CHAPTER I.

FIRST MEETING I.G. LUDWIGSHAFEN.

Tuesday 25th October 1938.

Present, from:

Standard New Jersey:	Scharmann
	Roetheli
	Spicer
Kellogg:	Keith
	Ward
	Johnson
	Ribblet
	Roberts
	Mansfeld
I.G.:	Pier
	Ringer
	Peters
	Hofeditz
	Wietzel
I.H.E.C.C.:	Tillmann
	Van 't Spijker
Shell:	Langen van der Valk
	Volkers.

Dr Ringer regretted to state that Ruhrchemie's report was unavailable for distribution, as consent of a certain authority had not yet been received, which, however, was expected any moment. Proposed to study report the next few days and after that visit Ruhrchemie at Holten. Ringer furthermore stated that I.G. had also done some work on this subject, but preferred not to give detailed information before the middle of February.

After discussions during the next few days, I.G. resolved to give information after visit to Ruhrchemie as reported below.

The Ruhrchemie's report was handed over on Wednesday evening and it was agreed that on Friday Ruhrchemie would give further verbal information.

Friday and Saturday 28th and 29th October.

Present: same as mentioned above. Moreover from:

Ruhrchemie:	Feiszt Willke	v. Asboth Schaller
I.G.:	Winkler Sabel Fritsche Meisenheimer.	Duftschmidt Kratz

The first subject to be discussed was the catalyst, the manufacturing of same and, subsequently, the purification of the gas and the catalyst plant proper.

CATALYST.

Information given by Dr Feiszt (Ruhrchemie).

HISTORICAL DATA.

~~Dr Feiszt started with a few historical data.~~

Ten years ago tests were commenced with Fe and also with Ni. Synth. gas ($CO + H_2$ in proportion 1 : 2), with Ni as catalyst, produced mainly saturated hydrocarbons with a rather large percentage of methane. Thereafter Co was used, with the addition of Cu, which allows working at lower temperature and reduction of catalyst in situ. This catalyst produces less saturated hydrocarbons and was the first to be used on a pilot-plant scale at Holten. Activity and lifetime of Co + Cu were rather small.

Therefore, Co-Th catalysts were tried out and with satisfactory results. In the meantime they had succeeded in reducing the catalyst in a special furnace and filling the reduced catalyst in the converters. This was a difficult problem, as the reduced catalyst is highly pyrophoric. Up to 18 % of Th oxide calculated on Co metal was used. The metals were deposited on Kieselguhr as a carrier and precipitated as carbonates or hydroxides. After drying, reduction with H_2 took place at temperatures between 350 and 400°C. Reaction temperature is lower than with Fe and Ni, with a smaller production of methane. The plant at Holten was started with this catalyst. Afterwards trials were started to replace ThO by MgO, the latter being cheaper and available in Germany. The results were satisfactory, if not better. The lifetime of Mg is 1 - 2 months longer and the formation of methane is also less than when using Th.

In general it can be said that the composition of Ni, Fe and Co is different. Additions of Th and Mg to Co do not change the characteristics. The following figures may illustrate this:

		GAS CO : H_2 = 1 : 2		CO:H_2 = 2:1
		Co	Ni 2)	Fe 2)
	(I.B.P.	35°	35°	35°
refers	(up to 100°C	28.5 % by wt	34 % by wt	38 % by wt
to	(up to 200°C	61.5 "	72 "	80 "
liquid	(up to 320°C	88.5 "	95 "	98 "
products	(sp.gr.of fractions up to 200°	0.693	0.670	0.665
only	(% olef.of fractions up to 200°	35	15	42
	(acid content mg KOH/g prod.	up to 0.005	up to 0.005	roughly 0.1
	g $C_3 + C_4$ 1)	12	18	24
	g CH_4 1)	32	42	42
	g total product 1)	120	95-100	90-95
	CO_2	3	4	large
	useful reaction temp. range	185-198	190-210	210-240

1) per m3 normal/synthesis/ gas
2) figures given from memory

Ideal! =

The reaction temperature increases from the minimum to the maximum in the course of the run, which is for Cobalt-Th about 4 months.

The content of Th oxide can be varied from 10 - 20 % in relation to the metal Co. The same applies to MgO without important changes in the product. If the ThO and magnesium content is more than 20 % or less than 10 %, the activity decreases and also the lifetime of the catalyst. A higher Th content results in heavier products. No definite data are available regarding Mg. Low Th content entails higher temperatures, which, however, affect the lifetime unfavourably.

In general at higher temperature lower boiling products are formed; a Co catalyst at higher temperature increases $C_1C_3C_4$ production, whereas its lifetime is shortened.

THE CAPACITY OF THE CATALYST.

The average load on Co-Th contact for the yields reported is 1 m3 synthesis gas per kg Co/h. With Mg this can be 50 - 70 % more and such at a one to two months' longer lifetime. With fresh contact the load can be higher, e.g. 1.200, which decreases then to 0.800 at the end of the period.

In fig. 1 x) curves I and II show the variation of yields against catalyst life for Co-Th catalysts at different, but constant loads of 1.0 and 1.5 m3 synthesis gas/kg Co/h respectively. Actually when running a plant the load is gradually decreased in order to obtain a more constant CO % conversion; this is illustrated in curve III for a Co-Mg catalyst.

x) The figures of this chapter relate to annexes A, if not stated otherwise.

Throughputs of from 1700 - 1800 m3/h have already been attained. It has been proven advantageous to arrange 2 steps working on 70 - 75 % CO conversion in the first stage. A higher percentage of conversion in this stage would result in an abnormal production of methane and gasol. If a catalyst works very well and converts 90 % of the CO, it is possible to reduce the temperature which, however, will only help for a short time and it is preferable to increase the throughput.

SYNTHESIS AT ATMOSPHERIC PRESSURE.

In running a plant two different procedures can be followed: A converter can be placed in the first stage and after about 2000 hours in the second stage, or the converter can be kept for its whole lifetime in the first stage, using separate converters for the second stage only. The proportion of the number of furnaces in first and second stage will be kept at a constant figure in both cases.

For design purposes, when working at atmospheric pressure, the average load on the converters is taken at 750 m3/h in first and second step together. Per converter 850 - 900 kg of Co metal is used, which is equal to about 3 tons of catalyst with an apparent density of 0.26 - 0.30. At Holten all the "atmospheric" converters can be used for first and second stage. However, for future plants it would be sufficient to make arrangements that only 50 % of the furnaces can be connected either to the first or to the second step. Thus part of the converters are always used in the first stage, the CO conversion percentage being regulated by adjusting throughput and temperature. The important point for conditions in Germany is to arrive at a maximum overall yield of liquid products of the total plant. It is possible that other procedures will prove to be of advantage, especially as experience with the pure Co-Mg contacts is still insufficient.

INFLUENCE OF PROCEDURE ON QUALITY OF PRODUCTS AND CONVERSION.

1. The first factor of influence is temperature.

With Co-Th or Co-Mg contacts the starting temperature is about 180°. The products contain a rather large quantity of paraffin wax and a high percentage of products boiling between 140° and 280°C. As the catalyst gets older, the temperature has to be increased, resulting in a lower boiling range of the products. During the run the propane-butane production increases from 10 - 15 g/m3; at the end the temperature of the converter attains a maximum, producing still lighter products. The following figures will illustrate this:

first period	37 - 39 %	boiling below 150°C
middle period	47 %	" " 150°C
end period	55 - 57 %	" " 150°C

~~At the same time the olefine content and the~~ acid figure show variations. The olefine content in the product boiling up to 200°C varies from 30 % in the beginning to 35 % in the middle and 40 % at the end. Variations in octane numbers are only slight.

These changes find their principal explanation in temperature variations. Ageing of catalyst is presumably of no influence.

2. Influence of variation of $CO:H_2$ ratio on products.

Increasing the $CO:H_2$ ratio from 1:2 to 1:1.8 results in a higher yield of olefines, e.g. of 5 % in the fraction boiling up to 150°C. The proportion between high- and low-boiling products changes only slightly; the octane number increases only by 1 - 3 points.

The % olefines in C_3C_4 increases from 50 to 60 - 65 % (a maximum of 72 % was found).

When decreasing the $CO:H_2$ ratio below 1:2, gradually more and more methane is produced, e.g. with a gas consisting of 95 % H_2 and 5 % CO, only methane is obtained.

3. Variation of the inert content.

More inerts increase the percentage of low-boiling products, for which reason in the second stage more low-boiling products are produced.

4. Effect of space velocity.

Higher space velocity results in production of lighter products. The question has been put whether the height of the catalyst layer can be increased. It was answered that 2½ m has been chosen on account of the experience in semi-technical experiments, also because this was the largest dimension that could be used in view of the size of railway waggons. The following graph gives an idea of the changes in product when applying a larger velocity.

The graph fig. 2 gives an idea of the change in production of one converter when increasing the space velocity. The curve shows a maximum, which, according to Dr Feiszt, for the atmospheric converters at Holten, will lie between 1,700 and 2,000 m3 throughput. Refer also to annex E fig. 2.

Everything that has been stated above relates to working at atmospheric pressure. The temperatures mentioned are always steam temperatures in the boilers. It is estimated that the temperature of the gas flow is about 10 - 15°C higher. On the active catalyst centres the temperature will be still higher, maybe up to 100°C.

Reversing the flow of gas from downflow to upflow gave unfavourable results, which must be attributed to the fact that too much high-melting paraffin wax remains in the upper layers of the catalyst, finally resulting in clogging up of the converter.

The pressure drop in a converter on normal operation, which means downflow, is about 50 - 150 mm water. After 50 - 60 days' run a converter had already accumulated its own weight = 3 tons as paraffin wax. The dimensions of the converters are about 5 m long x 1.5 m wide x 2.5 m high. The free space in the oven is about 10 - 12 m3. The average load per oven is about 1000 m3 synthesis gas at 0° and 760 mm Hg.

RE-ACTIVATION OF CATALYST.

When working at a constant temperature (say 185°) the CO conversion falls off rapidly during operation. By gradually increasing the reaction temperature (say from 188 - 198°) this decline in activity can be partly counteracted, but still the CO conversion during operation of the catalyst decreases gradually. This is mainly due to the accumulation of paraffin waxes and resins. It is then necessary to re-activate the catalyst, which is done at Holten by replacing the synthesis gas flow by a flow of pure H_2 at temperatures of 200 - 210°C (see graph fig. 3). A re-activated catalyst gives a slightly lower yield than a fresh one and also the CO conversion shows a faster decline. The average activity is shown by the dotted line. In actual operation, in addition to the above, the throughput is gradually decreased in order to assist in keeping up the CO conversion.

The re-activation with H_2 results in a cracking of paraffin wax, yielding about 45 % of heavy oil boiling between 200 and 320°C and about 5 % gasoline, the balance being converted into methane. (When working at higher pressures (in the pilot plant), this re-activating has not yet been necessary, firstly because temperature increase is very slow; secondly because products formed partly condense and dissolve paraffin wax .

Re-activation can also be done by dissolving the paraffin wax and resins in heavy benzine, and also in benzol or acetone. In this way the total yield of the plant could be increased by about 1½ - 2 g/m3, because in this case no cracking occurs. However, this procedure is cumbersome and has only been applied in the low pressure pilot plant.

The Co-Th cat. produces about 1½ - 3 tons of wax per about 1000 hours per converter, the Co-Mg catalyst giving about 60 % of this quantity.

This re-activating procedure at Holten is repeated 3 to 4 times in about 4 months, after which the catalyst is removed from the converter for complete re-working in the catalyst plant.

SYNTHESIS UNDER PRESSURE.

Besides the synthesis at atmospheric pressure, a method has been developed for working under a higher pressure; the pressures applied at Holten vary between

5 and 10 atm. In general the influence of variations in operation under pressure have the same tendency to change the product as with atmospheric pressure. The products change in the same way as when working at atmospheric pressure. The operating temperature range is wider, being from 180 to 200° (probably even 210°). When working at 7 atm. with Co-Mg catalyst, a product with the following characteristics was obtained:

I.B.P.	35°
up to 100°	17 % by wt
" " 150°	29 % " "
" " 200°	42 % " "
" " 320°	72 % " "
spec.gr.of fraction boiling below 200°	0.690
olefine content " " " "	18 %
acid value	0.005 mg KOH/g
CO_2	≥ 2 g/m3
C_3C_4	7-8 g
CH_4	25-27 g
liquid product	145 g

It appears that there is no great difference in products between 7 and 10 atm.

The catalyst has a longer lifetime than at atmospheric pressure. It is estimated that the life will be increased by at least 30 %.

The temperature can even be increased to 210° without excessive production of methane.

The average throughput may be 15 - 20 % more than when working at atmospheric pressure. This figure is felt to be conservative.

Pressure experiments in pilot plants have been started from the beginning with Mg or mixed Th-Mg catalysts. The figures mentioned above relate to these catalysts. It may, however, be possible that for Mg alone the figure of 1200 can be surpassed. It is intended to start the full-scale high-pressure converters (expected in the next few weeks) with an initial throughput of 1700 m3/h.

Synthesis under pressure yields more total product, which at the same time is heavier. The process needs more energy for compression and no conclusion can as yet be drawn as to which of the two processes is the better. This will depend also on the prices of the various products obtained and the costs of electrical energy.

When producing gasoline as a final product, the products balances may be given as follows:

	prim.prod.		gasoline
a. L.P.	120 g	50 % straight-run up to 145°C	60 g
		50 % reformed at 73 %	43 "
	12 "	gasol polym. incl. pol. of gasol of cracked gases	5 "
			108 g
b. H.P.	145 g	20 % straight-run up to 125°C	29 g
		116 g reformed at 73 %	85 "
		+ polym. of gasol	6 "
			120 g

In both cases the final mixed gasoline has an octane number of 66. There is practically no difference between research and motor method.

The lifetime of the high pressure catalyst is not yet definitely known; 6 months may be accepted as a conservative figure. This lifetime relates to an average yield of 120 - 145 g. The catalysts are at present the same as with low pressure synthesis.

It was asked why the throughput could not be increased proportionally with increase of pressure. Dr Feiszt stated firstly that the increase in throughput of 15 - 20 % given by him must be considered as very safe. The upper limit of increase in throughput has not yet been investigated. Secondly, although absorption velocity increases with pressure, desorption of the hydrocarbons produced from the catalyst surface seems to be relatively independent of pressure.

Energy consumption.

For synthesis at atmospheric pressure at Holten, a blower is used, to deliver the gas at 3000 mm water-gauge. The capacity is 40,000 m3/h. The blower takes 600 kW. The figure in the report of 600 - 800 kWh per ton primary product includes all electrical consumption, assuming that all blowers, etc. are driven electrically. About 50 % of this is used for the gas production from coke at Holten.

In the Holten plant, for part of the energy, steam is used. The total steam production of the catalyst ovens would be sufficient for the production of all electrical energy and there would still be a surplus of about 400 kWh per ton of product. When working at higher pressure, the power consumption is much higher.

ORGANIC SULPHUR REMOVAL.

The purification of watergas is relatively simple, as practically no tar and no ammonia and no resin-formers are present in this gas. Inorganic sulphur is removed in the usual manner; organic sulphur is eliminated by passing the gas through a mass consisting of a mixture of iron oxide and sodium carbonate at temperatures of 200 - 300° in towers, where special care is taken to ensure a good gas distribution. Two types of these towers are in use:

In the first type the gas is passed through different layers of purifying mass in 2 towers which are connected in series, each tower containing about 65 tons mass. One set of two towers has a capacity of 20,000 m3/h.

10 + 2 = 12 T
für 200 [illegible]

When using a normal quality of German coke for the production of watergas, the organic sulphur content varies from 12 - 15 g per 100 m3. Every 83 days one tower is taken out of operation for renewing the mass.

For the organic sulphur removal, the so-called final purification, 5 sets of 2 towers are available at Holten. When one tower of a set is taken out of use, the other is also cut out. Each set of towers is equipped with a furnace for heating the gas and a circulation blower, to attain the necessary velocity in the pipe-heater, whilst the air for combustion is taken from a main line. The towers are also equipped with one heat-exchanger between the 2 towers, which, however, has been found to be not necessary.

Gases produced from bituminous substances like coal and lignite may contain resin and resin-forming substances. However, the latter will be destroyed at high temperatures of, say, 1100°; if the gas in the generators has been heated sufficiently, the resin-forming substances are cracked and eliminated. If elimination of resin-forming substances is impossible, an active charcoal unit has to precede the organic sulphur removal.

The purifying towers of the second type have cylindrical screens; two towers are connected also in series of two. The gas passes through the mass in the towers in a radial direction. This construction renders it possible to empty the towers through the centre and is to be preferred when no heavy hoisting equipment is available. At Holten a 30 ton portable crane is available, which is necessary for lifting the heavy inorganic sulphur-purifying boxes.

CONDENSATION.

The gas from the converters is passed through vertical coolers shaped as towers, where the water is injected in 3 stages. The towers are lined with acid-proof brickwork, which has to be finished very carefully, all supports being made of stainless steel. Water and condensed products are taken off in also carefully lined trenches. The water is kept in circulation and cooled in normal cooling towers constructed of wood, whilst care has been taken that all screws and bolts are made of stainless steel. The water lines have to be made of alloy steel or of aluminium, as is done at Holten.

The temperature at the top of the tower is 27°, the condensed product mainly boils above 145°C. After the tower the gas is passed through a charcoal absorption plant of normal type. If it is necessary to attain a high yield of C_3 and C_4, a low saturation of the charcoal is necessary.

When desorbing (with steam), during the first 5 minutes the gas containing a large quantity of CO_2 is passed into the air. Then a gas containing about 60 % of C_3C_4 and 20 - 25 % CO_2 is driven out. This gas is compressed at 35 atm. and the condensate passed through a stabilizer.

At high-pressure-synthesis, condensation is much simpler. The cooling procedure is then as follows: In the converters proper about 35 % of condensate is formed, with a boiling range of from 200 - 320°C. After separation, the gas is then passed through a simple pipe cooler with tubes of acid-proof alloy steel. It is possible to apply a hot soda-wash and thus avoid the use of special tube material; the price difference, however, is only small.

The very light fractions and also C_3 and C_4 are condensed in a normal oil absorption plant, dimensioned according to the necessity of producing more or less C_3 or C_4. At Holten active coal is used for this purpose, but only on account of the latter being available from the low pressure plant.

The acid content of the cooling water is about 200 - 400 mg per litre, consisting of organic acid and dissolved CO_2. The organic acid contains 70 % acetic acid, further formic- and propionic-acid.

It is possible to condense different fractions separately, which can be cracked separately. The tail gas from H.P. synthesis may be used (expanded) for generating electrical energy or for refrigeration purposes in stabilizers, etc.

After the first synthesis stage, the gas needs only partial cooling, thus condensing only the high boiling fractions, whereas the low boiling fractions pass on with the gas to the second stage. It is possible to pass the gas from the first stage through a charcoal absorption, freeing the gas entering the second stage from gasoline. Definite experience as to the desirability of the latter procedure is not yet available.

The absorption oil to be used, consists of a fraction produced in the plant itself.

The gas entering the second stage converters is not preheated.

MANUFACTURING OF CATALYST.

Every oven contains 10 (H.P.) and 12½ (L.P.) m3 of catalyst respectively, with an apparent density of 0.26 - 0.30. It is important that the catalyst should be dust-free. At present Holten's converters contain catalyst consisting of about 2 tons of Kieselguhr, one ton Co metal and 50 kg ThO and 80 g MgO. The quantities of ThO and MgO can be reduced, but definite figures are not yet available. The catalyst is manufactured in a separate plant, which has to serve two purposes:

1. manufacturing of fresh catalyst;
2. regeneration of used catalyst.

1. MANUFACTURING OF FRESH CATALYST.

A plant needs about 3 - 5 % fresh catalyst to make up for all the losses during the year, which figure is based on a re-generation frequency of 2½ times per year. The components of the catalyst are:

MATERIALS:

a. Co metal.

The Co arrives at the plant in the form of concentrate or as a metal (Belgian or German origin). The method of purifying and further treatment depends on the origin. The Co may not contain more than 0.2 % Ca and 0.5 % Cu. A certain percentage of Ni is necessary, say 0.2 %.

b. Kieselguhr.

Specific gravity 0.25 - 0.28 is normal. On a sieve of 400 holes/cm2 no more than 5 % may be retained.

The contents of Fe and Ca must be a minimum. German Kieselguhr, so-called "abgebrannt" or calcinated, is suitable as is also Kieselguhr of Japanese and American origin. If necessary, a chemical purification can be applied. It has been found that a certain but yet undefinable structure of the Kieselguhr is necessary.

c. Thorium and Magnesium.

These products are purchased in normal commercial quality; analyses may be had at Holten.

OPERATION.

Briefly the operation is as follows: The Co is dissolved in nitric acid, the solution is purified and, after addition of Th or/and Mg nitrate at a temperature of 90 - 100°, precipitated with sodium carbonate on Kieselguhr; the resulting mass is filtered and washed with hot distilled water, after which the wet catalyst is dried and granulated. The product is called "green corn" and has to be reduced with H_2 before use.

The flow during the manufacturing is roughly shown in fig. 4.

The water used for washing the filter cake must be very pure, and at Holten distilled water is taken for this purpose.

The nitrate solution is made by adding Co, portion after portion, to nitric acid in a stainless steel container, equipped with powerful stirring apparatus.

The green corn is produced in different sizes, e.g. 1 - 3 mm or 2 - 4 mm, etc.

Pulverizing has to be avoided as far as possible; dust is recirculated.

2. THE RE-GENERATION OF USED CATALYST.

As stated above, in the course of time the catalyst mass becomes less active, most probably on account of deposits of paraffin wax, resins and also tar. Moreover, a certain sulphur content is detrimental. The spent catalyst from the converters is transported in special vessels to the catalyst plant. If the catalyst arriving at this plant contains more than 25 - 30 % of paraffin wax, the latter has to be removed either by dissolving in benzine or by steam.

If the mass is still pyrophorous, it has to be oxidized first with steam or carefully with air; when using air high temperatures (say above 150°C) have to be avoided, in order not to decrease the solubility of the Th.

The catalyst mass is thereafter dissolved in batches in nitric acid. Vigorous stirring is necessary.

The slurry is passed to a filter press and the Kieselguhr removed.

For a simplified flow scheme see fig. 5.

The solution is then heated with a limited quantity of sodium carbonate, precipitating the impurities such as Fe, Cu, Al, part of the Mg and also Th. If necessary, the Th can be recovered afterwards; it may, however, be of advantage to return the Fe-Th compound to special industries.

In a second stage, by the addition of sodium fluoride, the surplus quantity of calcium is removed. This calcium originates most probably from the attack of nitric acid on the Kieselguhr. Apparently this Ca had no detrimental effect on the catalyst when fresh Kieselguhr was used.

Now a Co nitrate solution is produced, which has the same properties as when manufacturing fresh catalyst.

The Kieselguhr could also be recovered, but even at Holten it is considered better practice to replace it by fresh Kieselguhr, using the spent dry product for other purposes, such as insulating, etc.

REDUCTION.

The reduction of the catalyst takes place at 390 - 450° and being an exothermic reaction it has to be accomplished in the shortest possible time, as the contact is unfavourably affected by high temperature.

The flow through the reduction plant in a simplified form is given in fig. 6.

An excess of H_2 is circulated, containing no CO, CO_2 or water. The circulating hydrogen is dried in a very extensive and careful way.

From the C of the carbonates a certain amount of methane is formed, which has to be bled off continuously.

The CO content of the fresh hydrogen gas is limited to 0.05 %. A larger amount would entail the formation of methane, whereby the heat produced would burn (sinter) the catalyst.

The green corn may not be too dry (water content about 10 %); with drier green corn practice has shown that the catalyst produced is less active.

Using air for the decomposition of carbonates would necessitate too high a temperature.

The methane content in the circulating gas should not exceed 1½ - 3 %; it is not the methane itself that is dangerous, but the formation of methane. Even if no methane should be formed, a certain quantity of hydrogen in circulation has to be blown off as other yet unknown detrimental substances are being formed. About 1000 m3 circulating gas per square metre per hour of catalyst surface is used.

The reduction takes place in vessels with a screened bottom, having a surface of 1½ m2, on which the green corn is spread in a layer 35 cm thick.

The flow is as in fig. 7.

After the reduction is finished, which takes about one hour, the catalyst is cooled with circulating nitrogen. By turning over the vessel the catalyst is discharged (without coming into contact with air) into a container, which can take about 16 charges, and saturated with carbon dioxide.

MANUFACTURING OF THE MASS FOR THE FINAL PURIFICATION.

For final purification a mass is used, consisting of lux mass and sodium carbonate. Lux mass, being mainly iron oxide, is left over from the manufacturing of aluminium from bauxite.

In a special mixer this lux mass, containing 50 - 60 % water, is mixed with dry sodium carbonate in the proportion: 2 dry lux mass to 1 soda. The plastic product obtained is transported to a so-called "Strangpresse", which produces short macaroni-like pieces, from which, in a revolving hot air drier, the water is removed. The resulting product should contain about 12 % water and is placed on a sieve mechanism, from which the dust is returned to the original mixer. The size of the end product is about 5 - 15 mm; it can take up about 10 % of its own weight of sulphur. After use this mass is not re-generated.

Fig. 8 shows a simplified flow of the manufacturing process.