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CALCULATION OF EXTRACTION COLUMNS FOR LUBRICATING OIL REFINING

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Modern chemical engineering work requires all the transport phenomena to be known which accompany the physical or chemical changes that occur in operational units.

A few years ago, studies were started which were aimed at finding a method that would enable the modelling of the operational units, procedures and apparatus used in the mineral oil and the petrochemical industry. This work was based on the known fundamentals of theoretical reactor techniques.

MATHEMATICAL DESCRIPTION OF THE EXTRACTION OF A MULTI-COMPONENT SYSTEM

It is known from literature [1, 2, 3] that the study of transport phenomena is based on the continuity rule, whose general expression is the following:

$$\operatorname{div} J - \frac{\partial \rho A}{\partial t} = 0 \qquad (1)$$

It follows from Equation (1) that the flux density vector is an unequivocal function of the density of the component. It is not possible to apply this formula in the case of systems in which the individual composition cannot be determined. This difficulty can also be overcome in the case of multi-component systems such as those encountered in the mineral oil and petrochemical industry in the following way: Equation (1) is divided by the mean density of the system, and accordingly the concentration will be characterized by the mass fraction in the equation. The general continuity equation expressed with mass fractions was described in literature [1 - 7] and this was applied for modelling the complex systems.

$$-\frac{\partial X_A}{\partial t} = \nabla X_A v - D\nabla^2 X_A + \omega\beta X_A \pm \nu_A r(X_A) \qquad (2)$$

The individual components are not known in complex systems. However, analytically well-defined component groups can always be separated and the mass fraction of these can be accurately determined.

The studied systems cannot be modelled with the application of the Equation (2) since they contain two or more phases. It is readily understood that with regard to phase distribution the definable component groups do not behave as individual compounds. Consequently, a second modification was introduced inasmuch as Equation (2) was not applied to each group of components, instead we selected the group most characteristic of the complex system. This group was termed the "basic component group" and the operational units were modelled only with the variations of this group in time. In this way the system could be described with a single mathematical expression that could be handled in a simple manner. Due to the twofold simplification, the mass flow equation expressed with the original density becomes distorted, since the dimension of Equation (2) is (hr^{-1}), and consequently the diffusion, material transfer, and kinetic constants contained in the equation cannot be compared to the constants determined during the basic research. However, the given complex systems can be very adequately described by these constants which are characteristic of the given system.

With the technique briefly described in the foregoing, we succeeded in modelling the asphalt-blowing reactor cascade of the Zala Mineral Oil Company [5], dimensioning the blowing reactors, their scaling-up and technological optimalization [6]. Commissioned by the International Atomic Energy Commission, it was developed a new technology based on similar theoretical fundamentals for embedding isotope waste in bitumen; this procedure was realized both in a batchlike and in a continuous process and dimensioning and designing problems were also solved [7].

At present, we are engaged in modelling a number of procedures and apparatus for the mineral oil industry using the above method. From these, the modelling of the phenolic mineral oil extraction column of the Duna Mineral Oil Company [8] will be described in this paper.

A number of methods were proposed in literature for the modelling and calculation of extraction processes. It is a unanimuous opinion that in the case of more than four components, these methods - which can be regarded as classical today - do not yield reliable results [9]. Accordingly, Equation (2) was selected as the basis of the modelling.

Extraction is a continuous, stationary operation in which no chemical reaction occurs and diffusion inside the phases is not dominant and, accordingly it is justified to take into consideration only two terms of the Equation (2): the convective and the transfer terms:

$$- B(X^{\alpha}_{A}o - X^{\alpha}_{A}) + V_{E}k_{trans}(X^{\alpha}_{A} - X^{\alpha}_{A*}) = 0 \qquad (3)$$

Equation (3) is a relationship which was applied for the basic component group and this allowed to solve the questions connected with lubricating oil extraction.

EXPERIMENTS

Calculations were carried out concerning the industrial-scale extraction column operated at the Duna Mineral Oil Company for a number of various feedstock—phenol systems. From among these, the calculations concerning a residue—phenol system will be dealt with here. The residue was obtained from a mineral oil of Romashkino origin by propane deasphalting. However, it should be stressed that the used method can also be applied to systems built up with other extraction solvents and other extraction columns.

The calculation of the extraction process by Equation (3) can be carried out only if the mass fraction of the basic component group designated by X_A^α in the lubricating oil, containing ten of thousands of components, can be determined in some way. For this purpose, the complex system had to be simplified to two groups of components, these two groups being different with regard to behaviour from the viewpoint of extraction.

Selection and Determination of the Basic Component Group

One of the two above-mentioned component groups - designated in the following by "A" - is immiscible or only partially miscible with the solvent, whereas the other - designated group "C" - is totally soluble in the solvent under the conditions of the extraction. The extracting solvent is component "B".

It is a basic requirement that the component groups follow the requirements of mass balance under the conditions encountered in the extraction process. In addition, the evaluation of the equilibrium states which develop among these component groups must unequivocally be possible.

Component group "A" comprises saturated aliphatic and naphtenic mineral oil hydrocarbons, whereas "C" is a group composed of monocyclic and polycyclic aromatic hydrocarbons.

From among the processes for the separation of saturated and aromatic hydrocarbons that are at present known, the elution liquid chromatographic technique was found to be most suitable. Aromatic and saturated hydrocarbons can be sharply separated from each other, provided that the adsorbent and the eluents are suitably chosen.

Chromatographic separation was carried out on a column of 23 mm I.D.and 1500 mm length,filled with wide-pore silica gel made in the German Democratic Republic. 3 per cent - with reference to the weight of the adsorbent - of the oil to be separated, dissolved in hexane,was placed on the adsorption column. 1,000 ml analytical-grade n-hexane, 1,000 ml analytical-grade benzene and 1,000 ml analytical-grade acetone were used as eluents.The eluates obtained with these solvents were separated from the solvents, their weights and refractive indices were determined. The first eluate, mainly comprising saturated hydrocarbons, is in the following described as component group "A", immiscible or only partially miscible with the solvent. The eluates obtained with benzene and acetone were united and designated as component group "C", mainly containing monocyclic and polycyclic aromatic hydrocarbons and resinuous substances.

The chromatographic analysis of a number of corresponding raffinate-extract pairs and feedstocks was carried out and it was found that the component balance established for the "A" and "C" component groups of the raffinate-extract pairs was in most cases in agreement with the content of the feedstock on the corresponding component to an accuracy of 1 per cent by weight.

The determination of the amounts of component groups "A" and "C" by the chromatographic technique is rather time-consuming. It was consequently studied the possibility of the determination of the composition on the basis of an additive qualitative parameter. There is a considerable difference between the refractive indices of fractions eluated with hexane and benzene, respectively; the determination of the refractive index is a simple, rapid procedure and it requires only a small amount of sample; furthermore, the connection between the refractive indices on the mixtures made of the pure hexane and benzene fractions, and their composition is a linear one. Accordingly, this qualitative characteristic was chosen as the basis of the concentration determination in the following. The concentrations of the "A" or "C" components in any of the feedstocks or extraction products can be calculated by a simple proportion if the refractive indices of the components and in addition those of the hexane eluate corresponding to the 100 per cent component "A" content and of the benzene eluate corresponding to the 100 per cent component "C" content are known.

In order to check whether the "A" and "C" component concentration values thus calculated conform to the requirements of mass balance, and to what extent they agree with the results of chromatographic analysis, they were compared with the component balances calculated on the basis of refractive indices. It was found that the difference between the component balance of the raffinate--extract pair and the corresponding component content of the feedstock is lower than one per cent.

In order to illustrate the foregoing, the "A" and "C" component content determined respectively by chromatography and refractive index measurement, the component balance of a feedstock, prepared from Romashkino crude oil, and in addition those of raffinate-extract pairs prepared from the same under different operational conditions and with different yields, as calculated with the two different methods, are summarized as an example in Table 1.

A comparison of the component amounts and balances determined by chromatography and those calculated on the basis of the refractive index measurement reveal that most of the data determined by these two techniques agree within 2 per cent. It should be stressed that in the Equation (3), which is the basis of the calculations, the basic component group designated X_A^α is always the mass fraction or amount (in percentage by weight), of the component group "A", calculated in accordance with the foregoing and referred to the refined phase.

Table 1. Component "A" and "C" amounts and balances in feedstock and a few extraction products, determined by chromatographic separation and calculated on the basis of refractive indices

Designation of material	Yield of extraction operation	Chromatographic analysis				Refractive index,	Calculated on the basis of refractive index			
		Composition		component balance			Composition		component balance	
	wt.%	A,wt.%	C,wt.%	"A" comp.	"C" comp.	n_D^{70}	A,wt.%	C,wt.%	"A" comp.	"C" comp.
Limit raffinate	-					1.4613	100.0	0.0	100.0	0.0
Limit extract	-					1.5353	0.0	100.0	0.0	100.0
Feedstock										
A	100.0	60.10	39.90	60.10	39.90					
B	100.0	61.50	38.50	61.50	38.50					
mean		60.80	39.20	60.80	39.20	1.4920	60.40	39.60	60.40	39.60
Experiment No.6.										
Raffinate	47.36	85.25	14.75	40.37	6.98	1.4715	88.10	11.90	41.77	5.59
Experiment No.6.										
Extract	52.64	37.30	62.70	19.63	33.00	1.5104	35.54	64.46	18.73	33.91
Total				60.00	39.98				60.50	39.50
Experiment No.12.										
Raffinate	85.50	69.70	30.30	59.59	25.90	1.4857	68.91	31.09	59.41	26.09
Experiment No.12.										
Extract	14.50	13.10	85.90	1.90	12.45	1.5269	13.24	86.76	0.85	13.65
Total				61.49	38.35				60.26	39.74
Experiment No.21.										
Raffinate	25.40	83.70	16.30	21.26	1.59	1.4704	89.59	10.41	23.66	1.74
Experiment No.21.										
Extract	74.60	52.60	47.40	39.24	35.35	1.5002	49.32	50.68	35.16	39.44
Total				60.50	36.94				58.82	41.18

During the industrial-scale experiments it were determined the relationship between raffinate qualities, yield data and technological parameters. As an example, the results obtained in experiments on the Romashkino residue oil-phenol system are described.

Industrial-scale experiments

Calculations were carried out in connection with the phenol refining column of the annual 300,000 to 350,000 tons capacity operated at the Duna Mineral Oil Company.

The extraction column is 33.1 metres high, 4 metres in diameter and equipped with 24 plain grids and 2 bubble cap plates. Its simplified drawing is shown in Fig.1.

In order to increase the sharpness of separation, water feeding and a temperature gradient were applied. Phenol is introduced over the top plate, the feedstock and an azeotropic water-phenol mixture, containing approximately 90 per cent by weight water, is introduced at the 21st plate.

The temperature gradient is controlled by circulation-type reflux. A given portion of the continuous phase is withdrawn and then after cooling in an external heat-exchanger is fed back below the plate. The raffinate and the extract solution are removed after adequate settling, at the column head and at the bottom.

The values of the material stream entering into and leaving the column in cu. metres per hour units, and the temperatures at different points of the column can be read from the instruments. There are nine sampling places on the column. The solvent-refined top-product is taken from the top of the column, and the solvent-extracted bottom product from its lower part. Sampling points designated I - V. are the sampling nozzles located at the upper section of the column, between the 5th and 13th plain grids, and locate the raffinate-extract phase boundary. In addition, two further samples can be taken from the lower third of the column, from

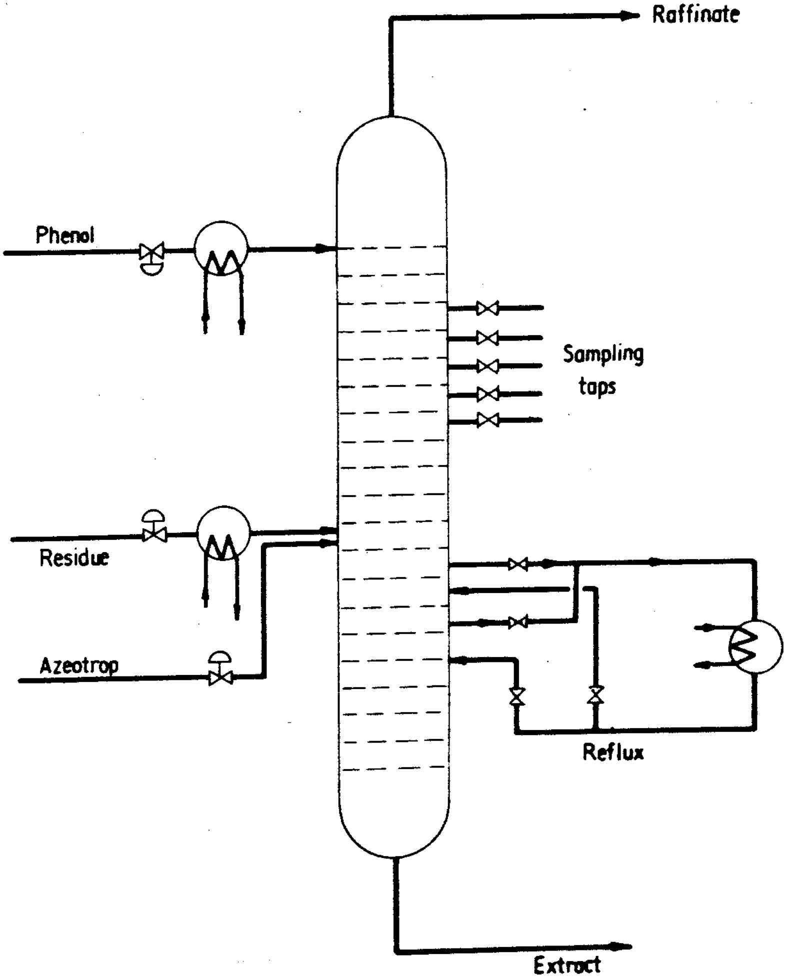

Fig.1. The extraction column.

the point of extract reflux removal, from under the 22nd and 24th plates. Due to technical difficulties, samples were not taken regularly from the extract reflux removal point under the 24th plate. In addition to solvent-containing samples taken from the column, solvent-free raffinate, extract, feedstock and azeotrope samples were also taken in each industrial-scale experiment.

In the laboratory processing of the 9 or 8 samples taken from the extraction column it was endeavoured to separate the phases in such a way as to obtain a composition identical to that actually prevailing at the place of sampling in the industrial extraction column. For this purpose the molten and homogenized samples were allowed to settle at a temperature equal to that measured at the sampling point of the extraction column. Separation to raffinate and extract phases was carried out in this way in a discontinuous-operation laboratory extraction apparatus.

The solvent was separated from the raffinate and extract phases by evaporation and the solvent content of the two phases was calculated. It was also determined the refractive indices of the solvent-free oils and from these were calculated the "A" and "C" component content of the oil with the method described in the previous section. The percentage composition of the three-component phases was calculated afterwards.

The compositions of the phases also were calculated as referred to the collective amounts of raffinate and extract phases; these data, plotted against the length of the extraction column are shown in Fig.2. The Figure shows, as an example, the results obtained in the laboratory processing of samples taken during a given industrial experiment of the phenolic refining of a Romashkino residue. The most important parameters were the following: top temperature 80°C, bottom temperature 60°C, feed 32 m^3/hr. oil, oil to solvent ratio 1/2.1, water content of phenol 3.05 wt.%. The concentration profile developed along the length of the extractor was determined in all industrial experiments. It is apparent from the Figure that the raffinate-extract phase boundary in this experiment was very sharp in the extraction column and was located between the 4th and the 5th plate.

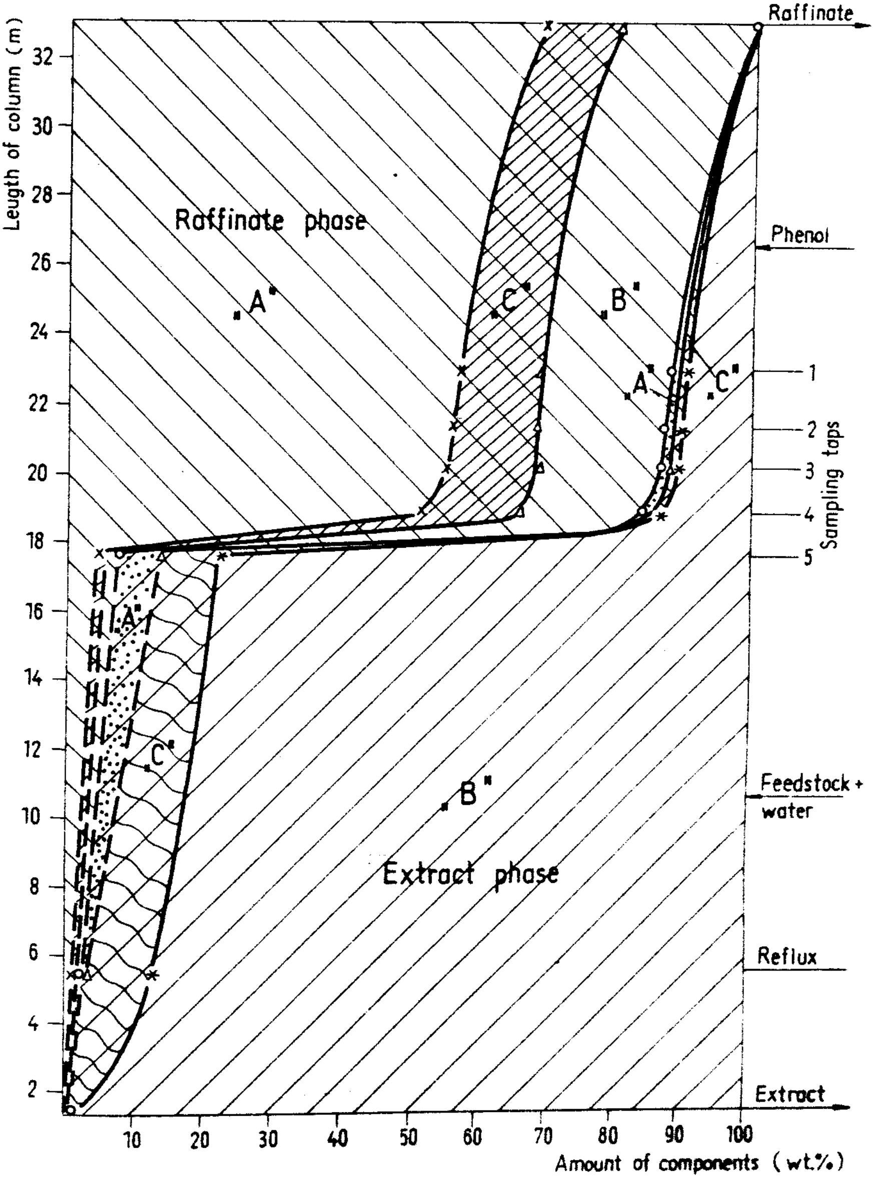

Fig.2. Concentration distribution of components along the length of the column at the experiment of December, 11.

EVALUATION OF THE INDUSTRIAL-SCALE EXPERIMENTS

After the laboratory analysis - according to the foregoing - of the samples taken during the industrial-scale experiments carried out with different parameters, the values of the combined mass transfer coefficient k_{trans} were calculated on the basis of the Equation (3). The "B" total feed expressed in cu. meters per hour represents the amount of feedstock,phenol and azeotropic mixture. V_E is the free volume between the feeding point of the feedstock and the sampling point of the extraction column. The actual concentration of component "A" at the sampling point of the raffinate phase is $X^{\alpha}_{A}o$, whereas the concentration of component "A" in the feedstock-solvent system is X^{α}_{A}, expressed in mass fraction.

The value of $X^{\alpha}_{A}*$ was determined by laboratory equilibrium measurements, at a temperature equal to that of the industrial extraction column and at an identical water content in the phenol and at the oil/solvent ratio prevailing at the point of sampling. In these experiments, a half-hour stirring and a one-hour settling period were applied. This time is sufficient for the equilibrium state to be reached. $X^{\alpha}_{A}*$ represents the component "A" content of the raffinate phase obtained in the equilibrium measurements.

The calculation of the combined mass transfer coefficient is shown, as an example, in Table 2. The data which were constant during an industrial experiment were especially emphasized. The data necessary for the calculations, which are different at each individual sampling point, were summarized. The first five columns of the Table contain the basic data necessary for the calculation of k_{trans}, whereas the sixth column contains the calculated k_{trans} values.

Theoretically, within one given industrial-scale experiment and at identical technological parameters, identical k_{trans} values should be obtained at any sampling point which is over the oil feeding level on the extractor. This was verified by the

Table 2. Calculation of the k_{trans} coefficient on the basis of the industrial-scale experiment of June, 7.

Constant data:

Feedstock component "A" 0.615
Oil/solvent vol. ratio 1:2.27
Mass fraction of oil at feeding 0.7592
Water content of phenol 2.55 wt.%
$X_A^{\alpha}o = 0.615 \cdot 0.7592 = 0.467$
$B = 132.4\ (m^3/hr.)$

Sample designation	B/V_E	Raff. "A" mass fraction	Raff. phase A + C mass fraction	X_A^{α}	$X_A^{\alpha *}$	k_{trans}
Raffinate	0.540	90.90	80.15	0.729	0.756	5.25
I.	1.029	76.76	76.62	0.588	0.611	5.37
II.	1.176	77.79	75.14	0.585	0.611	5.22
III.	1.321	77.43	75.42	0.584	0.611	5.67
IV.	1.528	76.47	75.85	0.580	0.611	5.52
V.	1.796	75.66	75.93	0.575	0.611	5.25
E. refl. II.	-6.724	59.78	75.92	0.454	0.690	0.14
E. refl. I.	-2.354	61.76	73.68	0.455	0.690	0.04
Extract	-1.236	61.35	65.50	0.402	0.691	0.24
Upper section mean k_{trans}						5.38
Lower section mean k_{trans}						0.14

experiments, since the k_{trans} values calculated for the six sampling points of the upper section showed a good agreement in each industrial-scale experiment. The k_{trans} values calculated for the individual sampling points differ from the mean value by max. ± 0.29 units which corresponds to a scattering of ± 5 per cent.

It is apparent from the Table illustrated as an example, and it was also observed in all the industrial-scale experiments that there is a difference between the k_{trans} coefficients, determined for a section of the extraction column over the oil feeding point and those determined for a section below it, which amounts to an order of magnitude. This is readily understood since enrichment of component "A" in the raffinate phase occurs in the upper section, whereas samples taken from the lower section contain very low amounts of raffinate phase, and even these contain very low concentrations of component "A": it is the enrichment of component "C" which is dominant in the extract phase. The absolute values of the transfer coefficients are very low in the lower section and the mean deviation from the mean value is ± 0.1 unit.

After having come to the conclusion that the X_A^α values can be calculated to a satisfactory accuracy by means of the combined material transport coefficient, i.e. that the elaborated method enables calculation of the X_A^α values - of decisive importance as regards the quality of the desired product - to a satisfactory accuracy, there remained no further task than to determine the values of k_{trans} as a function of the technological parameters by industrial-scale experiments:

$$K_{trans} = f(B, \text{wt.\% water}, T, \text{oil/solvent ratio})$$

These connections are illustrated in Fig.3. It is apparent from the Figure that the value of k_{trans} shows a considerable - though not linear - increase with increasing temperature. Increasing oil feeding rate causes a slight increase, increasing oil/solvent ratio causes a considerable increase in its value; increasing water content causes the k_{trans} value to decrease.

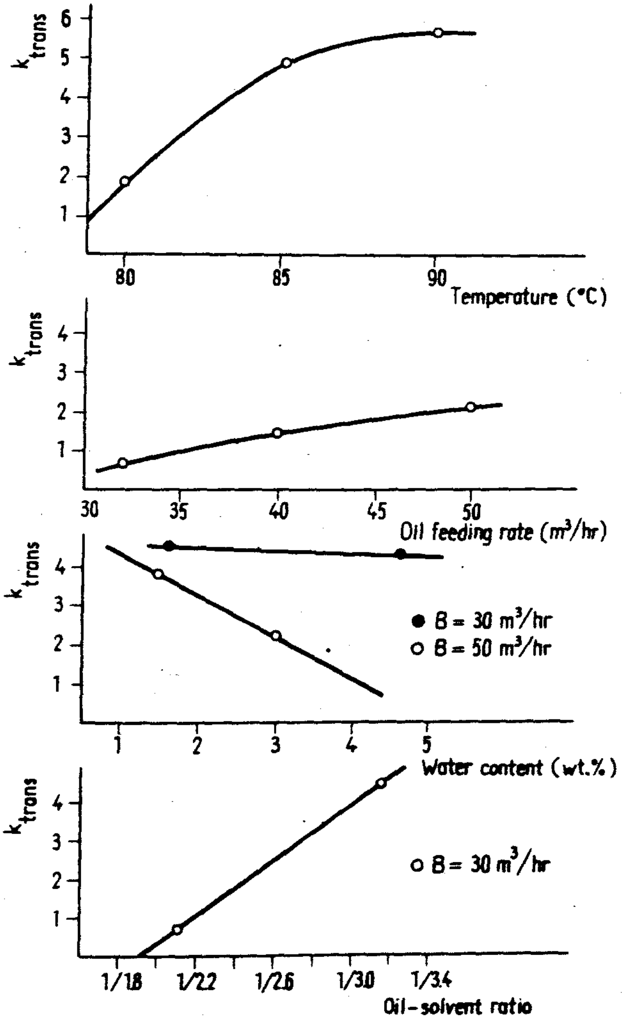

Fig.3. Changes in the transfer coefficient, plotted against various technological parameters.

Knowing the connection between the technological parameters and the combined material transfer coefficient, the k_{trans} values, corresponding to realistic parameter limits, can be established by interpolation to adequately varied values of the individual parameters or by slight extrapolation. Knowing these k_{trans} values, the X_A^α values can be calculated. If a sufficient number of experimental data is available, the solvent-free raffinate "A" component concentration values can be calculated by dividing the X_A^α values by the experimentally determined mean solvent content expressed in mass fraction. These values are brought into correlation by means of a calibration curve with one of the qualitative parameters of the raffinate which is important from a practical point of view.

Each of the starting materials studied by us - heavy paraffin distillates made of various raw mineral oils and residues mentioned in the foregoing - were processed to motor oil. Consequently, the parameter important from a practical point of view was the viscosity index of the raffinate which had been deparaffinized to a solidification point of -15 to -16°C.

A calibration curve was prepared representing the connection between the refractive index of the paraffin-containing oil and the viscosity index of the deparaffinized oil for the feedstocks and the raffinates made from them. This calibration curve is shown in Fig.4. It is apparent from the Figure that this connection can be determined only with a certain error.

The connection between the refractive index and the concentration of component "A" is also known, since the value of "A" is calculated on the basis of the measured refractive index values, as described in the previous Section. Accordingly, the quality of the product can unequivocally be characterized by the X_A^α and "A" component concentration values used for the calculation, and by the data on the refractive index and viscosity index.

During the industrial-scale experiment the raffinate yield data were also determined, partly on the basis of instrument

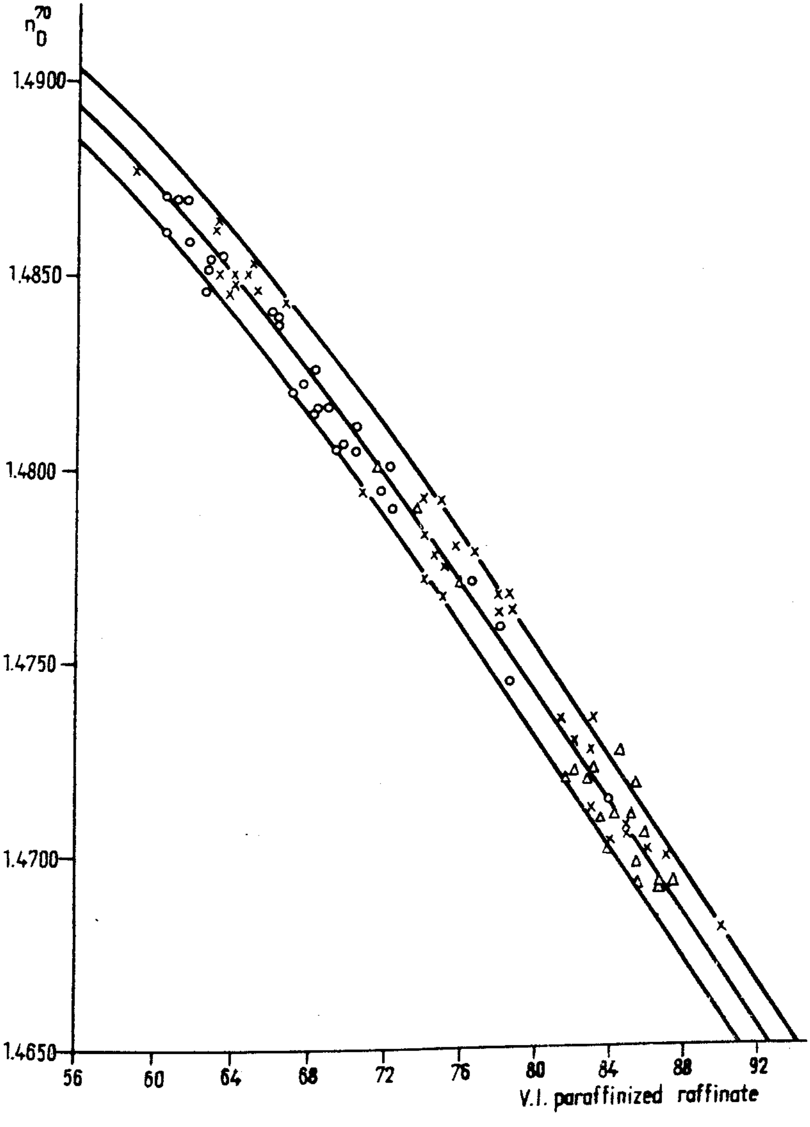

Fig.4. Refractive indices at 70°C of solvent-free raffinates, plotted against the viscosity index of the deparaffinized products. o residue, produced in 1966; x residue, produced in 1968; Δ residue, produced in 1969-1970.

Table 3. Main results of industrial-scale experiments carried out at the phenol refining plant of the Duna Mineral Oil Company with Romashkino residue

Time of experiment	Experimental conditions					k_{trans}	X_A^α	Raffinate, n_D^{70}	Deparaffinized raff.V.l.	Raffinate yield (wt.%)
	oil feed (m^3)	water content (wt.%)	oil/solvent ratio	top temperature (°C)	bottom temperature (°C)					
1969.										
VI. 7.	39.8	2.55	1/2.2	92	75	5.84	0.734	1.4712	84	58.7
X. 9.	39.7	3.16	1/2.0	81	61	1.51	0.681	1.4715	84	65.3
XI. 24.	50.0	3.05	1/2.0	79	61	2.20	0.695	1.4720	82	62.3
XII. 11.	32.0	3.05	1/2.1	80	60	0.70	0.643	1.4760	78	70.8
XII. 12.	30.3	1.60	1/3.1	80	61	4.54	0.743	1.4693	89	57.4
XII. 13.	30.0	4.60	1/3.2	79	62	4.31	0.697	1.4692	89	61.0
1970.										
I. 9.	50.4	1.50	1/2.0	80	63	3.87	0.717	1.4708	85	58.0
I. 10.	45.3	2.50	1/2.2	85	67	5.00	0.718	1.4702	86	59.7
I. 21.	45.4	2.60	1/2.2	90	71	5.60	0.687	1.4707	85	64.1
I. 22.	46.0	2.70	1/2.2	89	60	1.37	0.641	1.4722	82	60.3

readings and tank levels, and partly on the additive qualitative characteristics such as e.g. density and refractive index. The range of the parameters studied in the case of the Romashkino residue was as follows:

Volume ratio oil/phenol	1/2 ... 1/3.3
Water content of phenol (wt.%)	1.5 ... 5.0
Oil feeding rate (m^3/hr.)	30 ... 50
Top temperature of extractor (°C)	80 ... 90
Bottom temperature of extractor (°C)	60 ... 70

The influence of these parameters upon the raffinate yields and quality was studied in ten industrial-scale experiments. The experimental data and the main results are summarized in Table 3.

In Table 3. the yield data, k_{trans} values were summarized as the function of the technological parameters. The k_{trans} and the yiels values were determined by graphical interpolation for all of the following variations: different temperatures at 5°C steps, oil feeding rates at 5 (m^3/hr.) steps, phenol water content values at 0.5 wt.% steps and oil-solvent ratios in 1/0.2 and 1/0.4 steps, within the above mentioned ranges of the individual parameters.

The X_A^α values were calculated using the transfer coefficients. With the aid of the above-mentioned connections and calibration curve a connection was established between the component "A" concentration and refractive index, and the viscosity index of the deparaffinized raffinates.

The relations between product quality, yield and technological parameters were calculated on the basis of the ten industrial-scale experiments for 300 different variations of the technological parameters. The results of these calculations were plotted on nomographs similar to that shown, as an example, in Fig.5. Each nomograph shows the raffinate yield and refractive index data pertaining to constant temperature and oil feeding rate as a function of the oil/solvent ratio for the cases of various water contents in the phenol.

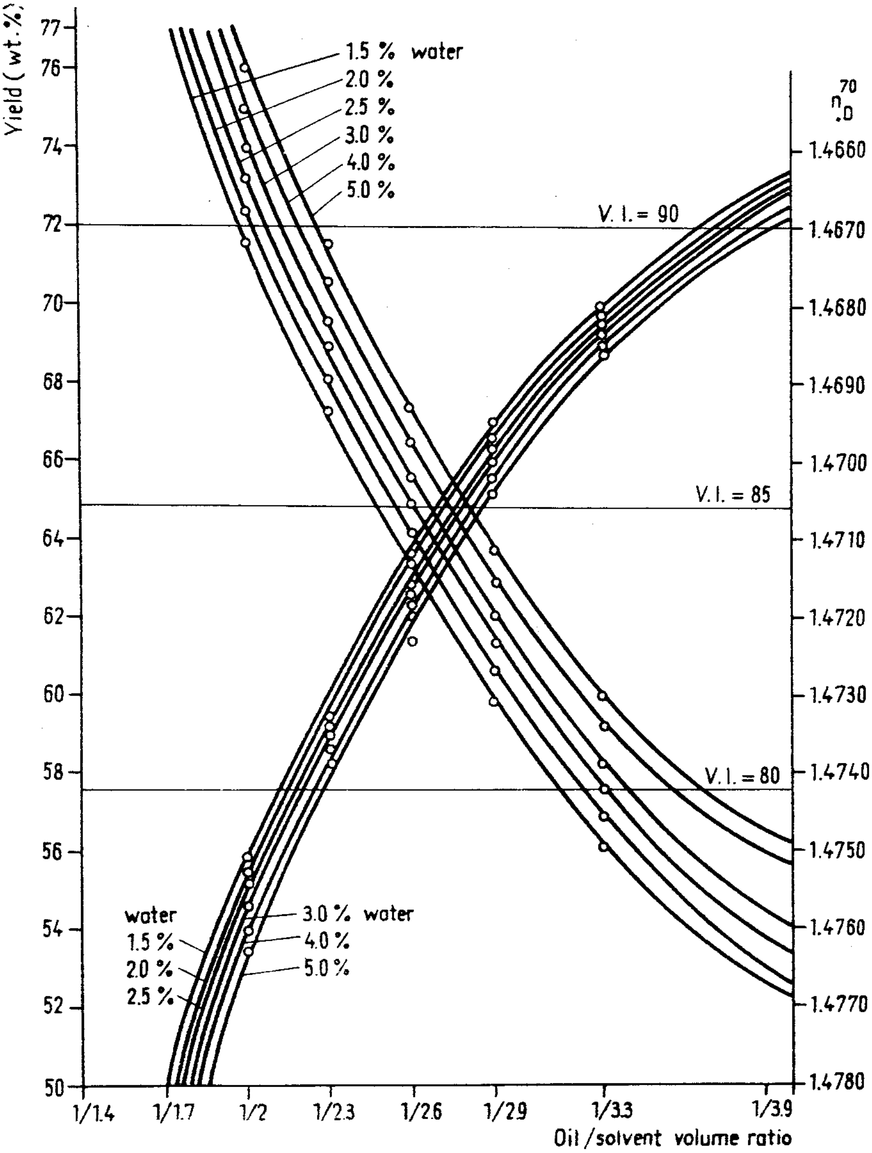

Fig.5. Variations in refractive index and yield of raffinate produced at 30 m^3/hr oil feeding rate and 80°C column top temperature, plotted against oil/solvent ratio.

In conclusion calculations were carried out in order to determine the optimum working conditions. For this purpose, Equation (3) was rearranged to the following form:

$$\frac{B}{k_{trans}} = \frac{V_E}{\dfrac{X^{\alpha}_{A}o - X^{\alpha}_{A}}{X^{\alpha}_{A} - X^{\alpha}_{A*}}}$$

This form of the Equation corresponds to the functional relation $y = \frac{c}{x}$. The value of V_E i.e. the total volume from the feeding point to the raffinate removal point of the extraction column is constant; in the case of the industrial-scale column it was 245.2 m^3. If it is constructed a system of coordinates on whose ordinate the $\frac{B}{k_{trans}}$ values and on whose abscisse the

$$\left[\frac{X^{\alpha}_{A}o - X^{\alpha}_{A}}{X^{\alpha}_{A} - X^{\alpha}_{A*}}\right]$$

values are plotted, we obtain a hyperbole. The concentration values of the quantity in brackets are interrelated according to the following:

$$X^{\alpha}_{A}o < X^{\alpha}_{A} < X^{\alpha}_{A*}$$

The above expressions were derived from data pertaining to various working conditions and they are illustrated in Fig.6. On the branch of the hyperbole adjacent to the y axis it were found pairs of values corresponding to higher feeding rates and poorer product qualities, whereas on the branch adjacent to the x axis the corresponding values of small amounts and good product qualities were found. Accordingly, the y axis is a coordinate proportional to quantity and the x axis is one proportional to quality. The technological optimum requires the maximum possible yield of

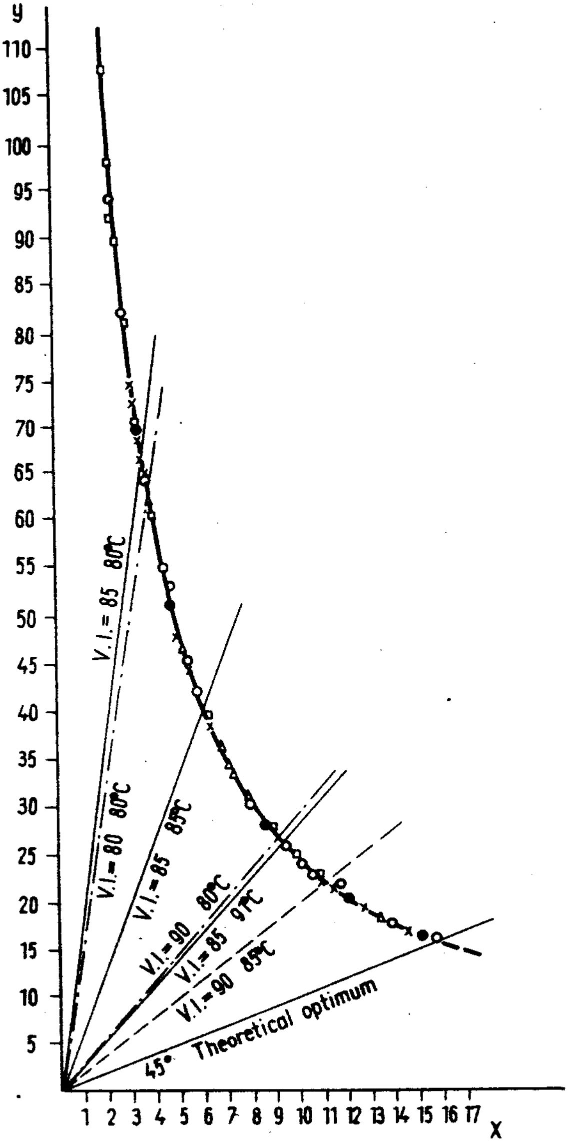

Fig.6. x and y values calculated from basic data defined for various experimental parameters. Oil/solvent ratio: o 1/3.3; Δ 1/2.9; x 1/2.6; • 1/2.3; ◻ 1/2.0.

product and simultaneously the best possible quality. However, these two characteristics are found on the two branches of the hyperbole in opposite directions, and consequently the optimum is expressed by the point of intersection of the hyperbole with a straight line drawn from the origo at a slope of 45 degrees. It is apparent from Figure 6. that this value is best approximated by the results of raffinations carried out at higher temperature, at 85 to 90°C.

The significance of the method lies in the fact that for one given feedstock-solvent system it is sufficient to determine these connections once and afterwards the production can continue. The technological data, which result in a produced of a required quality at the highest possible yield can be established for any raffinate quality.

However, the principles and methods described in the foregoing can not only be applied to extraction-type raffination processes carried out in industrial-size extraction columns, but also enable other techniques, used in mineral oil technology for processing multi-component mineral oil distillates and derivates - simplified by adequately chosen key fraction to two-component groups - to be studied and controlled.

USED SYMBOLS

B	total feeding rate (m^3/hr)
D	diffusion coefficient (m^2/hr)
J	flux density (amount/m^2hr)
k_{trans}	combined material transport coefficient = $\omega\beta$ (hr^{-1})
r(x)	reaction rate, expressed with mass fraction (hr^{-1})
t	time (hr)

v	linear velocity (m/hr)
V_E	volume of extractor (m^3)
X	mass fraction (dimensionless)
β	mass transfer coefficient (m/hr)
Δ	sign of difference
∇	sign of nabla vector (m^{-1})
ν	stoichiometric coefficient
ρ	density (kg/m^3)
ω	transfer surface area (m^2/m^3)

Indices

lower:

A refers to component "A"

A^o is the initial value of component "A"

A^* is the equilibrium value of component "A"

upper:

α sign of one phase

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РЕЗЮМЕ

Современный труд инженера химика сегодня уже потребует, чтобы ему были ясны и транспортные явления, сопровождающие химические или физические изменения, которые протекают в отдельных элементах процессов.

Несколько лет тому назад начались студии, целью которых являлась разработка метода, пригодного для моделирования нефтепромышленных и нефтехимических элементов процессов, производственных процессов и установок, исходя из уже известных теоретических основ по реакторной технике.