Bulletin PV (Bratislava) Roč. 30 (10), 1991, č. 1—2, s. 125—142

# System of nomographic charts used for the control of industrial process of non-isothermic catalytic triacylglycerol hydrogenation

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Abstract. The mathematical model elaborated in the form of two differential equations enabling in the simulation SIKOS language and by the method of numerical integration by Runge and Kutt of the 4th order optimization of the industrial non-isothermic process of partial catalytic triacylglycerol hydrogenation has been transformed into the system of alignment charts. Under the conditions of microprocessor non-controlled technologies charts remain the simplest checking and control method even at present. Due to their material modesty and availability they have a relatively highest expressive and predictive value. Due to the simplicity of the use and convenient accuracy the charts can be part of every technological equipment. The paper presents the system of 5 alignment charts, describes their construction and examples of their application, which can be satisfactorily substituted under the condition of industrial practice by the computer simulations of chosen or looked for optimum conditions of ten technological parameters of the non-isothermic process of catalytic hydrogenation.

In the process of industrial production of solid fats is the process of partial catalytic hydrogenation (PCH) limit when considering both the capacity and qualitative aspects. With regard to heterogeneity of the reaction of the PCH system (solid catalyst — gaseous $H_2$ — liquid oil), and a relatively high number of influencing conditions of technological variables the reproducibility and checking of the PCH control remain exceptionally complex and demanding also at present. Every component of the above specified system, as well as the whole heterogeneous system have their optima at specified temperatures, pressures, concentrations, purity, types of raw materials and the quality of preliminary refining. These conditions determine whether the PCH reaction takes place in diffuse of transition sphere, eventually which of the reaction types: additional,

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isomerization or pre-esterification will dominate. The final result will change all resulting physical, chemical and biological properties of the solidified product. Fundamental knowledge of catalytic hydrogenation of triacylglycerol fats and oils, as well as their technologies are presented in the monograph by Bailey [1] and Ullrich [2]. Therefore, more operative checking or control of the PCH process required.

With regard to the needs of the systematic checking of the PCH processes and its possibilities in the production practice which would be optimum from the aspects of simplicity, speed and accuracy specific charts or tables seem to be convenient. In fact, each non-cybernitized equipment can be ensured and checked by them.

The chart characteristics, approach and their construction, as well as the possibilities of their application are presented in the monograph by Danielová and Daniel [3]. A survey of charts elaborated till now for the field of triacylglycerols is shown elsewhere [4] including also a nomogram for the determination of iodine number from the results of the fatty acid analysis.

The combined chart for determination of 8 most important physico-chemical variables of fats and oils based on a single GLC analysis is described in [5].

The charts and tables as aids for the determination of selectivity of solidified fats eventually tables for reading-off the content of *trans*-isomers in them, which were constructed and summarized for this purpose, and based on elaborated computation programs, are presented for the first time in [6].

The mathematical model describing the non-isothermic process of industrial PCH, as well as resulting computation program for the possibility of simulation of all PCH conditions to advance chosen iodine number (eventually melting temperature), or reaction time, is presented in [7—9]. Otherwise, the possibilities of mathematical modelling of the process (isotherm) of PCH are considered in [10—12].

Transformation of the above-mentioned relations of the PCH checking into the system of easily and readily applicable charts has been considered in this paper.

## Experimental

1. Representation of sum relation using the alignment chart

1.1. Dependence of three variables

$$F(u) + G(v) = H(z), \tag{1}$$

where $F$ is the function of variable $u$, $G$ is the function of variable $v$ and $H$ is the function of variable $z$, can be represented by an alignment chart with three mutually parallel scales on supporting straight lines.

Representing equations in the coordinate system of $(0, x, y)$ are as follows:

$$x_1 = 0, \qquad y_1 = m_1 F(u), \tag{2a}$$

$$x_2 = d_1, \qquad y_2 = m_2 G(v), \tag{2b}$$

$$x_3 = d_2, \qquad y_3 = m_3 H(z). \tag{2c}$$

Modules $m_1$, $m_2$, $d_1$ can be choiced and then modules $m_3$, $d_2$ are given by equations

$$d_2 = d_1 \frac{m_1}{m_1 + m_2} \qquad m_3 = \frac{m_1 m_2}{m_1 + m_2}. \tag{3a, b}$$

1.2. Dependence of four variables

$$F(u) + G(v) = H(z) + J(w) \tag{4}$$

can be divided into two partial relation by introducing the auxiliary variable $s$

$$F(u) + G(v) = s, \tag{5a}$$

$$H(z) + J(w) = s. \tag{5b}$$

Equations (5a) and (5b) represent simple alignment charts, as was shown above. Both charts are then combined and so form the so-called combined alignment chart. Combination of the 2 alignment charts is carried out in such a way that the support of the auxiliary scale $s$ in the first chart and in the second chart are fused (the two pairs of corresponding points on them are made identical), which means that the auxiliary scale $s$ must have the same representing equations, including the modules, in both partial charts.

The $s$ scale is not necessary, as the values of this auxiliary variable are not required for the solution of the represented dependence — it would be sufficient to draw only its support on which reading straight lines of both partial charts intersect. However, in order to remember better the point of intersection the support is usually provided by a regular scale with well-distinguished points remarkered by numbers 0, 1, 2, etc.

1.3. Similarly dependence of more than 4 variables (more than 4 functions of which each is a function of one variable only) can be represented; by introducing the auxiliary variables $s_1, s_2, \ldots, s_n$ the given relation is divided into several partial relation every containing only three variables — thus these partial relations will be represent by simple alignment charts which can be then com-

bined into one so-called combined alignment chart by means of the scales of auxiliary variables $s_1, s_2, \ldots, s_n$ as described above.

## 2. Construction of charts for relation among parameters appearing in the PCH process

### 2.1. Construction of the chart for the following relation:

$$j_k = Jj_0. \tag{6}$$

We logarithm the relation (6) and transcribe it into the form

$$\log j_k - \log j_0 = \log J. \tag{7}$$

By comparing Eq. (7) with Eq. (1) we get: $F = \log j_k$, $G = -\log j_0$, $H = \log J$. Thus, the representing equations according to (2a—c) will be for chosen modules $m_1 = 50$ cm, $m_2 = 150$ cm and $d_1 = 18$ cm: $x_1 = 0$, $y_1 = 50$ cm . $\log j_k$, $x_2 = 18$ cm, $y_2 = -150$ cm . $\log j_0$, $x_3 = 4.5$ cm, $y_3 = 37.5$ cm . $\log J$.

### 2.2. Construction of the chart for the relations

$$t = \tau t, \tag{8}$$

$$B_p = b_p t^0. \tag{9}$$

We logarithm the relation (8) and transcribe it into the following form:

$$\log t^0 - \log t = -\log \tau. \tag{10}$$

By comparing Eq . (10) with Eq . (1) we get: $F = \log t^0$, $G = -\log t$, $H = -\log \tau$. Substituting this into the representation equations (2a—c) — if chosen modules are $m_1 = 15$ cm, $m_2 = 30$ cm, $d_1 = 18$ cm — we get: $x_1 = 0$, $y_1 = 15$ cm . $\log t^0$, $x_2 = 18$ cm, $y_2 = -30$ cm . $\log t$, $x_3 = 6$ cm, $y_3 = -10$ cm . $\log \tau$.

We work with Eq . (9) in a similar way; we logarithm (9) and transcribe it into the following form:

$$\log t^0 + \log b_p = \log B_p. \tag{11}$$

If comparing Eq . (11) with Eq . (1) we get: $F = \log t^0$, $G = \log b_p$, $H = \log B_p$; after their substitution into Eqs. (2a—c) — if modules are $m_1 = 15$ cm, $m_2 = 30$ cm, $d_1 = 18$ cm — we get the following represesntation equations: $x_1 = 0$, $y_1 = 15$ cm . $\log t^0$, $x_2 = 18$ cm, $y_2 = 30$ cm . $\log b_p$, $x_3 = 6$ cm, $y_3 = 10$ cm . $\log B_p$.

Both charts can be re-drawn so that we make identical the support of the scale of the variable $t^0$ appearing in both charts and in both cases was the same

representing equation; the scales for $\tau$ and $B_p$ have then the common support, as well as the scales for $\tau$ and $b_p$.

2.3. Construction of the chart for the following equation:

$$B_R = \frac{G_0 j_0 b_R}{t_V - t_E}, \tag{12}$$

where $t_E = 103°$ C.

We logarithm Eq. (12) and transcribe it into the form:

$$\log B_R + \log (t_V - t_E) = \log G_0 + \log j_0 = \log b_R. \tag{13}$$

By introduction of the auxiliary variables $s_1$ and $s_2$ Eq. (13) is divided into three partial relations

$$\log G_0 + s_1 = -\log j_0, \tag{14}$$

$$s_1 + s_2 = \log b_R, \tag{15}$$

$$s_2 - \log B_R = \log (t_V - t_E). \tag{16}$$

Then, Eqs. (14)—(16) are represented by three simple alignment charts which can be combined by means of the $s_1$ and $s_2$ scales. If the representing equations for all three partial charts are expressed relatively to the initial point of the first chart, then after chosing proper modules all representing equations for the total combined alignment chart can be written in the following form: $x_1 = 0$, $y_1 = 400$ cm . $\log G_0$, $x_2 = 10$ cm, $y_2 = 90$ cm . $s_1$, $x_3 = 8.16$ cm, $y_3 = -73.47$ cm . $\log j_0$, $x_4 = 20$ cm, $y_4 = 30$ cm . $s_2$, $x_5 = 17.5$ cm, $y_5 = 22.5$ cm . $\log b_R$, $x_6 = 35$ cm, $y_6 = -15$ cm . $\log B_R$, $x_7 = 30$ cm, $y_7 = 10$ cm . $\log (t_V - t_E)$.

2.4. Construction of the chart for relation

$$t^0 = \frac{1}{pkw(t_V - t_E)}, \tag{17}$$

where $t_E = 103°$ C is performed similarly as in the previous case.

We logarithm Eq. (17) and transcribe it into the following form:

$$\log t^0 = -\log p - \log k - \log w - \log (t_V - t_E). \tag{18}$$

By introducing the auxiliary variables $s_1$ and $s_2$ we divide Eq. (18) into three partial relations:

$$\log p + s_1 = -\log k, \tag{19}$$

$$s_1 + s_2 = \log w, \tag{20}$$

$$s_2 + \log t^0 = -\log(t_V - t_E). \quad (21)$$

Relations (19—21) can be represented by three simple alignment charts combined by the use of the $s_1$ and $s_2$ scales.

After chosing the proper modules all representing equations for the total combined chart can be written in the following form: $x_1 = 0$, $y_1 = 30$ cm . $\log p$, $x_2 = 10$ cm, $y_2 = 30$ cm . $s_1$, $x_3 = 5$ cm, $y_3 = -15$ cm . $\log k$, $x_4 = 20$ cm, $y_4 = 30$ cm . $s_2$, $x_5 = 15$ cm, $y_5 = 15$ cm . $\log w$, $x_6 = 35$ cm, $y_6 = 15$ cm . $\log t^0$, $x_7 = 30$ cm, $y_7 = -10$ cm . $\log(t_V - t_E)$.

## Results and discussion

Heterogeneity, quantity of influenced variables conditioning the complexity of reproducibility and PCH process production are demonstrated in Scheme 1.

The charts for checking, simulation, eventually optimization works under the conditions of the industrial process of partial catalytic hydrogenation being

Partial catalytic hydrogenation heterogeneous

| A. Liquid phase Oil | B. Gaseous Hydrogen | C. Solid Catalyst | D. Technological conditions |
|---|---|---|---|
| 1. Type of oil | 1. Purity % | 1. Metal | 1. Temperature |
| (i) easily hydrog. | 2. Soluble quantity | 2. Carrier | 2. Pressure |
| (ii) medium hydrog. | | 3. Activity | 3. Mixing efficiency |
| | | 4. Selectivity | |
| (iii) difficult to hydrog. | 3. Way of circul. | 5. % of metal | 4. Geometry — reactor hydrodynamics |
| 2. Degree of prerefining | | 6. % of sulphur (inhibitor) | |
| 3. Main unsaturated fatty acids | | | |
| 4. % of S-inhibitors | | | |

These variables influence

I. Hydrogenation rate;
II. Course of hydrogenation: (a) selective,
(b) non-selective;
III. Final properties: (a) chemical,
(b) physical,
(c) biological.

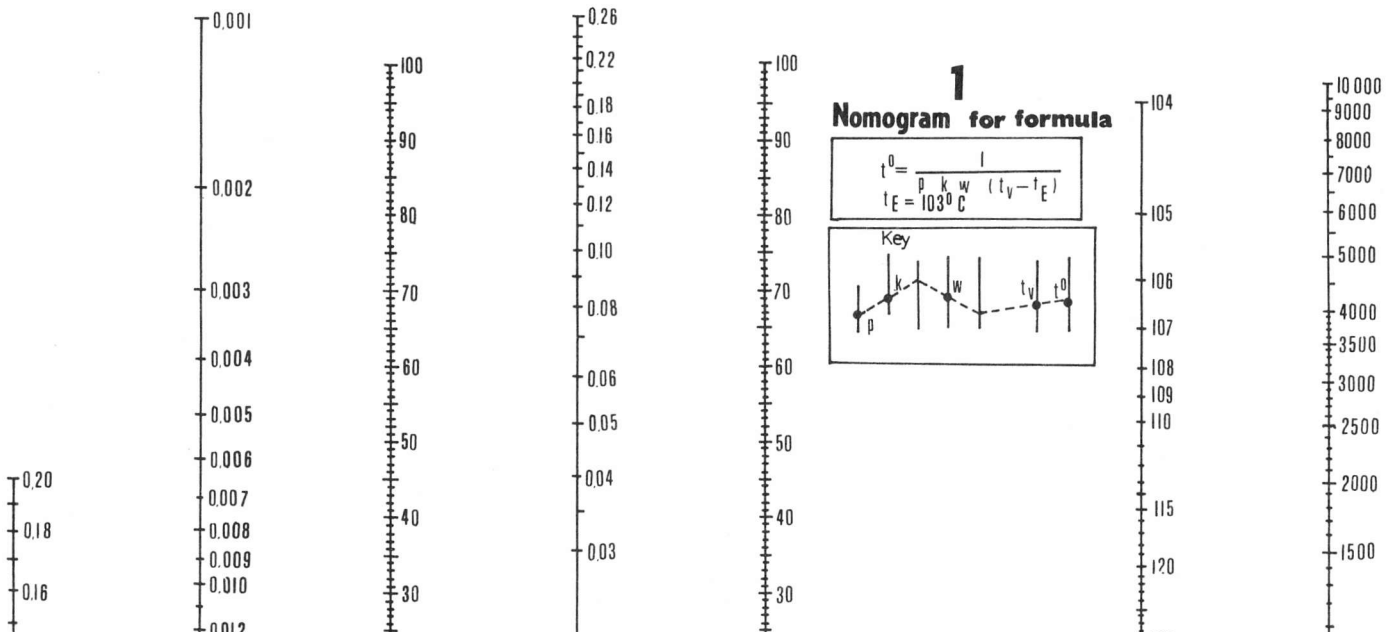
Scheme 1. Illustration of operational and technological effects and variables of the non-isothermic process of the industrial partial catalytic hydrogenation of triacylglycerol fats and oils.

carried out under the conditions described in the section Experimental and are shown in Figs. 1 to 3. The chart 1 represents $t^0 = 1/(\text{pkw}\,(t_V - 103))$, the chart $2\,B_R = G_0 j_0 b_R (t_V - 103)$, the chart $3\,t = t^0 \tau$ and $B_p = t^0 b_p$, the chart $4\,j_k = j_0 J$. These charts enable to find the triples, or the groups of five values satisfying the considered relations.

The way and the process of the application of each chart for the determination of the corresponding PCH values in dependence on the chosen technological-starting conditions is pre-labelled with a key.

It is evident from charts 1 to 4 that they combine all determining parameters considered in the conjunction with the PCH process. That means those whose chosen or random changes have an immediate impact on the resulting physical, chemical, or biological changes and properties of the final hydrogenation reaction product. Due to that, the presented charts offer the possibility of a relatively high number of selections and combinations of the initial reaction conditions with the possibility of direct and fast reading-off of corresponding and looked for resulting data which were chosen as the decisive ones, e. g. the period of a hydrogenation reaction, or the final value of the reaction degree, i. e. iodine number. At the same time, also a reverse process is possible, e. g. in the case of the need to find out all technological conditions which would be adequate to the advance chosen iodine number, or to the advance determined period of PCH duration.

In contrast to other checking systems, methods or instrumentation, the use of the charts is so simple that it does not require any special knowledge of the worker using them. This is the main importance and aim as thus optimization, control and checking of the PCH process can be systematic and permanent. Due to that it will be possible to ensure an increased reproducibility of not only the PCH process itself, but also reproducibility of the resulting physical, chemical and biological properties of solidified fats and all food fats made from them. Moreover, such aids are exceptionally efficient for getting large sets of exact results in the field of PCH. Their time evaluation is positively projected into the field of the basic research, too. The topical relevance of such needs was supported also by some our previous papers published in Bulletin of Foodstuff Industry (Bratislava) in 1982—1985. Currently, the industrial PCH process is checked and controlled only on the empiric basis. The only one practical checking value is the melting temperature of a sample product without detailed knowledge of its relationship to the technological conditions of the hydrogenation reaction. Elaborated mathematical model of the PCH process which is at present almost complete according to the relationships and observed parameters, is much more progressive for the given intentions and very operative in the graphical interpretations, and suitable for the users' conditions of the everyday practice.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Nomogram for formula
$t^0 = \frac{1}{\frac{p}{103^0\,C} \; k \; w \; (t_v - t_E)}$
$t_E$
Key
p
k
w
$t_v$
$t^0$
104
105
106
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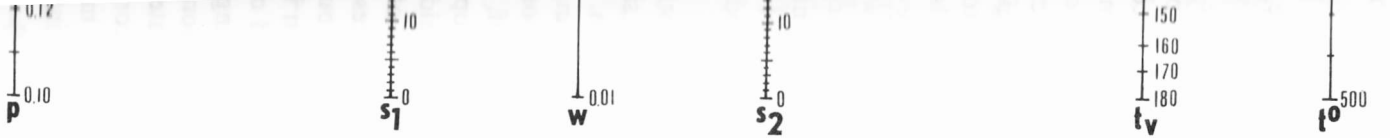
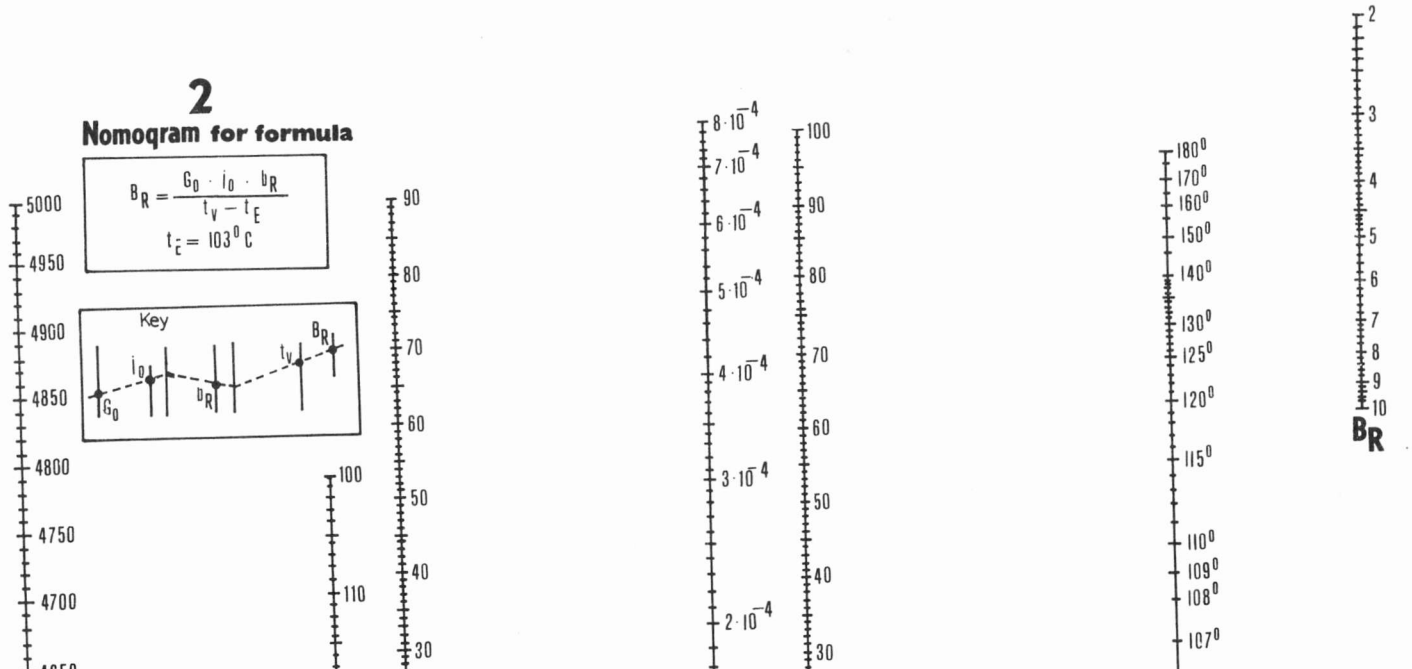



Fig. 1. Nomographic Chart (1) for reading the time unit $t^0$ in the concrete technological process of partial catalytic hydrogenation.



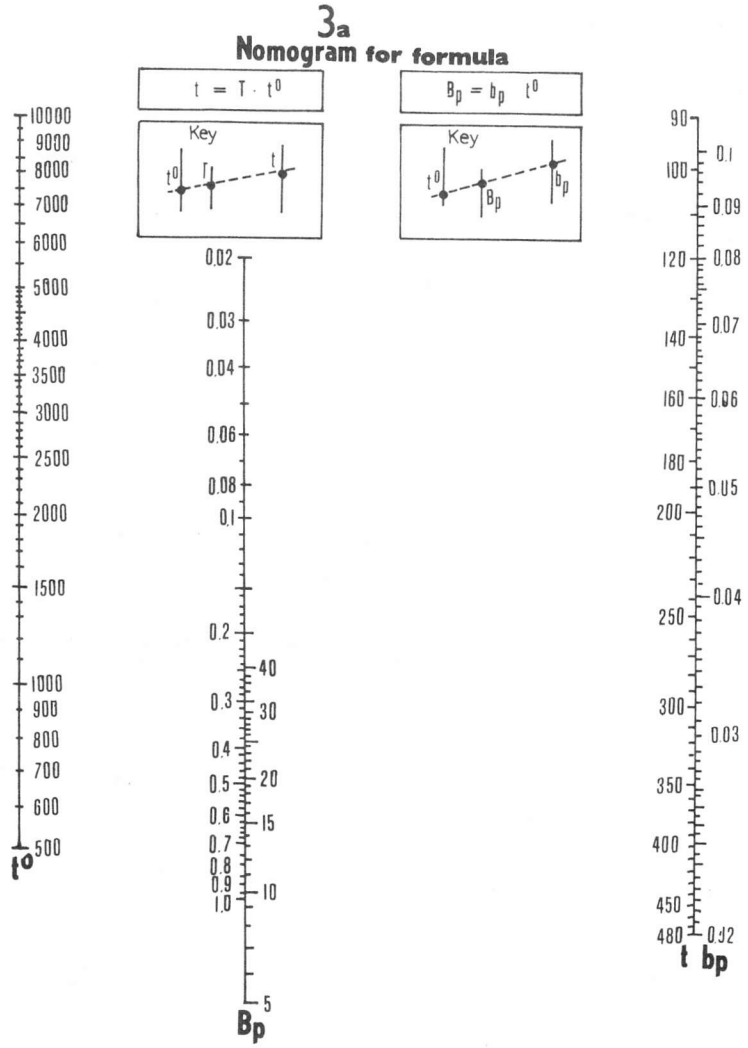



Fig. 3a. Nomographic Chart (3) for reading the dimensionless value of the $B_P$ parameter in the $b_P$ releations, event. heat exchange between the oil fill and outside medium of the hydrogenation reactor.

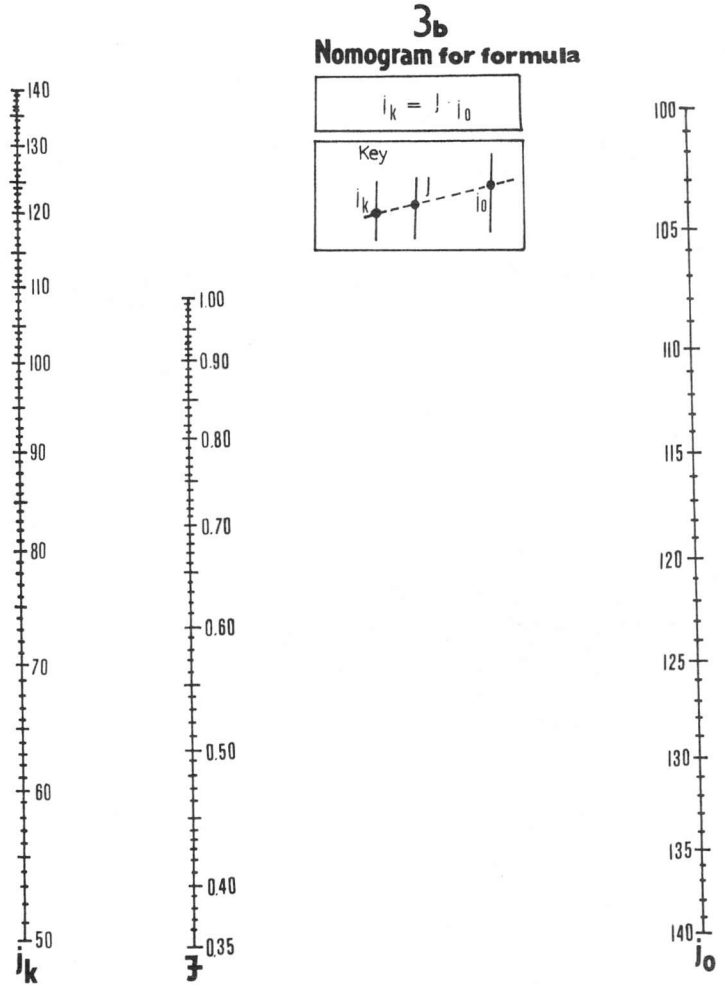



Fig. 3b. Nomographic Chart (4) for reading the final value of the iodine number corresponding to the given (chosen) conditions of the catalyzed hydrogenation of triacylglycerol oil.

Moreover, the original mathematical PCH model involves — along with the possibility of determination — changes in iodine number, period of PCH duration, also depending changes of refractive indices, melting temperatures and catalyst activity.

The checking simulation and optimization, as well as reproducibility of PCH will become exceptionally efficient by incorporation of the latter characteristics of non-isothermic PCH process into elaborated and presented chart conception.

The following two examples show how to use the above-mentioned alignment chart for real applications and processes.

Example 2 includes also co-application of chart 5 (Fig. 4). At the same time, it is an example that the whole conception of following PCH can be realized only on the base of reading the charts. However, with regard of these needs the originally elaborated system of differential equations [6] in their dimensionless form [7], i. e.:

$$\mathrm{d}J/\mathrm{d}T = -TJ \qquad J(T_0) = 1 \tag{22}$$

$$\mathrm{d}T/\mathrm{d}\tau = B_\mathrm{R}TJ + B_\mathrm{P}1 = T$$

$$T(\tau) = T_0 \tag{23}$$

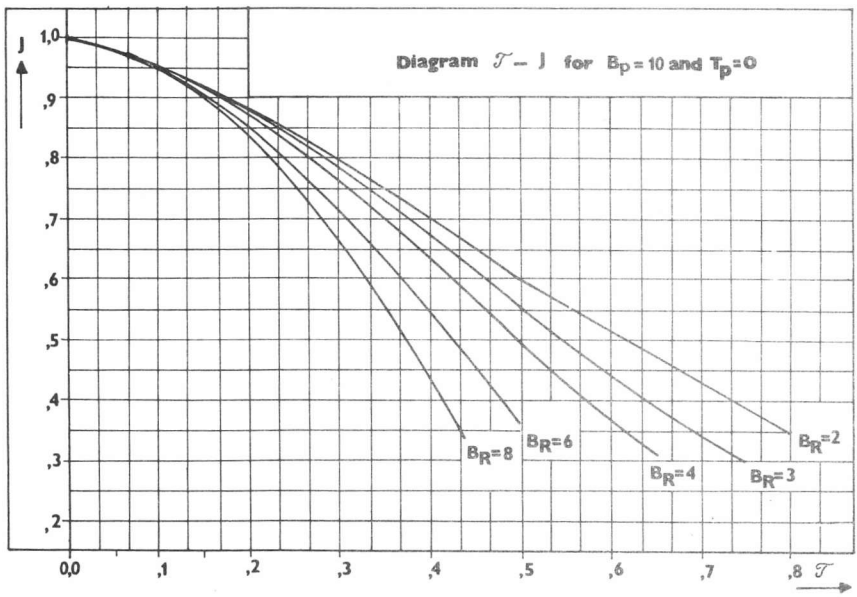



Fig. 4. Nomographic Chart (5) of the $\tau - J$ dependence for the possibility to read the value of the time interval of hydrogenation reaction $\tau_k$ using the $B_R$ parameter in the chart 2.

was solved numerically (as there is no analytical solution of this system know) by means of a simulation program called HYDOPT (hydrogenation optimization) in the SIKOS language (in the software of the SIEMENS 4004/150-ÚVT UK digital computer) using the integration method by Runge and Kutt of the 4th order.

Results of simulations illustrated then graphically, provide a new independent set of charts in the forms $\tau - J$ and $\tau - T$ at the following parameter values: $B_R = 2, 3, 4, 6, 8$. $B_P = 5, 10, 20, 40$ and $T = 0$. The charts presented in this paper, i. e. 1—4 in Fig. 1—3 can be completed by the system of these new charts, but this is subject discussed in another paper [13]. Their summary for the final use enables checking, simulation, control or optimization of the industrial process of partial catalytic hydrogenation based only on the use and reading of the diagrams.

Methods how to use the charts for dimensionless dependences. Chart indicating

N-1 chart for $\tau^0 = 1/(pkw(t_V - 103))$,
N-2 chart for $B_R = G_0 j_0 b_R (t_V - 103)$,
N-3 chart for $\tau = t^0 . T$ and $B_P = \tau b_P$,
N-4 chart for $j_k = j_0 J$.

## Symbols

$b_p$ — rate constant of the process of exchange, temperature between the charge and outer medium taking place without hydrogenation reaction, $min^{-1}$

$B_P$ — rate constant $b_p$ in the dimensionless form

$b_R$ — increase in the temperature of the reaction system (autoclave with a charge) caused by the decrease in iodine number of a unit quantity of oil by a unit at adiabatic hydrogenation, i. e. without heat exchange with environment
K (kg of oil)$^{-1}$ (unit of iodine number)$^{-1}$

$B_R$ — dimensionless form of the $b_R$ parameter

$G_0$ — quantity of oil in the autoclave, kg

$j$ — iodine number (IN) of oil, (iodine number unit)

$J$ — iodine number of oil, dimensionless

$k$ — parameter analogous with the frequency factor, in the Arrhenius equation for the rate constant thermal dependence of a chemical reaction
$K^{-1}$ $MPa^{-1}$ (Ni kg(100 kg of oil)$^{-1}$ $min^{-1}$

$p$ — hydrogen pressure in the autoclave, MPa
$t_v$ — efficient temperature of heat carrying medium, °C
$w$ — Ni concentration in oil, (Ni kg(100 kg of oil)$^{-1}$
$\tau_k$ — period of boiling (hydrogenation itself), min
$T_k$ — dimensionless for of $\tau_k$
$\tau^0$ — "new" time unit, i.e. time unit characterized for the concrete technological regime, min

Indices (lower)
0 — initial state
k — final state

1. Determination of the PCH duration (Problem 1)

Given:

— technological conditions: $k$, $p$, $w$, $j_0$, $G_0$, $t_v$, $b_R$, $b_P$;
— required degree of hydrogenation: $j_K$.

To be determined:

— time interval of boil duration: $\tau_k$.

Determination procedure:

1. Determine $\tau^0$ using the chart N-1;
2. Determine $B_R$ using the chart N-2;
3. Determine $B_P$ using the chart N-3;
4. Determine $J_K$ using the chart N-4;
5. Determine $\tau_k$ using the graph $\tau - J$
6. Determine $\tau_k$ using the chart N-3.

Example

Given:

$k$ = 0.0119 (min MPa % Ni K)$^{-1}$
$p$ = 0.12 MPa
$w$ = 0.042 % Ni
$j_0$ = 126.5 u IN
$G_0$ = 4905 kg
$t_v$ = 143° C
$b_R$ = $3.32 \times 10^{-4}$ K (kg oil)$^{-1}$ (u IN)$^{-1}$
$b_p$ = 0.0575 min$^{-1}$
$j_K$ = 75.5 u IN

## Determination

1. Using the chart N-1 for the given values of $p$, $k$, $w$, $t_v$ determine $\tau^0 = 430$ min.
2. Using the chart N-2 for the given values of $G_0$, $j_0$, $t_v$, $b_R$ determine $\beta_R = 5.2$.
3. Using the chart N-3 for the given value of $b_p$ and determined value $\tau^0$ (see the 1st step) determine $B_p = 25$.
4. Using the chart N-4 for the given values of $j_0$, $j_k$ determine $J_K = 0.60$.
5. Using the graph $\tau - J$ for the given values of $B_R$ (see the 2nd step), $B_P$ (see the 3rd step) and $J_K$ (see the 4th step), event. for the values close to the defined ones find $\tau_K = 0.34$.
6. Using the chart N-3 for the given values $\tau^0$ (see the 1st step) and $J_K$ (see the 5th step) determine $\tau_K = 150$ min

## Result

The period of boiling during which the iodine number (IN) decreases from 126.6 to 75.5 units under the given technological conditions is 150 min.

2. Determination of the hydrogenation degree (Problem 2)

Given:

— technological conditions: $k$, $p$, $w$, $j_0$, $G_0$, $t_v$, $b_R$, $b_p$;
— period of boiling: $\tau_K$.

To be determined:

— hydrogenation degree: $j_K$.

Determination process:

1. Determine $\tau^0$ using the chart N-1;
2. Determine $\beta_R$ using the chart N-2;
3. Determine $\beta_P$ using the chart N-3;
4. Determine $\tau_K$ using the chart N-3;
5. Determine $J_K$ using the graph $\tau - J$;
6. Determine $j_K$ using the chart N-4.

Note:

The steps 1 and 3 are identical with those of the problem 1.

## Example

Given:

$k = 0.0119$ (min MPa % Ni K)$^{-1}$
$p = 0.12$ MPa
$w = 0.042$ % Ni
$j_0 = 126.5$ u IN
$G_0 = 4905$ kg
$t_v = 143°$ C
$b_R = 3.32 \times 10^{-4}$ K (kg oil)$^{-1}$ (u IN)$^{-1}$
$b_P = 0.0575$ min$^{-1}$
$\tau_k = 125$ min

## Determination

1. $\tau^0 = 430$ min (see role 1).
2. $B_R = 5.2$ (see role 1).
3. $B_P = 25$ (see role 1).
4. Using the chart N-3 for the given value of $\tau_k$ and for the determined value $\tau^0$ (see the 1st step) determine $\tau_k = 0.29$.
5. Using the graph $\tau - J$ for the determined values $R_R$ (see the 2nd step), $B_P$ (see the 3rd step) and $\tau_K$ (see the 4th step), or for values close to the determined ones find $J_k = 0.67$.
6. Using the chart N-4 for the given value $j_0$ and determined value $J_K$ (see the 5th step) find $j_K = 84$.

## Result

The value to which the iodine number is reduced after 125 minutes of hydrogenation under the given technological conditions is 84 units.

*Acknowledgement.* We would like to thank Ing. Dr. A. Daniel for his valuable advice and comments, as well as to Mrs. M. Bystrická and Mrs. V. Grmanová for their technical assistance.

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## Система номограмм для возможности регулирования промышленного процесса неизотермической каталитической гидрогенизации триацилглицеринов

Резюме

Математическая модель, разработанная в форме двух дифференциальных уравнений, позволяющая на симулирующем языке SIKOS и по методу численного интегрирования по Рунге и Куте 4 порядка, оптимизацию промышленного неизотермического процесса парциальной каталитической гидрогенизации триацилглицеринов, была преобразована в систему номограмм из выравненных точек. В условиях микропроцессами неуправляемых технологий номограммы являются и в нынешнее время самым простым контролем и руководящим методом. Своей материальной нетребовательностью и доступностью они располагают относительно наивысшим увольнительным значением и степенью предикции. Из-за несложности применения и удовлетворительной точности могут быть номограммы составной частью каждого технологическо-производственного оборудования. В работе приведена система 5-ти номограмм из выравненных точек, условия их конструкции и примеры конкретного применения, которые могут приемлемым образом заменять счетчиковые симуляции избранных или искомых оптимальных условий десяти технологических параметров неизотермического процесса каталитической гидрогенизации в условиях промышленной практики.

## Sústava nomogramov pre možnosti regulovania priemyselného procesu neizotermickej katalytickej hydrogenácie triacylglycerolov

Súhrn

Matematický model, vypracovaný vo forme dvoch diferenciálnych rovníc, umožňujúci v simulačnom jazyku SIKOS a metódou numerickej integrácie Rungeho a Kutta 4. poriadku optimalizovanie priemyselného neizotermického procesu parciálnej katalytickej hydrogenácie triacylglycerolov, bol pretransformovaný do sústavy spojnicových nomogramov. V podmienkach mikroprocesorovo neriadených technológií zostávajú nomogramy aj v súčasnosti najjednoduchšou kontrolnou a riadiacou metódou. Pri svojej materiálovej nenáročnosti a dostupnosti majú relatívne najvyššiu vypovedaciu hodnotu i stupeň predikcie. Nomogramy môžu byť pre jednoduchosť použitia a vyhovujúcu presnosť súčasťou každého technologicko-výrobného zariadenia. V práci sa uvádza sústava piatich spojnicových nomogramov, podmienky ich konštrukcie i príklady konkrétneho použitia, ktoré môžu počítačové simulácie zvolených či hľadaných optimálnych podmienok desiatich technologických parametrov neizotermického procesu katalytickej hydrogenácie v podmienkach priemyselnej praxe prijateľne nahradzovať.