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# PRODUCTION OPERATING EXPERIENCE WITH OXYGEN IN THE KERPELY PRODUCER AT LOUISIANA, MO.

BY L. F. WILLMOTT, H. R. BATCHELDER, AND R. F. TENNEY

United States Department of the Interior—February 1955

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UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
J. J. Forbes, Director

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ILLUSTRATIONS



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## SUMMARY AND CONCLUSIONS


The production operation of a Kerpely gas producer at Louisiana, Mo., is described. This unit, originally designed for airblown operation was modified to permit using oxygen in the blast in place of air.

The first runs, for test purposes, were made in June 1950. After this, seven production runs were made and these are the subject of this report. Total gasification time was 245 days.

In each run, Nut or Pea coke or mixtures of both at a rate varying from 1,700 to 2,300 pounds per hour was converted with oxygen and saturated steam to produce synthesis gas - primarily carbon monoxide and hydrogen - approximating a predetermined rate of 80,000 to 95,000 cu. ft. per hour and a predetermined hydrogen-carbon monoxide ratio. The requirements per 1,000 std. cu. ft. of ($CO + H_2$) were 27.6 to 30 pounds of coke, 213 to 267 std. cu. ft. of oxygen, and 31.4 to 47.8 pounds of steam.

Work by others[4] had indicated that it might be possible to operate the Kerpely producer at a capacity that would require 4 tons of oxygen per hour or 4 times the oxygen supply available at Louisiana, Mo. However, in the work covered by this report, the requirements of the synthesis unit made it unnecessary to operate the producer at the capacity of the oxygen plant.

From the performance of the producer, the following conclusions were reached:

(1) A Kerpely producer, modified to permit oxygen blast, can be used as a reliable, continuous source of synthesis gas from coke.

(2) The prime operating variable at any given steam rate is the oxygen input. This is the principal controlling factor of the carbon dioxide content of the gas produced, and this in turn is the index of the hydrogen-carbon monoxide ratio of the gas.

(3) Changes in the size of coke (Nut, Pea, or mixtures of both) during a run require adjustment of the steam-oxygen ratio to maintain good fire conditions. Such changes cannot be made without change in yield and quality of the gas produced, and the time consumed before the desired yield and quality is restored depends primarily on operating skill.


## ACKNOWLEDGMENT


The work reported herein is the result of considerable cooperative effort, including contributions from personnel of the Koppers Co.


## INTRODUCTION

The Bureau of Mines Gas Synthesis Demonstration Plant at Louisiana, Mo., was designed and constructed to develop the complete gasification of coal and the

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4/ Blatchford, J. W., Water-Gas Production With Tonnage Oxygen: Pres. at Production and Chemical Conf., Am. Gas Assoc., May 1950.

conversion of the product gas into liquid fuels. As an alternate to the coal gasi-
fier a Kerpely producer was installed using coke as fuel but modified to permit
operation with an oxygen and steam blast. The demonstration plant has been des-
cribed previously,5/ information has been published on coal gasification,6/ on plant
purification of synthesis gas,7/ and on the experimental operation of the Kerpely
producer.8/ The latter publication described the preliminary operation of the
producer, the purpose of which was to test the installation to determine the process
variables and the quality and quantity of gas achievable and to train the operators.

The purpose of this report is to describe the subsequent operations of the
producer, all of which, as distinct from the preliminary operation, were for pro-
ducing gas for the experimental operation of the purification and/or synthesis units,
or for observing the effect of changes made to the producer and its auxiliaries. The
operation described differs from that previously reported9/ in that the fuel used
is Nut and Pea coke rather than run-of-oven, and the gas produced was to meet the
requirements of Fischer-Tropsch synthesis rather than ammonia synthesis.

## DESCRIPTION OF EQUIPMENT

Kerpely producers have been used principally for underfiring coke ovens, coke
having invariably been the fuel gasified. A drawing of the mechanical producer and
its auxiliaries is shown in figure 1 and the producer itself in figure 2. The in-
stallation was of one producer alone and not as part of a battery of producers. A
description of the producer and information concerning its operation have been pub-
lished.10/ After the preliminary operational period so described, a number of equip-
ment changes were made. These were mostly to facilitate smoother and more trouble-
free operation, although some were intended to improve the gas-making potentials of
the producer. The changes were not all made simultaneously but during the interim
periods between runs when the necessity for them had become apparent.

The weigh larry was removed, and all subsequent coke measurements were volu-
metric. Removing the larry not only reduced operating labor but also permitted
other than vertical roddings (namely, roddings closer to the inside wall of the
producer). This was to detect cavities in or collapse of the fuel bed at or near
the side wall. However, experience later proved such roddings to be unreliable,
whereupon vertical roddings and those toward the cap of the grate became standard
procedure. Fuel was charged to the producer manually. Although it was felt that
an automatic charging machine delivering small increments of fuel separated by small
time intervals would have made for smoother operation with a less variable "top"
temperature, the principal advantage of mechanical feeding, namely, the ability to

5/ Kastens, M. L., Hirst, L. L., and Dressler, R. G., An American Fischer-Tropsch Plant: Ind. Eng. Chem., vol. 44, March 1952, p. 450.

6/ Dressler, R. G., Batchelder, H. R., Tenney, R. F., Wenzell, L. P., Jr., and Hirst, L. L., Operation of a Powdered-Coal Gasifier at Louisiana, Mo.: Bureau of Mines Rept. of Investigations 5038, 1954, 35 pp.

7/ Wenzell, L. P., Jr., Dressler, R. G., and Batchelder, H. R., Plant Purification of Synthesis Gas: Ind. Eng. Chem., vol. 46, May 1954, p. 858.

8/ Batchelder, H. R., Dressler, R. G., Tenney, R. F., Kruger, R. E., and Segur, R. D., Operation of Kerpely Producer With Oxygen-Enriched Blast at Bureau of Mines, Louisiana, Mo.: Pres. at Annual Convention of the American Gas Assoc., Atlantic City, N. J., October 1950.

9/ See footnote 4.

10/ See footnote 8.

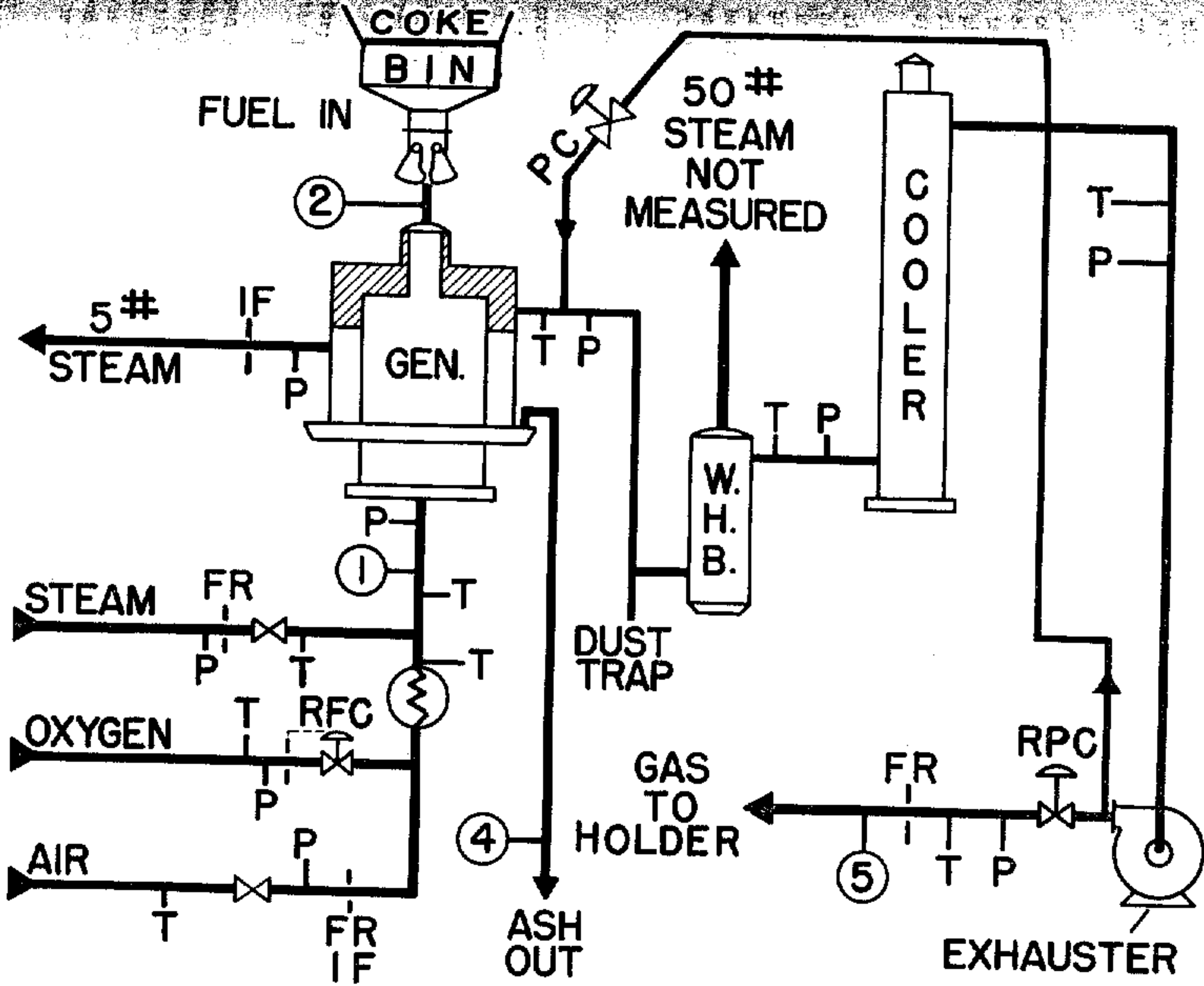


Figure 1. - Schematic flow diagram.

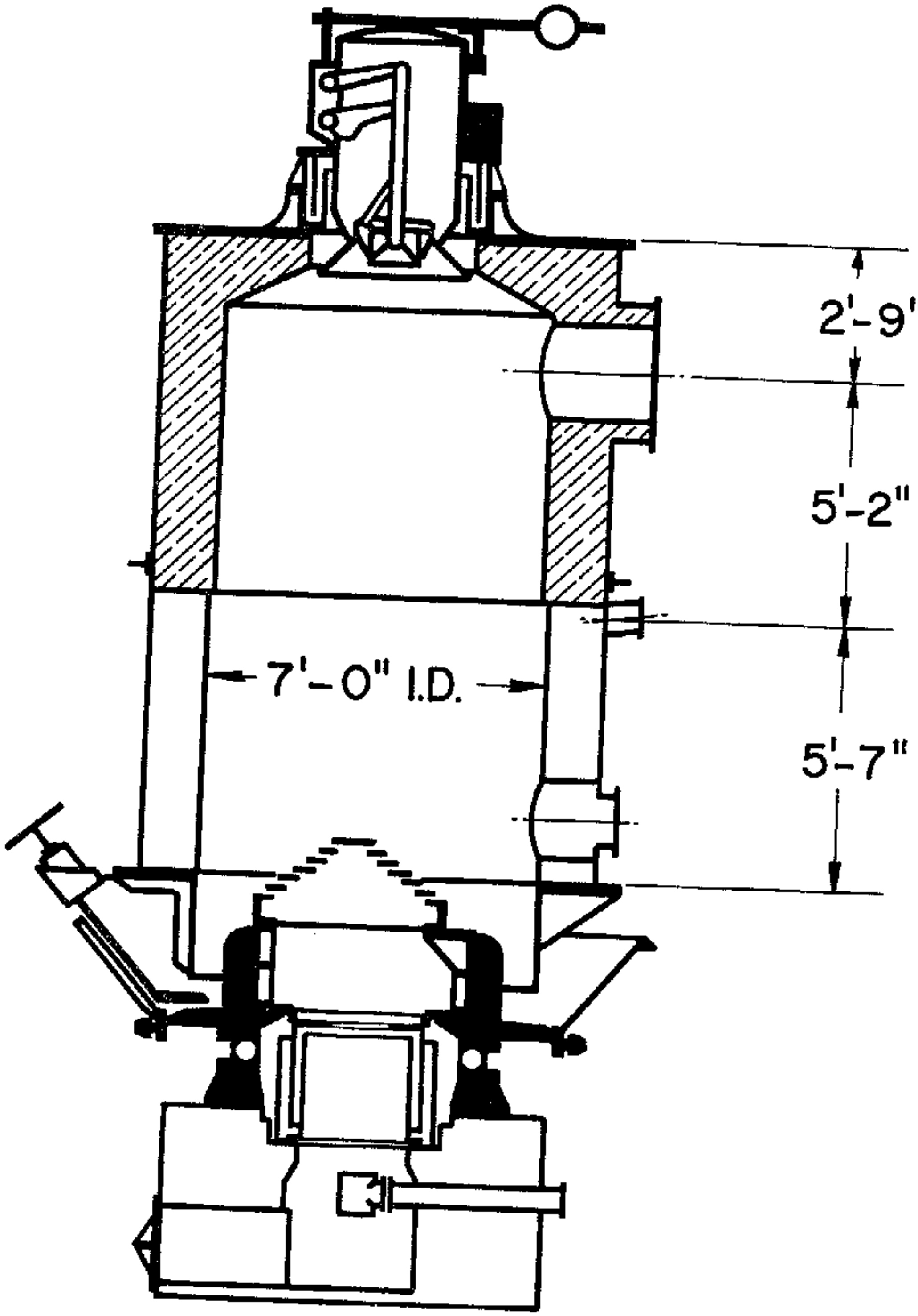


Figure 2. - Vertical section of producer.

vary the rate of fuel feed, would not have been put to use. The reason for this was that the synthesis-gas requirements of the Fischer-Tropsch reactor that the producer supplied were not subject to variation, so there was no occasion for sudden or wide variations in fuel feed to the producer.

Bell-and-hopper charging has the disadvantage of segregating the fuel when its size range is wide. No wide range of size consist of the fuel was expected, so this objection to bell-and-hopper charging was not valid in this case. In ordinary, non-slagging producer-gas practice, steam is admitted to control clinker formation. This is done even where the hydrogen so produced is less desirable than the CO it displaces, as, for instance, when a gas is required that will burn with a long, lazy flame. On the other hand, steam admission to a coke-fired Kerpely producer supplying synthesis gas makes a virtue of this necessity.

Improvements were made to the charging hopper linkage to facilitate center and rim charging. The water seal around the charging hopper was increased 2 inches to prevent loss of seal due to fluctuations in producer top pressure during coke charging. Another purpose of the increase in seal depth was to permit operating the producer with a top pressure high enough that a small positive pressure could be maintained in the first electrostatic precipitator. This Cottrell precipitator is between the outlet of the washer-cooler and the inlet to the exhauster. Provision was also made for preventing the overflow of water from the gasifier seal into the fuel bed.

A steam-distributor ring was installed in the charge hopper to purge the hopper more effectively during coke charging.

A heating coil was installed in the blast chamber under the producer grate to prevent water from condensing out of the steam-oxygen blast to the producer.

Provision was also made to recycle a portion of the make gas back to the outlet of the producer. The flow of the recycle gas was controlled by the top pressure of the producer, and it reduced the fluctuations in producer pressure caused by opening the charging hopper. Careful manual manipulation of the charging-bell levers also reduced the pressure fluctuations.

An additional water spray was installed in the gas inlet to the first precipitator; this prevented the deposition of tar on the outside surfaces of the tubes of the precipitator.

During preliminary operation of the producer, previously reported,[11] the ash pan and grate were rotated by an infinitely variable speed motor drive. The variable drive was installed in anticipation of varying ash content of the fuel to be supplied to the producer. In all subsequent runs a constant-speed reducer was used with a three-position linkage between it and the rachet-friction shoe arrangement driving the ashpan. One pen of a production recorder showed when the drive motor was running, while the other pen recorded the relative speed of the grate and ashpan and showed the position of the cap relative to the poke holes. This made it possible for the operators to rod to the cap on the first attempt.

The conditions of the fire was tested by thrusting a long rod vertically downward through it and withdrawing it after 1-1/2 to 2 minutes immersion. The depth of the fire zone and the ash zone and the presence of channeling were indicated by visual judging of the temperature of the rod over its immersed portion.

11/ See footnote 8.

As differing from the previously reported operation,12/ no attempt was made to determine, by condensation, the percent steam in the blast or the undecomposed steam in the make gas. Nor was the steam decomposition calculated from inlet steam orifice meter readings in conjunction with make-gas flows and analyses.

In the later runs a make-gas recorder was installed in the panelboard at the operating platform. This made it possible for the operators to maintain better control of the gas-making process.

## OPERATIONS

This report covers the operation of the Kerpely producer as a production unit rather than as a test unit. As mentioned previously, the coke was not weighed as charged, but with each change in size or source of the fuel the charging hopper of the producer was recalibrated for capacity by noting the weighed amount of coke required for full and half charges. The number of such charges fed to the producer was recorded on the run log sheet.

This report is also limited to those producer runs in the course of which the producer was oxygen blown. At the startup of each such run, the producer was blown with air and steam while the oxygen plant was being brought up to full production. Preceding the first of these runs, there were several airblown runs to train operators and test equipment changes. The principal items of operating information that were used to control gas production were as follows:

1. Analysis of gas.

2. Gas offtake temperature.

3. Steam and oxygen flow rates.

4. Conditions of fuel bed:
   a. Depth from top of producer to top of fuel bed (outage).
   b. Depth of raw fuel.
   c. Depth of fire zone.
   d. Depth of ash bed.

5. Rate of coke feed to the producer.

6. Examination of the ash and clinker.

Table 1 gives operating data from each of the oxygen-blown operating periods. The dates given are for the total duration of each run including the startup, air-blown periods, and periods during a run when, by reason of an interruption in the utilization of the gas or in oxygen production or for any other cause, it became necessary to temporarily switch back to air-blast operation.

Included in the table are the specified operating conditions set up at the beginning of each run. These were set up with the intention of producing a fairly definite volume of gas having a hydrogen-carbon monoxide ratio chosen for that particular operation of the Fischer-Tropsch synthesis unit. For the latter requirement the carbon dioxide in the make gas was chosen as being the most easily determinable index of the hydrogen-carbon monoxide ratio.

12/ See footnote 8.

TABLE 1. - Summary of operating results

| Run No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Date | 5/20/51-6/8/51 | 7/5/51-8/3/51 | 8/19/51-9/14/51 | 10/12/51-11/18/51 | 4/8/52-5/15/52 | 5/25/52-6/28/52 | 11/28/52-1/24/53 | 6/29/50-6/30/50 |
| Purpose of run | Initial operation of purification plant. | Operation of purification plant. | Operation of purification and gas synthesis plants. | Operation of purification and gas synthesis plants. | Operation of purification plant. | Operation of purification and gas synthesis plants. | Operation of purification and gas synthesis plants. | Test purposes only. |
| Size of coke used | Nut | Nut | Nut | Nut and mixtures of Nut and Pea. | Mixtures of Nut and Pea. | Mostly Nut - some Pea coke. | Mixtures of Nut and Pea. | Pea. |
| Specified operating conditions | | | | | | | | |
| Oxygen..........c.f.h. (uncorrected) | 14,500 | 16,000 | 15,000 | 16,700 | 17,500 | 16,500 | 17,000 | 13,000 |
| Outage[1/] | 7'6" | 7'6" | 6'0" | 6'0" | 6' to 7' | 6' to 7' | 6' to 7' | 6' |
| Approx. coke rate..........lb. per hr. | 1,700 | 2,200 | 1,800 | 2,000 | 2,700 | 2,300 | 2,300 | 2,000 |
| Approx. steam rate..........do. | - | - | 2,200 | 2,450 | 3,100 | 3,000 | 3,500 | 2,250 |
| Steam adjusted to give indicated percent $CO_2$ in make gas | 15-16 | 15-16 | 15-1/2 -16 | 15-16 | 19 | 19 | 20 - 20-1/2 | 15-1/2 - 16 |
| Make gas desired.....c.f.h. (uncorrected) | 80,000 | 94,000 | 85,000 | 90,000 | 95,000 | 90,000 | 80,000 | 80,000 |
| Actual (average) operating conditions | | | | | | | | |
| Oxygen (98.3%)..........std.c.f.h. | 14,580 | 16,860 | 15,730 | 17,710 | 17,820 | 18,680 | 16,410 | 13,890 |
| Coke rate..........lb. per hr. | 1,870 | 2,319 | 2,233 | 2,195 | 2,135 | 2,163 | 1,715 | 1,553 |
| Coke rate ..........lb. per hr. per sq.ft. | 48.6 | 60.2 | 58.0 | 57.0 | 55.5 | 56.2 | 44.6 | 40.3 |
| Steam rate..........lb. per hr. | 2,417 | 2,477 | 2,463 | 2,666 | 2,947 | 2,947 | 2,965 | 2,220 |
| Operating results (averages) | | | | | | | | |
| Make gas..........std.c.f.h. | 80,000 | 94,930 | 86,130 | 84,780 | 84,020 | 87,110 | 78,950 | 59,200 |
| $CO + H_2$..........do. | 67,600 | 78,910 | 71,350 | 68,840 | 66,690 | 70,274 | 62,032 | 57,600 |
| Make gas analysis, | | | | | | | | |
| $H_2$..........percent | 36.5 | 36.2 | 36.2 | 36.2 | 37.6 | 38.8 | 38.7 | 38.0 |
| CO..........do. | 48.0 | 46.9 | 46.6 | 45.0 | 41.8 | 41.9 | 39.9 | 45.3 |
| $CO_2$..........do. | 14.3 | 15.1 | 15.8 | 16.6 | 19.2 | 18.0 | 19.6 | 15.3 |
| Misc. ..........do. | 1.2 | 1.8 | 1.4 | 2.2 | 1.4 | 1.3 | 1.8 | 1.4 |
| $H_2S$..........grains per 100 cu.ft. | 125 | 138 | 143 | 107 | 82 | 77 | 75 | - |
| Ratios | | | | | | | | |
| $H_2$:CO .......... | 0.760 | 0.771 | 0.777 | 0.804 | 0.900 | 0.926 | 0.970 | 0.839 |
| Steam:coke..........lb. per lb. | 1.29 | 1.06 | 1.10 | 1.21 | 1.38 | 1.36 | 1.73 | 1.43 |
| Per M c.f. ($CO + H_2$), | | | | | | | | |
| Coke..........lb. | 27.7 | 29.4 | 31.3 | 31.8 | 32.0 | 30.8 | 27.6 | 27.0 |
| Process oxygen..........std. c.f.h. | 216 | 213 | 221 | 257 | 267 | 266 | 264 | 241 |
| Steam..........lb. | 35.7 | 31.4 | 34.5 | 38.7 | 44.2 | 41.9 | 47.8 | 38.6 |
| Ratios | | | | | | | | |
| Steam:oxygen..........lb. per 100 c.f. | 16.6 | 14.7 | 15.7 | 15.1 | 16.5 | 15.8 | 18.1 | 16.0 |
| CO:$H_2$.......... | 1.315 | 1.296 | 1.288 | 1.243 | 1.111 | 1.080 | 1.031 | 1.192 |
| Process oxygen:coke..........cu.ft. per lb. | 7.8 | 7.3 | 7.04 | 8.06 | 8.3 | 8.6 | 9.6 | 8.9 |
| Make gas..........std.c.f.h. per sq.ft. | 2,080 | 2,465 | 2,240 | 2,200 | 2,180 | 2,260 | 2,050 | 1,800 |
| Heating value of gas (gross).......... | 273 | 269 | 268 | 263 | 257 | 261 | 254 | 269 |
| (net).......... | 255 | 251 | 250 | 245 | 238 | 242 | 235 | 250 |

1/ (Depth-poke hole to top of fuel bed)

Because of the unavoidable time lag in getting back from the laboratory the results of mass-spectrometer analysis of continuously collected gas samples, the gas from the producer had already been utilized before its hydrogen-carbon monoxide ratio was accurately known. Consequently, a procedure was set up for the producer operators to make carbon dioxide determinations at the outlet of the producer and then immediately adjust the flow of steam in the blast if the carbon dioxide content of the make gas had departed from the desired value.

Modification of the previously specified conditions was permitted to maintain satisfactory fire and ash conditions within the producer or to restore these conditions once they had become upset. For the most part the fuel beds were shallow, advantage being taken of the reduced contact time necessary for heat exchange with the use of small-size coke (Nut and Pea).

In several of the earlier runs a lower carbon dioxide content in the make gas was called for than in the later runs. It was in these earlier runs, with but one exception, that it was found more difficult to maintain stable fire conditions. Although the ash plow was adjusted for the best ash-removal performance, it was often found that uneven and lopsided fires could only be corrected by manually removing ashes into the ash pan at selected places around the producer apron. Rodding and barring with chisel bars through the poke holes was required to break up clinkers, while blowthroughs were corrected by barring and selective charging. This latter operation gave quicker results when using Pea coke than when using Nut. In other respects, Pea coke was easier to work, providing care was exercised in operating the charging-bell handles and that there was enough steam in the blast to prevent clinkering. However, the greatest operating difficulties were encountered with mixed fuels, that is, with random mixtures of Nut and Pea coke.

So much more stable did the fire conditions become with the higher carbon dioxide target that it became possible to reduce the rodding of the fire from once every 1/2 hour to once every 2 hours.

The specified oxygen in the blast was attained by presetting the control points of a recording flow controller. Any departures in actual flow from that specified were principally due to changes in demand by the purification and/or synthesis plants during the course of a run, the operating instructions being to maintain the synthesis gas holder at a constant level. The actual flow of oxygen was also subject to adjustments necessitated to correct unsatisfactory fire conditions in the producer when adjustments in steam flow had failed to correct the adverse (clinkering) conditions.

Another requirement with respect to the steam-oxygen blast was that its temperature should be maintained at or above a specified minimum, usually about 220° F. This was to insure that the steam as metered was delivered into the fuel bed of the producer. Manual control of a preheater located upstream of the steam-oxygen mixer and producer blast ports allowed this requirement to be met.

An approximate coke rate was given as one of the specified operating conditions. Actually the operators did not control the coke rate, being merely instructed to charge the coke into the producer as required to maintain a specified outage (the vertical depth from the poke-hole level on the operating platform to the top of the fuel bed in the producer). Charging being a manual and intermittent operation with whole charges of 530 pounds for Nut coke to 650 pounds for Pea coke, the operators were given their cue as to when to charge by the top or outlet-gas temperature as recorded on the chart of a temperature recorder. When whole charges were being charged, this temperature fluctuated between 800° F. immediately after a charge and 1,200° F. when the producer was ready for another charge. With half charges the spread in temperatures was somewhat less. The rate of charging usually approximated four whole charges per hour.

The steam flow was adjusted by a manual globe valve, the flow being recorded on the chart of an orifice-type flow recorder.

Table 2 shows a typical analysis of the coke fed to the producer.

TABLE 2. - Typical analysis of coke

| | As received | Moisture-free | Moisture- and ash-free |
|---|---|---|---|
| Proximate analysis: | | | |
| Moisture ......... | 2.2 | | |
| Volatile matter .. | 2.0 | 2.0 | 2.2 |
| Fixed carbon ..... | 86.4 | 88.4 | 97.8 |
| Ash .............. | 9.4 | 9.6 | |
| Ultimate analysis: | | | |
| Hydrogen ......... | 0.8 | 0.6 | 0.7 |
| Carbon ........... | 85.9 | 87.8 | 97.1 |
| Nitrogen ......... | .4 | .4 | .4 |
| Oxygen ........... | 2.7 | .8 | .9 |
| Sulfur ........... | .8 | .8 | .9 |
| Ash .............. | 9.4 | 9.6 | |
| B.t.u. ........... | 12,515 | 12,780 | 14,150 |

Note: In the average, there was no difference in analyses of Nut and Pea grades of coke nor in the fusibility of the ash from the 2 grades. Typical determinations of ash fusibility are as follows:

Fusibility of ash, °F.

| Initial | Softening | Fluid |
|---|---|---|
| 2,570 | 2,690 | 2,860 |

## OPERATING LOG OF INDIVIDUAL RUNS

### Run 1

This operation was very smooth. The producer was airblown for 6 days, using a blast of 24,000 c.f.h. of air and 375 pounds per hour of steam, yielding a gas with 8 percent carbon dioxide. The air was then replaced with 14,580 c.f.h. of oxygen and the steam increased to 2,417 pounds per hour. These flows were maintained without interruption until the run was completed.

The exhauster and exhauster control damper had to be steamed at the completion of the run to remove accumulations of tar.

Run 2

The same initial air-steam blast was used as in run 1. After 3 days on air, oxygen was admitted. After 4 days running under specified conditions, the producer was switched back to air operation for 3 days followed by 1 day using a low-oxygen (10,000 c.f.h.) and low-steam (1,375 pounds per hour) blast. This interruption was made to permit making changes in the Girbotol purification equipment.

After 2 days on full production, air was again applied to the blast, and the producer continued airblown for 5 days to steam tar from the exhauster and start up the precipitators. Two days of operation with oxygen blast were followed by a day on air, to permit removal of tar from the exhauster butterfly control valve. Gasification with oxygen blast then continued uninterrupted until the producer was shut down 8 days later.

Fire conditions were good during the beginning of the run but became erratic toward the end. As an indication of fire conditions, in 51 percent of the total number of operating shifts when the producer was oxygen-blown, an adjustment was made to the oxygen flow and to the steam flow. In 43 percent of the shifts a change was made simultaneously to both the oxygen and steam flows.

As mentioned above, in the course of this run deposits of tar were found in the various pieces of equipment to and through which the gas from the producer was being sent. These included the gas exhauster, exhauster-outlet control-valve dampers, synthesis-gas orifice, and the valves and pistons of the synthesis-gas compressors.

None of the analyses of the coke used in the various runs showed the volatile to exceed 2 percent. However, it was not possible to determine whether the tar came from the coke or from coal with which the coke could have become contaminated in the fuel-storage yard. What portion of the tar produced was removed in the water-sprayed, wooden hurdle-filled washer cooler, is not known. Suffice to say, it was not completely removed from the make gas.

When the deposits of tar were found and removed, the 2 electrostatic precipitators were put into service, first with both of them in series downstream of the gas exhauster and later for run 3 and all subsequent runs, with 1 installed on either side of the exhauster.

Run 3

This run was not very smooth because the coke had an excessive amount of fines, particularly during the latter part of the run. (Upon completion of the run, facilities were installed for screening the fines from all coke going to the producer.)

The producer operated for 1 day on air and steam, 2 days on low oxygen and low steam (10,000 c.f.h. and 1,600 pounds per hour), and then on full oxygen and steam for 3-1/2 days.

The oxygen was then replaced with air for 2 days to permit tar removal from the exhauster. This was followed by 3-1/2 days steady operation when the producer was again airblown for 1 day to permit tar removal from the exhauster. Except for 12 hours on air while emergency repairs were being made in the oxygen plant, the producer operated thereafter on oxygen without interruption until completion of the run. There was considerable curtailment in gas production during this latter part of the run because coke with an unduly wide size range had been fired. This evidently led to segregation, the larger sizes proving much less reactive than the smaller. It was not possible to reduce the size range or to feed the different sizes sandwich fashion.

As an index of fire conditions, in 43 percent of the total operating shifts the oxygen flow was adjusted, in 67 percent of the operating shifts the steam flow, was adjusted and in 37 percent of the shifts both oxygen and steam flows were adjusted simultaneously.

Run 4

On the whole, this operation was smooth. Full gasification with oxygen was preceded by 3 days with air and steam blast (24,500 c.f.h. and 600 pounds per hour). After 1 day a switch was made to air blast to permit repacking the exhauster seals. Two more days on oxygen was followed with another switch to air blast to permit removal of tar from the exhauster. There was no other interruption after this except for 16 hours on air because of contamination in the 275-p.s.i.g. steam supply line.

Fire conditions were good, as evidenced by the fact that in only 11 percent of the total operating shifts was there any readjustment of the oxygen flow. In 51 percent of the shifts the steam flow was adjusted. In 10 percent of the total operating shifts both the oxygen and steam flows were adjusted simultaneously.

Run 5

This run was extemely smooth. For the startup (airblown operation), it was decided to run with a higher carbon dioxide content (11 to 14 percent) in the make gas to note the effect on the hydrogen-carbon monoxide ratio and also, if possible, to reduce the time in coming up to full gas production when the air blast was replaced with oxygen. A carbon dioxide content of 11 to 14 percent with air blast was equivalent to 23 to 29 percent carbon dioxide had an oxygen blast been used. The producer operated under these conditions - air, 24,400 cubic feet per hour; steam, 700 pounds per hour; carbon dioxide, 13.8 percent - for 3 days, when the steam in the blast was reduced to normal (400 pounds per hour) for 3-1/2 days. Oxygen then displaced the air, and it was then that it was found that the excessive steaming with air had produced a very fine ash (mud), which the ash plow could not remove from the ash pan. Blast ports on the conical grate had become plugged so that a high blast pressure was required to obtain the required oxygen-steam flow through the fuel bed.

During this run there were two very minor interruptions when, as customary, air blast was substituted for oxygen, and the gas so produced was sent to the flare stack instead of to the holder. One was due to an interruption in the purification plant and the other to failure of a cooling-tower pump. One short curtailment in oxygen flow was cuased by clinker trouble.

Fire conditions can be judged by the fact that in only 11 percent of the total operating shifts was any readjustment made to the oxygen flow, the steam flow was changed in only 17 percent of the shifts, and in only 7 percent of the shifts was there an adjustment of both the oxygen and steam.

Run 6

This run was very smooth. The only interruption to oxygen-blown operation was a 3-day standby period on air blast at the request of the synthesis plant. This period followed 5 days of curtailed gasification with oxygen blast, also at the request of the synthesis plant.

Fire conditions in the producer can be judged from the fact that in only 27 percent of the total operating shifts when on full production was it necessary to readjust the oxygen, 35 percent to readjust the steam flow, and 18 percent to readjust both oxygen and steam.

Run 7

This run was the longest and smoothest operation of the Kerpely producer.

Toward the end of the run the producer was put on air standby for a few hours to permit repair of a split in the gas-exhauster housing. After restoring full production on oxygen for 1 day, another split developed in the exhauster, and it was decided to terminate the run.

Fire conditions throughout the run were good, evidenced by the fact that in only 7 percent of the total operating shifts was it necessary to change the oxygen flow, in only 41 percent was it necessary to change the steam flow, and in only 2 percent was it necessary to change both oxygen and steam simultaneously.

In this and other of the later runs the lessened frequency of adjustment to the steam and oxygen flows was not only indicative of better fire conditions but reflected the improved skill of the operators in handling the producer.

## OPERATING TROUBLES

The Kerpely producer was not a new one; it had been in use for many years in St. Louis, Mo., before being reinstalled at Louisiana, Mo.

Consequently, it is not surprising that the conical grate casting wore through and eventually cracked. The erosion was on that portion of the face of the casting that is closest to the apron of the producer shell. The grate being eccentric to the producer shell, this face is responsible, in its rotary travel, for crushing any clinker between it and the apron and thus permitting it to fall into the ash pan. The worn condition was corrected by rotating the cone 180° with respect to the ash pan, thus allowing an unworn portion of the face of the casting to crush the clinker. The cracks were repaired by brazing. The wear on the grate, probably not inconsiderable when the producer was installed at Louisiana, was no doubt increased by the amount of clinker the grate was required to crush in the earlier runs. It is more than likely that the worn casting had already exceeded its normal life before the producer was reinstalled in its present location.

Where a local breakthrough of oxygen had caused an oxygen-producer gas flame to play on the inside face of the cast-steel skirt or apron of the producer shell, cracks developed. The cracks could also have been caused by localized overheating of the apron as a result of a portion of the primary reaction zone - its location established by the vertical roddings - slipping down along the producer side wall to the apron below it. Development of the cracks from this cause cannot be attributed solely to the oxygen blast. Similar cracks in the apron have been noted in producers of identical design, which have always been air-blown and never subjected to a process oxygen blast. The cracks were from 12 to 18 inches above the water level in the ash pan, the apron in its immersion below the water forming a gas-tight seal for the producer. These cracks had to be welded to prevent the escape of gas and flame.

In the course of operation there was spalling of the fire clay shapes around the poke holes, the same that form the crown of the producer. These caused hot spots to develop on the top casting of the producer.

The spalling of the fire-brick shapes in the crown may have been attributable to the cooling down of the refractory between runs and may not have occurred had the producer been operated more continuously. Another cause of the breaking of this crown brickwork may have been the more frequent and vigorous rodding and barring of the fire necessitated by oxygen operation.

## COMMENTS ON OPERATING RESULTS

As mentioned previously, the purpose of operating the Kerpely producer was to generate synthesis gas of a definite hydrogen-carbon monoxide ratio at a definite rate.

The process variables in accomplishing this were:

(a) Steam rate.

(b) Oxygen rate.

The coke rate was not controlling but was itself controlled by the quantity and composition of the oxygen-steam blast. Thus, figure 3 shows that, with a given oxygen rate, the rate of coke consumption decreased as the steam-oxygen ratio increased. With the undecomposed steam acting as a thermal burden, further increase in the steam-oxygen ratio with the same oxygen rate would have still further reduced the coke consumption and gas yield from the producer.

For all the runs reported, the average ratio, volume of steam to volume of oxygen, was 3.5. In a previously reported investigation of the gasification of coke in oxygen[13] the results are tabulated according to volumetric steam-oxygen ratio in the range 1.0 to 7.0. It was found that for best results in oxygen consumption, carbon utilization, and ash conditions, a ratio of 3 was the most desirable. At this ratio of 3, the results these investigators obtained......cold gas efficiency, oxygen consumption per therm, percent $CO_2$, and ratio $H_2$-CO in the product gas...... are in close agreement with averages of the results shown in table 1 of this report.

To maintain steady gas production it was also necessary to maintain stable fire and ash conditions within the producer. This required adjustments to the steam or oxygen flows or both. Moreover, since coke was fed to the producer intermittently rather than continuously, the utilization of the fuel in the producer was affected by changes in coke feeding, as between whole and half charges.

In addition, operation of the producer was affected by the grade of coke available, whether Nut coke or Pea coke or mixtures of both. To have attempted to blend

[13] F. J. Dent, Discussion on Gas Production in Perspective: Trans. Inst. Gas Eng., (London) Communication 141, 1946, pp. 849-851.

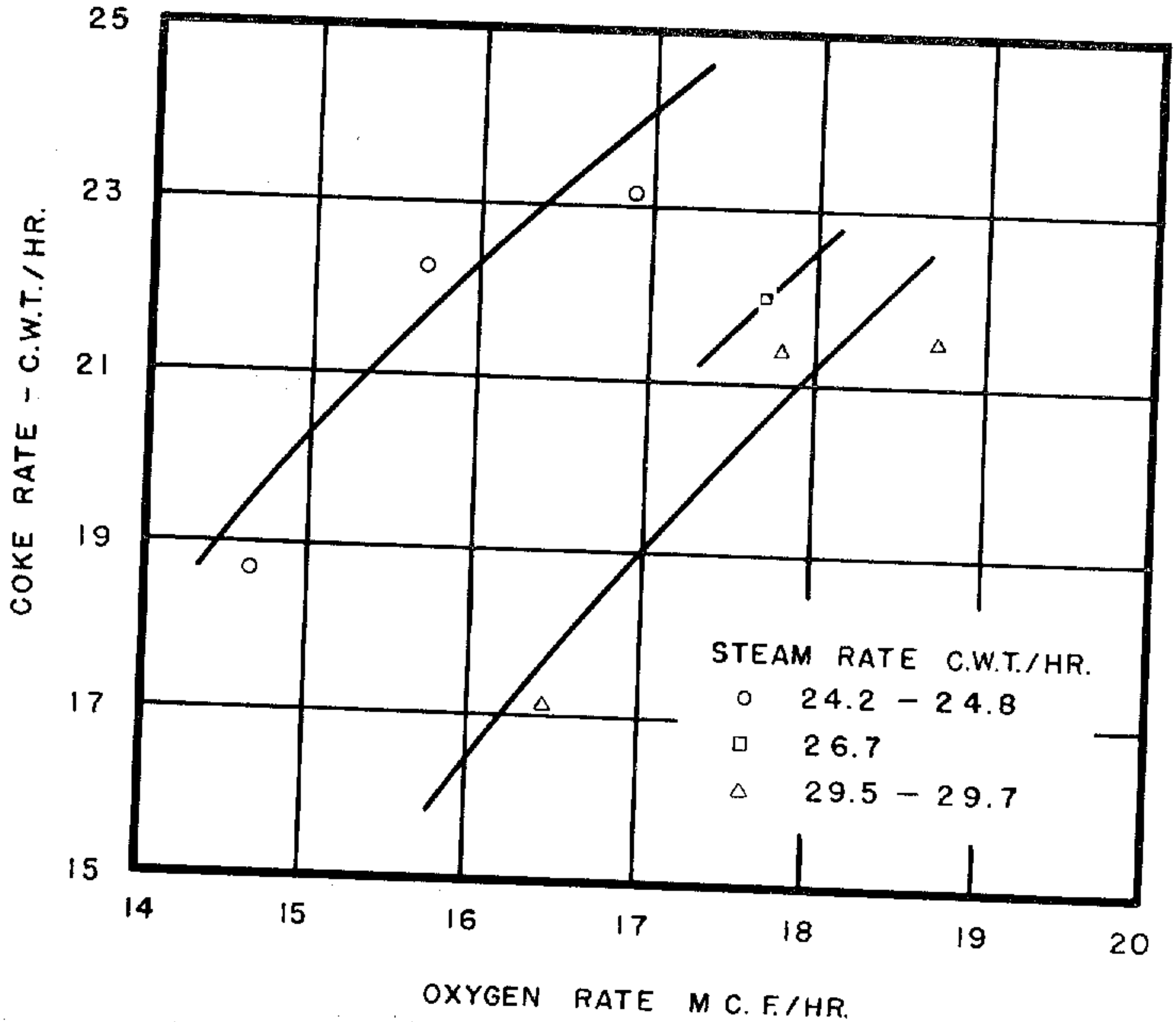


Figure 3. - Effect of steam-oxygen ratio on coke consumption.

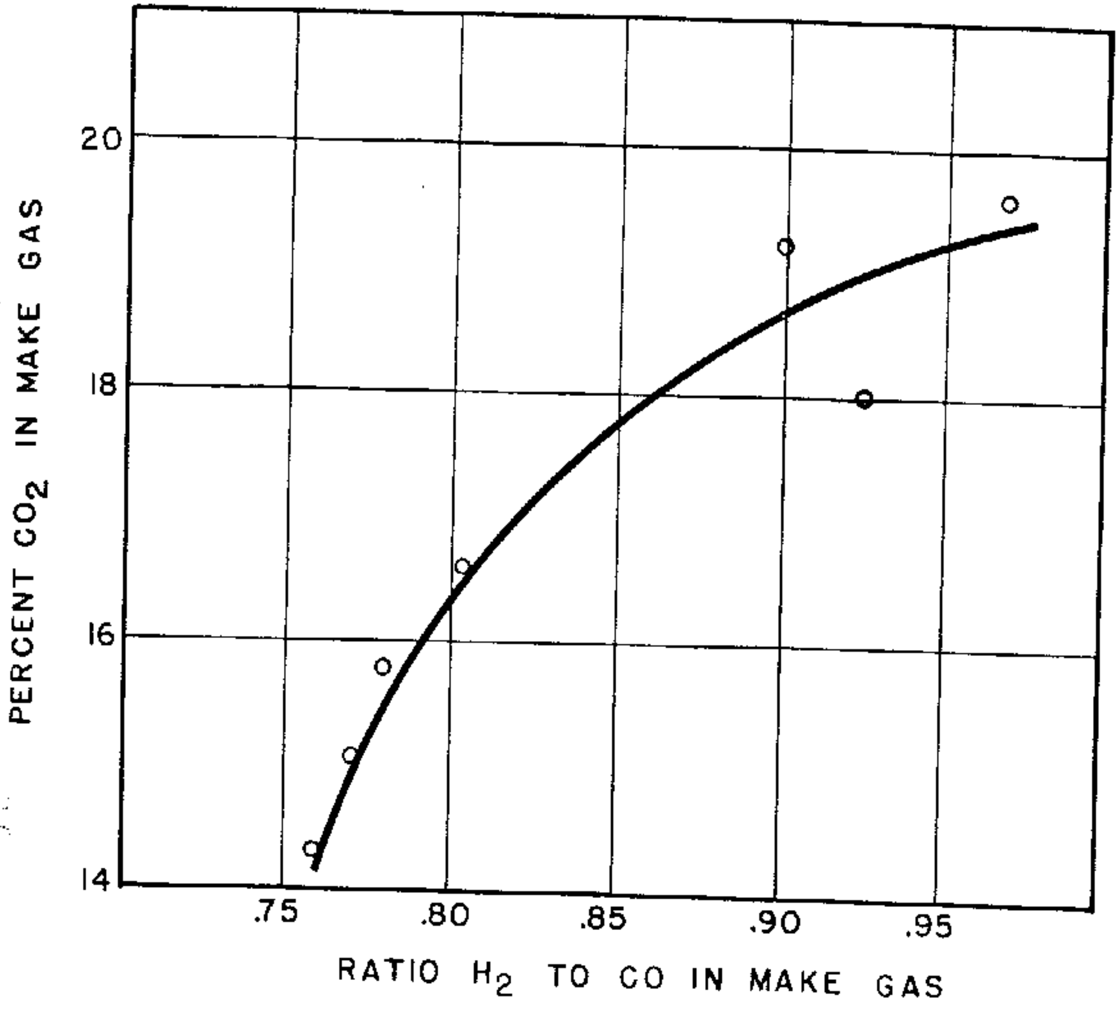


Figure 4. - Relation between carbon dioxide in make gas and hydrogen-carbon monoxide ratio.

the different grades of coke would have involved extensive double handling and considerable demurrage expense.

Another requirement of good operation was to keep to a minimum the amount of unburned coke in the ash. For good operation, too, a coarse ash was desired free from clinkers.

The "tools" available for satisfactory ash removal were the speed of the grate and the setting of the ash flow.

Notwithstanding all the variables involved in the gas-making operation, it was established that operations of the producer could be planned and executed to give reproducible results very closely approximating those desired.

## HYDROGEN-CARBON MONOXIDE RATIO

In operating the producer, the carbon dioxide content of the make gas was to be used as the index of the hydrogen-carbon monoxide ratio, with the steam-oxygen ratio in the blast being the process variable mostly responsible for the carbon dioxide content. From table 1 it is seen that in the first four runs, 15 to 16 percent was the desired content corresponding to a hydrogen-carbon monoxide ratio of 0.75 to 0.8. For runs 5 to 7 it was decided that a hydrogen-carbon monoxide ratio of 0.9 to 1.0 would result in longer life for the Fischer-Tropsch catalyst, so a carbon dioxide content of 19 percent was chosen as corresponding to this range in hydrogen-carbon monoxide ratio. (Run 8 is that shown under the heading Louisiana, Mo., in table 4 of a previous report.[14] It is included for purposes of comparison.)

Reference to the Operating results shown in table 1 and a plot of these results in figure 4 show the relation between the percent carbon dioxide in the product gas and its hydrogen-carbon monoxide ratio.

14/ See footnote 8.