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Fluid Flow Analysis of a Transmission Line of Jalalabad Gas Transmission and Distribution System Limited

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Abstract: In present world the prime concern of a country is energy. Bangladesh, a developing country, is also facing the challenge to meet its energy demand. For the energy, Bangladesh mainly depends on its natural gas. Bangladesh has a gas reach province in the eastern part. Gas produced in Bangladesh is mainly dry gas, but some fields are also producing condensates. Natural gas is transported by pipeline, which is the most cost efficient way. With the edge of economy, gas transmission through pipeline brings some difficulties. Before transmitting the natural gas, condensates are separated in the gas field. In spite of the separation, some condensates are formed in the pipeline while transmitting gas. This leads to pipeline blocking, corrosion, reduction of heating value. In this study the fluid flow through Khadim-Debpur-Kumargaon (KDK) pipeline is analyzed, which is a part of the pipeline network operated by Jalalabad Gas Transmission and Distribution System Limited. To analyze the fluid flow through pipeline, pressure was calculated by single phase flow equations like Weymouth, Panhandle A and panhandle B. The pressure was also calculated using software Feket (Piper) and a statistical analysis of error calculation was done. The research focuses on the following points: i) the fluid flow pressure was under designed ii) a record of liquid formation in the pipeline should be kept iii) a chromatographic test on Kumargaon station should be done for improvement of the study iv) liquid formation gives hints of two phase flow in the pipeline, which demands more investigation.

Keywords: Natural Gas, Transportation, Pipeline, Pressure Loss, Fluid Phase

1. Introduction

Bangladesh has been known as a prospective gas province since the discoveries of major gas fields in the east during 1960s. All the gas fields are located in the eastern part of the country [1].

Transporting natural gas through pipeline is the easiest means to transfer it from one location to further distant locations. Pipelines carrying natural gas usually buried underground and operate under higher pressure. Other means of transporting natural gas are liquefied form that is known as LNG (Liquefied Natural Gas) and hydrate form where gas is allowed to mix with water to form hydrate. Hydrate form is still under experimental stage. LNG and Hydrate requires huge capital investment and moderate operating cost. In contrary, gas pipeline needs huge initial cost but operating cost is very low [2].Bangladesh already has an established pipeline network and Khadim-Debpur-Kumargaon (KDK) pipeline is located in Sylhet District and operated by Jalalbad Gas Transmossion and Distribution System Limited (JGTDSL) (Figure.1). It mainly transports gas to northeastern part of Bangladesh. Total length of the KDK pipeline is almost 17 km and diameter varies from 10.02 to 11.376 inches. Most of the industries, power plant and fertilizer factory depend on this line. Any operation problems in this pipeline will severely affect the power sector and the industries. KDK line was divided into 02 (two) segments for calculation purposes.

Table 1 gives them below.

Table 1. *Description of KDK line.*

No. of the segment	Name of the segment	Length, Km	Diameter, inch
1	Khadim DRS-Debpur DRS	5	11.376
2	Debpur DRS – Kumargaon DRS	12	10.02

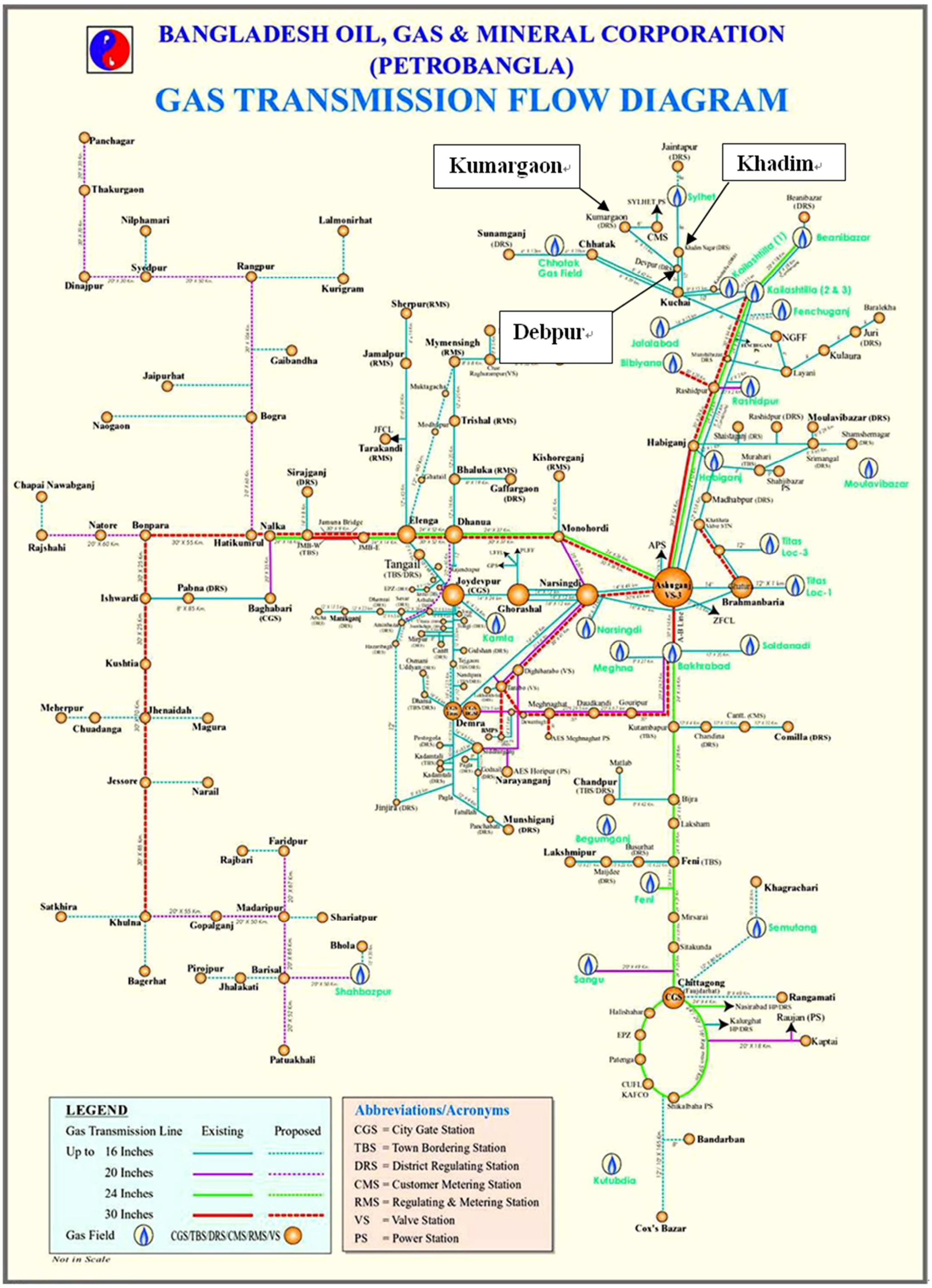

Figure 1. *Gas Transmission Flow Diagram of Bangladesh (www.petrobangla.org.bd/data/flow_large.jpg).*

When operating parameters i.e. flow rate, pressure and temperature changes or any operating condition change in the processing plants, liquid separate out from the gas stream because of multi- component nature of natural gas and its associated phase behavior. The separated out liquid might accumulate in the pipeline or carry over by the gas stream. Though gas is transmitted as dry gas, Jalalbad Gas Transmossion and Distribution Company Limited (JGTDCL) sometime having complains about excessive condensate in pipeline gas from her bulk customers. Sometimes they also face liquid accumulation in the pipeline; to remove it they do gas purging.

In this paper we tried to figure out a) the effect of pressure loss calculation by single phase correlations b) Build knowledge about fluid flow parameters. C) Build knowledge about problems associated with transmission of gas through pipeline.

2. Methodology

Daily Transmission data and average input to the different DRS were collected from the JGTCL. This daily report contains the operation variables like pressure, temperature and gas flow rates. Using FEKET-PIPER software pressure drop was calculated. The pressure drop was also calculated by single-phase equations like Weymouth, Panhandle A and Panhandle B. Later on a statistical analysis was carried out to find the best correlation for pressure drop.

2.1. Schematic Diagram

Figure 2, shows the schematic view of the KDK Pipeline, where major input and output were shown only. Pipeline was assumed straight line and undulation of pipeline was ignored.

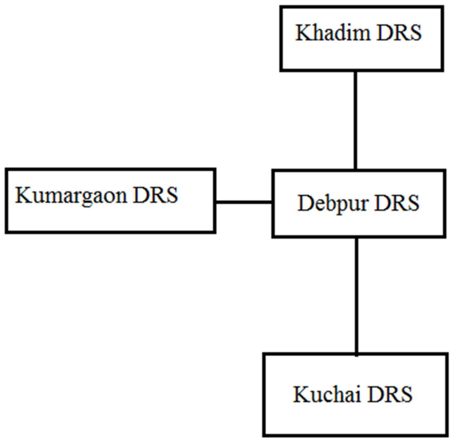

Figure 2. *The Schematic Diagram of Khadim-Debpur-Kumargaon Pipeline.*

2.2. Pressure Calculations

Engineering of long-distance transportation of natural gas by pipeline requires a knowledge of flow formulas for calculating capacity and pressure requirements. The basis for fluid flow calculations in pipes is conservation of mass, momentum and energy. Application of these principles allows the calculation of changes in pressure and temperature with distance.

There are several equations in the petroleum industry for calculating pressure in pipelines. In the early development of the natural gas transmission industry, pressures were low and the equations used for design purposes were simple and adequate. However, as pressure increased to meet higher capacity demands, equations were developed to meet the new requirements. Several equations are available that relate the gas flow rate with gas properties, pipe diameter and length, and upstream and downstream pressures. Probably the most common pipeline flow equation is the Weymouth equation, which is generally preferred for smaller-diameter lines (D 15 in. ±). The Panhandle equation and the Modified Panhandle equation are usually better for larger-sized transmission lines [3]. In commercial software like Fekete, Panhandle – B is used for pressure calculations. Assumptions for various pipeline flow equations are given in Table 2.

Table 2. *Assumptions of Various Pipeline Flow Equations.*

No. of Pressure Equations	Name of Pressure Equations	Assumptions
1	Weymouth	No mechanical work. Isothermal Steady –State flow. Constant Gas Compressibility Factor. No undulation. Negligible kinetic energy change. Fully turbulent flow in pipe with diameters around NPS 36.
2	Panhandle A	Pipe diameter from NPS 6 to NPS 24. Reynolds number greater than 300,000 with partially turbulent flow.
3	Panhandle B	Long pipelines with diameter greater than NPS 24.
4	Fekete Software (Piper)	Single-phase flow using Panhandle B as governing equation.

2.2.1. Weymouth Equation

The following form of Weymouth equation commonly used in industry [3]

$$q_h = 18.062\frac{T_b}{P_b}\left(\frac{(P^2-P^2)D^{16/3}}{\Upsilon_g \bar{T} L \bar{z}}\right)^{.5}$$

q_h = gas flow rate, cfh at pb and Tb
T_b = base temperature, R
P_b = base pressure, psia
P_1 = inlet pressure, psia
p_2 = outlet pressure, psia
D = inside diameter of pipe, in.
Υ_g = gas specific gravity (air = 1)
$\bar{T}$ = average flowing temperature, R
L = length of pipe, miles
$\bar{z}$= gas deviation factor at average flowing temperature and average pressure.

2.2.2. Panhandle A Equation—Horizontal Flow

The Panhandle A pipeline flow equation assumes that f varies as follows

$$f = \frac{0.085}{N_{Re}^{0.147}}$$

The pipeline flow equation is thus

$$q = 435.87\left[\left(\frac{T_b}{P_b}\right)^{1.07881}\left(\frac{{P_1}^2-{P_2}^2}{\bar{T}L\bar{z}}\right)^{.5394}\left(\frac{1}{\Upsilon_g}\right)^{.4604} D^{2.6182}\right]$$

Where
q is the gas flow rate, cfd measured at T_b and p_b
T_b = base temperature, °R
P_b = base pressure, psia
P_1 = inlet pressure, psia
p_2 = outlet pressure, psia
D = inside diameter of pipe, in.
Υ_g = gas specific gravity (air = 1)

$\bar{T}$ = average flowing temperature, R

L = length of pipe, miles

$\bar{z}$ = gas deviation factor at average flowing temperature and average pressure

2.2.3. Modified Panhandle (Panhandle B) Equation—Horizontal Flow

This is probably the most widely used equation for long lines (transmission and delivery) [3]. The modified Panhandle equation assumes that f varies as

$$f = \frac{0.015}{N_{Re}^{0.0392}}$$

and results in

$$q = 737\left(\frac{T_b}{P_b}\right)^{1.02}\left(\frac{P_1^2 - P_2^2}{\bar{T}L\bar{z}\gamma_g^{0.961}}\right)^{0.510} D^{2.530}$$

2.3. Statistical Analyses

Any correlation that is presented in this study should be checked statistically in order to obtain a quantitative measurement about the accuracy of the prediction. Some basic statistical parameters used for correlation performance evaluation are average percentage relative error (APRE), average absolute percentage relative error (AAPRE) and standard error of estimate (SEE).

Average Percentage Relative Error (APRE) is a measure of the relative deviation of the predicted values from the experimental values in the percentage. The equation is given as follows,

$$\text{APRE} = \left(\frac{1}{n}\right) \text{x} \sum \left[\frac{\{(\text{Ypred} - \text{Y exp})\text{x}100\}}{\text{Y exp}}\right]$$

The smaller the error is the more evenly distributed the positive and negative differences between predicted and experimental values.

3. Results and Discussion

In calculations pipeline network was simplified with considering all intakes and off takes into few major points. Effects of valves, strainer and geometry like elbow, undulation etc were ignored. As the gas flowing through the pipeline is produced from Horipur gas field, we consider the gas properties of Horipur gas field for the calculation of several physical properties of gas.

3.1. Segment 1(Khadim DRS- Debpur DRS)

3.1.1. Pressure Calculation

In pressure calculations, Reynolds's Number and all physical properties are determined in average temperature and pressure. Also, pressure was calculated by Weymouth, Panhandle A, Panhandle B and Fekete Software (Piper, using Panhandle B) for single-phase flow. All results are given in the tables below.

Table 3. *Comparison of measured and calculated pressure data for Segment 1.*

Date	Measured	Weymouth	Panhandle A	Panhandle B	Piper
01-02.07.14	954.7	1003.02	1010.809	1008.187	989.98
02-03.07.14	944.7	1002.135	1010.538	1007.705	989.76
03-04.07.14	984.7	1003.736	1011.03	1008.578	992.34
04-05.07.14	994.7	1005.675	1011.634	1009.639	995.67
05-06.07.14	994.7	1007.151	1012.1	1010.451	998.24
06-07.07.14	969.7	1002.801	1010.742	1008.068	997.89
07-08.07.14	954.7	1000.95	1010.177	1007.062	998.87
08-09.07.14	914.7	1000.145	1009.933	1006.625	991.76
09-10.07.14	914.7	1000.124	1009.927	1006.613	991.54
10-11.07.14	934.7	1001.063	1010.211	1007.123	990.75
11-12.07.14	960.7	1002.008	1010.499	1007.636	992.76
12-13.07.14	969.7	1001.322	1010.29	1007.263	991.23
13-14.07.14	944.7	1001.634	1010.385	1007.433	987.12
14-15.07.14	981.7	1001.656	1010.392	1007.445	989.23
15-16.07.14	954.7	1002.587	1010.676	1007.952	987.35
16-17.07.14	994.7	1002.967	1010.793	1008.159	988.34
17-18.07.14	964.7	1000.552	1010.056	1006.845	986.18
18-19.07.14	949.7	1002.549	1010.665	1007.931	990.87
19-20.07.14	954.7	1001.104	1010.224	1007.145	991.53
20-21.07.14	991.7	1002.059	1010.515	1007.664	987.79
21-22.07.14	929.7	1000.664	1010.09	1006.906	987.25
22-23.07.14	934.7	1000.451	1010.026	1006.791	986.52
23-24.07.14	939.7	1000.398	1010.009	1006.762	982.4
24-25.07.14	929.7	999.9933	1009.887	1006.542	989.27
25-26.07.14	934.7	1000.709	1010.103	1006.93	986.26
26-27.07.14	954.7	1001.247	1010.267	1007.223	993.26
27-28.07.14	989.7	1005.663	1011.63	1009.633	992.49
28-29.07.14	999.7	1010.56	1013.209	1012.341	997.76
29-30.07.14	1002.7	1012.687	1013.935	1013.536	996.27
30-31.07.14	1004.7	1013.234	1014.13	1013.847	994.25
31-01.08.14	984.7	1012.797	1013.974	1013.598	992.26

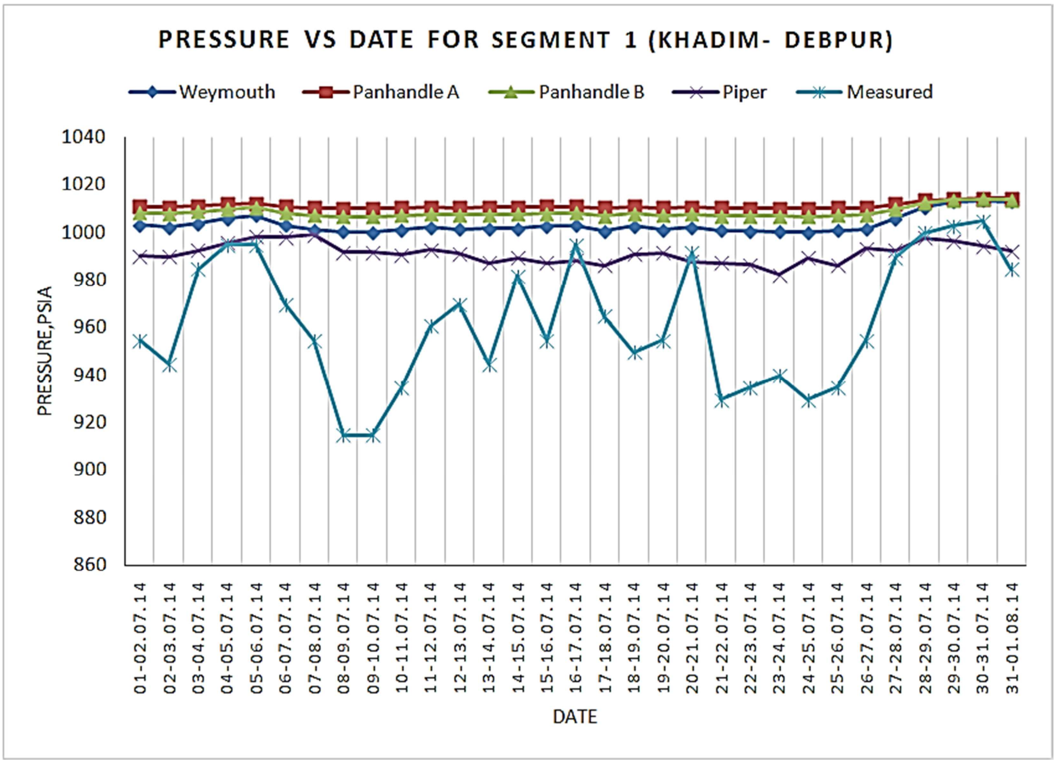

Figure 3. *Pressure vs. Date for Segment 1.*

3.1.2. APRE Values for Segment 1

APRE values for different pressure equations are given in the table below.

Table 4. *Comparison of measured and calculated APRE values for Segment 1.*

Date	Weymouth	Panhandle A	Panhandle B	Piper
01-02.07.14	5.061253	5.877137	5.602539	3.6954
02-03.07.14	6.079681	6.969155	6.669349	4.76977
03-04.07.14	1.933169	2.673897	2.424922	0.77587
04-05.07.14	1.103332	1.702407	1.501903	0.09752
05-06.07.14	1.251716	1.749316	1.583477	0.35589
06-07.07.14	3.413512	4.232415	3.956697	2.90708
07-08.07.14	4.844493	5.810915	5.484604	4.62658
08-09.07.14	9.341312	10.41138	10.04969	8.42462
09-10.07.14	9.339018	10.41069	10.04845	8.40057
10-11.07.14	7.099937	8.078638	7.748233	5.99658
11-12.07.14	4.29976	5.183596	4.885631	3.33715
12-13.07.14	3.260988	4.185797	3.873699	2.22027
13-14.07.14	6.026674	6.952973	6.640515	4.49031
14-15.07.14	2.032827	2.922637	2.622497	0.76704
15-16.07.14	5.015924	5.863215	5.577836	3.41992
16-17.07.14	0.831149	1.617868	1.353062	-0.63939
17-18.07.14	3.716428	4.701579	4.368766	2.2266
18-19.07.14	5.564827	6.419343	6.131512	4.33505
19-20.07.14	4.860632	5.815815	5.493368	3.85776
20-21.07.14	1.044594	1.8972	1.609786	-0.39427
21-22.07.14	7.632984	8.646865	8.304397	6.19017
22-23.07.14	7.03447	8.058789	7.712698	5.54402
23-24.07.14	6.459311	7.482117	7.136513	4.544
24-25.07.14	7.560858	8.625051	8.265278	6.40744
25-26.07.14	7.062017	8.067132	7.727645	5.51621
26-27.07.14	4.87561	5.820368	5.501504	4.03897
27-28.07.14	1.612902	2.215832	2.014031	0.2819
28-29.07.14	1.086373	1.351314	1.26445	-0.19406
29-30.07.14	0.99603	1.120513	1.080679	-0.64127
30-31.07.14	0.849438	0.938597	0.91042	-1.04011
31-01.08.14	2.853329	2.972886	2.934709	0.76775

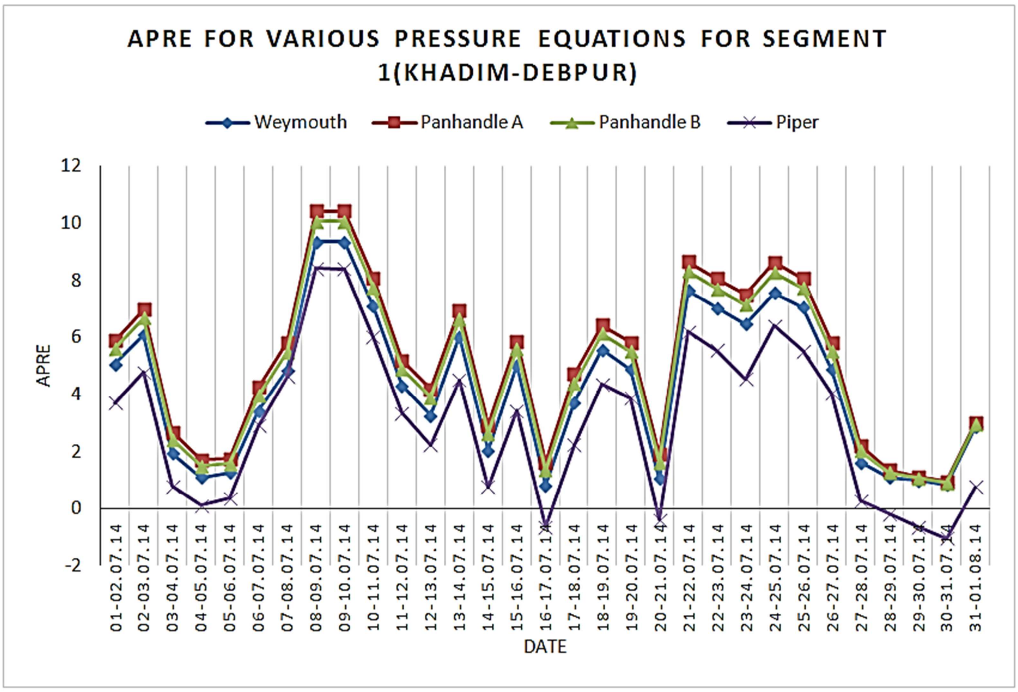

Figure 4. *APRE comparison for various pressure equations for Segment 1.*

3.2. Segment 2 (Debpur DRS- Kumargaon DRS)

3.2.1. Pressure Calculation

Pressure was calculated using different single phase equations and Feket (Piper) for Segment 2 (Debpur DRS- Kumargaon DRS). The comparison of different pressure values are given in the table below.

Table 5. *Comparison of measured and calculated pressure data for Segment 2.*

Date	Weymouth	Panhandle A	Panhandle B	Measured	Piper
01-02.07.14	922.782	951.531	954.357	764.7	940.72
02-03.07.14	916.737	948.4	951.288	804.7	945.26
03-04.07.14	927.787	954.146	956.909	844.7	942.36
04-05.07.14	938.379	959.755	962.347	884.7	952.73
05-06.07.14	946.724	964.254	966.669	914.7	951.35
06-07.07.14	929.048	954.809	957.554	784.7	951.65
07-08.07.14	914.36	947.176	950.085	774.7	949.47
08-09.07.14	909.91	944.897	947.84	884.7	949.67
09-10.07.14	908.937	944.401	947.35	791.7	949.36
10-11.07.14	911.788	945.857	948.787	774.7	947.3
11-12.07.14	916.873	948.469	951.357	802.7	949.37
12-13.07.14	911.357	945.636	948.569	764.7	942.36
13-14.07.14	914.921	947.464	950.369	874.7	947.36
14-15.07.14	916.724	948.393	951.281	884.7	947.47
15-16.07.14	927.656	954.078	956.842	791.7	948.37
16-17.07.14	937.205	959.129	961.742	864.7	951.33
17-18.07.14	917.253	948.665	951.549	854.7	950.36
18-19.07.14	922.421	951.343	954.173	800.7	947.36
19-20.07.14	917.776	948.936	951.814	869.7	946.98
20-21.07.14	930.654	955.654	958.376	769.7	947.35
21-22.07.14	921.62	950.926	953.766	880.7	949.36
22-23.07.14	920.002	950.087	952.944	802.7	948.13
23-24.07.14	922.745	951.512	954.338	864.7	949.25
24-25.07.14	918.915	949.524	952.392	764.7	947.36
25-26.07.14	924.461	952.406	955.212	784.7	947.49
26-27.07.14	929.737	955.171	957.907	764.7	943.46
27-28.07.14	951.917	967.094	969.375	874.7	947.37
28-29.07.14	981.372	984.106	985.054	914.7	951.36
29-30.07.14	985.746	986.894	987.459	884.7	947.32
30-31.07.14	985.476	986.716	987.31	914.7	948.27
31-01.08.14	982.191	984.617	985.501	864.7	957.26

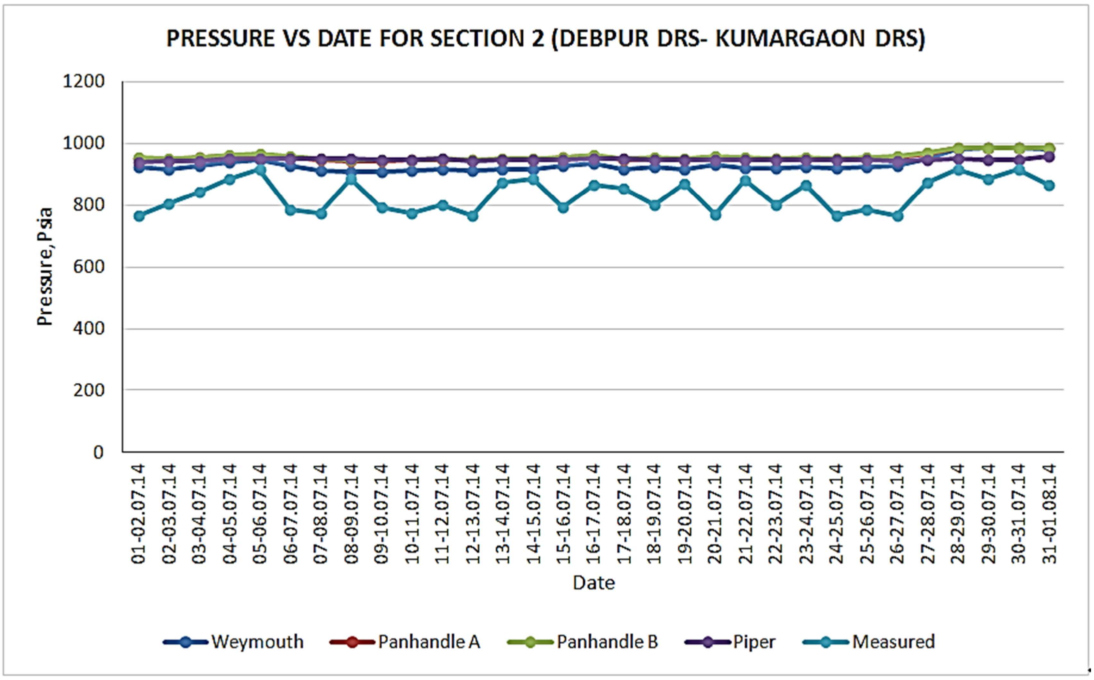

Figure 5. *Pressure vs. Date for Segment.*

3.2.2. APRE Values for Segment 1

APRE values for different pressure equations are given in the table below.

Table 6. *Comparison of measured and calculated APRE values for Segment 2.*

Date	Weymouth	Panhandle A	Panhandle B	Piper
01-02.07.14	20.67244	24.4319	24.801	23.01818
02-03.07.14	13.92289	17.8575	18.216	17.46738
03-04.07.14	9.836274	12.9568	13.284	11.5615
04-05.07.14	6.067435	8.48369	8.7767	7.689612
05-06.07.14	3.501037	5.41754	5.6815	4.006778
06-07.07.14	18.39532	21.6782	22.028	21.27565
07-08.07.14	18.02767	22.2636	22.639	22.5597
08-09.07.14	2.849557	6.80424	7.1369	7.343732
09-10.07.14	14.80822	19.2877	19.66	19.91411
10-11.07.14	17.69565	22.0933	22.472	22.27959
11-12.07.14	14.22357	18.1599	18.52	18.27208
12-13.07.14	19.17835	23.6611	24.045	23.23264
13-14.07.14	4.598237	8.31876	8.6508	8.306848
14-15.07.14	3.61975	7.19935	7.5259	7.09506
15-16.07.14	17.17269	20.51	20.859	19.78906
16-17.07.14	8.385004	10.9204	11.223	10.0185
17-18.07.14	7.318686	10.994	11.331	11.19223
18-19.07.14	15.20177	18.8139	19.167	18.31647
19-20.07.14	5.527933	9.1107	9.4417	8.885823
20-21.07.14	20.91127	24.1593	24.513	23.08042
21-22.07.14	4.646299	7.97394	8.2963	7.796071
22-23.07.14	14.61348	18.3614	18.717	18.1176
23-24.07.14	6.71274	10.0395	10.366	9.777958
24-25.07.14	20.16674	24.1695	24.545	23.88649
25-26.07.14	17.81081	21.372	21.73	20.74551
26-27.07.14	21.58191	24.9079	25.266	23.37649
27-28.07.14	8.827771	10.5629	10.824	8.307991
28-29.07.14	7.288962	7.58783	7.6915	4.007871
29-30.07.14	11.42149	11.5512	11.615	7.078106
30-31.07.14	7.737606	7.87323	7.9381	3.670056
31-01.08.14	13.58744	13.868	13.97	10.70429

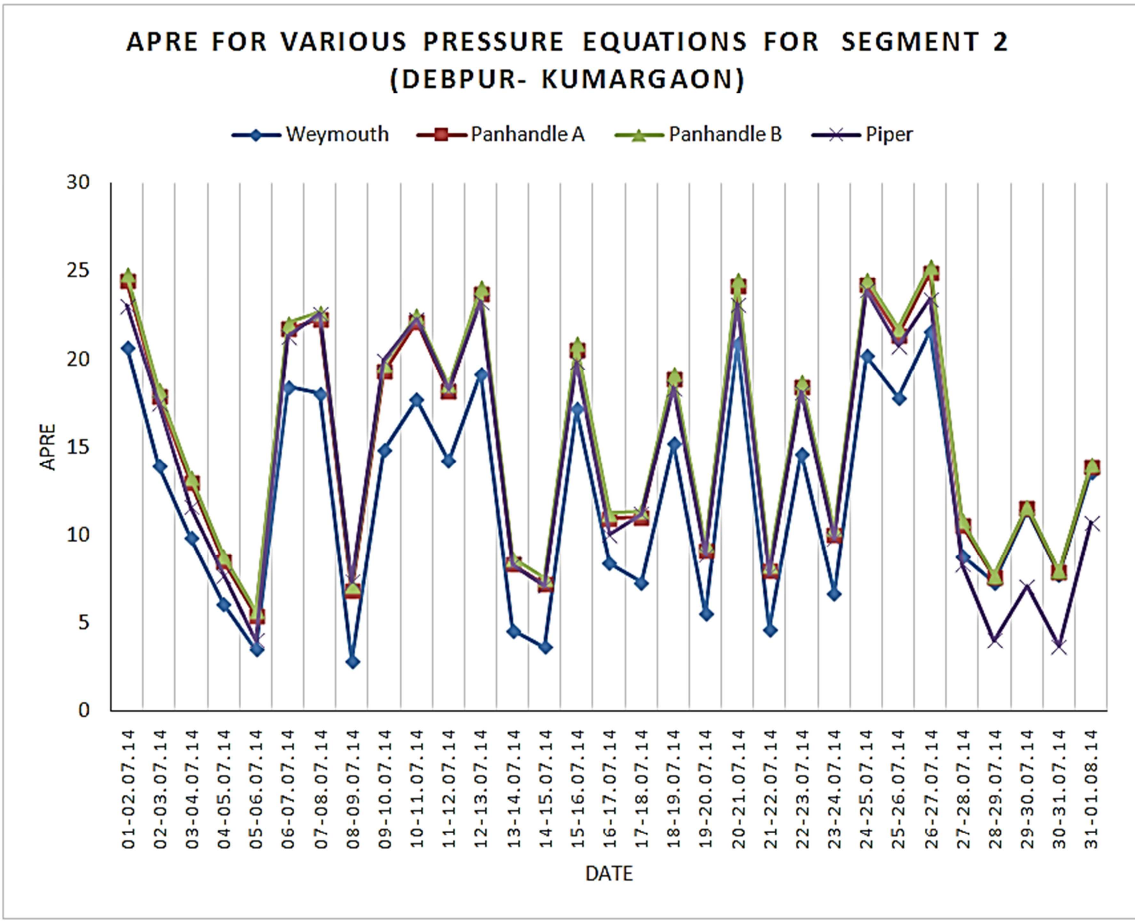

Figure 6. *APRE comparison for various pressure equations for Segment 1.*

Pressure calculated by Panhandle B method gave good results. As, Piper used panhandle B as a governing equation, it gave satisfactory result also. Weymouth equation is valid for pipeline diameter <15 inch±, so it follows the measured value line. Panhandle A gave unsatisfactory results.

3.3. Problems Faced By JGTDSL

While transmitting gas through KDK pipeline JGTDSL faces following problems: a) Liquid forms in the pipeline, which sometimes block the pipeline. b) Temperature and heating value decreases. c) There is always a volume gain at Kumargaon Station. JGTDSL takes following steps to overcome the above problems: a) They do the gas purging to clear the block. b) Before delivering the gas to their customers, gas is heated by a water bath heater at kumargaon station. c) Currently they are not taking any steps relating to this problem as their attention is on heating value.

4. Conclusion

4.1. Conclusion

The present study has led to following conclusions that are important from the authors' viewpoint. a) When pressure is calculated for single-phase flow, it is under designed. b) Statistical analysis supports this engineering problem. So, a computer generated pressure calculation may solve this problem. c) As liquids form in the pipeline during transmission, it indicates two phase flow in the pipeline, which demands further study.

4.2. Future Recommendation

As there are various assumptions in this work, it can be stated that improved results will come if proper information is used. In future, one can improve this work by making the following corrections. a) If physical parameters like gas and liquid flow rates, pressures, diameters are known at Kuchai point, this study will be improved by completing the network analysis properly. b) As JGTDSL does not have gas Chromatograph at Kumargaon Station, a gas sample can be collected and a gas chromatographic analysis report will improve the result. c) At Kuchai point, no pressure data is found from Daily Production Report provided by JGTDSL. So, calculated pressure cannot be compared with measured data at this point. A real pressure data can change the result.

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