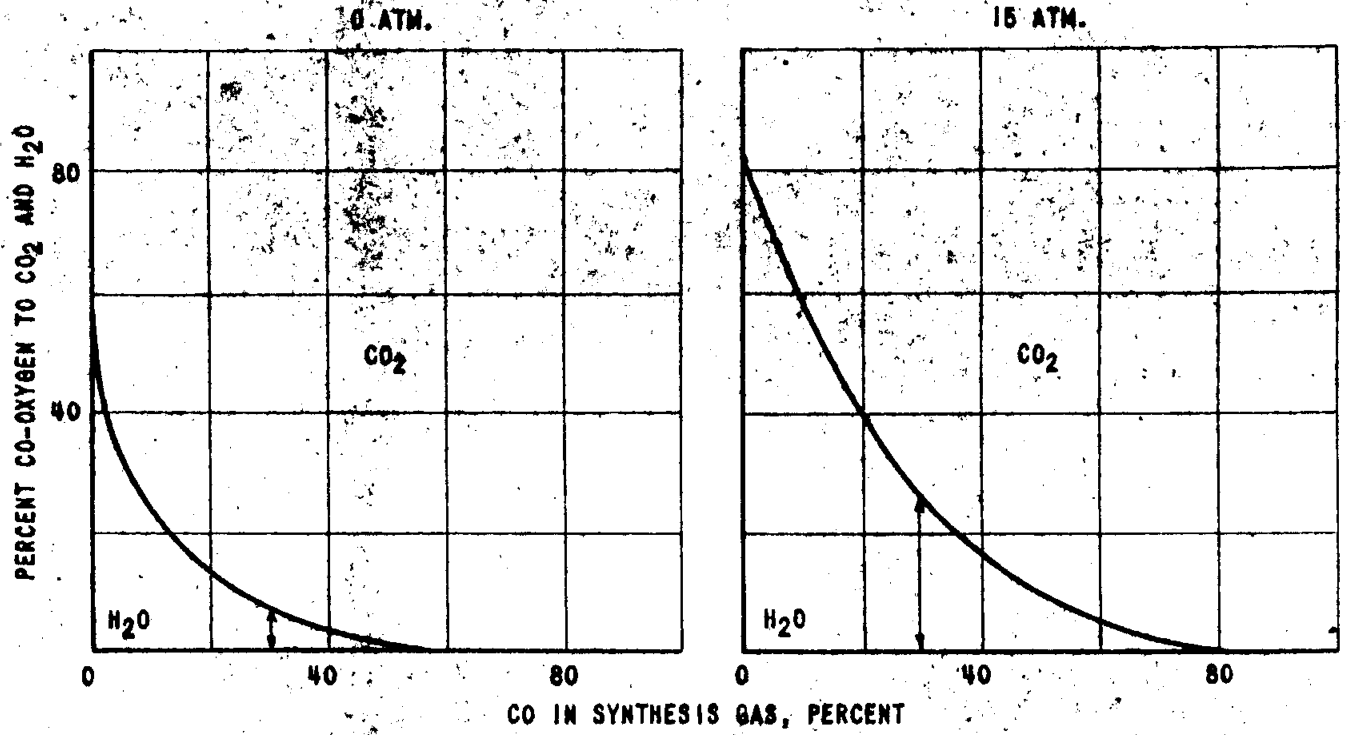

Figure 6. - Conversion of the CO-oxygen to CO_2 and H_2O, respectively, for various synthesis gas compositions at 0 and 15 atmospheres pressure.

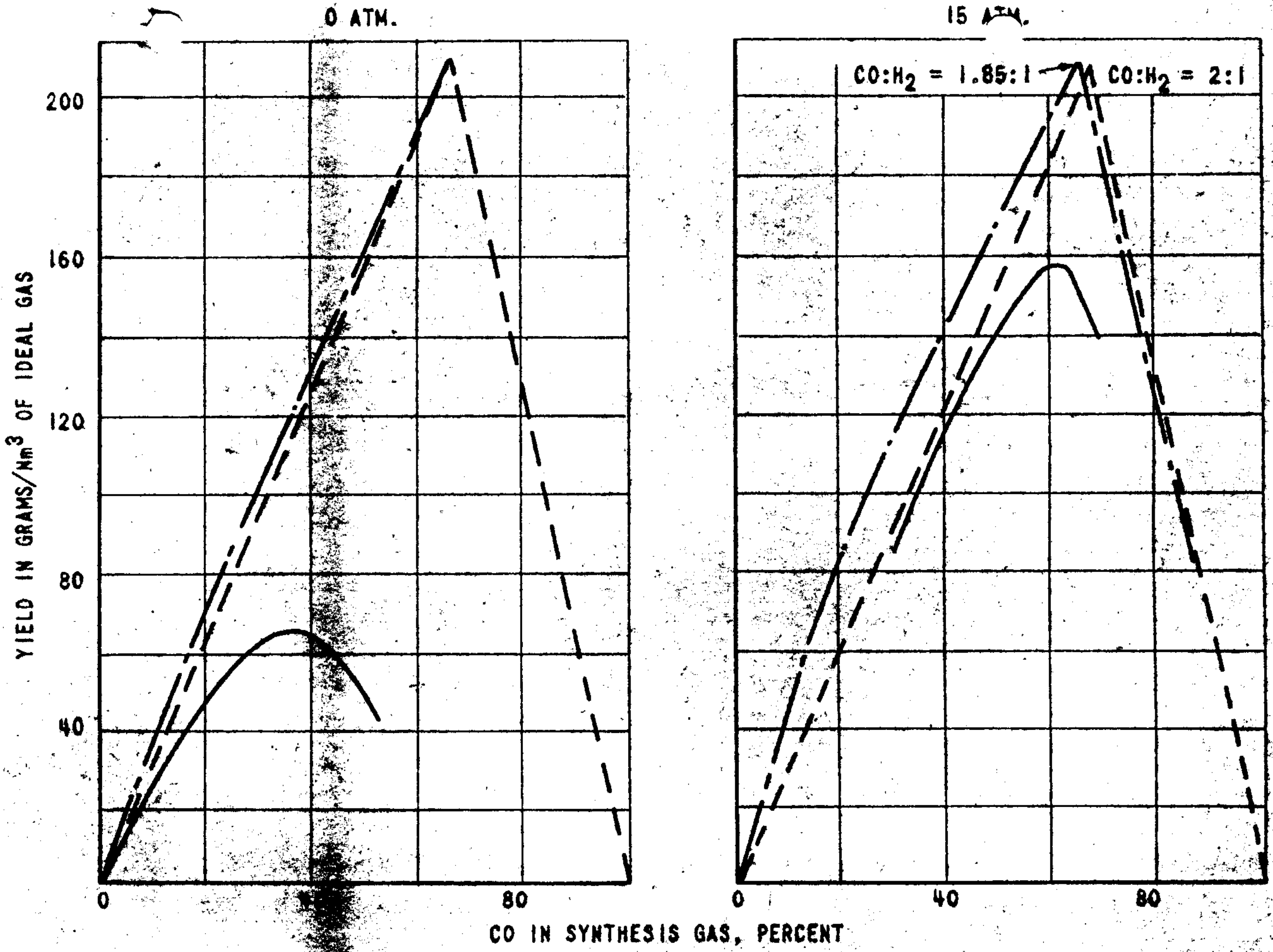

Figure 7. - Influence of synthesis gas composition upon the yields.

For the formation of CH_2 hydrocarbons, less hydrogen is required than for the formation of CH_4. Finally it seems to be advantageous for the activity of the catalyst if the final gas still contains a small excess of hydrogen. The ideal synthesis gas, therefore, contains 60 percent CO and 40 percent H_2. At this occasion let us mention something about the production of synthesis gas. In the Institute, this gas mixture was generated in a normal gas generator. We conducted CO_2 and steam over hot coke. Such a process could even be recommended in some instances for large-scale operation, since the synthesis carried out with the iron catalysts forms far more CO_2 than would be required for the production of the synthesis gas. From one cubic meter of synthesis gas with a ratio of $3CO:2H_2$, normally 250 liters of CO_2 are obtained, whereas according to $5C + 4H_2O + CO_2$ is equal to $6CO + 4H_2$ only 100 liters of CO_2 are required per cubic meter of CO-rich gas. Already a partial scrubbing of the CO_2 from the end-gas and addition of same to the gas generator could account for all the CO_2 needs of the generator.

The carbon requirement demanded by the above equation is no larger than that for the production of normal water gas.

The production of CO-rich gas in the water-gas generator of the Institute and the purification of the gas is taking place in the Institute already for years at the production rate of 100 cubic meters per hour. If one would work off not only the CO_2 but also the methane (5 to 10 percent) and the unreacted CO and H_2 (10 to 15 percent) one could approach the theoretical yield of 208 hydrocarbons per normal cubic meter of gas.

Another way to make synthesis gas is by the well-known gasification of coke or coal along with the addition of oxygen. It is unnecessary to elaborate on this.

3. The Synthesis Pressure.

In the chapter on the synthesis gas, we have already explained the reasons why, in the hydrocarbon synthesis on iron catalysts, work at atmospheric pressure is not practicable. Table IV brings some comparative experiments for which the synthesis was undertaken with the same catalyst at various elevated pressures.

We used a number of iron catalysts which had been inducted for 24 hours at 1/10 atm., and 325°C. with a CO-rich synthesis gas. Table IV shows the results of experiments completed at 5, 10, 30, and 60 atmospheres. All of these experiments were conducted at 235°C.

At 235°C. the catalysts did not give any conversion at atmospheric pressure, neither did they give a conversion on the second day at 250°C. (after switching, however, to 15 atmospheres and 235°C., the catalysts gave a contraction of 53 percent).

Table IV.- Reaction and Contraction at Various Temperatures
(The normal iron catalysts were inducted with
CO-rich gas at 235°C., and 1/10 atmosphere)

	5 atm.		10 atm.		30 atm.		60 atm.	
Days of operation	Temperature, °C.	Contraction, percent	Temperature, °C.	Contraction, percent	Temperature, °C.	Contraction, percent	Temperature, °C.	Contraction, percent
1	235	30	233	42	235	53	235	50
2	-	-	234	42	235	56	238	42
3	235	25	235	48	234	37	235	40
6	250	38	238	50	-	-	254	52
9	270	37	239	50	-	-	-	-
12	-	-	237	50	-	-	-	-

At 5 atm. the contraction amounted to 30 - 40 percent, hence, the conversion was still incomplete. This remained so even after the temperature was raised to 270°C. on the ninth day (a switch-over to 15 atmospheres caused a 50 percent contraction even here when the temperature was 235°C.). At 10 atm. a 50 percent contraction was reached at 235°C. This was the case also when working with 30 and 60 atms. However, when working at 30 atm. and 235°C. already after the third day, a considerable decrease in the amount of conversion occurred. For the 60 atm. run, this decrease set in after two days of operation. When the operating temperature was 254°C., the decrease in conversion did not set in earlier than the sixth day when a maximum of 52 percent had been reached.

The optimum pressure is found to lie between 10 and 30 atmospheres or somewhere around 15 atmospheres. (When operating under 15 atmospheres, the same catalyst operating at 237°C. still gave the same conversion after a whole month of operation, that is, approximately 50 percent contraction).

C. The Reaction Temperature.

Special attention was given the reaction temperature. We attempted to succeed with a lower reaction temperature in connection with iron catalysts to be used in the middle-pressure synthesis. This no only was important from a chemical viewpoint but economical as well. On the large scale, the reaction is kept at a uniform temperature by cooling with water, hence, lowering the reaction temperature will cause a lowering of the steam pressure. This will cheapen the equipment materially.

The influence of induction and synthesis temperature has been discussed in detail.

The influence of the gas composition is such that H_2-rich gases permit a lower working temperature than the CO-rich gases.

For example, an experiment performed with a H_2-rich synthesis gas of composition 1CO + $2H_2$ still yielded 47 percent contraction at a temperature of 184°C. after the second day of operation. The usage ratio of CO and H_2 pointed towards the formation of hydrocarbons and water. At those low reaction temperatures, the conversion, however, decreases after a very few days, and it is interesting to note that even if the temperature raised thereafter, the results do not improve any longer. It is more favorable to initiate the experiment at the high temperatures from the beginning.

With a gas containing $CO + H_2$ in the ratio 1:2, it was possible, however, to operate for several months at 200°C., and practically convert the entire CO with an average contraction of 47 percent and a yield of 90 g. per normal cubic meter of gas. The liquid and solid products obtained were entirely colorless. Essentially larger yields may not be obtained on iron catalysts when using such a gas.

When we used the CO-rich gas, we initiated the experiment usually at 225 to 235°C. (in order to get good time-yields). We did this in spite of the fact that a good degree of conversion could have been obtained if we would have operated at 210 to 220°C.

The temperature of the reaction exerts an essential influence upon the nature of the reaction products. Table V shows average yields which were obtained from iron catalysts carrying 1/4 percent of potassium carbonate and operating at 235, 275, and 280°C. The yield of solid paraffins amounted to 39 g. per normal cubic meter of gas for 235°C. and only 4 g. for 270°C. As the solid paraffins decreased when the temperature was raised, the liquid and especially the volatile hydrocarbons and the gasol hydrocarbons increased in quantity. At 280°C., the paraffin yields were even less, but at this temperature the yields of liquid and gasol hydrocarbons started to decrease also.

Table V. - Nature of the Reaction Products for Various Temperatures

Reaction Temperature, °C.	Yields, g. per normal cubic meter of ideal gas Solid Paraffin	Liquid Hydrocarbons	Gasol
235	39	83	26
270	4	94	46
280	2	82	35

D. The Influence of the Alkali Contents on the Iron Catalysts.

The method of production of the catalyst has been discussed at the beginning. The following table shows what influence the addition of alkali to the catalyst has upon the catalyst.

Table VI - Yields Obtained from Various Iron Catalysts Carrying Different Amounts of Alkali

Precipitant	Alkali addition	Solid and Liquid and Gasol HC g. Nm^3 of synthesis gas	Paraffin percent	Liquid HC percent	Gasol percent
NH_3	0	141	12	67	21
Na_2CO_3	0	140	13	67	20
"	1/4% K_2CO_3	148	26	56	18
Na_2CO_3	1% K_2CO_3	157	42	47	11
"	1% $KMnO_4$	155	41	45	14
"	1% K_2SiO_3	158	43	41	16
"	1% K_2F_2	163	46	42	12
"	1% K_2HPO_4	154	38	52	10
Na_2CO_3	2% K_2CO_3	143	43	44	13
"	5% "	161	45	43	12
"	5% "	155	46	44	10

The indicated quantities of potassium carbonate added to the catalyst are based on the iron metal contents. In the case of the other alkalized salts (permanganate, fluorides, etc.) the notation "1% $KMnO_4$" is to indicate that such a quantity was used which would be equivalent to one percent K_2CO_3.

Table VI shows the yield and nature of the reaction products which were obtained from catalysts containing different amounts of alkali. The temperature was 235°C. and the pressure 15 atm. The yields indicated as g. per Nm^3 of ideal gas are not quite constant for the first month of operation. This is due to the varying percent contraction. The yields are approximately 140 to 160 grams for this first month. If the nature of the products formed is disregarded, we see that the alkali addition to the catalyst has no important effect on the yield as such. The alkali-free catalyst precipitated with ammonia showed yields which were not essentially below those obtained from catalysts containing 1/4 percent K_2CO_3. The alkali contents of the catalyst, however, has a very marked influence upon the nature of the reaction products. When no alkali was present, the Butanon method revealed approximately 12 percent of paraffins in the product. When 1/4 percent potassium carbonate was added to the catalyst the paraffins amounted to 26 percent, with one percent potassium carbonate the products contained 42 percent of paraffins, with two percent potassium carbonate, 43 percent, and with 5 percent potassium carbonate, the final product contained 45 to 46 percent paraffins. The yield of liquid and gasol hydrocarbons decreases with increasing alkali content of the catalyst.

Table VI shows furthermore that the quantity and the nature of the reaction products was not effected by the type of alkaline salt added to the catalyst. No essential difference was discovered when the catalyst was alkalized by one percent potassium carbonate or the equivalent quantities of potassium permanganate, potassium silicate, potassium fluorides, or potassium phosphate.

The lifetime of the catalyst is longer at a low alkali content (for example, 1% K_2CO_3) than it is at higher alkali contents.

E. Treatment of the Catalyst with Hydrogen.

We have already pointed out that we may not substitute hydrogen for CO in the induction of the catalyst. Catalysts which are pretreated with hydrogen, that is reduced iron catalysts, are inactive at low temperatures. If the catalyst was pretreated with hydrogen before it is subjected to the action of CO no improvement results. Neither does an improvement result if the catalyst is treated with hydrogen between the induction period and the synthesis proper.

The treatment with hydrogen, however, has a different result if it is carried out on an iron catalyst during the synthesis. The situation is then similar to that of cobalt catalysts. To demonstrate this, we carried out the following experiment. We had available a catalyst which in order to give the best results should have been employed at a temperature a few degrees higher than 235°C. (at 15 atm. and 4 liters of CO-rich gas per hour). We allowed this catalyst to work at 235°C. During the first and second days of the operation, we observed a contraction of 52 percent (see Figure 8). After the second day, the contraction was 50 percent, and after three days, 47 percent. From the dotted curve, Figure 8, we are able to see that the contraction would have fallen to 40 percent had we continued to operate for a week at 235°C. However, after the third day of operation, the catalyst was treated with hydrogen for 15 hours with 8 liters per hour at one atmosphere and 325°C. After this hydrogen treatment, the catalyst caused a contraction of 55 percent in the following synthesis. It slowly decreased thereafter, however it remained above 51 percent up to the 12th day. On the 12th day, the same hydrogen treatment as described above was repeated. The contraction rose again to 57 percent and after 19 days of operation, decreased to 50 percent. After the third treatment with hydrogen, 55 percent contraction was observed which decreased to 51 percent after 3 days and after 4 days, 52 percent. When the synthesis was continued for two months thereafter at the temperature of 235°C., the contraction remained near 50 to 53 percent.

Figure 8 shows that an increase in catalyst activity results when the synthesis is interrupted and a hydrogen treatment is performed. This increase in activity was especially pronounced during the first few hours of the hydrogen treatment, and it also caused a better stability of the catalyst thereafter. When the activity of the catalyst was at a maximum after the hydrogen treatment, the usage ratio of CO and H_2 was no different from that of the normal synthesis occurring with 50 to 52 percent contraction. In both cases CO and H_2 were used up in the ratio 1.67-1.70:1. It is, therefore, noticeable that no carbon formation occurred during the time of optimum activity of the catalyst.

Iron catalysts which had been used for a long time already or which had decreased in activity to a great extent did not show a lasting improvement when treated with hydrogen. A lasting improvement may not be obtained even if another induction is given with CO. If it is desired to perform a hydrogen treatment, and if it is expected that the hydrogen pretreatment produces good results, the catalyst must be subjected to hydrogen before it gives as low a contraction as 45-50%.

I want to point out once more that we have operated with iron catalysts for several months even up to one year, and it was not necessary to carry out one single regeneration of the catalyst.

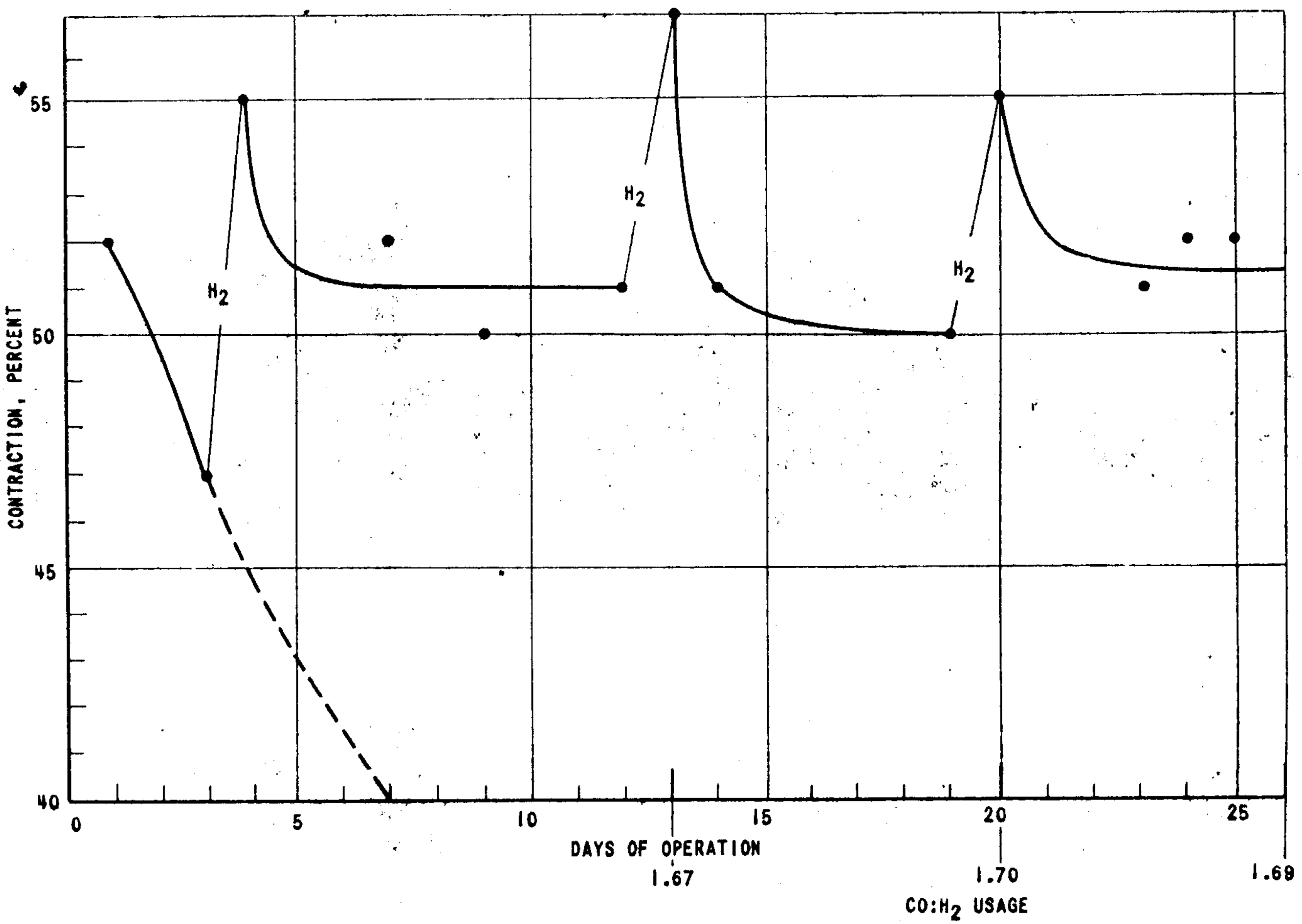

Figure 8. - Influence of a H_2 - pretreatment on the synthesis.

F. The Effect of Addition of Kieselguhr.

We have discussed the effect which alkali has when added to the catalyst; let us shortly mention the effect of Kieselguhr when mixed into the catalyst. It is well known that Kieselguhr is an essential carrier with cobalt catalysts. Good yields are only obtained with cobalt catalysts when Kieselguhr is used as a carrier for those catalysts.

This is not so with iron catalysts. The best results were obtained with catalysts free of Kieselguhr. However, it might be desired to add Kieselguhr to the catalysts for various reasons such as for instance, loosening of the iron catalyst or decreasing the danger of carbon formation. In general, the addition of Kieselguhr to iron catalysts causes an improvement in activity in the sense that more lower boiling and gaseous hydrocarbons are formed.

G. The Construction of the Apparatus.

The discussed time-tests were carried out in horizontal respectively, slightly tilted reaction tubes. A slight expansion of the catalyst may thus take place due to carbon deposition without any serious dangers of causing damages. (Fig. 9, Schematic Drawing 1). If the reaction tube is in a vertical position, the expansion of the catalyst causes a restriction between the catalyst granules and hence a shortening of the contact time of the gases passing over it. (Fig. 9, Schematic Drawing 2). In order to eliminate any possible disturbances from the viewpoint of construction, we are still in the process of carrying out experiments dealing with this subject. According to Figure 9, Schematic Drawing 2, (at a gas rate of 4 liters of synthesis gas per hour and 10 g. of iron), the space-time yield is approximately twice that of a normal cobalt-Kieselguhr catalyst. The apparatus is cooled by water and has to stand a pressure of 50-60 atm. (See Figure 4) If salt solutions would be used instead of water, the necessary steam pressures could be reduced somewhat.

Part IV

The Products of Reaction

When the iron catalyst is used in the middle-pressure synthesis, paraffin and olefin hydrocarbons of various molecular weights are produced as well as methane and lower gaseous hydrocarbons. It is possible to regulate the course of the reaction to form certain products in preference to others. In addition to the products listed above, oxygen-containing organic compounds are produced as well, products something similar to the Synthol having been described by Fischer and Tropsch several years ago.

A. Liquid Hydrocarbons.

The crude total liquid product obtained from CO-rich gases and alkalized catalysts, in general, is not quite colorless, but has a greenish-yellow tinge. After a distillation, however, one obtains a water-clear colorless benzine; whereas small traces of the formed oil remain back as a yellow residue. The benzine is stable and remains colorless even after months of storage.

Figure 8. - Schematic representation of positions of reaction tubes.

The quantity of the fraction boiling up to 180°C., in other words, the benzine fraction (slightly different in each case depending on working conditions varies in amount according to working conditions) may amount to 80 percent, or 40 percent or even less than that as referred to the total liquid and solid hydrocarbons produced.

Table VII shows the properties of the stabilized benzine washed with sodium hydroxide. Its knocking properties were determined in the I.G. testing engine. Approximately 2/3 of the total liquid product boiled in the range of 30-180°C. Table VII, No. 1, corresponds to the primary benzine. Its octane number is 61.

Table VII.

Properties of the Benzine Obtained in the Middle-Pressure Synthesis with Iron Catalysts

(with and without additional polymerization)

No.	$d_{15°}$	Olefins percent.	Boiling Characteristics 0 °C.	10% °C.	50% °C.	90% °C.	$P_{37.8°}$	Octane No.
1	.696	64	30	46	88	145	0.54	61
2	.705	65	32	53	100	150	0.48	77
3	.700	65	34	60	95	130	0.55	71

The two benzines listed under 2 and 3 are only shortly mentioned here. During the synthesis, the total end-gas (that includes the CO_2) was conducted over a phosphoric catalyst at 15 atm. pressure. The unsaturated hydrocarbons contained in the gas furnished primary polymer benzine, which was mixed in with the primary benzine. Such mixed benzine boiling up to 180°C. had an octane number, 77 (Benzine 2). If the distillation was interrupted at 150, the octane number was only 71 (Benzine 3). If 0.7 cc. lead tetra-ethyl per liter were mixed into Benzine 2, its octane number improved to 79, if the same quantity of lead tetraethyl was added to Benzine 3, its activity went up to 83.

If the benzine is not subjected to washing with sodium hydroxide a higher octane number is obtained too in the primary benzine. If washing is not carried out with sodium hydroxide, acid constituents are left in the benzine in addition to water soluble oxygen containing organic compounds such as alcohols. The high contents of unsaturated hydrocarbons is very favorable for the antiknock properties of the benzine. Should it be desired to produce lubricants from the unsaturated constituents, then it would be necessary to rework the oil in order to remove all traces of oxygen containing constituents which normally would disturb the polymerization with aluminum chloride.

3. Paraffin

The solid and liquid products of the liquid according to the Butanon method contain approximately 5 to 50 percent of solid paraffin. The paraffin is white to brownish-yellow when hydrogen-rich synthesis gas and alkali deficient catalysts are used. If a CO-rich gas and an alkalized catalyst up to one or more percent potassium carbonate catalyst is used, the paraffins are both yellow to dark yellow. The coloring matter may be due to iron compounds. In general, however, the coloring matter is due to small quantities of higher boiling oils, which may be removed by extraction or by hydrogenation.

The melting point of the paraffins range over the whole region of the known paraffin hydrocarbons. The so-called contact paraffin which remains behind in the catalyst contains constituents having an especially high melting point.

The usefulness of the paraffins is very great. It is not necessary here to discuss them. We did not think too much about oxidizing them to fatty acids used in the soap industry. The paraffins which are obtained from iron catalysts are not as ideal for fatty acid production as used in the soap industry as are the paraffins manufactured with cobalt catalysts. In order to make those paraffins available for the soap industry, they have to undergo a special treatment. It has not been shown whether the "iron paraffin" contains a greater number of branched-hydrocarbons than the "cobalt paraffin".

C. Gasol.

Quantity and composition of the gaseous hydrocarbons is also a function of the nature of the catalyst, and the reaction temperature. Table VIII shows yields of gasol hydrocarbons with their contents of unsaturated constituents produced under various synthesis conditions. All experiments refer to a synthesis gas of composition $3CO + 2H_2$ and a synthesis pressure of 15 atmospheres. The gasol yields are essentially larger here than in the case of the cobalt catalysts.

Table VIII.- Yields of Gasol Hydrocarbons with Different Catalysts

Catalysts	Temp., °C.	Grams of gasol per Nm^3 of gas	Percent of gasol of unsaturated HC
Fe NH_3 precipitated, 0% K_2CO_3	235	30	70
Fe,Na_2CO_3 precipitated 0% K_2CO_3	235	28	80
Fe, " " 1/4% "	235	26	76
Fe, " " 2% "	235	17	80
Fe, " " 1/4% "	270	46	47
Fe-kieselguhr 1% "	235	36	35

With the iron catalysts precipitated with ammonia or soda-ash at a synthesis temperature of 235°C., 20 to 30 grams of gasol hydrocarbons per normal cubic meter of gas were obtained with a total of 70 to 80 percent of unsaturated constituents. With increasing alkali contents and with all other conditions remaining the same, the quantity of the gasol produced decreases. With higher reaction temperatures, the quantities of gasol hydrocarbons increased, but their hydrogenation was favored too so that at a temperature of 270°C., the same amount (g./Nm^3 of ideal gas) of unsaturated hydrocarbons were obtained, namely, 20 g./Nm^3 of ideal gas.

When the iron catalyst contains kieselguhr, the gasol hydrocarbons produced at 235°C. differ from those of a catalyst without kieselguhr in that they contain a smaller amount of unsaturated hydrocarbons.

Iron catalysts not only produce gasol hydrocarbons containing 3 and 4 carbon atoms to the molecule, but they also form C_2 hydrocarbons. The gases from one experiment were subjected to a low-temperature distillation, and the following constituents were obtained: 11 g./Nm^3 of propylene, 6 g./Nm^3 of butylene, and 5 g./Nm^3 of ethylene The relatively high yields of unsaturated gasol hydrocarbons are especially favorable if one considers the further processing for high octane benzine.

D. Oxygen-containing Products.

At 235°C. and working with a CO-rich gas at 15 atmospheres, we obtained 13 grams of **aqueous** products with the iron-kieselguhr catalyst. They contain acids, aldehydes, and esters (the test for formic acid was negative, that for acetic acid was positive, the aldehydes showed a positive when fuchsine-sulphurous acids were used, and the esters could be demonstrated (saponification)). The **aqueous** compounds also contain alcohols, such as ethyl and a little methyl alcohol. Figure 10, shows a boiling point analysis of the constituents of the reaction water which boiled below 90°C. (28 percent of the total reaction water). The distillation was carried out by a micro-column.

The boiling point curve shows distinctly the ethyl alcohol fraction. It represents 7.5 percent of the total reaction water. The second constant temperature corresponds to the azeotropic mixture of propyl alcohol and water (87.7°C. and 28.3 percent of water).

Not only did we find synthol-like compounds in the reaction water, but they were also present in the hydrocarbons. They can be found in the low-boiling as well as the high-boiling fractions. The oxygen determined by analysis varies between 0.2 and 2 percent. The lower-boiling fractions contain more oxygen than the higher-boiling fractions. Alkali-defficient iron catalysts produce only small quantities of oxygen-containing products. More alkalized catalysts produced higher quantities. The normal iron catalyst produces at 180°C., a benzine which contains one to 2 percent of water soluble products. Other iron catalysts yield 5 percent or more. The acid number of products below 180°C. is one, that above 180°C. is 0.1. The corresponding esterification values are 1.6 respectively 0.5 and the saponification values are 2.6 respectively 0.6. Amongst others we were able to prove the presence of esters and alcohols. More detailed analytical information is left for a future report.

E. City Gas.

Before I end my discussion on the reaction products, I want to mention here that according to our newest experiences, the iron catalysts are well adapted for production of a standard city gas from water-gas.

Part V

Conclusion

The following may be said about the iron middle-pressure synthesis. The yields of solid, liquid, and gasol hydrocarbons are somewhere near 130 to 160 normal cubic meters of ideal gas. The longest lifetime obtained for the catalyst lasted for 1-1/2 years without any regeneration at a temperature of 260°C. At the same time it still gave a yield of 140 g./Nm^3.

The evenness with which iron catalysts are capable of working for long periods of time may be observed from the end-gas analyses which are summarized in Table IX

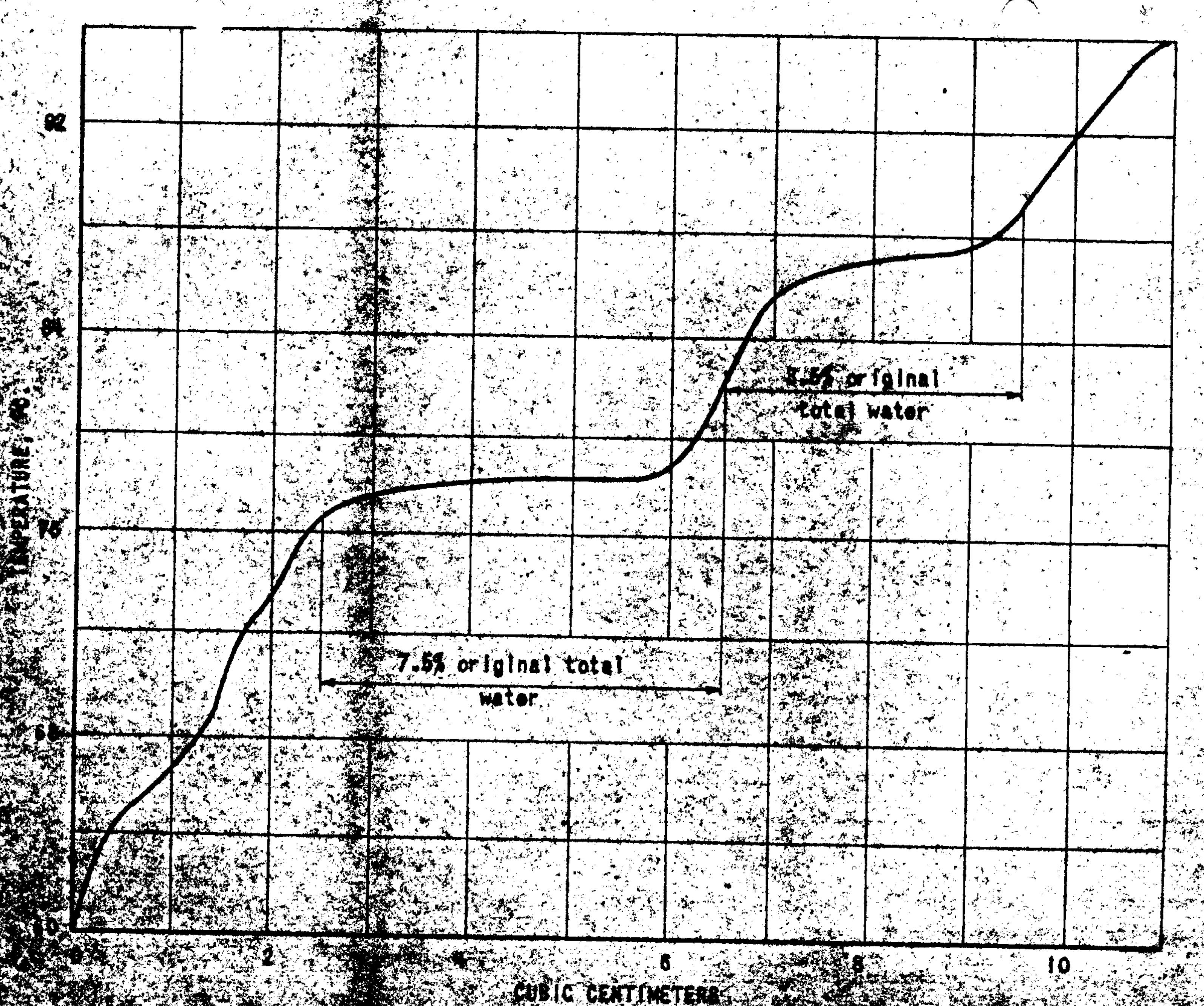

Figure 10c. - Boiling point analyses of the reaction water boiling below 90° C. (charge 15 cc.).

Table IX

Months of operation	Temp., °C.	Contraction percent	CO_2	sHC	O_2	CO	H_2	HC	-	N_2
A. End-gas analysis of an experiment performed at 255°C., iron catalyst inducted with CO at 1/10 atmosphere.										
1	235	50	49.6	2.2	0.1	15.0	13.3	8.8	1.9	11.0
14	254	50	50.1	2.8	0.2	14.9	11.9	7.3	1.7	12.8
B. End-gas analysis of an experiment with a catalyst inducted at 325°C., 1/10 atm.										
1	235	54	57.0	2.6	0.1	6.3	14.6	8.9	2.0	10.5
3-1/2	235	52	61.2	3.3	0.1	5.2	11.2	9.0	1.9	10.0

Table IX refers to a catalyst inducted at 255°C. with CO at 1/10 atm. It shows the same conversion for 14 months of operation uninterruptedly operated at 253°-254° at the same charge of gas through the converter of 400 liters of synthesis gas per kilogram of iron.

Table IX refers to a catalyst inducted at 325°C. at 1/10 atm. with CO. This catalyst yielded practically the same degree of conversion and optimum yields of 150-160 g./Nm^3 of gas, after 4 months of operation.

The iron catalysts are not only superior to the cobalt catalysts on account of the cheapness, but also for the cheaper apparatus which they require and for the more even lifetime which they exhibit. It should be added that the antiknocking properties of the iron benzine are better than those of the cobalt benzines, and that the unsaturated gasol hydrocarbons obtained with iron catalysts can be used to greater advantage for production of high quality benzine.

The following disadvantages come in with iron catalysts: They work at higher temperatures, hence greater steam pressure, if it is desired to cool with water, than in the case of cobalt catalysts. Furthermore the iron catalysts have a greater tendency to form carbon than the cobalt catalysts.

Gentlemen, the problem of using iron catalysts for the synthesis of hydrocarbons has been discussed. It all was conceived through the efforts of Dr. Fischer and his previous work.

The developments which I have told you about today on the iron middle-pressure synthesis are the result of the last 4 years of research. We have succeeded in raising the yield two to threefold as compared to the earlier experiments with cobalt, and we have succeeded in improving the lifetime ten to twenty times. Hence, the total yield improved 20 to 60 times. We succeeded in the following:

1. We used iron catalysts which were pretreated by CO.

2. We maintained the synthesis gas pressures at the same optimum as that of cobalt middle-pressure synthesis, namely, 10 to 20 atmospheres.

3. We used a ratio of H_2 + CO which was most ideally suited for the synthesis.

[redacted]

Already at the end of 1937, Dr. Fischer has reported to you the developments of iron catalysts. Today, we can say that a great significance is attached to the middle-pressure synthesis with iron. I want to express my thanks to Dr. Fischer who has assisted us with his council and advice in all this work. Finally, I want to express my thanks to all my co-workers who have helped in the same effort.

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