

Using the CONVAL® software for the petrochemical plant control valves checking.

Case study

C. Patrascioiu, G. Stamatescu, C. Lazar

Abstract — In the paper there are presented the researches into field of the CONVAL® software using to control valve checking. There are presented the main facilities of the CONVAL® software, including the description of the used functions. The CONVAL® software has been used to plant refinery control valves checking. The results have been validated 87 % of the investigated control valves.

Keywords — control, control valve, CONVAL software, refinery.

I. INTRODUCTION

The control valves are the most important control elements of the control systems. A detailed presentation is showed in specializes literature [1, 2]. A new component of the control valves is represented by the software for the control valve design.

The CONVAL® software, developed by the Ruhr University of Bochum, is used to simulate or design of the control valve [3]. The structure of this software contains the following elements [4]:

- a) A thermodynamic database;
- b) A mathematical model of the control valve;
- c) An industrial control valve database.

The CONVAL® software has been used to design the control valves in many industrial applications. For example, Siemers describes the priorities concerning of the control valves as follow: safety and reliability, control quality, environmental aspects, trouble-free life cycles and lowest cost [5]. The first element of the control valve design is the geometry of the plant s pipes. A good knowledge of a pipe pressure and drop pressure and in the same time the knowledge of the characteristics of the pumps is necessary.

C. Patrascioiu is with the Petroleum-Gas University of Ploiesti, Romania. He is now with the Automatics, Computers & Electronic Department. (e-mail: cpatrascioiu@upg-ploiesti.ro).

G.Stamatescu is with the Politehnica University of Bucharesti, Romania. He is now with the Automatics and Industrial Informatics Department. (e-mail: grigore.stamatescu@upb.ro).

C. Lazar was with FIWA Company, Sibiu, Romania. He is branch manager of the Romanian branch. (e-mail: office.ro@fiwagroup.com).

To obtaining the optimum control valve parameters, Siemers defines seven steps of the control valve design [6]. In this operation, the Conval® software is used to select the better control valve for the input conditions and with the graphical support to analyze the inherent and the work characteristics.

Another problem solved by the CONVAL® software is the estimation of the static controllability index, there is implemented in 8th version of the software.

The paper presents the author's researches in the field of the industrial control valves simulation. The control valves that have been investigated belong to the Romanian refinery plant. The investigation has been focused to verify the control valves in the new operating conditions.

II. THE CONVAL® SOFTWARE

In 1985, a team of experienced engineers from the fields of instrumentation and control, chemical processes and machine building, as well as various other branches of industry, joined forces with software development experts. At the end of a development phase lasting four years, they were able to present the first results - christened CONVAL® 1.0 - at INTERKAMA '89 [7].

The CONVAL® software is destined to design or checking the chemical plant elements, such as: pipes, heat exchangers, pumps, valves and control valves. Each component of the previous list may be activated using a specific command. To activate the control valves design / check, the user will activate the Control Valve command.

This program is based on:

- IEC 60534 2 1-3 standard to calculate liquid flow rate;
- VDMA 24422 standard to calculate the sound level;
- IEC 60534 8-3 and IEC 60534 8-4 standard to calculate the gas flow rate.

The main window of the Control Valve CONVAL® menu is presented in figure 1. The structure menu if the Control Valve window is follow:

- a) *Medium* – the menu used to data specification of the fluid that circulates into control valve;
- b) *Pipeline* – the menu associated to pipes data, upstream and downstream of the control valve;
- c) *Control valve* – the configuration menu of the design control valve parameters;

d) *Noise calculation* – the configuration menu of the fluid flow noise calculation.

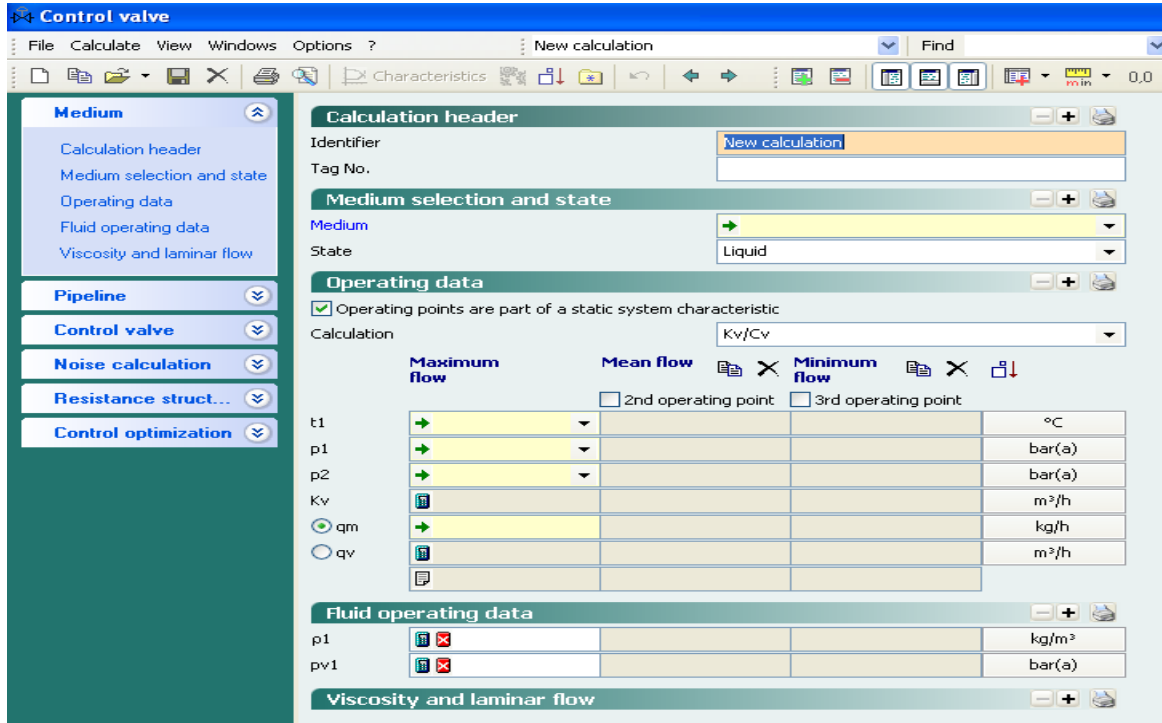


Fig 1 The *Control Valve CONVAL*® window.

All four Control Valve menus are the most used and for this reason there will be detailed in the next sections.

A. *The Medium menu*

In the Medium menu there are disposable five functions, as follow:

- 1) The *Calculation header* function has a obligatory character, there being destined to file specification (*Identifier*) and to name the control valve in the P&ID (*Tag No.*).
- 2) The *Medium Selection State* function specifies the fluid that circulates by the control valve. In this function exists the sub-function *Medium*, there is used to select the thermodynamic properties at thermodynamic data base. The *State* sub-function specifies the liquid or vapor fluid state.
- 3) In the *Operating data* function, the user must specify next information:
 - a) The calculated variable (*Calculation*), a variable selected from the list: demand flow module Kv/Cv ; mass flow rate q_m ; upstream pressure p_1 ; downstream pressure p_2 .
 - b) The operating point characteristics. These characteristics are dependent by the selected calculated variable. If the selected calculated is Kv/Cv , the operating point characteristics will be:
 - t_1 – the upstream temperature;
 - p_1 – the upstream pressure;
 - p_2 – the downstream pressure;
 - q_m or q_v – the mass or volume flow rate.

The user may define three operating points: first point is associated to minim flow rate, the second defines the nominal flow rate and the last point is represents the maximum flow rate.

- 4) *Fluid operating data* is the function used to calculate the fluid density (ρ_l) and the vapour pressure (p_{v1}), all properties being calculated in the upstream conditions. The calculus is made using the equilibrium equations and thermodynamic data of the CONVAL data base. If the user has better values, there may replace the calculated values.
- 5) The *Viscosity and laminar flow* function is used to determine the correction factor FR . This factor is calculated using the viscosity value and the Reynolds criterion. Viscosity is calculated with IEC 60534 standard. If the flow regime is turbulent, $Re > 100000$, the correction factor will be $FR = 1$.

B. *Pipeline menu*

The Pipeline menu contains the functions used to specify the pipes constructive characteristics. The functions are following:

- 1) The *Influence of fittings* function specifies the connection mode of the control valve to upstream and downstream pipe. The user may set the control valve nominal diameter with same pipe diameter. If this situation is not possible, the user must specify the following date:
 - a) *Flow coefficient of fittings*;

- b) *Piping geometric factor*, defined by the relation [6]

$$F_p = \left[1 + \frac{\sum K_i}{N_2} \left(\frac{C_v}{d^2} \right) \right]^{-0.5};$$

- c) *Valve modifier* for fittings.

- 2) The *Pipe downstream of valve* function is used to specify the pipe material and the pipe diameter. The CONVAL program has a data base which contains the pipe design information.

C. Control valve menu

The Control Valve menu is dedicated to select the calculated control valve from the produces data base. The Control valve menu has four functions, as follow:

- 1) The *Valve Selection* function is used to select:
 - a) *Valve manufacturer*;
 - b) *Series* of control valve;
 - c) *Valve selection*.
- 2) The *Valve data* function sets the user option of the next specifications:
 - a) *Size and pressure class*: Metric or ANSI.
 - b) *Valve type*, as follow: Globe valve, Rotary plug valve, Butterfly valve, Ball valve, Ball valve, Axial valve, Angle seat valve, Continuous globe valve, Diaphragm valve etc.
 - c) *Trim type*: Parabolic plug, V-port plug, Cage trim, Multihole plug and Seat-guided contoured plug.
 - d) *Flow direction* inside the control valve: FTO (fluid open), FTC (fluid close).
 - e) *Basic characteristic* of valve (intrinsic characteristic): Equal percentage, Linear, Modified and On/Off.

D. Noise Calculation menu

The Noise Calculation menu contains three functions for the control valve noise calculation. The functions implemented in this menu are:

- 1) *Noise prediction data* function is used to select:
 - a) *Calculation standard* – The standard used to calculate the noise generated by liquid flow: VDMA 24422(1979-05), IEC 60534-8-4(1994-05), IEC 60534-8-4(2005-08).
 - b) *Low noise design* is a special function used to select the control valve with the minimum sound level.
- 2) The *Minor noise prediction data* is a function which specifies the following data: Pressure ratio, Acoustical efficiency factor, Ring frequency, Peak

frequency, Sound velocity, Power loss, Mechanical stream power.

- 3) The *Spectrum* function is used to select the specifications of the spectral frequencies generated by the control valve.

III. PETROCHEMICAL CONTROL VALVES CHECKING

Technical sustainability check of a refinery plant consists in measurement systems checking, controller tuning and control valves checking. In this paper have been checked the control valves of a plant of catalytic reformer factory.

To check the control valves have been used the initial design data, an example being presented in table 1. These primary data contain:

- The name of the control valve system TAG;
- Information about the chemical composition of the stream;
- Specific gravity of the fluid;
- Temperature of the fluid;
- The input pressure of the valve;
- The output pressure of the valve;
- The flow rate of the stream;
- The type of the control valve.

There have been analyzed 38 control valves of the plant. In table 2 there is presented a partial list of the results obtained by using the CONVAL[®] software for the FV-001 control valve. The properties associated to the operating control valve are calculated for 25, 50, 75 and 100% of the stroke displacement. The relative stroke displacement s/s_{100} is identical with the test values. The flow module K_v has values between 11 and 237 m³/h, the higher value being higher than the maximal value of the input data (125 m³/h). In all situations (25, 50, 75 and 100% of stroke) the stream flow is non-critical. The fluid velocity increases up to 3.1 m/s, value that is acceptable for the higher flow rate that passes in the control valve. The noise of the control valve is 50 dB for the normal flow rate and the maximum noise value is 55 dB, value that is in admissible domain.

The CONVAL[®] software calculates the work characteristic of the control valve, figure 2. This characteristic is typical for the control valve characterized by *Equal percentage* inherent characteristic. The operating point of the control valve is a very good choice because the operating point is $s/s_{100}=0.76$, there represents that the operating point is into linear variation of the characteristic.

Table 1 Initial data about the control valves

Fluid	TAG	Stream		Specific gravity	T [°C]	P_1 [bar]	P_2 [bar]	Q ¹ [m ³ /h] ² [Nm ³ /h] ³ [kg/h]	Control valve type
Heptane	FV-001	Naphtha to V1	Normal	0.690	40	4.47	4.00	¹ 125	Fisher ET FTC
			Maxim	0.690	40	5.70	4.00	¹ 165	
Heptane	FV-002A	Naphtha to V1	Normal	0.690	40	9.80	4.00	¹ 20	Fisher ET FTC
			Maxim	0.690	40	9.80	4.00	¹ 45	
Octane	FV-005-1	Naphtha pass 1	Normal	0.690	38	69.01	4.00	¹ 20	Fisher ET FTC
			Maxim	0.690	38	69.01	4.00	¹ 40	
Octane	FV-005-2	Naphtha pass 2	Normal	0.690	38	69.01	4.00	¹ 20	Fisher ET FTC
			Maxim	0.690	38	69.01	4.00	¹ 40	
Octane	FV-005-3	Naphtha pass 3	Normal	0.690	38	69.01	4.00	¹ 20	Fisher ET FTC
			Maxim	0.690	38	69.01	4.00	¹ 40	
Octane	FV-005-4	Naphtha pass 4	Normal	0.690	38	69.01	4.00	¹ 20	Fisher ET FTC
			Maxim	0.690	38	69.01	4.00	¹ 40	
Methane	FV-006	Comb gas to H1	Normal	0.700	35	2.50	1.00	² 1540	Fisher EZ
			Maxim	0.700	35	3.00	1.00	² 2000	
Heptane	FV-006A	Naphtha from P1A	Normal	0.735	40	70.01	4.00	¹ 25	Fisher EZ
			Maxim	0.735	40	70.01	4.00	¹ 25	

Table 2 Selected results obtained with CONVAL[®] software

CONVAL[®] by F.I.R.S.T. Version 8.0 (Build 8.0.4)
Control valve: 001 1/29/2014 1:57:19 PM

Calculation header

Identifier

FV-001

Characteristics values table

Caption	Unit	25%	50%	75%	100%
s/s100	%	25.0	50.0	75.01	100.0
t1	°C	40.0	40.0	40.0	40.0
p1	bar(a)	4.47	4.47	4.47	4.47
p2	bar(a)	4.0	4.0	4.0	4.0
Kv	m ³ /h	11.02	39.06	119.4	237.0
qv	m ³ /h	9.247	32.78	100.2	198.9
qm	kg/h	6,1... 0	21,8... 0	66,8... 0	132,7... 0
Type of flow	-	Non-critical	Non-critical	Non-critical	Non-critical
va	-	1.0	1.0	1.0	1.0
pv1	bar(a)	0.1191	0.1191	0.1191	0.11...
ρ1	kg/m ³	667.4	667.4	667.4	667.4
LpAe	dB(A)	20.0	34.4	48.0	55.35
u1	m/s	0.1454	0.5152	1.574	3.126

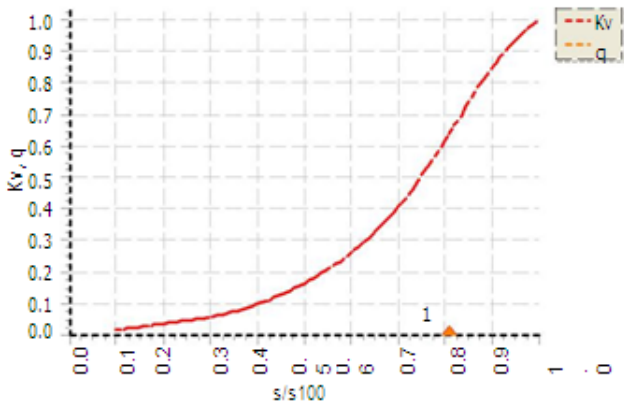


Fig 2 The flow characteristic of the FV-001 control valve.

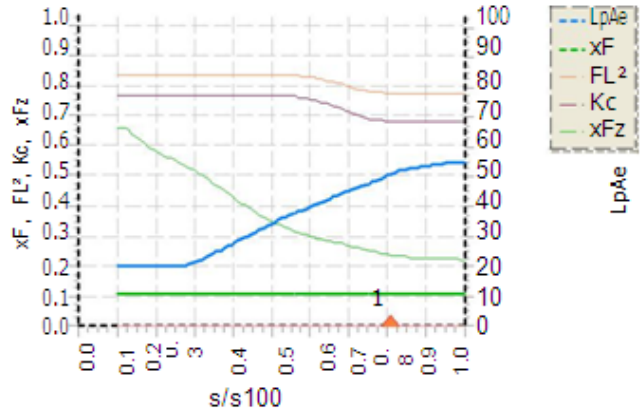


Fig 3 The characteristics of the associate parameters of the FV-001 control valve.

Figure 3 represents the following parameters:

- Sound pressure level $LpAe$;
- The recovery factor for valves installed without fittings attached, value can be found in the flow coefficient tables, xF [6];
- Rated liquid pressure recovery factor FL^2 , Kc , xFz .

Table 3 presents a comparison between the control valve specification and the simulation CONVAL results. The numerical results analysis has four components: the nominal flow Kvs , the valve open, the flow velocity and the sound pressure level.

Table 3 Example of the results obtained by using the CONVAL software

TAG	Specifications	The simulation CONVAL results				Observation
	Q ¹ [m ³ /h] ² [Nm ³ /h] ³ [kg/h]	Kvs Nominal flow [m ³ /h]	Valve Open [%]	Flow velocity [m/s]	Lp [dB(A)]	
FV-001	¹ 125	237.0	63.8	1.99	50.9	Acceptable
FV-002A	¹ 20	21.0	36.9	3.50	75.7	Acceptable
FV-005-1	¹ 20	21.0	24.9	2.81	54.7	Acceptable
FV-005-2	¹ 20	21.0	24.9	2.81	54.7	Acceptable
FV-005-3	¹ 20	21.0	60.3	2.81	54.7	Acceptable
FV-005-4	¹ 20	21.0	60.3	2.81	54.7	Acceptable
FV-006	² 1540	13.7	10.0	0.01	20.0	Acceptable
FV-006A	¹ 25	1.3	100.0	3.71	55.3	Non-acceptable

For example, at the input data presented in table 1 there have been validated 7 control valves. For these control valves, the nominal flow is greater than the input flow rate, the valve open is less than 60 %, the liquid flow velocity is less than 4 m/s and the sound pressure level is less than 75 dB(A).

The analyzed plant has are 38 control valve, each control valve being checked with CONVAL[®] software. For five of the analyzed control valves, the flow module value is less than the nominal flow rate value, there do not assure a gut function of the control valve.

IV. CONCLUSION

The paper presents the facilities of the CONVAL[®] software for the control valve checking. researches into field of the using to. The main facilities of the CONVAL[®] software are classified in Medium menu, Pipeline menu, Control valve menu and Noise calculation menu. The CONVAL[®] software has been used to check the plant refinery control valves. The results have been validated 87 % of the investigated control valves.

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