STUDY ON GAS FLOW NETWORK ANALYSIS AT SHAH ALAM INDUSTRIAL AREA BY USING COX'S METHOD

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"I declare that this project entitled *"Study on Gas Flow Network Analysis at Shah Alam Industrial Area by Using Cox's Method"* is the result of my own research except as cited in the references. The project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

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ABSTRACT

Natural gas is a vital component of the world's supply of energy. It is one of the cleanest, safest, and most useful of all energy sources. In industry, natural gas is used as an input to manufacture pulp and paper, metals, chemicals, stone, clay, glass, and to process certain foods. Natural gas is also used to treat waste materials, for incineration, drying, dehumidification, heating and cooling, and cogeneration. The major transportation of natural gas is carried through pipelines. High demand for natural gas primarily to the customers who live in big cities around the world. This also happens in major cities in Malaysia. Gas transport networks around Shah Alam present a large set of highly integrated pipe networks operating over a wide range of pressures. Growing demand for gas makes it necessary to adapt and expand these systems while ensuring safe delivery and cost-effective engineering. To avoid from the natural gas was stop from supply the gas supply and to make sure the continuity and reliability to the consumers the pressure drop for each junction of the pipeline must be decrease. At one time the method of solving network flow problem was a manual trial-and-error procedure by doing Cox's method. In this method, the pressure drop and pipe size of each pipeline can be determined for each junction of the pipe. The parameters needed to calculate the pressure drop are flow rate, distance, pipe size, specific gravity and pressure inlet. From this research, the pressure drop from Cox's method calculation is less than pressure drop calculation from NFPA method by Gas Malaysia Berhad.

ABSTRAK

Gas asli merupakan komponen penting untuk bekalan tenaga dunia. Ia adalah salah satu daripada tenaga yang bersih, selamat dan paling berguna untuk semua sumber tenaga. Di dalam industri, gas asli digunakan sebagai input untuk mengeluarkan pulpa dan kertas, logam, bahan kimia, batu, tanah liat, kaca, dan untuk memproses makanan tertentu. Gas asli juga digunakan untuk merawat bahan buangan, pembakaran, pengeringan, penyahlembapan, pemanasan dan penyejukan, dan penjanaan bersama. Pengangkutan utama gas asli dibawa melalui saluran paip. Permintaan yang tinggi terhadap gas asli terutamanya kepada para pengguna yang tinggal di bandar-bandar besar di seluruh pelusuk dunia. Perkara ini juga berlaku di bandar-bandar utama di Malaysia. Pengangkutan gas dan rangkaian pengagihan di sekitar Shah Alam yang hadir satu set rangkaian paip yang sangat bersepadu akan beroperasi lebih daripada pelbagai tekanan yang besar. Permintaan yang semakin meningkat menjadikannya perlu untuk menyesuaikan diri dan mengembangkan sistem-sistem ini dan pada masa yang sama memastikan penghantaran yang selamat dan harga yang berpatutan. Kejatuhan tekanan untuk persimpangan setiap perancangan mesti akan menurun bagi mengelakkan daripada gas asli berhenti daripada mengalir dan memastikan kesinambungan dan kebolehpercayaan kepada pengguna. Kaedah Cox merupakan salah satu cara menyelesaikan masalah aliran rangkaian melalui proses cuba-cuba. Dengan kaedah ini, saiz kejatuhan tekanan dan paip setiap saluran paip boleh ditentukan untuk persimpangan setiap paip. Parameter yang diperlukan untuk mengira kejatuhan tekanan ialah jarak, saiz paip, graviti gas asli dan tekanan masuk. Melalui kajian ini, kejatuhan tekanan dengan menggunakan kaedah Cox’s adalah kurang daripada pengiraan susutan tekanan dari kaedah NFPA oleh Gas Malaysia Berhad.

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mm	-	millimeter
ft	-	Feet
m	-	meter
kW	-	Kilo Watt
kWh	-	Kilo Watt hour
lb	-	Pound
GMB	-	Gas Malaysia Berhad
MJ/hr	-	Mega joule per hour
Sm^3/hr	-	Centimeter cubic per hour
UMP	-	Universiti Malaysia Pahang
U.S.	-	United State
ºC	-	Degree of Celcius
º F	-	Degree of Farad

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

According to (Kelkar, 2008) natural gas is a vital component of the world's supply of energy. It is one of the cleanest, safest, and most useful of all energy sources. Natural gas, as a fuel, has been used for more than 150 years. Although used as a fuel over a long period, natural gas has achieved prominence as an important energy supply only recently. When produced as an associated gas in the oil fields, natural gas was rarely used efficiently. In most instances, oil production was considered important, and gas production a nuisance. Natural gas was used as a supply for energy requirements for the oil field, and the rest was flared. Even today, this practice continues in many part of the world. Part of the reason oil company's burn off natural gas is that it cannot be stored easily. It has be utilized or transported as soon as it is produced. If the end user is far away, an efficient infrastructure has to be established before gas can be transported from one location to another. The major transportation of natural gas is carried through pipelines. Throughtout the world, major efforts are under way to increase the gathering, transmission, and distribution capacity in order to promote and support projected growth of natural gas demand (Kelkar, 2008). Network analysis techniques the only method of solving networks was by 'trial and error' (Kelkar, 2008). Its mean that making an initial estimate of the flow in each pipe and making arbitrary adjustment until a balance was achieved and a solution abtained. Network analysis is applied in many other industries, for example in process pipework design and power station cooling water system. Water companies use network analysis to medel their distribution system in the same way that local gas distribution companies model low pressure distribution network. By using the network analysis when applied to gas supply system the flows in all the pipes and the pressure at all the pipe junctions can be determined. Cox's method is the one of the method that uses to determine the pressure drop in the gas pipe line system (Analysis of Pipe Networks, 2008). In case where piping cost is affected then one should consider two or more pipe sections or portions that might be opted for bigger pipe size. However the downstream pipe size must be bigger size than upstream pipe.

$$Q = k\sqrt{\frac{(P_1^2 - P_2^2)D^5}{SL}}$$

Equation 1.1: Equation of Cox's method
(Analysis of Pipe Networks, 2008).

Where :

P_1 = inlet pressure in kPa abs

P_2 = outlet pressure in kPa abs

S = Specific gravity

Q= Flow rate (Sm3/hr)

L = Distance (m)

D= Pipe diameter (mm)

k= Cox's coefficient = 1.69 10^{-3}

1.2 Problem Statement

Gas transport and distribution networks around the world present a large set of highly integrated pipe networks operating over a wide range of pressures. High demand for natural gas makes it necessary to adapt and expand these systems while ensuring safe delivery and cost-effective engineering. The complex networks of pipes that comprise gas distribution system present formidable flow analysis problem (Kelkar, 2008). Gas may be fed into a system from several transmissions pipeline city-gate stations, from one or more peak-load gas production plants or from storage facilities scattered through the system. In addition, many distribution systems consist of several superimposed networks of piping operated at different pressure levels. Networks of 200-300 loops and 500-600 pipe section are very common. Many networks contain over 1000 pipe sections and some larger cities have interconnected piping networks containing tens of thousands of pipe section. At one time the only method of solving network flow problem was a manual trial-and-error procedure by doing Cox's method. In this method, the pressure drop can be determined for each junction of the pipe. The Newton loop node method essentially solves the set of loop equations. The loop method has the disadvantage of having to define the loops in the networks. The advantage of the loop method over the nodal method is its good convergence characteristics. The nodal method having easy to solve the set of equation but the main disadvantage of the nodal method is the poor convergence characteristics. The algorithm used the Hardy-Cross technique, which is widely used in distribution system. The Hardy-Cross method solves the same set of loop and nodal equations as do the Newton-loop and Newton-nodal multi-dimensional methods. However, the Hardy- Cross method solves each equation of the set individually, whereas the Newton multi-dimensional method solves the set of equations as a whole.

1.3 Research Objectives

There are three objectives in this study:

a) To validate and promote Cox method by studying a Shah Alam industrial area.
b) To compare the actual pressure drop from GMB with the current results of NG piping network based on Cox method.
c) To suggest the new gas distribution network by developing looped gas distribution network based on Cox method.

1.4 Scope of Research

Shah Alam is one of the cities in Malaysia that currently growing with much of industrial sector and increasing people population. The increasing of the one city will make the increasing of transmission and distribution pipelines supply to the consumers. To avoid from the natural gas was stop from supply the gas supply and work smoothly to the consumers the pressure drop for each junction of the pipeline must be decrease. Cox's method play a major role in system planning and design, enabling the designer to optimize the network and the pipelines themselves. Cox's method allows us to predict the behavior of gas network systems under different conditions. Such predictions can then be used to guide decisions regarding the design and calculation operation. This package is used for selecting pipe sizes, calculating pressures and flows in gas distribution networks for steady state condition.

1.5 Significance of Research

From this research the pressure drop for each section and junction of the pipelines can be determine by using Cox method. The algorithm used the Hardy-Cross technique, which is widely used in distribution system. The Hardy-Cross method solves the same set of loop and nodal equations as do the Newton-loop and Newton-nodal multi-dimensional methods. From this method the new flow for each pipeline added can be determined.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Natural gas is an extremely important source of energy for reducing pollution and maintaining a clean and healthy environment. In addition to being a domestically abundant and secure source of energy, the use of natural gas also offers a number of environmental benefits over other sources of energy, particularly other fossil fuels. Despite its importance, however, there are many misconceptions about natural gas. For instance, the word 'gas' itself has a variety of different uses, and meanings. When we fuel our car, we put 'gas' in it. However, the gasoline that goes into your vehicle, while a fossil fuel itself, is very different from natural gas. The 'gas' in the common barbecue is actually propane, which, while closely associated and commonly found in natural gas, is not really natural gas itself. While commonly grouped in with other fossil fuels and sources of energy, there are many characteristics of natural gas that make it unique (Wilson, 1982).

Natural gas, in itself, might be considered an uninteresting gas. It is colorless, shapeless, and odorless in its pure form. Quite uninteresting, except that natural gas is combustible, abundant in the United States and when burned it gives off a great deal of energy and few emissions. Unlike other fossil fuels, natural gas is clean burning and emits lower levels of potentially harmful byproducts into the air. We require energy constantly, to heat our homes, cook our food, and generate our electricity. It is this need for energy that has elevated natural gas to such a level of importance in our society, and in our lives (Wilson, 1982).

Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane and pentane. The composition of natural gas can vary widely, but below is a table outlining the natural gas composition (Wilson, 1982).

Table 2.1: Composition in Natural Gas

Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen sulphide	H_2S	0-5%
Rare gases	A, He, Ne, Xe	trace

(Wilson, 1982)

In its purest form, such as the natural gas that is delivered to your home, it is almost pure methane. Methane is a molecule made up of one carbon atom and four hydrogen atoms, and is referred to as CH4. The distinctive “rotten egg” smell that we often associate with natural gas is actually an odorant called mercaptan that is added to the gas before it is delivered to the end-user. Mercaptan aids in detecting any leaks (Wilson, 1982).

Ethane, propane, and the other hydrocarbons commonly associated with natural gas have slightly different chemical formulas. Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, the natural gas is 'wet' (Wilson, 1982).

Natural gas has many uses, residentially, commercially, and industrially. Found in reservoirs underneath the earth, natural gas is often associated with oil deposits. Production companies search for evidence of these reservoirs by using sophisticated technology that helps to find the location of the natural gas, and drill wells in the earth where it is likely to be found. Once brought from underground, the natural gas is refined to remove impurities such as water, other gases, sand, and other compounds. Some hydrocarbons are removed and sold separately, including propane and butane. Other impurities are also removed, such as hydrogen sulfide (the refining of which can produce sulfur, which is then also sold separately). After refining, the clean natural gas is transmitted through a network of pipelines, thousands of miles of which exist in the United States alone. From these pipelines, natural gas is delivered to its point of use (Wilson, 1982).

Natural gas can be measured in a number of different ways. As a gas, it can be measured by the volume it takes up at normal temperatures and pressures, commonly expressed in cubic feet. Production and distribution companies commonly measure natural gas in thousands of cubic feet (Mcf), millions of cubic feet (MMcf), or trillions of cubic feet (Tcf). While measuring by volume is useful, natural gas can also be measured as a source of energy. Like other forms of energy, natural gas is commonly measured and expressed in British thermal units (Btu). One Btu is the amount of natural gas that will produce enough energy to heat one pound of water by one degree at normal pressure. To give an idea, one cubic foot of natural gas contains about 1,027 Btus. When natural gas is delivered to a residence, it is measured by the gas utility in 'therms' for billing purposes. A therm is equivalent to 100,000 Btu, or just over 97 cubic feet, of natural gas (Wilson, 1982).

2.2 Composition of Natural Gas

Fossil fuel is one of the example for natural gas. Like oil and coal, this means that it is, essentially, the remains of plants and animals and microorganisms that lived millions and millions of years ago.There are many different theories as to the origins of fossil fuels. The most widely accepted theory says that fossil fuels are formed when organic matter (such as the remains of a plant or animal) is compressed under the earth, at very high pressure for a very long time. This is referred to as thermogenic methane. Similar to the formation of oil, thermogenic methane is formed from organic particles that are covered in mud and other sediment. Over time, more and more sediment and mud and other debris are piled on top of the organic matter. This sediment and debris puts a great deal of pressure on the organic matter, which compresses it. This compression, combined with high temperatures found deep underneath the earth, breaks down the carbon bonds in the organic matter. As one gets deeper and deeper under the earth’s crust, the temperature gets higher and higher. At low temperatures (shallower deposits), more oil is produced relative to natural gas. At higher temperatures, however, more natural gas is created, as opposed to oil. That is why natural gas is usually associated with oil in deposits that are 1 to 2 miles below the earth's crust. Deeper deposits, very far underground, usually contain primarily natural gas, and in many cases, pure methane (Smith, 2008).

Natural gas can also be formed through the transformation of organic matter by tiny microorganisms. This type of methane is referred to as biogenic methane. Methanogens, tiny methane-producing microorganisms, chemically break down organic matter to produce methane. These microorganisms are commonly found in areas near the surface of the earth that are void of oxygen. These microorganisms also live in the intestines of most animals, including humans. Formation of methane in this manner usually takes place close to the surface of the earth, and the methane produced is usually lost into the atmosphere. In certain circumstances, however, this methane can be trapped underground, recoverable as natural gas. An example of biogenic methane is landfill gas. Waste-containing landfills produce a relatively large amount of natural gas from the decomposition of the waste materials that they contain. New technologies are allowing this gas to be harvested and used to add to the supply of natural gas (Smith, 2008).

A third way in which methane (and natural gas) may be formed is through abiogenic processes. Extremely deep under the earth's crust, there exist hydrogen-rich gases and carbon molecules. As these gases gradually rise towards the surface of the earth, they may interact with minerals that also exist underground, in the absence of oxygen. This interaction may result in a reaction, forming elements and compounds that are found in the atmosphere (including nitrogen, oxygen, carbon dioxide, argon, and water). If these gases are under very high pressure as they move toward the surface of the earth, they are likely to form methane deposits, similar to thermogenic methane (Smith, 2008).

2.3 Uses of Natural Gas

2.3.1 Residential Users

Residential applications are the most commonly known use of natural gas. It can be used for cooking, washing and drying, water warming, heating and air conditioning. Domestic appliances are increasingly improved in order to use natural gas more economically and safely. Operating costs of natural gas equipment are generally lower than those of other energy sources (Buoyan Guo et al, 2005).

2.3.2 Commercial users

Main commercial users of natural gas are food service providers, hotels, healthcare facilities or office buildings. Commercial applications include cooling (space conditioning and refrigeration), cooking or heating (Buoyan Guo et al, 2005).

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2.3.3 Industry Users

Natural gas is used as an input to manufacture pulp and paper, metals, chemicals, stone, clay, glass, and to process certain foods. Gas is also used to treat waste materials, for incineration, drying, dehumidification, heating and cooling, and cogeneration (Buoyan Guo et al, 2005).

2.3.4 Power Generation Users

Electric utilities and independent power producers are increasingly using natural gas to provide energy for their power plants. In general, gas fuelled power plants have lower capital costs, are built faster, work more efficiently and emit less pollution than other fossil fuel power plants. Technological improvements in design, efficiency and operation of combined cycle gas turbines and co-generation processes are favouring the use of natural gas in power generation. A combined-cycle power plant uses waste heat to produce more electricity, while natural gas co-generation, also called combined heat and power, produces power and heat that is useful for industry as well as commercial users. This cogeneration reduces pollution emission considerably (Buoyan Guo et al, 2005).

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2.4 Advantages by Using Natural Gas

There are many advantages by using the natural gas. First, the natural gas is environment friendly than oil or coal. It is largely because of the fact that it has only one carbon and hence, produces less emissions. It is a known fact that for same amount of heat, natural gas emit 30% less carbon dioxide than burning oil and 45% less carbon dioxide than burning coal. Thereby, improving the quality of air. Is cheap (less expensive than gasoline) therefore, very cost effective. Can be safely stored and burned. Most of the natural reserves of natural gas fields are still underutilized Emits 60 to 90% less smog-producing pollutants. Due to clean burning process, doesn't produce ashes after energy release. Has high heating value of 24,000 Btu per pound (Mohan Kelkar, 2008).

Table 4.13: Pressure Drop Comparison at Loop 3

NODE	BEFORE ADDING NEW PIPELINE (KPA)	AFTER ADDING NEW PIPELINE (KPA)	PERCENTAGE (%)
E	336.4283	-	-
F	-	336.42	
G	335.98	336.07	0.026787309
H	335.15	335.73	0.17305684