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MODELLING THE NATURAL GAS TRANSPORTATION PROCESS USING THE FACTORIAL EXPERIMENT METHOD

The research presented in detail in this scientific paper refers to the modelling of process parameters for natural gas transmission in a centralized system. The method of the factorial experiment was used to model some parameters considered to be vital, namely the gas temperature, the air temperature as well as a certain correction factor on the flow delivered to the population. The study was conducted by accessing information provided by a regulation-measurement station that delivers gas to an important locality in a locality in central Romania. Experimental data collected over 24 hours on a summer day but also on a winter day were used. After a previous study with classical experimental research methods, the factorial experiment was used, which allows the delivery of much more detailed information and the graphical representations are much more precise and detailed, in other words, relevant and useful conclusions can be obtained on objective studied in the research approached.

Keywords: Design of Experiment; natural gas; experimental research; active experiment; quality and quality management

1. Introduction

The company in which the research was carried out operates in the natural gas industry and specializes in natural gas distribution services. This company provides the distribution service for natural gas consumers from over 1.000 localities in urban and rural areas, who are served by a distribution network of 18.500 kilometers and covering an area of approx. 122.600 km² from the northern part of the country. The company is thus among the most important natural gas distributors in Romania.

The fundamental objective of the research based on the samples taken from the populations is to extract the maximum information on the studied population, based on the data provided by the sample, and in general this implies that based on the sample to deduce the frequency distribution in the whole population for the studied characteristic [1].

The purpose of statistical analysis of an experiment is to determine the extent to which data can provide information about the true outcome [2]. In such problems the sample is concrete, but the population can also be hypothetical. In this case, it is the population of all the determinations that could be made, under the same conditions, if the necessary means and time were available.

2. Research methodology

In experimental modelling, as a rule, a certain form of the mathematical model is accepted, which is considered to best approximate the real model, following the development of the experiment to provide the data necessary to explain the model [3].

For commercial measurement of the amount of natural gas, only commercially certified and technically approved measuring instruments approved in accordance with the current metrological legislation are used [4,5].

The natural gas regulation and regulation-measurement stations are installed in their own constructions.

The control, regulation-measuring, measuring stations are mounted in niches, cabins or directly in the installation for use by technical units [6-8].

The measuring systems will be chosen and positioned in accordance with the requirements of the norms in force [9-10].

The type, location and installation conditions of the metering device shall be in accordance with the manufacturer's specifications [11-16].

To analyze the influence of gas temperature, air temperature, gas pressure and correction factor (input data), these parameters

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were monitored and recorded for 24 hours [17-20]. The flow to the population was read on a turbine meter every hour, starting at 1:00 and ending at 24:00.

The study was conducted for one day in the warm season, summer (10.06.2021) and for one day in the cold season, winter (11.12.2021) using the factorial experimentation strategy.

3. Measurements and interpretation of results

TABLE 1 presents the experimental data: inlet values at the location of the regulation-measurement station – summer, respectively gas temperature, natural gas inlet pressure circulated through the main transport pipelines; the volume of natural gas delivered to the population, respectively the corrected volume for each hour from 1:00 to 24:00 (hourly flow).

TABLE 1

Experimental data collected in the summer

Hour	T_gas [C°]	T_air [C°]	P_entry [bar]	K_corection	Q_corected [m^3/h]
1	14	18	12.6	12.775	958
2	13	17	12	12.198	938
3	13	16	11.6	11.781	597
4	13	15	11.3	11.469	577
5	12	14	11.5	11.722	640
6	12	14	11.7	11.93	1143
7	12	15	11.8	12.035	1888
8	14	16	11.9	12.048	2848
9	14	17	11.9	12.048	2392
10	15	19	12	12.106	2580
11	17	20	12.1	12.118	2257
12	18	22	12.3	12.277	1971
13	18	23	12.5	12.481	2155
14	17	25	12.7	12.733	1969
15	17	25	12.9	12.939	2397
16	18	26	12	11.97	1698
17	20	26	11.4	11.275	1711
18	23	26	11	10.753	1707
19	18	24	10.8	10.749	1728
20	17	23	10.5	10.483	1698
21	16	22	10.4	10.419	2014
22	15	20	10.2	10.253	1835
23	15	19	10.2	10.253	1541
24	15	18	10.2	10.253	1440

TABLE 2 presents the experimental data: inlet values at the location of the regulation-measurement station – winter, respectively gas temperature, natural gas inlet pressure circulated through the main transport pipelines; atmospheric temperature at the location of the regulation-measuring station; the correction factor (conversion) and the output value of the volume of natural gas delivered to the population, respectively the corrected volume for each hour from 1:00-24:00 (hourly flow).

TABLE 2

Experimental data collected in the winter

Hour	T_gas [C°]	T_air [C°]	P_entry [bar]	K_corection	Q_corected [m^3/h]
1	5	–11	18.8	20.02	10608
2	5	–11	19	20.242	10608
3	5	–11	19	20.242	10730
4	4	–12	19.2	20.55	10722
5	4	–12	19.2	20.55	10910
6	4	–12	19.2	20.55	11398
7	4	–10	18.4	19.657	12837
8	4	–12	18.4	19.657	11499
9	4	–12	18.2	19.434	12281
10	4	–11	18.2	19.434	14399
11	4	–9	18.2	19.434	13631
12	4	–5	18.3	19.546	9774
13	5	–3	18.4	19.576	12461
14	6	–1	18.6	19.716	10634
15	6	0	18.8	19.937	10669
16	6	0	18.8	19.937	10171
17	5	–2	18.6	19.798	10895
18	5	–5	18.6	19.798	12026
19	4	–5	18.4	19.657	11872
20	4	–6	18.2	19.434	12585
21	4	–8	18.1	19.323	12650
22	4	–8	18.1	19.323	12420
23	4	–9	18.2	19.434	11770
24	5	–10	18.6	19.798	11129

A factorial experiment facilitates the implementation of 3D graphs that lead to accurately interpret the initial data and the corresponding conclusions obtained for the analyzed object.

The following are the most important graphics that can prompt relevant comments for use.

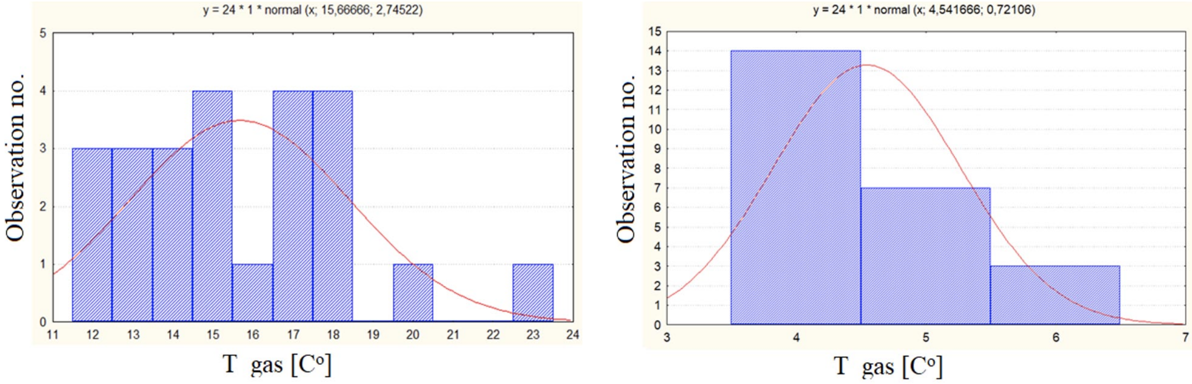
When processing the data in TABLES 1 and 2, an active-type software package was utilized, which is dedicated to statistical data processing, which makes it possible to implement 2D very accurately and efficiently and 3D graphics.

Data interpretation is performed for an objective function that correlates with two controllable parameters, so the resulting graphs allow to track the relation of the atmosphere temperature and the gas, the correction factor, and the pressure in the corrected hourly flow rate.

Based on the data set, first, the model of the distribution of each guideline and objective tasks was examined – a point is given in Figs 1-10.

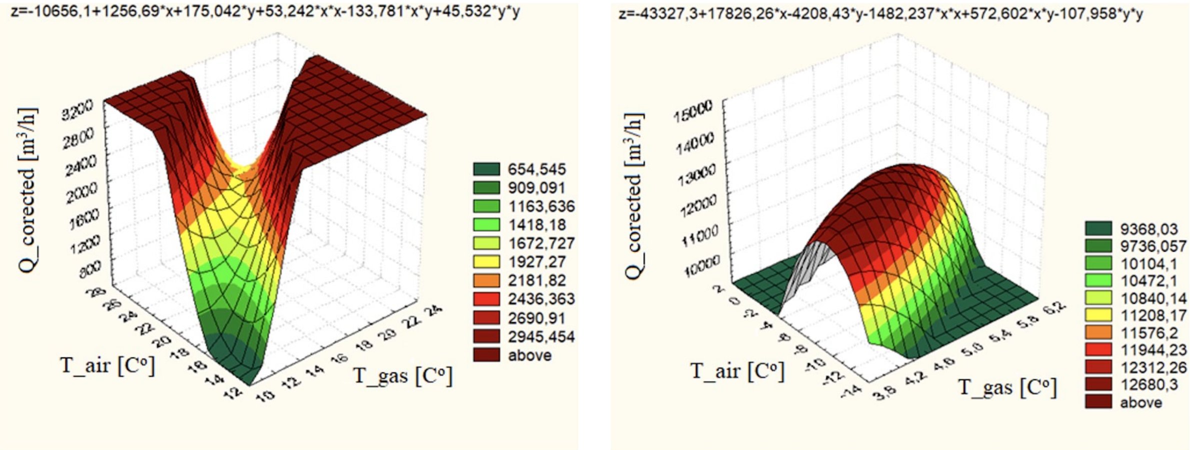
Interpreting the obtained results, one can notice a series of aspects related to the influence of the studied factors on the natural gas flow delivered to the population.

The first factor refers to atmospheric temperature, which, as can be seen from the graphs, affects the corrected flow rate and the gas temperature in summer, because in winter the temperature is controlled by heating natural gas with the help of a control station heaters bring it to the reference temperature.



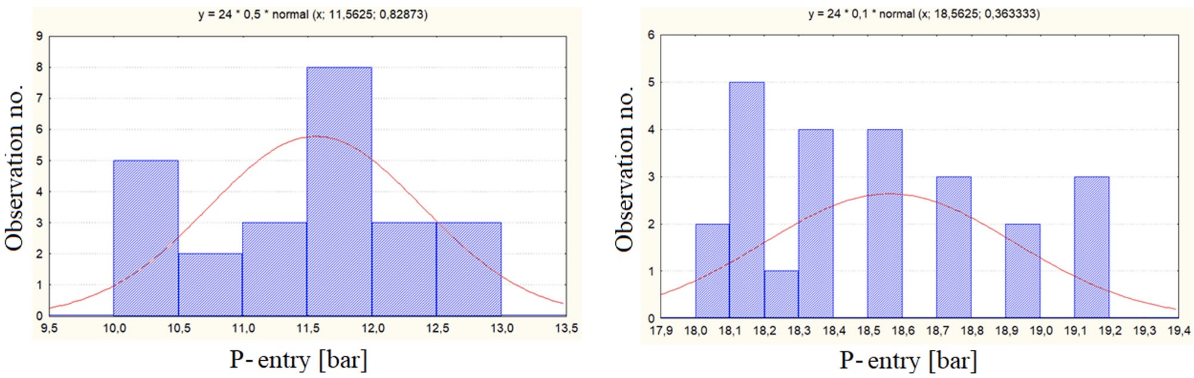
a) Summer b) Winter

Fig. 1. Gas temperature frequency distribution



a) Summer b) Winter

Fig. 2. Quadrant representation of the flow variation corrected for atmospheric temperature and gas temperature

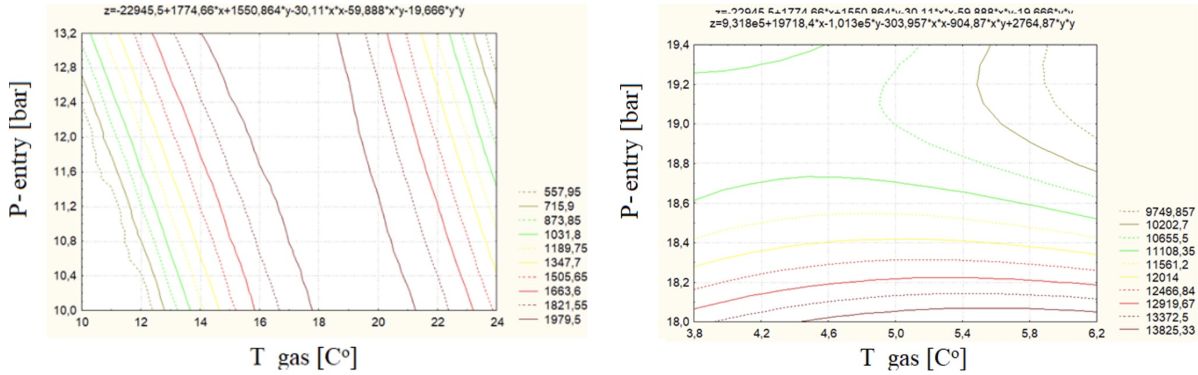


a) Summer b) Winter

Fig. 3. Inlet pressure frequency distribution

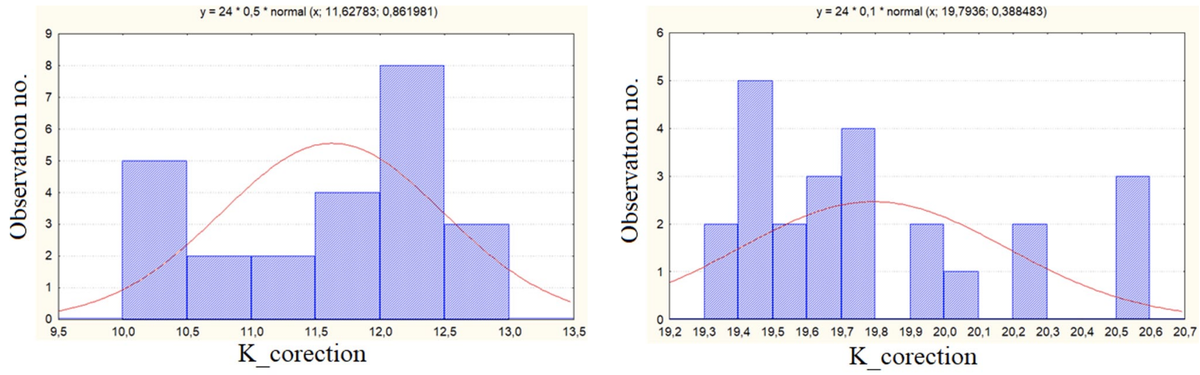
An approximate correction may show that its effect on flow correction is the same in both winter and summer because the facts include the adhesive supplied by the chemical (per chromatography bulletin) and the gas temperature and pressure. Regarding the inlet weight, this shows a large effect because the lower the inlet pressure is, the greater is the volume of the gas supplied.

Since during the distribution in summer no thermal expansion joints are used, but only for cooking, the amount of gas supplied is less than the volume in winter, although the correlation coefficient should be higher than this.



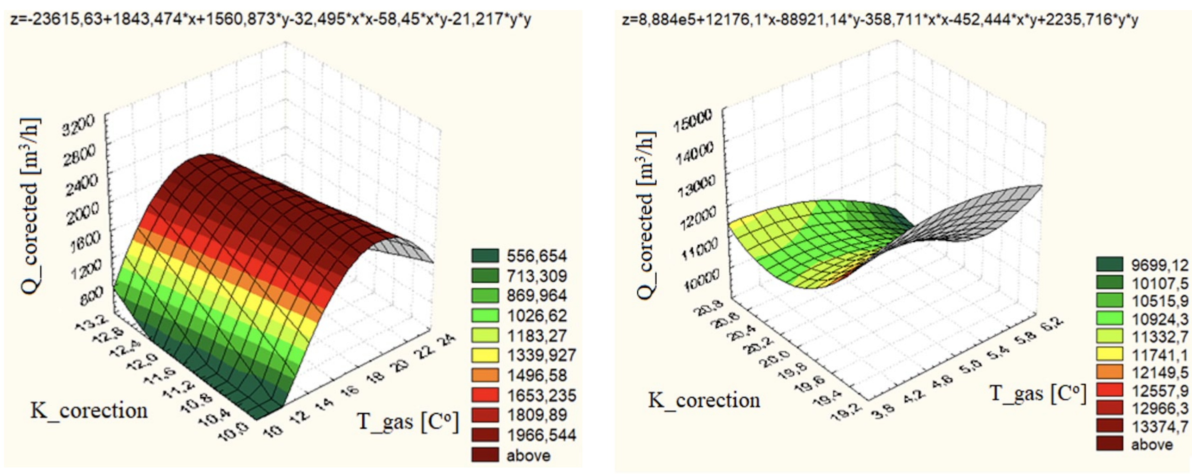
a) Summer b) Winter

Fig. 4. Section through the response area for the corrected hourly flow target function



a) Summer b) Winter

Fig. 5. Frequency distribution of the correction factor



a) Summer b) Winter

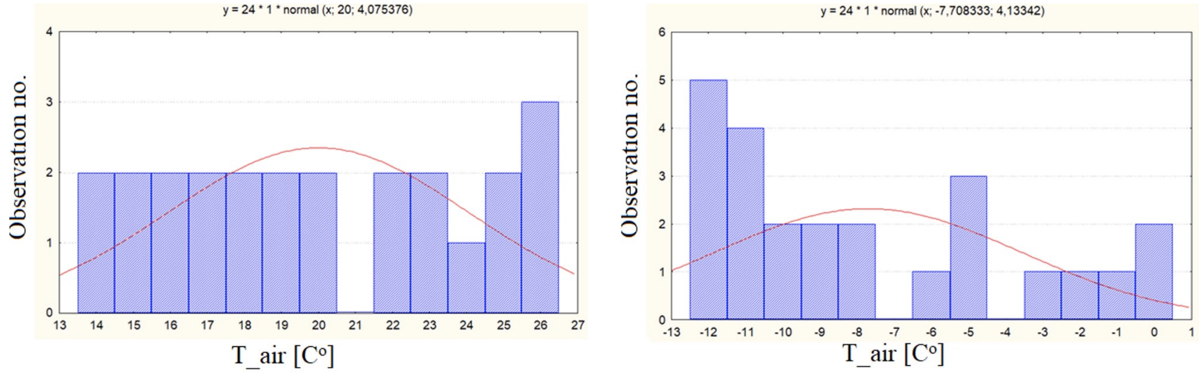
Fig. 6. Quadrant representation of the variation of the corrected flow rate according to the correction factor and the gas temperature

In this context, the research addressed an important and topical issue of modeling the process parameters for natural gas transportation in a centralized system.

Therefore, the obtained results were evaluated and discussed, these being accompanied by the evidence presented.

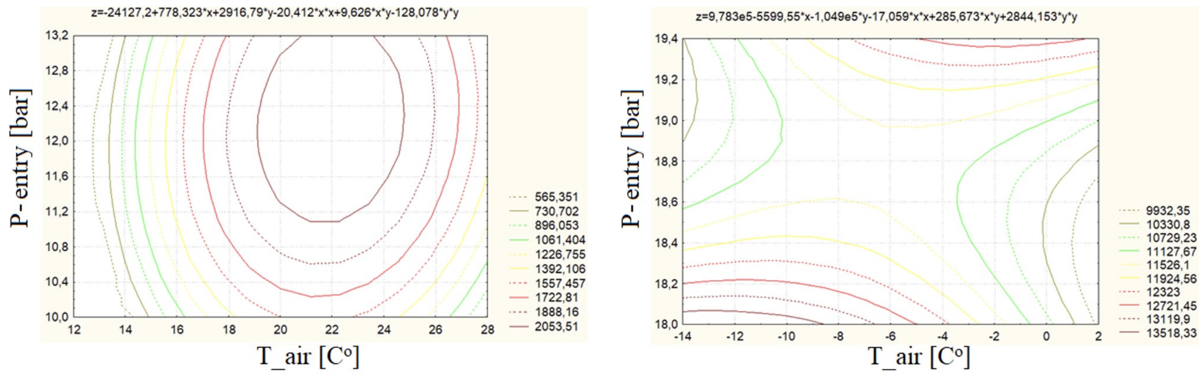
4. Conclusion

The sizing and equipment of the stations and of the regulation – measurement stations were made considering the flow parameters, their range of variation, as well as the quality of natural gas.



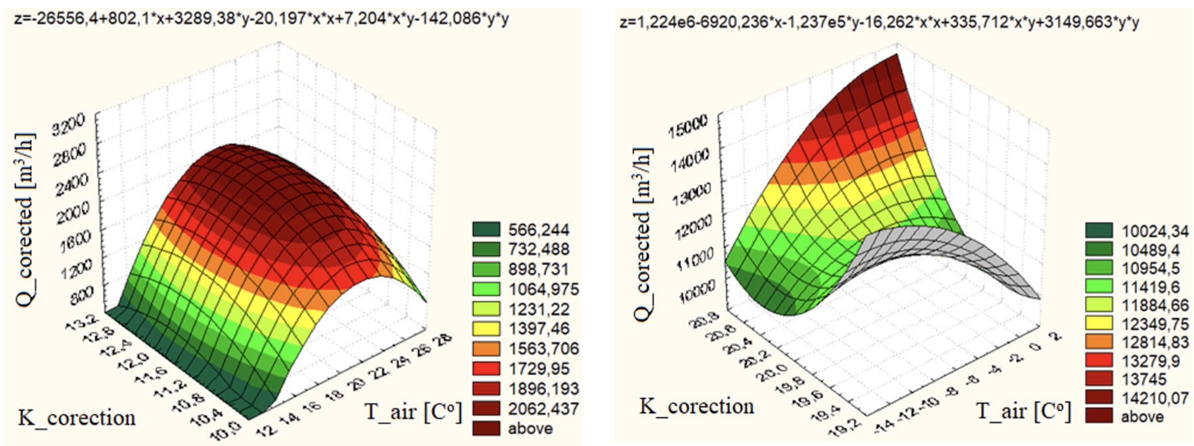
a) Summer b) Winter

Fig. 7. Atmospheric temperature frequency distribution



a) Summer b) Winter

Fig. 8. Section through the response area for the corrected hourly flow target function



a) Summer b) Winter

Fig. 9. Quadrant representation of the variation of the corrected flow depending on the atmospheric temperature and the correction factor

The measuring systems have been selected and maintained in accordance with the requirements of the applicable regulations.

For commercial purposes of natural gas measurement, only technically certified and approved metering devices will be used in accordance with applicable meteorological legislation.

With the agreement of a licensed natural gas distribution operator on the basis of the manufacturer's specifications, the type, place and conditions for installing the meter are determined by the designer.

It can be stated that the enunciation of the hypotheses underlying the elaboration of the mathematical models stated in the case of each spatial graph implies a good prior knowledge of the object under research, including the character of functional cause-effect relationships.

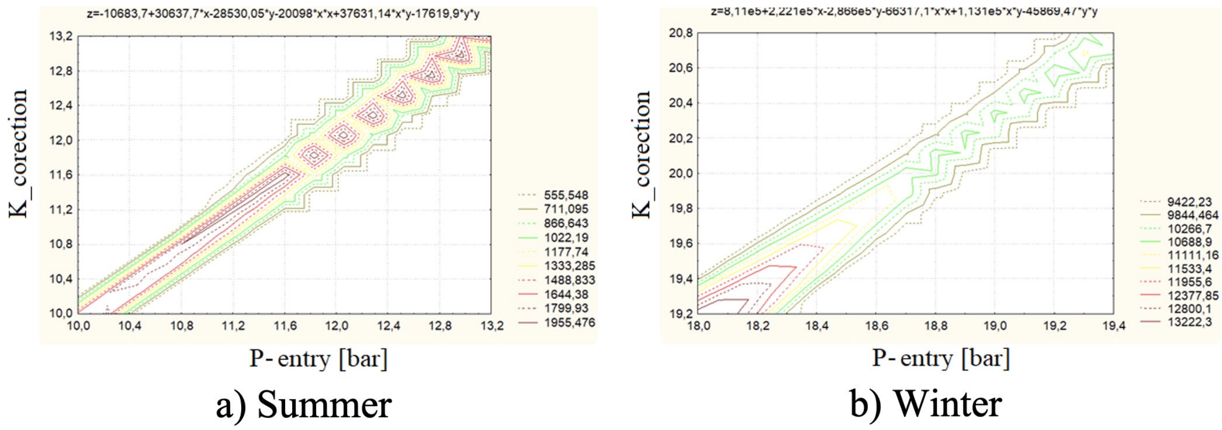


Fig. 10. Section through the response area for the corrected hourly flow target function

In the present situation, the analyzed systems are complex, having many influencing factors, of different physical-chemical nature; strong interactions between variables can be observed.

In the experimental modeling, the form of the mathematical model specified on the basis is accepted, considering that it approximates the real model best, following that the development of the experiment will provide the necessary data to explain the model.

Following the application of the approached factorial strategy, it was possible to progressively acquire information according to the experiments, with the possibility of making a minimum number of determinations to formulate conclusions.

Mathematical models were estimated with high accuracy in accordance with the established number of measurements.

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