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ITEM No. 22

FILE No. XXII-22

SYNTHETIC RUBBER PLANT BUNA WERKE-SCHKOPAU A.G.

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE

LONDON - H.M. STATIONERY OFFICE

SYNTHETIC RUBBER PLANT
BUNA WERKE - SCHKOPAU A.G.

Reported By

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CIOS Target Number 22/82
Miscellaneous Chemicals

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

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SUMMARY.

Buna Werke, Schkopau, is the largest Buna S synthetic rubber plant in Germany with a rated capacity of 6000 tons per month. Production in 1943 was 68,000 tons, and for several months was slightly in excess of the rated capacity. After July of 1944, production dropped off sharply because of low supplies of hydrogen from the Leuna synthetic oil plant which was being bombed heavily. By January 1945, production was reduced to 25% of capacity. Aside from minor bomb damage, this Plant is in good operating condition.

Acetylene for acetaldehyde and ethylene manufacture is produced from calcium carbide. Butadiene is made from acetaldehyde by the so-called aldol process and ethylbenzene for styrene manufacture is made from ethylene and benzene. Buna S and S-3 are polymerized from butadiene and styrene continuously. Buna 32, Buna 85, and miscellaneous organic chemicals are also produced.

This Plant was primarily concerned with maximum production, conditions permitting. Consequently, unlike Hüls, very little research and development work was carried out.

PART I - GENERAL

PART I - GENERAL

Target:

Buna Werke A.G.
(I.G. Farbenindustrie)
Schkopau, Kreis Merseburg, Germany.

CIOS Black list target No. 22/82

Team:

J.D. Fennebresque,	U.S.A.,	T.I.I.C., Leader.
C.C. Monrad,	U.S.A.,	T.I.I.C.
J.E. Troyan,	U.S.A.,	T.I.I.C.

Introduction:

After investigation of the Chemische Werke at Hüls, it was evident that the major technical details of butadiene, styrene, and polymerization processes used by the Germans had been obtained at that target. However, the opportunity arose to make a quick investigation of the plant at Schkopau, by taking advantage of combining a CAFT assessment of the overall operations with the CIOS investigation of the synthetic rubber sections. Approval for this combined operation was granted by 12th Army Group Headquarters.

In the technical parts of this report, no attempt will be made to discuss in detail the sections of the synthetic rubber operations at Schkopau which are similar to those at Hüls, but emphasis will be placed on discussing those parts of the processes which differ.

Itinerary of Team:

After the team consisting of Messrs. Handley, Monrad, Garvey, Rowzee, Troyan, Juve, and Fennebresque had completed the investigation of Hüls (22/6), they proceeded to Leverkusen (22/2) on April 24, 1945. The morning of April 25, Monrad, Troyan and Fennebresque left by truck for Schkopau and the remainder stayed at Leverkusen for investigation of that target.

The Schkopau team first travelled to Wiesbaden to obtain clearance through 12th Army Group Advance Headquarters, arriving there the night of April 25. The morning of the 26th the team left by truck for Schkopau and arrived at the target the evening of the same day. Investigation of the target was carried out on the 27th and 28th of April, during which time the team stayed at the plant with the battery of artillery assigned by the U.S. First Army to guard the premises.

On the morning of April 29, the team left Schkopau by truck and spent that night at Wiesbaden, the next night at Verdun, and arrived at Versailles the afternoon of May 1. SHAEF then provided air transportation to London the morning of May 2.

Plant Personnel:

All of the key personnel were available at the plant and were interviewed. These are as follows:

Dr. Wulff, Managing Director.
Dr. Moll, Technical Director.
Herr Biedenkopf, Chief Engineer.
Dr. Ecarius, Personnel Director.
Dr. Bohring, Chief Accountant.
Dr. Klein, Technical Supervisor of Polymerization.
Dr. Kehlen, Technical Supervisor of Aldol manufacture.
Dr. Strobele, Technical Supervisor of Butylene glycol manufacture.
Dr. Jacobi, Technical Supervisor of Butylene glycol distillation.
Dr. Broich, Technical Supervisor of Butadiene manufacture.
Dr. Shafer, Technical Supervisor of Ethylbenzene and styrene manufacture.
Dr. Emmler, Interpreter and dye chemist.

Documents:

The greater part of the important technical and production files were removed in January, 1945, from the plant to a mine shaft at the Wintershall A.G., Werk Bismarkshall in Bischofferode, C. Bleicherode. These documents include yield and cost data, production performances, future production programs, process write-ups, etc.

The following documents were removed from the plant and cleared through proper military channels for delivery to CIOS Secretariat at London:

19 - Loose leaf files of photographs of the plant.
3 - Ledgers of 1944 Production, Costs, and yields.
12 - Engineering files (primarily of maintenance interest).

- 2 - Styrene mfg.
- 1 - Zahlen Buna (Buna 32 and 85)
- 1 - Aldol mfg.
- 1 - Acetaldehyde mfg.
- 1 - Aldol hydrogenation.
- 1 - Ethylbenzene mfg.
- 2 - Butadiene mfg.
- 1 - Butylene glycol mfg.
- 2 - Buna S mfg.

1 - Plant layout drawing.
1 - Key to plant layout.

At the time of the investigation of the Ludwigshafen target (22/3) on March 21-30, certain documents relating to the Schkopau operations were obtained. These included 1943 production, cost and yield data, and five reports on distillation practice in various parts of the butadiene and styrene processes. A list of these documents will be found in the Ludwigshafen report.

General description of Plant:

Buna Werke A.G. is owned and operated by the I.G. Farbenindustrie. It was the first Buna S synthetic rubber plant to be constructed in Germany. Design of the installations was on the basis of the original research and pilot plant work carried out at Leverkusen and Ludwigshafen. With a rated capacity 6000 tons of Buna S per month, it is the largest synthetic rubber plant in Germany. The plant is self-sufficient from the standpoint of producing its own requirements of butadiene and styrene. Acetylene, for the manufacture of butadiene by the aldol process is produced from carbide. For the production of styrene, benzene is shipped in by rail and ethylene is produced at the plant. Buna 32, Buna 85, vinyl chloride, diglycol and other related organic chemicals are also manufactured.

Construction of the plant was begun in 1937 and completed in 1939 at which time it was put into operation. The plant operated up until occupation of the area by troops of the U.S. First Army on April 19, 1945. The plant site covers an area of approximately 1½ square miles. The main entrance is at the east end. There is no main administration building, but the community center building No. B12 immediately on the left on entering the main gate has been serving that purpose. Plans had been drawn up for the construction of an elaborate administration building. The directors of the company had their offices in a small building C 37, in the middle of the area. The plant is divided up in blocks, and numbered alphabetically from south to north, and numerically from east to west. Buildings and operating units are numbered accordingly. Railroad switching yards are along the southeast end.

The power plant has a rated capacity of 120,000 KW. For full operation of the plant there is required 240,000 KW, the additional 120,000 KW being supplied through the REW system. Of the total, 160,000 KW are required for the manufacture of calcium carbide for acetylene generation.

For capacity operation, the plant required 15,000 employees, of which 4,500 were foreign workers during the last several years.

From the synthetic rubber standpoint it was evident that the Schkopau plant was primarily concerned with production at a maximum level, conditions permitting. Very little research and development work was carried out. This is in contrast to the condition found existing at the Hüls plant.

Condition of Plant and Effect of Bombing.

The plant is generally in good condition. A small air raid in January, 1945, resulted in some damage to the chlorine, Buna polymerization, polyvinyl chloride, and phthalic anhydride units. The damage to Buna polymerization facilities was limited to one building B 39, effecting a 20% reduction in total capacity. It was estimated by Dr. Wulff that repairs to these units could be completed in two to three months. During the fourth quarter of 1944, and the first quarter of 1945, production of Buna S was reduced to 25% of rated capacity. This resulted primarily because of severe reduction in hydrogen from the Leuna plant required for the manufacture of butylene glycol from aldol, and shortage of benzene deliveries because of bomb damage to rail facilities. During this period some butylene glycol was shipped in from Hüls.

Outline of Operations:

Note: Operating capacities of the impotant units in plant and production of Buna S by quarters for 1943 and 1944 are shown by tables in the appendix.

The primary hydrocarbon raw material, acetylene, is produced from coke and lime through calcium carbide by the conventional process. Power requirement for the electric furnace averaged 3300 KWH/ton carbide. Acetylene is converted to acetaldehyde using mercury in presence of ferric sulfate and sulfuric acid as catalyst. The concentration of the mercury solution is higher than that used at Hüls because the higher purity acetylene permits it. This results in somewhat higher yield, which at Schkopau averaged 95% of theory.

Butadiene is manufactured from acetaldehyde by the aldol process similar to the Hüls operations. The hydrogen for the production of butylene glycol from aldol was supplied by pipe line from the Leuna synthetic oil plant. The overall yield from acetaldehyde to butadiene averaged 65% of theory. No inhibitor is used in the purification and storage of butadiene. Ethanol, butanol, hexantriol, and crotonaldehyde are by-products recovered from the butadiene process.

Ethylene for the manufacture of ethylbenzene is produced from acetylene by catalytic hydrogenation. Some ethylene for ethylene oxide is produced by dehydration of ethyl alcohol over CaO catalyst. The manufacture of ethylbenzene using $AlCl_3$ catalyst and catalytic dehydrogenation to styrene are similar to the Hüls and Ludwigshafen operations, with the exception of minor operating details.

Butadiene and styrene are polymerized in emulsion continuously with each line consisting of ten or twelve reactors in series. Buna S was made exclusively until the end of the second quarter of 1944, at which time large scale production of Buna S-3 commenced. The reason for the change in formula was identical with that at Hüls - critical shortage in Germany of linseed oil required for the manufacture of linoleic acid, which was the polymerization regulator used in the Buna S recipe. Schkopau never produced Buna SS or Buna SR, but did make experimental quantities, in recent months, of Buna S-4 (no fatty acid). Nekal (Emulgator 1000), used as the emulsifying agent in polymerization, is manufactured at the plant from butanol and naphthalene. When war conditions did not interfere, the rated capacity of 6,000 tons of Buna S per month was met and actually exceeded.

The two sodium polybutadienes, Buna 32, and Buna 85, are produced by mass polymerization at this plant. Buna 85 is polymerized continuously, the design details of which were obtained. Buna 32 is polymerized batchwise, but plans had been laid out for continuous equipment. Buna 32 was used primarily as a softener in Buna S tire manufacture, and Buna 85 for hard rubber goods.

Ethylene oxide, for the manufacture of diglycol is produced from ethylene through ethylene chlorhydrin. Ethylene chloride equivalent to 15% of the ethylene oxide is recovered as by-product. Chlorine and by-product caustic soda are made in mercury cells. The reaction of ethylene oxide to diglycol and glycol is controlled to give primarily diglycol by recycling glycol and operating at the higher range in pressure. Diglycol is shipped out for nitration to an explosive as substitute for nitro-glycerine.

The original pilot plant for the manufacture of tetrahydrofuran from acetylene and formaldehyde by the Reppe Process was constructed and operated at Schkopau. (Refer to Ludwigshafen report for details of the manufacture of tetrahydrofuran and butadiene by the Reppe Process.) The unit continued to operate and the output was shipped to Ludwigshafen for conversion to butadiene. Methanol from Leuna was oxidized to formaldehyde (30% solution) in a small unit.

Phthalic anhydride is made by vapor phase oxidation of naphthalene using V_2O_5 catalyst. Less than 0.5% of maleic anhydride is formed in the reaction. Hexantriol, a by-product from the butadiene process, is condensed with phthalic anhydride to a resin for use in lacquer manufacture.

Vinyl chloride is produced from acetylene and HCl in vapor phase using $HgCl_2$ on activated charcoal as catalyst. Approximately 25% of the vinyl chloride output is polymerized continuously in emulsion to polyvinyl chloride plastic. There is also a small unit for batchwise polymerization of styrene in emulsion. Ethylene is polymerized using $AlCl_3$ catalyst to a liquid polymer (Polyethylene) known as SS oil (lubricating oil).

Plans had been made and engineering designs completed for the construction of a plant to produce 50 tons per month of Koresine, a rubber tackifier. The process is similar to that used at Ludwigshafen, which is discussed in the report for that target. Originally this unit had been scheduled to come into operation in January 1945. However, because of delays in obtaining equipment, etc., the construction was never started. Apparently the need for this unit resulted from bombing damage to the Ludwigshafen facilities.

German Synthetic Rubber Plant Capacities:

Information was obtained by discussion with Dr. Wulff on his estimate of the ultimate rated capacities of the Buna S synthetic rubber plants in Germany. These are as follows:

Ludwigshafen	2000	tons/month
Hüls	4000	" "
Schkopau	6000	" "
Auschwitz	3000	" "

In general these data confirm those previously obtained from other sources. It was also confirmed that Auschwitz did not come into operation on Buna S, but had started production of acetylene (CaC_2) to acetaldehyde at the time that the plant was captured by the Russians.

Note: Dr. Wulff was a member of the central syntheti rubber technical committee under Dr. Ter Meer, so that his statement on the projected capacity and state of operations for the Auschwitz plant can probably be accepted as essentially correct.

(r)	Bldg	J - 6	-
		J -15	Electrode manufacture
		J--16	-
		J -18	-
		J -21	Carbide oven
		J -28	CO gasholder
		J -30	Gas - compressed air
		J -32	Linde Plant.
(s)	Bldg	J -36	H_2 gasholder
		J -39	Dorr Thickener
		J -40	Acetylene holder
		J -42	Oxygen gas holder
		J -45	Lime
		J -46	Waste lime
		J -54	Salt electrolysis
		J -72	Power house
		J -75	Power control
		J -78	Return cooler
	Bldg	K -76	Coal bunker
		K -76a	Clay bunker
		K -79	Clay drier
		K -80	-

2951 - 6. Plant layout and key to buildings.

RATED CAPACITIES.

Endproducts.	Tons per month.
Buna S	6,000
Buna 32	200
Buna 85	100
Vinyl chloride	2,500
Polyvinyl chloride	600
Polystyrene	50
Ethyl alcohol	800
Butanol	500
Acetic acid	700
Acetone	200
Phthalic anhydride	540
Formaldehyde	800
Diglycol	700
SS oil (lubricating oil)	500
Tetrahydrofurane	300
Trichlor ethylene	400
Ethyl chloride	120
Waste lime ($Ca(OH)_2$) (used as fertilizer)	14,000
Caustic soda	4,500
Aluminium chloride	700

Intermediate products.	Tons per month.
Ethylbenzene	1,800
Styrene	1,600
Calcium carbide	30,000
Acetylene	10,000
Acetaldehyde	12,000
Aldol	11,000
Butylene glycol	10,000
Butadiene	4,800
Chlorine	4,000

PRODUCTION IN METRIC TONS.

YEAR 1943	Butadiene	Styrene	Buna S	Buna 32 + 85
1st quarter	13154	4212	16,249	772
2nd quarter	13308	4556	16,229	879
3rd quarter	14453	5017	17,357	864
4th quarter	14534	5013	17,868	873
	55449	18798	67,703	3388
1944				
1st quarter	14,255	4748	17,845	760
2nd quarter	11,761	3962	14,020	718
3rd quarter	5,372	1921	6,836	615
4th quarter	5,456	2084	6,412	497
	36,844	12715	45,113	2590

SCHKOPAU

SUMMARY OF PRODUCTION AND COSTS (INCLUDING AMORTIZATION & INTEREST)

YEAR 1943

MATERIAL	1ST QUARTER Tons	1ST QUARTER Cost RM/100 Kg.	2ND QUARTER Tons	2ND QUARTER Cost RM/100 Kg.	3RD QUARTER Tons	3RD QUARTER Cost RM/100 Kg.	4TH QUARTER Tons	4TH QUARTER Cost RM/100 Kg.
Calcium Carbide	70,037	14.25	71,501	14.65	75,224	15.43	80,988	14.64
Pure Acetylene	24,588	47.65	24,417	49.24	26,178	51.03	26,906	49.31
Acetaldehyde	31,741	35.68	30,909	36.65	32,586	37.51	33,815	37.25
Aldol	44,006	29.01	44,997	30.28	46,010	32.87	44,761	32.58
Butylene Glycol	28,783	45.92	29,061	47.91	31,549	47.87	30,686	47.49
Butadiene	13,155	116.67	13,308	121.69	14,454	117.83	14,534	115.38
Benzol	3,896	42.52	3,862	41.10	5,878	41.29	4,640	40.97
Ethyl Benzene	4,907	60.05	5,182	59.04	7,744	57.06	6,091	57.09
Styrene	4,212	86.80	4,556	84.29	5,017	81.27	5,013	79.59
Buna S	16,249	145.13	16,229	156.51	17,357	151.46	17,868	151.00
Numbered Bunas	772	159.47	879	163.67	864	163.17	873	169.14

SUMMARY OF YIELDS (1944) SCHKOPAU.

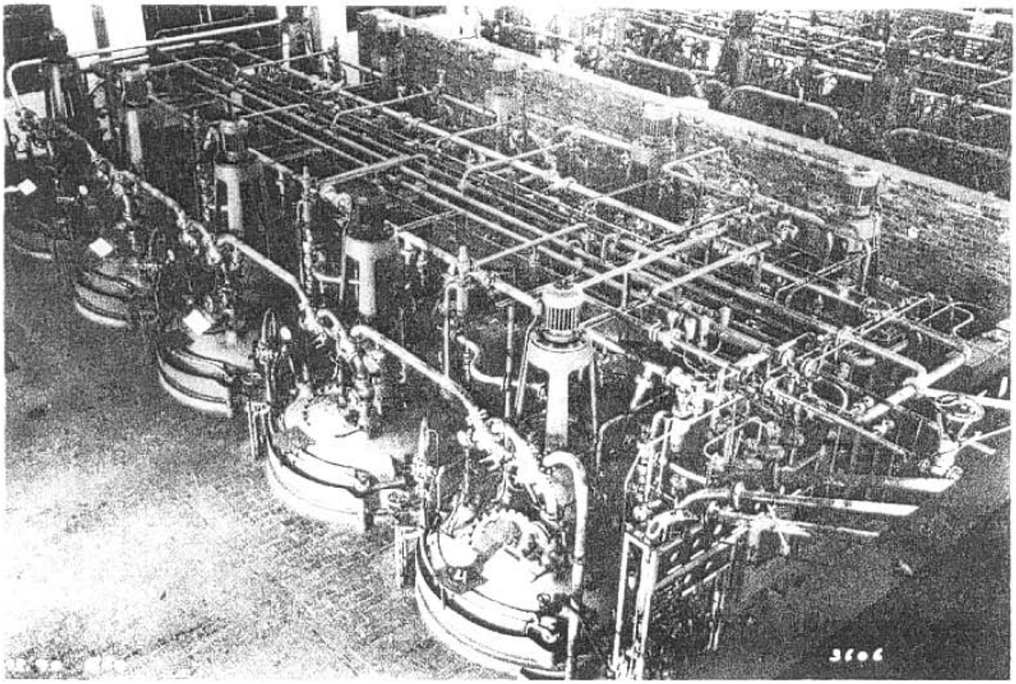
BUTADIENE.

CARBIDE.	I Quarter	II Quarter	III Quarter	IV Quarter
Input.				
Lime	105.11	103.63	108.15	107.89
Anthracite	19.57	18.39	16.32	6.70
Coke	43.21	43.50	47.53	56.55
Output.				
Carbide	100.00	100.00	100.00	100.00
Gas (m^3)	30.67	29.99	23.83	22.95
ACETYLENE.				
Input.				
Carbide	294.05	300.05	312.22	305.40
NaOH (100%)	0.65	0.66	0.70	0.70
Chlorine	0.51	0.53	0.52	0.42
Output.				
Acetylene	100.00	100.00	100.00	100.00
Lime	370.53	338.99	365.93	313.66
ACETALDEHYDE				
Input.				
Acetylene	62.98	62.96	64.38	64.26
Mercury	0.07	0.07	0.05	0.11
Iron sulfate	0.49	0.54	0.71	1.15
H_2SO_4	0.14	0.25	0.37	0.60
HNO_3	0.36	0.52	0.79	0.80
NaOH	0.53	0.57	0.63	0.66
Output				
Acetaldehyde	100.00	100.00	100.00	100.00
Crotonaldehyde	0.22	0.19	0.23	0.10
ALDOL (80%)				
Input				
Acetaldehyde	94.40	86.51	87.86	87.39
Phosphoric acid (as P_2O_5)	0.23	0.23	0.16	0.18
Output				
Aldol	100.00	100.00	100.00	100.00
Potassium phosphate	0.21	0.23	0.08	0.08

SUMMARY OF YIELDS (1944) Contd... SCHKOPAU.

BUTADIENE.

CRUDE BUTOL	I Quarter	II Quarter	III Quarter	IV Quarter
Input.				
Aldol	98.37	98.58	98.17	98.72
Hydrogen (m^3)	31.75	31.93	40.35	35.72
Catalyst	0.07	0.08		0.10
Output.				
Crude butol	100.00	100.00	100.00	100.00
Residue	-	0.04	-	-
BUTOL DISTILLATION				
Input.				
Acetaldehyde	0.03	0.09	-	0.09
Crude butol	145.97	146.74	144.21	148.01
Recycle butol	1.70	2.14	1.34	2.19
Crotonaldehyde	0.24	0.21	0.14	0.50
Output.				
1,3 butol	100.00	100.00	100.00	100.00
Ethanol	7.82	8.02	8.12	9.70
Butanol	7.43	7.30	6.96	5.08
Hexanol	0.35	0.14	0.72	-
Residue	6.07	6.36	5.11	5.52
Butanol P	0.10	0.12	0.33	0.32
Hexanol bottoms	0.01	0.02	0.09	0.06
Butolacetal	0.06	0.19	-	0.18
Butol-toppings	0.42	0.07	0.23	-
BUTADIENE MANUFACTURE				
Input.				
Butol	208.33	207.35	205.18	208.16
Catalyst.	13.39	14.75	14.30	16.02
Output.				
Butadiene	100.00	100.00	100.00	100.00
Butyraldehyde	1.47	1.36	1.34	0.70
Butadienoil	0.67	1.18	2.05	2.33
" H	1.34	1.04	0.63	-
" K	4.78	2.95	1.64	0.80
Propylene	3.22	2.73	2.20	2.55
Carboresin D	3.73	4.43	8.91	7.14
Butadiene Oil	0.19	0.33	0.19	0.27
Carboresin A	0.11	0.28	-	-
Residue	-	0.01	0.01	0.01
Solvent A48	-	0.35	-	0.15



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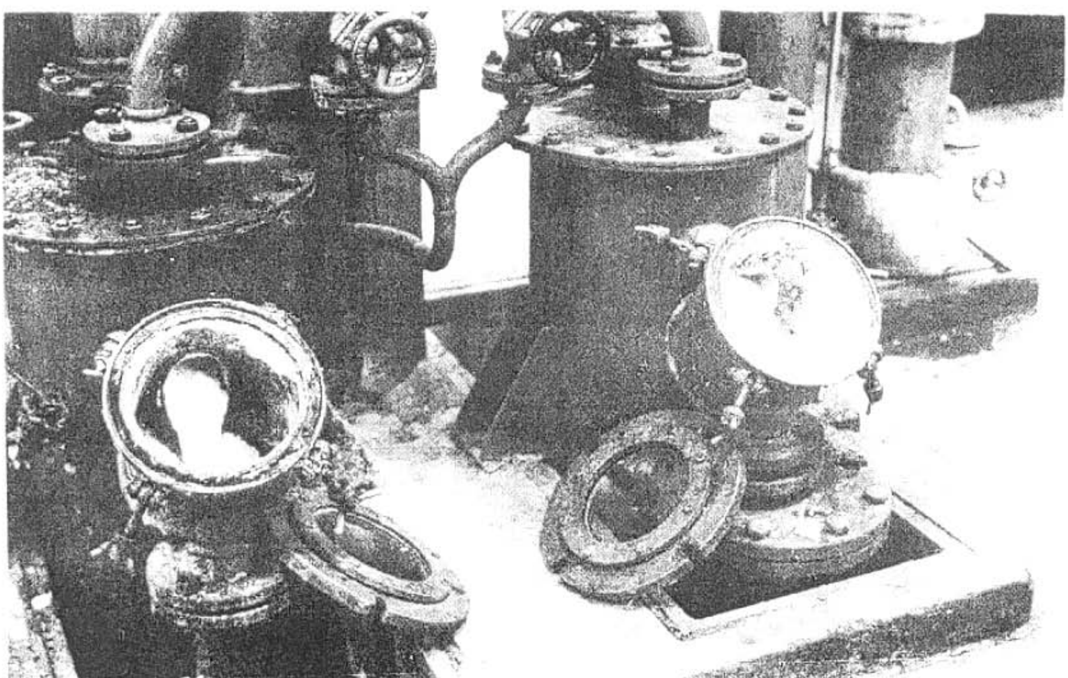
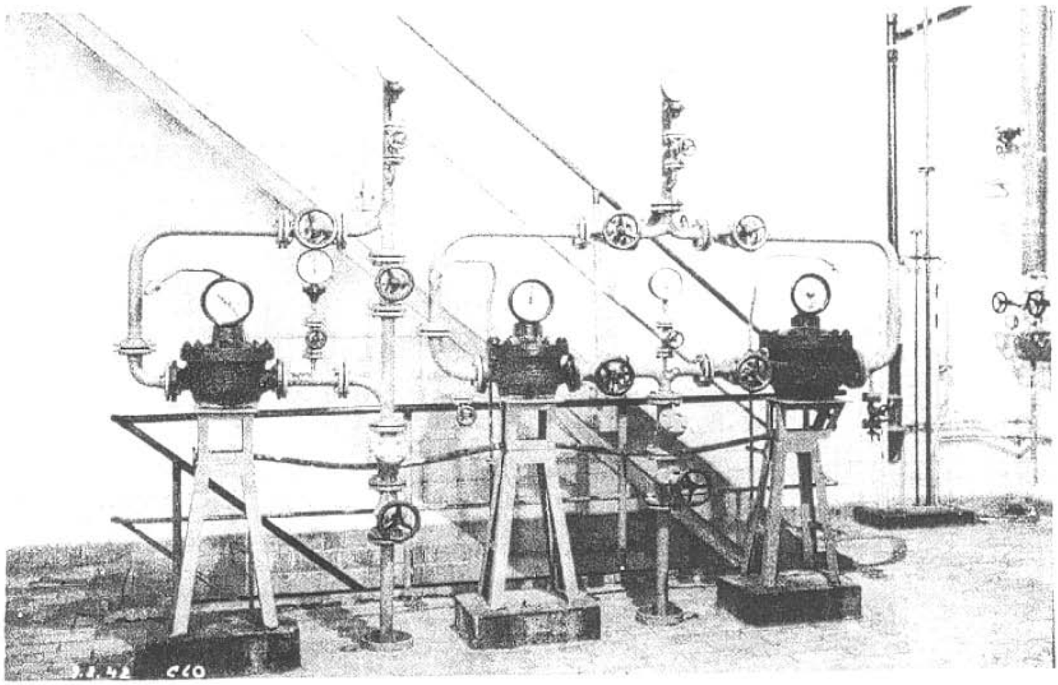


BUNA-S BLDG C-60 LATEX TO STORAGE AFTER STRIPPING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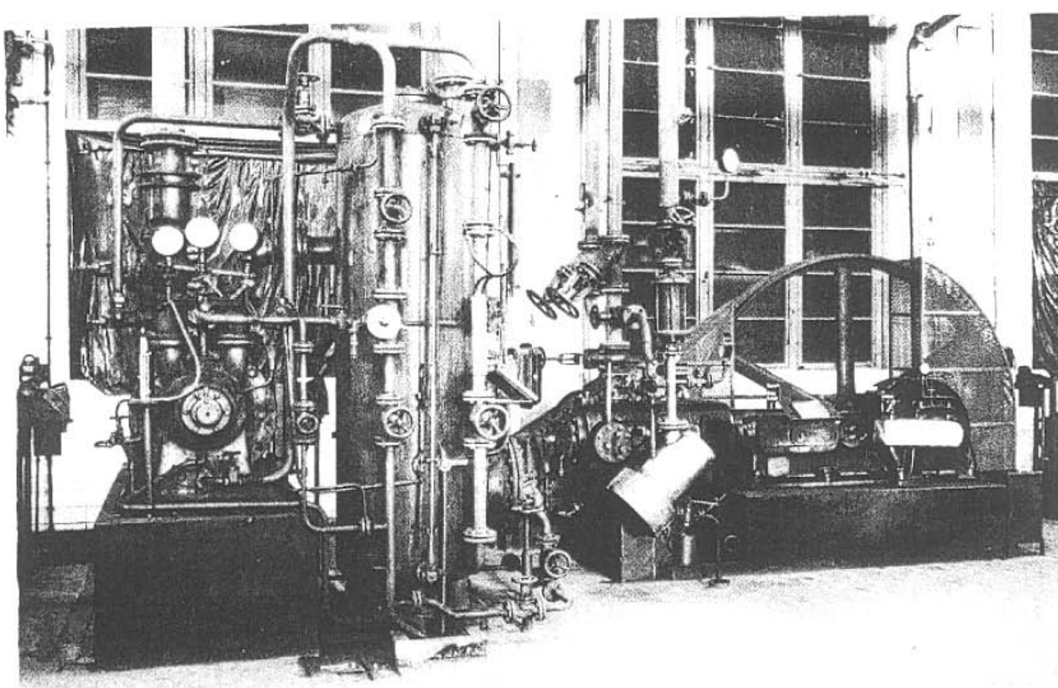
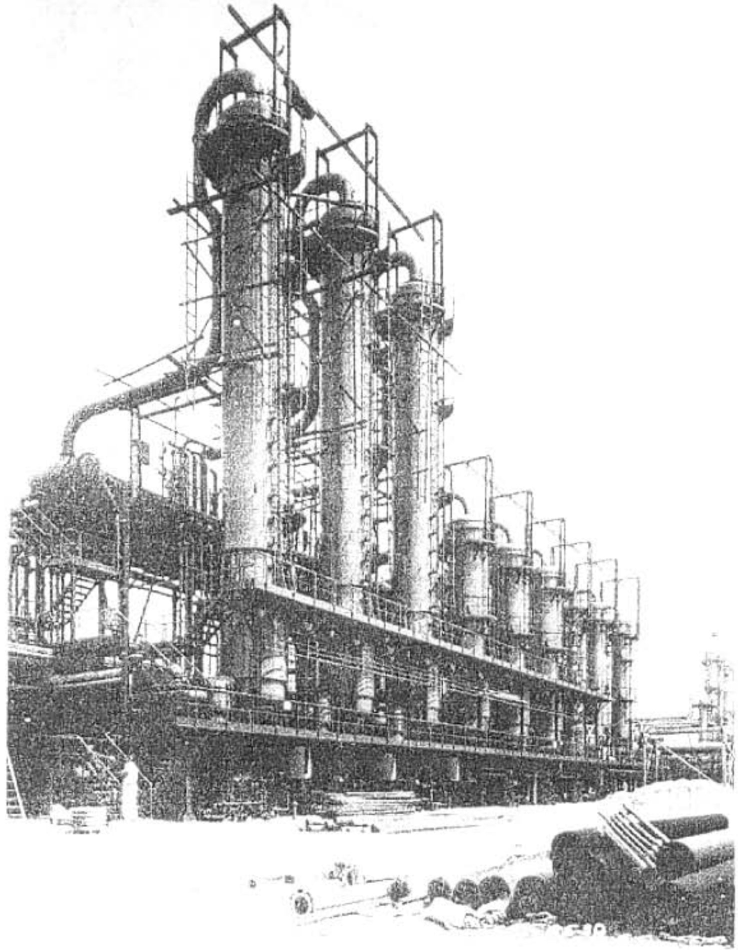
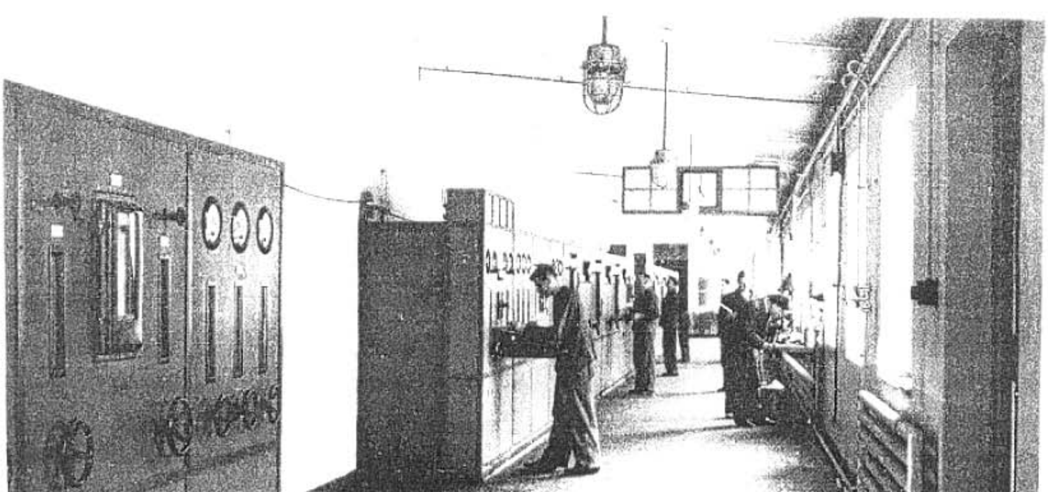
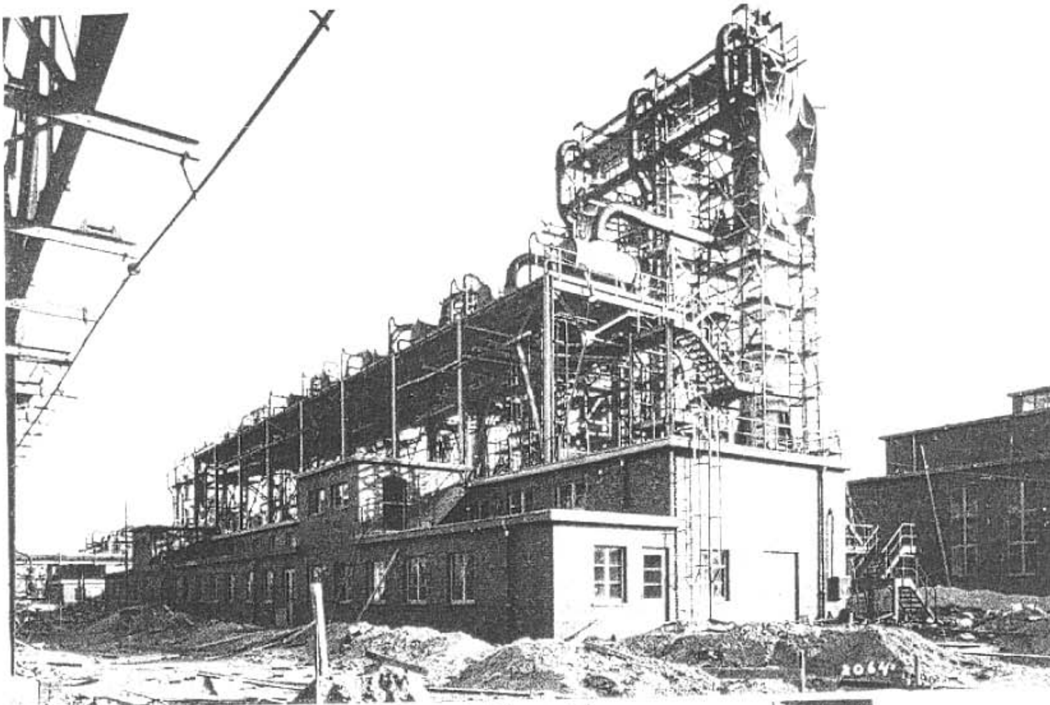




STYRENE DISTILLATION BLDG C-53

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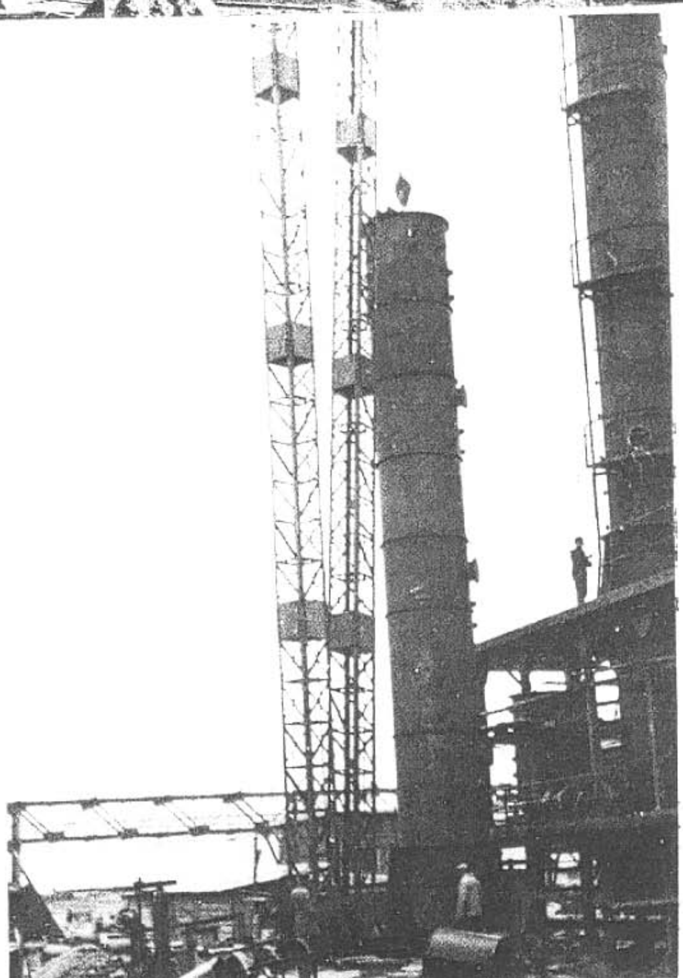
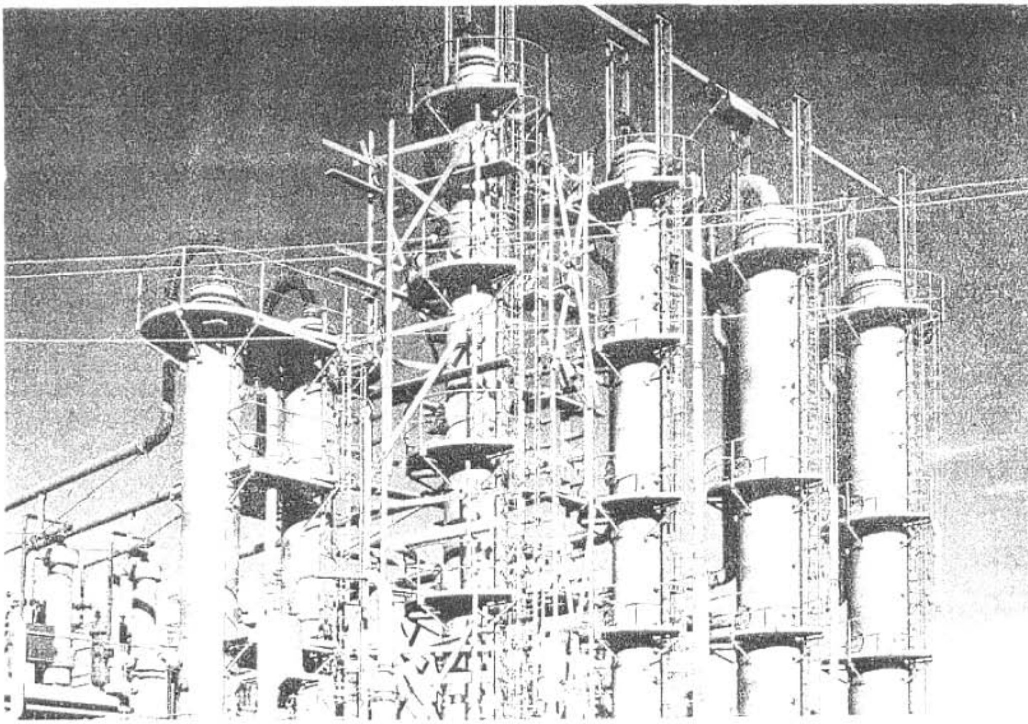
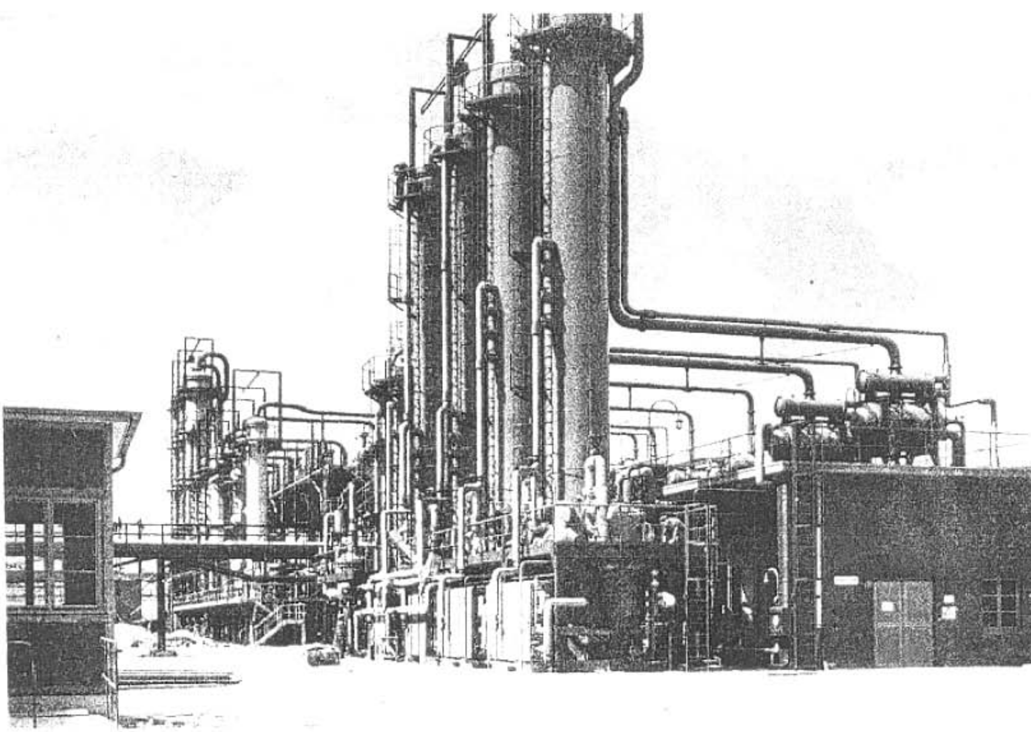
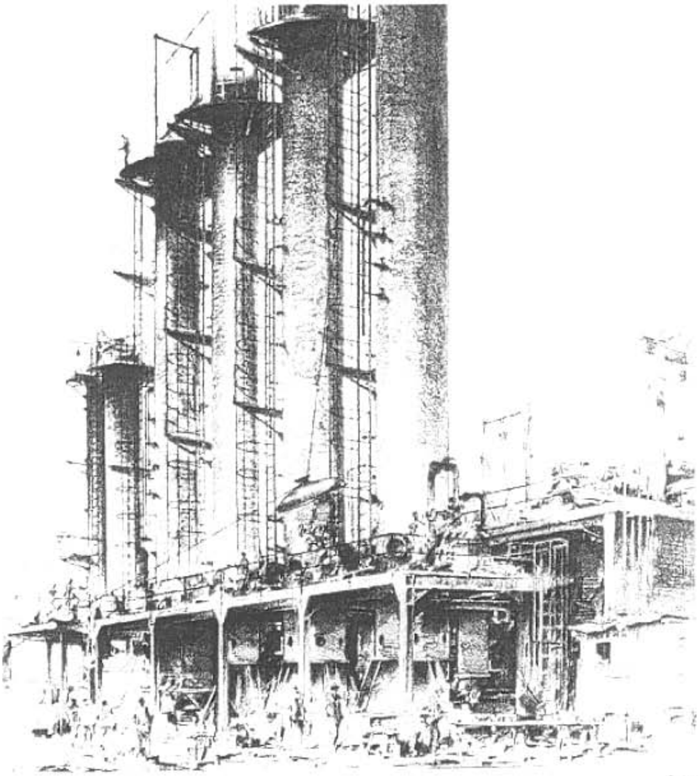
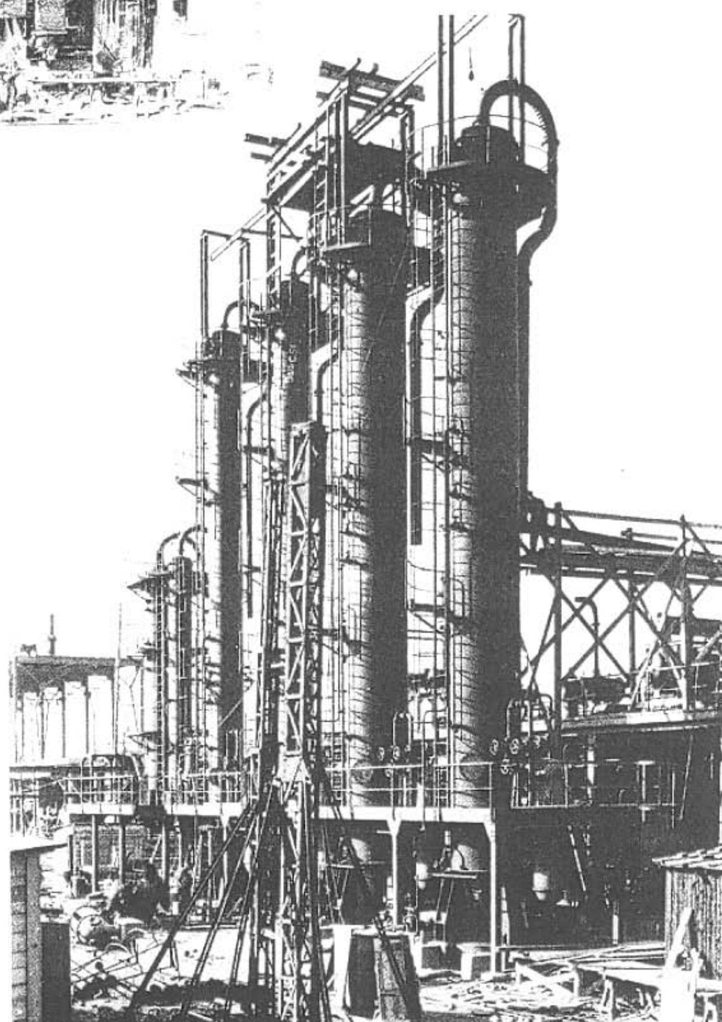


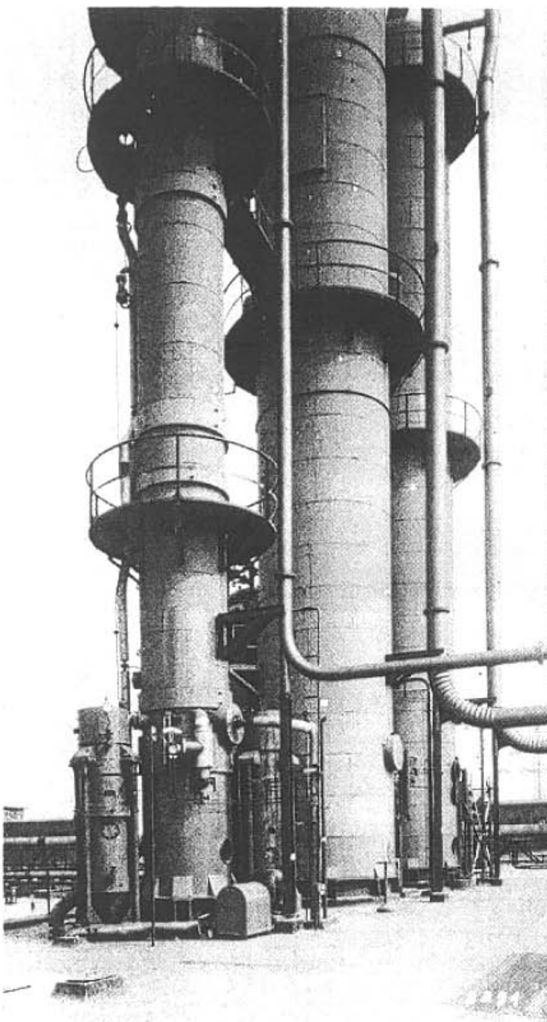
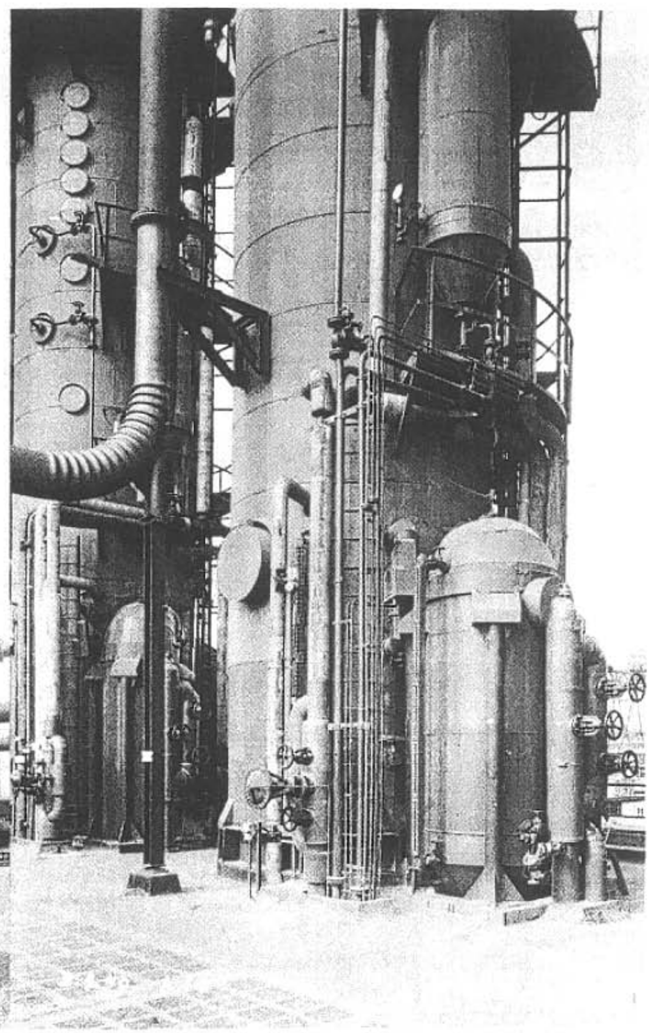


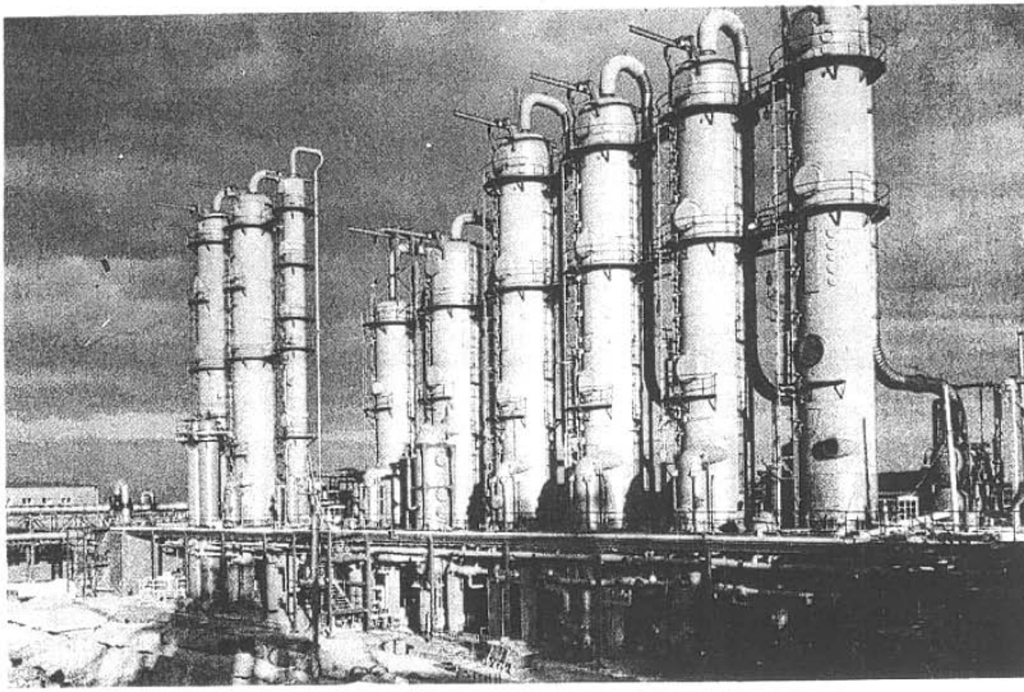
ETHYLBENZENE DISTILLATION BLDG C-51

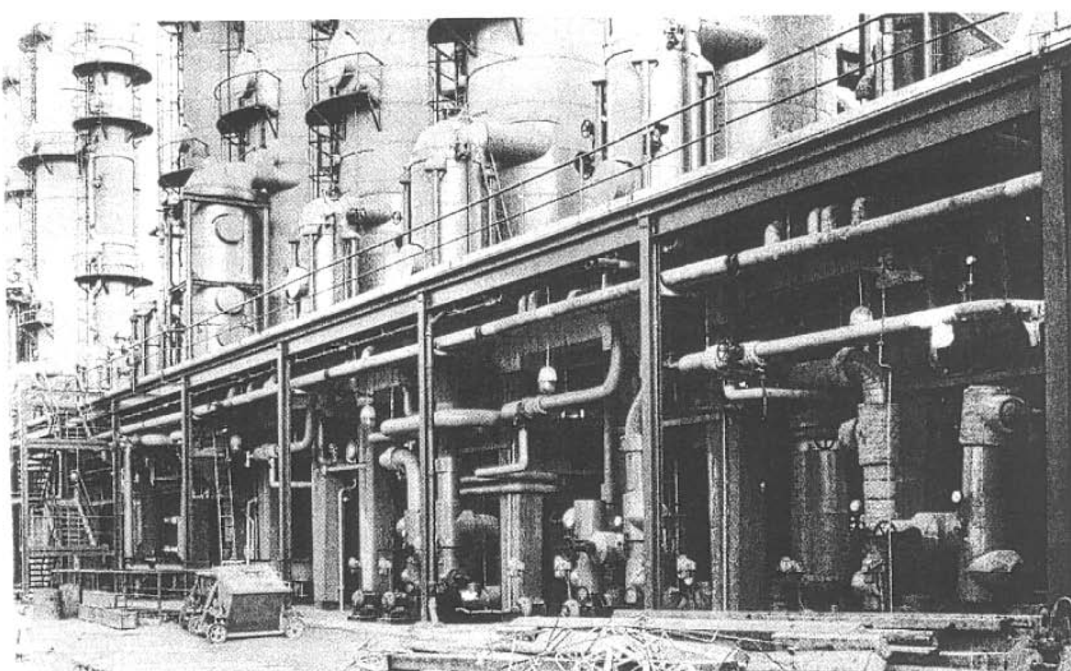


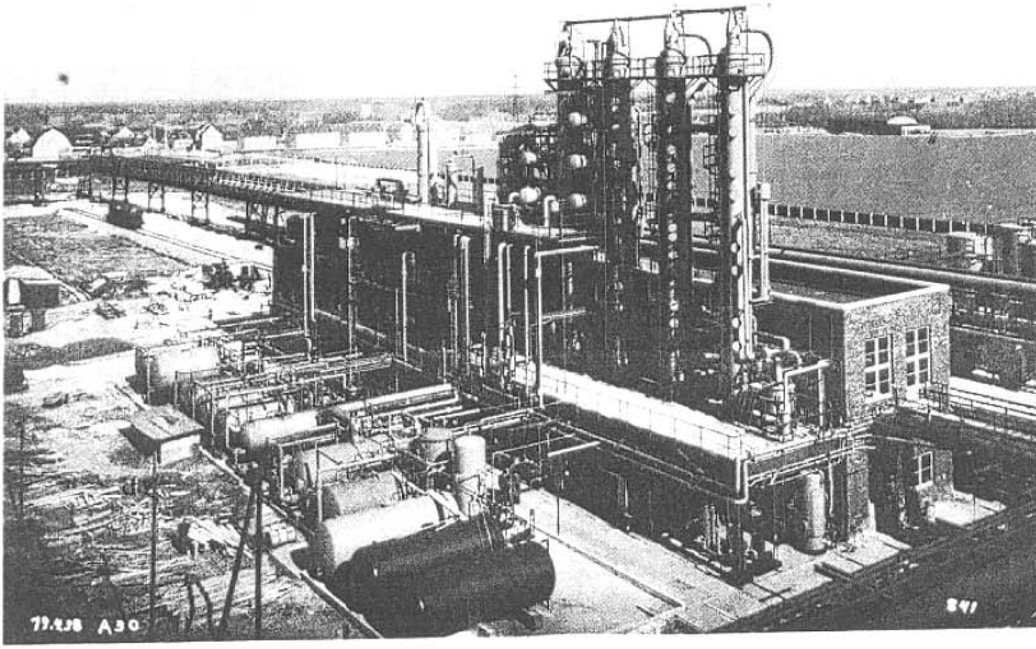




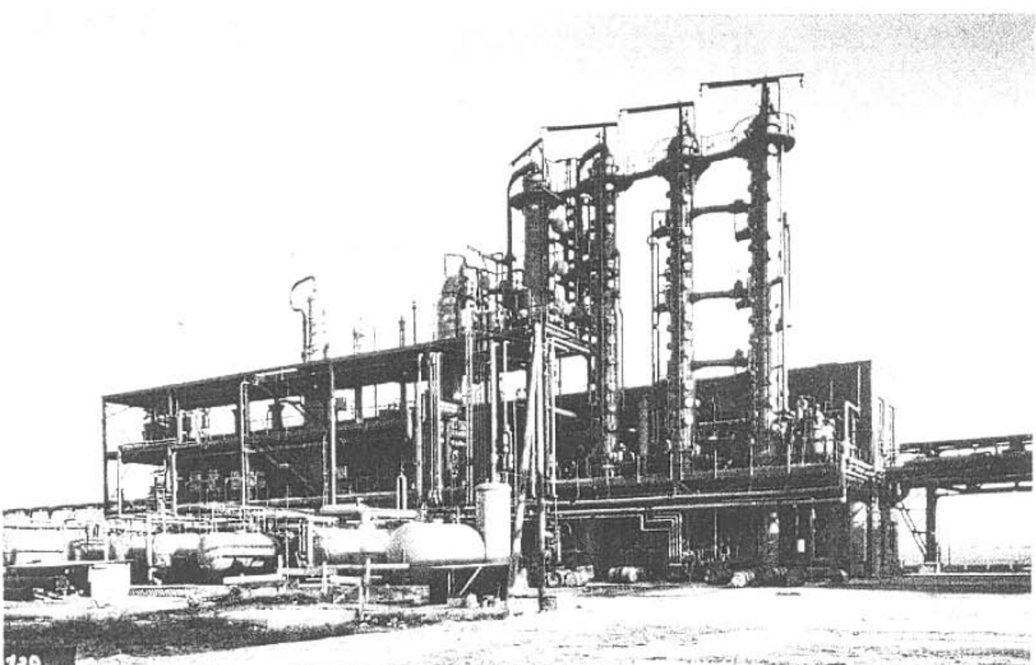



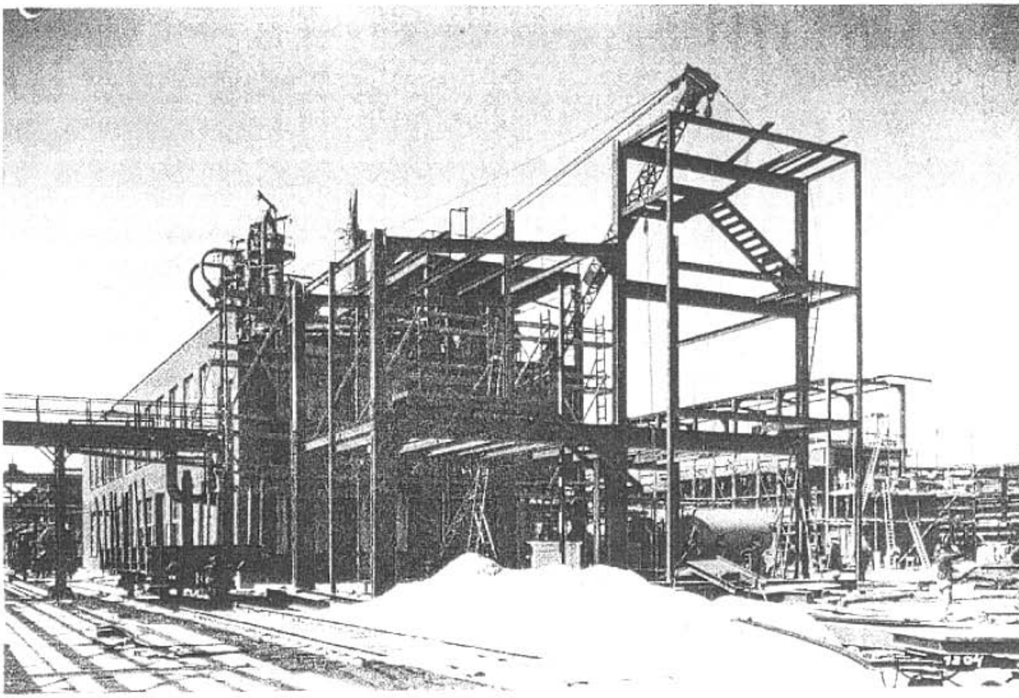


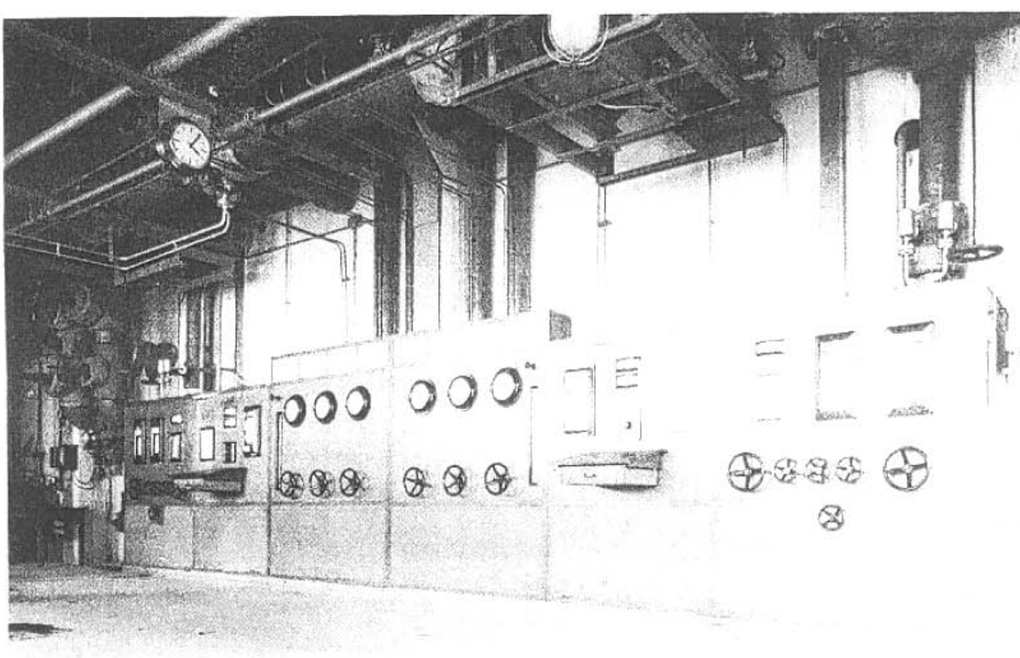


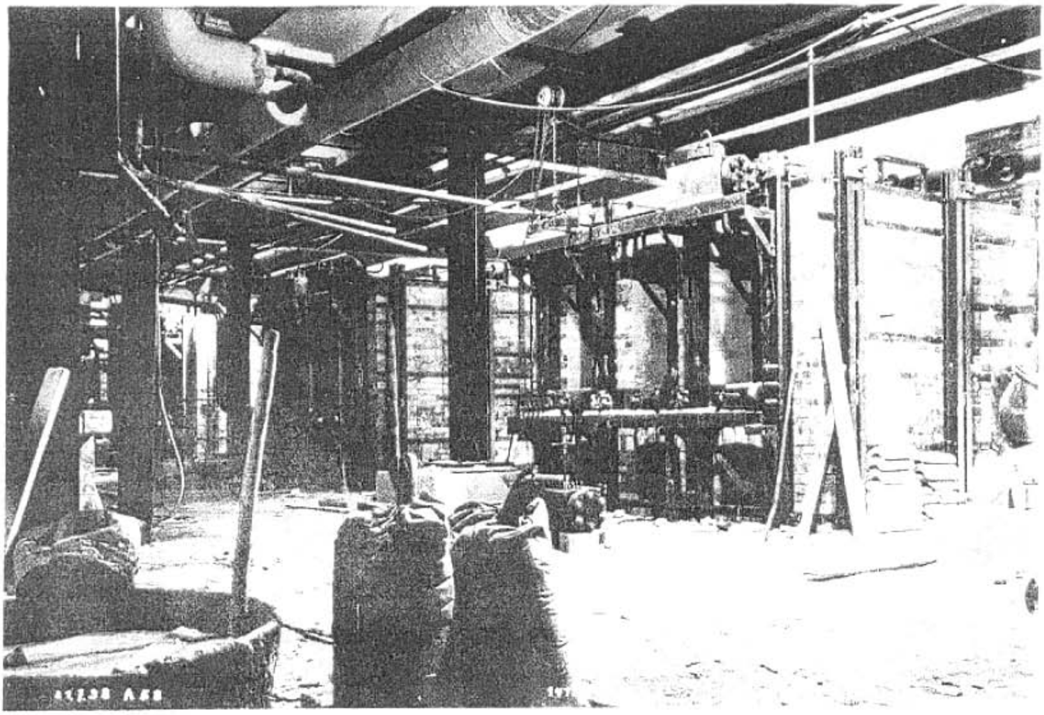


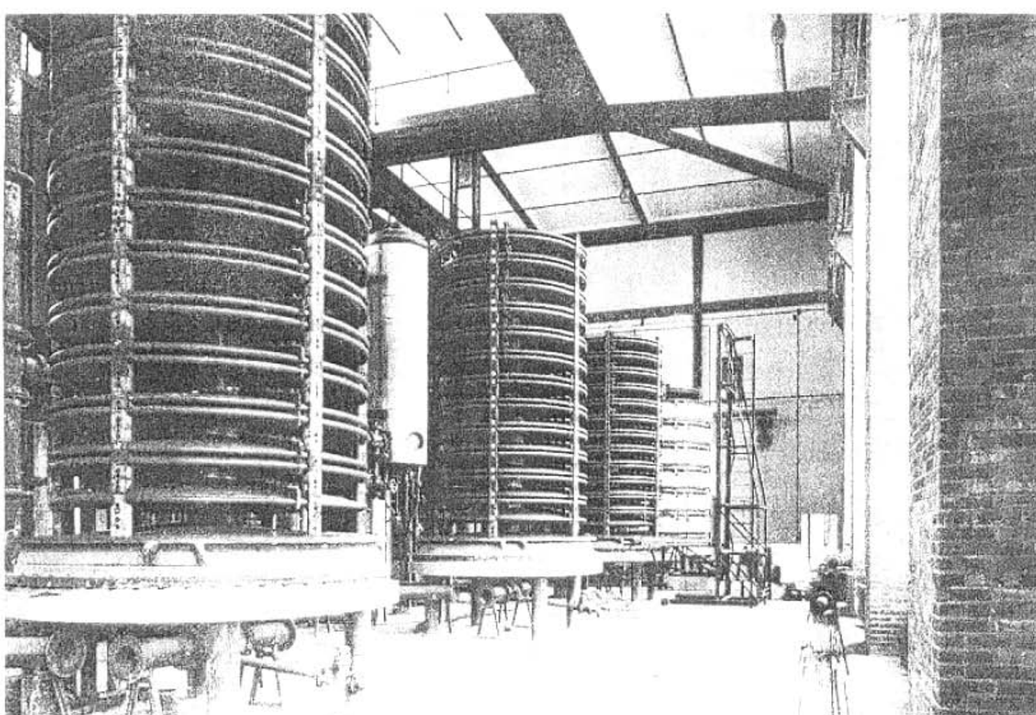
ALDOL DISTILLATION BLDG A-30

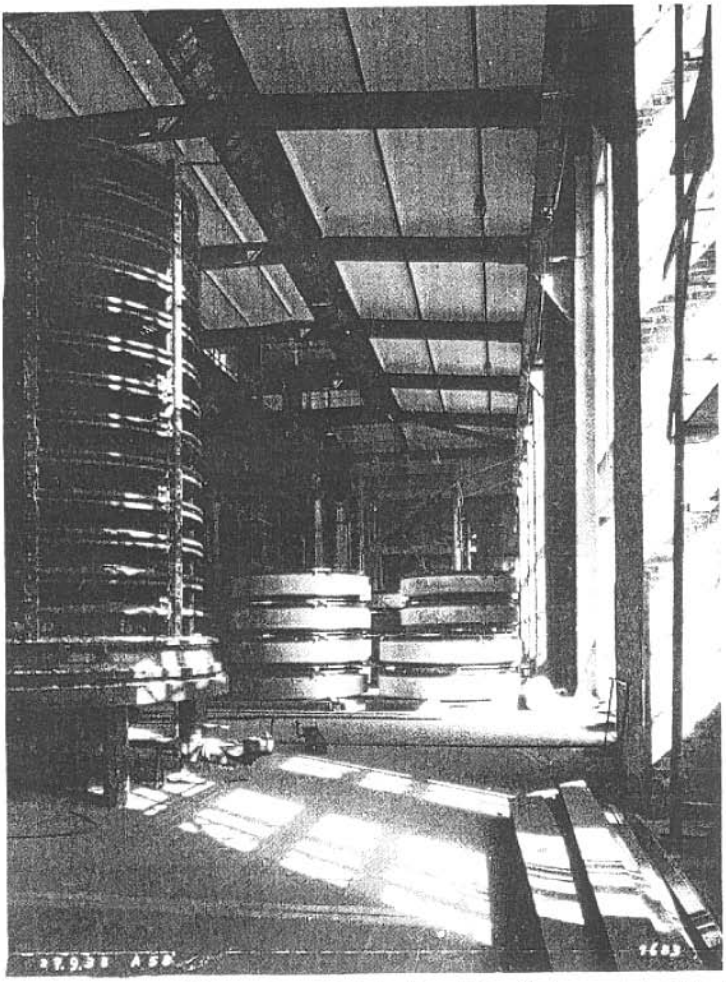




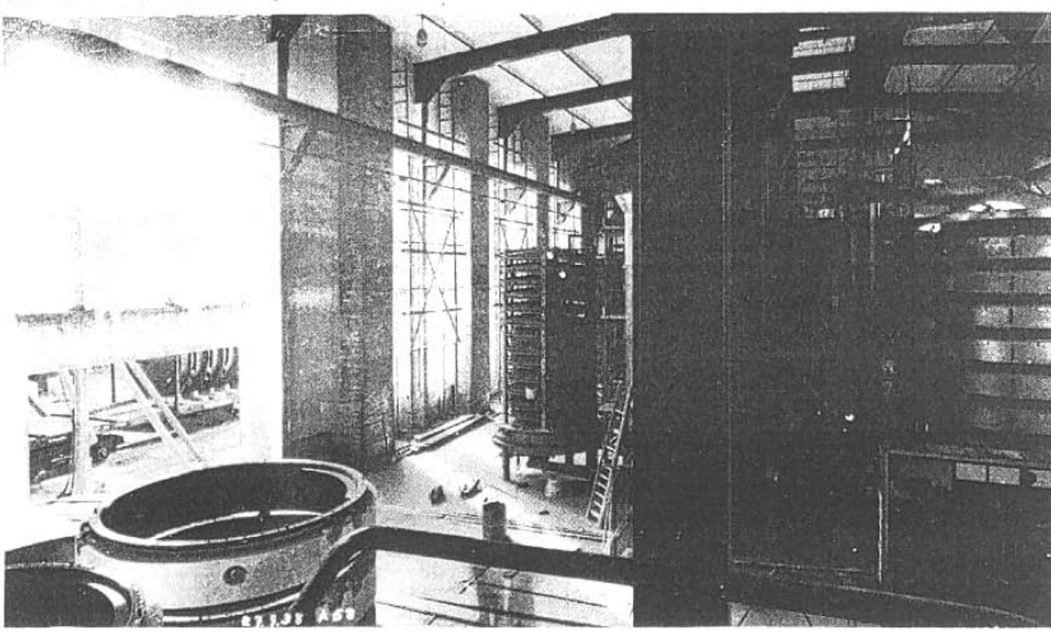


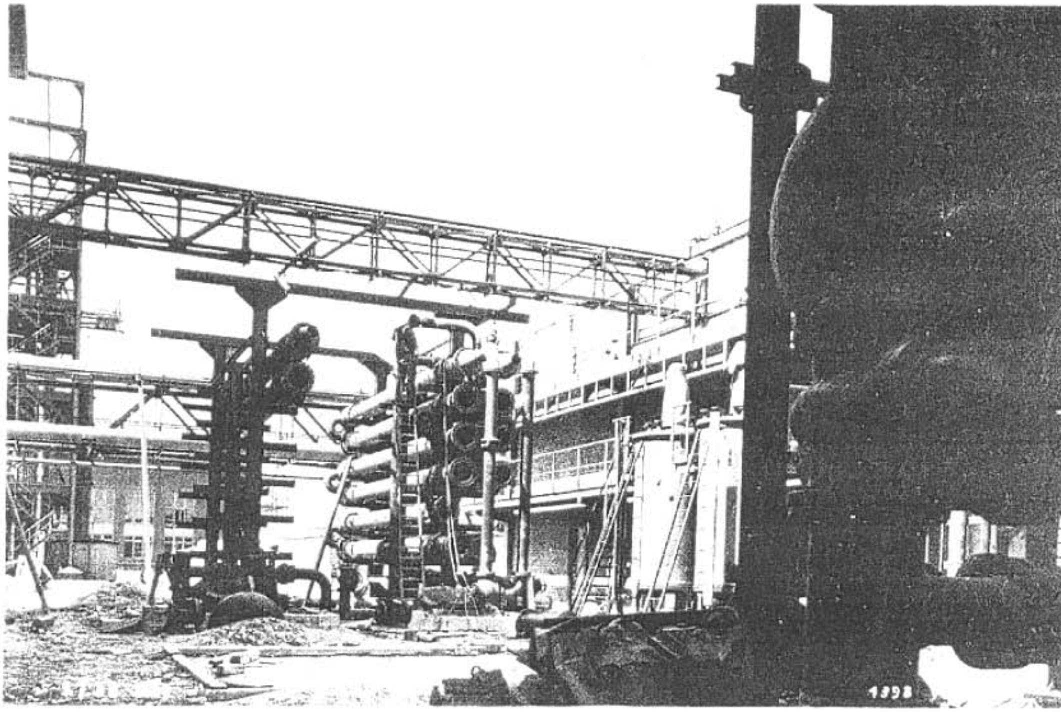


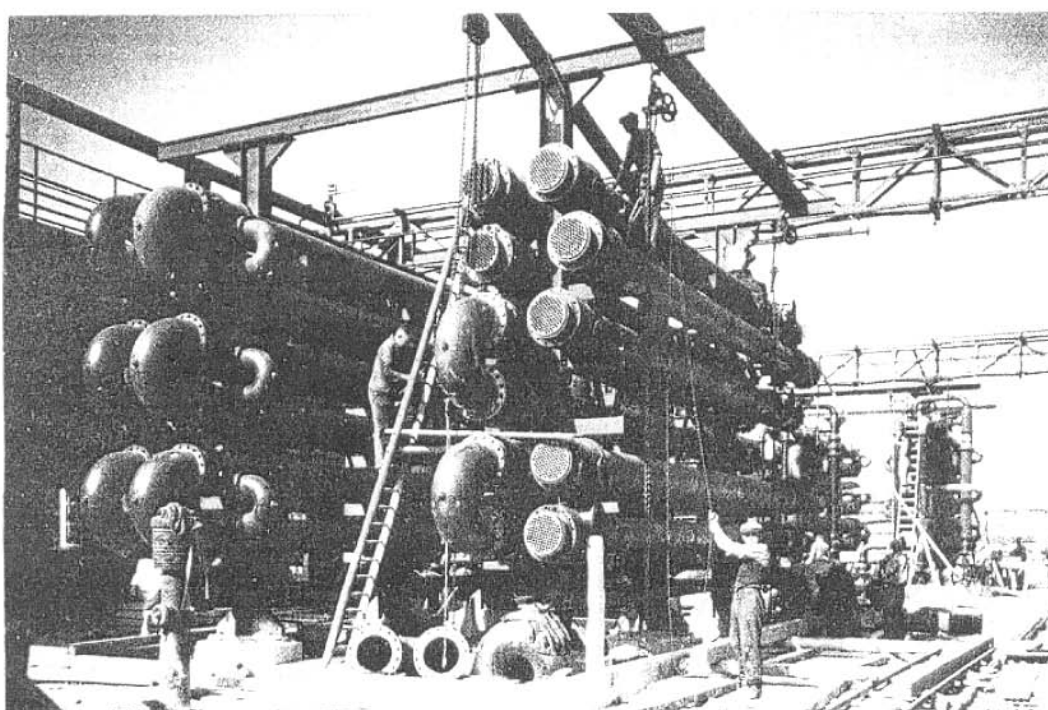


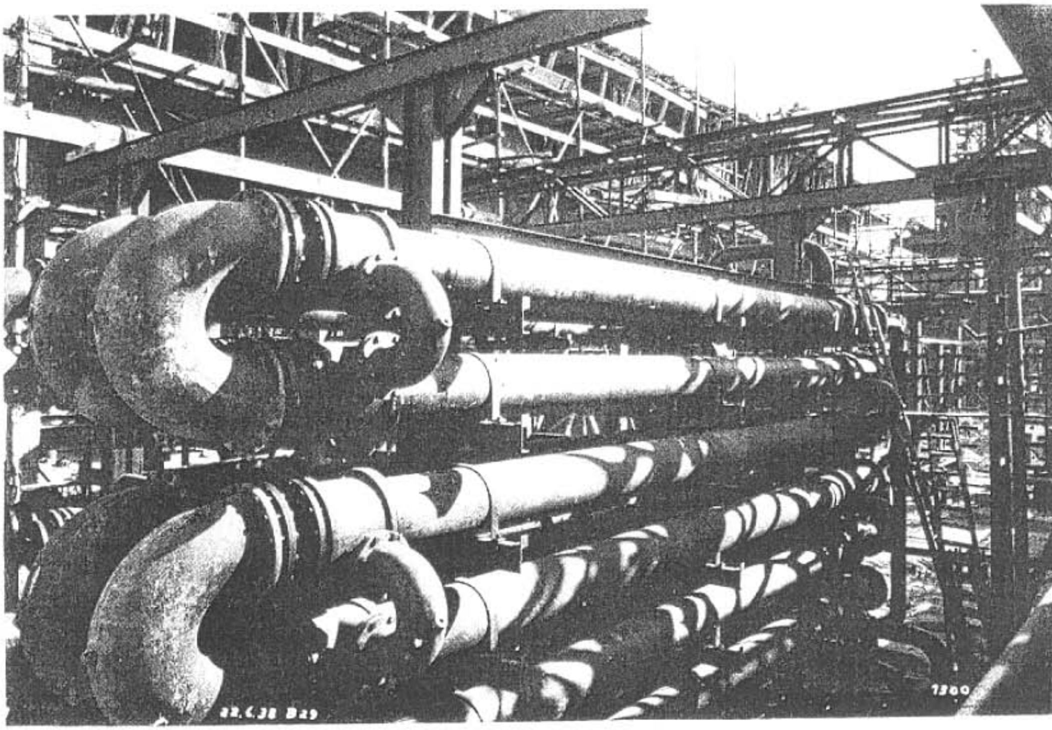


REACTORS FOR BUTADIENE MANUFACTURE
BLDG A-58 (DEHYDRATION OF BUTYLENE CYCOL

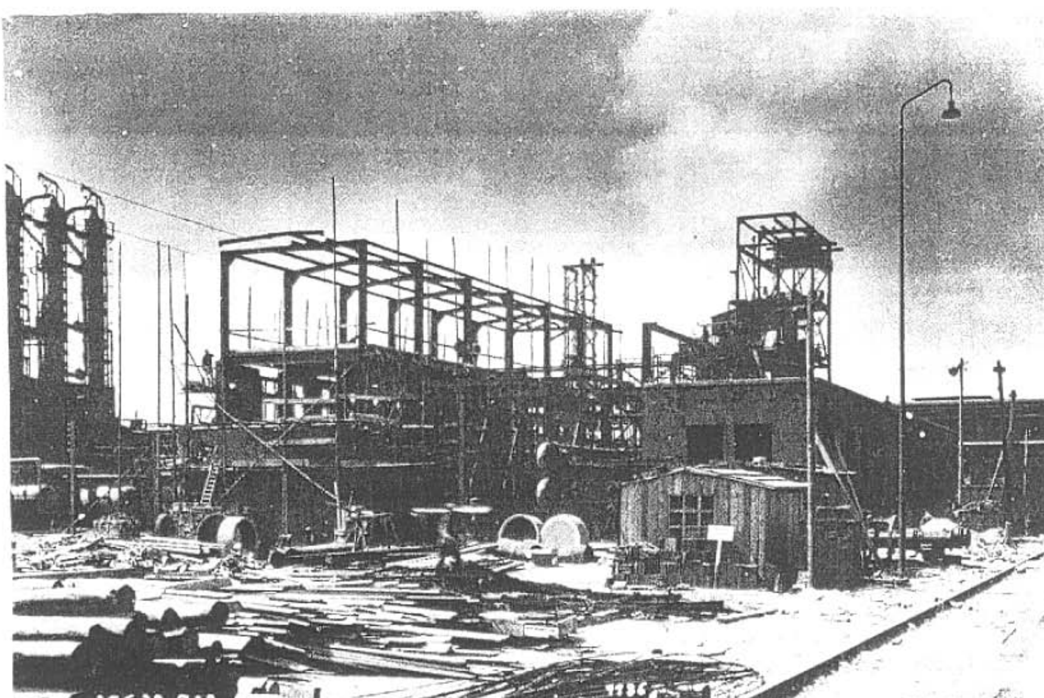


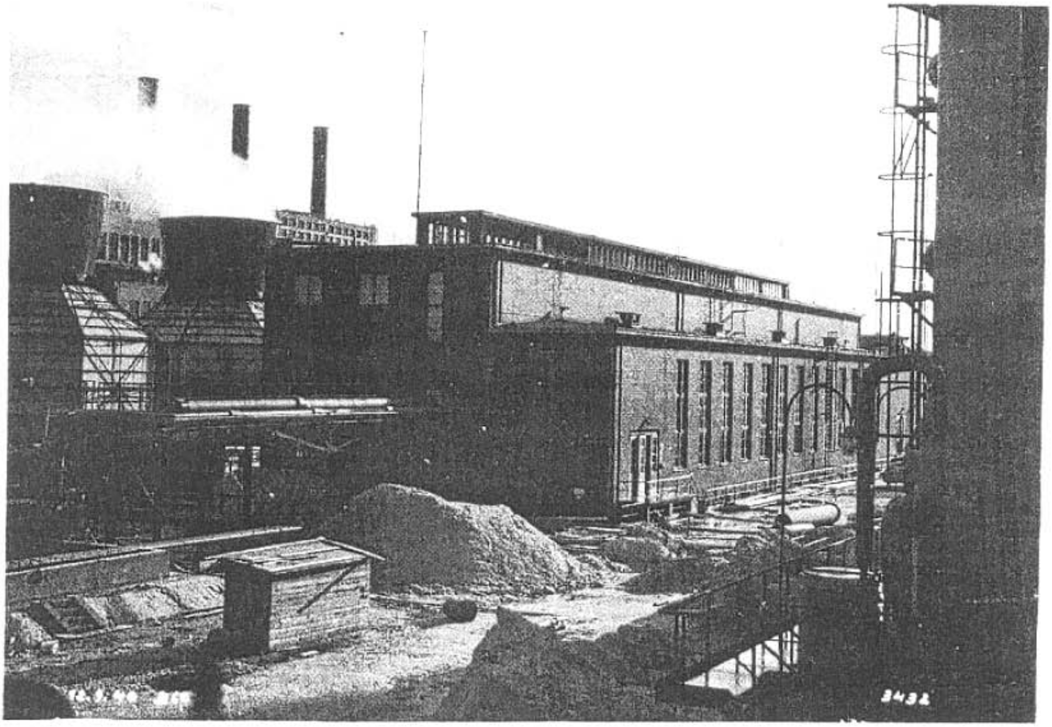


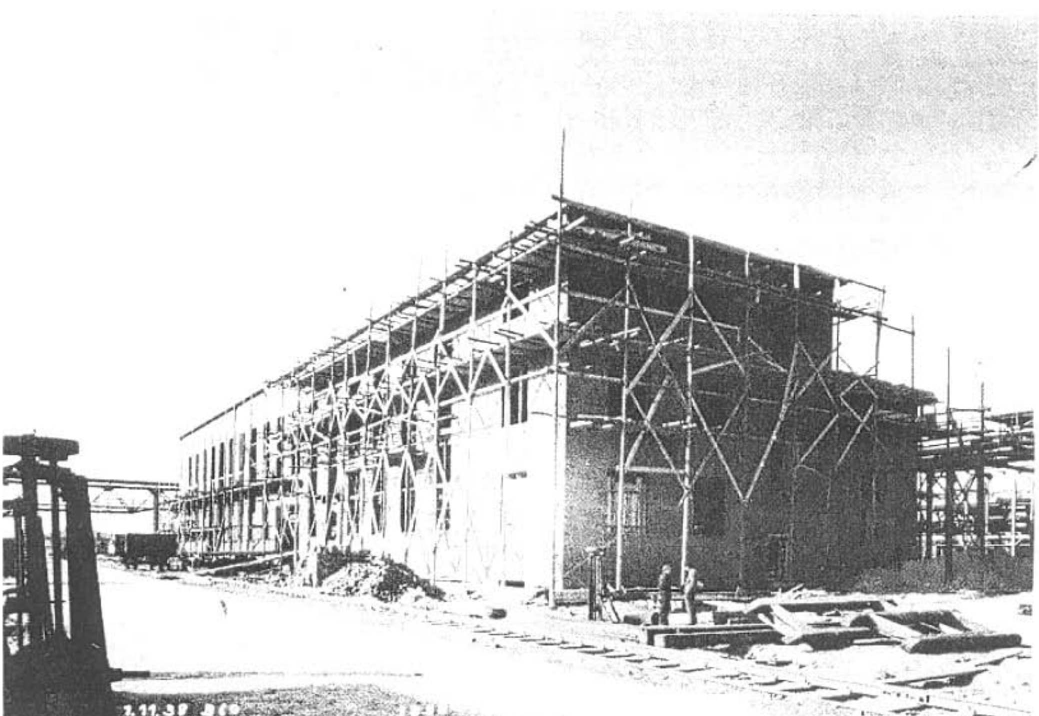


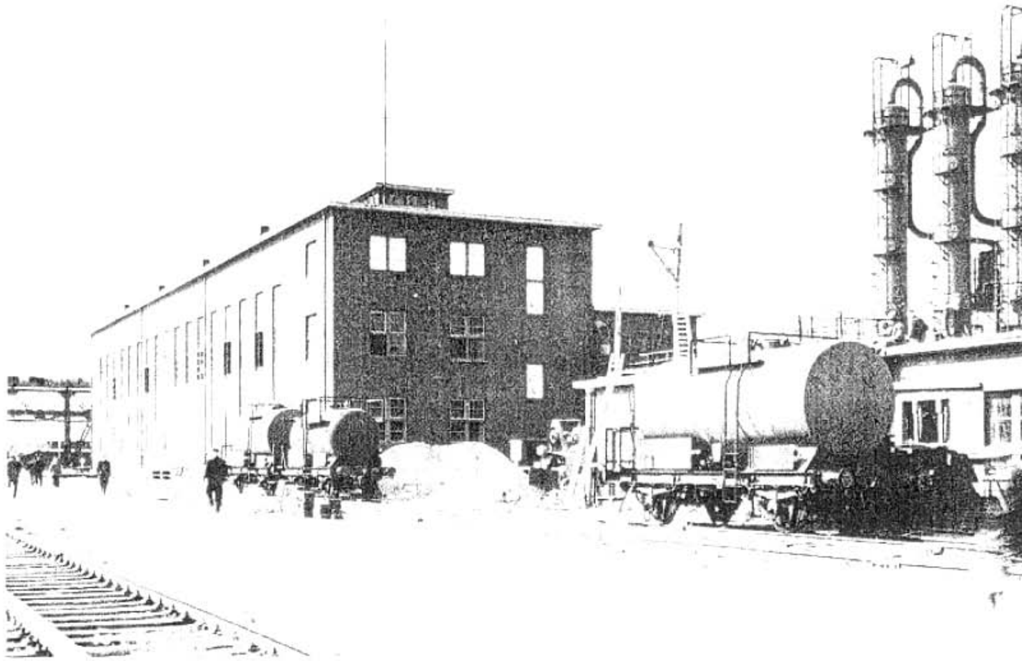


ALDOL MANUFACTURE BLDG B-29

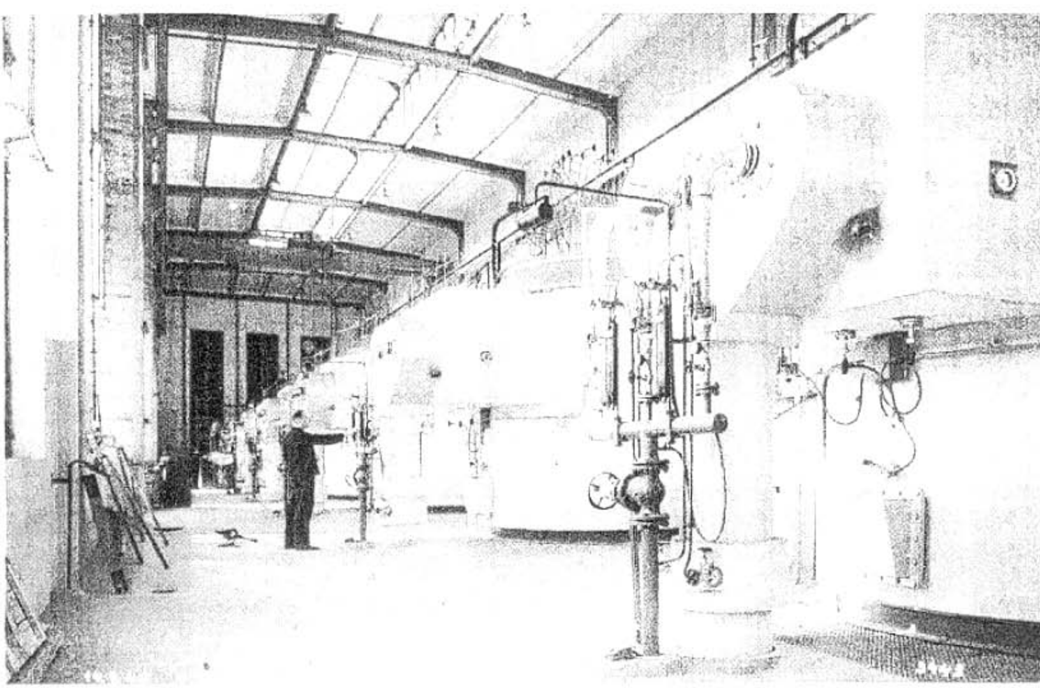


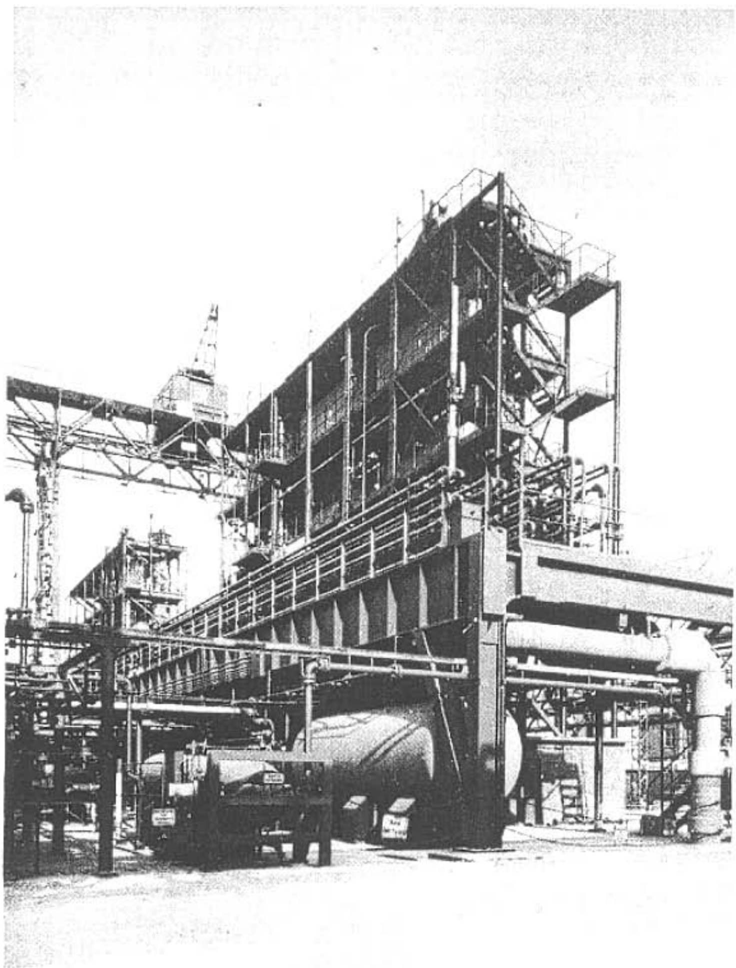

3432

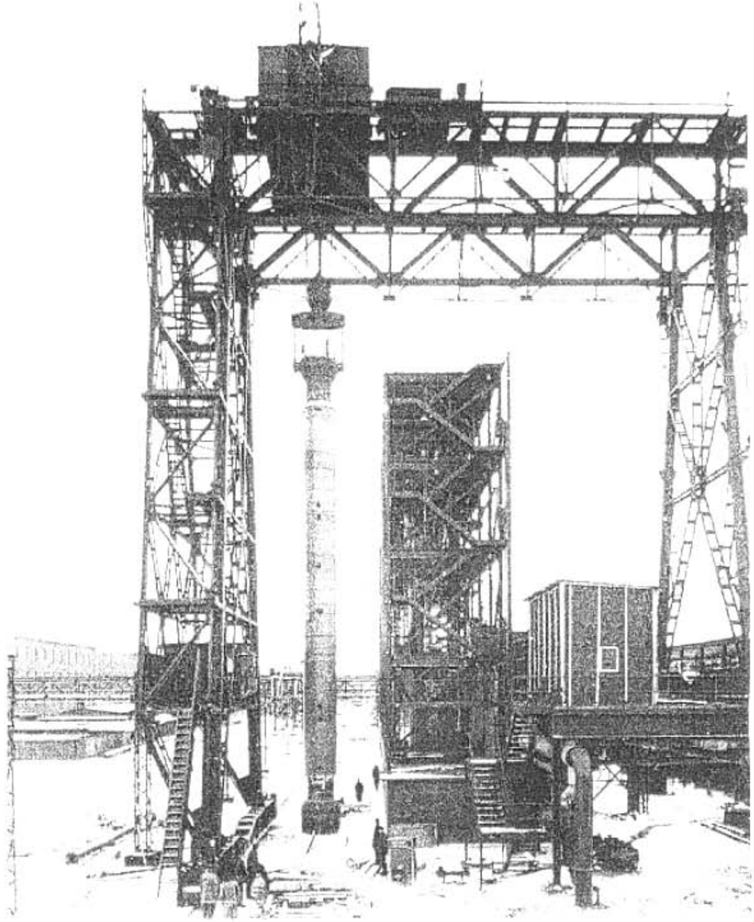




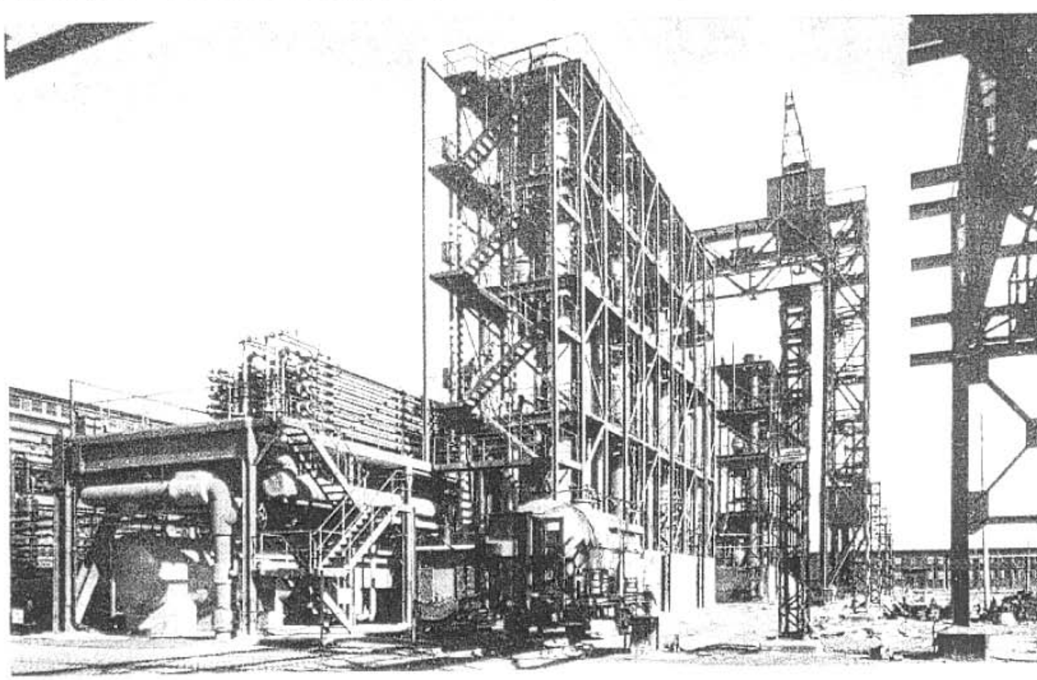
STYRENE REACTORS BLDG B-60

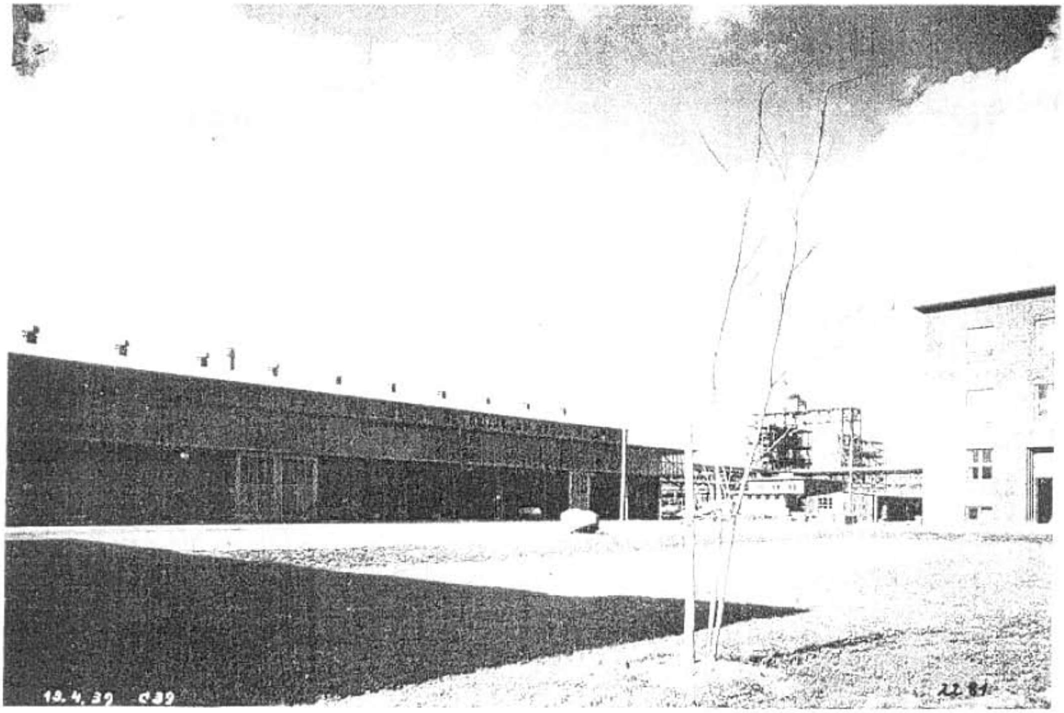






ALDOL HYDROGENATION TO BUTYLENE GLYCO





ALDOL HYDROGENATION TO BUTYLENE GLYCOL BLDG C 50