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Optimization of energy consumption and offering a procedure for cooling gas compression facilities at gas compression stations

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ABSTRACT

One of the most important methods of transporting natural gas in Iran and other parts of the world is the utilization of a network of pipelines. Compression station and turbo compressor units play an important role in gas supply through pipelines. One of the primary concerns in these units is the reduction of fuel consumption. By cooling of exhaust gas from the source station, the pressure drop in the pipeline and fuel consumption can be reduced. In this research, two stations were investigated while ASPEN HYSYS software was used to evaluate the effect of various parameters on pipeline pressure and power compressors. Based on the results of the simulation, the cooling gas at a higher flow was more economical. Moreover, with reducing ambient temperature, there was a decrease in power consumption, which was required for electro fans. Thus, higher rates and lower temperatures of the environment resulted in more profit from cooling operations. Although highest economic efficiency was obtained at the highest flow rate (60 MMSCMD) with cooling at 25℃ and lowest ambient temperature of -8℃, but the conditions for hydrate formation in the pipeline became suitable and these conditions could affect the safety of process. In this study, and taking cognizance of the the limitations of hydrate formation and economic conditions, the cooling operational guidelines for use in Qazvin station are provided.

Keywords: ASPEN HYSYS, Compressor Stations, Economice Valuation, Naturalgas, Pipeline.

1. Introduction

Natural gas is a flammable gas with a high calorific value which provides an abundant and cheap energy source. Its combustion is very good and as well as can be transmitted easily through pipelines. Thus, this gas is used for large-scale industrial and domestic purposes [1,2]. One of the most important ways to transfer natural gas in Iran and in the world is a network of pipelines [3,4]. Compressor and turbo-compressor units of gas through pipelines play an important role in gas transmitting. One of the primary concerns in the Compressor Stations is the reduction of fuel consumption, while keeping the capacity of natural gas transportation constant [5].

In this study, after providing the environmental conditions of different seasons and geographic pipeline information, the effects of environmental operating conditions on pressure drop and energy consumption in turbines have been studied in detail. For this purpose, the ASPEN HYSYS software was employed in order to use the database and its thermodynamic package, and then accurate results and realistic economic analysis of

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various parameters was studied. Finally, in a natural gas compression station, in order to achieve an optimum in terms of fuel consumption and economic parameters a guideline was offered [6,9].

2.Process simulation

Innatural gas compression process simulation, the Peng-Robinson equation of state as a package of thermodynamic relation was used. This equation canpredicts the physical and thermodynamic properties of oil and gass treams. In order to validate the accuracy of the software, the simulation results with real data of line between Qazvin and Khorramdarreh were compared [5,10,11].

2.1.Description of the process

In a compressor station, the gas pipeline crosses the station. The gass treamenters the scrubbert wigs and is transmitted after filtration to three parallel compressors. Depending on the requirements, a certain number of compressors will be placed in service. Gas flows through the compressors and is then transmitted into the heat exchanger units (air coolers). After cooling in the air-cooled heat exchanger, the gas flows to the next station [12,13]. Figure 1 illustrates an overview of Qazvin process gas compression station 2.

2.2. Ambient temperature

Heat transfer between the pipeline and the environment and the effects of climate change, are the most important factors responsible for changes in the gas temperature along the pipelines. Thus, the ambient temperature is so impressive on the

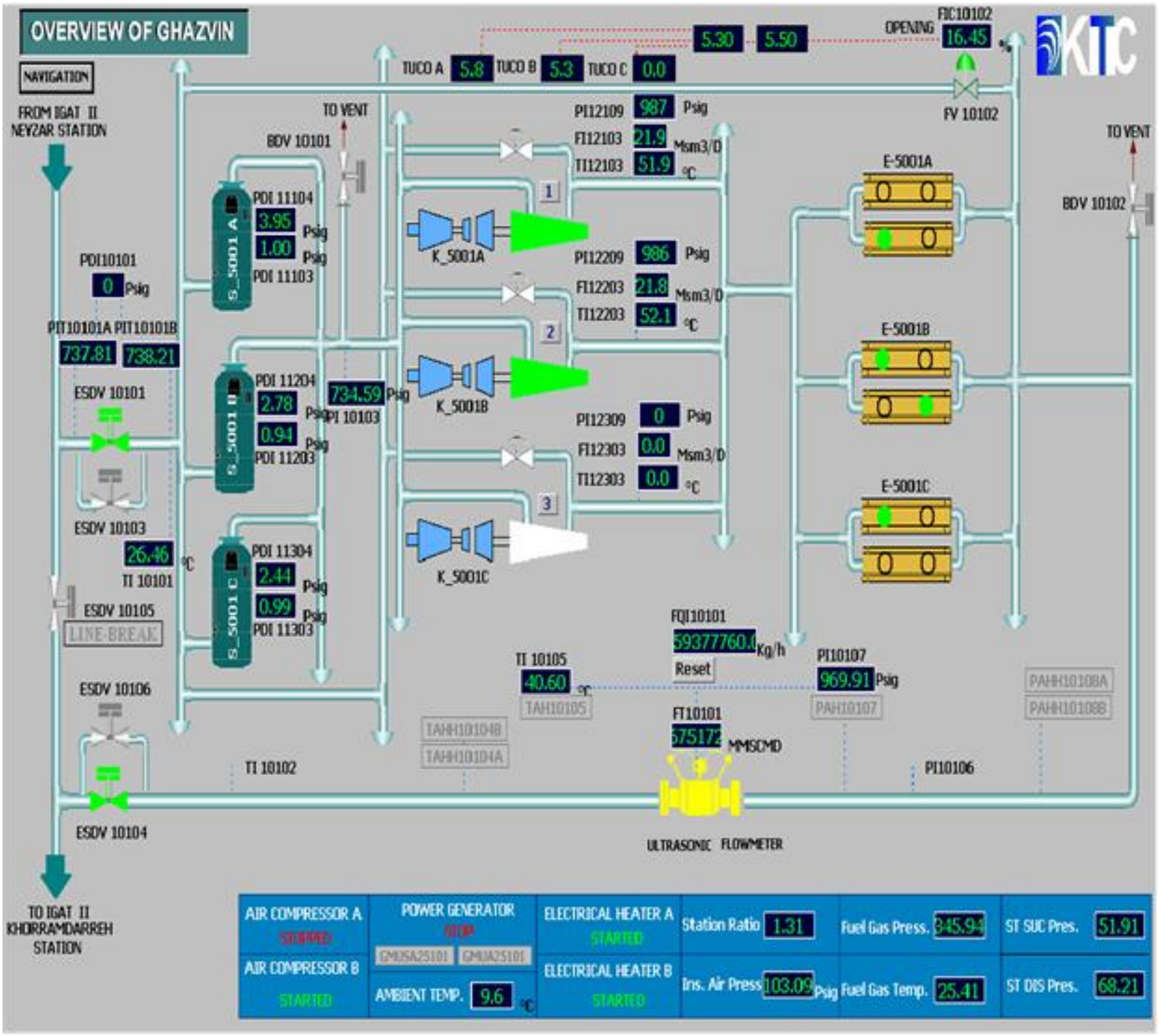

Fig. 1. Schematic of equipment and pipelines at compressor stations [1]

cooling and heat transfer in the pipeline. Figure 2 shows the temperature at the Qazvin station on different days. The lowest and highest temperatures in the station are -6 and 27℃, respectively.

2.3. Gas composition and profile of pipelines

HYSYS, using a combination of the physical properties such, as density, viscosity and heat capacity, can calculate the thermodynamic properties, such as enthalpy and internal energy at different temperatures and pressures. The composition of the gas flowing through the pipeline and the condition of the pipeline are represented in Tables 1 and 2, respectively.

2.4. Profile of pipeline

Changes in the height of the pipeline has effect on the pipeline pressure and information from the the exact profile of pipe height is of great importance. For this purpose, the information between the pipeline stations of Qazvin and Khorramdarreh is extracted precisely, piece by piece. Figure 3 shows the height of pipeline based on its distance from the Qazvin station.

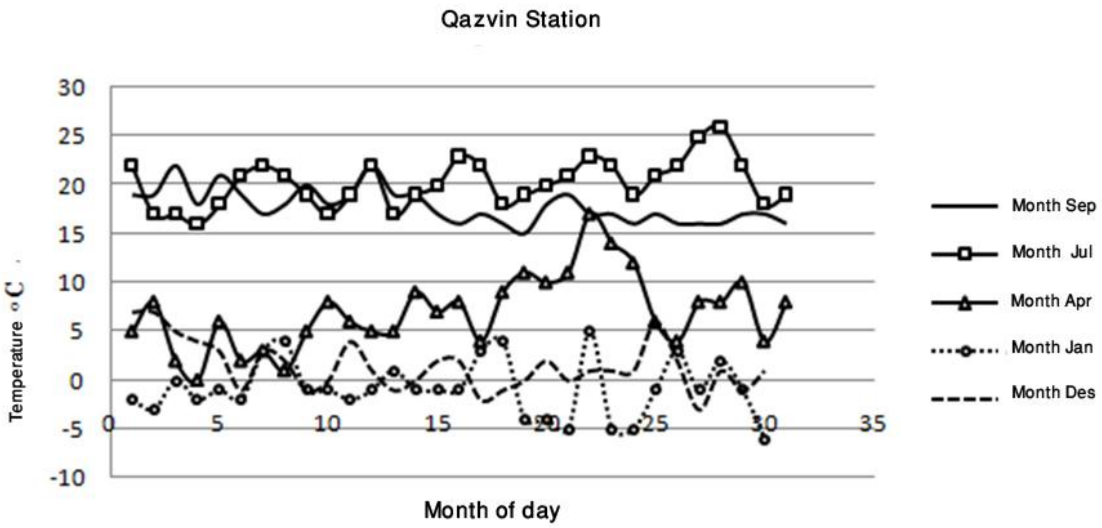

Fig. 2. The air temperature (day time) of different months in Qazvin station

Table 1. The molar composition of the gas flow inside the pipeline

Formula	CH_4	C_2H_6	C_3H_8	i-C_4	n-C_4	i-C_5	n-C_5	C_6^+	N_2	CO_2	H_2S
Composition Percent	0.883	0.0384	0.0118		0.0033	0.0013	0.0009	0.0025	0.058	0.006	0.0123

Table 2. Pipelines Information

The depth of pipe Buried in the ground	Insulation Material	Insulation Thickness	Pipe Material	Diameter of Pipeline	The total length of pipeline
1.2 to 1.4 m	Three-Layer Polyethylene	35mm	API5LX65	48 inch	92275.79m

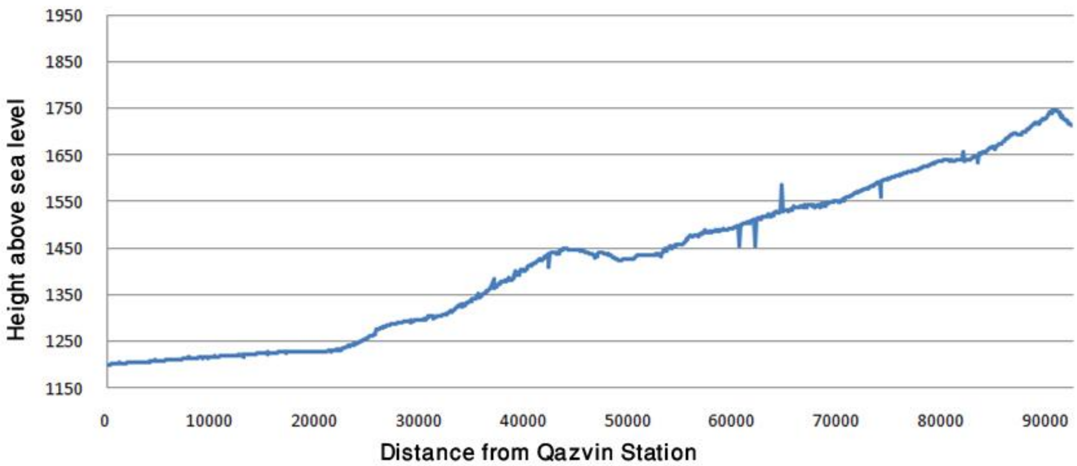

Fig. 3. The height of pipeline (based on the sea level) versus to the length of pipeline

2.5. Evaluation of hydrate formation

A reduction in the operating temperature increases the risk of hydrate formation in pipelines. The refore, restrictions should be considered to avoid hydrate formation. Based on the given pressure in the pipeline, the hydrate formation temperature curve was calculated using the HYSYS software (Fig. 4).

2.6. Validation of results

The output flow data was extracted from Qazvin station on two different days, and using these data on simulation, the temperature and pressure of the pipeline at the entrance of Khorramdarreh station were obtained. The results were compared with actual data at the entrance of Khorramdarreh station and the corresponding differences have been presented in Table 3.

3. Sensitivity analysis

According to Table 3, the results of the software are in good agreement with the actual data measured at Khorramdarreh station and the software can be used to evaluate the effect of various parameters of interest. For the purpose of this step, the software was considered in order to provide three levels of discharge (40, 50 and 60 MMSCMD) and three levels of ambient air temperature (-8, 10 and 30°C).

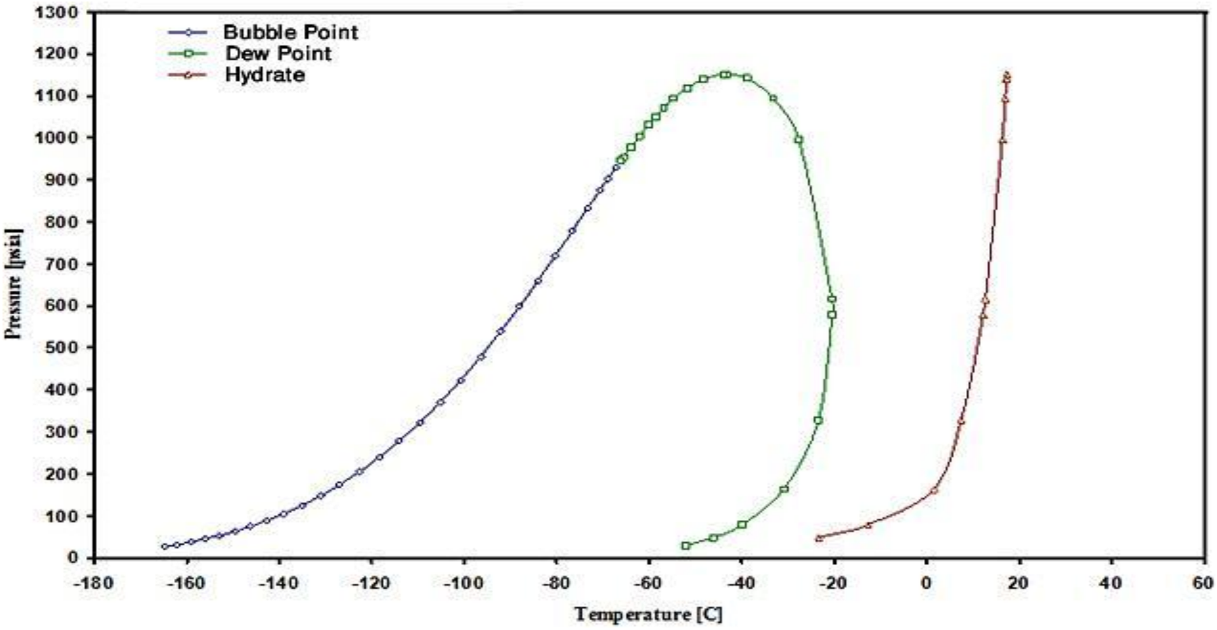

Fig. 4. Phase diagram and hydrate formation condition

Table 3. Simulation results of Qazvin to Khorramdarrehpipelines

Date	Time	Outlet Data on Qazvin Station			Average Ambient Temperature	Inlet Data onKhorramdarrehStation					Percentage Error	
						Simulation Results		Actual Data				
		Flow	Pressure	Temperature		Pressure	Temperature	Pressure	Temperature	Flow	Pressure	Temperature
		MMSCMD	kg/cm^2	℃	℃	kg/cm^2	℃	kg/cm^2	℃	MMSCMD	%	%
07/05/2014	2:00	39.0	66.6	43	22	56.31	34.1	55.9	34	41.5	0.73	0.29
	6:00	39.3	67.3	43	19	56.96	33.6	56.7	34	41.5	0.46	-1.18
	10:00	39.4	67.8	44	25	57.32	35.4	57.1	34	42	0.39	4.12
	14:00	39.2	67.9	44	31	57.61	36.3	57.2	34	42	0.72	6.76
	18:00	39.2	68.3	44	28	58.05	35.9	57.7	34	42	0.61	5.59
	22:00	39.4	68.3	44	20	57.99	34.7	57.7	34	42	0.50	2.06
12/22/2014	2:00	50.0	66.6	44	0	50.87	30.9	49.1	31	51.0	3.60	-0.32
	6:00	49.6	66.2	44	-1	50.62	30.5	49.0	31	51.0	3.31	-1.61
	10:00	49.9	66.0	44	-1	50.19	30.3	48.7	31	50.0	3.06	-2.26
	14:00	50.4	66.6	44	7	50.61	31.4	48.7	31	51.0	3.92	1.29
	18:00	49.3	65.7	44	5	50.1	31.2	48.5	31	51.0	3.30	0.65
	22:00	48.7	64.8	44	2	49.41	30.8	47.9	31	49.0	3.15	-0.65
		The average accuracy simulationtemperature(%)				1.1	The average accuracy simulation pressure(%)					1.91

3.1. The effect of ambient temperature on the thermal profile pipeline

According to Fig.5, a decrease of 33°C in ambient air temperature resulted in onto 5 degree reduction in the temperature of the pipeline, indicating that there were no drastic changes in the temperature at a depth of 1.2m. However, with increased cooling, the drop in gas pressure increased in the cooling devices; however, the change was small and not significant.

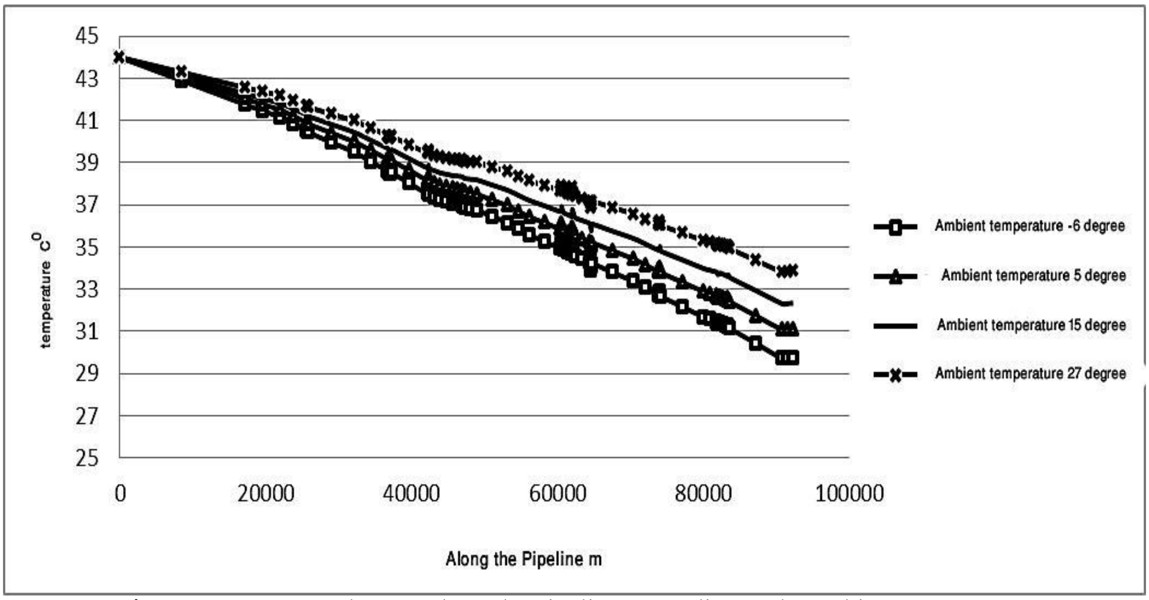

Fig. 5. Temperature changes along the pipeline, according to the ambient temperature

3.2. The cooling effect on the profile of temperature and pressure pipeline

Figure 6 presents the effect of cooling of Qazvin station on the temperature profile of the pipeline for the coldest days of the year. Based on the figure, the length of the pipeline was insufficient enough for the gas to become isothermal with the environment. However, this can be achieved by reducing the temperature of the gas at the pipeline inlet temperature.

Figure 7 presents the cooling effect on the profile of the Qazvin station pressure pipeline on the coldest day of the year. Based on the figure, a reduction in temperature of the gas at the source resulted in a decrease in the pressure drop in the pipeline. This enabled for the reduction in the cooling operation of the fuel gas compressor at the destination station. Table 4 presents the amount of pressure drop based on the amount of cooling.

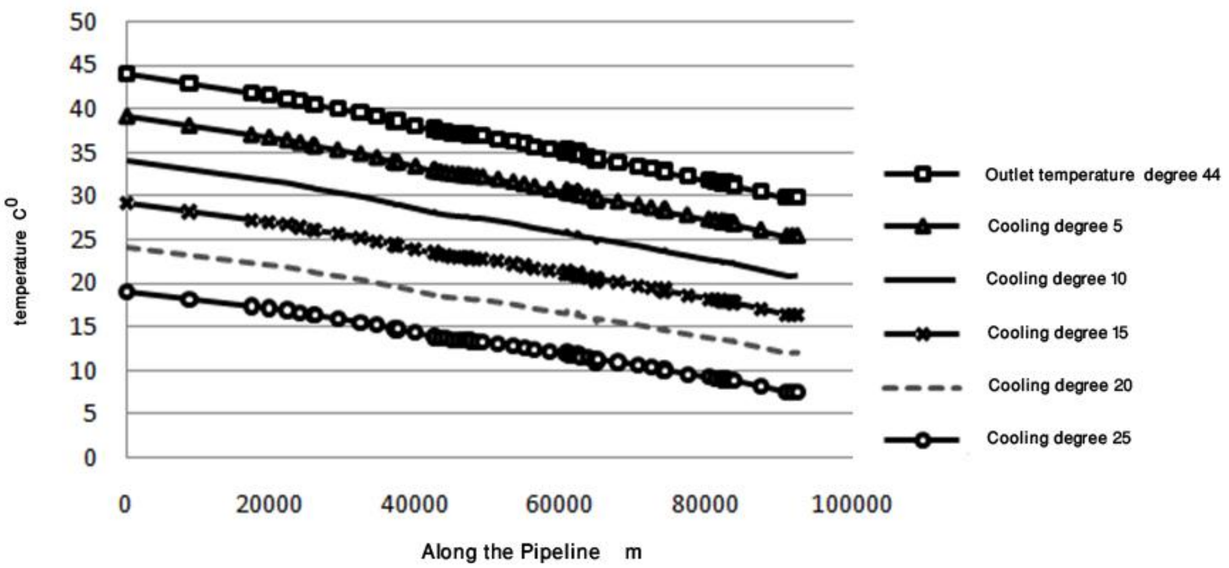

Fig. 6. Temperature changes based on the pipeline- ambient temperature -6°C

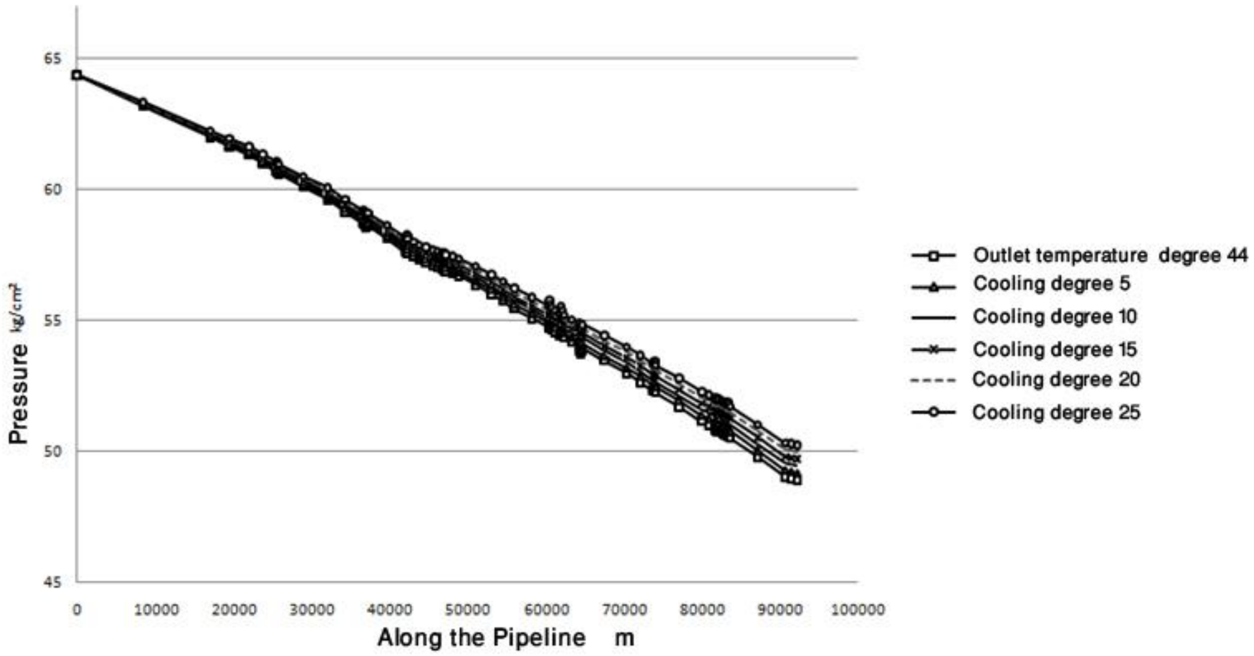

Fig. 7. Pipeline Pressure profile based on the cooling degree at the source - ambient temperature -6°C

3.3. The cooling effect of the electric power consumed by Fans

The ASPEN HYSYS software is able to calculate the amount of the pressure drop in the air-cooled exchangers and electric power consumption based on the cooling temperature. The results showed that at most times, the outlet temperature of Qazvinstation (after air-cooled: the information derived from this software for air-cooled exchangers is summarized in Table 5 converters) was set at 47°C, and the amount of cooling was considered by reducing this temperature. In other words, all the calculations and simulations for cooling levels of 10, 15, 20 and 25°C by taking 37, 32, 27and 22°C as the outlet temperature station was done.

Table 4. Gas pressure drop in air-cooled exchangers for cooling and gas flow conditions

Cooling amount gas	C̊10	C̊15	C̊20	C̊25	Gas flow
Gas pressure drop in the cooling system(psi)	6.8	6.65	6.55	6.4	MMSCMD60
	4.7	4.65	4.6	4.52	MMSCMD50
	3	2.95	2.86	2.81	MMSCMD40

Table 5. Qazvin electro power station in different cooling conditions

Cooling amount gas	C̊10	C̊15	C̊20	C̊25	Ambient temperature
Electrical Fan power consumption(kW) Flow 40MMSCMD	90	148	205	318	-8
	146	260	399	792	10
	534	*	*	*	30
Electrical Fan power consumption(kW) Flow50MMSCMD	115	190	266	421	-8
	187	342	533	*	10
	724	*	*	*	30
Electrical Fan power consumption(kW) Flow 60MMSCMD	144	241	340	548	-8
	237	441	699	*	10
	967	*	*	*	30

*outside of cooling

3.4. The cooling effect of the reduction in pipeline pressure drop and power consumption of compressors

With increasing cooling and reduction in the temperature of the gas at the beginning of the pipeline, pressure drop reduced along the pipeline. This reduction resulted in a lower power consumption and a reduction in the amount of fuel consumption in compressors at its destination point (Khorramdarreh). Table 6 shows the amount of reduction in pressure drop of gas pipeline. Based on these values, the power consumption was calculated by HYSYS and its values have been reported in Table 7. A reduction in the temperature of the flow through the cooling or by heat exchange with the soil in the transmission path reduces the viscosity of the gas flow. Thus, the Reynolds number increases, and the friction coefficient decreases. The pressure drop in the flow within the pipeline route reduces and then the power (power turbine) consumption is decreased. The gas flow rate increases, resulting in a lower loss of electrical power and pipeline pressure drop.

Table 6. The amount of reduction in pipeline pressure drop in various cooling conditions

Cooling amount gas	C°10	C°15	C°20	C°25	Ambient temperature
Reduced pressure drop [kg/cm^2] Flow40[1]MMSCMD	0.406	0.607	0.806	1.00	-8
	o.295	0.440	0.583	0.723	10
	0.293	*	*	*	30
Reduced pressure drop[kg/cm^2] Flow50[2]MMSCMD	0.837	1.250	1.659	2.066	-8
	0.595	0.889	1.183	*	10
	0.594	*	*	*	30
[kg/cm^2] Flow 60[3]MMSCMD	1.835	2.713	3.567	4.401	-8
	1.090	1.628	2.162	*	10
	1.114	*	*	*	30

* outside of cooling

Table 7. The amount of reduction in power of Khorramdarreh station in various operating conditions

Cooling amount gas	C°10	C°15	C°20	C°25	Ambient temperature
Reduce power consumption turbine [kW] Flow 40MMSCMD	972.1	1442.4	1903.0	2353.9	-8
	316.0	463.1	602.8	735.0	10
	259.2	*	*	*	30
Reduce power consumptionturbine [kW] Flow 50 MMSCMD	2689.9	3970.1	5209.3	6412.1	-8
	1114.5	1642.9	2152.2	*	10
	1492.5	*	*	*	30
Reduce power consumption turbine [kW] Flow 60 MMSCMD	9274.4	13401.9	17243.0	20831.8	-8
	3075.9	4519.1	5903.0	*	10
	3777.6	*	*	*	30

*outside of cooling

4. Economic assessment

Based on the cost of energy (electricity and gas), the energy rate of 1000 Riyal/m^3 for natural gas and 1130 Riyal/kWh for Power consumption are determined. According to Figure 8, in all cases, with exception of two cases (flow of 40 MMSCMD at 30°C ambient temperature and flow of 40 MMSCMD at 10°C ambient temperature) cooling is economically effective. As shown, an increase in the gas flow rate results in an increase in the economic cost of cooling. In addition, by increasing the amount of cooling to lower temperatures, more profits can be achieved. It should be noted that for a convergence of the discharge curve for 40 MMSCMD to zero the cooling rates lowers the operating profitability and decreases to negative values. The best case is concluded when the flow rate and ambient temperature is 60 MMSCMD and -8°C, respectively, and cool-work is done until 25°C. By this procedure, results show that the annual profit is nearly 201 billion riyals in the year.

4.1. Evaluation of hydrate formation

In Fig. 8, in all cases apart from two cases, significant profits can be achieved by cooling. However, the possibility of hydrate formation in the pipeline must be considered. For this purpose, inlet temperature and ambient temperature of cooling stations in different situations for Khorramdarreh is evaluated and the results are reported in the table. According to Fig.4 the maximum pressure in the pipeline in which hydrate is formed was equal to 1050 psi and hydrate formation temperature was equal to 18°C. Thus, the temperature of the pipeline, considering the safety factor 3.5 degrees higher than the temperature of hydrate formation (120%), was considered as equal to 21.5°C. Therefore, the conditions that led to the cooling inlet temperature (in the inlet of Khorramdarreh station) below this value, because of the risk of hydrate formation in terms of safety, are not recommended.

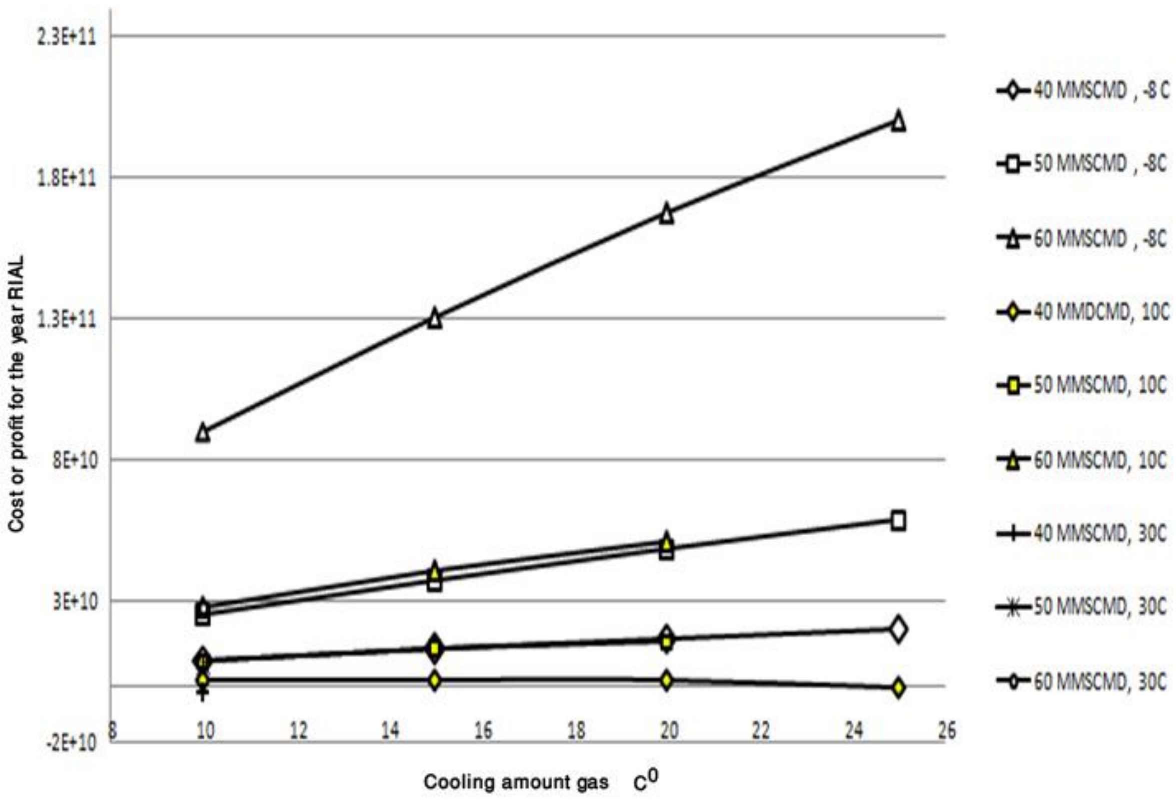

Fig. 8. Net profit of cooling at ambient temperature (-8, 10 and 30°C) and different volume flows (40, 50 and 60)

Table 8. Net profit of cooling at ambient temperature (8, 10 and 30 °C) and different volume flows (40, 50 and 60)

Cooling amount gas	C°10	C°15	C°20	C°25	Ambient temperature
Inlet temperature to Khorramdarreh °C Flow 40 MMSCMD	23.07	18.79	14.50	10.2	-8
	25.86	21.56	17.26	12.97	10
	28.95	*	*	*	30
Inlet temperature to Khorramdarreh °C Flow50MMSCMD	23.14	18.70	14.25	9.80	-8
	25.35	20.89	16.43	*	10
	27.80	*	*	*	30
Inlet temperature to Khorramdarreh °C Flow60MMSCMD	20.62	16.09	11.55	7.02	-8
	22.50	17.96	13.42	8.88	10
	24.60	*	*	*	30

*outside of cooling

5. Cooling instructions

Considering the restrictions of hydrate formation, Table 9 presents a special instruction for cooling. According to Table 9, in flow of 60 MMSCMD, the best possible cooling condition (in ambient temperature of 10°C) is obtained. In this case, the annual profit of 28.1billion riyals is obtained from cooling. Gas cooling in all conditions was studied for more than 10°C due to the formation of hydrate, and in a temperature range of 10°C to 30°C and for flow of more than 50 MMSCMD, cooling to 10°C is permitted and will be economically feasible.

Table 9. Net profit obtained by cooling in a safety condition

Cooling amount gas	C°10	C°15	C°20	C°25	Ambient temperature
Net profit per billion RIAL Flow 40MMSCMD	8.73	12.8	16.8	20.2	-8
	1.68	2.01	2.02	-0.67	10
	-2.72	*	*	*	30
Net profit per billion RIAL Flow 50MMSCMD	25.5	37.4	48.9	59.3	-8
	9.18	12.9	16.0	*	10
	7.61	*	*	*	30
Net profit per billion RIAL Flow 60MMSCMD	90.4	130.3	167.3	200.7	-8
	28.1	40.4	51.5	*	10
	27.8	*	*	*	30

* outside of cooling
/ Hydrate formation(with Safety factor 20%)

6. Conclusion

In this study, by using ASPEN HYSYS software, the impact of various factors on pressure, power and fuel consumption was studied. For this purpose, geographic information and climatic location of pipelines were collected at two stations. After confirmation of the accuracy of the results, the software for the analysis of process parameters such as sensitivity and temperature of the cooling air was used. Based on the results, the temperature at a depth of 1/2 m experienced little changes with change in the ambient temperature, with a significant reduction in the total pressure drop in the pipeline under this condition. Since a reduction in the temperature of the gas at the inlet resulted in a rough decrease in the temperature of the pipeline with the same ratio, the length of the pipeline was insufficient enough for the temperature of pipeline and soil to be the same. The results showed that a reduction in the gas temperature at the source resulted in a reduction in the pressure drop in the pipeline. Thus, the use of cooling and temperature reduction in Qazvin station can reduce reduced pressure drop in pipeline and hence reduce fuel consumption in the next station. The sensitivity analysis on three levels offlow (MMSCMD 40, 50 and 60), three levels of ambient temperature (-8, 10 and 30°C) and 4 levels of cooling (10, 15, 20 and 25°C) was investigated. Based on the results of simulation, with temperature reduction, the power consumption required for electro ambient is reduced. In addition, an increase in the amount of cooling resulted in an increase in pressure drop. Therefore, the profit from cooling operations is increased at lower temperatures and an increase in the temperature increases the power consumption of electro ambient. Thus, the profit from cooling operations, at higher flow rate and lower temperature, increases. The most economic efficiency at the highest flow rate (MMSCMD 60) and the lowest ambient temperature (-8°C) is obtained, and by cooling to 25°C the Qazvin station experiences a 4/4 kg/cm^2 reduction in pressure drop in pipeline pressure. Furthermore, by reducing power consumption and applying a cooling compressor, a 201 billion reduction in cost of gas transmission pipeline, annually, is achieved. However, due to the formation of hydrates in these conditions, the possibility of adopting this method was not feasible.

By eliminating the possibility of hydrate formation, it is possible to achieve this method in order to ensure proper safety procedures by which this work is done according to Table 9. Using the results of this software based on the Table 9, a practical solution in order to save fuel consumption in compressor stations can be obtained. It should be noted that the reduction of fuel consumption in Khorramdarreh station was related to electro-Qazvin station and the separation of these two stations for the purpose of investigation is not possible.

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