
# Developing of a Computer Program for Natural Gas Networks Design

By

**KHALED IBRAHIM ABD EL-ALEEM ALI SALEM**

A Thesis Submitted to the
Faculty of Engineering - Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
**MASTER OF SCIENCE**
**In**
**PETROLEUM and NATURAL GAS TECHNOLOGY**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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2017

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**Title of Thesis:**

**Developing of a Computer Program for Natural Gas Networks Design**


**Key Words:**

Natural Gas; Pipelines; Networks Design; GIS; MATLAB.



**Summary:**

The main aim of this thesis is developing of a computer program for natural gas networks design by using Arc-GIS and MATLAB programs, in order to unify the software which used of natural gas networks design in the petroleum sector companies which working in the field of natural gas delivery for the domestic, commercial and industrial building, to avoid the problems caused by the multiplicity of the computer programs which used in these companies, such as the difficulty of data exchange, data entry duplication and the impossibility of unification of the database.

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# Dedication

Profound and deep thanks are dedicated to my father, my mother, my sister, my wife, my daughters, my uncle (Tarek Mohammed) and my precious family for their love, care, continuous support and endless encouragement.

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# Nomenclature

| | |
|---|---|
| **[∆P]** | Pressure drop on pipes vector. |
| **[µ]** | Gas absolute viscosity vector. |
| **[Ad]** | Discharge nodes flow direction matrix. |
| **[As]** | Sources flow direction matrix. |
| **[Di]** | Pipes internal diameters vector. |
| **[dnn]** | Discharge nodes names vector. |
| **[e]** | Pipes efficiency vector. |
| **[FE]** | Flow equation vector. |
| **[G]** | Gas specific gravity vector. |
| **[h21]** | Elevations differences vector. |
| **[L]** | Pipes lengths vector. |
| **[n]** | Additional pipes in parallel vector. |
| **[P]** | Discharge nodes pressure vector. |
| **[Pb]** | Base pressure vector. |
| **[pn]** | Pipe name vector. |
| **[Ps]** | Sources pressures vector. |
| **[Q]** | Consumption flow rates vector. |
| **[q]** | Flow rate on pipes vector. |
| **[Qs]** | Flow rates of gas sources vector. |
| **[R]** | Pipes roughness vector. |
| **[snn]** | Sources names vector. |
| **[$T_{avg}$]** | Average temperature vector. |
| **[Tb]** | Base temperature vector. |
| **[Ve]** | Gas velocity on pipes vector. |
| **[Visc.]** | Gas absolute viscosity vector. |
| **∆P** | Pressure drop, (psi) |
| **µ** | Gas absolute viscosity, (lbf·sec/$ft^2$). |
| **A** | Cross section area, ($in^2$). |
| **Acc.** | Access. |
| **AD** | Attributes Data. |
| **AGA** | American Gas Association |
| **C.R.N.** | Customer Reference Number. |
| **CNG** | Compressed Natural Gas |
| **CNGA** | California Natural Gas Association |
| **Com.** | Commercial. |
| **D** | Pipe internal diameter, (in) |
| **e** | Pipeline efficiency, (dimensionless) |
| **$E_h$** | Elevation head, (ft) |
| **ERD** | Entity Relationship Diagram. |
| **f** | friction factor, (dimensionless) |
| **FD** | Fundamental pipe equation with constant friction factor. |

| | |
|---|---|
| **FM** | Fundamental pipe equation with variable friction factor. |
| **G** | Gas specific gravity, (dimensionless) (air = 1) |
| **g** | Gravitational constant, ($ft/sec^2$) |
| **GD** | Graphical Data. |
| **GIS** | Geographical Information System |
| **GP** | General pipe equation. |
| **GPS** | Global Positioning System. |
| **GUI** | Graphical User Interface. |
| $h_1$ | Upstream node elevation, (ft) |
| $h_2$ | Downstream node elevation, (ft) |
| $h_L$ | Head losses, (ft) |
| **ID** | Inner Diameter. |
| **IG** | IGT distribution pipe equation. |
| **Indus.** | Industrial. |
| **L** | Pipe length, (mi) |
| **LNG** | Liquefied Natural Gas |
| $L_p$ | Pipe length, (ft) |
| **M.F.** | Multi Family. |
| **MATLAB** | matrix laboratory |
| **MTO** | Material Take off. |
| **MU** | Muller pipe equation. |
| **n** | Number of additional pipes in parallel, (dimensionless) |
| **N** | The number of pipes, (dimensionless). |
| **N.A.** | No Access. |
| **N.G.** | No Gas. |
| **NGNG** | The National Grid of Natural Gas. |
| **OD** | Outer Diameter |
| **P** | Absolute pressure, (psia) |
| **P&A survey** | Property and Appliances survey. |
| **P.R.S.** | Pressure Reduction Station. |
| $P_1$ | Upstream node pressure, (psia) |
| $P_2$ | Downstream node pressure, (psia). |
| **PA** | Panhandle A pipe equation. |
| $P_{avg}$ | Gas average pressure or average pipeline pressure, (psia) |
| $P_b$ | Base pressure on the standard conditions, (psia). |
| **PB** | Panhandle B pipe equation. |
| $P_c$ | Critical pressure of gas, (psia) |
| **PE** | Polyethylene |
| $P_r$ | Reduced pressure, (dimensionless) |
| **q** | Flow rate in pipe, ($ft^3$/day). |
| $q_h$ | Flow rate in pipe, ($ft^3$/hr). |
| **R** | Universal gas constant, (10.73 psia ft3/Ib mole °R) |
| **R.G.** | Refused Gas. |
| **Re** | Reynolds number, (dimensionless). |
| **S** | Number of sources nodes. |

| | |
|---|---|
| **SL** | Spitzglass low pressure pipe equation. |
| **SP** | Spitzglass high pressure pipe equation. |
| **St** | Steel |
| **$T$** | Absolute temperature of gas, (°R) |
| **$T_{avg}$** | Gas average temperature, (°R) |
| **$T_b$** | Base temperature on the standard conditions, (°R). |
| **$T_c$** | Critical temperature of gas, (°R) |
| **$T_r$** | Reduced Temperature, (dimensionless) |
| **U.C.** | Under Construction. |
| **U.D.** | Under Demolition. |
| **$V$** | Gas volume, ($ft^3$) |
| **Vac.** | Vacancy. |
| **$V_e$** | velocity,(ft/sec) |
| **WE** | Weymouth pipe equation. |
| **WT** | Wall thickness of pipe, (in). |
| **$X$** | Number of pipes. |
| **$Y$** | Number of discharge nodes. |
| **$Z$** | Gas compressibility factor, or Gas deviation factor (dimensionless) |
| **$\rho$** | density, ($lbm/ft^3$) |
| **$\rho_r$** | Reduced density, (dimensionless) |

# Abstract

The National Grid of Natural Gas (NGNG) in Egypt is considered as one of the most complicated systems to be designed, operated, monitored and controlled especially during making any modifications to add new customers. Consequently, all the companies that working in the field of natural gas delivery to domestic, commercial and industrial buildings need a special computer programs to execute the planning process of its projects from the land survey step to the network design step.

It is well known that, there is a great and rapid development of such specialized programs, this leads to a rapid increase in the cost of licenses of using such programs. Meanwhile, the Egyptian companies still using commercial computer programs created by international entities, these programs are expensive and need a periodical update. In addition each company working in this field has its special package of programs which have its own format. So, it is impossible to assemble the data from all companies without missing some of them. Also, there is difficulty in data exchange when assigning work from one company to another, and a lot of data conversions are needed to transfer the data between the used programs from the land survey step to the network design step and this transfer must be done manually.

The main objective of this thesis work is overcome this problem by developing a new computer program for natural gas networks design. This program should be compatible with the execution system that used in the Egyptian companies and must be able to storage and collect all the land survey data, Property & Appliances (P&A) survey data and network data, and being compatible with Geographical Information System (GIS) program, it should be also being able to use the most important traditional flow equations such as Fundamental, Panhandle A, Panhandle B and Weymouth equations which used in the field of natural gas networks design and being also able to use the library of the MATLAB program.

The reliability of this new program was tested and approved through its use to solve four different case studies and comparing its results with the results obtained when using the most common commercial (SynerGEE) program in natural gas network design. The comparison showed a good match between the results obtained by the two programs when used to solve these four case studies.

# Chapter 1 : Introduction

Natural gas is the most important energy source in Egypt up to now because it is clean, environment friendly due to its low combustion emissions, safe source and considered as an economical source compared by the other fuels. So natural gas used as a fuel or raw material for many industries such as sets of chemical industry, cement industry, steel industry and used also as a domestic fuel.

Transporting the natural gas from oil and gas fields after processing to the cities and industrial places by safe and reliable way at low cost is considered as important goal, this goal can be achieved only by using pipeline and distribution networks.

The design and operation of such these distribution networks needs huge and tedious calculations which impossible to be done manually. So the only way to design these networks is to use computer programs. In the petroleum industry there are much ready-made commercial software that are used to design and operate the pipeline and distribution networks such as Pilot, Snap, PIPESIM and SynerGEE.

Actually, the Egyptian natural gas network is a huge network that is extends from Alexandria in the north to Aswan in the south and from Sinai in the east to Marsa Matrouh in the west and covered by more than 40000 km pipe network with different diameters. This national network feeds about 6.9 million domestic units, over than 14.5 thousand commercial units and over than 2.2 thousand industrial entities up to end of June 2015 and it is planned to extend this network more and more. So there are many companies that are working in the field of natural gas delivery to the Egyptian cities such as GASCO, EGYPT GAS, TWON GAS, SIANCO, REGAS, CAIRO GAS, etc.

All these companies use a commercial computer programs to survey, design and execute the process of extending the network to new cities or to new customers in the same city. The most commercial software programs in the industry are AutoCAD, Oracle, Microsoft Access, Microsoft Excel, Geo Media, ArcGIS and SynerGEE.

All these programs are not using to implement the same job but each program uses to execute one step from the planning steps of the execution process. AutoCAD program used to draw the data of land survey step, Oracle or Microsoft Access or Microsoft Excel used to store the customer data from P&A survey step, Geo Media or ArcGIS used to display the P&A survey data and drawing the network by dummy diameters on the land survey data and making the load file of the customers consumption to use it in the network design step by using SynerGEE program, after that need to back to Geo Media or Arc GIS to correct the pipes diameters of the network, all these steps to transport the data from one program to another program occur by manually ways and need to repeat all of these steps in case of any update in the P&A survey or land survey which requires great effort and time.