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SYNTHETIC RUBBER PLANT CHEMISCHE WERKE—HÜLS

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COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE

LONDON - H.M. STATIONERY OFFICE

SYNTHETIC RUBBER PLANT

CHEMISCHE WERKE - HÜLS

Reported By

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CIOS Target Number 22/6
Miscellaneous Chemicals

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
G-2 Division, SHAEF (Rear) APO 413

SUMMARY.

Chemische Werke, Hüls represents the latest and most modern design of German Buna S synthetic rubber operations. The plant has a rated capacity of 4000 tons per month of Buna S. Production at this rate was obtained during the early part of 1944 when operations were essentially uninterrupted by war conditions. During the last quarter of 1944 and first quarter of 1945, production was reduced to approximately 35% of rated capacity because of severe bomb damage to the nearby synthetic oil plants which supplied Hüls with its major requirements of hydrocarbon gases for acetylene manufacture.

At the present time, the plant is in excellent condition with the exception of minor bomb damage to several units sustained just prior to occupation of the area by Allied Forces. It is estimated that the plant could be returned to full operation within two to three months provided that it were supplied with the necessary raw materials.

Hüls is the only plant in Germany which manufactures acetylene by the electric arc cracking of hydrocarbon gases. Acetylene is converted to acetaldehyde and butadiene is produced from the latter by the so-called aldol process. For styrene production, benzene is obtained from coal tar plants in the Ruhr and ethylene is produced at Hüls. Butadiene and styrene are polymerized continuously in emulsion to Buna S. Four types of Buna S have been produced at Hüls: Buna S, Buna SS, Buna SR, and Buna S3. Related organic chemicals including rubber softeners are also manufactured.

Details of the butadiene, styrene, and polymerization processes were obtained.

J.D.F

PART I GENERAL

Target:

Chemische Werke Hüls G.M.B.H.
Hüls K52/A54 ; part of the
village of Marl, Kreis Recklinghausen

CIOS Black list target No. 22/6

Team:

E.T. Handley, U.S.A., T.I.I.C., Leader
C.C. Monrad, U.S.A., T.I.I.C.
B.S. Garvey, U.S.A., T.I.I.C.
N.R. Rowzee, Canada, Ministry of Supply
R.D. Juve, U.S.A., T.I.I.C.
J.E. Troyan, U.S.A., T.I.I.C.
J.D. Fennebresque, U.S.A., T.I.I.C.

Itinerary of Team.

Messrs. Monrad, Rowzee, Juve, Troyan, and Fennebresque left London April 17, 1945, by special plane and flew directly to Krefeld, Germany. The next morning, April 18, they proceeded by truck to T Force Headquarters at Herten (Kreis Recklinghausen), and arrived at the target the early afternoon of the same day. The balance of that day was spent in obtaining an overall view of the plant operations.

Mr. Fennebresque, previously had spent the week of April 1 to 7 at the target for the purpose of assessment and preliminary investigation under the auspices of C.A.F.T. He left this target the morning of April 20 to assess Leverkusen (22/2) on C.A.F.T. assignment.

Mr. Handley left from Paris by truck, the morning of April 17, arriving that evening at Verdun (12th Army Group Headquarters). Dr. Garvey arrived at Verdun the same afternoon, having come from Frankfurt by truck. Messrs. Handley and Garvey then proceeded by truck from Verdun the morning of April 18, spending that night at Krefeld and arriving at the target at noon of the next day (April 19).

The team remained at the plant through April 23, at

which time Mr. Fennebresque rejoined them. On the morning of April 24, they proceeded to Leverkusen (22/82) Messrs. Handley, Garvey, Rowzee, and Juve remained at Leverkusen for investigation of that target, and Messrs. Monrad, Fennebresque and Troyan left on the morning of April 25 for investigation of Schkopau (22/82).

Plant Personnel.

The two managing directors, Dr. Ulrich Hoffmann, and Dr. Hans Günther had left the area just prior to occupation by American troops. Dr. Paul Baumann, deputy managing director, had been left behind and had taken over all managerial duties. Under the organization plan, he was also director of the technical division which included production, research, and development. During 1930-1935, Dr. Baumann had been in the United States as liaison officer for I.G. Farbenindustrie with Standard Oil Development Co. Consequently, he speaks English fluently. Dr. Beckman, in charge of engineering, who is the fourth director of the company, was also available. A complete organization plan for the company was found and included in the documents removed.

The following key personnel were interrogated by the investigating team, in addition to those previously mentioned: Drs. Zobel, Haberl, and Weichert, acetylene manufacture and gas separation; Drs. Bub, Haag, Frank, and Saurwein, aldoling, hydrogenation, and butadiene manufacture; Drs. Roh, Hillemann, and Brunotte, ethylbenzene and styrene manufacture; Drs. Meis, Knoche, Wollthan, Hormuth, Rosenberg, and Schneider, Buna operations including production, rubber testings, and pilot plant.

Documents:

Apparently no important technical documents had been removed from the plant prior to occupation by American troops. The managing directors, Drs. Hoffmann and Günther, were known to have taken some secret data and files primarily of a financial nature with them at the time of their flight from the area.

The investigating team removed three CIOS bags of documents from the plant and delivered them to T-Force Headquarters for transmittal through proper channels to the C.I.O.S. Secretariat in London. These documents include: process and research reports; production; cost and yield data; minutes of I.G. Farbenindustrie rubber

technical committee meetings; engineering drawings of important equipment items; drawings of plant layout, etc. In addition, the investigators requested Dr. Baumann and his staff to prepare process descriptions and schematic flow sheets of all operations relating to Buna production. A complete list and explanation of all documents removed can be found in the appendix.

Two hundred kilograms of catalyst used for dehydrogenation of ethylbenzene to styrene was obtained for testing by the Allies in comparison with currently used materials.

General Description of Plant.

Chemische Werke Hüls is controlled and operated under the direction of I.G. Farbenindustrie. The plant is valued at 500,000,000 RM. It was primarily designed for the production of Buna-S type synthetic rubbers, having a rated capacity of 4000 metric tons per month, making it the second largest Buna plant in Germany. It is self-sufficient from the standpoint of producing its own requirements of Butadiene and styrene. Acetylene for the manufacture of butadiene by the well known aldol process is produced by the electric arc cracking of hydrocarbon gases. For styrene production, benzene is obtained from coal tar plants in the Ruhr, and ethylene is produced at Hüls. Related organic chemicals including rubber softeners are also manufactured.

Construction of this plant was commenced in 1938 and put into operation in August, 1940. The plant operated until March 29, 1945, the day prior to occupation of the area by troops of the U.S. 9th Army. The plant site covers an area of approximately ¾ square miles. The main gate is at the south end and the manufacturing buildings are arranged in blocks running east and west, and north and south, and numbered accordingly. The administration office is located on the right in the first block after entering the south gate and is numbered 139. The main research building, No. 141, is directly west of the administration building. Railroad switching yards are along the east side of the plant. A barge canal borders the north side with dock unloading facilities at the northeast corner.

The power plant has a rated capacity of 125,000 KW., and a maximum capacity of 175,000 KW. It represents the most modern power plant design in Germany. High pressure steam at 125 atmospheres is produced. Low pressure steam from the primary turbines, and condensate from the secondary turbines are available for chemical processing.

Mercury arc rectifiers are used for converting to D.C. current where required. The power plant is tied into the R.E.W. and V.E.W. systems for the north Ruhr area. The major coal requirements are supplied by the Zeche Auguste Viktoria A.G., a coal mine approximately two miles south east of the plant. There is also a small colliery adjacent to the plant on the east side.

For full operation, the plant required a total personnel of 7000 employees, of which 1000 were foreign workers during the last three years. 2000 employees were involved in maintenance and construction operations. 95 PhD. chemists, and 150 mechanical engineers were employed.

The butadiene, styrene, and polymerization operations at Hüls represented improvements over the design of the Schkopau plant which was the first Buna-S type synthetic rubber plant in Germany to be put into production. It is evident that the Hüls management was allowed considerably more latitude in process research and improvements than at Schkopau.

The bottleneck in increasing production of Buna was in the equipment for acetylene manufacture and gas separation. Consequently, plans were made and construction started in 1942 for the expansion of that part of the plant. This work was subsequently halted because of inability to obtain high pressure compressors required in gas separation and purification.

Condition of Plant and Effect of Bombing.

The plant is essentially in good operating condition. Some minor damage to facilities was done by fighter-bomber attacks during the two weeks prior to occupation of the area. The unit for production of the catalyst for butylene glycol dehydration was partially destroyed, but it was estimated by the plant management that it could be repaired in two to three months. Other damage is limited to certain manufacturing units, warehouses, railroad sidings, and overhead process lines. A short review of the damage to units involved in the Buna operations is included in the appendix. The power plant suffered no damage. If the plant were supplied with its requirements of raw hydrocarbon gases, benzol and other miscellaneous raw material chemicals, it is estimated that full production could be resumed in two to three months. There is on hand a normal inventory of in-process intermediates.

The only major bombing raid on the plant was a daylight attack on June 22, 1943. This resulted in a direct

hit on the main acetylene gas holder which exploded and did considerable damage, particularly to the facilities for manufacturing acetylene. The plant was shut down entirely for two months. By that time repairs had progressed so that partial operations could be carried out by having acetaldehyde shipped in from the Knapsack plant. Repairs were continued on that part of the plant for producing acetylene, and six months after the raid, the plant was returned to full operation.

Production gradually declined during the last two quarters of 1944 and the first quarter of 1945 because of the effect of bombing on the two plants supplying the major portion of the raw hydrocarbon gases - Gelsenberg Bergin A.G., at Gelsenkirchen, and the Hydrierwerk Scholven A.G., at Scholven. Following very heavy air raids, these two plants were unable to deliver any gases to Hüls after October, 1944. Thereafter, the primary source of gas was from the Bentheim natural gas wells, which, however, was limited to approximately 35% of Hüls normal requirements. (Refer to Buna S production data in appendix.)

Outline of Operations.

Unlike the other synthetic rubber plants in Germany, acetylene was produced at Hüls by the electric arc cracking of hydrocarbon gases (methane and/or methane-ethane mixtures). The primary sources of the gases were from the two nearby coal hydrogenation plants at Gelsenkirchen and Scholven. The total gas requirement for capacity operation was 130,000 to 140,000 metric tons per year, obtained as follows:

Scholven	... ...50,000 tons/yr.
Gelsenkirchen	... ...50,000 " "
Zeche Auguste Viktoria	... ...15/20,000 " "
Zweckel	... ...15/20,000 " "

The gas from Auguste Viktoria is by-product from coke oven operations. At Zweckel, there is a plant for manufacture of ethylene oxide. For this operation, by-product coke oven gases are obtained from Scholven, the ethylene is fractionated off and the remaining saturated hydrocarbon gases are delivered to Hüls.

Approximately two years ago, Hüls contracted with the Bentheim natural gas wells to deliver up to 50,000 tons per year. This was contracted for in anticipation of the plant expansion referred to previously. No gas was obtained from this source until Gelsenkirchen and Scholven

PRODUCTION IN METRIC TONS.

Date.	Butadiene	Styrene	Buna S	Buna SS	Buna SR	Buna S3	Latex S	Latex SS	Total Buna.
1940									
Jan.									
Feb.									
Mar.									
April.									
May.									
June.									
July.									
Aug.	143			212					212
Sept.	-	74		345					345
Oct.	209	125	180	-					180
Nov.	399	276	175	347					522
Dec.	457	244	-	967					967
Total	1208	644	355	1870					2045
1941									
Jan.	507	461	70	721					791
Feb.	784	315	589	316					706
Mar.	729	545	601	721					1323
April.	1290	749	582	1168					1749
May.	1417	930	720	1423					2141
June.	1016	521	642	735					1377
July.	1454	683	933	741					1674
Aug.	1723	975	1230	1180					2409
Sept.	1793	1151	1472	1271					2744
Oct.	2531	1295	1871	1355					3226
Nov.	2530	1230	2093	1438					3531
Dec.	2326	1224	1815	1334					3149
Total	18100	10082	12619	12401					25020

PRODUCTION IN METRIC TONS (Continued)

Date.	Butadiene	Styrene	Buna S	Buna SS	Buna SR	Buna S3	Latex S	Latex SS	Total Buna.
1942.									
Jan.	623	302	222	752	41			-	1015
Feb.	1892	1078	815	1315	509			1	2641
Mar.	2649	1502	1912	1321	248			1	3482
April.	2278	1523	1197	1435	373			2	3007
May.	2317	1269	967	1616	238			4	2855
June.	2231	1313	1094	1536	442			8	3080
July.	2632	1400	1488	1329	480			9	3307
Aug.	2619	1446	1436	1207	576			16	3235
Sept.	2654	1578	1774	1112	470			8	3364
Oct.	2903	1658	1706	1230	584			4	3524
Nov.	2816	1738	1777	1198	612			10	3597
Dec.	2984		1614	1362	583			14	3574
	28596	16474	16030	15415	5158			77	36680
1943									
Jan.	2942	1480	1947	1364	612		-	19	3942
Feb.	2625	1498	1460	1235	835		20	7	3557
Mar.	3148	1703	1500	1313	993		1	21	3828
April.	2907	1532	1497	1332	952		-	14	3795
May.	2944	1616	1723	1336	897		-	-	3956
June.	1966	1052	1285	983	221		9	-	2498
July.	-	-	20	4	1		8	-	33
Aug.	656	613	184	960	43		11	-	1197
Sept.	1255	906	300	1115	10		1	13	1438
Oct.	2639	1269	1402	1250	238		17	4	2910
Nov.	2726	1463	1701	1307	563		10	11	3593
Dec.	2954	1583	2088	1206	411		20	18	3744
	26782	14714	15109	13404	5777		97	107	34693

PRODUCTION IN METRIC

PRODUCTION IN METRIC TONS.

Date.	Butadiene	Styrene	Buna S	Buna SS	Buna SR	Buna S3	Latex S	Latex SS	Total Buna.
1944									
Jan.	3124	1572	1664	1587	611	-	7	20	3889
Feb.	2916	1734	1983	1939	13	-	15	10	3960
Mar.	3257	1783	2094	1266	695	-	-	24	4079
April	2826	1590	2125	1113	40	-	-	20	3660
May.	2419	1214	1820	1095	24	11	2	18	2970
June	2787	1365	921	1108	1017	224	19	2	3291
July	2559	1428	1399	1242	-	493	-	20	3153
Aug.	2691	1355	1055	1270	302	609	-	12	3247
Sept	2738	1171	1800	1142	-	621	-	23	3587
Oct.	2734	1267	1345	1201	-	996	18	7	3568
Nov.	1459	903	410	354	153	1338	11	10	2276
Dec.	1409	609	-	-	202	1210	-	4	1415
	30918	15993	16616	13317	3418	5502	72	180	39105

December 1944 made 43 tons of Perbunan.

SUMMARY OF COSTS - HÜLS.*
RM/100 kg.

		Ethyl-ene	Acetyl-ene	Ethyl-benzene	Styrene	Acetal-dehyde	80% Aldol	Butol	Buta-diene	Buna S	Buna SS	Buna SR
1940	III				322				243			
	IV	142	76	56	218	97	76	144	366			
1941	I	228	71	114	170	73	53	91	229			
	II	116	60	83	139	57	49	77	184			
	III	90	48	66	111	48	42	66	155			
	IV	59	36	55	82	37	34	52	123			
1942	I	70	51	61	96	49	42	67	157			
	II	84	46	66	100	42	38	62	150	186.94	192.29	191.51
	III	84	54	67	100	45	40	65	154	194.23	202.96	200.63
	IV	81	50	56	80	40	39	64	150	169.60	174.16	174.18
1943	I	64	45	50	77	36	35	54	127	157.50	161.55	161.67
	II	67	45	53	79	38	38	59	137	156.58	160.42	168.28
	III	223		120	176	-	110	122	439	603.80	547.50	530.04
	IV	91	60	66	104	47	47	75	130	205.51	209.18	215.44
1944	I	55	40	52	76	32	32	48	115	141.03	146.46	148.28
	II	73.39	50.19	54.34	84.72	40.95	38.62	60.76	142.13	174.25	169.90	170.56
	III	92.27	65.79	68.18	100.52	51.58	47.81	73.00	169.22	205.04	198.33	206.83
	IV											

* Numbers without decimals estimated from chart in Doc.2925 - 53.

SUMMARY OF YIELD 1944 (100 kg output)

BUTADIENE PROCESS.

I. Acetaldehyde Manufacture. Input.		Output.		Yield % of theory
Acetylene	64.48	Acetaldehyde	100.00	91.7%
Nitric acid	1.52	Recycle acetylene.	0.11	
Iron sulfate	0.80	Acetone	trace	
96% H_2SO_4	0.65			
NaOH	1.00			
Mercury	.01			

II. Aldol Manufacture				
Acetaldehyde	82.75	Aldol (80%)	100.00	99.1
KOH (100%)	0.13	Potassium phosphate	0.15	
H_3PO_4 (as P_2O_5)	0.12	Sodium phosphate.	0.003	
NaOH (100%)	0.01			

III. 1,3 Butylene Glycol manufacture.				
Aldol (80%)	98.83	Crude butol	100.00	98.9
Hydrogen (m^3)	26.99	Hydrogen (m^3)	.35	
BBE catalyst	0.05			

IV. 1,3 Butylene Glycol distillation.				
Crude butol	146.00	1,3 butylene glycol	100.00	81.9
		Butanol (100%)	5.56	
		Sec. butanol	0.20	
		Ethanol (100%)	7.29	
		Hexanol.	0.39	
		Toppings.	0.01	
		Residue	3.78	

GERMAN PLANNED PRODUCTION OF SYNTHETIC RUBBER. Contd....

Quarter	1943 I	II	III	IV	Total	1944 I	II	III	IV	Total
Schkopau										
Buna S	15.0	15.0	15.0	15.0	60.0	15.0	15.0	15.0	15.0	60.0
Buna SS	-	-	-	-	-	-	-	-	-	-
Numbered Bunas	0.9	0.9	0.9	0.9	3.6	0.9	0.9	0.9	0.9	3.6
Hüls										
Buna S	3.45	3.5	3.5	3.5	13.95	3.5	3.5	3.5	3.5	14.0
Buna SS	9.0	9.0	9.0	9.0	36.0	9.0	9.0	9.0	9.0	36.0
Ludwigshafen										
Buna S	7.5	7.5	7.5	7.5	30.0	7.5	7.5	7.5	7.5	30.0
Auschwitz										
Buna S	-	-	1.2	3.0	4.2	4.8	6.7	9.0	12.5	33.0
Leverkusen										
Buna SS	0.3	0.45	0.45	0.45	1.65	0.45	0.45	0.45	0.45	1.80
Buna N	1.2	1.35	1.35	1.35	5.25	1.35	1.35	1.35	1.35	5.40
Total Buna SS	9.3	9.45	9.45	9.45	37.65	9.45	9.45	9.45	9.45	37.80
Total Buna S	25.95	26.00	27.0	29.0	108.15	30.8	32.7	35.0	38.5	137.0
Total Numbered Bunas.....	0.9	0.9	0.9	0.9	3.6	0.9	0.9	0.9	0.9	3.6
Total Buna N	1.2	1.35	1.35	1.35	5.25	1.35	1.35	1.35	1.35	5.40
GRAND TOTAL	37.35	37.70	38.90	40.70	154.65	42.50	44.40	46.70	50.20	183.80

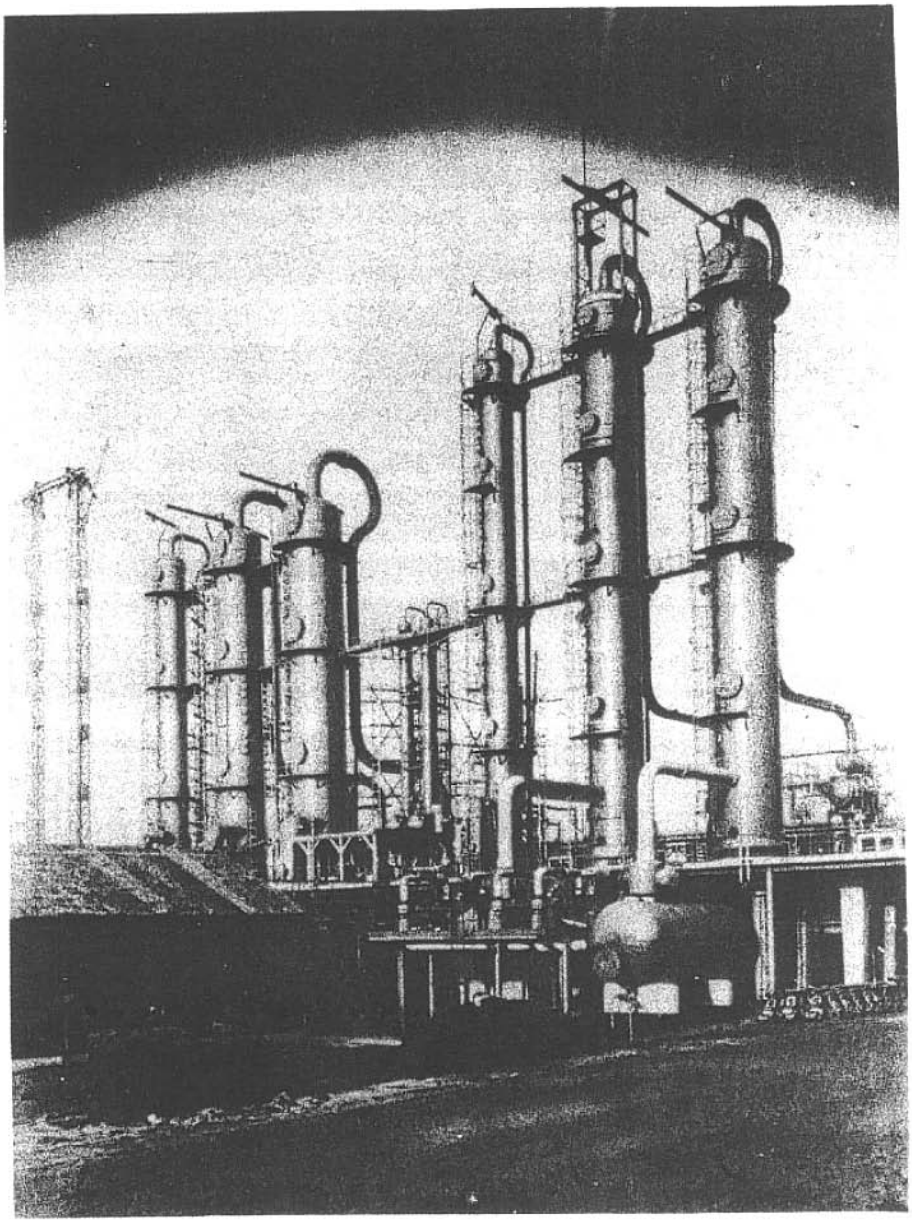
TOTAL BUBBER PRODUCTION IN GERMANY (Metric tons)

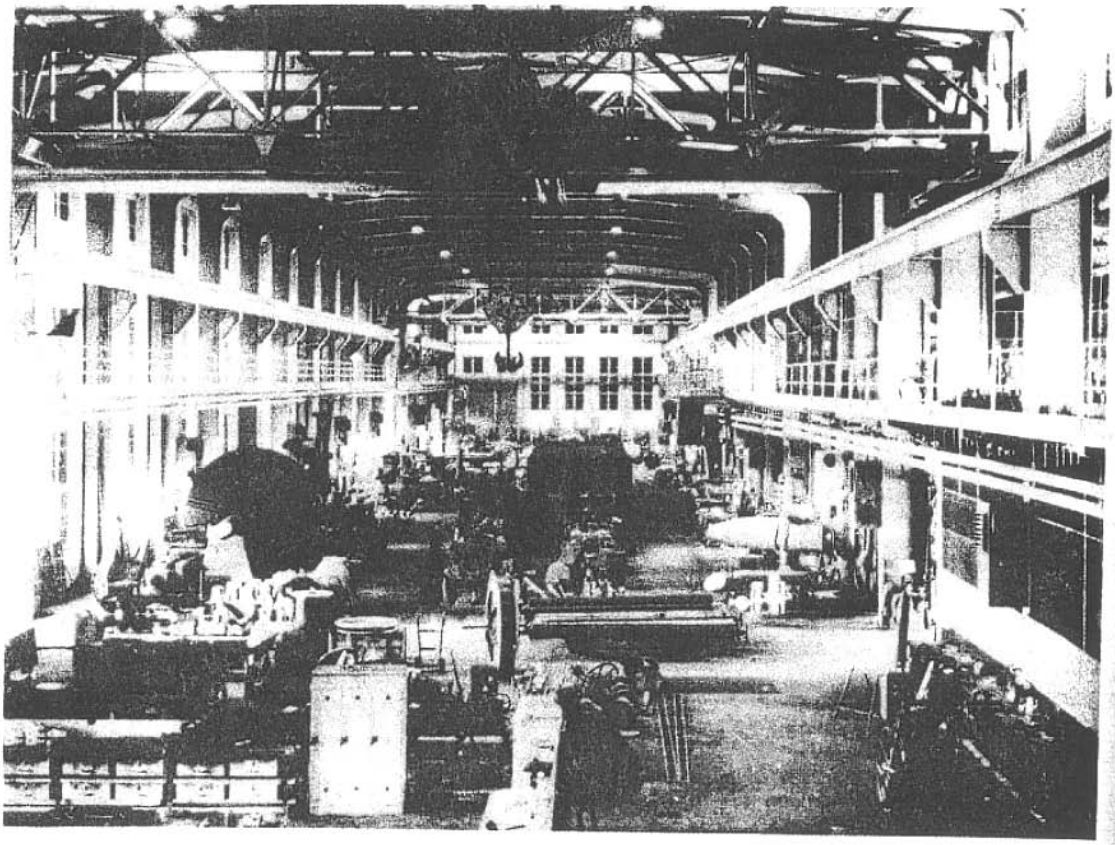
Buna S types	1937	1938	1939	1940	1941	1942	1943	1944
Schkopau	2110	3994	20173	34899	40705	57313	67703	45113
" Hüls	-	-	-	2045	25020	36680	34693	39105
Ludwigshafen	-	-	-	-	-	-	7181	11955
Leverkusen	***	***	403	193	164	173	992	1320*
TOTAL BUNA S	2110	3994	20576	37137	65889	94166	110569	97493
Buna N								
Leverkusen	** 400	** 640	1126	1898	2631	2824	3656	3129*
" Hüls	-	-	-	-	-	-	-	43
TOTAL BUNA N	400	640	1126	1898	2631	2824	3656	3172
Numbered Bunes								
Schkopau	637	848	649	1431	1955	2721	3388	2590
GRAND TOTAL SYNTHETICS	3147	5482	22351	40466	70475	98711	117613	103255

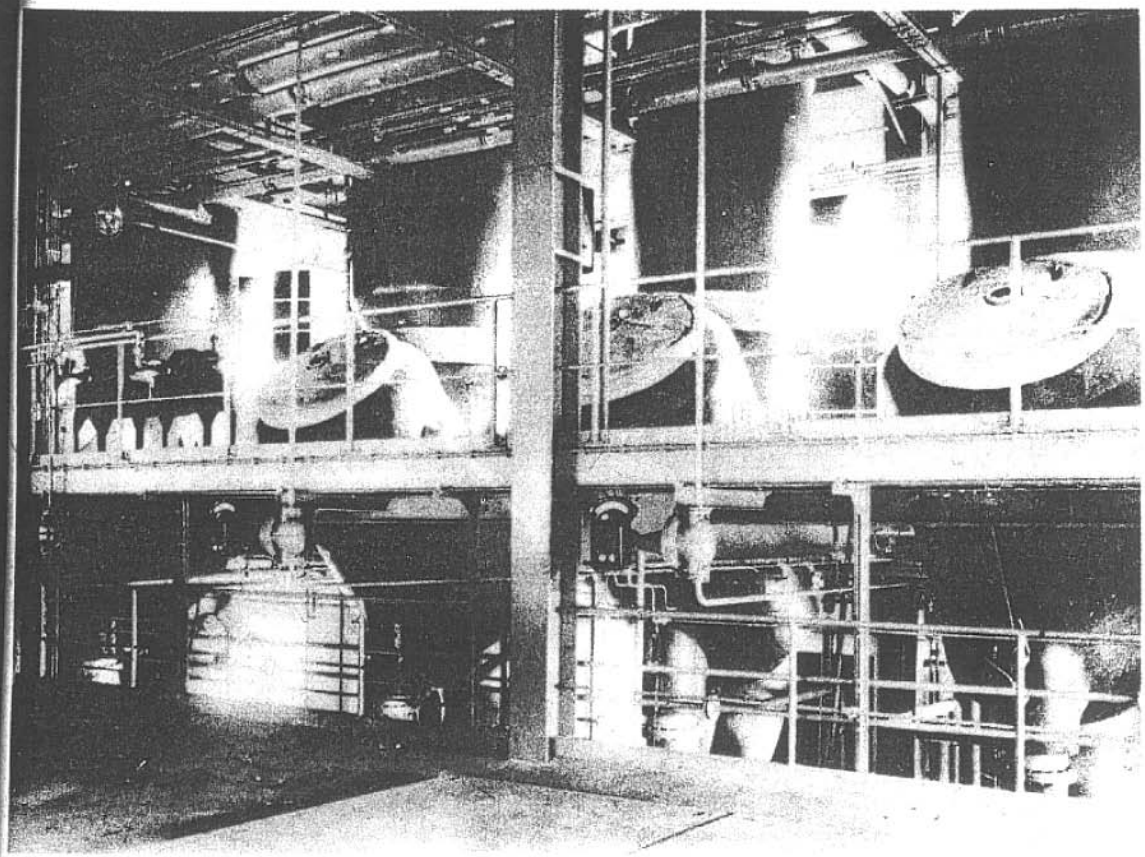
* To Oct 26/44

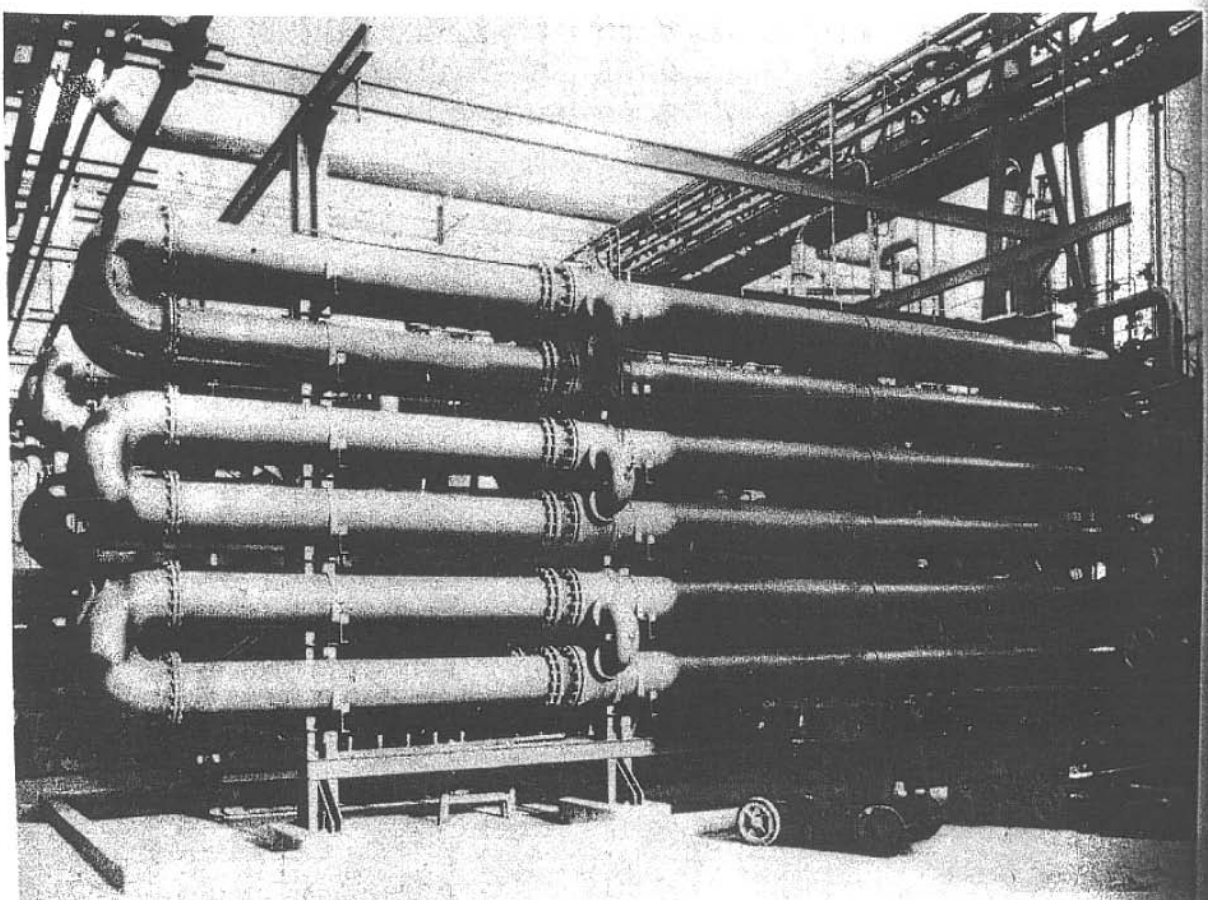
** Approximate.

*** Not available.

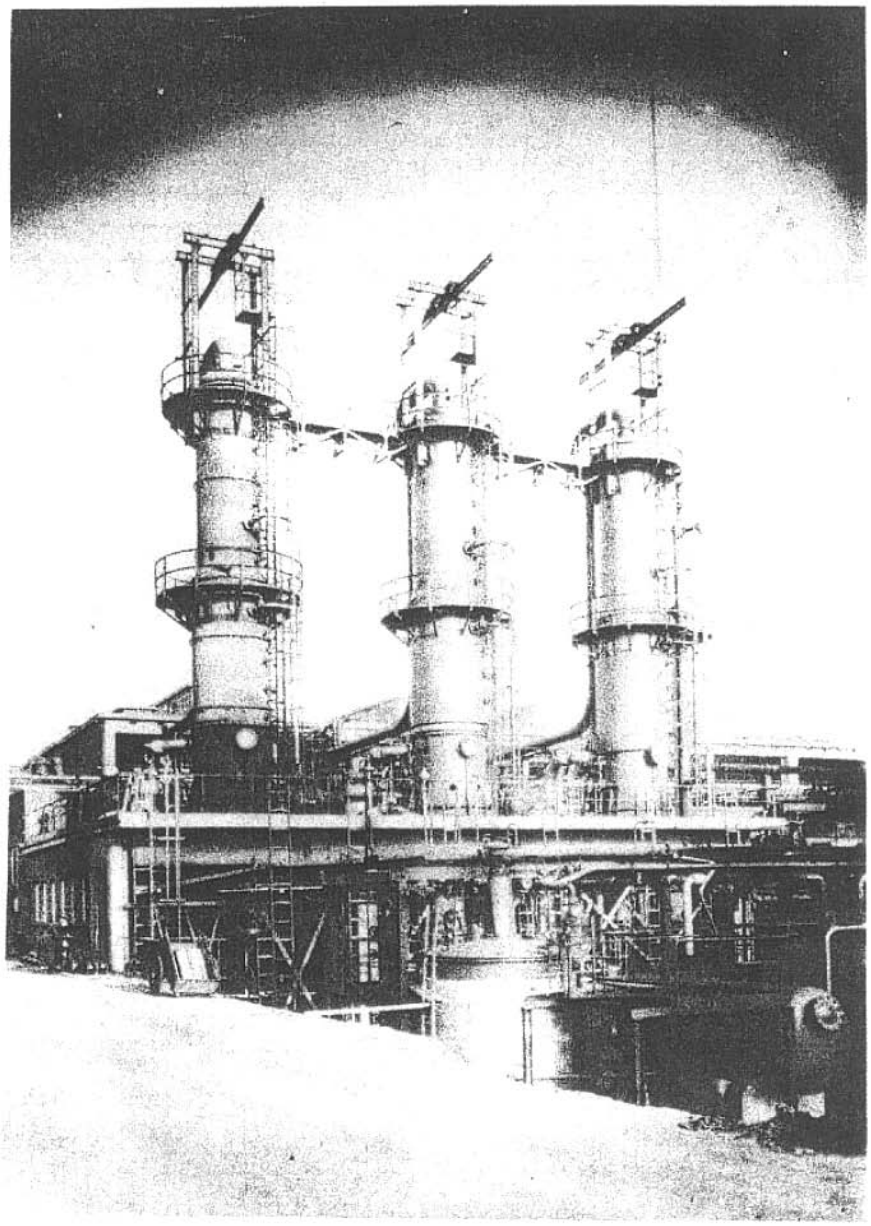








ALDOL MANUFACTURE REACTOR



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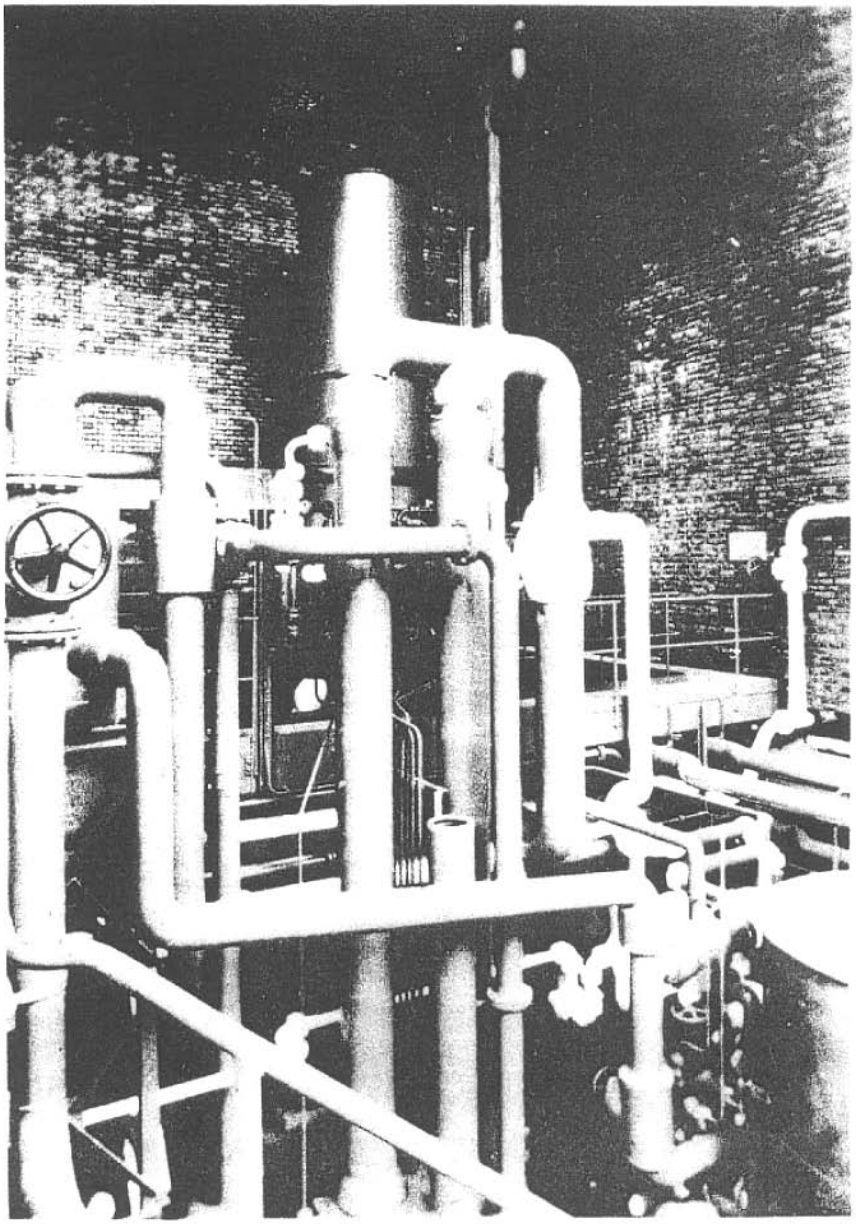
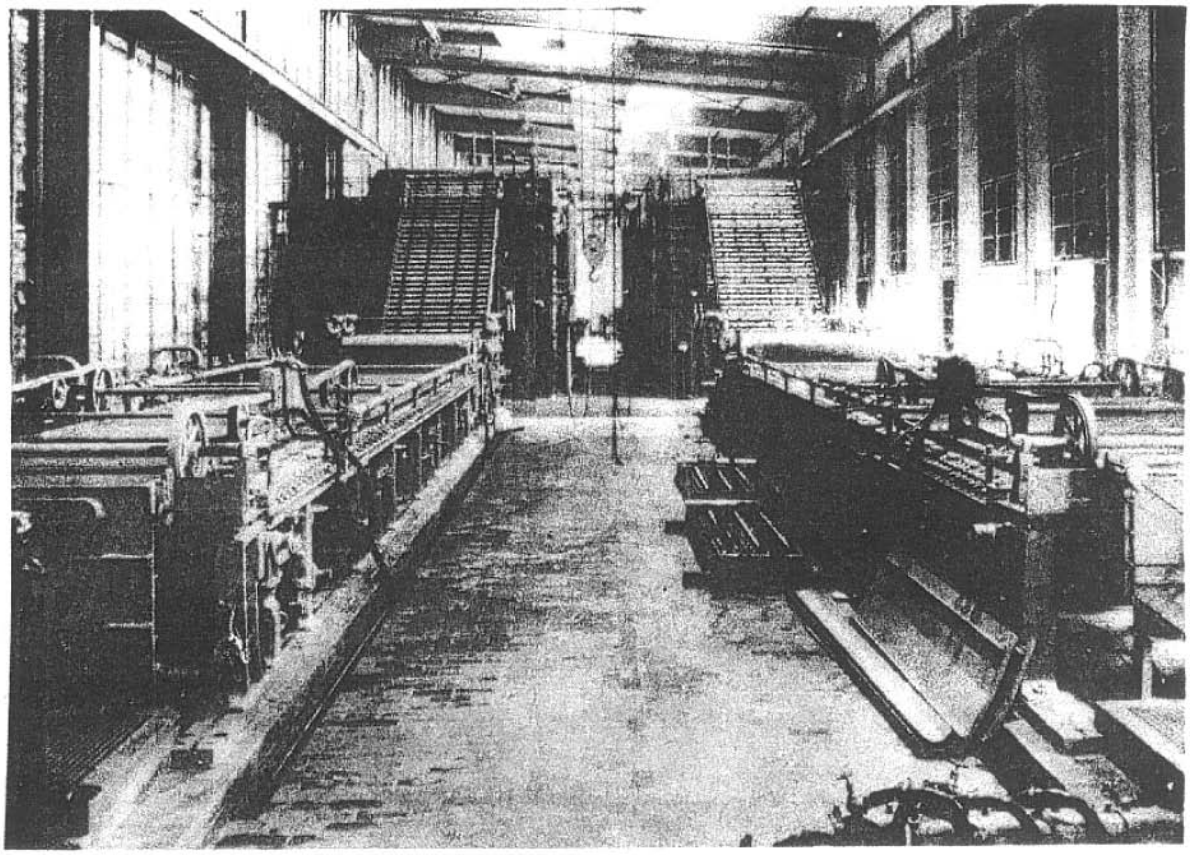
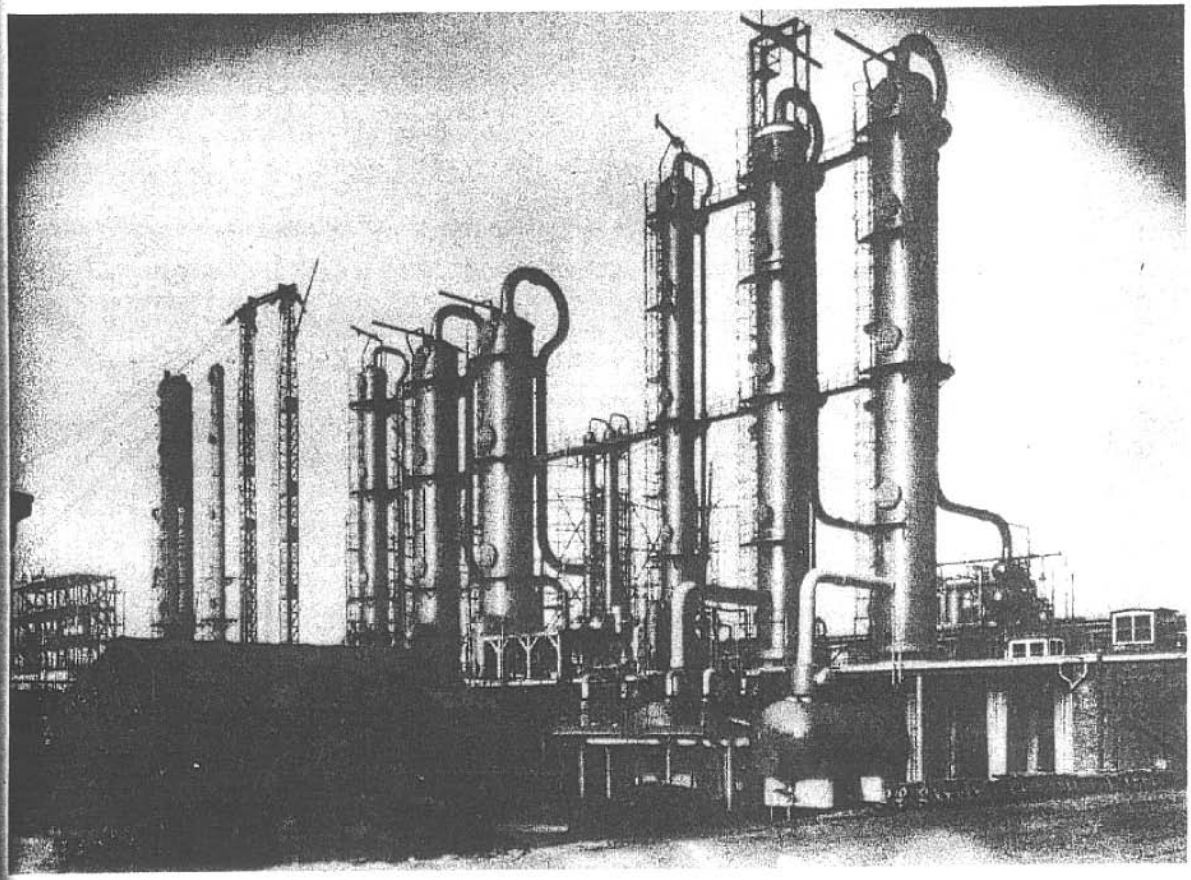


BUNA S HYDROCARBON RECOVERY



BUNA S FOURDRINIER MACHINES AND DRIERS



BUTADIENE DISTILLATION