Quest Journals
Journal of Software Engineering and Simulation
Volume 7 ~ Issue 10 (2021) pp: 05-15
ISSN(Online) :2321-3795 ISSN (Print):2321-3809
www.questjournals.org

Research Paper

Modelling Of LPG Distribution Pipeline Network for Household Consumption- A Case Study

Noble Ukela Odoi[1] Ogbonna F. Joel[2]Sunday S. Ikiensikimama[2]
Neeka B. Jacob[3]

[1]*Ph.D Candidate, African Center for Excellence, Center for Oilfield Chemicals Research (ACE-CEFOR), University of Port Harcourt, Port Harcourt, Rivers State, Nigeria.*
[2]*Professor, Department of Petroleum and Gas Engineering, University of Port Harcourt, Port Harcourt, Rivers State, Nigeria.*
[3]*Head, Research and Development Unit, Petroleum Technology Development Fund, Federal Capital Territory, Abuja, Nigeria.*

ABSTRACT:
Until the last 10 years, the gas industry in Nigeria has remained grossly underdeveloped and thus its utilization remained below expectation of a nations with such an abundance of Natural Gas resource. This study is an attempt to present simplified and unique models for LPG distribution in a residential region of a new city- Greater Port Harcourt City.The housing arrangement fund in the city are the grid and series. The pipeline layout was modelled using Aspen HYSYS 11.0 with current and available data. Pressure drop and temperature profiles were modelled against the pipe length and was found to be exponential and logarithmic respectively for the grid housing arrangement whereas the pressure drop and temperature profile model against the pipe length for the series were found to be of the polynomial form of the third and second order respectively, with all models having coefficient of determination lying between 87.38 and 99.99%. Another discovery made is the conformance of the model to the general fluid flow equation modified for low pressure systems.

KEY WORDS: *Natural Gas, Liquefied Petroleum Gas, Pipelines, Modelling, Temperature, Simulation, Pressure drop, Pipelength, Aspen Hysys.*

Received 27 September, 2021; Revised: 08 October, 2021; Accepted 10 October, 2021 © The author(s) 2021. Published with open access at www.questjournals.org

I. INTRODUCTION

Natural gas is a colourless, dourless and tasteless combustible gas which gives off minimal emissions compared to other fossil fuels (Mokhtab S et al, 2015) (1). Gana (2015) opines that it is much safer to transport and store natural gas compared to other fossil fuels (2).It has served many useful purposes all over the world, including space heating, electricity generation, domestic use, feedstock for the petrochemical industry and transportation fuel (4).

For any resource to be used, it has to be transported from where it is being formed/produced to where it will be used and the transportation method is key as safety, efficiency and economics are the focal point in every engineering project (3). In the case of natural gas, there are currently 4 popular ways of transporting natural gas. They are: Pipelines (Pipeline Natural Gas, PNG), Liquefaction (Liquefied Natural Gas, LNG), Compression (Compressed Natural Gas, CNG) and Hydrates (Natural Gas Hydrate, NGH).Studies evaluating the profitability of natural gas transportation from one location to anotherare available, they show critical distances where a given transportation method would become most profitable (5)(6)(7).In Nigeria, natural gas is largely transported using the LNG, PNG and CNG technologies. LNG is purely for export purposes while CNG is for transportation over distances within the country by land. Prior to the commencement of the Ajaokuta-Kaduna-Kano 614km long natural gas pipeline project, pipeline projects have not been so popular in the region and most pipeline projects have been industrial area biased with non for domestic consumption (8).This research has become very necessary in line with the Nigeria gas master plan, to increase the rate of domestic consumption of the commodity and thus the need to contribute meaningfully towards achieving that by presenting a technical insights which provides answers and guidance useful for the originating application (9).

There have been methods of achieving a model with involves data gathering and the mathematical manipulation of those data to draw relationships and identify useful trends (10). In many climes, these relationships can be drawn via computer aided simulation from the appropriate software and carrying out a regression analysis and/ or using Microsoft excel solver (11)(12).

In Nigeria, today, there is no known area where liquefied petroleum gas (LPG) is channeled directly to domestic homes making this research a novel approach at showcasing models for preliminary design and detailed design in the Nigerian space. This research is carried out using Greater Port Harcourt City as case study. It is located towards the south-east of the city stretching south from Oyigbo to and include Onne port while the second much larger one expands north of the city to include Port Harcourt International Airport and amongst others Araba, Umuechem, Igbo-Etche, Igwruta, Omagwa, Ozaha and Ipo settlement. The area's eastern boundary is defined by Otamiri-Etche River, its couthern boundary by the old city, its western boundary is between Omagwa and Isiokpo settlements and its northern boundary is less defined allowing space for commercial development around the international airport (13).

II. MATERIALS AND METHODS

A. *Overview*

Gas distribution pipeline networks are a system of long lengths of pipes with associated accessories such as elbows, flanges, tubes, valves and regulators. Critical in modelling gas pipelines are the equivalent lengths of the gas pipeline, the flow regime and hydraulics, the expected delivery flow rate and pressure drop studies and the line pack volume calculations.The simulation of the gas distribution pipeline takes bearing from the product of the gas processing plant and then routed to the two major housing arrangement under consideration – the Grid and the series housing arrangement as contained in the Greater Port Harcourt City master plan. The CNG from the plant is passed through a cooler and a depresuriserto the end that it meets final delivery specification of pressure and temperature before being separated by successions of pipes, tees and headers and terminated by sinks/ tanks.

Feed stream Parameters

Table 1: Properties of LPG from the Gas Plant

Property	**Value**
Temperature (^oC)	14.18
Pressure (kPa)	960.5
Molar Flowrate (MMSCFD)	0.1263
Mass Flow rate (kg/h)	350.0
Composition	**Mole fraction**
Nitrogen	0.0000
Carbon dioxide	0.0000
Methane	0.0000
Ethane	0.0196
Propane	0.1444
Iso Butane	0.0006
Normal Butane	0.8310
Iso Pentane	0.0016
Normal Pentane	0.0023
Normal Hexane	0.0002
Normal Heptane	0.0002
Normal Octane	0.0000
TEGlycol	0.0001
H_2O	0.0020

B. Determination of Gas Demand

LPG has which will be distributed in the household of the Greater Port Harcourt city is determined based on the assumption that a 1.0kW table top cooker burner is used in every household of the new city. The characteristics of the cooker is contained in Appendix 1. The gas demand for this burner is as presented on the nameplate, the estimated cooking time and number of cooling per day. Thereafter estimated in terms of demands per hour. The equation used is as stated in Eq. 1:

$$Q = \frac{1}{\eta}(a \times t_c x N \times X) \qquad \text{Eq. 1}$$

ŋrepresents the efficiency of the LPG supply for cooking.
arepresents LPG used per person per hour for cooking.
t_c represents themaximum cooking time.
Nrepresents the average number of times for cooking plus boiling water in a day.
Xrepresents the average number of the family in a household in the study area.

This will enable us in the determination of the appropriate flowrate for each household as well as the pipeline storage need in terms of peak and off-peak period.

C. Design of the Pipeline Network

Simulation Tool

There are a number of simulation packages available, however, ASPEN HYSYS provides one of the best process modelling environments for conceptual design and operations improvement of oil and gas process. This modeling tool has been used by researchers and engineers for decades to achieve improved engineering design and energy efficiency as well as reduce capital cost thus the choice of ASPEN HYSYS 11.0. Peng-Robinson thermodynamic model was chosen fluid property package (14) (15).

Equipmentand Design Dynamics

In the design model, the equipment necessary for its optimal process are; cooler, depressuriser, different diameters and lengths of pipe,Tees, and storage tanks(16) (17). The cooler is placed to reduce the temperature of the LPG while the depressuriser is to reduce the pressure of the gas entering into the housing units given that the existing pressure is too high for the equipment and environmental requirement. In The greater Port Harcourt City Master plan, there are majorly two housing arrangements – the grid and the series, therefore, the pipeline outlay follows this model as shown in Figure 2. The complete outlay is presented in Appendix 2.

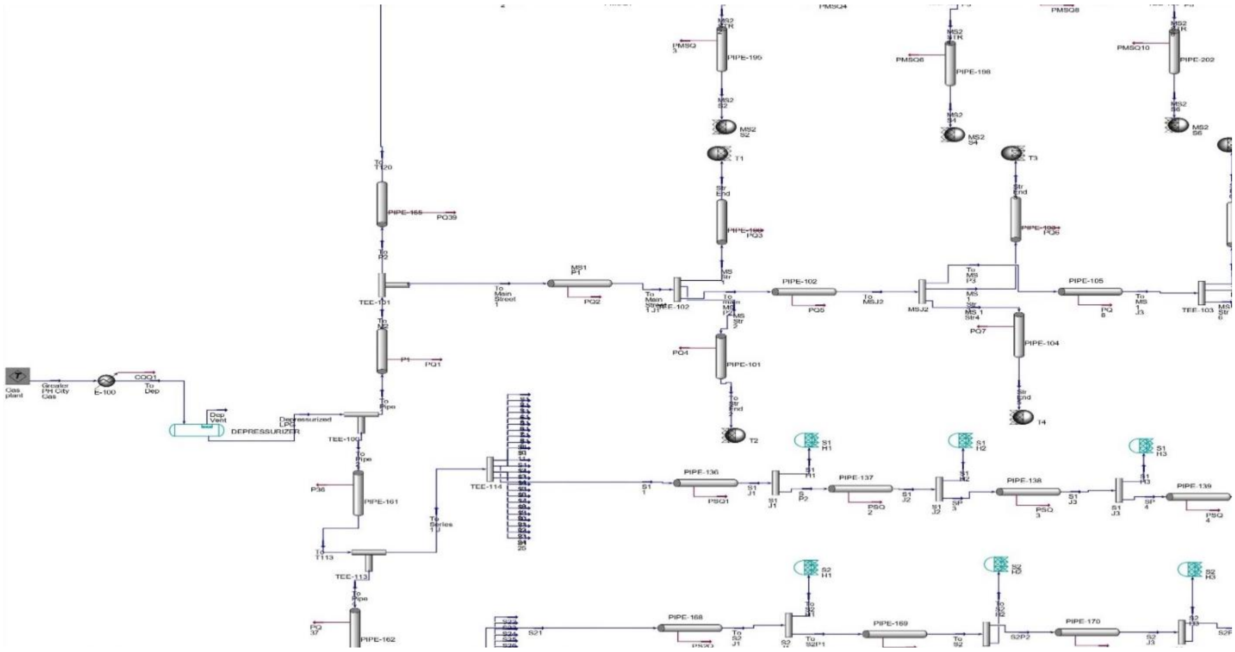

Figure 1: Simulated Flow-sheet for Grid and Series Pipeline Configuration using Aspen HYSYS 11.0

The T-100 separates the total volume of gas coming into the residential area into two equal parts, one for the grid housing arrangement and the other to the series housing arrangement.

For the grid, the gas is channeled to a 150m pipeline and separated by TEEs (TEE-101) as it enters into the main streets through a pipelines (MS1P1). The gas goes into the houses via a left and right wing pipelines coming from a junction TEE-102, with 50 houses situated on the left and 50 on the right wings of the pipeline (Pipe-100) and terminated with a storage tank at the end of that street (T1). Same applies to PIPE-101 wherein there are 50 houses to the left and 50 houses to the right terminated by a storage tank T2 and it continues as seen on Figure 2. The pipes running horizontally through Main Street1 (PIPE-102, PIPE-105 etc.)are pipes through which LPG flows to get to the streets on the left and right, they are 100m in length. The grid houses have 4 main streets bringing us to a total of5,000housing units.Each of the pipes flanked by 50 houses on both sides is 2,500 meters long. For the series housing arrangement, the TEE-114 distributes the gas to 25 streets which have 25houses lined up in series with the sink representing the house into which the gas is distributed S1H1 representing the first house on the first street and it continues as seen on Figure 2 above. For the 4 major lanes results in a total of 2,500 houses on the series side.

The details of the process flow pipeline design parameters for both series and parallel is as seen on Table 2.

Table 1: Pipe Design Parameters
FOR GRID HOUSING ARRANGEMENT

Table 2a: Pipe through the main street 1 - 4

S/N	Description	Unit of Measurement	Value
1	Equivalent Length	m	100
2	Elevation Change	m	0.0000
3	Material	-	Mild Steel
4	Roughness	m	0.00004572
5	Pipe wall Conductivity	W/m-K	45.00
6	Insulation Type	-	Urethane Foam
7	Ground Type	-	Dry Peat
8	Increments	-	5

Table 2b: Pipeline to the Houses

S/N	Description	Unit of Measurement	Value
1	Equivalent Length	m	2500
2	Elevation Change	m	0.0000
3	Material	-	Mild Steel
4	Roughness	m	0.00004572
5	Pipe wall Conductivity	W/m-K	45.00
6	Insulation Type	-	Urethane Foam
7	Ground Type	-	Dry Peat
8	Increments	-	5

FOR SERIES HOUSING ARRANGEMENT

Table 2c: Pipe through the main street 1 - 4

S/N	Description	Unit of Measurement	Value
1	Equivalent Length	m	2500
2	Elevation Change	m	0.0000
3	Material	-	Mild Steel
4	Roughness	m	0.00004572
5	Pipe wall Conductivity	W/m-K	45.00
6	Insulation Type	-	Urethane Foam
7	Ground Type	-	Dry Peat

Table 3: Flow Assurance Models for both Grid and Series Housing Arrangement

S/N	Description	Models Used
1	CO_2 Corrosion: Corrosion Model Corrosion Inhibitor	 NORSOK-506 Nil
2	Erosion: Empirical Constant	API-RP-14E Continuous service
3	Hydrates: Model Hydrate calculation Model	 Ng & Robinson Symmetric Model
4	Slug Analysis: Translational Model Holdup Model Frequency Model Friction factor Model	 Bendikson Gregory et al Hill & Wood ColebrookWhite

Microsoft Excelis used extensively in this work for ease of computation and to achieve sensitivity analysis. It aids in plotting of graphs and used to perform analysis such as regression analysis and the generation of equationsto plotted points.In this study, the Goal Seek function of Excel is used to solve the Colebrook White equation. The Goal Seek function is generated from the DATA tab at the top of the Excel Sheet is under the What-If Analysis. The friction factor is gotten using the following steps:

a) Creating a column for the friction factor
b) Imputing the formula on the left hand side of the equation
c) Imputing the equation on the right hand side of the equation
d) Creating a column called CHECK which is the difference between the value of the right side and the left side
e) Applying the goal seek function wherein in we input by setting the CHECK cell to 0 by changing the values on the left hand side and the right hand side.

III. RESULTS AND DISCUSSION

A. Gas Demand

The gas demand in m^3/day is obtained from equation 1 above and is computed with the Equation 1 above. This computation presents a total gas demand of 12.6kg per month per household this implies that each household will need a supply of 0.0175kg of gas every hour. This is consistent with the discoveries of Adegobla et al (2021)(18) and corroborated by earlier research by Idris I.O et al (2019) (19), however, Idris et al presented their findings in m^3/day.

B. The Effect of Pipeline Elevation on Delivery Pressure.

Through this pipeline transmission gas delivery, the concept of pipeline design is established through its location, the type of fluid being carried and its operating pressure and temperature are also very important within the process. It is therefore imperative that we model the performance of temperature and pressure along the pipelines for both the grid and series housing arrangement. The plot of pressure drop along the pipeline and temperature gradient is presented below from the Hysysdata extracted in the Excel Spreadsheet contained in Appendix 3. The plot and the regression was done using Microsoft Excel version 2013.

Grid

Pressure Drop vs Pipeline Length

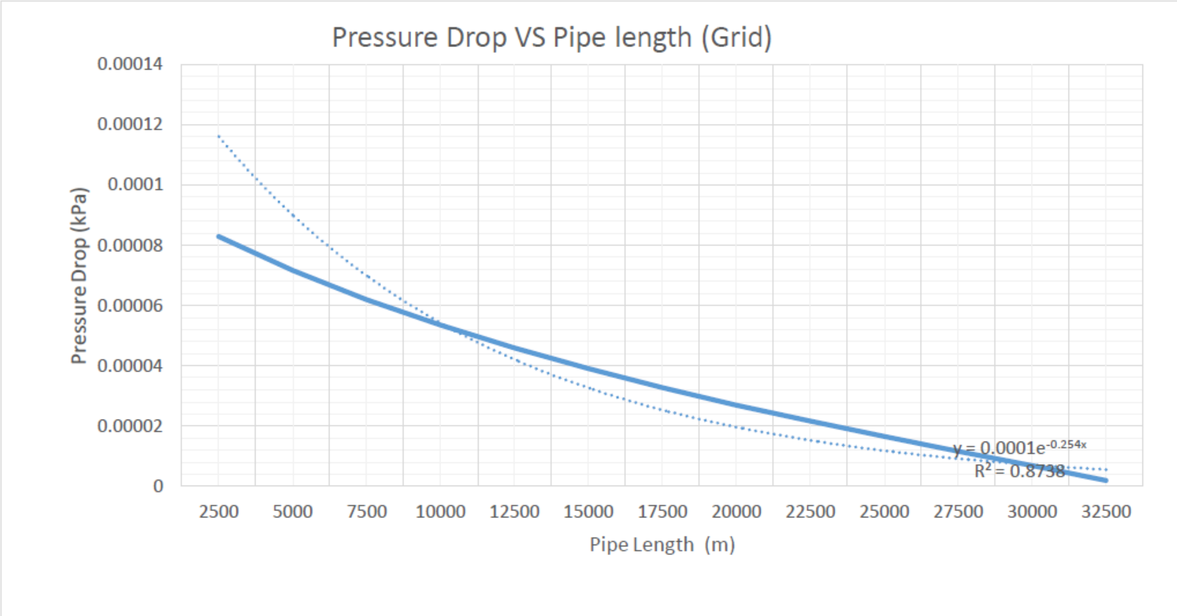

Figure 2: Plot of Pressure Drop vs Pipeline Length for Grid Housing Arrangement

The resulting equation is of the exponential form. However, the variation in the dependent variable that is predictable from the independent variable (coefficient of determination) is 0.8738. This is considered acceptable haven crossed the 85% mark.

The resulting model is $y = 0.0001e^{\mathbf{-0.254X}}R^2 = 0.8738$. The model developed is of the form $y = ae^{bx}$ where a = 0.0001 and b = -0.254.

Temperature vs Pipeline Length

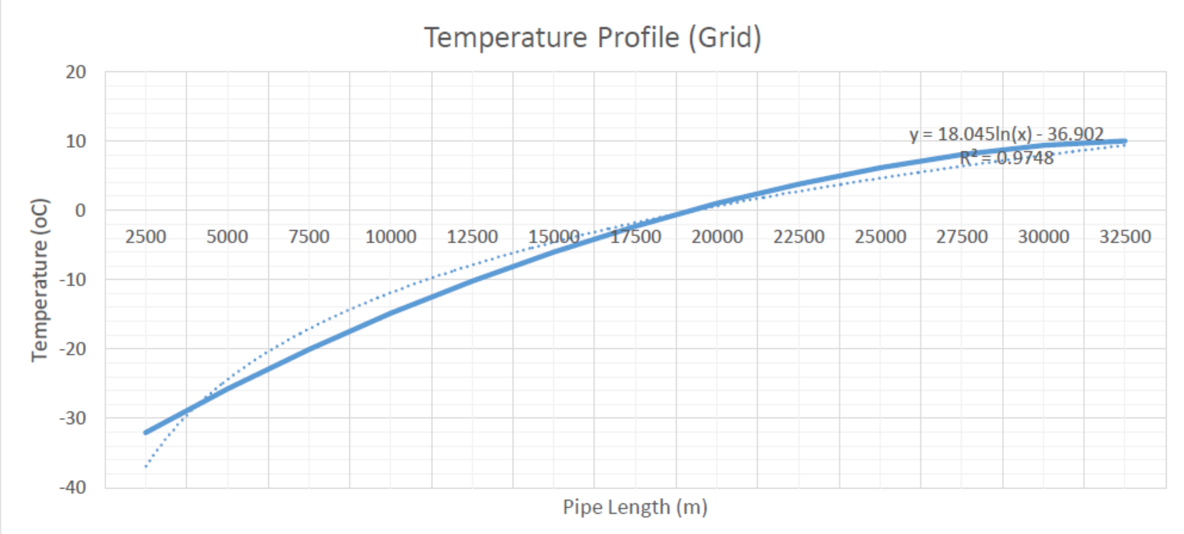

Figure 3: Plot of Temperature vs Pipe Length for Grid Housing Arrangement

The resulting equation is of the logarithmic form. However, the variation in the dependent variable that is predictable from the independent variable (coefficient of determination) is 0.9748. This is considered acceptable haven crossed the 85% mark. The resulting model is **y = 18.045ln(x) – 36.902** R^2 = 0.8738. The model developed of the form y = aln(x) + b where a = 18.045 and b = -36.902.

Series

Pressure Drop vs Pipeline Length

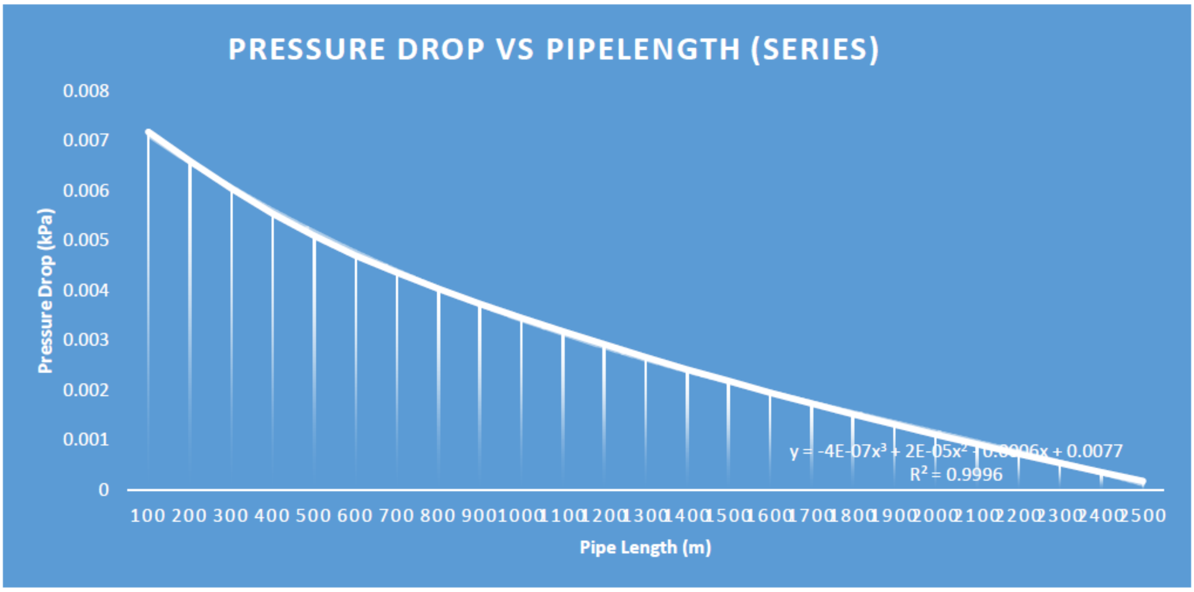

Figure 4: Plot of Pressure drop vs Pipe length for Series Housing Arrangement

The resulting equation is of the polynomial form of the third order. However, the variation in the dependent variable that is predictable from the independent variable (coefficient of determination) is 0.9996. This is considered acceptable haven crossed the 85% mark. The resulting model is $\mathbf{y = -4E\text{-}07X^3 + 2E\text{-}05X^2 - 0.0006X + 0.0077}$ R^2 = 0.9996. The model developed of the form $y = aX^n + bX^{n-1} + CX^{n-2} + D$ wherea = -4E-07 b = 2E-05 c = – 0.0006 and D = 0.0077.

Temperature vs Pipe Length

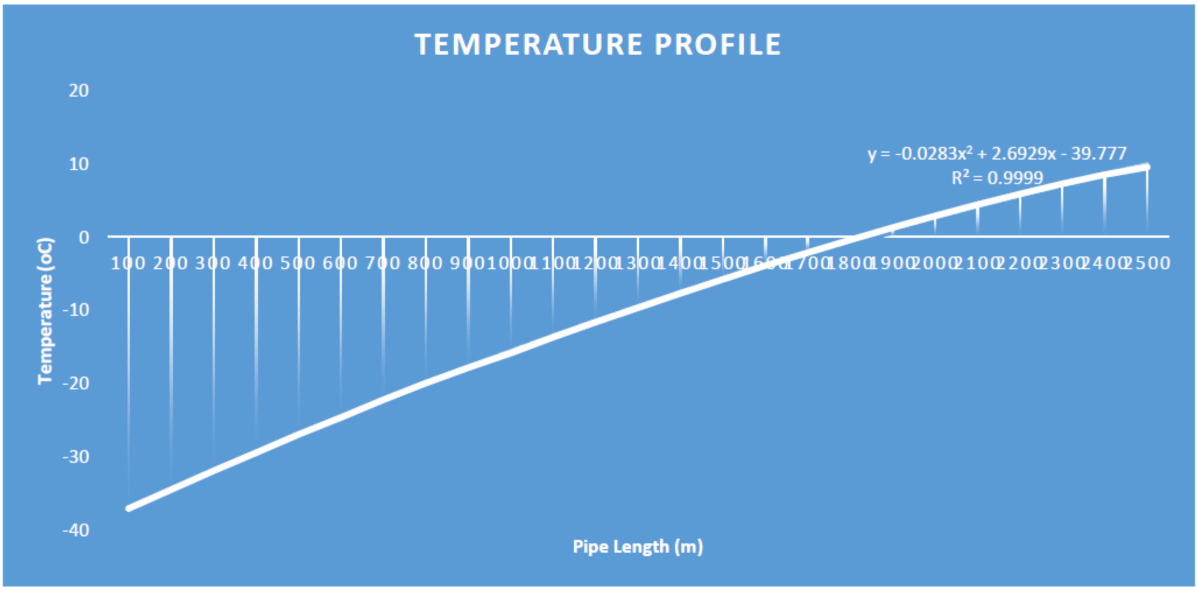

Figure 5: Plot of Temperature vs Pipe length for Series Housing Arrangement.

The resulting equation is of the polynomial form of the second order. However, the variation in the dependent variable that is predictable from the independent variable (coefficient of determination) is 0.9999. This is considered acceptable haven crossed the 85% mark.

The resulting model is **$y = -0.0283X^2 + 2.6929X - 39.777$** $R^2 = 0.9996$. The model developed of the form $y = aX^n + bX^{n-1} + c$ where a = -0.0283 b = 2.6929 c = – 39.777.

C. Line pack Volume Determination

The quantity of gas contained within the pipelines under pressure is imperative to ascertain if the volume of gas contained within the pipeline is high enough to sustain gas supply at peak demand while ensuring pipeline integrity to mitigate against bursting. In [20], we find an equation for line pack volume of gas in a pipeline as:

$$\Delta V_s = \frac{0.7854}{10^6}\frac{T_s}{p_s}\frac{L.d^2}{T}\left[\left(\frac{p_m}{Z_m}\right)_1 - \left(\frac{p_m}{Z_m}\right)_2\right] \qquad \text{Eqn. 2.1}$$

Where ΔV_s is the volume of line-pack storage expressed at the standard condition T_s and P_s and Z_m (1and 2) are the maximum and minimum flow rates.

$$P_m = \frac{2}{3}\left[P1 + P2 - \left(\frac{P1P2}{P1+P2}\right)\right] \qquad \text{Eqn. 2.2}$$

Where P1 is the upstream pressure while P2 is the downstream pressure what is, the pressure at the end of the pipeline system.

Using Microsoft Excel for the computation, we have as the results presented in the table below:

Grid

Table 4a: LPG Flow Results for Grid Housing Arrangement

S/N	Parameters	Unit of Measurement	Value
1	Linepack Volume ΔVs	m^3	340.1620586
2	Linepack Volume ΔVs	Kg	623.0068103
3	Linepack Volume ΔVs per Household	Kg	0.062300681
4	Average Pressure P_m	bar	4.99000668
5	Number of days in a month	-	30
6	Conversion factor of m^3 of LPG to Kg	-	1.8315
7	Number of Households	-	10000
8	Monthly LPG requirement per household	Kg	12.6

Series

Table 4b: LPG Flow Results for Series Housing Arrangement

S/N	Parameters	Unit of Measurement	Value
1	Linepack Volume ΔVs	m^3	30.69600914
2	Linepack Volume ΔVs	Kg	56.21974075
3	Linepack Volume ΔVs per Household	Kg	0.022487896
4	Average Pressure P_m	bar	4.999500017
5	Number of days in a month	-	30
6	Conversion factor of m^3 of LPG to Kg	-	1.8315
7	Number of Households	-	2500
8	Monthly LPG requirement per household	Kg	12.6

D. Model Validation

Simulation Output from the Grid System

Equation (5) is the flow equation which applies over all pressure ranges and is the basis for many of the flow equations used in the analysis of transmission and distribution networks. The general flow equation, using gas industry units is given by this equation.

$$Q = \frac{7.574 \ x\ 10^{-4}}{\sqrt{f}} \frac{T_s}{p_s} \sqrt{\frac{(P_1^2 - P_2^2)\ d^5}{S.L.Z.T}} \qquad \text{Equation 5}$$

Equation 5 above can be simplified for Medium Pressure systems to give:

$$Q = \frac{1.269 \ x\ 10^{-2}}{\sqrt{f}} \sqrt{\frac{(P_1^2 - P_2^2)\ d^5}{S.L}} \qquad \text{Equation 6}$$

Equation 5 above can also be simplified for Low Pressure systems to give:

$$Q = \frac{5.712 \ x\ 10^{-4}}{\sqrt{f}} \sqrt{\frac{(P_1 - P_2)\ d^5}{S.L}} \qquad \text{Equation 7}$$

The friction factor applied here is the HaginPoisuille equation consistent with that used in the HYSYS Model which uses the Colebrook white equation and is presented below:

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{e}{3.7D} + \frac{2.51}{R_e\sqrt{f}}\right) \qquad \text{Equation 8}$$

Because of the appearance of friction factor on both sides of the Colebrook White Equation, we cannot solve it by algebraic method thus it needs a numeric solution which when solved manually is prone to errors because of the number of iterations needed. We therefore use the Goal Seek function in Excel to solve it.However, the friction factorused here was gotten by the friction factor ofHaginPoisuille equation for laminar flow given by the formula:$f = \frac{64}{R_e}$ where Re is Reynolds number given by $\frac{\rho V d}{\mu}$. $\rho = density$ v= fluid velocity d = pipe diameter$\mu = dynamic\ viscosity$.

The result using Microsoft Excel for computation. The result is as shown on Table 5 with further details of this computation is on Appendix 3

Table 5: Resulting flowrates from the different variants of the general fluid flow equation

S/N	Pressure Range	Flow Rate (m^3/hr)	Absolute Percentage Error (%)	Remark
1	All Pressure Range	2.91977	100,547	Inappropriate
2	Medium Pressure	0.20236	6,875.49	Inappropriate
3	Low Pressure	0.00288	0.6837	Appropriate
4	Result from Hysys Model	0.002901	0	-

The model is consistent with the low pressure variant of the general flow equation and therefore applies in this case study.

IV. CONCLUSION

Liquefied Petroleum Gas transportation system for domestic consumption can be modeled using Aspen Hysys version 11.0 with a high level of accuracy exceeding 99.3%. Presenting pertinent parameters – temperature and pressure along a pipeline is imperative and showcases a basis for design and further studies.

The study modeled the pressure drop and temperature profile of the flowing LPG with respect to the pipe length. In this study, it was discovered that for the grid system, the temperature drop against the pipe length gave an exponential relationship and the temperature profile against the pipe length gave a logarithmic relationship. For the series housing arrangement, pressure drop against pipe length has a polynomial relationship of the third order which the temperature profile against the pipe length gave a polynomial relationship of the second order with all models having a coefficient of determination (R^2) greater than 85% making the relationship a good fit. The model was validated and found to be consistent with the general gas flow equation modified for low pressure systems.

REFERENCES

[1]. SaeidMokhatab and William A. Poe. Handbook on Natural Gas Transmission and Processing: Principles and Practice Second Edition. Chapter 1: Natural Gas Fundamentals. Gulf Professional Publishing. 30 Corporate drive Suite 400, Burlington,01803 MA USA, 2016.

[2]. GnanaShekaraArumugam. Alternative Models to Natural Gas Transportation System Performance Optimisation. M.Sc Thesis, University of Kentucky, Lexington, 2015.

[3]. Peter Debney. An Introduction to Engineering Optimisation Methods. Methods. Structural Engineer, 2016. 94(3): 34-41.

[4]. Ubani, E.C. and Ani, G.O. Natural Gas Utilisation and Its Effect on Nigeria's Economy. International Journal of Scientific Engineering and Technology, 2016. 12(5): p. 532-536.

[5]. Javanmardi J. et al. Natural Gas Transportation: NGH or LNG? World Review of Science Technology and Sustainable Development, 2007. 4(2).

[6]. American Petroleum Institute. Oil and Gas Transportation and Storage Infrastructure: Status, Trends and Economic Benefits. Report Substianted by HIS Global Inc, Wshington, DC 20036, 2013.

[7]. Sinor J.E et al. Comparison of CNG and LNG Technologies for Transportation Applications. Final Subcontract Report, National Renewable Energy Laboratory, 1992

[8]. National Petroleum Investment Management Services (NAPIMS). www.napims.nnpcgroup.com-iar-services/Pages/Gas-Operations.aspx., 2021.

[9]. SefaDundar et al. Mathematica Modelling at a Glance: A Theoritical Study. Procedia-Social and Behaviousal Science, 2012. 46: 3464-3467.

[10]. Ian C. Zink et al. Review of Salinity Effects and Abundance, Growth and Survival of NearshoreLifestages. Ecological Indicators, 2017. 81(3): 1-17.

[11]. DraganCretkovic. Modelling and Computer Simulation. Singidunum University, 2019.

[12]. Drsalim Saleh and Thekra I. Latif. Solving LProg Problems by Using Excel Solver. Tikrit Journal of Pure Science, 2009. 14(2): pp 87-98.

[13]. Ministry of Urban and Regional Planning. Greater Port Harcourt City Master Plan, 2008.

[14]. Eric .O.E. The Application of Matrix Algorithm in Aspen Hysys Modelling Guides Refinerines Crude Oil Selection. International Journal of Engineering Trends and Technology, 2019. p. 89-91

[15]. Hassan B. et al. Aspen Hysys Simulation of Methanol to Dimethylether (DME). International Journal of Engineering Trends and Technology, 2017. 46(4): 214-220.

[16]. Aspen Technology Incorporation. An Integrated Approach to Modelling Pipeline Hydraulics in a Gathering and Production System.

[17]. Jones A. Integrating Pipelines and Topsides Modeling. Genesis Oil and Gas Consultants at Aspen Tech OPTIMZE 2011 Conference, Washington, D.C., 2011.

[18]. Adegbola et al.Conceptual Design of Gas Distribution Pipeline Network for Estates in Nigeria. Nigerian Journal of Technology, 2021. 40(1): pp25-36.

[19]. Idris I. Ozigis et al. Design of an Anaerobic Digester for Generation of Biogas Fired in a Burner and Lamp. FUOYE Journal of Engineering and Technology, 2019. 4(1).

[20]. Nasr G.G and N.E Connor. Natural Gas Engineering and Safety Challenges. Springer International Publishing, Switzerland, 2014.

APPENDIX

APPENDIX 1

Table 6: Properties of the Table top gas burner under consideration

S/N	Description	Unit	G-30/G31	G-30/G31
1	Burner type		Standard	Small
2	Model CG.1 4G		Semifast	Auxiliary Burner
3	Calorific Value Consumption	Kcal/hr	1500	860
4	Inlet gas pressure	mbar	28-37	28-37
5	Pan size diameter	mm	140	140
6	Gas consumption	Kg/hr	0.13	0.07
7	Nozzle diameter	mm	1.85	1.45
8	Heat input	kW	1.75	1.0kW
9	Efficiency	%	>52%	>52%

APPENDIX 2

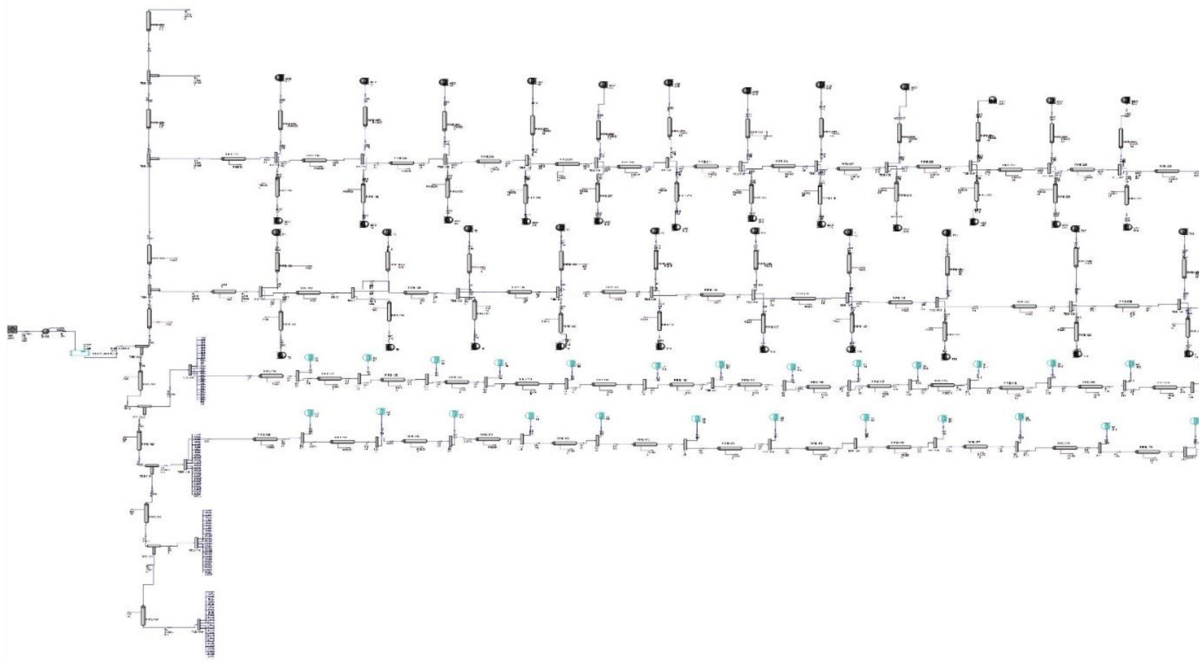

Figure 6: Full view of the Simulated Flow-sheet for Grid and Series Pipeline Configuration using Aspen HYSYS 11.0

APPENDIX 3

Temperature Profile

Grid				
Description	**Pressure Drop (Kpa)**	**Cum. Pipe length (m)**	**In (oC)**	**Out (oC)**
	0.00008287	2500	-38.82	-32.02
	0.00007164	5000	-32.02	-25.69
	0.00006196	7500	-25.69	-20.01
	0.00005346	10000	-20.01	-14.85
	0.00004589	12500	-14.85	-10.19
	0.00003905	15000	-10.19	-6.006
	0.00003279	17500	-6.006	-2.287
	0.000027	20000	-2.287	0.9788
	0.00002158	22500	0.9788	3.794
	0.00001646	25000	3.794	6.147
	0.00001157	27500	6.147	8.015
	0.000006862	30000	8.015	9.338
	0.000002016	32500	9.338	10
Total	**0.000473148**			
Series				
Description	**Pressure Drop (Kpa)**	**Cum. Pipe length (m)**	**In (oC)**	**Out (oC)**
	0.007181	100	-39.8	-37.11
	0.006591	200	-37.11	-34.49
	0.006039	300	-34.49	-31.94
	0.005537	400	-31.94	-29.44
	0.005092	500	-29.44	-27
	0.0047	600	-27	-24.62
	0.004349	700	-24.62	-22.21
	0.004027	800	-22.21	-19.95
	0.003729	900	-19.95	-17.88
	0.003448	1000	-17.88	-15.86
	0.003175	1100	-15.86	-13.73
	0.002912	1200	-13.73	-11.66
	0.002659	1300	-11.66	-9.649
	0.002415	1400	-9.649	-7.688
	0.002179	1500	-7.688	-5.783
	0.001952	1600	-5.783	-3.933
	0.001731	1700	-3.933	-2.141
	0.001518	1800	-2.141	-0.4074
	0.001311	1900	-0.4074	1.264
	0.00111	2000	1.264	2.871
	0.0009137	2100	2.871	4.406
	0.0007227	2200	4.406	5.864
	0.0005363	2300	5.864	7.229
	0.0003541	2400	7.229	8.476
	0.0001755	2500	8.476	9.537
Total	**0.0743573**			

$$A\Delta V_s = \frac{0.7854}{10^4}\frac{T_s}{P_s}\frac{Ld^5}{T}\left[\left(\frac{P_m}{Z_m}\right)_1 - \left(\frac{P_m}{Z_m}\right)_2\right]$$

$$P_m = \frac{2}{3}\left[P1 + P2 - \left(\frac{P1P2}{P1+P2}\right)\right]$$

LPG Flow Calculation for Grid Housing Arrangement

A (m2)	412335	$\Delta V_{s\,(M3)}$	"="	26.1663122
$V_{s\,m3}$		Δ Vs (Kg)	"="	47.92360079
Ts (K)	273.15	ΔVs (Kg)/ Household	"="	0.479236008
Ps (bar)	1.01325			
L (m)	2500			
d (mm)	52.5	Pm (bar)	"="	4.99000668
T (K)	287.18	Number of days in a Month	"="	30
Pm1	5	1m3 of LPG to Kg	"="	1.8315
Zm1	0.003883	Number of House holds	"="	100
Pm2	4.98	Monthly LPG Requirement per Household (K	"=	12.6
Zm2	0.003883			
P1 (bar)	5			
P2 (bar)	4.98			
Pm1/Zm1	1287.6642			
Pm2/Zm2	1282.5135			
S	0.549			

LPG Flow Calculations for Series Housing Arranement

A (m2)	412335	$\Delta V_{s\,(M3)}$	"="	30.69600914
$V_{s\,m3}$		Δ Vs (Kg)	"="	56.21974075
Ts (K)	273.15	ΔVs (Kg)/ Household	"="	2.24878963
Ps (bar)	1.01325		"="	
L (m)	2500			
d (mm)	52.5	Pm (bar)	"="	4.999500017
T (K)	287.18	Days in a Month	"="	30
Pm1	5	1m3 of LPG to Kg	"="	1.8315
Zm1	0.00331	Number of House hold	"="	25
Pm2	4.98	Monthly LPG Requirement per Household (K	"="	12.6
Zm2	0.00331			
P1 (bar)	5			
P2 (bar)	4.999			
Pm1/Zm1	1510.574			
Pm2/Zm2	1504.5317			

Figure 7: Excerpt from the excel sheet containing the values of the parameters which were used in the research and the calculations done with them.

						MODEL VALIDATION							
						Q (All Pressure Range)	=	$\frac{7.574 x 10^{-4}}{\sqrt{f}} \frac{T_s}{p_s} \sqrt{\frac{(P_1^2 - P_2^2)\, d^5}{S.L.Z.T}}$				2.919773	
Parameter	Unit o	Sign											
Gas Flowrate	m3(st]	Q =	2.91977										
Colebrook White Friction factor	(-)	f =	0.056			Q (Medium Pressure)	=	$\frac{1.269 x 10^{-2}}{\sqrt{f}} \sqrt{\frac{(P_1^2 - P_2^2)\, d^5}{S.L}}$				0.202359	
Temperature	K	Ts =	273.15										
Pressure at Standard Condition	bar	Ps =	1.01325										
Upstream Pressure	bar	P1 =	5										
Down Stream Pressure	bar	P2 =	4.9945			Q (Low Pressure)	=	$\frac{5.712 x 10^{-4}}{\sqrt{f}} \sqrt{\frac{(P_1 - P_2)\, d^5}{S.L}}$				0.002881	
Diameter	mm	d =	52.5										
Sepcific Gravity at Standard Condition	(-)	S =	0.495										
Pipe length	m	L =	2500			Hysys Result	=					0.002901	
Gas Compressibility Factor	(-)	Z =	0.00388										
Gas Temperature	oC	T =	287.18						Percentage Error				
Relative Roughness	m	e	4.6E-05			Q (All Pressure Range)						100547.1	
Diameter	m	d =	0.0525			Q (Medium Range)						6875.489	
						Q (Low Pressure)						-0.68367	
		Q (All Pressures)	=			Given Information							
		Q (Medium Pressure)	=		Relative roughness =	0.000870857			f	LHS	RHS	CHECK	
		Q (Low Pressure)	=		NRe =	1137.349277			0.024	6.478680241	6.479148	0.000467	
					D	0.0525							
	d	Rel. Rough											
$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon}{3.7D_h} + \frac{2.51}{R_e\sqrt{f}}\right)$		Dynamic Viscosity (Kg/ms)	0.00027										
		Mass Density (kg/m3)	626.3										
					Area	0.002165034							
		Flow rate (m3/s)	2E-05						Flow rate (ft3/s)	0.000705398		Area	0.023292
		length (m)	2500						length (ft)	8202			
		diameter (m)	0.0525						diameter (ft)	0.1722			
		velocity (m/s)	0.00923						velocity (ft/s)	0.0302846			
Kinematic Viscosity in cSt	0.43	Kinematic Viscosity (V)	4.3E-07						Kinematic Viscosity	4.58757E-06			
		NRe	1137.35		Nre	1137.473112			NRe	1136.768129			
		f	0.05627						f	0.05629996			
		Nre	1137.35						Other Flow Equations				
									Blasius =		0.013602		
									Muller =		0.014301		
									Polyflo		0.011989		
									Panhandle A		0.007579		

Figure 8: Excerpt from the excel sheet wherein the model validation was conducted

APPENDIX 4

Worksheet | Attachments | Dynamics

Worksheet

- Conditions
- Properties
- Composition
- Oil & Gas Feed
- Petroleum Assay
- K Value
- User Variables
- Notes
- Cost Parameters
- Normalized Yields
- Emissions

Stream Name	MS 1 Str 3	Liquid Phase	Liquid Phase
Molecular Weight	55.62	141.6	55.62
Molar Density [kgmole/m3]	11.14	8.169	11.14
Mass Density [kg/m3]	619.8	1157	619.7
Act. Volume Flow [m3/h]	2.901e-003	2.956e-007	2.901e-003
Mass Enthalpy [kJ/kg]	-2686	-5509	-2685
Mass Entropy [kJ/kg-C]	0.6702	0.6127	0.6702
Heat Capacity [kJ/kgmole-C]	116.5	267.1	116.5
Mass Heat Capacity [kJ/kg-C]	2.094	1.887	2.094
LHV Molar Basis (Std) [kJ/kgmole]	2.550e+006	3.043e+006	2.550e+006
HHV Molar Basis (Std) [kJ/kgmole]	2.747e+006	3.314e+006	2.747e+006
HHV Mass Basis (Std) [kJ/kg]	4.939e+004	2.341e+004	4.940e+004
CO2 Loading	<empty>	<empty>	<empty>
CO2 Apparent Mole Conc. [kgmole/m3]	3.970e-005	1.334e-005	3.970e-005
CO2 Apparent Wt. Conc. [kgmol/kg]	6.405e-008	1.154e-008	6.406e-008
LHV Mass Basis (Std) [kJ/kg]	4.584e+004	2.149e+004	4.584e+004
Phase Fraction [Vol. Basis]	0.0000	9.622e-005	0.9999
Phase Fraction [Mass Basis]	0.0000	1.902e-004	0.9998
Phase Fraction [Act. Vol. Basis]	0.0000	1.019e-004	0.9999
Mass Exergy [kJ/kg]	58.45	<empty>	<empty>
Partial Pressure of CO2 [bar_g]	-1.013	<empty>	<empty>
Cost Based on Flow [Cost/s]	0.0000	0.0000	0.0000
Act. Gas Flow [ACT_m3/h]	<empty>	<empty>	<empty>
Avg. Liq. Density [kgmole/m3]	10.24	7.953	10.24
Specific Heat [kJ/kgmole-C]	116.5	267.1	116.5
Std. Gas Flow [STD_m3/h]	0.7643	5.709e-005	0.7642

Figure 9: Excerpt from one of the stream exiting the pipeline in the grid housing arrangement.