digestion and those who are ill should consult a competent physician.

While breakfast foods of this class are usually not predigested, as they claim to be, they are, on the other hand, quite free from harmful ingredients and have much the same nutritive value as other preparations of similar grains and have a flavor which many like. They are on an average higher priced than the others, but aside from this consideration of economy there is no reason why those who like them should not use them as they do other ready-to-eat cereals.—From Farmer's Bulletin 249, issued by the U. S. Department of Agriculture.

THE MOND PRODUCER.

By DR. J. D. PENNOCK.

THE Solvay Process Company, at its plant at Detroit, installed the first Mond producer plant in the United States in 1898, and I believe this is the only one being operated at the present time. The plant consists of six Mond and two modified Mond producers, which convert to gas about 110 tons of coal per day. I would say that the plant has worked satisfactorily, and with only a reasonable amount of repairs. The acid tower, however, had soon to be rebuilt because of unsuitable tiling with which it was first lined.

Not all coals are suitable for the Mond producer. First, a bituminous coal low in percentage of bitumen, and inferior in coking qualities, must be used to avoid clinkering; second, as it is necessary to obtain a high yield of ammonia to offset the extra cost of installation, depreciation, and operation of the by-product portion of the producer plant, a coal high in percentage of nitrogen must be employed. After a careful ultimate analysis of the slack used in the Mond producer in England, we were fortunate in finding one corresponding closely to it in the Hocking Valley coal fields. It is a coal approaching a lignite in composition, having 6 to 7 per cent of water of constitution, and a high percentage of oxygen, and is especially desirable because of a high percentage of nitrogen. The analyses of the English coal and the Hocking Valley are as follows:

	Hocking Valley Nut Coal.	English Producer Coal.
Moisture (chemically combined)	Per cent. 7.84	Per cent. 6.85
Volatile matter	27.95	33.14
Fixed carbon	50.75	48.93
Ash	13.46	11.10
Sulphur	1.50	1.68
Nitrogen	1.45	1.35

The relation of the hydrogen to the oxygen in the coal, which is an important factor in the clinkering and the yield of ammonia and tar, is as follows:

	Hydrogen.	Oxygen.	Available Hydrogen.
	Per cent.	Per cent.	Per cent.
English coal	3.90	12.08	2.32
Hocking Valley	4.65	10.86	3.26

The Mond gas at Detroit is somewhat different from that obtained in England, as the following comparison shows:

	Mond Gas.	
	Detroit.	England.
Carbon dioxide	Per cent. 14.6	Per cent. 16.5
Oxygen	0.5	11.0
Carbon monoxide	10.3	2.0
Methane	5.3	27.5
Hydrogen	23.5	43.0
Nitrogen	55.8	40.5
Total combustible	39.1	40.5
Gross B.T.U. per cb. ft.	163.5	145.5
Net B.T.U. per cb. ft.	146.6	129.7

The yield of ammonia amounts to 70 to 75 pounds of sulphate per long ton of coal. Tar amounting to 55 to 65 pounds per ton of coal is also recovered; this is much lighter in gravity than the ordinary coal tar and has little value except as a fuel and as such is worth about 1s. per gallon.

Taylor Producer.

I might say a few words in addition to what has already been stated about ordinary producer gas.

For the production of gas to be used under drying furnaces we have at the works of the Solvay Process Company, at Syracuse, thirty Taylor producers, which gasify 134 tons of anthracite buckwheat coal per day. The air is introduced by means of live steam injector, and the coal for the steam used is about 10 per cent of that gasified. These producers are not supplied with automatic and continuous feed. The analysis of gas advertised as attainable by the promoter of the Taylor producer is seldom obtained in practice. The temperature of the producer chamber above the fuel bed is so high, due to unevenly covered surface of the bed and the holes through the bed, that the water is dissociated, hydrogen formed and the percentage of carbonic acid gas increased.

Temperatures taken, with electrical pyrometers at various points in the producer were as follows:

	Number of Producer.			
	1	3	5	7
Temp. at top of fuel	°C. 950	°C. 955	°C. 965	°C. 970
2 ins. above surface	900	910	910	905
1 ft. above surface	650	650	660	650
2 ft. above surface	600	600	605	595
at outlet.				

The analyses of producer gas, as made at Syracuse and that advertised by Mr. Taylor, are:

	Syracuse.	Mr. Taylor.
	Per cent.	Per cent.
Carbon dioxide	8.4	4.5
Oxygen	0.2	0.6
Carbon monoxide	22.7	25.5
Methane	1.0	1.0
Hydrogen	16.2	12.0
Nitrogen	51.5	56.4
B.T.U. per cb. ft.—Gross	136.4	131.7
B.T.U. per cb. ft.—Net	127.5	124.8

Theoretical Considerations.

I wish to call attention to a few theoretical considerations which have a bearing upon the efficiency of the various gases in the gas engine. The table at foot of

FIG. 1.

page gives the analyses of gases, their heat value, the theoretical amount of air required for combustion and the corresponding pressure, and the relative volume of gases before and after combustion under the same conditions of temperature. The sample of coke oven gas represents that which is available during the first eight hours of the coking process.

Composition: Per Cent by Volume.

In the theoretical calculations in this paper the following values have been used:

	Calories per M ³ (0°C. and 760 mm.)		B.T.U. per cb. ft. (60° F. and 30 ins.)	
	Gross.	Net.	Gross.	Net.
Hydrogen	3061	2600	326.2	277.1
Carbon monoxide	3036	3036	323.5	323.5
Methane	9478	8531	1010.0	909.1
Ethane	16558	15151	1764.6	1614.6
Ethylene	14900	13957	1588.0	1487.4
Acetylene	13857	13391	1476.7	1427.1
Benzene	35725	34298	3807.2	3655.1
■luminants {1/4 C ₆ H ₆ , 3/4 C ₂ H ₄ }	20096	19042	2141.6	2029.3

	Composition: Per Cent. by Volume.					
	Taylor Producer.	Mond Producer.	Coke Oven.	Blast Furnace.	Natural Gas (Pittsburg).	Natural Gas (Ohio).
Carbon dioxide	8.4	14.6	1.8	11.7	0.8	0.2
Benzene	—	—	1.0	—	3.6 (ethane)	—
Ethylene	—	—	4.8	—	0.7	0.2
Oxygen	0.2	0.5	0.2	—	1.1	0.4
Carbon monoxide	22.7	10.3	4.2	27.5	1.0	0.6
Methane	1.0	5.3	36.7	—	72.2	92.8
Hydrogen	16.2	23.5	45.5	—	20.0	1.9
Nitrogen	51.5	45.8	5.8	60.8	—	3.8
Calories per M ³ } —Gross	1280	1533	6071	835	8185	8901
(0°C and 760 mm.) } —Net	1196	1376	5454	835	7352	8012
B.T.U. per cb. ft. } —Gross	136.4	163.4	647.2	89.0	872.0	948.0
(60° F. and 30") } —Net	127.5	146.6	581.2	89.0	783.7	854.0
Combustion with the theoretical quantity of air—						
Vol. air per 1 vol. gas	1.00	1.27	5.64	0.65	7.92	8.79
Theoretical temperature °C.	2678	2634	3459	2227	3380	3331
Theoretical pressure atm.	8.9	12.2	7.5	—	12.2	12.2
Theoretical pressure, lbs. per sq. in.	131	179	110	—	179	179
Vol. decreased by combustion (original vol.=100 per cent.)	9.8	7.5	3.7	8.4	0.9	0.1

Sp. Hts. at const. vol. used in calculation: Water, 0.37; carbon dioxide, 0.17; nitrogen, 0.17.

By gross is meant that the temperature is brought to the same point before and after combustion (figured for 18 deg. C.) and that the water formed is condensed.

By net is meant that the temperature is brought to the same point before and after combustion (figured for 100 deg. C.) and that the water is not condensed.

Calculations based on Thompson's results "Thermo-chemische Untersuchungen."

The practical value of efficiency of a fuel gas within the cylinder of a gas engine is ordinarily considered to be in direct proportion to the heat units of that gas, but this is not strictly true; fuel gases of the various kinds have different percentages of a number of different gases, each having its own individual qualities which in the explosion effect the transference of thermal energy into mechanical.

For instance, there is a difference in the inflammation temperature of the various constituents of the gases; hydrogen ignites at 550 deg. C., carbon monoxide at 655 deg. C., methane at 656 deg. C. It is said that a gas containing a high percentage of hydrogen is particularly liable to pre-ignition. While we know the temperature of ignition of the gases singly, nothing is known concerning the ignition temperature of a mixture of these gases in various proportions at atmospheric and other pressures. Experiments in this direction would doubtless be of great assistance to designers of gas engines.

Then there is the question of propagation of flame and its relation to the economical production of power in the gas engine. The normal propagation of flames (according to Berthelot) of hydrogen is 4.3 meters per second, methane 0.62 meter, and carbon monoxide 2 meters per second.

The experiments made at the Institute of Technology in Boston give the rapidity of explosion of hydrogen with the theoretical quantity of air as more than ten times that of illuminating gas. Berthelot says when two combustible gases, such as hydrogen and carbon monoxide, are burned in oxygen, the rate is by no means the mean of that of the two gases. They appear to burn separately each with its own rapidity. Further, water, one of the products of explosion, dissociates at 874 to 900 deg. C., and may this not take

FIG. 2.

place at the expense of thermal energy and may it not happen that there should be sufficient cooling of the cylinder to prevent recombination and giving up of that heat before the exhaust opens? The dissociation of carbon dioxide begins at 1,300 deg. C., but, of course, this is never reached. All of these considerations doubtless have some bearing on the efficiency of the gas for power development.

Mean Pressure Efficiency and Calorific Values.

From the Technology measurements of the mean pressures obtained during the first 0.2 second after explosion, using all proportions of air to gas, it appears that, in the case of water gas, the best efficiency results when using that quantity of air which gives a theoretical maximum pressure of about 8.4 atmospheres (124 pounds per square inch). Using this quantity of air with the above gases (except the blast furnace gas) the results shown at top of next page are obtained.

By the above charts, one of some explosion experiments made with the Mond gas at Detroit under direction of Mr. A. F. Shattuck, and the other of some explosions of illuminating gas of 721 B.T.U. (gross) mixed with various percentages of air, made by a student at the Institute of Technology in Boston, it will be observed that the maximum pressure obtained is about one-half the theoretical; further, that this maximum pressure is obtained when 80 to 85 per cent of the theoretical air necessary for combustion is used.

Coke Oven Gas.

We now come to the consideration of retort coke oven gas for gas engines. While it is true that a coke oven gas is similar in analysis to coal gas, or illuminating gas made in the well-known gas retort, the composition of the coke oven gas is within the control of the operator; the ovens may be so regulated that the hydrogen may be low or high in percentage; that the carbon dioxide may be reduced to a minimum or almost eliminated, or it may be of such a percentage as to materially deteriorate the gas for illuminating or power. This is made possible because of the large size of the charge of coal in the by-product oven; the possibility of regulating the temperature of coking and the time of coking. In coal gas manufacture, a small re-

	Syracuse Producer.	Detroit Producer.	Coke Oven.	Blast Furnace.	Natural Pitts.	Natural Ohio.
Vol. of air per 1 vol. gas	1.09	1.50	8.93	0.65	12.4	13.5
Theoretical temperature, °C.	2560	2435	2358	2227	2313	2302
Theoretical pressure (max.) atm.	8.4	8.4	8.4	7.5	8.4	8.4
Theoretical pressure, lb. per sq. in.	124	124	124	110	124	124
Ratio of mean pressure efficiency equal vol. of gas ..	1	1.20	4.76	0.70	6.41	6.96
Ratio of calorific values of equal vol. of gas ..	1	1.18	4.56	0.70	6.15	6.70

tort of 300 or 400 pounds capacity, fired with coke and coked in five or six hours, is used. In the by-product oven, eight or nine tons of coal are coked in a space approximately 30 feet long, 8 feet high, and 17 inches wide, during a period of twenty-two to twenty-four hours; by manipulating properly the valves between the oven and the hydraulic main, turning the gas first into one and then into the other main, the quality of the gas may be regulated to a nicety; by the proper regulation of the supply of the gas to the oven for the coking process and by the regulation of the temperature of the flues by electrical pyrometers and Seger cones, the temperature of the distillation within the oven may be maintained at any desired degree. We may thus obtain by proper manipulation gas of varied composition, as is shown by the following analyses:

Analyses of Gas.

	Gas first 8 hours.	Gas for 16 hrs. after.	Average Gas for 24 hours.	Enriched Gas as delivered.
Carbon dioxide	Per cent. 1.7	Per cent. 1.9	Per cent. 1.8	Per cent. 1.6
Benzene	0.5	0.2	0.3	0.9
Ethylene	4.7	1.5	2.9	4.8
Oxygen	0.4	0.5	0.5	0.5
Carbon monoxide	4.8	4.5	4.6	4.8
Methane	42.0	32.0	36.5	42.0
Hydrogen	35.0	51.0	43.8	35.0
Nitrogen	10.9	8.4	9.5	10.4
B.T.U. per cu.ft.	683	565	618	701
Gross	614	502	551	631
Net	6078	5027	5500	6235
Calories per M ³	5466	4471	4901	5618
Gross				
Net				

Nine hundred thousand cubic feet per day of enriched gas of 18 candle-power were delivered during the year 1904 from the Semet-Solvay Company plant of forty ovens at Chester, Pa., to the Chester Gas Company, which, in turn, dealt it out to consumers for illuminating, gas engines, and fuel purposes.

Gas of the quality shown in the table of analyses, containing a high percentage of benzene and methane, and low percentage of hydrogen, is formed during the early stages of the coking process. The gas formed in the latter part is practically devoid of benzene and ethylene, the illuminants, and high in percentage of hydrogen. As it is desirable for power purposes to have a gas of minimum hydrogen to avoid possibility of pre-ignition, gas of the quality represented by the first analysis is the best.

The following chart shows how the British thermal units fall off in the tenth hour, and likewise how the per cent of methane diminishes and the hydrogen increases.

The distillation process proceeds from the top downward, and the heat reaches the center of the mass of coal very slowly.

Experiments were made and temperatures taken by the electrical pyrometer every fifteen minutes from several locations in the oven, and also above the mass of coal; here the lowest temperature was about 720 deg. C. The temperature of the heating flues, three in number, horizontally placed, was 1,050 to 1,150 deg. C.

Quality of Gas Dependent on Composition of Coal and Heat of Oven.

The quality of the gas is not only dependent upon the heat of the oven, but also very largely upon the quality of the coal. This is well known and recognized when considering the Pennsylvania bituminous coking and gas coals and their relation to heavy hydrocarbons or illuminants in the gas, but that different coals when coked in tight ovens, which exclude the air, give varying percentages of carbon dioxide, is not well known. Some coals of the Illinois and Indiana region and the Far West, more or less of a lignitic nature, give a gas containing as much as 7 or 8 per cent of carbon dioxide gas, whereas a Pennsylvania coal under the same oven conditions would give only 1.5 to 2 per cent. This naturally would cut down the B.T.U. considerably, and reduce largely the efficiency in a gas engine. The reason for this high per cent of CO₂ in the gas is the high percentage of oxygen in the coal. An analysis of an Illinois coal, Big Muddy, for instance, shows 12 per cent oxygen. In it there is a large excess of oxygen over that required to combine with hydrogen in the coal, and this excess combines with carbon to form an abnormally high percentage of carbon monoxide and dioxide.

Coke Oven Gas at Detroit and Milwaukee.

It will be observed from the following table that the gas at Detroit and Milwaukee is considerably richer in heat units than that previously described as being made at Chester. The increase in energy for gas engines per unit of gas is due to the greater amount of benzene, toluene, and xylene it contains. The process by which this is accomplished may be described as follows:

As before stated, the gas evolved during the early part of the coking period is richest in heat-giving constituents; and hence this rich gas, that evolved during the first seven or eight hours, is separated from that made during the remaining sixteen hours, and afterward further enriched by means of the benzene and its homologues taken from the lean gas.

The Semet-Solvay coke ovens, 120 at Detroit and 80

Analysis of Gas for February, 1905.

	Milwaukee.	Detroit.
	Per cent.	Per cent.
Carbon dioxide	1.4	1.3
Benzene	1.3	1.2
Ethylene	4.3	4.2
Oxygen	0.4	0.5
Carbon monoxide	4.0	5.1
Methane	36.8	35.5
Hydrogen	47.0	48.0
Nitrogen	4.8	4.2
B.T.U. per cu. ft.—Gross	692	679
B.T.U. per cu. ft.—Net	621	610
Calories per M ³ —Gross	6154	6044
Calories per M ³ —Net	5528	5430

at Milwaukee, during the year 1904 have delivered to the gas companies of these cities gas of about 675 B.T.U. (gross) and of 19 to 21 candle-power, at the rate of 2,700,000 cubic feet and 1,900,000 cubic feet per day.

Daily Production During First Half of March, 1905.

	Coal Coked.	Gas Delivered.	Gas per Ton Coal.
Milwaukee	Tons. 588	M. 1,999	Cub. Ft. 3400
Detroit	888	2,752	3100

M=1000 cu. ft.

Objection to Coke Oven Gas on Account of Sulphur.

Objection to the use of coke oven gas, without previous treatment to remove the sulphur, cannot be invariably maintained. Our own experience at Syracuse for several years with a 125-horse-power Westinghouse engine developing 85 B.H.P.—90 pounds pressure—on coke oven gas of 450 B.T.U. (net) (28 cubic feet gas per B.H.P.), made from a coal containing 1.1 per cent, is that no serious corrosion has taken place due to sulphureted hydrogen or sulphuric acid.

If, however, water were mixed with the lubricating oil in the crank case, enough sulphuric acid would be soon absorbed to cause attack on the metal.

FIG. 3.

Of twenty-two gas-engine installations in Germany, of a total of 13,000 horse-power, working on coke oven gas, eleven, or 50 per cent, do not find it necessary to purify the gas. The others use bog-ore or saw dust. With efficient tar extractors and ammonia washers, tar and dust are readily removed. One of these German installations was using a gas with 0.2 per cent sulphur without injurious effect on the iron.

Pre-ignition.

Pre-ignition or explosion before the completion of the compression is said to more often happen with coke oven than with other fuel gases, like producer and natural gas, and the reason given for it is the high percentage of hydrogen. Authorities vary as to the cause of pre-ignition. If pre-ignition is chargeable to high percentage of hydrogen, coke oven gas is no more liable to pre-ignition than Mond producer, or ordinary producer gas; unquestionably we must consider the percentage of hydrogen in the explosive mixture. By the following it will be seen that the coke oven gas, used in the above table of gases, when mixed with that amount of air which gives the maximum efficiency in the engine, contains less hydrogen than the proper mixture of producer gas and air.

Pre-ignition is not common with small engines up to 50 horse-power, and with large engines is no more

frequent with coke oven gas than with other fuels. Of eight managers of plants using coke oven gas in engines up to 750 horse-power, whose opinion was asked concerning pre-ignition, two stated that they had had some pre-ignition, and six had never been troubled with it, though the hydrogen ran as high as 50 per cent in some instances. One of the managers who had trouble said that he had overcome it by varying the compression in inverse proportion to the value of the gas mixture.

One of the greatest authorities in England, who has installed many engines of various types and worked them with gases of different kinds, in writing to our company said that he had used coke oven gas in a 40-horse-power, 107 pounds compression, and 140-horse-power, 95 pounds compression engine without being troubled with pre-ignition, that he had worked a Vogt engine to a pressure of 200 pounds on coal gas, practically the same as coke oven gas without trouble, and many others from 100 to 650 horse-power. He further says, "that probably when a gas contains more than 30 per cent of hydrogen the additional hydrogen has but little effect upon the question of pre-ignition." He further states, "in probability the effect of free hydrogen in producing pre-ignition is not the question of temperature at which free hydrogen combines with the oxygen of the air present, but has to do with the effect of free hydrogen on the iron of the cylinder and possibly on the layers of partly burned oil."

I believe coke oven gas to be the power gas of the future, in places where it is impossible to get blast furnace gas or natural gas, on account of its high calorific value, freedom from dirt and tar, and its adaptability to pumping great distances under pressure in comparatively small pipes.

AIR IN RELATION TO THE SURFACE-CONDENSATION OF LOW-PRESSURE STEAM: AN EXPERIMENTAL STUDY OF CONDENSER PROBLEMS.*

By JAMES ALEX. SMITH.

TO some extent the present is a sequel to a former paper dealing with "Air in Relation to Boiler Feeds," read before this Institute on June 4, 1904.

The principal object is to contribute to the knowledge of an imperfectly investigated subject, fundamental data derived from direct experimental researches by the writer. The aim is to stimulate discussion and examination of hypotheses that have been accepted upon premises that are no longer sufficiently accurate to meet the exigencies of modern design.

The keynote is the effect of gases—specifically, atmospheric air—upon working efficiencies and capital investment.

The chief deduction is that air, even in minute traces hitherto considered innocuous, should be, by initial design and subsequent management, rigorously excluded from high-grade surface-condensing installations. Certain laws of condensation are also enunciated.

PRELIMINARY.

Steam engine practice is inferred throughout. The method of extending the deductions to the condensation of steam for potable water, or vapors for manufacturing processes, will be obvious.

Even a superficial glance reveals the inadequacy of the older data. First, because the trend is to expand steam to degrees undreamt of in the past, when those data were collected, and to reject it at temperatures so low that crude rules, simply embodying obsolete average conditions, are useless. Second, because it appears to be tacitly assumed that generalizations derived from incomplete investigations of pure steam are equally, and without modification, applicable to mixtures of steam and gas.

Experiment shows that such assumptions are fallacious, and that the presence of air in quantities that might have been deemed insignificant may, in fact, become the factor limiting the efficiency of a whole steam plant. For instance, air equal in pressure to only 1-20th of an inch by the mercury gage will, at 90 deg. F., reduce thermal transmission some 25 per cent, while 3-20ths will lower it about one-half. Before these special effects could be determined it was necessary to investigate the whole subject of surface-condensation.

EFFECT OF CONDENSER TEMPERATURE UPON ENGINE EFFICIENCY.

The necessity for dealing with the main issue will be inferred from an elementary analysis of the effects upon the thermal efficiency of the reduced temperatures aimed at. It must, however, be clearly understood that in the cases of engines, reciprocating or rotating, not specially designed to utilize these temperatures, it may be inadvisable to attempt their use.

* Read before the Victorian Institute of Engineers. Revised by the author.

	7.5 Atmos.					
	Syracuse Producer.	Detroit Producer.	Coke Oven.	Natural Pittsburg.	Natural Ohio.	Blast Furnace.
Hydrogen	Per cent. 7.77	Per cent. 8.16	Per cent. 4.60	Per cent. 1.50	Per cent. 0.13	Per cent. 0.00
Carbon monoxide	10.88	3.00	0.42	0.08	0.04	16.67
Methane	0.48	3.08	3.70	5.38	6.37	—
Ethylene	—	—	0.48	0.05	0.01	—
Benzene	—	—	0.10	C ₂ H ₆ =0.27	—	—
Carbon dioxide	4.03	6.04	0.18	0.06	0.01	7.09
Oxygen	0.09	0.44	0.02	0.08	0.03	—
Nitrogen	24.69	19.28	0.58	—	0.26	36.85
Air	52.06	60.00	89.92	92.58	93.15	39.39