TRANSPORTING GAS LIQUID MIXTURES

One of the most challenging aspects of dealing with multi-phase flow is the fact that it can take many different forms.

Figures 1-6 illustrates the flow regimes we can encounter in horizontal two-phase gas-liquid flow. Stratified flow has the strongest tendency to occur in downhill or horizontal flow with relatively small gas and liquid flow rates.

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1 - Dispersed bubble flow

2 - Annular flow with droplets

3 - Elongated bubble flow

4 - Slug flow

5 – Stratified flow

6 - Stratified wavy flow

Figures 1-6 – Gas-liquid flow regimes in horizontal Pipes

2 FLOW REGIME MAPS

Simulating pipes of any elevation involves determining what kind of flow regime we are facing as well as doing calculations for that particular regime. Flow regime maps of the sort shown in figure 7 are useful when we want to gain insight into the mechanisms creating the flow regimes. Along the horizontal axis the superficial gas velocity has been plotted. Along the vertical axis we have plotted the superficial liquid velocity. .

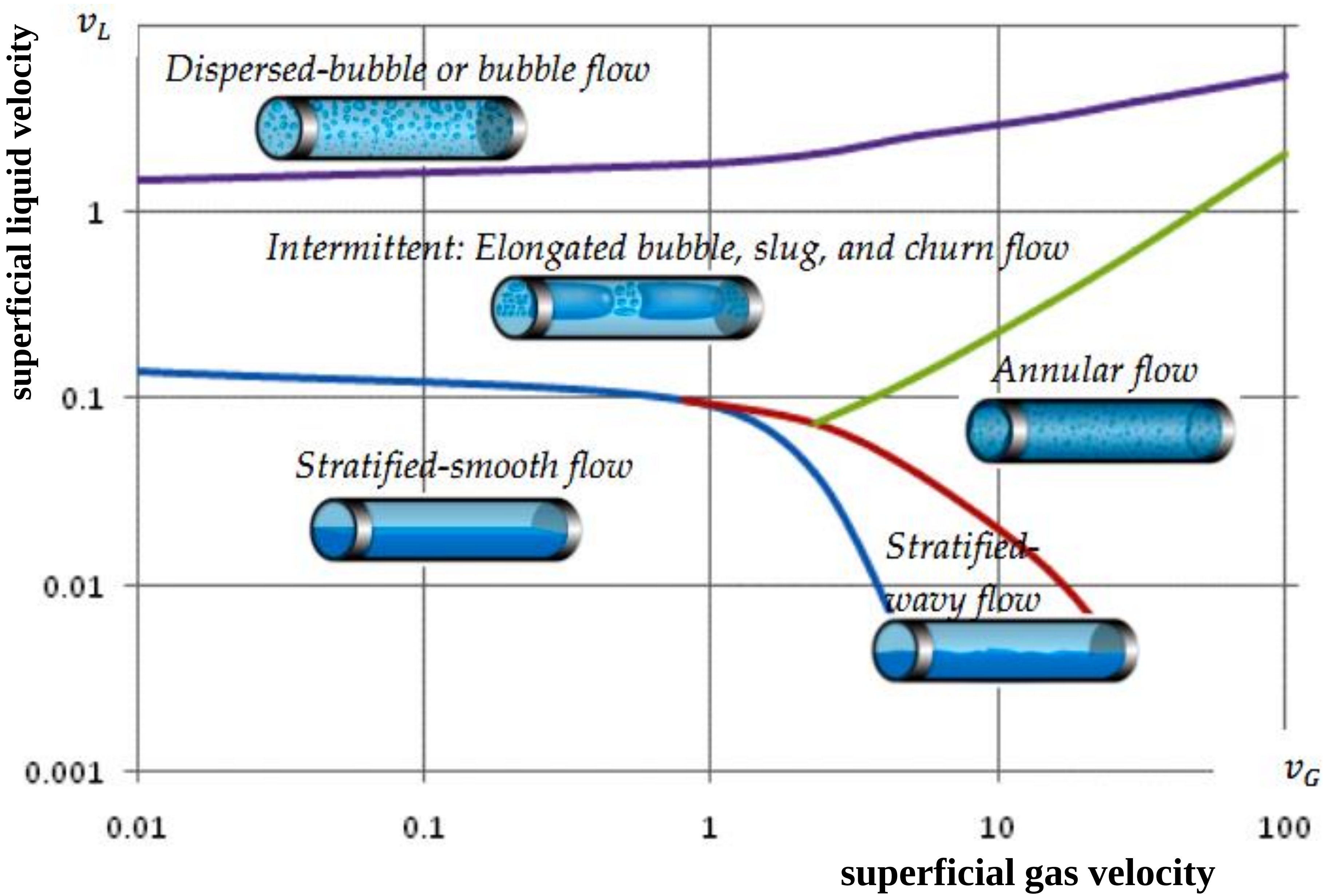

Figure 7 - Example of steady-state flow regime map for a horizontal pipe

Superficial gas velocity this is velocity of gas (through pipes, etc.) is equal to the volumetric flow rate divided by the cross-sectional flow area. .

$$V_g = \frac{Q_g}{F_g}$$

Superficial liquid velocity this is velocity of liquid (through pipes, etc.) is equal to the volumetric flow rate divided by the cross-sectional flow area .

$$V_\ell = \frac{Q_\ell}{F_\ell}$$

Main structural flow forms of gas liquid mixtures can also determined using parameter Froude and consumption gas content β (**Fig. 8**) .

The **Froude number** characterizes the relationship between the force of inertia and the external force, in the field of which the motion takes place, acting on the elementary volume of a liquid or gas $Fr_m = \frac{v_m^2}{g d_{in}}$.

At the increased gas content and relatively small value of the Froude parameter (1-10), the continuous gas phase and stratified flow structure form. At all the flow structures, the gas phase velocity in horizontal pipes is greater than the liquid phase velocity, i. e. there is a relative phase flow. Further increase of the Froude parameter initially leads to loss of the clear phase separation (wave structure) and then it causes emergence of the slug structures. .

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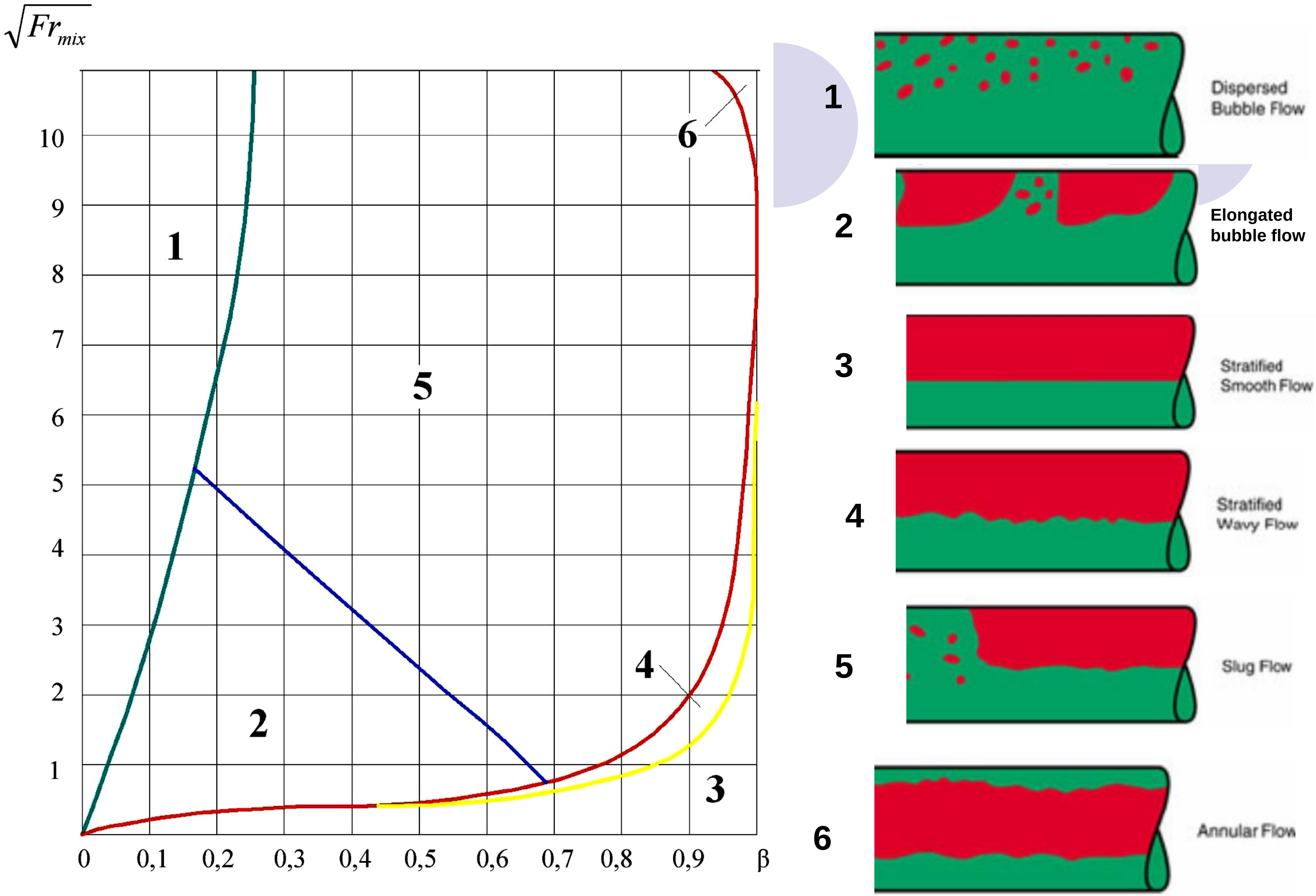


Figure 8 - Example of steady-state flow regime map for a horizontal pipe (depending on Froude mixture and consumption gas content)

Design Calculation of Lines when Transporting Gas Liquid Mixtures

There are a lot of methods and empirical formulas to calculate the actual gas content φ that were obtained on the basis of processing of the results of the laboratory and field studies of the gas liquid mixtures flow in vertical and horizontal lines.

The simplest of them take into account only the mixture flow rate Vm or Froude parameter Fr.

The Wallis formula for horizontal and upstream sections, as well as for slug and emulsion flow structures, looks like the following: $\longrightarrow$ (1.1)

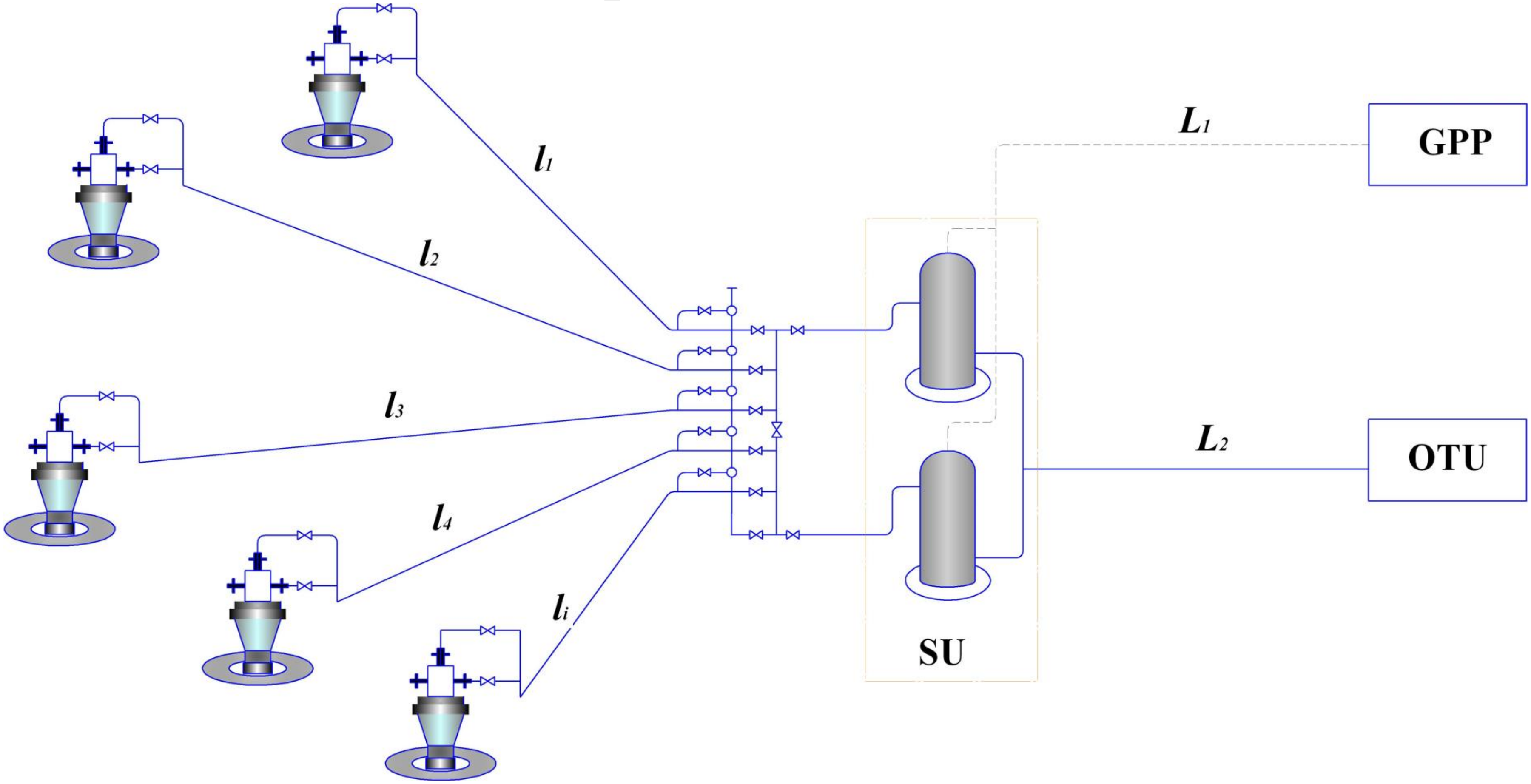
At the known (set) value of pressure, for example, at the line beginning point, liquid and gas flow rates, its length and diameter, the calculation procedure of pressure losses is carried out in the following sequence: 25_02_20

1. The mixture flow rate Vm is determined.

Volumetric gas flow rate Qg depends on the thermodynamic conditions during its transportation. If the volumetric gas flow rate is determined by the known gas ratio G, then

Qg=

We set in the first approximation the probable pressure at the wellhead, higher than the pressure at the inlet of the separation unit.



After that, the average pressure in the pipeline is found where P is an arithmetic mean value of pressure in the line; . Since the value P2 is not known, it must be assigned. It is clear that P2<P1. T - mean temperature along the line length, K; α-gas-in-oil solubility coefficient, m3/m3*Pa.

2. The consumption gas content and Froude parameter are calculated.

3. The actual gas content is determined on the basis of one of the methods mentioned above.

4. The oil liquid mixture density is determined.

At the same time, it is necessary to remember that gas density ρg also depends on the pressure and temperature.

5. The mixture viscosity μm or νm is also determined

6. The Reynolds parameter of the mixture is calculated, as well as the coefficient λm and final friction pressure losses are determined on the basis of the correspondent formulas.

Thus, the calculated value of pressure in the line end will be equal to 2_03_20

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If the difference between the preset value P_2 and calculated value is less than the admissible error $|P_2 - P_{2.1}| \leq 0,1$ MPa, the calculation stops thereupon. Otherwise, it is assumed that $P_2 = P_{2.1}$ and the calculation is repeated (iteration method).

- determine the critical density of gas ρ_{cr}

- determine the molecular weight of gas M

- define complex parameter ε

- depending on the pressure and temperature determine the density of the reduced gas ρ_r

- determine the coefficient of dynamic viscosity of the gas at atmospheric pressure and temperatures μ_0

- determine the coefficient of dynamic viscosity of the gas at pressures and temperatures T, P depending on the density of gas present μ

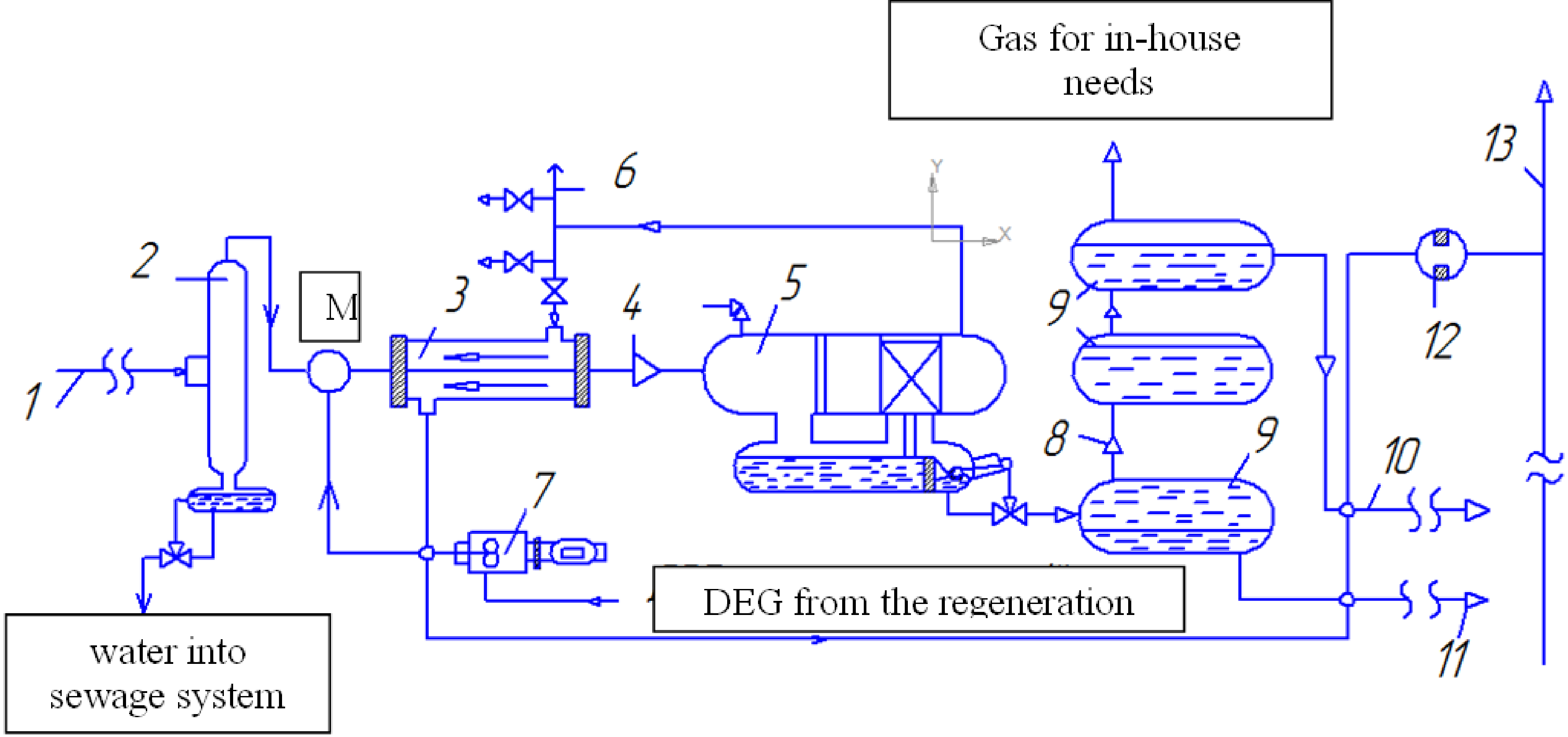
- **DEHYDRATION OF NATURAL GAS AND SEPARATION OF CONDENSATE DUE TO THROTTLING EFFECT**

DEHYDRATION OF NATURAL GAS AND SEPARATION OF CONDENSATE DUE TO THROTTLING EFFECT

Most fields of natural gases in their initial period of operation have high formation pressures, which can be sometimes equal up to 60 MPa. .

High initial pressures of natural gas are used in such cases in order to obtain cold and separate moisture and hydrocarbon condensate from the gas due to this cold. .

The cold at the high pressures of natural gas can be obtained with the help of the special units called low temperature separation units. .

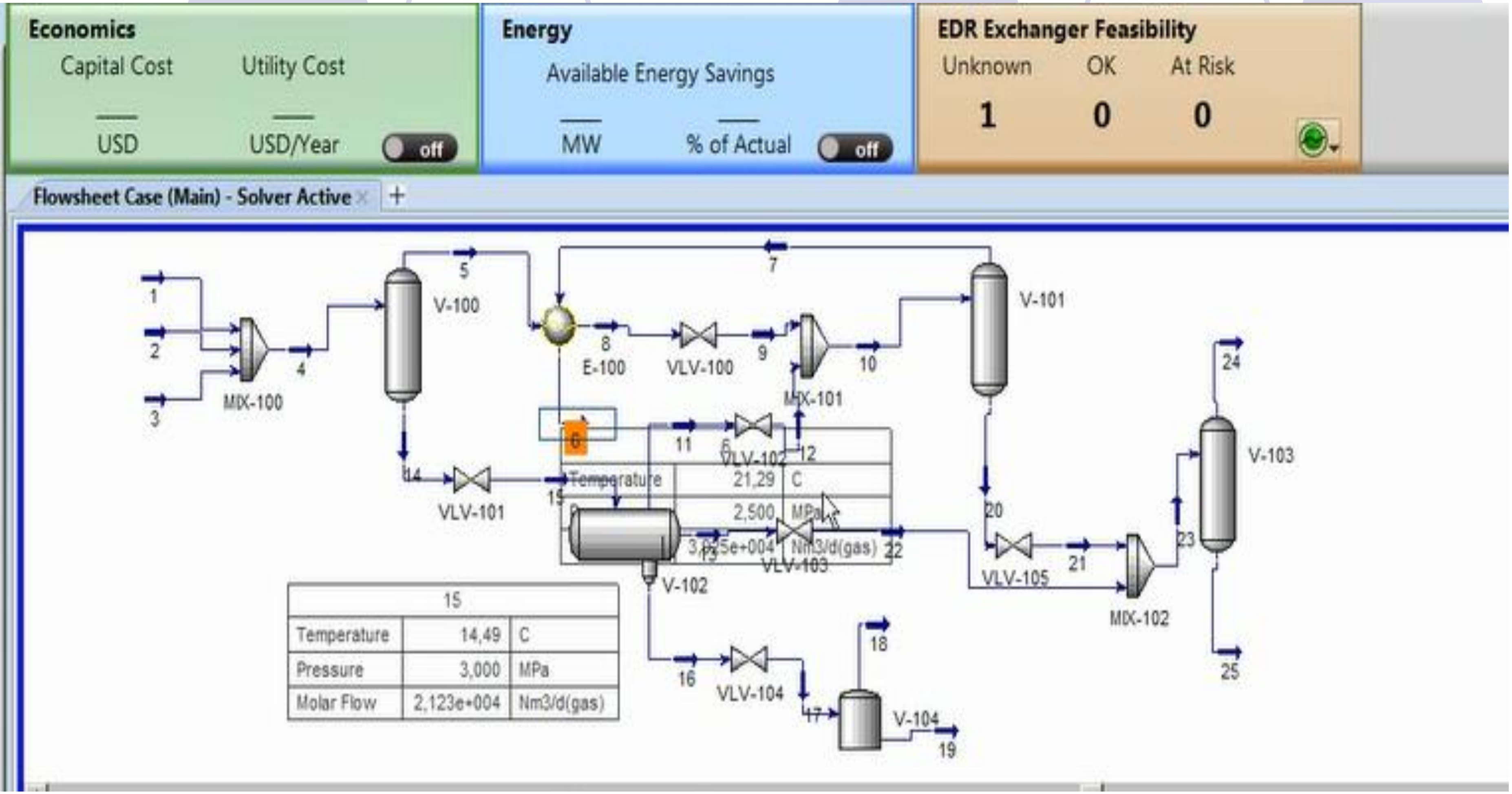


1 – pipeline; 2 – separator; 3 – pipe-in-pipe heat-exchange unit; 4 – throttle; 5 – low temperature separator; 6 – gas line with low (subzero) temperature; 7 – dosing pump to supply the hydrate development inhibitor; 8 – throttle to reduce the pressure in the condensate gathering tank; 9 – condensate gathering tanks; 10 – condensate pipeline; 11 – pipeline to supply the diethylene glycol (DEG) to the regeneration unit; 12 – orifice plate dry gas; 13 – dry gas manifold. M - mixer

Figure 1 – Diagram of Low Temperature Separation Unit Using Throttling Effect

It was determined in practice that the gas temperature decreases by 0,3 ^{0}C on the average when throttling the gas in the adapter by 0,1 MPa (1 atm.). If, for example, the pressure of the natural gas is reduced with the help of the adapter by 100 atm., the temperature of the gas will decrease by 30oC and this will result in the separation of the significant amount of water and hydrocarbon condensate from the gas.

The low temperature separation unit (shown in fig. 1) works as follows.


Economics
Capital Cost
Utility Cost
USD
USD/Year
off
Energy
Available Energy Savings
MW
% of Actual
off
EDR Exchanger Feasibility
Unknown
OK
At Risk
1
0
0
Flowsheet Case (Main) - Solver Active
MIX-100
V-100
E-100
VLV-100
MIX-101
V-101
VLV-101
VLV-102
VLV-103
V-102
VLV-104
V-104
VLV-105
MIX-102
V-103
Temperature
21,29
C
2,500
MPa
Nm3/d(gas)
15
Temperature
14,49
C
Pressure
3,000
MPa
Molar Flow
2,123e+004
Nm3/d(gas)

The gas gets under high pressure into the first stage separators from manifolds 1 and there it is separated mostly from the water drops. Afterwards, the gas goes through the mixer "M" and then, together with the DEG, it is supplied into the pipe-in-pipe heat-exchange unit 3, where it is preliminarily cooled by the cold gas, which gets there from the low temperature separator 5. The pressure of the high pressure gas, which was preliminarily cooled, is reduced in the throttle 4 down to the pressure of maximum condensation that results in a sharp decrease of its temperature. When the sharp decrease in the gas pressure and temperature occurs, some water and hydrocarbon condensate separate from it and gradually accumulate in the condensate gathering tank of the low temperature separator 5.

The mixture of water with the DEG and liquid hydrocarbons gets from the separator 5 through the throttle 8 into the first condensate gathering tank 9, where the DEG separates from the hydrocarbon condensate. The DEG under its own pressure (5 MPa) gets through the pipeline 11 into the regeneration unit and the hydrocarbon condensate goes gradually through the condensate gathering tanks 9, where its pressure successively decreases due to the pressure reduction in the throttle 8. The successive (and not sharp) reduction of the pressure of the hydrocarbon condensate is carried out in order to obtain the maximum output of the stable condensate.

CALCULATION OF LOW GAS SEPARATION USING A THROTTLING EFFECT

INITIAL DATA:

- **The gas temperature at the inlet to the unit;**
- **The gas pressure at the inlet to the unit**;
- **Pressure separation**;
- **The separation temperature**;
- **Gas flowrate**;
- **Relative density of gas**;
- **The temperature at the outlet of the heat exchanger annulus**;
- **The diameter of the inner tube heat exchanger**;
- **The diameter of the external pipe heat exchanger**;
- **Number of fused hydrocarbon condensate**;
- **Heat of evaporation of water**;
- **Heat of evaporation of hydrocarbon condensate**.

CALCULATION

1. Determine the critical pressure and temperature $

2. Determine reduced pressure and reduced temperature at the inlet to the unit;

3. Determine the function of the reduced pressure and temperature correlation Gourman and Nagaev;

4. Determine the molecular weight and molar isobaric heat capacity of natural gas;

5. Determine the Joule-Thomson coefficient;

6. Determine the temperature of the warm gas flow at the outlet of the heat exchanger pipe space;

7. Determine the moisture content before and after gas throttle;

8. Determine the amount of water condensation occurs with gas at low temperatures from t_1 to t_3