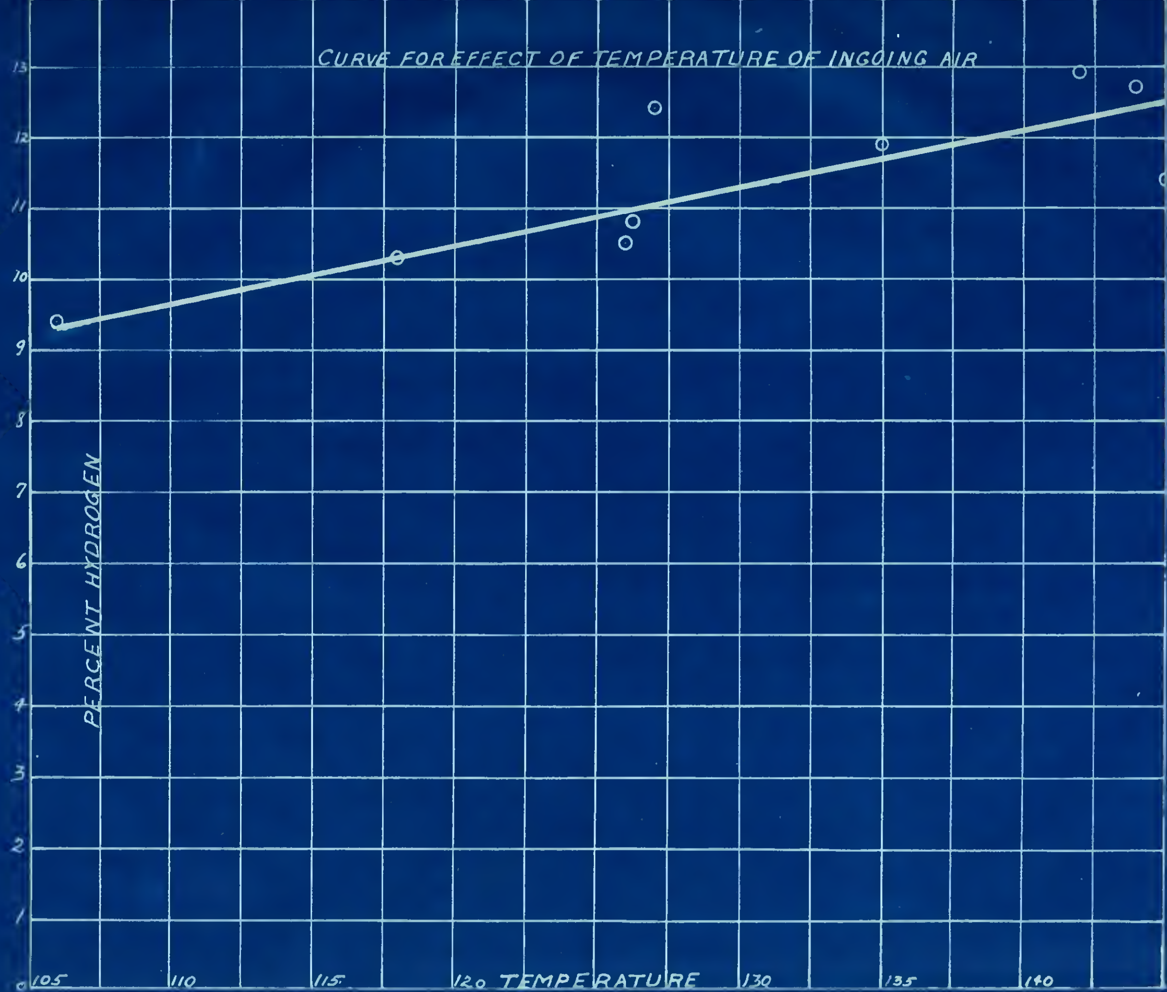
Effect of accumulation of clinker

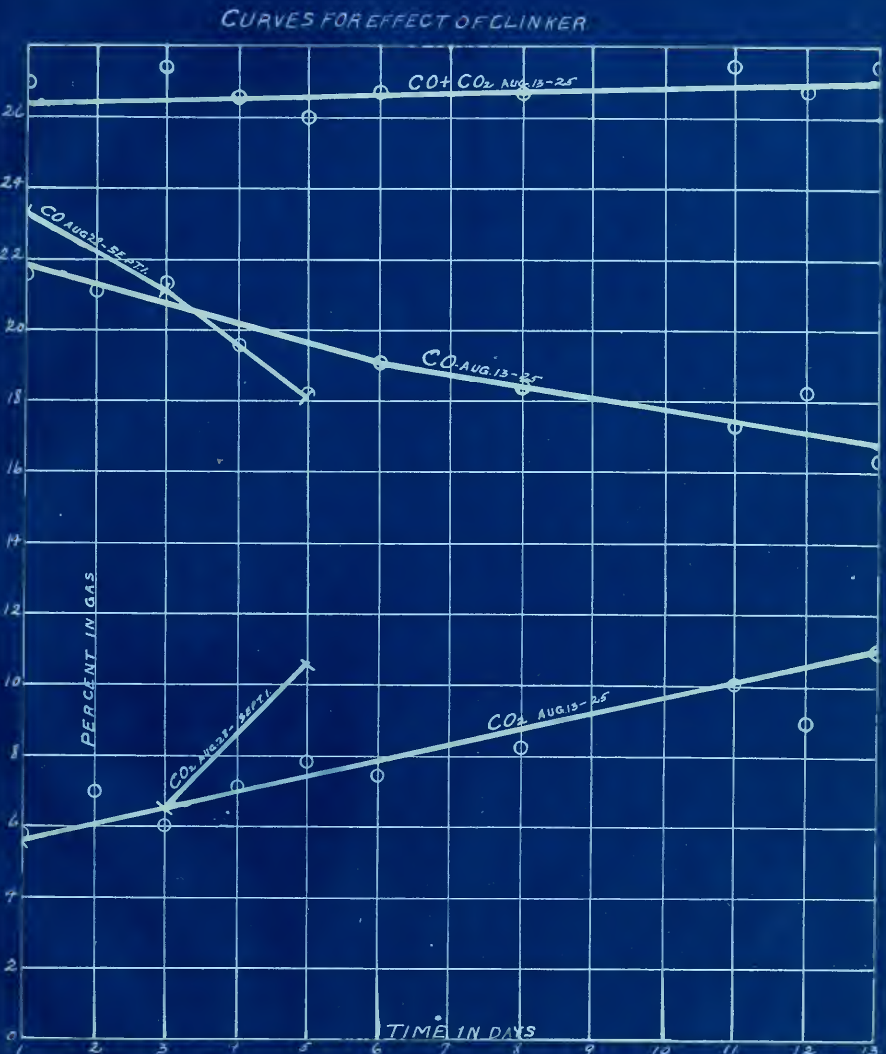
1906 DATE		PERCENT COMPOSITION CO_2	O_2	CO	H_2	N_2	B.T.U. PER CUBIC FOOT STANDARD PRESSURE (CALCULATED) 62°F	32°F
Aug. 13		4.8	2.2	21.6	3.4	68.0	80	85
" 14		7.0	0.8	21.1	9.8	61.3	99	105
" 15		6.0	1.0	21.4	5.8	65.8	87	93
" 16		7.2	0.6	19.5	12.5	60.2	103	109
" 17		7.9	0.7	18.2	13.0	60.2	100	106
" 18		7.6	0.2	19.2	11.5	62.5	99	105
" 19	Sunday							
" 20		8.3	0.6	18.4	11.5	61.2	96	102
" 21	No data taken							
" 22	" " "							
" 23		10.1	0.4	17.4	12.8	59.3	97	103
" 24		9.0	0.8	17.8	10.3	62.1	90	96
" 25	Fire raked out at 2:00 P.M.	11.0	0.5	16.4	11.0	61.1	87	93
" 28		5.8	1.8	23.2	9.4	60.8	106	112
" 30		6.6	0.8	21.0	12.4	59.2	109	115
Sept. 1		10.8	0.0	18.0	11.4	59.8	95	101

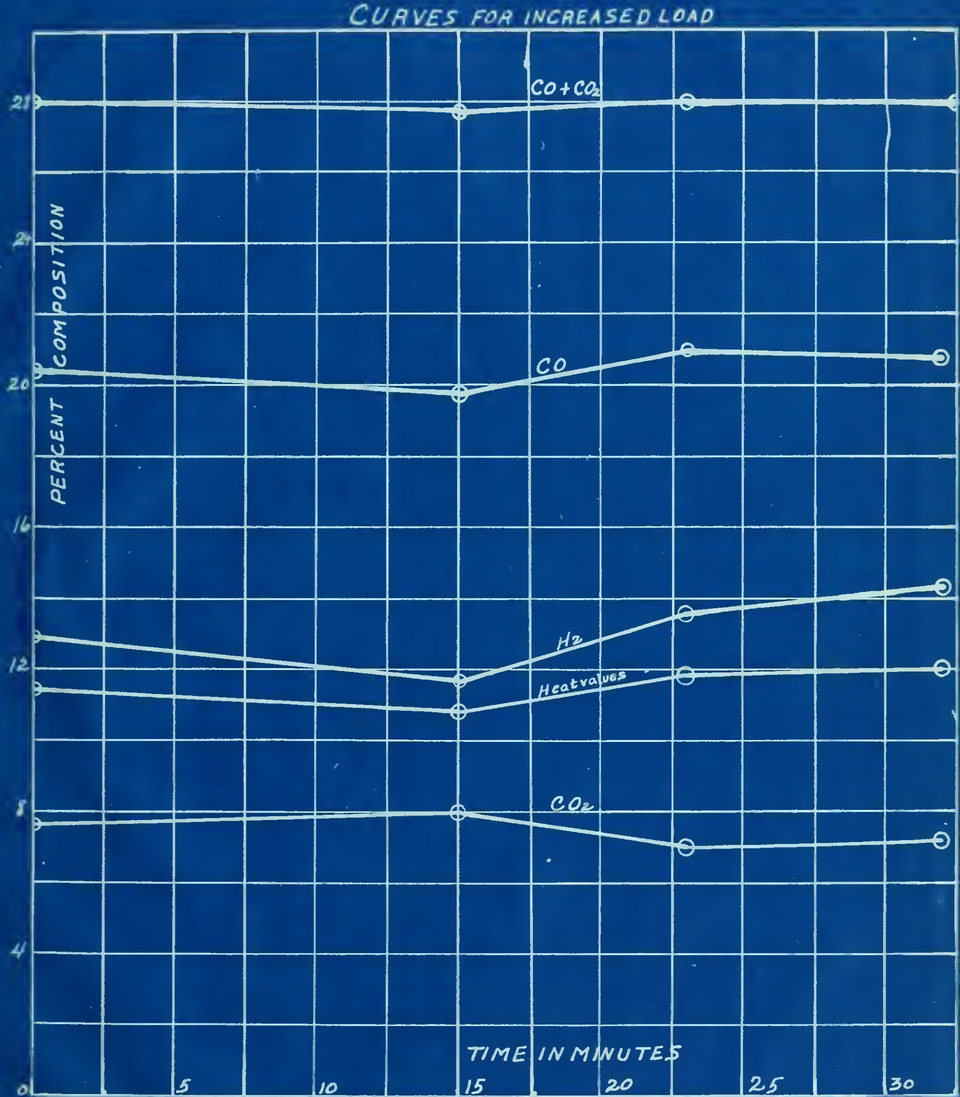
TABLE V

Effect of increased load

	1906	TIME OF						PERCENT COMPOSITION					B.T.U PER CUBIC FOOT STANDARD PRESSURE (CALCULATED)		EXPLOSIONS PER MINUTE	
NUMBER	DATE	CLEANING GRATE	FILLING FEEDER	POKING FROM TOP	TAKING SAMPLE	STARTING ANALYSIS	SAMPLE TAKEN	CO_2	O_2	CO	H_2	N_2	62°F	32°F	TIME	NUMBER
33	Sept. 14	10:45		10:45	10:55	11:40	as	7.6	0.4	20.4	12.9	58.7	108	114	10:57	45
34	" 14				11:10	12:05	as	8.0	0.4	19.8	11.7	60.1	102	108	11:03 11:09	53 59
35	" 14				11:18	12:40	as	7.0	0.4	21.0	13.6	58.0	113	119	11:10 11:20	64 53
36	" 14				11:27	1:30	as	7.2	0.2	20.8	14.4	57.4	115	121	11:25 11:28	64 60


CURVE FOR EFFECT OF TEMPERATURE OF INGOING AIR
PERCENT HYDROGEN
TEMPERATURE
105
110
115
120
130
135
140
0
1
2
3
4
5
6
7
8
9
10
11
12
13


CURVES FOR EFFECT OF CLINKER
CO+CO2 AUG. 13-25
CO AUG 28-SEPT. 1.
CO-AUG. 13-25
CO2 AUG. 28-SEPT. 1.
CO2 AUG. 13-25
PERCENT IN GAS
TIME IN DAYS
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
13



CURVES FOR INCREASED LOAD
CO + CO2
CO
H2
Heatvalues
CO2
PERCENT COMPOSITION
TIME IN MINUTES
21
24
20
16
12
8
4
0
5
10
15
20
25
30

GENERAL DATA

GENERAL DATA

NUMBER	DATE 1906	TIME OF CLEANING GRATE	TIME OF FILLING FEEDER	TIME OF POKING FROMTOP	TIME OF TAKING SAMPLE	TIME OF STARTING ANALYSIS	SAMPLE TAKEN	PERCENT COMPOSITION CO_2	O_2	CO	H_2	N_2	B.T.U. PER CUBIC FOOT STANDARD PRESSURE (Calculated) 62°F	32°F	EXPLOSIONS PER MINUTE TIME	NUMBER	MANOMETER READINGS TIME	AT A	AT B	AT C	TEMPERATU OF AIR AND STEAM AT TIME	DEGREES
1	Aug. 7						B.S.	8.2	1.0	18.1	15.6	57.1	110	116								
2	" 7						A.S.	7.4	0.8	18.3	10.6	62.9	96	101								
3	" 13				7^{30}	10^{30}	" "	5.8	2.6	17.2	6.6	62.8	76	81								
4	" 13				12^{00}	12^{05}	" "	4.8	2.2	21.6	3.4	68	80	85	Blower on							
5	" 14		9^{30}	9^{30}	9^{35}	9^{40}	" "	6.2	1.2	20.4	8.7	63.5	94	100								
6	" 14				10^{20}	10^{25}	" "	7.6	0.6	20.6	6.6	64.6	87	93								
7	" 14	11^{02}		11^{00}	11^{04}	11^{05}	" "	6.8	1.0	21.9	12.5	57.8	112	118								
8	" 14				11^{50}	11^{55}	" "	7.2	0.2	21.4	11.4	59.8	107	113								
9	" 14				12^{12}	12^{25}	" "	7.2	0.0	21.5	5.2	66.1	86	91	Load off at 11^{55} Blower on till							12^{4}
10	" 15	9^{30}	9^{30}		10^{50}	11^{20}	" "	6.0	1.0	21.4	5.8	65.8	88	93								
11	" 15	11^{02}		11^{00}	$11\,^{01}_{05}$	11^{55}	" "	6.4	1.4	20.0	3.6	68.6	75	80								
12	" 15				$11\,^{06}_{06}$	12^{25}	" "	2.6	0.0	19.7	11.6	60.4	101	107								
13	" 16	9^{30}	9^{30}		10^{40}	10^{50}	" "	7.2	0.6	19.5	12.5	60.2	104	110								
14	" 17				9^{25}	9^{40}	" "	7.5	0.9	18.7	12.6	60.3	101	107	9^{57}	44						
15	" 17	9^{33}	9^{32}		9^{37}	10^{20}	" "	7.8	1.2	18.6	13.5	58.9	104	110	9^{57}	44						
16	" 17	11^{02}		11^{00}	11^{06}	11^{10}	" "	8.4	1.2	17.4	11.2	61.8	92	98	10^{30}	43						
17	" 17				11^{50}	11^{55}	" "	8.4	0.6	17.6	13.4	60.0	100	106	12^{45}	39						
18	" 18				11^{55}	2^{50}	" "	2.6	0.2	19.2	11.5	62.5	99	105	11^{59}	43						
19	" 20	9^{30}	9^{30}		10^{10}	11^{00}	B.S.	8.4	0.6	18.2	11.9	60.9	98	103	10^{55}	45	10^{20}	2	5	6	10^{20}	13
20	" 20				10^{25}	11^{40}	A.S.	8.2	0.6	18.6	11.1	61.5	96	102							11^{40}	14
21	" 20			11^{00}	12^{12}	12^{30}	" "	10.0	1.6	16.2	2.5	69.7	59	63	Load off at 12^{00} Blower on till							12^{1}
22	" 23	10^{-}	9^{30}	9^{30}	10^{50}	10^{55}	" "	9.0	0.6	17.2	12.9	60.3	98	103	11^{47}	46		2	5	6	10^{48}	14
23	" 23				11^{50}	12^{00}	" "	11.2	0.2	17.6	12.7	58.3	98	103				2	5	6	11^{50}	14
24	" 24		9^{28}		$9\,^{28}_{30}$	9^{30}	" "	7.8	0.2	17.0	11.7	63.3	93	98	9^{20}	43		2	5	6	11^{00}	11
25	" 24	10^{25}			10^{30}	10^{50}	" "	7.4	1.6	18	10.5	62.5	93	98	10^{15}	48		2	5	6	11^{50}	12
26	" 24	11^{00}		11^{00}	11^{20}	11^{25}	" "	9.0	0.8	17.8	10.3	62.1	91	97	11^{17}	44						
27	" 24				11^{55}	12^{00}	" "	8.0	0.6	20.2	10.8	60.6	100	106	11^{49}	48						
28	" 25			9^{30}	10^{20}	10^{30}	" "	10.4	0.8	17.2	11.5	60.1	93	98	10^{28}	48						
29	" 25	11^{00}		11^{20}	11^{20}	11^{25}	" "	11.6	0.2	15.6	10.6	62.0	84	89	11^{54}	45						
30	" 28	8^{30}	9^{40}	9^{40}	10^{40}	11^{15}	" "	5.8	1.8	23.2	9.4	6.8	106	112	10^{51}	46	Small leak at storage tank				11^{10}	106
31	" 30	9^{30}	9^{30}		10^{40}	11^{00}	" "	6.6	0.8	21.0	12.4	59.2	109	115	11^{28}	43		2	5	6	10^{30}	12
32	Sept. 14	9^{30}	9^{30}	11^{00}	11^{40}	11^{45}	" "	10.8	0.0	18.0	11.4	59.8	95	101	11^{46}	48		2	5	6	11^{45}	14
33	" 14	10^{45}		10^{45}	10^{55}	11^{40}	" "	7.6	0.4	20.4	12.9	58.7	108	114	10^{57}	43		2	5	6		
34	" 14				11^{10}	12^{05}	" "	8.0	0.4	19.8	11.7	60.1	102	108	11^{03} 11^{09}	53 59						
35	" 14				11^{18}	12^{40}	" "	7.0	0.4	21.0	13.6	58.0	113	119	11^{10} 11^{20}	64 53						
36	" 14				11^{27}	1^{30}	" "	7.2	0.2	20.8	14.4	57.4	115	121	11^{25} 11^{28}	64 60					11^{25}	140