12. Materials of Construction (b)(cont'd.)

stalls from buckling in the case of fire, the supports for the converters and connecting girders were insulated. A layer of Diatomit blocks about 65 m/m thick was laid around the outside of the structural steel and held in place by a wire mesh. A coating of 15-20 m/m of cement was applied over the top to protect against weather and to make a smooth finished surface. Other structural steel members were also covered with either brick or Diatomit and finished with a cement coat. These precautions helped to prevent more serious accidents in the case of fires, since the steel could stand intense heat for 30 minutes or longer when so protected.

The following table No. IV shows the I.G. Farbenindustrie application of various types of insulating materials for different applications. The ordinates show the temperature ranges and the services, while the blocks show the type of material and the thickness for different diameters.

13. Conclusions.

In a planned economy and in anticipation of war, a nation may artificially stimulate the production of potentially strategic materials. In this light the chronological development in Germany of the high pressure hydrogenation processes are of interest. The earliest commercial plants were the Haber units for the hydrogenation of nitrogen to ammonia. Developed prior to 1913, this process made Germany independent of Chile saltpeter imports for explosives production during World War I.

The experience gained in design and operation of these units proved helpful when the Germans expanded their search for materials and started in the early 1920's to hydrogenate carbon monoxide to methanol. The designs of auxiliaries, safety precautions, and materials of construction could be applied directly, and the designs of the converters, heat exchangers, and separators, could, with suitable modification, be used. Thus the Germans had two large scale high pressure processes in operation prior to the next expansion

TABLE IV

Isoliertabell

Temperaturen °C	Art der Leitungen	Äußerer Rohrdurchmesser in mm. bis 40	bis 133	bis 216	bis 260	bis 350	bis 420	bis 520	bis 620	bis 720	bis 900	bis 1100	bis 1[illegible]
—80	Cold Service Kälteleitungen	150/160		200/210						250/260			
—60		100/110		150/160						200/210			
—40		30/50		100/110						150/160			
—30			50/60	100/110									
—20				30/60						100/110			
20–100	Warm Water and Condensate Warmwasser- u. Kondensatleitung.	20/25	40/50 bis 80		50/60					60/70			
			50/60		60/80								
100–200	Low Press. Steam Niederdruckdampfleitungen.	30/35	50/60		60/70					70/80			
					90/110			110/130					
200–300	High Pressure Steam Hochdruckdampfleitungen.	40/45	60/80	70/90	90/110		110/130		130/150				
300–400	Very High Press. Steam Höchstdruckdampfleitungen.	70/80	90/110		110/130		130/150		150/170				
400–450	Very High Press. Steam Höchstdruckdampf- und Heißgasleitg. and Hot Gas.		110/130	130/150		130/170		150/200					
450–500			120/140 [illegible]	140/160 (2 Lagen 70)		160/180 (2 Lagen 80)		190/210 (2 Lagen 90)					
500–600	Hot Gas Heißgasleitungen.			160/180 (2 Lagen 70, 90)		180/200 (2 Lagen 80)			210/230 (2 Lagen 70)				
600–700	Hot Gas Heißgasleitungen.			180/200 (2 Lagen 80)		210/230 (3 Lagen 60)			230/250 (2 Lagen 80, 1 Lage 50)				

Bemerkungen: Bei Isolierung gegen Frostgefahr ist Isolierstärke u. Art von Fall zu Fall zu bestimmen.

Eiskork · Wärmekork (Nicht verwendbar wo Feuersgefahr besteht) · Diamag · Schlackenwolle-Stopfverfahren · gebr. Kieselgur · Glasgespinst

Kleine Zahl = Schalen- bzw. Stopfstärke.
Große Zahl = Gesamtisolierstärke.

Leunawerke, den 7. März 1936.

N3

13. <u>Conclusions.(cont'd.)</u>

in 1926 when the first coal hydrogenation plant was started at Leuna. Here again much of the early work on ammonia and methanol was applied directly; however, this operation, involved the handling of solids, and it was necessary to gradually evolve specialized equipment such as converters, preheaters, and heat exchangers. This latter operation was much more difficult than the straight handling of gases and clean liquids as in the ammonia and methanol systems. New techniques were developed and the high pressure stage changed so that either coal or tar could be handled in the same equipment. A second, gas phase hydrogenation was developed that could process middle oil from any of several sources to produce a variety of motor fuels. Thus in the two stage hydrogenation process the Germans had a fairly flexible process capable of handling a wide variety of raw materials to produce end products of nearly the same characteristics or widely different, as desired.

Mention has been made of the enormous size of these plants in relation to their throughputs. The largest plants were Leuna and Bruex each of which produced approximately 600,000 tons of motor fuel per year. Each used ten to twelve high pressure stalls with all of the auxiliaries, such as gas manufacture, gas purification, power and steam production, gas compression and recycle units, product treatment, and covered an area of roughly fifteen square kilometers. It is difficult to evaluate the cost of these German plants on account of an arbitray relationship between the reich mark and the dollar. An indication may be obtained from a proposal made by the I.G. Farbenindustrie to the U.S.S.R. in 1939 giving the cost of a plant to produce 180,000 annual tons of aviation gasoline by the hydrogenation of brown coal.(28) The total cost of the high pressure plant and all auxiliaries was estimated at 47,800,000 R.M. Since this production corresponds to only 4,000 barrels a day, the cost per barrel per day is 12,000 R.M. At a 40 cent R.M. this corresponds to an investment of approximately $5,000 per barrel of aviation gasoline per day. This investment is high, and the operating cost would also be quite high on account of the large amount of labor required. Automatic controls were virtually unknown, as compared with

13. Conclusions.(cont'd.)

American practice, and instead manual operation was used in all but the simplest positions. Undoubtedly American engineering and instrumentation could materially cut the labor requirement, but it would still be a major item. The utilities also formed a large fraction of the operating cost. For every ton of bituminous coal processed, it required approximately four or five tons to supply the power, steam, and hydrogen.

In anticipation of and during the course of war, the present Germany again resorted to high pressure hydrogenation to produce certain materials regardless of cost. With little petroleum accessable, Germany planned to use other raw materials, such as coal, to supplement the meager supplies of crude oil obtainable from outside sources. Altogether eleven large installations were constructed for processing coal and tar with a total production of aviation gasoline (the principal product) in 1942 of about 3,900,000 tons or 32,000,000 barrels per year. While relatively large and a tribute to German engineering this output was entirely too small to support the war needs of Germany and was further diminished by strategic bombing during the later war years.

The high pressure hydrogenation of hydrogen-poor materials as developed by the Germans was a very interesting process from the scientific viewpoint. The possibilities of altering the compositions and/or quantities of various materials by changes in operating conditions or catalyst naturally attracted the interest of technical men. The economy of the process, however, was not so easily determined. The huge investment cost and the large number of men required to operate a plant that would produce 13,000 barrels per day (output of the largest units) made for high production costs. For a country that did not have any appreciable supply of petroleum, a high pressure plant could possibly compete in a protected home market. In the United States with its still large reserves of low-cost petroleum the process at present could not hope to make headway without a subsidy. Outside of small scale experiments in government supported laboratories such as the Bureau of Mines, and certain research institutions like Armour Research Foundation and Battelle Memorial Institute, there are

13. Conclusions.(cont'd.)

no known applications of coal hydrogenation to produce gasoline or liquid fuels in the United States.

Certain phases of the hydrogenation process might be considered to advantage, since it is highly probably that they might soon become economically feasible. The Standard Oil Company of New Jersey is conducting a limited hydrogenation of lube oils in order to saturate them and improve the viscosity index, but this is practiced only on a very small and limited scale. This company at its Baton Rouge refinery has also conducted many tests on the hydrogenation of cracked residues to obtain an additional yield of gasoline. This work is still in progress, and has reached the point where an increase in the price of either crude or gasoline will make the process economically attractive. The Standard Oil Company has followed the development of high pressure hydrogenation for many years, learning much of the technique from the I.G. Farbenindustrie. It is now in a position to exploit the process as soon as the economies are favorable.

Another point in favor of hydrogenating residues is the conservation of crude reserves. For every barrel of gasoline obtained from residuum about two barrels of crude may be left in the ground. Obviously the marketing of residues as fuel oil is only done because of the low selling cost of gasoline. Therefore, the further investigation of the advisability of processing these heavy hydrogen-poor materials in stages such as the Germans used for tars might well be considered.

Along the same line it might be economically feasible to process the heavy ends of crude petroleum in order to increase the hydrogen content before cracking. Such measures would raise the yields of gasoline per barrel of crude and at the same time decrease the amount of residue to be either reworked or sold. Undoubtedly the two processes could be advantageously worked together so that a heavy fraction from the crude petroleum would be blended with the cracking recycle stocks and hydrogenated, the ultimate products being only gasoline and gas.

13. Conclusions. (cont'd.)

In conclusion it does not appear that coal hydrogenation as practiced by the Germans offers any immediate prospect of competing with petroleum in the United States. It is quite possible, however, that certain features of the process may soon become justified from both a conservation and economic standpoint. The work of the Germans should be carefully studied by any industry undertaking to exploit any phases of high pressure operation. Such a study should be of considerable help in the design and operation of high pressure plants.

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