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[illegible] the [illegible] Industries in [illegible]

[illegible], 21 - [illegible] 1969

PET.SYMP. B/4

MA[illegible]ICAL MODELLI[illegible] IN T[illegible] DEV[illegible]OPMENT

OF PETROCH[illegible]1/

by

[illegible]. Fr[illegible]isch
[illegible] Chemical Works
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1/ [illegible] expressed in this paper are those of the author [illegible] the views of the secretariat of UNIDO. [illegible] reproduced without formal editing.

[illegible]

Petrochemistry is today characterised by the steady increase of the unit capacities of the producing plants. The second characteristic feature is the complex utilization of the by-products. Since these two factors affect favourably the production costs, we may draw the conclusion that the construction of a modern petrochemical industry necessitates large capital investments. It is necessary of course to have sufficient market needs for selling products produced in such quantities. The demand on the market depends upon

- the degree of industrial development of the country,
- the use of chemicals by industry and agriculture,
- the population of the country.

Since the developing countries in some cases have not sufficient capital at their disposal, neither do the market needs justify the construction of big capacities, it becomes increasingly difficult to start a reasonably sized and viable petrochemical industry. It is therefore necessary - when making plans for the development of the petrochemical industry - to consider the possibilities of cooperation between the various production facilities planned in the country and to go further and explore cooperation between plants situated in neighbouring countries.

One of the aims of this lecture is to outline some mathematical models, suitable for assessing the economic effect of petrochemical cooperation.

From the technical - economical point of view - cooperation may be realised at various levels. If each of the companies A, B and C /which may be situated in the same country or in neighbouring countries/ are considering the construction of a petrochemical complex having a specified assortment of products, then the cooperation may be effected on three levels.

1/ The cooperation affects the production of olefines, thus allowing a big capacity naphtha cracker to be constructed. The olefins are transported to the companies A, B and C, but the assortment of products remains unchanged.

2/ The cooperation affects the assortment of products too, with the aim that each product should be produced only on one site, thus ensuring the construction of bigger - capacity units.

United Nations Industrial Development Organization

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ID/WG.34/19 SUMMARY
23 July 1969

ORIGINAL: ENGLISH

Interregional Petrochemical Symposium on the Development of the Petrochemical Industries in Developing Countries

PET.SYMP. B/4

Baku, USSR, 20 - 31 October 1969

SUMMARY

MATHEMATICAL MODELLING OF THE DEVELOPMENT OF PETROCHEMISTRY 1/

by

M. Proisich
United Hungarian Chemical Works
Budapest, Hungary

Petrochemistry in the industrially developed countries is characterised by the steep increase of the unit capacity of the producing equipment. This is due partly to the marked growth of the needs in petrochemical products, partly to the aim at lowering the production costs.

The developing countries on the other hand generally do not have either sufficient market needs, nor in some cases enough capital to construct such petrochemical complexes, which approach the capacities nowadays built and which therefore prove to be competitive in the perspective. When formulating the development conception of a petrochemical industry giving favourable economic results it is advisable to

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id.69-3826

reveal the possibilities of co-operation between the various production facilities planned in the country and to assess their economic effect. This survey may be extended in some cases to cooperation between plants situated in neighbouring countries.

The lecture introduces three models, suitable to solve tasks of this type.

The first model answers the following question. Which is the economically sounder solution,

- to construct simultaneously on different sites naphtha crackers having relatively small capacities, or
- to construct a single high-capacity one-stream naphtha cracker and to supply the olefines to the consumers by pipe-line or by other means.

The model provides information about the optimum size of the central naphtha cracker.

The second model selects the optimum combination of petrochemical activities leading to achieve the optimum rate of return of the investment. For this purpose the market needs have to be revealed. The available investment sum determines - as the upper limit - the solution of the task. The model is based on linear programming.

The third model investigates the specialization of the production inside the country or between neighbouring countries, with the purpose of obtaining high-capacity plants and to lower hereby the production costs. The economic optimum is reached, when the sum of the production costs of the plants figuring simultaneously in the model, attains minimum value. The model is based on integer programming.

The examples discussed in the lecture support the importance of adopting mathematical methods for the elaboration of conceptions for the development of the industry.

[illegible]

[illegible]

[illegible] individual [illegible]

[illegible] curves [illegible]

Con[illegible], [illegible] to Fig. [illegible] consumption [illegible]

[illegible] of the [illegible] economic[illegible] individual [illegible] local [illegible]

[illegible] economic [illegible] individ[illegible] which curve [illegible] For th[illegible] [illegible]

This [illegible] calculation of the [illegible] production [illegible] for [illegible] investment [illegible] of [illegible] 000, [illegible] tion cost of [illegible] is equal.

[illegible] size [illegible] cracking [illegible] site we [illegible] sum of all [illegible] value.

The transport [illegible] calculation of the [illegible] transport cost [illegible]

$$T = d_1 . S_1$$ where

$$d_1 = 1{,}1 . \sqrt{/x-x_1/^2 + /y-y_1/^2}$$ The multiplier 1,1

takes into account the deviation of pipelines, roads etc. from the straight connection, it can be changed according to local conditions.

The unit transport cost is computed by a subroutine for each of the necessary pipelines and for tank-car transport /propylene/.

The sum of transport costs is expressed by the following equation:

$$T = \sum_{1=1}^{i+j+p} S_1 . d_1$$

where i - number of naphtha producers,

j - number of ethylene consumers,

p - number of propylene consumers.

To find the minimum value of the function T, i.e. to find the lowest point of this potential surface it is necessary to differentiate partially with respect to x and y and to search those values of x and y, where the differential is equal to zero:

$$\frac{\partial T}{\partial x} = \sum_{e=1}^{i+j+p} S_e \frac{\partial d_e}{\partial x} = \sum_{e=1}^{i+j+p} \frac{S_e(x - x_e)}{d_e} = 0$$

$$\frac{\partial T}{\partial y} = \sum_{e=1}^{i+j+p} S_e \frac{\partial d_e}{\partial y} = \sum_{e=1}^{i+j+p} \frac{S_e(y - y_e)}{d_e} = 0$$

[illegible]

[illegible]

[illegible]

	[illegible]	[illegible]
Tot[illegible]	[illegible]	[illegible]
Cro[illegible]	-	[illegible]
Unit [illegible] and [illegible]	-	[illegible]
Unit [illegible] on sit[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Unit cost [illegible] on site [illegible]	[illegible]	[illegible]
Unit cost price of [illegible] on site [illegible]	[illegible]	[illegible]
Unit cost price of [illegible] on site [illegible]	58,[illegible]	[illegible]
Unit cost [illegible] of [illegible] on site [illegible]	56,0	[illegible]
Total produc[illegible], million [illegible]	[illegible]	[illegible]

[illegible] 1 - continued

[illegible]		
[illegible]	-	2,55
Investment [illegible]		
[illegible]	-	6,0

[illegible] example presented about 1[illegible] % of the investment [illegible] production costs may be saved.

[illegible] of utilities on site [illegible] are equal to those [illegible] may not be correct, since the site X defined [illegible] may be unsuitable for the location of industry. [illegible] of the deviation from the optimal coordinates [illegible] moved the plant X on a circle /radius [illegible] km/ and [illegible] production cost on four sites. The values [illegible]. Thereupon we concluded, that the system [illegible] on an area of ~ 3000 km^2 a suitable [illegible]

[illegible] of cooperation cannot be determined [illegible], that the crucial consumer is [illegible] its distance relative to the smaller [illegible], [illegible] which co-operative activities may take place.

Case 2

If we assume [illegible] market for the total quantity of the products figuring in the [illegible] of the companies A, B and C, then further savings in investment cost and production costs are possible by specializing the production. Specialization is only possible if the envisaged production programs of the companies considered [illegible] cooperation contain identical products.

To introduce [illegible] model which may be used in such circumstances, let us start from the following suppositions:

- two companies [illegible] and [illegible] are considering the specialization of their production,
- both companies [illegible] the production of two ethylene - derivates [illegible]$_1$ and [illegible]$_2$/ and two propylene - derivates /P_1 and P_2,

[illegible]

- [illegible]
- [illegible]

but [illegible] difl [illegible] prod [illegible]

[illegible]

[illegible]

into [illegible] sit [illegible]
- [illegible] or [illegible] only [illegible]

[illegible]

[illegible] comp [illegible]

[illegible]

[illegible] to reach significant

[illegible] r 20 [illegible].

[illegible] connected

[illegible] cooper-

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Table 2

Region	[illegible]					[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]1	10,0	[illegible]	[illegible]	15,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]2	4,0	8,0	5,6	7,6	6,6	[illegible]	11,4	10,2
T1	5,0	[illegible]	6,0	[illegible]	10,6	[illegible]	13,[illegible]	11,0
T2	9,0	11,0	3,7	[illegible]	15,0	[illegible]	[illegible]	7,8
[illegible]	10,[illegible]	[illegible]	4,4	[illegible]	[illegible]	–	–	[illegible]
Total	20,0	33,[illegible]	27,[illegible]	10,[illegible]	14,[illegible]			

Table 3

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	1,[illegible]
[illegible]	1,[illegible]
[illegible] " B	0,00[illegible]0
[illegible] " "	0,[illegible]00
[illegible] " "	0,[illegible]00
[illegible] " "	0,[illegible]
[illegible] "	1,[illegible]00
[illegible] " "	1,[illegible]
[illegible] " "	0,00[illegible]
[illegible] " "	[illegible],0000[illegible]
Olefin plant, site [illegible]	1,00000
[illegible]	[illegible] mil. [illegible]/y
Investment [illegible]	74,[illegible] mill. [illegible]
Added for propylene transport facilities	1,0
Total investment	75,[illegible] mill.
Individual investment	[illegible]
Sum of individual production costs	68,3 mill. [illegible]/y

[illegible]

1. [illegible]

2. [illegible]

[illegible]

The next point I would like to [illegible] it affects the [illegible] starts [illegible] given [illegible] from [illegible], [illegible] or [illegible].

Although [illegible] may be impossible [illegible] research. [illegible] it is necessary to [illegible] very many [illegible].

[illegible] I would like to [illegible] handling of [illegible] solution of the sample example.

The company, which [illegible] has only [illegible] its disposal. [illegible] available. The market survey [illegible]

[illegible]

[illegible] produ-

[illegible] (ration [illegible]

[illegible] of [illegible] survey [illegible]

[illegible] for [illegible] study,

[illegible] complet [illegible]

[illegible] to [illegible] by

[illegible] the [illegible] ty of

[illegible]

[illegible] that [illegible] change

[illegible] of this

[illegible] necessary to produce

[illegible] of mor [illegible]

[illegible]

[illegible]

[illegible]

[illegible] products, [illegible] of the product, [illegible]

[illegible]

This type of economic function [illegible] the investment. [illegible] economic [illegible] functions [illegible] had to be [illegible] construction of the model. [illegible] price-based calculations. [illegible] based our calculations [illegible] published in the literature. For the purpose of [illegible] ability of [illegible] cannot [illegible] tions have to be made for the purpose of preparing [illegible] reliable information will have to be collected.

3/ The value of the economic function of an olefine plant [illegible] is zero [illegible] production cost of [illegible] lower capacity [illegible] plant [illegible] unit [illegible] olefine plant for the [illegible] Therefore for the olefine plant [illegible] capacity [illegible] is above [illegible] unit production cost of the olefines decreases [illegible] tion in a [illegible] manner and the profitability of the [illegible] increases. For this reason column [illegible] is [illegible]

4/ The [illegible] of propylene has [illegible] according to [illegible] column [illegible]. The economic function has a negative [illegible] [illegible]

5/ Columns [illegible] - [illegible] confine the capacity of [illegible] 30 [illegible] - [illegible], since, according to our control calculations [illegible] small errors, if we assume linearity between these limits.

[illegible] 30 [illegible] should [illegible] selected, then /columns 20 –
[illegible] enough [illegible] ive val[illegible] comes
[illegible] of the economic func-
[illegible] location [illegible] capacity under

[illegible] linear programming technique
[illegible]

[illegible] computation of each alternative on our
[illegible] 11 – [illegible] iterations [illegible] necessary and
[illegible].

[illegible]
[illegible] different conditional

[illegible]. We showed only the sal
[illegible] that th[illegible] obtained by
[illegible] plant [illegible] capacity
[illegible] of propylene, since the
[illegible]
[illegible], it has been compared exactly
[illegible] Fig. 4. [illegible] of the system does not
[illegible] mentally, without
[illegible]

[illegible] solution demonstrates, that
[illegible] for chemical par-
[illegible] increasing the profitability of
[illegible].

Ethylene	t/y	[illegible]	[illegible]	[illegible]
Polyethylene [illegible]	"	[illegible]	[illegible]	[illegible]
Polyethylene [illegible]	"	[illegible]	[illegible]	[illegible]
Ethanol	"	[illegible]	[illegible]	[illegible]
Ethylene oxide	"	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]
Polypropylene	"	[illegible]	200[illegible]	
Phenol	"	[illegible]	30[illegible]	[illegible]
Propylene oxide	"	60[illegible]	[illegible]	[illegible]
Ethylene from propylene	"	-	32[illegible]	[illegible]
Investment	mill.	[illegible]	[illegible]	[illegible]
Objective function		[illegible]	22035	[illegible]
Average value of objective function, related to 1 ton product		0,[illegible]	[illegible]	[illegible]

[illegible] pyrolysis [illegible]

[illegible]

[illegible]

selected [illegible] some of the variables [illegible] programming [illegible] used.

Conclusions

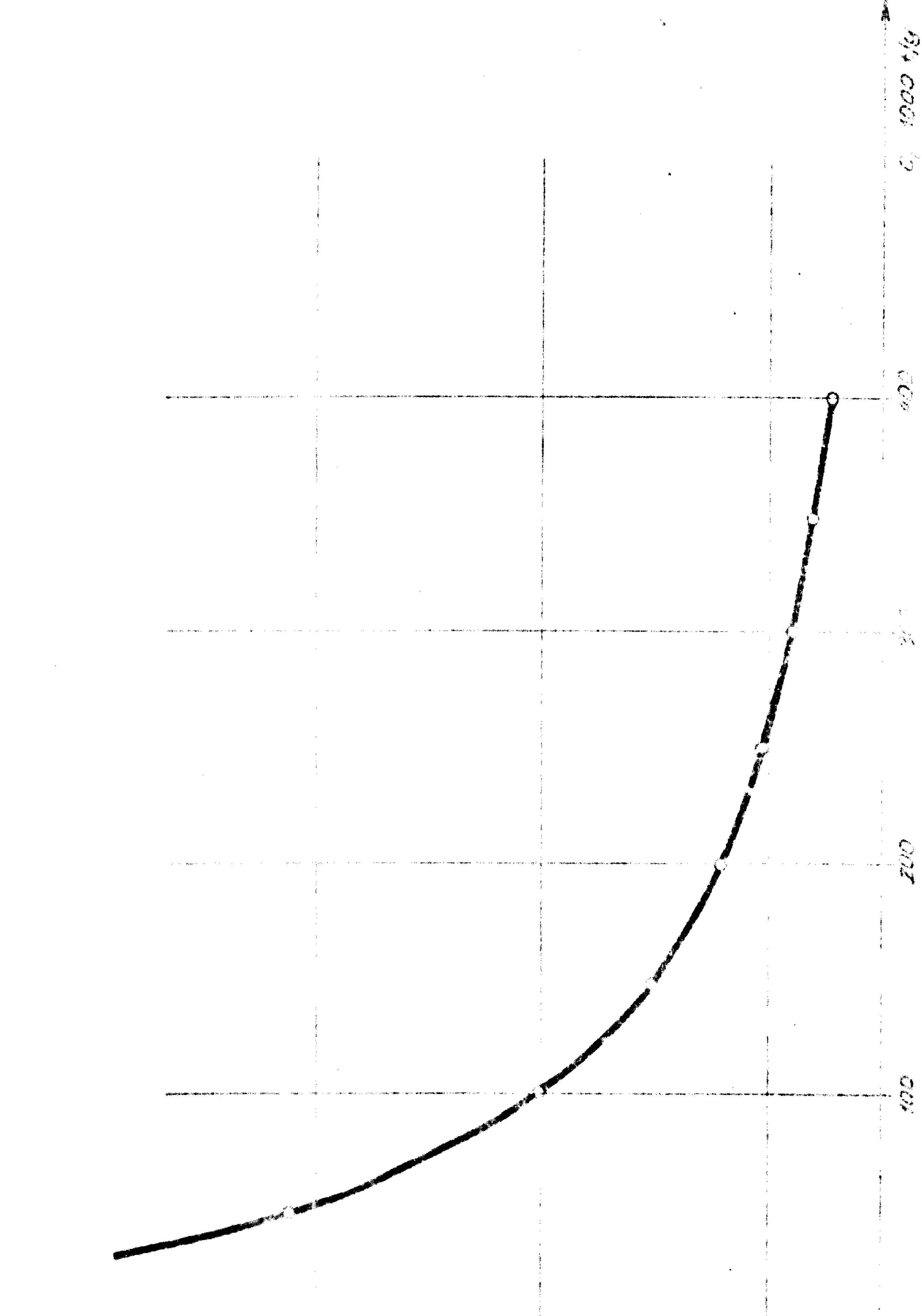
[illegible] tion [illegible] since [illegible] research [illegible] control [illegible]

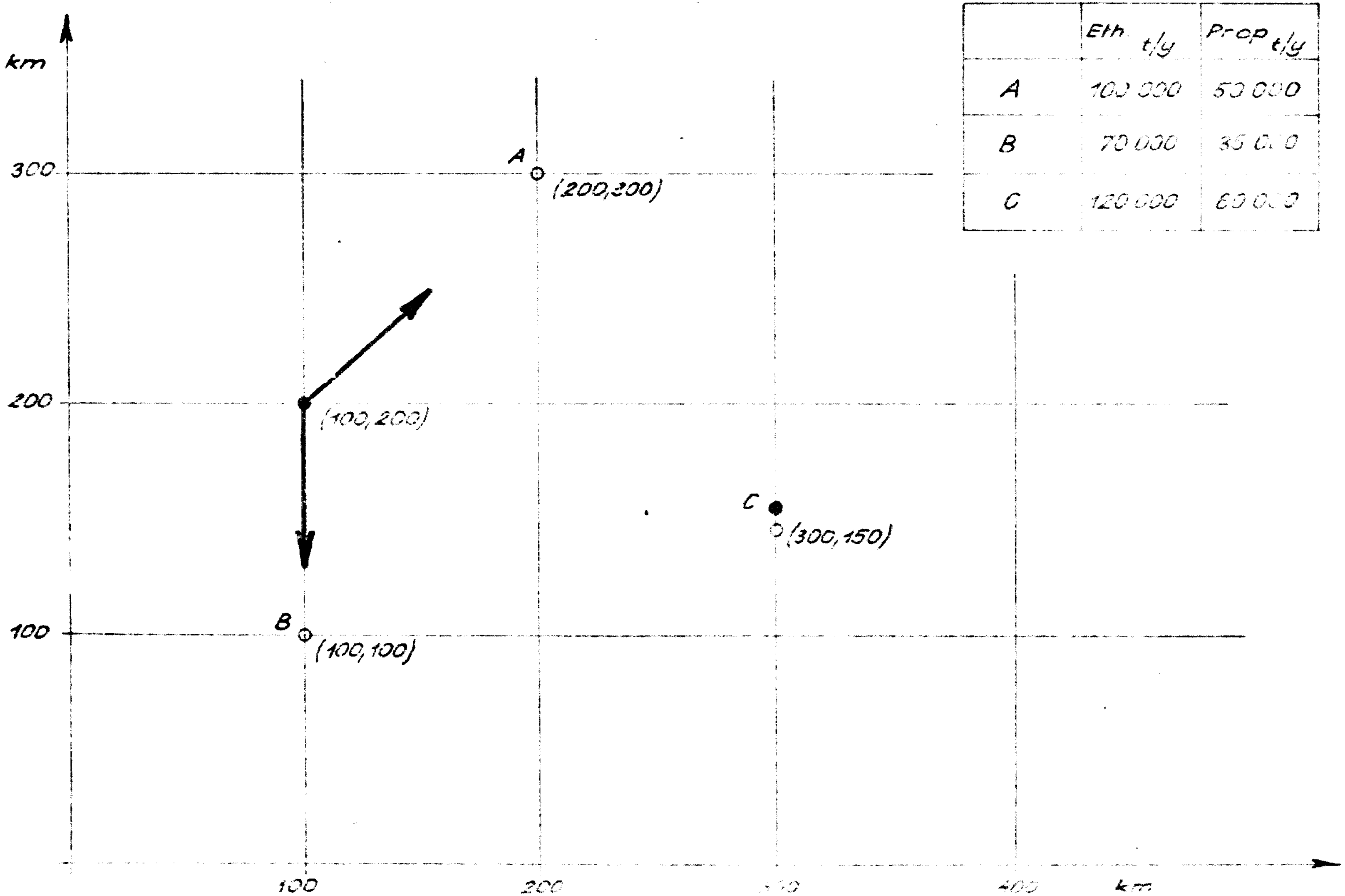
[illegible] ramming.

Acknowledgements

[illegible] Mr. [illegible], [illegible].

Figure 1.





	Eth t/y	Prop t/y
A	100 000	50 000
B	70 000	35 000
C	120 000	60 000

Figure 2.

		1 E_1 on site A	2 E_2 on site A	3 P_1 on site A	4 P_2 on site A	5 E_1 on site B	6 E_2 on site B	7 P_1 on site B	8 P_2 on site B	9 E_1 on site X	10 E_2 on site X	11 P_1 on site X	12 P_2 on site X	13 Olefine plant site X	14 Ethylene transport A	15 Propylene transport A	16 Ethylene transport B	17 Propylene transport B	18 Residual capacities E_1 site A	19 E_2 site A	20 P_1 site A	21 P_2 site A	22 E_1 site B	23 E_2 site B	24 P_1 site B	25 P_2 site B	26 E_1 site X	27 E_2 site X	28 P_1 site X	29 P_2 site X	30 Economic function	31	32
Ethylene for E_1	1	110				110				110				-110																		=	0
Ethylene for E_2	2		60				60				60			-60																		=	0
Propylene for P_1	3			50				50				50		-50																		=	0
Propylene for P_2	4				50				50				50	-50																		=	0
Investment, site A	5	20	8	10	16																											≤	34
Investment, site (B+X)	6					20	8	10	16	20	8	10	16	20																		≤	48
Production cost	7	20,1	10,9	12,8	7,8	21,2	11,4	13,2	8,2	19	10,2	12,5	7,5	9	-0,001	-0,0005	-0,002	-0,001	1,6	0,8	1,3	0,8	1,7	0,85	1,35	0,85	1,5	0,85	1,25	0,75	1	=	0
Olefine plant	8													1																		=	1
Ethylene transport to A	9	110	60												1																	≤	170
Propylene transport to A	10			50	50											1																≤	100
Ethylene transport to B	11					220	120										1															≤	340
Propylene transport to B	12							100	100									1														≤	200
Tr lim: Ethylene A	13														1																	≤	85
Tr lim: Propylene A	14															1																≤	50
Tr lim: Ethylene B	15																1															≤	170
Tr lim: Propylene B	16																	1														≤	100
Plant capacity limits: E_1 site A	17	1																	1													=	1
E_2 site A	18		1																	1												=	1
P_1 site A	19			1																	1											=	1
P_2 site A	20				1																	1										=	1
E_1 site B	21					1																	1									=	1
E_2 site B	22						1																	1								=	1
P_1 site B	23							1																	1							=	1
P_2 site B	24								1																	1						=	1
E_1 site X	25									1																	1					=	1
E_2 site X	26										1																	1				=	1
P_1 site X	27											1																	1			=	1
P_2 site X	28												1																	1		=	1
	29																																
Economic function	30																														1	→ min	

Figure 3

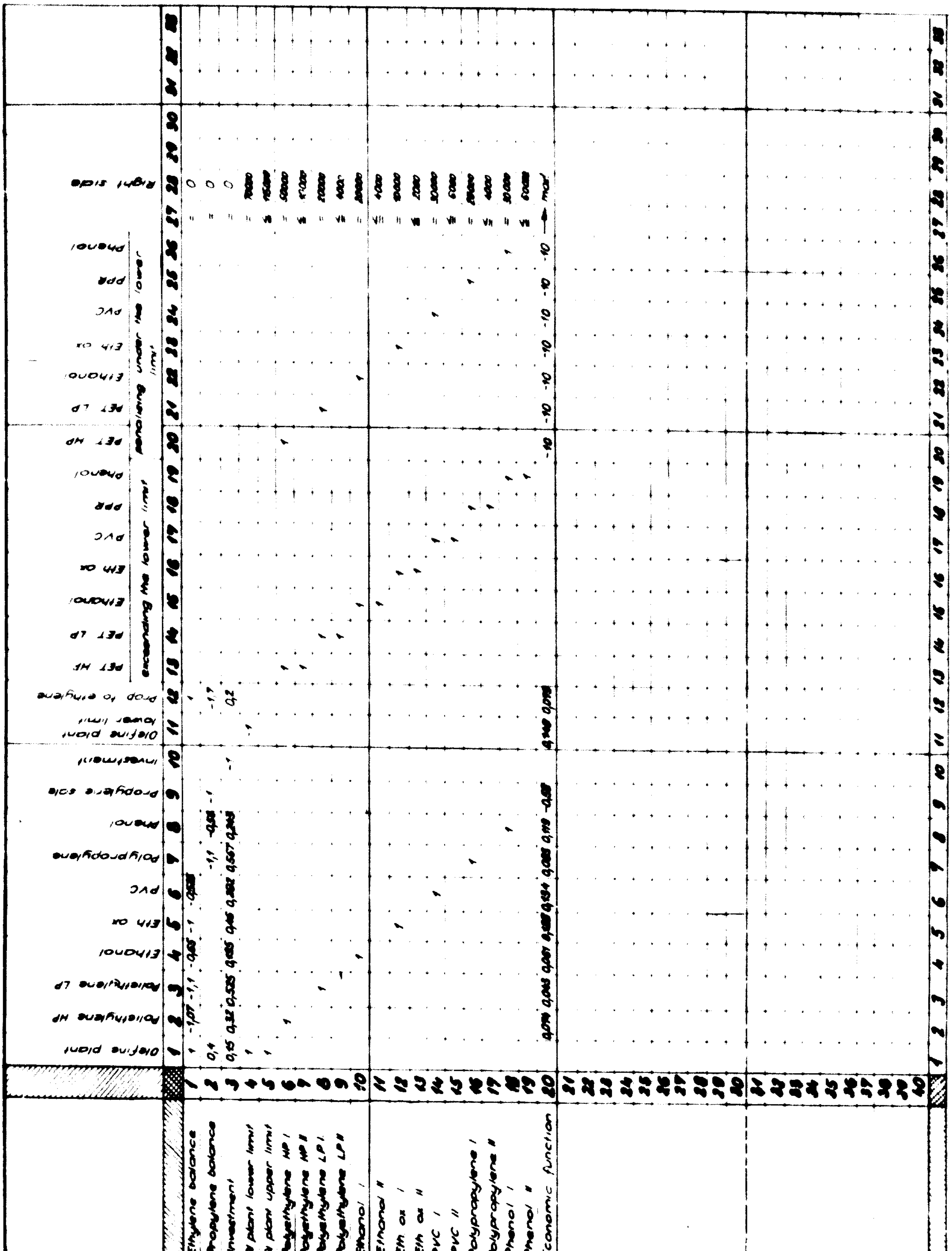

Ethylene balance
Propylene balance
Investment
Ol plant lower limit
Ol plant upper limit
Polyethylene HP I
Polyethylene HP II
Polyethylene LP I
Polyethylene LP II
Ethanol I
Ethanol II
Eth ox I
Eth ox II
PVC I
PVC II
Polypropylene I
Polypropylene II
Phenol I
Phenol II
Economic function
Right side

Figure 4.

16. 3. 72