DESIGN OF AN IDEAL GAS REGULATING AND METERING STATION FOR GAS SUPPLY TO A 50 MW POWER PLANT

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DESIGN OF AN IDEAL GAS REGULATING AND METERING STATION FOR GAS SUPPLY TO A 50 MW POWER PLANT

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by

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CANDIDATE'S DECLARATION

It is hereby declared that this project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Signature of the Candidate

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RECOMMENDATION OF THE BOARD OF EXAMINERS

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Invocation of who might be the sources for the blessings of Allah in completion of this study

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ABSTRACT

In gas transmission and distribution system, the gas pressure and flow rate are controlled by using CGS, TBS, DRS and RMS. It is important to supply uninterrupted gas at a desired pressure and flow rate to the customer premises. The Regulating and Metering Station (RMS) is generally used for controlling the gas pressure and measuring the gas volume for fiscal purpose. It is apparent that proper design of RMS is very important for a customer for supplying desired amount of gas at a required pressure as well as measuring the supplied gas accurately which is very much crucial for gas supplier in fiscal context. A large number of RMSôs are used for gas supply to different customers in the Titas franchise area.

The major objective of this project is to design an ideal gas Regulating and Metering Station for uninterrupted gas supply to a 50 MW power plant. In this project work, fluid characteristics, process data, gas safety rules, International codes and standards (ASTM, ASME ANSI, API) have been followed for the proposed RMS design. Design considerations, selection criteria and installation of RMS equipments are incorporated. Safety and Environmental issues have been considered in designing the gas facilities for the power plant. The negative effects on environment are negligible. The gas load of the power plant is calculated around 12 MMSCFD at minimum outlet pressure of 50 psig. Design has been checked allowing variation of some related variables such as inlet pressure, specific density, specific heat, compressibility factor and heating value. Variation of these parameters needs no change in the design. Instrumentation and piping diagrams of the proposed RMS are also shown in the report. Some recommendations have been made for improvement of the RMS design. Finally, cost estimation is performed for the project.

The cost estimation of the project have been calculated on the basis of preconstruction expenditure, construction cost and material cost. The total cost of the project is estimated as Tk. 494.463 Lakh.

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AGA	American Gas Association
API	American Petroleum Institute
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineers
AFV	Axial Flow Valve
BS	British Standards
BTU	British Thermal Unit
CSA	Canadian Standard Association
CPP	Captive Power Plant
DN	Nominal Diameter
DCS	Distributed Control Systems
DOE	Department of Environment
ESD	Emergency Shut Down
EVC	Electronic Volume Corrector
ERW	Electrical Resistance Welding
EIA	Environmental Impact Assessment
FC	Flow Computer
FPD	Flame Photometric Detector
FID	Flame ionization Detector
GC	Gas Chromatograph
GSA	Gas Sells Agreement
HART	High Way Addressable Remote Transmitter
IGE	Institution of Gas Engineers
ISA	International Society of Automation
IEC	International Electro technical Committee
ISO	International Standards Organization
IPP	Independent Power Producers
IJ	Insulating Joint
JGTDSL	Jalalabad Gas Transmission and Distribution System Ltd.

KOD	Knock Out Drum
MSCFH	Thousand Standard Cubic Feet per hour
MMSCF	Million Standard Cubic Feet
MMSCM	Million Standard Cubic Meter
MW	Mega Watt
NDT	Non-destructive Testing
NRV	Non Return Valve
OIML	Organization International De Metrology Legal
PSIA	Pound Per Square Inch (Absolute)
PSIG	Pound Per Square Inch (Gage)
P & I	Piping and Instrumentation
PN	Nominal Pressure
PLC	Programmable Logic Controllers
PID	Photo-Ionization Detector
RTU	Remote Terminal Units
ROW	Right of Way
SAR	Submerged Arc Welding
SCADA	Supervisory Control and Data Acquisition
SSV	Slam Shut off Valve
SPP	Small Power Plant
TGTDCL	Titas Gas Transmission and Distribution Company Limited
TCD	Thermal Conductivity Detector
CP	Cathodic Protection

CHAPTER 1

INTRODUCTION

A network of transmission pipeline system transports natural gas from producing fields to consumers. Gas transmission pipeline normally operates at high pressure of 1000/960/850/350 psig (GTCL, 2007). The customers usually do not use gas at such high pressures. It is necessary to control the pressure and flow rate for supplying gas to a customer at desired pressure and flow rate. In gas transmission and distribution network, the gas pressure and flow rate are controlled at pressure reduction stations located at suitable places. There are known as City Gate Station (CGS), Town Bordering Station (TBS), District Regulating Station (DRS), Regulating and Metering Station (RMS). After reducing pressure through these stations, gas is supplied to different bulk customers like Power and Fertilizer Producer of Government Sector, Independent power producers (IPP), Small Power Plant (SPP), Captive Power Plants (CPP) and Non bulk customers such as industrial, commercial and domestic customers.

Regulating and Metering Station means a station comprising of Regulator, Meter and other equipments necessary for the delivery of specification gas to a customer. Pressure Regulator means all devices required to maintain a specified pressure at the outlet of the RMS under variable gas flow conditions. Meter means all devices to be installed, operated and maintained by the company for measuring, recording and computing the gas flow volumes delivered to the customer.

This study aims to undertake and estimate of design an ideal Regulating and Metering Station for gas supply to a 50 MW power plant in accordance with International codes and standards (ASTM, ASME ANSI, API). The design will be carried out according to the fluid characteristic and process data. Technical details of different equipments of the RMS will be studied. The findings can then be incorporated in designing an improved RMS. Cost estimation will be conducted for the proposed RMS design and construction for gas supply to the said power plant.

A schematic diagram of pipeline network is shown in the following Figure-1.1

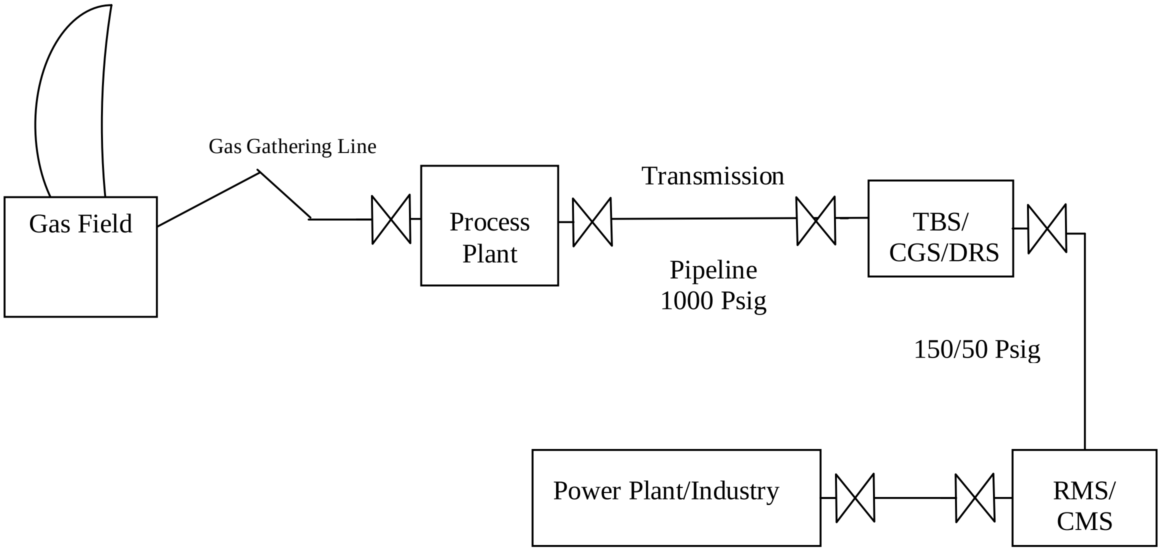

Fig 1.1: Pipeline Network

1.1 Objectives

The main objectives of this study are as follows

- Design of an ideal gas Regulating and Metering Station to supply conditioned gas at a desired pressure as per requirement of the power plant.
- Cost estimation of the proposed RMS.

1.2 Methodology

- Literature review of different equipments of the Regulating and Metering Station.
- Surveying of the proposed power plant RMS area including gas source such as CGS/TBS/DRS or any high pressure gas line.
- Gas load calculation as per catalogue of gas based power station.
- Consult International Standards and Codes (ASTM, ASME ANSI, API) and there practiced by Titas Gas Transmission and Distribution Company Ltd.
- Design of the proposed ideal RMS considering all criteria.
- Cost estimation of the proposed RMS based on preconstruction expenditure, construction cost and material cost etc.

CHAPTER 2

LITERATURE REVIEW

Regulating and Metering Station (RMS) means a station comprising of Regulator, Meter and other equipments necessary for the delivery of specification gas to the customer. Pressure Regulator means all devices required to maintain a specified pressure at the outlet of the RMS under variable gas flow conditions. Meter means all devices to be installed, operated and maintained by the company for measuring, recording and computing for fiscal purpose the gas flow volumes delivered to the customer.

In this chapter, typical gas regulating and metering system, different types of RMS equipments and their working principle, advantages and disadvantages will be discussed.

2.1 Typical Gas Regulating and Metering System

Typical gas regulating and metering systems are gas conditioning, regulating and metering which described below.

2.1.1 Conditioning

Natural gas quality has a strong effect on operation of the regulating and metering station and measurement system. The gas should be pipeline quality gas. Gas conditioning is the technique to remove surge of liquid, condensate, water and entrained solids from gas stream by using separator and rising up the temperature of gas at a desired level to prevent hydrate formation by using heater to prevent the damage of regulator and meter

2.1.2 Regulating

Regulating is the technique to control the flow of gas and maintain the system pressure and flow with certain acceptable limit of a regulating station.

2.1.3 Metering

Gas metering is the technique to measure the gas volumes for transmission system, CGS, TBS, DRS and RMS. The metering bank consists of meter runs according to AGA report for the computation of the gas volume. Different types of meters are used for gas metering.

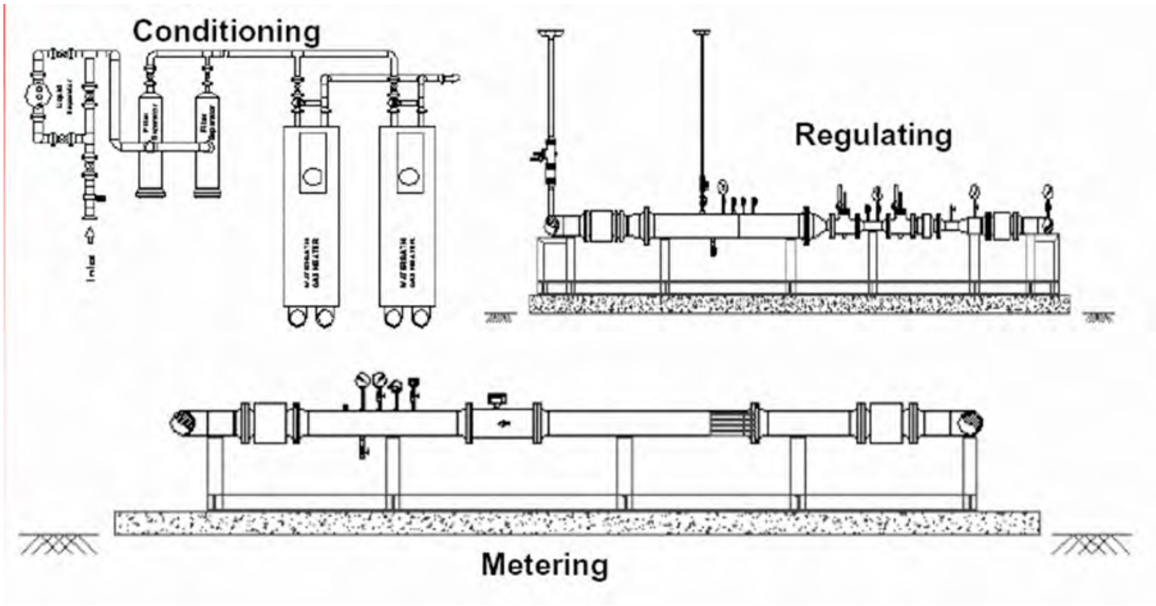

Fig 2.1: Typical Gas Metering and Regulating System
(Source : ZICOM Equipment Pvt. Ltd.)

A typical gas regulating and metering system is shown in Fig 2.1

2.2 Equipment of a Regulating and Metering Station

The Regulating and Metering Station (RMS) consists of inlet pipeline with filter separator pressure regulator, relief valve and meter. Details of the station are given below:

(i) Insulating joint
(ii) Inlet emergency shut down (ESD) valve
(iii) Knock out drum (KOD)/ scrubbers and filter separators.
(iv) Gas heaters or heat exchanger
(v) Valves and valves actuators
(vi) Slam shut valve
(vii) Relief valves
(viii) Pressure regulators
(ix) Silencers
(x) Meters
(xi) Liquid separator.
(xii) Pressure Gauge

(xiii) Temperature Gauge

(xiv) Chart recorder

(xv) Differential pressure transmitter

(xvi) Temperature transmitter

(xvii) Density and specific gravity transducer

(xviii) Gas Chromatograph

(xix) Flow Computer

(xx) Electronic Volume Corrector (EVC)

(xxi) Supervisory Control and Data Acquisition (SCADA) System

(xxii) Condensate tank

(xxiii) Weld-neck Flanges, Blind Flanges, Metallic and Asbestos Gaskets, Tees, Elbows, End caps, Reducers, Saddle/weld-o-lets, Needle valves, Screwed gate and ball valves, Socket welded fittings (Flange, Tee, Elbow, Reducer etc.), Screwed Fittings, SS tubes, Compression Coupling and Stud Blots (As per requirements), etc.

Fig 2.2 : Fenchugonj 90 MW Power Plant RMS
(Source : JGTDSL)

Partial view of a gas regulating and metering station is shown in Fig 2.2

Function of the equipments are described as follows

2.2.1 Inlet and outlet connections

The piping to and from regulator should be supported adequately to minimize pipe strains. The piping should be designed to have adequate capacity for the expected maximum flow and the pressure conditions. Velocities in regulator valve passages can reach sonic velocity conditions. High velocities create noise so piping should be sized to keep gas velocities at a reasonable level. There are specific pipeline velocity limits used by many companies to maintain a relatively quiet pipeline system and to keep pressure losses low. Such limiting velocities range between 50 feet per second to a maximum of approximately 400 feet per second. There are situations where higher velocities may be required for short distances; however, the designer should calculate the pipe velocities to be encountered and determine the steps that may be necessary to maintain satisfactory noise levels.

2.2.2 Insulating joint

To protect eddy current producing from transmission and distribution network which damage the pipeline of RMS, insulating joints are used at station inlet and outlet of RMS.

2.2.3 Emergency shut down (ESD) valve

To isolate the RMS from transmission network in case of emergency, ESD valve is placed at inlet of the station.

2.2.4 Headers

A header is a way to combine multi sources or multi-outlets into a single source or outlet. Headers need to be designed to distribute the gas symmetrically. They are typically larger sized pipe, tees, and caps. Headers are used when more than one regulator or meter run are required. In sizing headers it is a rule of thumb that the cross sectional area of the header be 1.5 times larger than the sum of the inlet or outlet cross sectional area (which ever is larger).

2.2.5 Knock out drum (KOD)/ scrubbers and filter separators

Knock out drum (KOD) is one kind of liquid separator and two stage filter separator. Liquid, Condensate are separated through the KOD.

2.2.6 Liquid Separation System

The liquid separation system is composed by two identical filtering lines to provide separation of liquid condensate mist from gas down stream pressure reduction . Each of them is designed for the maximum station flow rate, so that during the normal operation of the plant one filter will be in service and the second will be stand-by. Each filter will be put in/ on of service only manually operating through the inlet/outlet filter gear operated ball valves.

Types of Separators

Separators can be categorized into three basic types. These are vertical separator, horizontal separator, and spherical separator.

2.2.6.1 Vertical separator

The well stream is feed to the vertical separator tangentially through an inlet diverter that causes the primary separation by three simultaneous actions on the stream ï gravity settling, centrifugation, and impingement of the fluids against the separator shell in a thin film. Figure 2.3 is depicting a vertical separator.

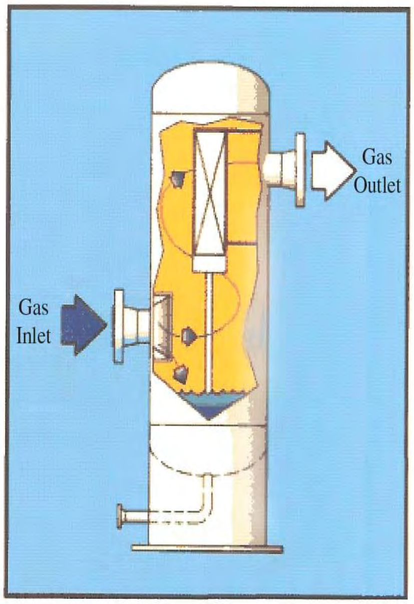

Figure 2.3 : Vertical Separator
(Source : Shanghai Fiorentini, 2008)

2.2.6.2 Horizontal Separators

Horizontal separators may be of a single-tube or a double-tube design. In the single-tube horizontal separator, the well stream upon entering through the inlet strikes an angle baffle and then the separator shell. The liquid drains into the liquid accumulation section, via horizontal baffles as shown in Figure 2.4. These baffles act as sites for further release of any dissolved gas. Gas flows horizontally in a horizontal separator.

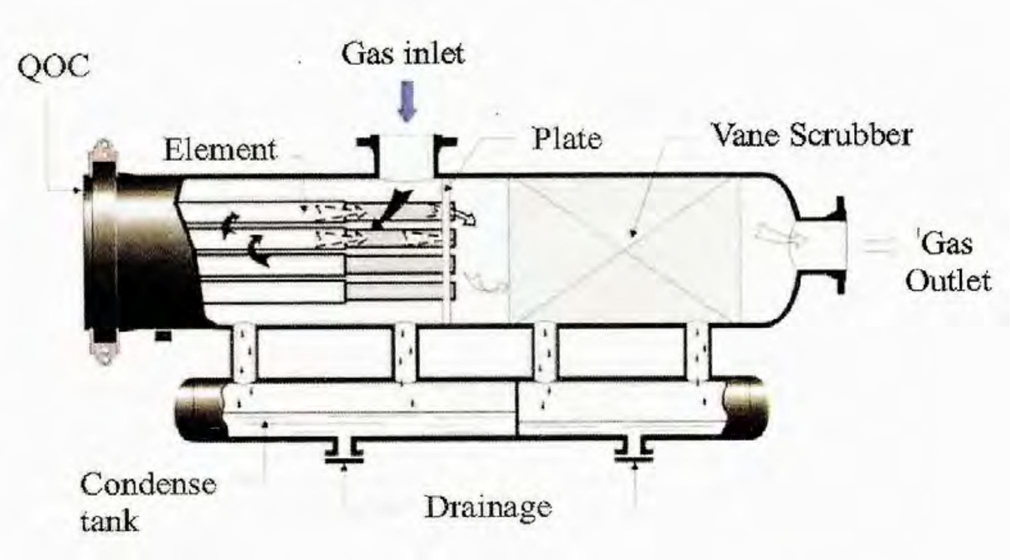

Figure 2.4 : Horizontal separator

(Source : Shanghai Fiorentini, 2008)

2.2.6.3 Spherical Separators

The spherical separator is designed to make optimum use of all the known means of gas and liquid separation such as gravity, low velocity, centrifugal force, and surface contact. An inlet flow diverter spreads the entering well stream tangentially against the separator wall. The liquid is split into two streams that come together after going halfway around the circular vessel wall and then fall into the liquid accumulation section. Liquid droplets from the gas are removed mostly by the velocity reduction imposed upon the gas inside the vessel. A mist extractor is used for the final removal of smaller liquid droplets in the gas.

2.2.7 Condensate Collection and Storage System

Water and liquid hydrocarbons coming from the filtering system and liquid separators will be collected and stored in the condensate tank. The condensate storage tank will be manually emptied with local control. It will be equipped with a safety valve to prevent any internal over pressure and level indicator with a high level alarm in control room.

2.2.8 Gas Regulator

The primary function of any gas regulator is to match the flow of gas through the regulator to the demand for gas placed upon the system. At the same time, the regulator must maintain the system pressure with certain acceptable limits. A typical gas pressure system might be similar to that shown in Fig-2.5 where the regulator is placed upstream of the valve or other device that is varying its demand for gas from the regulator.

If the load flow decreases, the regulator flow must decrease also. Otherwise, the regulator would put too much gas into the system and the pressure (P_2) would tend to increase. On the other hand, if the load flow increases, then the regulator flow must increase also in order to keep P_2 from decreasing due to a shortage of gas in the pressure system. If the regulator were capable of instantaneously matching its flow to the load flow, then we would never have major transient variation in the pressure (P_2) as the load changes rapidly.

Regulator Types

- Pressure reducing regulators
- Backpressure regulators
- Pressure relief valves
- Pressure switching valves
- Shutoff valves

2.2.8.1 Pressure reducing regulators

A pressure reducing regulator maintains a desired reduced outlet pressure while providing the required fluid flow to satisfy a downstream demand. The pressure which the regulator maintains is the outlet pressure setting (set point) of the regulator. Pressure reducing regulators can be direct-operated or pilot-operated.

1. Direct-operated (Self- operated)
2. Pilot-operated

2.2.8.1.1 Direct-operated (Self-operated)

Direct-operated regulators are the simplest style of regulators. At low set pressures, typically below 1 psig (0.07 bar), they can have very accurate (+/-1%) control.. At high control pressures, up to 500 psig (34.5 bar), 10 to 20% control is typical.

In operation, a direct-operated, pressure reducing regulator senses the downstream pressure through either internal pressure registration or an external control line. This downstream pressure opposes a spring which moves the diaphragm and valve plug to change the size of the flow path through the regulator.

2.2.8.1.2 Pilot-operated

Pilot-operated regulators are preferred for high rates or where precise pressure control is required. A popular type of pilot- operated system uses two-path control. In two-path control, the main valve diaphragm responds quickly to downstream pressure changes, causing an immediate correction in the main valve plug position. At the same time, the pilot- diaphragm diverts some of the reduced inlet pressure to the other side of the main valve diaphragm to control the final positioning of the main valve plug. Two-path control results in fast response and accurate control.

In the evolution of pressure regulator designs, the shortcomings of the direct-operated regulator naturally led to attempts to improve accuracy and capacity.

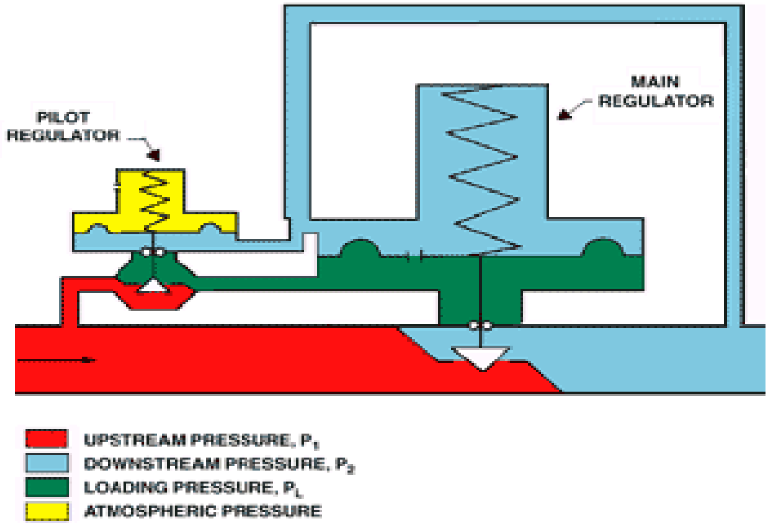

Fig 2.5: Pilot-operated regulator
(Source: Fisher Controls, 2005)

- Regulator Pilots
- Set point
- Spring Action

Regulator Pilots

The major function of the pilot is to increase regulator sensitivity. If it can sense a change in P_2 and translate it into a larger change in P_L, the regulator will be more responsive (sensitive) to changes in demand.

Set point

Set point and many performance variables are determined by the pilot. It senses P_2 directly and will continue to make changes in P_L on the main regulator until the system is in equilibrium. The main regulator is the "muscle" of the system, and may be used to control large flows and pressures.

Spring Action

Notice that the pilot uses a spring-open action as found in direct-operated regulators. The main regulator, shown in Figure 1, uses a spring-close action. The spring, rather than loading pressure, is used to achieve shutoff. Increasing P_L from the pilot onto the main diaphragm opens the main regulator.

2.2.8.2 Overpressure protection

To prevent personal injury, equipment damage or leakage due to escaping gas or bursting of pressure-containing parts, it is necessary to install adequate overpressure protection when installing a pressure reducing regulator. Adequate overpressure protection should also be installed to protect all downstream equipment in the event of regulator failure. Some regulators are made with internal overpressure relief, whereas others require the installation of a separate relief valve or an additional regulator to act as a monitor. There are also shut-off devices that are designed specially to handle overpressure.

2.2.8.2.1 Pressure relief valves

A pressure relief valve limits pressure buildup (i.e, prevents overpressure) at its location in a pressure system. The relief valve opens to prevent a rise of inlet pressure in excess of a specified value. The pressure at which the relief valve begins to open pressure is the relief pressure setting. Pressure relief valves can be direct-operated or pilot- operated.

Relief valve and backpressure regulators are the same devices. The name is determined by the application.

2.2.8.2.2 Automatic Shutoffs/Slam-Shuts valves

A pressure shutoff or slam-Shut device Shuts off the flow whenever the sensed control pressure violates a set limit. Depending on the capacity of the device selected, it may be able to shut off in response to a low-pressure condition only a high- pressure condition only or both.

2.2.8.2.3 Backpressure regulators

A backpressure regulator maintains a desired upstream pressure by varying the flow in response to change in upstream pressure.

2.2.8.3 Pressure switching valves

Pressure switching valves are used in pneumatic logic systems. These valves are for either two-way or three-way switching. Two way switching valves are used for on/off service in pneumatic systems. Three-way switching valves direct inlet pressure from one outlet port to another whenever the sensed pressure exceeds or drops below a preset limit.

2.2.9 Valve

A valve is a device that regulates the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways. Valves are technically pipe fittings, but are usually discussed as a separate category. In an open valve, fluid flows in a direction from higher pressure to lower pressure.

Valves are used in oil and gas, power generation, mining, water reticulation, sewerage and chemical manufacturing.

Valves may be operated manually, either by a hand wheel, lever or pedal. Valves may also be automatic, driven by changes in pressure, temperature, or flow. These changes may act upon a diaphragm or a piston which in turn activates the valve, examples of this type of valve found commonly are safety valves fitted to hot water systems or boilers.

2.2.9.1 Types of valve

There are different types of valves are used such as Gate valves, Globe valves, Ball valves, Plug valves, Diaphragm valves, Butterfly valves and Check valves.

Gate valves are generally used in systems where low flow resistance for a fully open valve is desired and there is no need to throttle the flow. Globe valves are used in systems where good throttling characteristics and low seat leakage are desired and a relatively high head loss in an open valve is acceptable. Ball valves allow quick, quarter turn on-off operation and have poor throttling characteristics. Plug valves are often used to direct flow between several different ports through use of a single valve. Diaphragm valves and pinch valves are used in systems where it is desirable for the entire operating mechanism to be completely isolated from the fluid. Butterfly valves provide significant advantages over other valve designs in weight, space, and cost for large valve applications. Check valves automatically open to allow flow in one direction and seat to prevent flow in the reverse direction. A stop check valve is a combination of a lift check valve and a globe valve and incorporates the characteristics of both. Safety/relief valves are used to provide automatic over pressurization protection for a system.

2.2.10 Gas Heating System

The heating system is provided to prevent the possibility of gas freezing and hydrates formation, due to the pressure drop during the reducing step in regulating system and pipelines, caused by the Joule-Thomson effect. A convenient rule of thumb indicates that a 15 psig reduction in pressure of natural gas is associated with a 1°F decrease in temperature (Roy,1989). Preheating of the gas is necessary for smooth operation of the gas station and correct flow measurement. Pre heaters are installed to heat the gas after the gas has passed the filter and before pressure reduction.

There are several types of heaters which may be used in regulating and metering station. Water bath heater, Heat exchangers and electric heater may be used depending on the station capacity and design.

2.2.10.1 Water bath heater

Water bath heater is one kind of indirect fired heater. Water bath heaters are often used in regulating and metering stations. The purpose is to heat the gas so that after a pressure drop is taken across a pressure regulator, the gas will be above the hydrate point. It consists of tubular elements, carrying the gas immersed in a water bath, which is maintained at the required constant temperature by the use of a burner fitted with standard controls and safety devices to maintain the desired exit temperature in the gas stream. The capacity range of water bath heater within 15 kw to 1170 kw according to heat required for heating gas.

2.2.10.2 Heat Exchangers

Heat exchangers are used to increase the temperature (above the dew point) of natural gas. Their performance is based on the heat exchanger between water (or steam) and the gas to be treated. Heat exchangers are designed to be suitable for an easy inspection and cleaning of all the parts.

2.2.10.3 Electrical Heater

This may take the from of a pressure vessel located in the gas stream in which are inserted electric immersion heaters. Such an arrangement would normally be confined to relatively small gas flow. A form of heating suitable for low input needs, such as impulse piping is that of heating tapes wrapped around the section of piping and thermally insulated on the outside.

2.2.11 Gas Metering System

Gas metering is very important for transmission and distribution system and metering station. Throughout the world, gas measurement utilizes two basic principles to measure gas volumes, positive displacement meter and inferential meters. Positive displacement meters comprise the large majority of measurement devices in use while inferential meters are used primarily for large volume measurement and thus fewer applications.

In RMS the metering bank consists of one metes runs design accordance to AGA report no.3 for the computation, of the gas volume flow delivered. Different types of meters are used for gas metering which describes as follows :

- Positive displacement - Diaphragm meter ,Rotary meter & Turbine meter
- Differential pressure measurement ï Orifice, Venturi and nozzle meter
- Ultrasonic flow meter - Doppler flow meter
- Fluid oscillatory ï Vortex meter, Swirl meter
- Electro magnetic flow meter ï Magnetic flow meter
- Direct mass ï Coriolis mass flow meter.
- Thermal - Thermal profile flow meter.

2.2.11.1 Positive displacement Meter

Positive displacement meter measures gas volume passing through it by repeatedly filling and discharging one or more chambers in sequence. Each chamberôs volume is known & the operating cycles are counted to get the volume passed. Meters incorporating the positive displacement principle of measurement are of the diaphragm and rotary type Meter.

a) Diaphragm Meter

In diaphragm meters there are two chambers alternately fill and empty, with slide values at the top of the meters controlling the flow to the chambers. The gas volume is obtained through a mechanical linkage mechanism, which connects the diaphragm motion to the mechanical readout system, where the number of displacements is counted.

A basic characteristics of diaphragm meters is their capability to accurately measure flow rates varying from small pilot loads to the maximum capacity the meter. The capacity is termed the frangibility. Diaphragm meters have excellent rangeability. The operation of this meter is simple and proven. This type of displacement meters are available in sizes and it can also be used for commercial and small industrial applications. These meters are produced with a Gï rating range from G ï 1.6 to G ï 10 with operating pressure 0.4 bars.

b) Rotary Meter

This type of meter contains two oppositely rotating impellers, which are the measuring mechanism. The volume of gas is directly related to the number of revolutions of one of the impeller shafts. The rotary meterôs capacity rating is much greater than the diaphragm meter. Rotary meters are available in ranges of 800 to 102,000 CFH. It can be used in high pressure applications with up to an ANSI 600 rating available. These meters are compact and reliable, however since the operation depends on maintaining proper clearance between the impellers and the case, they can be susceptible to stress and if a malfunction occurs, then the gas flow could be stopped. The rotary meter is limited at high pressure. Therefore this meter although an excellent performance is not regarded as appropriate for large capacity, high pressure metering of natural gas.

C) Turbine Meters

The turbine meter is classified as a rotary inferential meter. These flow meters are used successfully in both liquid and gas measurement. Turbine meters are velocity sensing meters with the volume of fluid being derived from the rotations of the turbine rotor. The speed of this rotor is proportional to flow rate. Turbine meters has been established as a means of measuring fluid for nearly 80 years. Since the 1950s, they have been considered favorably for the measurement of large volume gas flows. The designs have proved receivable, accurate and repeatable. As well as being used as the primary measurement standard, axial flow gas turbine meters are increasingly being used as calibration and reference meters.

The turbine meter (Figure-2.6) has wide range ability (to 200:1 depending on meter size and line pressure), greater accuracy potential and more versatility in adding mechanical and electronic auxiliary devices. Like an orifice meter, a turbine meter does not impede flow if there is damage or failure. This is important when maintaining gas service to a downstream consumer is critical.

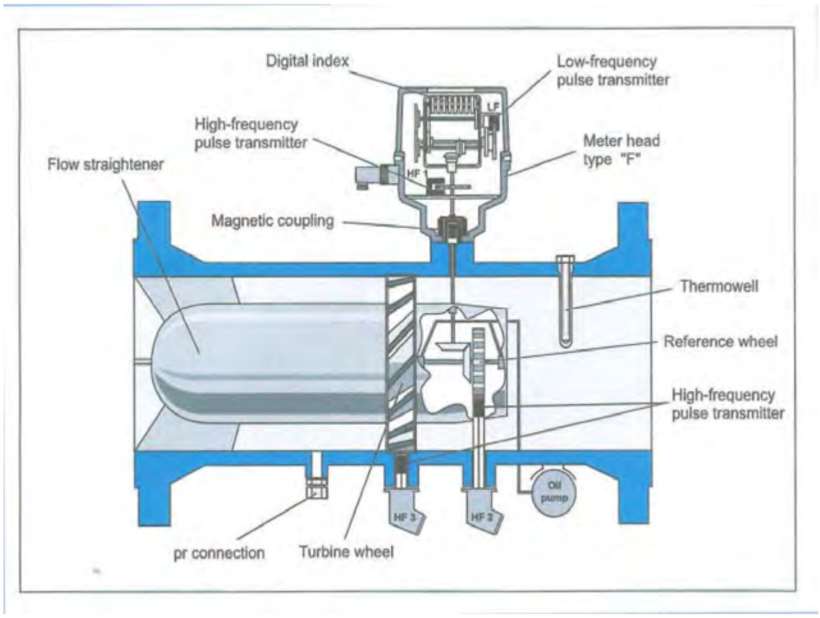

Figure-2.6: Turbine Meter

(Source: RMG-GmbH, 2008)

Two basic assumptions relate to the operation of the turbine meter:

1) The angular velocity of the rotor is proportional to the volumetric flow rate passing through the meter.

2) The pulsed output frequency of the pick-up is proportional to angular velocity of the rotor.

The axial flow gas turbine meter comprised of three main components:

a) The body through which the gas passes.
b) A rotor with bearings and supporting structure.
c) A device to transfer the internal revolutions of the rotor to an external counter.

Gas flowing through the meter impinges on turbine blades located centrally along the axis of the unit. Turbine blades are free to rotate, and do so in a manner directly proportional to the velocity of the gas passing the blades.

The area of the rotor face as defined by the mean radius of the rotor can be determined. Permanent magnets installed in the hub of the rotor, turn with the rotor to produce a magnetic field, which passes through a coil. As each of the magnets pass the coil a separate and distinct voltage pulse is created. The frequency of these pulses is proportional to the velocity of the rotor is also proportional to the flow rate. Each pulse is also proportional to a small unit of volume. The pulses, the effective flow rate and total flow are transmitted by frequency and by counting the pulses. The output frequency has been conditioned into a square wave through a preamplifier. This conditioning allows it to be transferred to a remote flow computer. Each pulse represents only a small incremental volume of flow. Since the turbine meter measures volume at line conditions, the gas laws can be applied to change the register volume to base conditions.

2) Inferential Meters

Orifice and turbine meters operate on the inferential measurement principle. Here the flow rate is found by inferring from other measured variables.

a) Orifice Meters

Orifice Metering is the most common form of gas metering used throughout the world for the accounting of large volumes of natural gas. It is also used for the measurement of liquids.

Based on the differential pressure method, the rate of flow is computed on the basis of long established physical principles. The common equation used for determining the total flow volume being based on the current AGA or ISO Standard.

The orifice plate meter is classified as a differential pressure (dp) meter. There are a number of types of flow meters, with different shapes and sizes, which fit into this category of inferring flow rate from the pressure drop across a restriction. An Orifice plate flow meter system consists of three discrete components the meter tube, the orifice assembly, and the differential pressure gauge. The meter tube and orifice assembly are considered to be the primary element and the differential pressure gauge, pressure and temperature gauge or recorder are being referred to as secondary element.

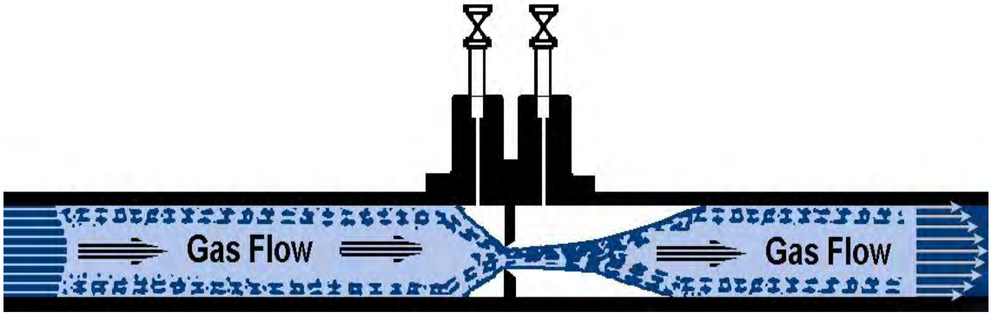

Figure-2.7: Orifice Meter
(Source : AGA Report no 3)

Orifice meters must be designed, fabricated and installed according to AGA Report no 3 (ANSI/API 2530). When designing an orifice meter run, differential pressure should range between 10ò and 90ò of water column for a 100ò chart and 20ò and 180ò of water column for a 200ò chart. This avoids large measurement errors at low differential pressures and overhanging the chart. Although AGA Report no 3 does not specify upper or lower differential pressure limits, industry standard is 10ò to 200ò of water column. If the differential pressure falls below 10ò of water column, it does not stabilize and measurement errors result.

The orifice plate meter is classified as a differential pressure (dp) meter. There are a number of types of flow meters, with different shapes and sizes, which fit into this category of inferring flow rate from the pressure drop across a restriction. An orifice plate flow meter system consists of two basic elements, namely the primary flow element, which is the orifice plate, and secondary elements which include the differential pressure transmitter, or differential pressure indicating device such as a manometer, and the associated pipe work and valves. The orifice plate meter relies on the principle of when a fluid is flowing a closed medium (a pipe) and encounters a restriction, a pressure drop is developed. This pressure drop is related to the flow rate of the fluid. By measuring the differential pressure across the orifice plate (upstream and downstream of the plate) and the condition at which the orifice is being used, then this pressure differential can be translated into a volume flow rate according to a formula. Accurate measurement is definitely possible with this type of flow meter, if malfunctions occur the flow of gas will not be stopped. Orifice meters are not limited by high pressure or high flow so they can therefore be considered for high flow, high pressure gas metering. Naturally the correct selection of orifice plate type is important.

The rangeability of a single orifice meter is about 3:1, by adding further orifice meter runs in parallel, this rangeability increases by the square. That is, a dual run meter station would have a theoretical rangeabilitiy of approximately 9:1. Rangeability is the term used with meters to express the flow range over which a meter operates whilst continuing to meet a given accuracy tolerance. The rangeability can also be expressed as ‘turndown’, which is a ratio of the maximum flow divided by the minimum flow, again over a given accuracy tolerance.

Ultrasonic Meters

Ultrasonic meters, as custody transfer devices, are relatively new to the gas industry. A.G.A. Report no-9 refers to the industry accepted standard for installation of an ultrasonic meter. Report no- 9 is vague compared to Report no-3. It leaves a lot of the design and installation up to the manufacture of the ultrasonic. This is due to the fact that there is not a good understanding of installation effects of Ultrasonic's yet. Choosing the appropriate meter, out of all the meters available, a designer must choose a meter to fit the need of the station. First look at the flow rates and pressures and decide what type of meter would best fit for the application. Positive displacement meters are usually used for low flow applications. Orifice and ultrasonic meters are usually considered for large flow applications. After choosing a meter the regulators may be sized.

2.2.12 Auxiliary devices Used with Meters:

The following auxiliary devices can be used with meters.

1) Electronic Volume Correctors

The electronic volume corrector (EVC) accomplishes the same functions electronically as its mechanical counterparts.

Because they are microprocessor based, they are more versatile (perform more tasks) and flexible (in date retrieval, manipulation and transmission) than mechanical devices. They are also less subject to accuracy loss due to vibration, wear and other mechanical failures. Features include:

- pressure and temperature correction
- calculated super compressibility factor using fixed gas quality values
- various volume outputs: uncorrected, corrected, totals
- imperial or metric unit choice
- built-in alarms indicating battery condition, pressure and temperature over under ranges, etc.
- telemetry capability (with data transmission devices added)

EVCs are mounted above the meter's output drive shaft. They conserve battery power by remaining dormant between flow calculations, which are only performed on every complete revolution of this shaft. They are used on diaphragm, rotary and most turbine meters.

2) Flow Computers :

A flow computer has more program options than an EVC. Features include those listed for EVC's with the following:

- Calculated super compressibility factor using full gas composition data (if available)

- Wide variety of alarm settings
- Most are not approved for use in hazardous areas
- Continuously calculated flow using AGA Report no3 or 7 equations
- Reprogrammable for other applications
- Performs some logic functions
- Calculated flows for several meter runs simultaneously
- Differential pressure (in mA) or pulse input accepted
- Pulse output for an odorant injection system.

An orifice meter requires a flow computer with a differential pressure input. The unit usually used in this case is approved for use in a Class 1, Division 1, Group D hazardous area. All other flow computers can not be used in hazardous areas, so must be installed in a site control building.

3) Chart Recorder

Chart recorder is standard for accurate, reliable measurement and recording of pressure, differential pressure and temperature in a wide variety of applications.

Although very significant advances have been made in the direct processing of flow measurement data by means of microprocessor based equipment, a need still exists for the chart recorder because it is reliable. The use of the direct reading chart has the advantage that the measurement being recorded can be read at a glance. Some organizations retire charts as a permanent record for accounting purposes. The recording and calculation process is the final consideration for obtaining accurate flow measurement. In the evaluation of equipment, one significant factor tends to be overlooked in the selection process ï that of the skill and training of operators. The proper operation of complex data processing equipment in many cases gets down to the skill.

Chart recorders are simple and fairly robust and therefore do not require highly skilled operators or expensive diagnostic equipment, however malfunctions can occur if they are not serviced properly or incorrect charts are used. Cost wise, the chart recorder can be an attractive option. When a back correction is required or a prior event needs investigation, a chart recording can be invaluable.

By using the concept of Bellows, Bourdon tube and thermos well mechanical recorder are produced by the manufacturer of different ranges and sizes, which are used to measure the differential pressure, static pressure of gas with circular chart. The accuracy of their device is

a) Differential pressure element: ± 0.5% of full scale.

b) Static pressure: ± 1% of full scale.

Chart recorders are mainly two types one type is VPT recorder and another is flow recorders for orifice meters.

4) Flow Recorders

The flow recorders are a differential flow recorder for orifice meters. They are used as the primary record of flow through an orifice meter. The chart records static pressure, pressure differential and flowing temperature. Chart drives are available to turn the charts faster or slower, but in most installations 24 hour or 7 day charts are used.

Chart ranges are:
Static pressure : 0 to 3 450 kPa or 0 to 6900 kPa

Pressure differential : 0 to 25 kPa (o to 100ò WC) or 0 to 50 kPa (0 to 200ò WC)

Flowing temperature: 0 to 38^{o}C.

Flow recorders are no longer used for backup in new installations because EVC's have proven reliable and contain their own internal backup. Technical services, measurement and electronics' standard is Graphic Controls disposable pens for all recorders.

5) Pressure Gauge

There are a number of devices and instruments available for the measurement of pressure. The simplest pressure-measuring device is the pressure gauge, and the most common of all the pressure gauges utilizes the óBourdon tubeô.[The principle of operation of Bourdon tube, which is a thin metallic tube closed at one end, is that when pressure is applied to the tube internally the tube will tend to straighten out from its normal cylindrical form. The sealed top of the tube moves linearly with the applied internal pressure, therefore this movement can be translated to a scale. When the pressure is removed the tube will return to its normal state. Care must be taken not to over range a Bourdon tube type pressure gauge otherwise damage through distortion of the tube may occur]. An accuracy of about ± 1% should be available for at least the upper range value of a good Bourdon tube type pressure gauge. These are some master pressure gauge with an accuracy of ± 0.25%.Pressure gauges also adopt bellows as the means of translating the pressure into a visual scale.

6) Temperature measurement

Two scales tend to be more commonly used these being the Celsius and the Fahrenheit scales. For the international system of units (SI), the Kelvin (K) is the unit used and for F. P. S. system it is Rankine (R). Among the process variables temperature is very difficult to control. Temperature must be measured without any interference. This can be achieved by a number of ways ad includes expansion and contraction of liquids and metals. Changes in electrical resistance, change in intensity of emitted radiation and changes in volume or pressure of gas the most common temperature measurement devices are:

a) Filled thermal system
b) Thermocouples
c) Liquid in glass thermometer
d) Thermistors
e) Resistance temperature detectors (RTDôs)
f) Radiation pyrometers
g) Bimetallic devices
h) Smart temperature transmitters.

Selection of the best sensor for a given application can be a function of temperature range, sensitivity, response time, initial cost, maintenance, accuracy, reliability and power requirements. Overall control requirements are also important. This can lead to the selection of a mechanically or pneumatically transmitted system, giving freedom from external power sources and simple maintenance requirements. On the other hand higher accuracy and sensitivity and multi sensing ability may make the electronic system more attractive. Temperature measurement and its conversion have a strong effect on measurement. Incorrectly measured temperature value can alter the actual flow quantity. Now we can discuss some of the potential error of temperature measurement.

7) Density measurement

Measurement of density is necessary not only for mass flow measurement system but also for a computerized volumetric flow measurement system.

The traditional methods for density measurement are to measure the mass of a fixed volume of fluid or the volume of a fixed mass. This usually involves taking a sample of the fluid from the process vessel or a pipeline to a laboratory for weighing. Although this method can produce accurate results, it is impractical for most process and pipeline applications. Due to the requirement for an in-site measurement device, the densitometer was developed. Densitometer sometimes shows higher value than the actual due to condensation of gas in the device. This may alter the value of actual gas used. So it has a strong effect on system loss.

2.2.13 Supervisory Control and Data Acquisition (SCADA) System

The Supervisory Control and Data Acquisition (SCADA) system allows users safety and efficiency operate RMS by providing remote monitoring and processing, control functions, data collection and analysis and report generations.. The system consists of electronic sensors and controls installed remotely on the pipeline system and that are linked via network to a set of computers.

From a SCADA terminal authorized users can

- Open and closed valves
- Monitor the flow, pressure and chemical composition of the gas
- View current conditions in the system
- View and print detailed information about the operation of the system and the data received by the system

SCADA makes it possible to

- Quickly access accurate information
- Detect and respond to problem conditions very quickly
- Effectively manage the system operation
- Maximize the efficient use of available human resources
- Carefully oversee operations in remote areas.

CHAPTER 3

RMS DESIGN CONSIDERATIONS

Sustained safety, accuracy and control are the primary considerations in the design of regulating and metering station. Many factors must be considered and assembled into specifications and drawings to ensure safety and to provide accuracy, accessibility and work space for operations. These factors can be combined into a piping structure with adequate foundation and a partial or complete shelter arranged to fit the site. The station should be designed with predicted load changes considered and to require a minimum of piping alteration with unpredicted load change. Most regulating and metering stations are likely to be in service for a long time.

After considering the safety, purpose and cost of a high pressure measuring and regulation station one can follow a few steps in selection of basic components to design a reliable, accurate, safe and cost efficient station. There are a variety of sources available for information details on all the components of a high pressure measuring and regulation station, including A.G.A. Report no-3, A.G.A. Report no-7, Bangladesh natural gas safety rules,1991(Amendment 2003), National Regulations, company policy and manufacturer's literature. Also consulting with the field operations personnel for ideas during the design will help give practical perspective to the design of a station.

In this chapter, the basic design considerations and procedures in designing a regulation and measuring station will be discussed. The equipment selection criteria are also elaborated here.

3.1 Design Parameters

To achieve safety, accuracy and dependability in a high pressure measuring and regulating station the following parameters must be considered in order to design RMS.

- The amount of gas that must flow through the RMS and expected future changes in volume requirements
- Inlet and outlet pressure

- In order to ensure supply continuously, alternate system must be taken for emergency and scheduled maintenance of important equipment (By pass system)
- Provision of filter separator to protect valuable and sensitive regulators and meters from dirt and condensate
- Provision of slam shut valve to protect down stream station from unexpected high pressure
- Provision of emergency shut down (ESD) valve to isolate main station from transmission network in case of any emergency situation
- Provision of heater to prevent the possibility of gas freezing due to the pressure drop during the reducing step and low atmospheric temperature
- Use of silencer to reduce the noise level due to gas de-pressurization
- Meter selection
- Control device selection
- The requirements for maintenance
- Establish sophistical Flow computer/Supervisory Control and Data Acquisition (SCADA) System

Safety, cost, site location, constructability, operation and maintenance, environmental impact, government regulations. All of these will impact the design parameters.

3.2 Regulating and Metering Station Configuration

Regulating and Metering Station configuration has a strong effect on system loss if it is not installed or built as per the internationally recognized or prescribed standard with maintaining the entire requirement for filtering, regulating, metering and safety. At least minimum requirement should be meet. In this regard Institution of Gas Engineers (IGE) recommendation, IGE/TD/9 and American Petroleum Institute (API) recommendation should be used as a guideline. The pipe and fittings should be installed in such a way that turbulence can be avoided.

3.2.1 Recommended Minimum Requirements

The overall design of Regulating and Metering Station (RMS) should comply as a minimum requirement as per Institution of Gas Engineerós recommendation IGE TD-9.

- Two or more high-pressure inlet filters with suitable valving and connections to permit design throughput to be maintained with one unit out of action. Means to avoid the entertainment of liquids in the gas entering a regulator assembly and, if necessary suitable provision made for their removal. It is particularly important that the gas supply to regulator control instruments should be fee of liquids and dust and suitable filters or filter/separators should be installed as appropriate.

- Two or more streams of pressure regulators each stream to contain at least two regulators, so impulse that if any one fails, the remainder will maintain safe conditions. Where the installation is not a major supply or is reinforcement off take, consideration may be given to the provision of a single stream of regulators only. Upstream slamï shut valves should be fitted on all streams of regulators. This requirement for the provision of slam-shut valves may be waived at the discretion of a responsible engineer in the case of very small installations where the potential gas release via a relief valve can be allowed.

- Installations should be designed to withstand inlet pressure conditions through to the final outlet valve. Where this is not reasonably practicable, the design should include inter-stage relief valves in each stream where more than one stage of pressure reduction is involved. Such relief valves should be at least of sufficient capacity to off-set the effects of gas passing due to tail use of regulators to ñlock-upò at times of no flow. Protection may also be afforded by providing an auxiliary trip switch for the slam shut valve.

- In certain circumstances failure of a pressure reduction installation to ñlock-upò at periods of low flow may cause the normal working pressure of the system into which it delivers to be exceeded. The use of a relief valve and vent of sufficient capacity to offset this failure to lock-up may be considered if the operation of the slam-shut system is unacceptable.

- It is necessary to consider whether or not preheating of the gas is required to avoid unacceptable low temperature in the down stream pipe work and auxiliary systems following pressure reduction. If heater is installed then they should be controlled in such a way as to avoid high gas temperatures, which can damage any seals, diaphragms or valve seats in equipment such as regulators, meters, relief valves etc.

3.3 Station specifications

There are many details to assemble in the development of station specifications. These details are basically volume and pressure data with many other considerations to ensure safe and proper operation.

3.3.1 Volume

The gas volume passing through a station is a very important factor to design a regulating and metering station.

The design should be based on peak load requirements and not the daily average. regulating and metering station. The peak load conditions must be considered in sizing meters and regulators. Peak loads will be different from average volumes determined by the average daily load.

3.3.2 Pressure conditions

The pressure conditions for each installation are the inlet pressure to the station and the outlet pressure of the station. Each condition influences the design of the station.

3.3.2.1 Inlet pressure

The inlet or supply pressure to a station will vary depending on the system feeding the particular station. The minimum inlet pressure is the basic factor in sizing regulators and the metering equipment for the maximum demand rate. The maximum pressure will be the factor determining the shell strength of the regulation and measurement equipment and is also needed to size over- pressure protection equipment. The pressure condition may vary between winter and summer and these variations must be considered in the design.

3.3.2.2 Outlet pressure

The outlet pressure of a regulating station will be set by operational requirements. Metering station without regulating equipment will have an outlet pressure rating equal to the inlet pressure. The regulating station specifications should indicate the quality of outlet pressure control required and the minimum and maximum outlet pressure acceptable to the system. The amount of pressure reduction is a major indication of whether a single stage pressure regulator will be satisfactory or if multiple stage reduction is required.

3.3.3 Type of load

The type of load, economics of meter selection and the variation in station inlet pressure may dictate that the metering pressure be held constant at some value below the minimum inlet pressure and a second cut be made to supply the proper outlet pressure level for the system. Load characteristics also influence the type of meter selection for the installation.

3.3.4 Gas conditions

Usually the gas contract will specify the minimum BTU content of the gas and may specify the maximum allowable amount of H_2O in the gas. Other conditions concerning the gas such as amount of H_2S, CO_2 , N_2 etc, may also be specified in the contract. Most pipeline quality gas is dry and clean but dust conditions could cause severe velocity erosion of regulator trim. If dust or other particular matter is present, filtering equipment should be installed upstream of the station.

3.3.5 Ambient conditions

The maximum, minimum and average ambient temperatures for the area should be known. Very low temperatures will require special considerations to prevent freezing of the equipment. Likewise, the station site elevation will indicate the average barometric pressure to be used in measurement calculations. If orifice meter measurement is used, the latitude of the station should be determined to permit the use of the location factor in the orifice meter calculation. High relative humidity can cause external ice for motion on piping if the piping temperature reaches 32^0 F due to the temperature drop caused by pressure reduction.

3.3.6 Site condition

The characteristics of the station site or proposed area should be considered to determine the type of external station design. A regulating station creating noise levels of greater than 85 db will not be tolerated in a populated area, while the same station in a rural area may be satisfactory. If population growth is in the direction of the site, then this should be considered early in the design because it will have an influence on what protective measures must be taken to make the station satisfactory over a long period of time. Prior to design, in addition to becoming familiar with local in ordinances and regulating concerning site improvements, consideration should be given to flooding ease of access to the site during adverse weather and outlet lines crossing roadways and presenting frost-heaving problems. These and many other details should be considered when gathering facts to prepare the station design.

3.4 Pipe sizing

3.4.1 Velocity formula

Pipe sizing is generally done by using the velocity of the gas through the pipe. Higher gas velocities create greater pressure drops per foot and generate excessive noise. The velocity through a pipeline should be 35-50 feet per second with above ground facilities of velocities of 100 feet per second.

The sizing of pipe is performed by the following formula:

$$V = (0.75*Q)/(P*D^{2}) \text{ -- } (3.1)$$

Where,

V = Limiting velocity of gas, feet per second

Q = Maximum flow rate, cfh

P = Minimum operating pressure, psia

D = Internal diameter, inches

3.4.2 Panhandle formula

For high pressure and long distance pipeline the Panhandle formula is suitable.

The Panhandle formula is given below.

$$Q_{mmscfd} = 0.00128084\ ((P_1^{2} - P_2^{2})/L)^{0.51}*d^{\,2.53} \text{ -- } (3.2)$$

Where,

Q_{mmscfd} = Flow rate, MMSCFD

P_1 = Up stream pressure, PSIA

P_2 = Down stream pressure, PSIA

d = Inside diameter of pipe, Inches

L = Length of pipeline, Miles

3.4.3 Wall thickness of pipe

Now it is time to determine the pipe wall thickness. Pipe wall thickness for each nominal pipe size commercially available, the outer diameter (OD) is specified. For each OD a variety of wall thicknesses are available. For above ground pipe it is generally recommended that a minimum of standard wall thickness be used.

3.4.3.1 Yield strength

Pipeline steel is available in many strengths. The designer must choose a pipe grade and wall thickness together to meet the pressure requirements of the station. Barlowôs Formula is used to determine steel pipe selection.

Using Barlowôs Formula one can determine the size and strength of pipe needed for the station.

Below is Barlowôs Formula :

P = (2St/D)xFxExLxT --(3.3)

Where,

P = Design pressure, PSIG

S = Yield strength, tensile strength of the metal, PSI

t = Nominal wall thickness, Inches

D = Outside diameter, Inches

F = Construction type design factor (safety factor)

E = Longitudinal joint factor

L = Location factor

T = Temperature de rating factor

Where,

F - above ground pipe = 0.5 or 0.4

E - seamless or electric resistance welded pipe =1

T - temperatures between 20 °F and 250 °F = 1

3.4.3.2 Minimum yield strength (Y)

The properties of steel used in the construction of pipeline are divided into two API specification. 5L for normal quality steel and 5LX for high strength steels. These specifications are now accepted throughout the world. Table 3.1 gives the strength properties of most widely used steels.

Table 3.1 Strength of Line pipe Steel

Specification	Grade	SMYS (psi)
5L	A	30,000
5L	B	35,000
5LX	X 42	42,000
5LX	X 46	46,000
5LX	X 52	52,000
5LX	X 56	56,000
5LX	X 60	60,000
5LX	X 65	65,000
5LX	X 70	70,000
5LX	X 75	75,000

(SMYS = Specified Minimum Yield Strength)

3.4.3.3 Joint factor (E)

The joint factor varies with the type of joint used in manufacturing the pipe. For different manufacturing process joint factor are given in Table 3.2.

Table 3.2 :Value for joint factor (E)

Weld type	ASME B31.8
Seamless	1
ERW	1
SAR	1
Butt Welded	0.6
Spiral seam welded	0.8

(ERW= Electrical Resistance Welding, SAR = Submerged Arc Welding)

3.4.3.4 Design factor (F) and class location factor (L)

American Society of Mechanical Engineers (ASME) suggests design of 0.8. Location factor are designated in ASME B 31.8 code for high pressure gas transmission and distribution piping are given in Table 3.3.

Table 3.3 : Location factor (L)

Areas	Class Location	ASME	CSA
Desert	1	0.72	0.80
Village	2	0.60	0.72
City	3	0.50	0.56
Metropolitan	4	0.40	0.44

(ASME = American Society of Mechanical Engineers,
CSA = Canadian Standard Association)

The effect of the Location factor is to increase pipe wall thickness for a given size and grade of pipe as the construction area becomes more populated and the failure of a pipeline would be more serious.

3.4.3.5 Temperature de rating factor (T)

The temperature de rating factor for steel pipe varies from 1.0 for operating temperature up to 250 ^{0}F and 0.87 for an operating temperature of 450 ^{0}F or above. Temperature de rating factor for different temperature ranges are given in Table 3.4.

Table 3.4:Temperature de rating factor (T)

Temperature (^{0}F)	Value as per ASME B31.8
Up to 250	1.00
251-300	0.97
301-400	0.93
401-450	0.91
451 and above	0.87

3.5 Headers

A header is a way to combine multi sources or multi-outlets into a single source or outlet. Headers need to be designed to distribute the gas symmetrically. They are typically larger sized pipe, tees, and caps. Headers are used when more than one regulator or meter run are required. In sizing headers it is a rule of thumb that the cross sectional area of the header be 1.5 times larger than the sum of the inlet or outlet cross sectional area (which ever is larger).

The following equation is used for header sizing

ʧ $D^2/4 = [($ ʧ $d_1^2/4 +$ ʧ $d_2^2/4 + \text{-----} +$ ʧ $d_n^2/4)*1.5]$ ------------------------ (3.4)

Where,

ʧ $D^2/4$ - Cross sectional area of the header, square inches

ʧ $d_1^2/4$ ï Cross sectional area of the 1st inlet or outlet pipe line, square inches

ʧ$d_2^2/4$ - Cross sectional area of the 2nd inlet or outlet pipe line, square inches

ʧ$d_n^2/4$ - Cross sectional area of the nth inlet or outlet pipe line, square inches

Headers may be placed above ground or below ground. One must consider noise when placing a header above ground and liquid removal when placed below ground. A straight or U-shaped header may be used, but it is a good idea to know the gas velocity through the header after sizing.

3.6 Filtering system

The vessel of filters separator will be designed and manufactured in accordance with ASME section-8, Division1 and welding the vessel with AP1-1104 Code. The followings are important matter in order to design filter separator:

1. Permissible particle size (5 micron is allowable)
2. Filtering efficiency
3. Pressure should not be reduce with filtering operation.

Maximum gas velocity for filtering system.

Up stream filtering system **:** 60 feet per second

Down stream filtering system **:** 120 feet per second

3.6.1 Liquid separation system

The liquid separation system is composed by two identical filtering lines to provide separation of liquid condensate mist from gas down stream pressure reduction . Each of them is designed for the maximum station flow rate, so that during the normal operation of the plant one filter will be in service and the second will be stand-by. Each filter will be put in/on of service only manually operating through the inlet/outlet filter gear operated ball valves. The liquid separation system is designed for the following operating condition.

3.6.1.1 Criteria of a well designed separator

To perform efficiently, a well designed separator should meet the following criteria ï

- Control and dissipate the energy of the well stream as it enters the separator, and provide low enough gas and liquid velocities for proper gravity segregation and vapor-liquid equilibrium. For this purpose, a tangential inlet to impart centrifugal motion to the entering fluids is generally used.

- Remove the bulk of the liquid from the gas in the primary separation section. It is desirable to quickly achieve good separation at this stage.

- Have a large settling section, of sufficient volume to refine the primary separation by removing any entrained liquid from the gas, and handle any slugs of liquid (usually known as ñliquid surgesò).

- Minimize turbulence in the gas section of the separator to ensure proper settling.
- Have a mist extractor (or eliminator) near the gas outlet to capture and coalesce the smaller liquid particles that could not be removed by gravity settling.
- Control the accumulation of froths and foams in the vessel.
- Prevent re-entrainment of the separated gas and liquid.
- Have proper control devices for controlling the back-pressure and the liquid level in the separator.
- Provide reliable equipment for ensuring safe and efficient operations. This includes pressure gauges, thermometer, liquid level indicator, safety valve etc.

3.6.2 Filter separator design criteria

The separator sizing is depends on gas capacity, liquid capacity of separator and pressure drop through it.

3.6.2.1 Gas capacity design of separator

The Souders- Brown Equation is used for calculation of gas capacity of gas-liquid separator (Kumar,1987).

$v_g = K_l\ [(\rho_l - \rho_g)/\rho_g]^{0.5}$ ---(3.5)

Where, v_g = allowable gas velocity at the operation conditions, ft/see

ρ_l = liquid density at the operation conditions, lbm/ft^3

ρ_g = gas density at the operation conditions, lbm/ft^3

K_l = coefficient of separator

Table 3.5: Values of separator coefficient, K_l (Kumar,1987)

Separator type	Range of K_l	Most commonly used K_l Value
Vertical	0.06 to 0.35	0.117 without mist extractor
		0.167 with a mist extractor
Horizontal	0.40 to 0.50	0.382 with a mist extractor
Spherical	0.40 to 0.50	0.35 with a mist extractor

The gas capacity at the operation conditions ρ_g, in ft^3/sec is given below:

$\rho_g = Av_g = (\pi D^2/4)\ K_l\ [(\rho_l - \rho_g)/\rho_g]^{0.5}$ ---(3.6)

Where,

$A =$ cross sectional area of the separator, ft^2

$D =$ internal diameter of the vessel, ft

Here the gas velocity, v_g is based upon the total separator area and it is therefore more appropriate to refer to it as the superficial gas velocity. The gas capacity at standard condition (14.73 psia and 60 ^0F), generally reported in units of MMSCFD is thus given by:

$q_{gas} = 2.40D^2\ K_l\ [p/Z(T+460)][(\rho_l - \rho_g)/\rho_g]^{0.5}$ -------------------------------------(3.7)

Where,

q_{gas} = Gas capacity at the operation conditions, MMSCFD

$p =$ Operating pressure, PSIA

$T =$ Operating temperature, ^0F

Z = Gas compressibility factor at the operation conditions.

Above two Equation can be used to calculate the separator diameter required to handle a given gas rate or to calculate the gas rate that a separator of a given size can to handle.

The area of the mist extractor A_m can be obtained as follows.

$A_m = q_g/v_m$ ---(3.8)

Where, v_m is the gas velocity through the mist extractor, determine using the first Equation with K = 0.35 for mist extractor (wire mesh type).

3.6.2.2 Liquid capacity design of separator

The liquid capacity of a separator depends upon the volume of the of separator available to the liquid and the retention time of the liquid within the separator (Kumar,1987).

$w = 1440\ (V_L)/t]$ ---(3.9)

Where, w = liquid capacity, bbl/day

V_L = liquid setting volume, bbl

t = retention time, min (1440 is the conversion factor to convert bbl/day into bbl/min)

The liquid setting volume, V_L can be used to calculate as follows:

$V_L = 0.1399D^2h$ for vertical separators

$V_L = 0.1399D^2$ (L/2) for horizontal single tube separators

$V_L = 0.1399D^2$ L for horizontal double tube separators

$V_L = 0.0466D^3 (D/2)^{0.5}$ for spherical separators

Where, h = height of liquid column above the bottom of the liquid outlet in the vertical separators, ft

L = separator length (height), ft

For good separators, a sufficient retention time, t must provide. From field experience, the following liquid retention times have been suggested (Kumar,1987).

Oil-gas separation : 1 min.
High pressure oil water gas separation : 2 to 5 min.
Low pressure oil water gas separation : 5 to 10 min. at > 100 ^{0}F
10 to 15 min. at > 90 ^{0}F
15 to 20 min. at > 80 ^{0}F
20 to 25 min. at > 70 ^{0}F
25 to 30 min. at > 60 ^{0}F

3.6.3 Vessel design consideration

For designing separator some basic factors that must be consider are point out bellow (Kumar,1987):

- The length to diameter ratio, L/D, for a horizontal or vertical separator should be kept between 3 and 8, due to considerations of fabrication and foundation cost.
- For a vertical separator, the vapor-liquid interface (at which the feed enters) should be at least 2 ft from the bottom and 4 ft from the top of the vessel. This implies a minimum vertical separator length (height) of 6 ft.
- For horizontal separator, the feed enters just above the vapor-liquid interface that must be off-centered to adjust for a greater gas (or liquid) capacity as needed. The vapor-liquid interface must be kept at 10 inch from the bottom and 16 inch from the top of the vessel. This implies minimum horizontal separator diameter of 26 inch.

3.7 Regulators

The regulator is a component of the system and therefore its selection and installation should be based on the system requirements. After these have been selected the designer must then determine how many pressure cuts are needed to meet the design requirements. Due to large pressure drops across the station there may be a need for multiple pressure cuts to eliminate freezing and maintenance problems. The making of multiple pressure cuts will reduce or eliminate noise caused by large pressure drops across a control valve. Another way to eliminate noise is to increase the wall thickness of the piping. Next, a regulator or control valve should only be sized for 75% of its capacity at the maximum volume and minimum inlet pressure of the station. Properly sizing the regulator is essential to the design of the station in order to reduce maintenance cost and operational problems.

It is recommended that regulators be installed with 5 pipe diameters upstream and 8 pipe diameters downstream. This will allow time for the control valve or regulator to sense and react to a change in the process.

The selection of a regulator requires some consideration of the following

- Maximum volumes
- Site location
- Operation and Maintenance
- Environmental impact
- Safety

The first step in selecting a regulator is to know what type of control is desired

- Volume
- Pressure

The second step is to determine what type of regulator is needed

- Spring operated
- Pilot operated
- Controller operated

In the RMS both axial flow valve (AFV) and on line maintenance type regulators are used .

3.7.1 Regulators installed

It is recommended that regulators be installed with 5 pipe diameters upstream and 8 pipe diameters downstream (AGA Report 7). This will allow time for the regulator to sense and react to a change in the process.

3.7.1.1 Parallel installation of regulators

Although many regulator designs can operate over a wide flow and pressure range often it is necessary to consider parallel runs to provide proper control. A regulator required to operate nearly closed over long periods of time will have more valve and seal damage than a unit that is sized to have the valve open at least ten percent. A small regulator can be installed in the one line to handle low flows and a large regulator installed in the parallel line to handle large flows up to the required capacity for the station. Good practice would also dictate the use of parallel regulators for the purpose of redundancy. Since there are different types and sizes of regulators.

3.7.1.2 Pressure sensing point

All regulators have a pressure sensing point and those with an external control line should have a sensing pressure tap several pipe diameters downstream of the regulator on a straight run of pipe. Each regulator should have a separate sensing tap and control line. A common practice is to use ten pipe diameters downstream for the sensing pressure tap with five pipe diameters usually considered to be minimum. The control line may be ¼ inch, ½ inch or ¾ inch pipe or tubing, depending on the type of regulator and the distance from the pressure sensing point to the regulator. Long sensing lines should be adequately supported and should slope slightly toward the point of connection to the pipe. Pressure taps should not be located on elbows, expanders or other fitting that would introduce false or unstable pressure registration. At the pressure sensing connection, a valve should be installed to enable isolation of the sensing line, thus permitting the regulator to be taken out of service without shutting down the station. In addition to the sensing line connection, another tap with a valve for checking or recording pressure should be located as near as possible to the sensing line connection. A single tap with a tee can be used to provide the attachments.

3.7.2 Inlet and outlet connections

The piping to and from regulator should be supported adequately to minimize pipe strains. The piping should be designed to have adequate capacity for the expected maximum flow and the pressure conditions. Velocities in regulator valve passages can reach sonic velocity conditions. High velocities create noise so piping should be sized to keep gas velocities at a reasonable level. There are specific pipeline velocity limits used by many companies to maintain a relatively quiet pipeline system and to keep pressure losses low. Such limiting velocities range between 50 feet per second to a maximum of approximately 400 feet per second. There are situations where higher velocities may be required for short distances; however, the designer should calculate the pipe velocities to be encountered and determine the steps that may be necessary to maintain satisfactory noise levels.

3.7.2.1 Regulator sizing

The following must be consider in order to sizing regulator :

- Inlet pressure
- Outlet pressure
- Gas flow rate
- Over pressure protection device such as monitor, relief valve and slam shut valve
- No. of pressure staging.

Two Equations are used for sizing regulator all over the world :

1.Universal gas sizing Equation and

2. ISA gas sizing equation.

ISA gas sizing equation is more precisely used for pressure control valve. But Universal gas sizing Equation is popular in natural gas industries. This Equation is described as follows:

1. Subsonic Flow ($P_1 - P_2 / P_1 \leq 0.55$)

   $C_g = Q/ P_1[\sqrt{\ } 520/GT \sin [(3417/C_1)\sqrt{(P_1 - P_2)/P_1}]^{\text{Degrees}}$ -------------------------- (3.10)

2. Sonic Flow ($P_1 - P_2 / P_1 \geq 0.55$)

   $C_g = Q/ (P_1 * 1.29)$ -- (3.11)

Where,

Q= Flow rate (SCFH)
C_g = Gas sizing co-efficient
P_1 = Inlet Pressure (Psia)
P_2 = Outlet Pressure (Psia)
$C_1 = C_g/C_v$ = Valve recovery co-efficient
G = Specific gravity
T = Temperature, ^{0}Rankine (460+F^0)

In order to choose the best type of regulator for a particular application it is need to know the outlet pressure (delivery pressure) and C_g value. The following Table 3.6 is used for conversion of C_g value to regulator size. Then refer to the regulator selection chart (Fig. 3.1) to determine the type of regulator that is best for the application.

Table 3.6: C_g value of regulator

Regulator Size (Inch)	Fisher EZR		Tartarini FL		Mooney	
	C_g	C_1	C_g	C_1	C_g	C_1
1	509	32.5	550	29	450	34.0
2	2030	36.1	2300	27	1600	35.0
3	3830	37.2	5200	29	3450	36.0
4	6000	37.9	8300	27	6500	38.0
6	12360	35.5	17500	28	12500	40
8	20700	38.8	30600	30	20200	38
10	-	-	-	-	22000	40
12	-	-	-	-	40400	38

(Source : Fisher Controls, 2005 and Richard J. Mooney,1999)

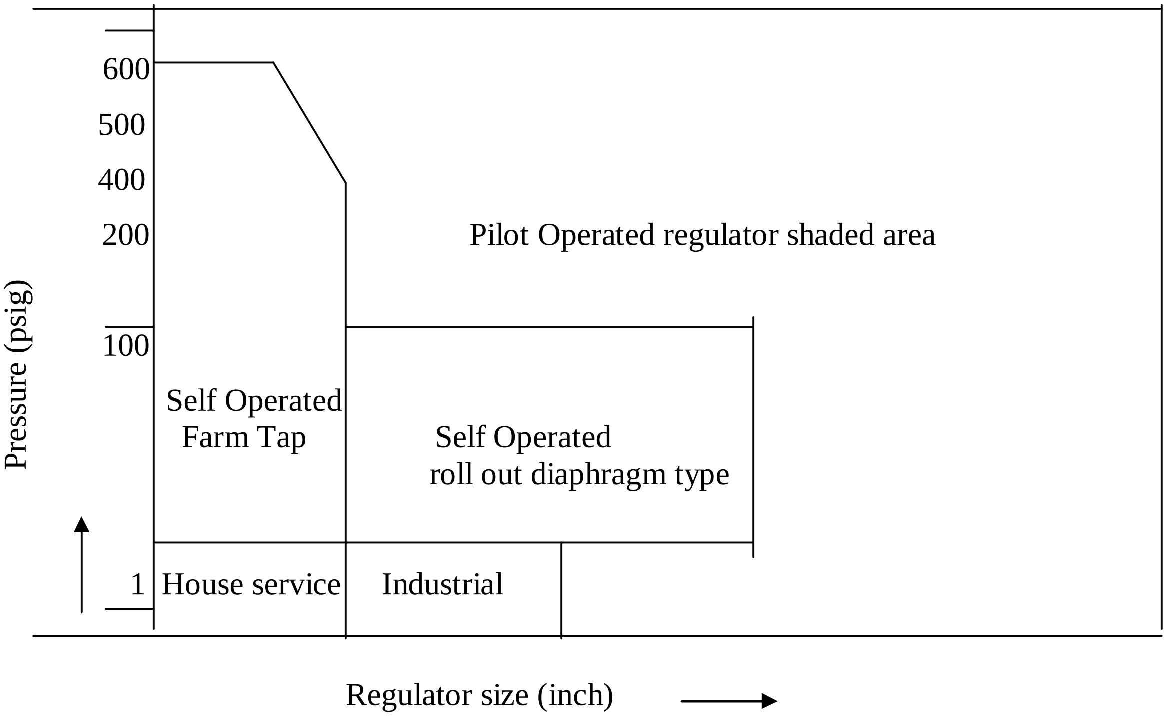

Fig. 3.1 : Regulator selection chart

(Source: Richard J. Mooney,1999)

Outlet velocity and noise

Another consideration in selecting a regulator size is outlet velocity, especially when noise is a concern. Velocities in excess of 0.5 of mach or sonic velocity will increase the noise produced and can cause excessive vibration and subsequent valve and piping damage in extreme cases. The following Table 3.7 lists the approximate maximum flow rates by regulator sizes and outlet pressure for 0.5 mach (50% of sonic velocity). Sonic velocity for natural gas at 60 ^{0}F is 1400 feet/sec but recommendation is not to exceed 70% of sonic velocity.

Table 3.7: Maximum flow rates of regulator

Regulator sizes (Inch)	Approx. Maximum flow (MSCFH) if outlet velocity is 0.5 Mach (0.5 Mach = 700 feet/sec for natural gas)					
	7 Inch. W.C	15 Psig	30 Psig	125 Psig	250 Psig	500 Psig

1	14.3	28.2	42.3	132	249	484

Table 3.7: Maximum flow rates of regulator(contôd)

Regulator sizes (Inch)	Approx. Maximum flow (MSCFH) if outlet velocity is 0.5 Mach (0.5 Mach = 700 feet/sec for natural gas)					
	7 Inch. W.C	15 Psig	30 Psig	125 Psig	250 Psig	500 Psig
2	57.4	113	169	526	996	1936
3	129	253	381	1184	2242	4357
4	229	451	677	2106	3986	7746
6	516	1015	1523	4738	8968	17428
8	918	1804	2707	8422	15942	30982
10	1434	2820	4230	13160	24910	48410
12	2065	4060	6091	18950	35870	69710

(Source : Richard J. Mooney,1999)

Inter stage pressure

When the station is a two or more stage pressure reducing station, it should be determine the inter stage pressure to optimize noise abatement or to optimize capacity. The following formula gives the inter stage pressure that is equalize the $(P_1 - P_2)/P_1$ values for the first and second stage pressure reduction. This pressure will be very close to the optimum pressure for quietest operation.

$P_i = [\sqrt{(P_1 . P_2)}]$ -- (3.12)

Where,

P_i = Inter stage pressure, PSIA

P_1 = Inlet Pressure, PSIA

P_2 = Outlet Pressure, PSIA

The following steps are required to size and select a pilot operated regulator

- Calculate the C_g required form the service conditions. Adding 20-25 % with C_g value to ensure good performance.

- Dividing the C_g value by 0.70 or multiplying by 1.43 to determine the size of monitor and active regulator. Because when two regulators are used in series their capacity is approximately 70% of a single regulator of the same size.
- Select a body class rating for the inlet pressure requirements.
- Select a body size based on published C_g values or sizing tables.
- Select a pilot pressure range for the outlet pressure desired.

3.7.2.2 Pressure setting

Regulator can be used as a single or jointly as Active-Monitor. The relief valve is installed at outlet portion of the regulating run. The setting pressure of relief valve is higher than regulator pressure. The setting of Active regulator, monitor regulator, relief and shut off valve are described as follows:

Active Regulator = X psig
Monitor Regulator = (X +5% of X) psig
Relief valve =(X +10% of X) psig
Slam shut off valve = (X +20% of X) psig

3.8 Heating capacity of gas heater

The heaters are designed on the basis of maximum inlet pressure, maximum outlet pressure, minimum inlet temperature and maximum flow expected after ten years of installation. Heat (Enthalpy) required to rise up the temperature of a specific density gas with different pressure is the main criteria of heater design. For a gas of specific density , ρ (kg/m^3); flow rate, Q(m^3/s) and enthalpy change, E (kJ/kg) for rise up temperature to two different pressure, rate of heat absorption, W (kJ/s or kw) is written (Roy,1989) by.

$$W = E.Q.\rho \text{ --- } (3.13)$$

Heat required for preheating the natural gas can also be calculated by using the Joule-Thomson effect Equation (McAllister,1998).

$$W = q_n.\Delta t_{gas}.\rho_n.C_p \text{ -- } (3.14)$$

Where, W = heat quantity, kJ/h
q_n = gas volume or flow rate, m^3/h
Δt_{gas} = total temperature = $\Delta t_1 + \Delta t_2$ in K

Δt_1= Joule-Thomson effect = (P_i ï P_o) 0.5 in K

Δt_2 = temperature different between minimum gas inlet temperature and
temperature required after gas pressure reduction in K

ρ_n = Specific density of natural gas, kg/m^3

C_p = Specific heat of natural gas, kJ/kg

P_i = Inlet pressure of natural gas, bar

P_o= Outlet pressure of natural gas, bar

On the basis of the heat required to rise up the temperature of gas a suitable capacity heater is designed. The vessel size of heater will be design in accordance with ASME section 8, Devission-1.

3.9 Meter selection

For custody transfer application, it is very important to select a proper meter considering the load nature of the RMS. In regulating & metering station design, both orifice and turbine meters are used. The orifice meter is simple, accurate, relatively inexpensive rugged and reliable but hence a limited rangebility (3:1) and are difficult to adapt to automation. For this reason very low and very high quantity of volume are not measured by the same orifice plate. Low quantity of volume is measured by small size of orifice plate. Accuracy and rangebility (20:1) is very high for turbine meter.

3.9.1 Parameters for meter selection

Gas metering is very important for transmission and distribution. No universal meter exists; each type possesses some limitations. Some meters may only be useful for specific applications, where as others can be widely adopted. It is necessary to consider not only from a measurement requirements, but also from economic, supply, security, safety and even customer confidence, that the correct meter is selected for the given application. Certain parameters must be tested against to ensure the meter selection is optimal. Some of these parameters are:

- Maximum and minimum flow rate.
- Physical & chemical properties of gas (Composition, specific gravity).

- The extremes of pressure and temperature at measurement conditions.
- The consequences of the gas flow being stopped by meter malfunction.
- Duration of operation of the meter. (continually or intermittently).
- The economic consequence of uncertainties in the measurement.
- Available for the installation of such meters.
- Legal metrology requirement ï Approval of legal metrology (OIML ï Organization international metrology de legal).
- Cost effectiveness.

3.9.2 Meter type selection procedure

Generally meter is selected on the basis of hourly load. As per approved load diaphragm displacement type meters are used for metered domestic and commercial type customers. Rotary and turbine meter is used for industrial customer. A Chart is shown as below for selection of meter type:

Fig. 3.2 : Meter type selection Chart

(Source: Instromet, 2001)

3.9.3 Meter sizing

Meter sizing has a strong effect on system loss. If meter sizing is not appropriate such under or over size then it cannot measure properly. In this context turn down ratio is very important. It is the ratio of the maximum to minimum volume of gas that can be measured properly and safely with desired accuracy. Meter should be sized so that it can cater minimum flow rate and also maximum flow rate properly with out any damage. Meter is generally sized and selected on the basis of hourly load. Presently meter is selected on the basis of G-rating. G rating is a standard established by Organization International De Metrology Legal (OIML). Flow rate in cubic meter at line condition can be get if we multiply the G-rating with 1.6.

The following type of Gas meter is used for Natural Gas Metering system

Table : 3.8 : G-Rating & Meter Type

SL. No.	G-Rating of Meter	Meter Type	Where Used
01	G-1.6 to G-16	Diaphragm Displacement type meter	Metered domestic and commercial customers RMS
02	G-25 to G-65	Rotary type meter	Industrial customers
03	G-100 to G-4000	Turbine type meter	Industrial, bulk customer RMS (power and fertilizer produced) Town Border Station (TBS), District Regulating Station (DRS)
04	-	Orifice meter	Sales and intake metering station, and Power and fertilizer producer metering established by contract
05	Un metered	Flat rate	Domestic customer

As per approved load, Diaphragm, Displacement type meter are used for metered domestic and commercial type customers. Rotary and turbine meter is used for industrial customer. Presently rotary meter is produced with G-rating from G-10 to higher rating. Due to compact size rotary meter is easy to installed in the customer yard. All most all the domestic customer has no meter. They use gas on the basis of flat rate billing system imposed by the government. Purchase point meters are orifice meter. Bulk users meters are turbine meter. Some of the individual power producers (IPP) customers used orifice meter for gas billing.

3.9.4 Meter run design

To obtain reliable and accurate metering it is just not a matter of selecting an appropriate flow meter. The choice of flow meter will affect the meter run, however the design of the meter run is paramount if the flow meter is to perform reliable and accurately. Therefore a strong interdependence exists between the meter and the meter run design.

The meter run design requirements and limitations must be reviewed in conjunction with the flow meter characteristics. Taking this into account, together with meter manufacturers recommendations and those given in the appropriate standards generates a list of items may include but not be necessarily be limited to;

- Reynolds number sensitivity
- Rangeability limits
- Flow characteristics (intermittent, continuous, etc.)
- Maximum and average line pressure
- Allowable pressure drop across meter
- Space availability
- Calibration/proving requirements (legal metrology requirements are now becoming a major issue with potential impact on how metering is undertaken)
- Maximum and average operating temperature, cost expectations (capital, operating)
- Properties of measured fluid (corrosive, viscosity etc.).

3.9.5 Turbine meter installation

The most common installation configuration is in line. A minimum of ten (10) pipe diameters of straight pipe must be placed between any flow disturbing device (other than flow-throttling) and the inlet flange of the turbine meter. An additional eight (8) pipe diameters must be added between the meter inlet flange and any throttling device (regulator, control valve etc) installed upstream of the meter. Inlet piping must be of the same nominal diameter as the meter body.

Minor variations in piping ID caused by different wall thickness will not affect meter accuracy. In-line straightening vanes located four or five pipe diameters upstream of the meter are recommended.

To ensure a proper velocity profile at the meter inlet, the two 90^0 turns into the inlet end of the meter run must be in the same plane. Elbows or tees can be used for the 90^0 turns. Reducing fitting may be used as long as the reduction at the inlet end does not exceed one nominal pipe size. Fitting sizes downstream from the meter are not critical, as long as the ID of the connection to the meter outlet flange is equal to the meter ID.

A ¼ NPT pressure connection for instrumentation is located on each meter body. Temperature connection for sensors or recorders should be located within two pipe diameters down-stream of the meter.

3.9.5.1 Installation of turbine meter for gas flow measurement

The turbine meter is a velocity measuring device. The piping configuration immediately upstream of the meter should be such that the flow profile entering the meter has a uniform distribution and is without jetting or swirl. Straightening vanes are recommended, without proper location they will not eliminate the effect of strong jetting. The integral straightening vanes which is installed in the entrance part of a meter will eliminate minor swirl condition of flow. So a straightening vanes needed to install upstream position of the meter. The installation of a throttling device such as a regulator or partially closed valve is not recommended in close proximity to the meter. Where such installations are necessary, the throttling device should be placed an additional eight nominal pipe diameters upstream of the meter.

According to AGA Report No.07 the necessary installations for accurate flow measurement through turbine meter are mainly piping configurations(Minimum length), Straightening vanes, strainers or filters, over-range protection, By-pass, Accessory installations that would be discussed below:

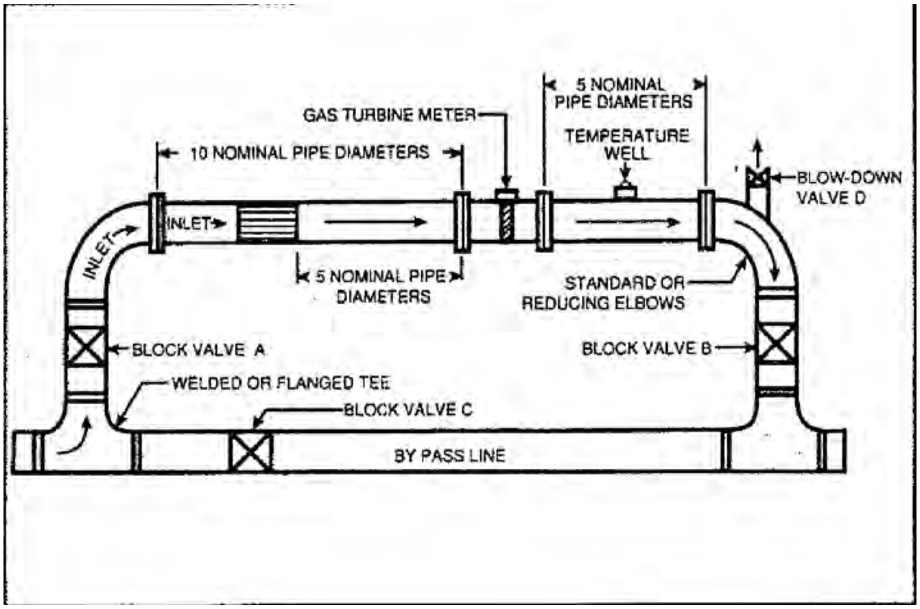

Fig :3.3 : Installation of turbine meter for gas flow measurement
(Source : AGA Report No.7)

3.9.5.2 Recommended installation for in-line meters

The recommended installation requires a length of 10 nominal pipe diameters upstream with the) straightening vane outlet located at five nominal pipe diameters from meter inlet as shown in Figure 3.4. A length of five nominal pipe diameters is recommended down stream of the meter. Both inlet and outlet pipe should be of the same nominal size as the meter.

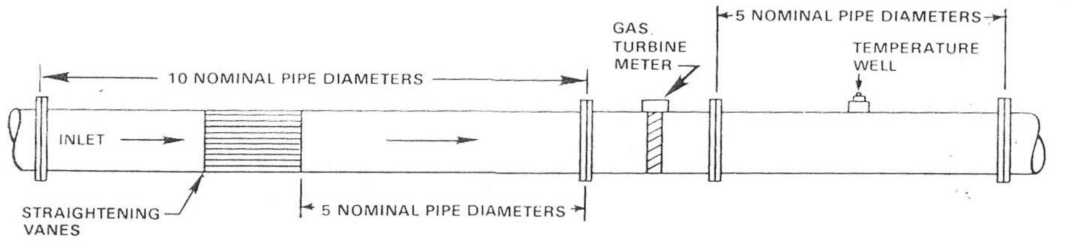

Figure 3.4 Recommended Installation of an in-line gas turbine meter (Minimum Length)
(Source: AGA Report No.7)

3.9.5.3 Optional installations for in-line meters

The use of optional installations may result in some degradation in meter accuracy.

3.10 Optional short-coupled installation

In those instances where the required space for the recommended installation of Figure 3.4 is not available, a short-coupled installation may be employed as shown in Figure 3.5 This configuration utilizes minimum of four nominal pipe diameters upstream with straightening vanes located at the inlet of piping. The distance between the straightening vane outlet and the meter inlet should be a minimum of two nominal pipe diameters. The meter is connected to the vertical risers using a standard Tee or elbow. The maximum pipe reduction to the risers is one nominal pipe size, valving, filters or strainers may be installed on the risers.

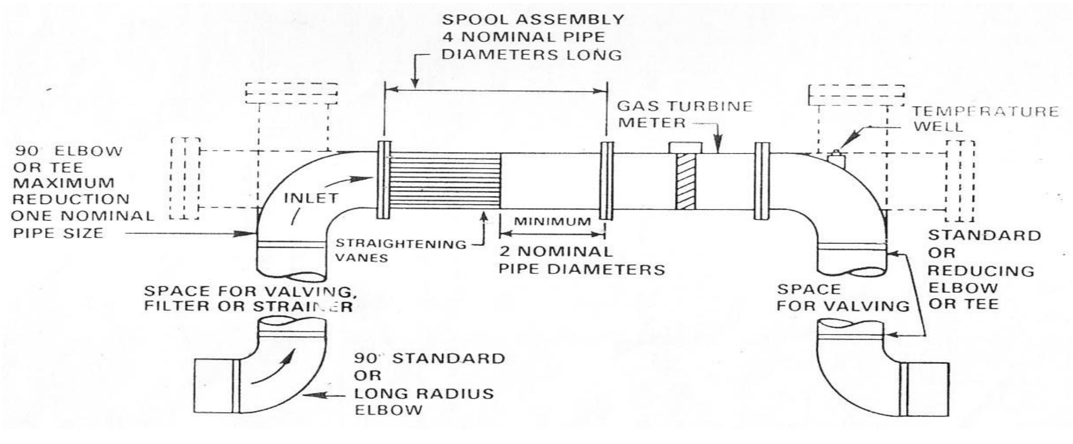

Figure 3.5 Short coupled installation of an in-line gas turbine meter (Minimum Length)
(Source : AGA Report 7)

3.11. Straightening vanes

The purpose of a straightening vane is to eliminate swirls and cross currents set up by the pipe fitting valves or regulators preceding the meter inlet piping. While the specifications which follow up particularly to the type of vanes shown in figure 3.6, vanes of other designs can be used if they meet the specifications.

In construction of vanes the maximum transverse dimension, ñaò of any passage through the vane should not exceed one- fourth the inside diameter, ñDò of the pipe. Also the cross sectional area, ñAò of any passage within the assembled vanes should not exceed one-sixteenth of the cross sectional area of the containing pipe. The length, ñLò of the vanes should be at least 10 times the maximum inside dimension, ñaò.

The vanes may be built of standard weight pipe or thin- walled tubing either welded together securely attached into the meter inlet piping or mounted into two end-rings small enough to slip in the pipe. Square, hexagonal or other shaped tubing may be used in making the vanes. It is not necessary that the vane passages be of the same size, but their arrangement should be symmetrical.

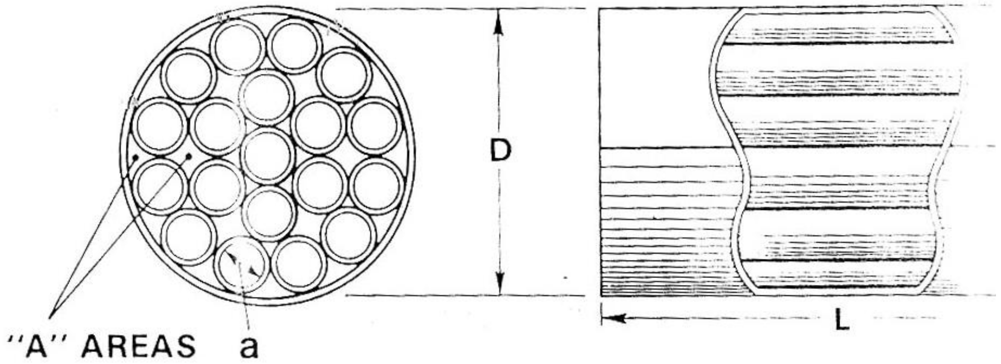

Figure 3.6 Straightening Vanes

(Source : AGA Report 7)

3.12 Strainers or Filters

Foreign substances in a pipe line can cause serious damage to turbine meters. Strainers are recommended when the presence of damaging foreign material in the gas stream can be anticipated. Strainer should be sized so that at maximum flow there is a minimum pressure drop and flow distortion.

A greater degree of meter protection can be accomplished through the use of dry-type or separator type filter installed upstream of the meter inlet piping. It is recommended that the differential pressure across a filter be monitored to maintain it in good condition so as to prevent flow distortion and possible customer outage.

3.13. Over-range protection

Sudden rotor over speeding caused by extreme gas velocities encountered during pressuring m, venting or purging can cause sever damage. Some meters and readout devices may be damaged when they are run backwards. Therefore, the pressure blow-down valve should be located downstream of the meter. While turbine meters can be operated up to 150% of rated capacity with no damaging effects for short period of time, over-sized blow-down valves can cause rotational speeds greatly in excess of this amount. Therefore, the blow-down valve should be sized as follows (Source: AGA Report No.7):

Meter run	Valve size
2″	1/4″
3″	1/2″
4″	1/2″
6″	1″
8″	1″
12″	1″

As a rule of thumb, the blow-down valve should not be larger than one-sixth of the meter size. In those installations where adequate pressure is available, either a critical flow orifice or sonic venture nozzle may be installed in the piping downstream of the meter and should be sized to limit the meter to approximately 120% of its maximum rated capacity. A critical flow orifice so designed will result in a 50% permanent pressure loss and a sonic venture nozzle will in a 10-20% permanent pressure loss.

3.14 By- pass

It is good practice to provide a by-pass so the meter can be maintained and calibrated without a service interruption. This should include proper valving relative to the type of calibrating equipment to be used.

3.14.1 Additional installation requirements

- The meter and meter piping should be installed so as to reduce strain due to pipeline stresses.
- A concentric alignment of the companion pipe flanges with the meter inlet and outlet connections should be obtained. This concentric alignment will eliminate any appreciable effect upon the meter accuracy that might be caused by an offset in the internal diameters that may occur in some installations.
- A gasket protrusion into the bore or flow pattern at the meter connections should not be permitted.
- Pipe interior should be of commercial roughness, and the flange I.D. should be the same as that of the pipe. Welds on piping at the meter inlet and outlet should be ground to the I.D of the pipe.
- Installations where liquid can be encountered should be designed to prevent liquid accumulation in the meter.
- No welding should be done in the immediate area of the meter to prevent possible internal meter damage.

3.15 Accessory installation

Accessory devices used for integrating uncorrected volume to base conditions or for recording operating parameters must be properly installed and their connections made as specified herein.

3.15.1 Temperature measurement

Since upstream disturbances should be kept to a minimum, the recommended location for a thermometer well is downstream of the meter. It should be located within five pipe diameters of the meter outlet and upstream of any valve or flow restrictor. The thermometer well should be installed to insure that the temperature is not influenced by heat transfer from the piping and well attachment.

3.15.2 Pressure measurement

A pressure tap as provided by the manufacturer on the meter body should be used as the point of pressure sensing for recording or integrating instruments.

3.15.3 Density measurement

In the use of densitometers, while it is desirable to sample the gas as close as possible to the rotor conditions, care must be exercised not to disturb the meter inlet flow or to create an un metered by-pass. Reference should be made to manuals on the various densitometers for further information.

3.16 Flow conditions:

The pipe line or installation conditions, which can be made up of a number of variables can have a major influence on the operation and accuracy of an orifice plate metering system. It is very important to understand the influence of these variables for accurate flow measurement through orifice or turbine meter. Before the fluid measurement process is initiated, some fundamental characteristics of fluid to be measured and most common field conditions must be determined. Some of these are as follows:

- Velocity profile and distortion
- Swirl
- Reynolds number
- That fluid is Newtonian in behavior
- the composition
- influence and/or presence of foreign material

3.16.1 Velocity profile and swirl

under ideal conditions, ideal flow exists. Ideal flow is said to be flow that follows theoretical assumptions. The simplest interpretation of fluid flow is represented by ñideal conditionsò. ideal conditions means that there is no friction between adjacent fluid particles or between fluid particles and a stationary surface. Under ideal conditions all of the particles flowing in a pipe will travel at the same velocity and the position of particles relative to each other does not change with time.

Under ñreal conditionsò there is friction present between adjacent fluid particles as well as between fluid particles and a stationary surface. The particles immediately adjacent to a stationary surface will have nearly zero velocity.

The Reynolds number also characterize the velocity profile and stability of the fluid flow pattern. For laminar flow (Re < 2000) the profile is parabolic and it is not influenced by the pipe wall roughness. At these conditions, a particle at the centre of the flow would be traveling at about twice the velocity of the average of the fluid particles. In the total turbulent region, the flow profile is nearly flat, with particles traveling at same velocity. The exception being particles close to the pipe wall interface which travel at a lower velocity.

The more common factors are the upstream and downstream pipe length, the location of bends, valves, reciprocating plant, changes in pipe diameter and general conditions of the internal pipe walls within the immediate and general proximity of the orifice plate. these conditions can result in non-ideal flow conditions such as swirl, flow transients and profile distortion or jetting. Swirl and profile distortion are the two more common dominant disturbances. they may occur separately or together, especially where poor pipe work design is present. These non-ideal flow conditions can produce errors which magnitude is higher than the basic uncertainty in the orifice meter co-efficient. Swirl is caused by adjacent bends in different planes in the pipe work, whereas irregularities in the pipe, such as partially closed valves or partially blocked flow conditioners, other fittings like headers, tees and reducers are the cause of the profile distortion. It may also occur alone within a pipe line system or together with velocity profile distortion.

The use of straight lengths of pipe can reduce or eliminate swirl. With the viscosity of the fluid influencing the length of straight pipe required. This means a liquid would require a much shorter pipe length than would say natural gas.

Of course flow conditioners can also be used for reducing swirl within a pipe. The decay of swirl is also influenced by the pipe wall roughness. For a very smooth internal pipe wall, swirl may persist for well over 100 pipe diameters downstream of the source.

3.16.2 Reynolds number

Reynolds number Re is a dimensionless variable which represent the nature of flow in a pipe.

$$Re = (vd)/k \quad \text{--} \quad (3.15)$$

Where Re = Reynoldôs number

v = flow velocity m/s

d = inside diameter of pipe, m

k = kinematics viscosity at p and t m2/s

Reynolds number has been found to be an acceptable correlating parameter that combines the effect of viscosity , density and pipe line velocity. A flow coefficient that is obtained for water at a specified Reynoldôs number will be the same for oil and gas at the same Reynolds number. A high Reynoldôs number means that viscous forces are small whereas a low value means that viscous forces dominate.

The Reynoldôs number should be kept above 1000000 if flow accuracy is to be maintained. When the value of Reynoldôs number is below 2000, the flow is termed as laminar. Turbulent flow is said to exist when the value is above 40000. For Reynoldôs numbers which fall between these two values, the flow may be laminar or turbulent ï this being termed the transition area.

$Re < 2000$	laminar flow
$2000 < Re < 40000$	transition area
$Re > 40000$	turbulent flow.

For the measurement of natural gas, the Reynoldôs number will be normally well above the transition zone. It is always advisable to check the Reynoldôs number sensitivity when considering a particular flow meter type for a given application.

3.17 Orifice meter selection

The following factors must to be consider in choosing an orifice metering system:

1. Flow rate: Flow rate uniformity, maximum and minimum flow rates expected.
2. Pressure: expected station and differential pressure, and their range: permissible pressure variation.

3.17.1 Installation requirements of orifice meter

For determining the orifice plate co-efficient accurately at first to be maintained favorable flow conditions that is achieved installing the primary device and other necessaries as per standard requirements, would be described briefly in the following:

The primary device shall be installed in the pipeline at a position such that the flow conditions immediately upstream approach those of a fully developed profile and are free from swirl.

The primary device shall be fitted between two sections of straight cylindrical pipe of constant cross-sectional area, in which there is no obstruction or branch connection other than those specified by ISO. The pipe is considered as straight when it appears so by visual inspection.

The pipe bore shall be circular over the entire minimum length of straight pipe required. The internal diameter D of the measuring pipe shall comply with the values given for each type of primary device.

The inside surface of the measuring pipe shall be clean and free from encrustations, pitting and deposits and shall conform with the roughness criterion for at least a length of 10D upstream and 4D downstream of the primary device.

The pipe may be provided with drain holes and/or vent holes for the removal of solid deposits and fluids other than the measured fluid. However, there shall be no flow through the drain holes and vent holes using the measurement of flow.

The drain holes and vent holes shall not be located near to the primary device, unless it is unavoidable to do so. In such cases the diameter of these holes shall be smaller than 0.08D and their location shall be such that the distance, measured on a straight line from one of these holes to a pressure tapping of the primary device placed on the same side of this primary device, is always greater than 0.5D

3.17.2 Minimum upstream and downstream straight lengths required for installation

If any flow conditioner shall be installed in the upstream straight length between the primary device and the disturbance or fitting closet to the primary device and unless it can be verified that the flow conditions at the inlet of the primary device conform with fully developed profile and free from swirl. In such a cases the straight length between this fitting and the conditioner itself shall be equal to at least 20D, and the straight length between the conditioner and primary device shall be equal to at least 22D. These length are measured from the upstream face and the downstream face respectively of the conditioner. Conditioners are only fully effective if their installation is such that the smallest possible gaps are left around the resistive elements of the device, therefore permitting no by-pass flows which would prevent their proper functioning.

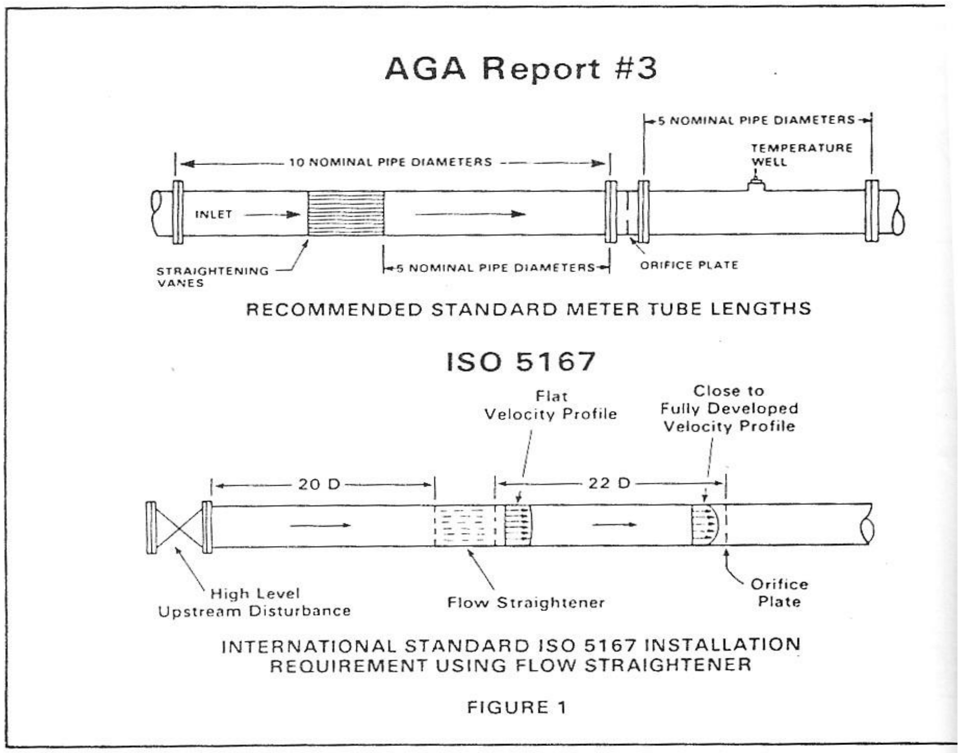

Figure :3.7 Standard meter tube length for Orifice meter

(Source : AGA Report No.3)

CHAPTER 4

GAS LOAD CALCULATION

4.1 Gas source

The location of the proposed 50 MW Power plant is at Sreepur in Gazipur district. A 4"DN×500 psig Off take point of Dhanua TBS exists at a approximate distance of 0.5 km from the plant site. The Dhanua TBS is presently receiving gas through Monohordi-Elenga 24" DN ×1000 psig pipe line (Appendix O). A 0.5 km 4" DN ×500 psig pipe line can be constructed to transmit gas to the Power plant through the RMS at a required quantity and pressure.

A schematic line diagram of 4" DN ×500 psig pipe line network from Dhanua TBS to power plant RMS is shown in Fig 4.1.

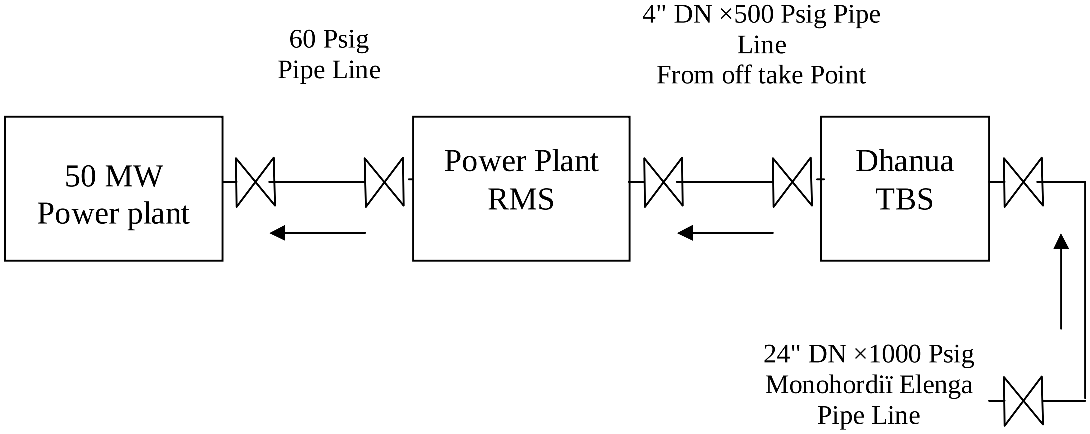

Fig 4.1. Schematic diagram of 4" DN ×500 psig pipe line

4.2 Gas based Power Plant

Bulk electric power is produced by special plants known as generating stations or power plants. A generating station essentially employs a prime mover coupled to an alternator for the production of electric power. Depending upon the form of energy converted into electrical energy, the power plants are classified various classes such as Steam power plants, Hydro- electric power plants, Diesel power plants and Nuclear power plants. The

Power Generating Station that generate electricity by using natural gas is called gas based Power Plants. These type of Power Plants are Gas Turbine, Steam Turbine and gas generator.

4.2.1 Gas load for 50 MW power plant

The proposed power plant considered as gas based power plant has an installed capacity of 50 MW. The plant will produce electricity using gas generators. Six gas generators, each having 8.425 MW capacity will be required for the power plant.

Considering Rolls-Royce generator for proposed power plant, the required data is given as follows (Appendix D).

Engine Type- B 35 :40 V 20 AG

- Generating capacity of each generator = 8425 KW or 8.425 MW (Mega watt)
- Thermal overall efficiency = 42 %
- Fuel type = Natural gas
- Minimum gas feed pressure to engine inlet = 50 Psig
- Gas feed temperature to engine inlet = 20 ^{0}C
- Lower calorific value of natural gas = 915 Btu/SCF (Appendix C)

For 50 MW power generation = 50/8.425 = 6 (Six) generating sets are required

The gas load for 50 MW power plant is calculated is as follows:
Gas load calculation on the basis of electrical output :
Electrical output of each generator = 8425 KW
Heat input of each generator = 8425/0.42 KW (Thermal overall efficiency, ɖ = 42%)
= 20060 KW
Input heat of each generator = (20060X1000)W
= (20060X1000) Joule/See
= [(20060X1000)/4.2] Cal/See
= [(20060X1000)/(4.2X252)] Btu/See
= [(20060X1000 X3600)/(4.2X252)] Btu/hr
= 6,82,31,293 Btu/hr

Lower calorific value of natural gas = 915 Btu/SCF (Appendix C)

Gas required for each generator = (6,82,31,293/915) SCFH
= 74,570 SCFH
= 1.8 MMSCFD
Gas required for 6 (Six) generators = 1.8 X 6 MMSCFD
=11 MMSCFD

Therefore, the gas consumption for the 50 MW power plant is 11 MMSCFD.

The selected type of gas generators requires minimum 50 psig pressure for their operation. Therefore, the total gas will be required around 11 MMSCFD at pressure of above 50 psig for the power plant.

For designing, the gas flowing capacity of the RMS should be consider as the sum of power plant consumption, heater RMS consumption and decreasing the efficiency of the power plant.

From the above discussion, it is recommended 10% additional load for RMS design.

Assume, 10% additional load for RMS design
The gas flowing capacity of the RMS = 11 MMSCFD*1.1 = 12 MMSCFD

From the data, it is seen that the maximum flowing capacity of the RMS is 12 MMSCFD and the minimum flowing capacity of the RMS is 1.8 MMSCFD. Therefore, the turn down ratio of the RMS is 12:1.8, which should be consider for proper size selection of the RMS equipments.

CHAPTER 5

DESIGN OF PROPOSED RMS

In this chapter, the detail design procedure of the proposed RMS will be discussed. The related calculation for size selection of the various components of RMS are also elaborated here as per internationally recognized recommendation of Institution of Gas Engineers (IGE-TD-9), AGA Part-9, American Petroleum Institute (API) and Natural Gas Safety Rules of Bangladesh, 1991 (Amendment 2003). After designing the RMS a Piping and Instrumentation (P & I) diagram will be drawn.

5.1 Gas facilities for the proposed RMS

The required gas facilities comprise the following components for supplying gas to a 50 MW Power plant.

- Inlet Pipe line section- From 4"DN×500 psig off take point of Dhanua TBS to RMS Inlet
- Outlet Pipe line section- RMS Outlet to gas inlet of the Power plant
- One Regulating and Metering Station (RMS) of 12 MMSCFD capacity.

5.2 Brief description of proposed RMS

The RMS consists of inlet pipeline with filtering unit, heating unit, regulating unit and metering unit. The filtering unit consists of two filter separators and one liquid separator. The filter separators are installed at the inlet point of the station having 100% capacity each to provide the separation of any solid particles from gas. The liquid separator is installed at the outlet point of the second stage regulating unit of the station having 100% capacity to provide the separation of liquid particles from gas. The heating unit consists of one water bath heater and it is installed after filter separator at the inlet point of the station having 100% capacity. The regulating unit has a two stage pressure reduction provision. In first stage, pressure cuts from 500 psig to 200 psig and in second stage pressure cuts from 200 psig to 60 psig. There are two regulating runs (streams), each regulating unit to ensure a continuous gas supply to the power plant. These two are identical runs each of 100% capacity and each regulating runs will consist of inlet isolating valve (01 no), slam shut off valve (01 no), regulator (2 no), outlet isolating valve (01 no) and safety relief valve (01 no) installed at the outlet header of the each regulating unit. The details of pressure reduction is stated in article 5.4.5 of this chapter. Metering unit consists of two metering runs (streams) with turbine meters for gas flow measurement and each of 100% capacity. The meters are installed after regulating unit and immediately before the delivery point of the RMS. The metering unit also includes mechanical 2 pen chart recorder to record static pressure and flowing temperature for gas flow rate calculation. The metering runs comprise with isolation valves. One insulating joint is installed at inlet and another is out of the RMS to protect the eddy current. In the station outlet, a Non return valve (NRV) is used to prevent the back pressure. There is a condensate storage tank in the RMS premises to collect the condensate through discharge lines from filter separator and liquid separator. The RMS is also well equipped with a Flow computer (FC) and Gas chromatograph (GC) for automated billing from field data.

5.3 RMS Design Considerations

The design of the RMS will be carried out according to the fluid characteristic and process data

5.3.1 Process Data

Natural gas of 0.6 specific gravity (air =1)

Flow rate (max) :12 MMSCFD
Inlet pressure (maximum) : 500 Psig
Inlet pressure (minimum) : 400 Psig
Outlet pressure : 60 Psig [As per engine requirement]
Inlet temperature : 20-25° C (68-77° F)
Outlet temperature :18-22°C (64-71° °F)
Velocity of gas, V= ft/sec
(Before filtration 60 ft/sec and after filtration 120 ft/sec)

5.3.2 Fluids Characteristics

The RMS which is required to be designed for supplying conditioned gas suitable for delivery to the power plant. It is not possible to indicate very precisely the composition of the inlet gas to the RMS. A sample gas composition analysis report that shows the extent of variability of different components is given in the Appendix C.

5.3.3 Other factors

The minimum inlet pressure is the basic factor in sizing piping, regulating and metering equipments for the maximum demand rate. The maximum pressure will be the factor determining the strength of the piping, regulating and metering and over pressure protection equipments. The API, ANSI code and standards have been followed for selection of pressure rating of RMS equipments and pipe schedule (Appendix H, I).

5.4 Detail design calculation

5.4.1 Inlet Pipe line section (TBS to RMS Inlet)

Pipe diameter calculation

$Q = 12$ MMSCFD

Off take point pressure (minimum), $P_1 = 425$ psig = 439.73 psia

RMS inlet pressure (minimum), $P_2 = 400$ psig = 414.73 psia

Length, L = 0.5 Km = 0.5x0.621 = 0.310 miles

By using Equation no-(3.2)

$12 \text{ MMSCFD} = 0.00128084\ [(439.73)^2 \text{ ï } (414.73)^2]/0.310)^{0.51} * d^{2.53}$

or, Diameter, d = 3.93 inches

Therefore, the line pipe diameter size is 4 inch DNx Schedule-40

5.4.2 RMS Inlet

The sizing of inlet pipe and valve :

By using Equation no-(3.1)

Inlet pipe and valve size, $D = (0.75*Q/V*P)^{1/2}$

$$= [0.75*(12000000/24)/(60*414.73)]^{1/2}$$

$$\text{or, } D = 3.882 \text{ inch}$$

Therefore, the inlet pipeline size : 4 inch DNx Schedule-40

Inlet valve size : 4 inch RF ANSI CL-300

Inlet I/J size : 4 inch RF ANSI CL-300

5.4.3 Filtering system

The vessel of filter separator will be designed and manufactured in accordance with ASME section-8, Division1 and welding the vessel with AP1-1104 Code. The followings are important matters in order to design filter separators:

1. Permissible particle size (5 micron is allowable)
2. Filtering efficiency
3. Pressure should not be reduced with filtering operation
4. Turn down ratio for efficient filtration 5 micron is allowable at all flowing rate

Maximum gas velocity for filtering system.

Up stream and down stream of filtering system **:** 60 feet per second

Filtering operation condition :

1. Flow rate (max) : 12 MMSCFD
2. Inlet pressure (maximum) :500 Psig
3. Inlet pressure (minimum) : 400 Psig

5.4.3.1 Filter Separator connection size calculation

By using equation no-(3.1)

Inlet and outlet connection: $D = (0.75*Q/V*P)^{1/2}$

$$= [0.75**(12000000/24)/(60*414.73)]^{1/2}$$

$$= 3.88 \text{ inch}$$

Inlet and outlet size will be same because the pressure is same pressure reduction occurs after filtration.

Therefore, the pipeline size of inlet and outlet connection is 4 inch DN

Size : Inlet connection 4 inch RF, ANSI CL 300

Outlet connection 4 inch RF, ANSI CL 300

5.4.3.2 Filter separator size calculation

Using Equation no (3.7) and data from Appendix C.

$$D^2 = [12*1*520*(4.452)^{0.5}]/[K_l(2.40)(514.7)(48.6- 4.452)^{0.5}]$$

$$= 1.6040/K_l \text{ -- } (5.1)$$

Applying separator coefficient, K_l for vertical, horizontal and spherical separator

A) *Vertical separator*

From Table 3.5 for vertical separator with a mist extractor, $K_l = 0.167$

Putting the value of K_l in Equation no-5.1, the diameter of the vertical separator is

$$D = [1.6040/0.167]^{0.5} = 3.099 \text{ ft}$$

According to design consideration for vertical separator, minimum length (height) should be 6 ft (Kumar,1987), So L/D = 6/3.099 = 1.936

But this value does not satisfy the design consideration. Length verses diameter ratio should be between 3 to 8 (Kumar,1987).

For Length, L = 6 ft = 72 inch and maximum L/D ratio = 8, So L/D = 8 or 72/D = 8 or Diameter, D = 9 inch.

Therefore, a vertical filter separator of size 9 inch (dia)x 6 ft (length) is required for the proposed RMS.

B) Horizontal separator

From Table 3.5 for horizontal separator with a mist extractor, $K_l = 0.382$

Putting the value of K_l in Equation no-5.1, the diameter of the horizontal separator is

$$D = [1.6040/0.382]^{0.5} = 2.049 \text{ ft} = 24.60 \text{ inch}$$

But design consideration for horizontal separator should be of minimum diameter 26 inch (Kumar,1987).So the diameter of horizontal separator should be 26 inch (2.166 ft).

According to design consideration for horizontal separator, Length verses diameter ratio should be between 3 to 8 (Kumar,1987).

For diameter, D = 2.166 ft and minimum L/D ratio = 3,
The separator length, L is 3xD = 3X2.166 = 6.5 ft

Therefore, a 26 inch(dia)x 6.5 ft (length) horizontal separator is required for the proposed RMS.

C) Spherical separator

From Table 3.5 for spherical separator with a mist extractor, $K_l = 0.35$
Putting the value of K_l in Equation no-5.1, the diameter of the spherical separator is

$$D = [1.6040/0.35]^{0.5} = 2.14 \text{ ft} = 25.68 \text{ inch}$$

Therefore, a spherical separator of diameter 26 inch is required for the proposed RMS.

From the above calculated values all the dimensions of separator are tabulated as follows

Table 5.1 Dimensions of separator

Types of Separator	Dimensions	Remarks
Vertical separator	9 inch (dia)x 6 ft (length)	Selected
Horizontal separator	26 inch (dia)x 6.5 ft (length)	-
Spherical separator	26 inch (dia)	-

Vertical filter separator should be more suitable because this type of separator provides better liquid surge control without carryover into the gas outlet and occupies less floor space. A Vertical filter separator of size 9 inch (dia)x 6 ft (length) have been selected for the proposed RMS. A schematic diagram of filter separator unit of the RMS is shown in Fig 5.1.

Fig 5.1. Schematic diagram of filter separator unit of the RMS

5.4.3.3 Liquid separator size calculation

Filtering operation condition :

1. Flow rate (max) :12 MMSCFD
2. Operating pressure (maximum) : 65 Psig (After regulating of pressure)
3. Gas liquid ratio (GLR) : 0.10 bbl/MMSCF (Assumed)

At 65 psig operating pressure liquid-water separation, retention time, t = 25 minute and amount of liquid collection (considered) from the RMS inlet gas,
Liquid collection, w = (0.10)(12) bbl/day

= 1.2 bbl /day -- (5.2)

Putting the value of liquid collection (w) and retention time (t) in Equation no-3.9,

The liquid-setting volume, V_L = wt/1440 = (1.2)(25)/1440 = 0.0208 bbl

From Figure J1(Appendix J) at 65 psig operating pressure, a 48 inch(dia)x10 ft(length) vertical separator will handle 12 MMSCFD gas.
From Table K2 (Appendix K), the liquid-setting volume(V_L) of 48 inch(dia)x10 ft(length) vertical separator is 3.04 bbl.

By using equation no (3.9), the liquid capacity of a separator can be calculated.

w = (1440)(3.04)/25 bbl/day = 175 bbl/day ----------------------------------- (5.3)

From equation no (5.3), the liquid capacity of a 48 inch(dia)x10 ft (length) vertical liquid separator is175 bbl/day, but from equation no (5.2), the estimated amount of liquid collection through the RMS is 1.2 bbl /day.

A 48 inch(dia)x10 ft(length) vertical liquid separator is capable for handling of gas and liquid 12 MMSCFD and 1.2 bbl/day respectively.
Vertical liquid separator should be more suitable because this type of separator provides better liquid surge control without carryover into the gas outlet and occupies less floor space.
Therefore, a vertical liquid separator of size 48 inch(dia)x10 ft(length) have been selected for the proposed RMS. A schematic diagram of liquid separator unit is shown in Fig 5.2.

Fig 5.2. A schematic diagram of liquid separator unit

5.4.4 Gas heating system

Preheating of the gas is necessary for smooth operation of the gas station and correct flow measurement. Pre heaters are installed to heat the gas after the gas has passed the filter and before pressure reduction. The requirement of heater is explained in details in chapter 2 and 3.

Process Data

Natural gas of 0.6 specific gravity (air =1)
q_n = Gas Flow rate (max) = 12 MMSCFD = 12524 nm^3/h
P_i = Inlet pressure of natural gas = 500 Psig = 514.73 Psia = 35.7451 bar(abs)
P_o= Outlet pressure of natural gas = 60 Psig = 74.73 Psia = 5.190 bar(abs)
Minimum inlet temperature of gas = 20 °C (50° F)
Minimum outlet temperature of gas = 18 °C (64 °F), (As per engine requirement)
ρ_n = Specific density of natural gas = 0.71 kg/m^3
C_p = Specific heat of natural gas = 0.60 kcal/kg
Velocity of gas , V= ft/sec
(Before filtration, 60 ft/sec and after filtration, 120 ft/sec)

5.4.4.1 Heat requirement calculation

Total temperature drop due to Joule Thomson effect (Kumar,1987).

Δt_1= Joule-Thomson effect = (P_i ï P_o). 0.5 ^{0}C

$$= (35.745-5.190)*0.50\ ^0C = 15.30\ ^0C$$

Total temperature drop due to Joule Thomson effect = 15.30 ^{0}C

Therefore, the temperature of gas will be raise up as per engine requirement (Appendix D),

Δt_{gas} = (Minimum gas temperature required at outlet + temperature drop due to Joule Thomson effect- Minimum temperature of gas at RMS inlet)

Or, Δt_{gas} = (18 +15.30-20) ^{0}C = 13.3 ^{0}C

Heat required for preheating the natural gas can also be calculated by using the Joule-Thomson effect Equation (McAllister,1996).

Heat quantity, $W = q_n.\Delta t_{gas}.\rho_n.C_p$

$W = q_n.\Delta t_{gas}.\rho_n.C_p$

= 12524x13.3x0.71x0.60 kcal = 70958 kcal = 297087 kJ = 82.52 kw

The efficiency of heater is 85 % (Assumed)

Heat to be required = 82.52 kw/0.85 = 97.082 kw

Though 97.082 kw capacity of heater is not available in the market, Therefore a 100 kw capacity heater is recommended to raise up the temperature of gas.

5.4.4.2 Heater RMS

The water bath heater is a self contained with gas, so there is a small heater RMS for supplying gas to the heater. The gas is taken in heater RMS from the main RMS (Outlet of second stage regulating unit) at 60 psig and regulate the pressure from 60 psig to 18 inch W.C. It is comprising with two regulating runs, inlet valve, strainer, slam shut off valve and outlet valve. A common relief valve should be installed for safety purpose and a meter is used for gas measurement of heater RMS. The heater RMS should be place on a steel structure skid placed on civil foundation. The gas consumption for the water bath heater is calculated as follows.

Gas consumption calculation of water bath heater :

Heating capacity of water bath heater = 100 KW

Input heat of water bath heater = (100X1000)W

= [(100X1000 X3600)/(4.2X252)] Btu/hr

= 340136 Btu/hr

Lower calorific value of natural gas = 915 Btu/SCF (Appendix C)

Gas required for heater = (340136/915X 24) SCFD = 0.01 MMSCFD

Though the power plant RMS will be design for 10% additional load, so there is a provision for gas consumption of the heater RMS. A schematic diagram of heating unit of the RMS is shown in Fig 5.3.

Fig 5.3.A schematic diagram of heating unit of the RMS

5.4.5 Pressure regulating unit

The regulating run is designed as per internationally recognized recommendation of International Gas Engineers, IGE-TD-9, AGA Part-9.

No single type of regulator can maintain an exactly constant outlet pressure under all flowing conditions. Due to large pressure drops across a single regulator excessive noise, vibration and hydrate formation may occur.

For good performance, the regulatorǿs valve opening should be maintained within a range to 25% to 75% of its maximum flowing capacity and minimum inlet pressure of the station. In this context turn down ratio of regulator is very important. The turn down ratio of a single regulator is about 5:1(Appendix G). On the other hand turn down ratio of the power plant is 6:1 according to gas consumption of the engine (Chapter-4).

The number of pressure reduction stage of the RMS runs depends on turn down ratio of regulator, noise level and temperature drop across a regulator.

If the regulating unit is faulty in design then there may arise various technical problems in operation of the RMS. To avoid the possibility of excessive noise, vibration and damage of the regulator and piping, multiple stage pressure reduction provision is needed.

From the above discussion, it is recommended a two stage pressure reduction provision for the proposed RMS to ensure a continuous gas supply and smooth operation.

The proposed RMS is a two stage pressure regulating station, so the inter stage pressure can be determined by using the equation no-(3.2).

The following are the process data

P_1 = Maximum inlet pressure of RMS = 500 Psig = 514.73 Psia

P_2 = Required outlet pressure of RMS = 60 Psig = 74.73 Psia

Putting the value in equation no-(3.2).

The inter stage pressure, $P_i = [\sqrt{(514.73*74.73)}] = 196$ psia

Therefore, the inter stage pressure is assumed 200 psig. In first stage pressure reduction unit the pressure cuts from 500 psig to 200 psig and in second stage pressure cuts from 200 psig to 60 psig. There are two identical regulating runs (streams) each having 100% capacity of the maximum flow and each run consists of inlet isolating valve (01no), slam shut off valve (01no), regulator (2no), outlet isolating valve (01no) and safety relief valve (01no) installed at the outlet header of the each regulating unit. One regulating run is operational and another is stand by mode.

5.4.5.1 First stage pressure regulating unit

Inlet pipe size of first stage pressure regulating unit

By using Equation no-(3.1)

$$D = (0.75*Q/V*P)^{1/2}$$

$$= [0.75*(12000000/24)/(120*414.73)]^{1/2}$$

$$= 2.745 \text{ inch}$$

Therefore, the inlet pipeline, valve size and Slam shut off valve (SSV) size of first stage pressure regulating unit are 3 inch DNx Sch-40, 3 inch RF ANSI CL-300 and 3 inch RF ANSI CL-300 respectively.

Outlet pipe and valve size of first stage pressure regulating unit

$$D = (0.75*Q/V*P)^{1/2}$$

$$= [0.75*(12000000/24)/(120*214.73)]^{1/2}$$

$$= 3.815 \text{ inch}$$

Therefore, the outlet pipeline and valve size of first stage pressure regulating unit are 4 inch DNx Sch-40, 4 inch RF ANSI CL-300 respectively.

By using Equation no-(3.3)

Outlet header size of the first stage pressure regulating unit :

$$\pi D^2/4 = [(\pi d_1^2/4 + \pi d_2^2/4)* 1.5]$$

Where,

ʧ$D^2/4$ - Cross sectional area of header, square inches

ʧ$d_1^2/4$ ï Cross sectional area of the 1st stream, square inches

ʧ$d_2^2/4$ - Cross sectional area of the 2nd, square inches

or, $D = [(d_1^2 + d_2^2) * 1.5]^{½} = [(4^2 + 4^2) * 1.5]^{½} = [(32) * 1.5]^{½} = 6.928$ inches

As the both regulating runs are 100% capacity of each and both the runs will not be operated simultaneously, so there is no problem to use the outlet header size is 6 inch.

Therefore, the outlet header size of the first stage pressure regulating unit 6 inch DNx Sch-40.

Regulator sizing

At minimum inlet pressure

$P_1 - P_2 / P_1 = (414.73-214.73)/414.73 = 0.48$

Since, $P_1 - P_2 / P_1 \leq 0.55$ so the flow is sub critical

By using the universal gas sizing Equation no-(3.10)

Now for sub critical flow,

$C_g = Q/[P_1\sqrt{(520/GT)} \sin [(3417/C)\sqrt{(P_1 - P_2)/P_1}]$

$= [(12000000/24)/414.73[\sqrt{520/0.5817*520}\sin[(3417/35)\sqrt{(414.73-214.73)/414.73}]$

$= 993$

Monitor & Active regulator correction = 993*1.43 =1420

$C_{g\,(\text{recommended})} = 1420*1.25 = 1775$

From Table :3.6 :Two 2 inch regulators are required.

From Fig. 3.1 : Pilot operated or self operated regulator with roll out diaphragm is required. Since Pilot operated regulator has very good regulation characteristic, we chose Pilot operated regulator.

From Table :3.7 : Outlet velocity is not a problem.

$V = (0.75*12000000/24)/(214.73*2^2) = 436$ ft/see

Therefore, the regulator type and size : Fisher- 2 inch RF, ANSI CL 300

Relief valve Size : 1 inch RF, ANSI CL 300

Slam shut valve Size :3 inch RF, ANSI CL 300

Sensing or control line :

A common practice is to use 10 pipe diameters down stream for the sensing pressure tap with 5 pipe diameters usually considered to be minimum because this will allow time for the regulator to sense and react to change in the process.

As, the outlet pipeline size of first stage pressure regulating unit is 4 inch DN, so the length of sensing line of this regulating stream is recommended as follows

Sensing line length = 10 pipe diameters

= 10*4 inch = 40 inch = 3.33 feet

5.4.5.2 Second stage pressure regulating unit

Regulator sizing

At minimum inlet pressure

$P_1 - P_2/ P_1 = (214.73-74.73)/214.73 = 0.65$

Since, $P_1 - P_2/ P_1 \geq 0.55$ so the flow is critical

Now for critical flow ,

$C_g = Q/ P_1*1.31$

$C_g = [(12000000/24)/(214.73*1.31)]$

$= 1776$

Monitor & Active regulator correction = 1776*1.43 = 2540

$C_{g\ (recommended)} =$ 2540*1.25 = 3175

From Table :3.6 :Two 3 inch regulators are required.

From Fig :3.1 : Pilot operated or self operated regulator with roll out diaphragm is required.

From Table :3.7 : Outlet velocity is not a problem.

$V = [(0.75*12000000/24)/(74.73*3^2)]$ = 558 ft/see

Therefore, the regulator type and size : Fisher- 3 inch RF, ANSI CL 300

Slam shut valve size : 4 inch RF, ANSI CL 300

Relief valve size : 1 inch RF, ANSI CL 300

Inlet and outlet pipe and valve size of second stage pressure regulating unit

Inlet pipe size of second stage pressure regulating unit

By using Equation no-(3.1)

$$D = (0.75*Q/V*P)^{1/2}$$

$$= [0.75*(12000000/24)/(120*214.73)]^{1/2}$$

$$= 3.815 \text{ inch}$$

Therefore, the inlet pipeline & valve size of second stage pressure regulating unit are 4 inch DNx Sch-40, 4 inch RF ANSI CL-300 respectively.

Outlet pipe and valve size of second stage pressure regulating unit

$$D = \sqrt{}(0.75Q/VP)$$

$$= \sqrt{}[(0.75*12000000/24)/(120*(74.73)]$$

$$= 6.47 \text{ inch}$$

Though 7 inch pipe and valve size is not available, therefore the regulator outlet valve size 8 inch DN, ANSI CL 300

Outlet header size of the second stage pressure regulating unit is calculated By using Equation no-(3.3)

$$D = [(d_1^2 + d_2^2)* 1.5]^{½} = [(8^2 + 8^2)* 1.5]^{½} = [(64+64)* 1.5]^{½} = 13.856 \text{ inch}$$

As the both regulating runs are 100% capable and both the runs will not be operated simultaneously, so there is no problem to use the outlet header size is 12 inch.

Therefore, the outlet header size of the second stage pressure regulating unit is 12 inch DNx Sch-40.

Sensing or control line :

As, the outlet pipeline size of second stage pressure regulating unit is 8 inch DN, so the length of sensing line of this regulating stream is recommended as follows.

Sensing line length = 10 pipe diameters

= 10*8 inch

= 80 inch

= 6.66 feet

Noise attenuation

The selected regulators are designed to produce maximum noise level of 80 dBA at 1 meter distance (Fisher Controls, 2003). The regulating system of the RMS is a two stage regulating unit, so comparatively low level noise will be produced due to several pressure cut. The noise level will be approximately 70 dBA (Fisher Controls, 2003). The environmental quality standards for Bangladesh have set noise guide for industrial sites in Bangladesh, 85 dBA is usually nattered as the critical level for human ear damage (DOE,1991). According to this standard, noise level should not exceed 75 dBA in daytime and 70 dBA at night (Appendix L).

Therefore, no additional silencer is required to reduce noise for the proposed RMS.

Schematic diagram of first stage and second stage regulating unit of the RMS are shown in Fig 5.4 and Fig 5.5 respectively.

Fig 5.4 Schematic diagram of first stage regulating unit of the RMS

Fig 5.5: Schematic diagram second stage regulating unit of the RMS

5.4.6 Metering unit

The metering run is designed as per internationally recognized recommendation of Institution of Gas Engineers, IGE-TD-9, AGA Part-9 and AGA Report No.7

Rangeability or turn down ratio is very important for meter selection. Turn down ratio has a strong effect on system loss. Because meter with improper ranged can not measure accurately. In this context turn down ratio is very important. The turn down ratio of a single orifice meter is about 3:1(AGA-3). On the other hand turn down ratio of turbine meter is very high. At lower or medium pressure it is 20:1 and it increases as pressure increases (AGA-7). Another considering factor is the turn down ratio of the power plant is 6:1 according to gas consumption of the engine (Chapter-4). Where the gas consumption is stable or where there is no load variation, it can be used orifice meter and for load variation it can be used turbine meter.

Considering the above factors of both metering system, it is recommended for installation of turbine meter in the RMS for accurate instantaneous gas flow measurement and smooth operation of the station.

The configuration of the meter runs depends on the flow rate which have to be handled and their turn down ratio.

For custody transfer application, the metering unit of the RMS consists of two metering runs (streams) for uninterrupted gas flow measurement and each having 100% capacity of the maximum flow. One metering run is operational and another is stand by mode. If there is a provision of metering by pass run, the customer or RMS operators may miss use of the metering by pass without any reason. Therefore, there is no provision of metering by pass run to prevent theft or pilferage of gas.

From the above discussion it is recommend that, no by pass would be required for metering unit and turbine meter is selected over orifice meter for the proposed RMS.

5.4.6.1 Turbine Meter sizing

Turbine meter size calculation

Maximum required flow = 500000 SCFH =14158 m^3/hr

Maximum pressure = 65 Psig = 79.73 Psia

Minimum line pressure = 55 Psig = 69.73 Psia

Base pressure = 14.73 Psia

Velocity of Gas =120 ft/sec

Pressure factor = Line pressure/ Base pressure = 69.73/14.73 = 4.734

Equivalent line flow = Maximum required flow/ Pressure factor

= 14158/ 4.734 m^3/hr = 2990 m^3/hr

It is suggested that maximum flow should be within 90 % of the maximum meter flow capacity.

Recommended meter capacity = Equivalent line flow/0.9

= 2990/0.9 m^3/hr

= 3323 m^3/hr

From the above value meter size will be 12 inch ANSI 150 CL, G-2500 (Appendix F) and also the pipe size is 12 inch DNx Sch-40.

5.4.7 Straightening vanes

The purpose of a straightening vane is to eliminate swirls and cross currents set up by the pipe fitting valves or regulators preceding the meter inlet piping. The straightening vane length should be at least 10 times the maximum inside dimension of single vane (AGA Report 7).

The piping and meter diameter size is 12 inch, so the straightening vaneés should be installed at a distance of 5 nominal pipe diameters of piping from the up stream of the turbine meter inlet. The straightening vaneés position and length in the metering stream of the proposed RMS is as follows.

Location of straightening vane = 5 DN of piping = 5*12 inch = 60 inch = 5 ft

Length of straightening vane = 2 DN of piping = 24 inch = 2 ft

Therefore, it is recommended to install the straightening vane at 5 ft upstream of turbine meter inlet and the length should be 2 ft.

Now a days, most of the turbine meters are built in straightening vane, which is attached into the meter inlet piping, so this type of turbine meter should be used to avoid swirls and turbulence.

5.4.8 Flow Computer

There are many choices today for flow computer measurement. Not only are there calculations and meter standards to choose from many time the application requires selection of the right packaging.

5.4.8.1 Flow computer consideration

When confronted with measurement decision, lot of factors be considered for each application. Some key elements are typically as follow.

- System integrators
- Multiple K- factors and linearization
- Densitometer
- Proving
- Batching Reports
- Manufactured pulse meter conditioning
- Predictive maintenance through diagnostics
- Multi-product measurement using density
- Communication devices such as Gas chromatograph, SCADA, RTU, DCS etc. through industry standard protocol.

Primary inputs for the flow computers are as follows.

- Pressure signal (4-20 mA) from pressure transmitter.
- Temperature signal (4-20 mA) from temperature transmitter.
- Pulse signal from turbine meters index.
- Gas components from Gas chromatograph.

From these primary inputs the minimum calculations performed by the flow computers are usually:

- Volume rate
- Volume total
- Corrected Volume
- Uncorrected Volume
- Average density
- Total mass
- Average temperature
- Average static pressure
- Heating value and gas composition

5.4.9 Gas chromatograph

Gas chromatograph is an electronic device which capture a representative sample from line gas and analyses the gas to its constituent components. Analyzer types are as follows.

a) Depending on sample capture and analysis

    1. On line gas chromatograph
    2. Off line gas chromatograph

b) Depending on fluid phase

    1. Gas chromatograph
    2. Liquid chromatograph

On line gas chromatograph category depending on analyzing capacity

- Controller assembly
- Analyzer assembly with sampling

Both can be in separate module or can be integrated in single module.

5.4.9.1 Gas chromatograph selection

A gas chromatograph type may be selected after considering some parameters which is described as follows.

- Fluid phase: Gas or liquid
- Components to be analyzed

- Carrier gas compotation : Should be low consumption of carrier gas.
- Detector technique : TCD, FPD, FID etc.
- Power supply and consumption : 220 VAC/24 VDC, low power consumption
- Area location : Hazardous or safe area.
- Column : Micro packed column or capillary column
- Detector accuracy : Should be capable to detection components up to PPM range
- Date and chromatograph storage capacity : Should be able to store in 3 days analysis data @ each hour.
- Accuracy and repeatability: 0.05 Btu/1000Btu
- Stand along device to operate in field
- Analysis time per cycle : Typically 3-7 minutes
- Analysis and Heating value calculation are as per ISO 6976, GPA 2172

As per requirement of analysis and calculation it is recommended an on line gas chromatograph of Daniel brand, Model- Danalizer 500 with C_6+ application for the proposed RMS according to Gas Sells Agreement (GSA) between buyer and seller.

A schematic diagram of metering unit of the RMS is shown in Fig 5.6.

Fig 5.6. A schematic diagram of metering unit of the RMS

5.4.10 Measurement accuracy of RMS equipment

The measurement accuracy of the custody transfer metering system is related to the accuracy of the following equipments.

a) Turbine Meter
b) Pressure Transmitter
c) Temperature Transmitter
d) On line gas Chromatograph
e) Flow Computer

5.4.10.1 Turbine Meter accuracy

The measurement accuracy (M_a) of turbine meter is within ±1% over a wide range of both pressure and flow rate. They are capable of ±0.25% accuracy over a specified flow range. They can maintain high accuracy level for a period of 2 years.

5.4.10.2 Mechanical recorder accuracy

The accuracy of mechanical recorder is as follows
Static pressure element accuracy, P_{tu} is ±0.5% of full scale
Temperature element accuracy, T_{tu} is ±1% of full scale

5.4.10.3 Flow computer accuracy

Flow computer accuracy, Fc_{conv} is ±0.5%

The accuracy of the measuring device can be determined by following formula as per ISO 5168 (2005).

Accuracy = $\pm\sqrt{(M_a^2+Fc^2_{conv}+P^2_{tu}+T^2_{tu})}$
= $\pm\sqrt{(1^2+0.5^2+0.5^2+01^2)}$ [Putting the value of M_a, Fc_{conv}, P_{tu} and T_{tu}]
= ±1.58

Therefore, the overall measurement accuracy of the measuring device with turbine meter of the proposed RMS is ±1.58%.

5.4.11 Condensate Storage Tank:

A condensate tank of about 500 gallons capacity will be required to store gas condensate separated from sweet natural gas. The liquids will be stored under moderate pressure. The tank should designed for maximum pressure of 10 bar. The condensate will be stored at a pressure of 4.8 bar. The tank has been designed, fabricated and tested in accordance with the ASME Boiler and pressure vessel code section V111 DIV 1. One inch diameter drain line connection from filter separator and liquid separator equipped with dip pipe.

5.4.12 Pipe length of different sections of RMS

Pipe length of different sections of RMS can be calculated as per AGA Report no-7, IGE TD-9, AGA Part -9 and manufacturer catalogue or manual. The pipe length of different sections of RMS have been summarized in Tabular form.

Table 5.2 : Pipe length of different sections of RMS

Sl No.	Section name	Pipe dia (inch)	Basis of calculation	Pipe length (feet)
1	Station Inlet piping	4	10 DN	3
2	Filter separator unit piping section	4	30 DN	10
3	Heater piping section	4	30 DN	10
4	First stage regulating unit piping section	4	60 DN	20
		3	30 DN	10
		6	100 DN	30
5	Second stage regulating unit piping section	6	60 DN	20
		8	60 DN	20
6	Liquid separator unit piping section	12	100 DN	30
7	Metering unit piping section	12	100 DN	30
8	Station outlet piping	12	20 DN	6

(DN = Nominal Diameter)

5.4.12 Wall thickness of pipe line

Calculation results for pipe wall thickness of line pipe of different sections have been summarized in Tabular form.

Table 5.3 Pipe wall thickness

Location of Pipe line	Design Pressure (psig)	Pipe Grade	Outside Diameter (inch)	Inside Diameter (inch)	Wall thickness (inch)
Station Inlet	750	API 5L-X46	4.00	3.86	0.068
Inlet of Filter Separator	750	API 5L-X46	4.00	3.86	0.068
Outlet of Filter Separator	750	API 5L-X46	4.00	3.86	0.068
Inlet of Heater	750	API 5L-X46	4.00	3.86	0.068
Outlet of Heater	750	API 5L-X46	4.00	3.86	0.068
Inlet Header of first regulating run	750	API 5L-X46	4.00	5.80	0.102
Outlet Header first stage regulating run	500	API 5L-Gr. B	6.00	5.86	0.068
Inlet Header of second stage regulating run	450	API 5L-Gr. B	6.00	5.88	0.061
Outlet pipe of second stage regulating run	90	API 5L-Gr. B	8.00	7.96	0.021
Outlet Header of second stage regulating run	90	API 5L-Gr. B	12.00	11.94	0.032
Inlet of Liquid separator	90	API 5L-Gr. B	12.00	11.94	0.032
Outlet of Liquid separator	90	API 5L-Gr. B	12.00	11.94	0.032
Meter run	90	API 5L-Gr. B	12.00	11.94	0.032

5.4.13 The major components size for the proposed RMS

Size of the major components for the proposed RMS have been summarized in the flowing Table 5.4 on the basis of detailed calculations.

Table 5.4 RMS components size

Sl.No	Item Name	Specifications	Overall material	
			Quantity	Unit
Station Inlet				
1	Inlet Pipe	4" DN, API 5L G-B	20	Meter
2	Insulating Joint (IJ)	4" DN, ANSI 300	1	Number
3	Valve	4" DN, ANSI 300	9	Number
Separating Unit				
4	Filter Separator	4" DN ANSI 300 Capacity :12 mmscfd at 80 psig with max 100 mbar pressure drop	2	Number
5	Liquid Separator	12" DN, ANSI 150 Capacity :12 mmscfd at 80 psig with max 100 mbar pressure drop	1	Number
Heating Unit				
6	Water Bath Heater	Heat duty :100 KW, Class : ANSI 300 , :Flanged 4"x4" DN Pressure range: Upto 1460 psig,	1	Number
First stage pressure regulating run				
7	Inlet valve	4" DN, ANSI 300	2	Number
8	Outlet valve	4" DN, ANSI 300	2	Number
9	Pressure Regulator	2" DN, ANSI 300, Pilot-operated	4	Number
10	Slam shut off valve	3" DN, ANSI 300	2	Number
11	Safety Relief valve	1" DN, ANSI 300	1	Number
12	Inlet header	4" DN, API 5L G-B	10	Meter
13	Outlet header	6" DN, API 5L G-B	10	Meter

Table 5.4 RMS components size (Contôd)

Sl.No	Item Name	Specifications	Overall material	
			Quantity	Unit
Second stage pressure regulating run				
14	Inlet valve	6" DN, ANSI 150	2	Number
15	Outlet valve	8" DN, ANSI 150	2	Number
16	Pressure Regulator	3"DN, ANSI 150, Pilot-operated	4	Number
17	Slam shut off valve	4" DN, ANSI 150	2	Number
18	Safety Relief valve	1" DN, ANSI 150	1	Number
19	Inlet header	6" DN, API 5L G-B	10	Meter
20	Outlet header	12" DN, API 5L G-B	10	Meter
Metering Unit				
21	Turbine Meter	12" DN, ANSI 150, G-4000	2	Nos
22	Gas Flow Computer (FC)	Multi-stream	1	No
23	Gas Chromatography (GC)	On Line gas Chromatography	1	No
24	Mechanical Chart Recorder	2 (Two) Pen, Pressure Range:0~100 Psig, Temperature Range:0~150 F	2	Nos.
25	Pipe	12"DN, API 5L G-B	20	Meter
Station Outlet				
26	Outlet Pipe	12" DN, API 5L G-B	10	Meter
27	Insulating Joint (IJ)	12" DN, ANSI 150	1	No
28	Valve	12" DN, ANSI 150	1	No
29	Non-Return valve	12" DN, ANSI 150	1	No

5.5 Piping and Instrumentation diagram of the Proposed RMS

On the basis of size calculation and selection of equipments and materials, a Piping and Instrumentation diagram and a top view of the Proposed RMS are shown in Figure 5.7 and Figure 5.8 respectively.

Figure 5.7: Piping and Instrumentation diagram

Figure 5.8: Top view of the Proposed RMS

CHAPTER 6

SAFETY AND ENVIRONMEMTAL ASPECT OF RMS

Safety and environmental impacts are the first considerations in the design of regulating and metering station. Many factors must be considered in the design to ensure safety of pipeline and RMS operation.. International codes and standards (ASTM, ASME, ANSI, API), A.G.A. Report no-7 and Bangladesh natural gas safety rules,1991(Amendment 2003) have been followed for design of gas pipelines and RMS. In this chapter, safety and environmental aspects in designing a regulating and metering station will be discussed.

6.1 Environmental impacts of proposed gas facilities for the power plant

The impacts of a gas facilities project can be direct, such as the effect of toxic discharge on air, noise and water quality or indirect, such as the effect on human health from exposure to particulates or contaminants. It increases the possibility of explosion and leakage due to accidents, malfunction of joints or corrosion and lack of skillness and carefulness of related persons. These negative effects on the environment will be negligible due to implementation of the project.

Taking proper precautions, these negative effects can be mitigated. The positive impacts of the project will out weigh the negative one.

The negative impacts of the power plant are much more compared to that of RMS and pipeline. Running of power plant will produce more noise, vibration, wear and rear compared to RMS, so more protection should be taken to reduce the negative impacts of power plant. The negative impacts of RMS and pipeline are less likely.

6.2 Environmental Consideration

For environmental reasons in additional to the necessary reliability the station should be of the smallest practicable size with a high degree of safety against leakage and as silent as possible in operation. The generated sound level shall not exceed 85dBA (DoE Report,1991). In this regard, all of the equipments and instruments have been selected as per ASTM, ASME, ANSI, API, A.G.A. Report no-7 and Bangladesh natural gas safety rules,1991 (Amendment 2003), so that sound level dose not exceed 85dBA .

6.3 Safety Consideration

In order to enhance the occupational health and works safety of gas pipeline and RMS project, the following monitoring works have been done.

6.3.1 Gas quality

Gas quality should be maintained to minimize the possibility of any kind of corrosion, wear and tear, burning quality, so gas should be dust, water and sulfur free. In this view, liquid separator, filter separator and heater have been used to maintain the gas quality of the proposed RMS.

6.3.2 Wall thickness of pipe

Pipe is selected with sufficient wall thickness or installed with adequate protection to withstand anticipated external pressures and loads that will imposed on the pipe after installation. Due consideration is given to the safety of life and property while selecting a valve and pipe. For this purpose the American code (ASME B 31.8) has been followed.

6.3.3 Pressure rating of materials

Considering the safety and environmental aspects, the pressure rating of RMS materials have been selected as per maximum allowable operating pressure in accordance with National Standards Institute (ANSI) pressure class and API (Appendix H, I).

6.3.4 Control of overpressure in the system

To prevent personal injury, equipment damage or leakage due to bursting of pressure-containing parts, it is necessary to install adequate overpressure protection when installing a pressure reducing regulator. Overpressure protection equipment should be installed to protect all downstream equipments in the event of regulator failure.

To prevent accidental over pressure, the flowing protective devices are used in the proposed RMS.

- Pressure relief valve is used to prevent a rise of inlet pressure in excess of a specified value in the pressure system..
- Slam shut valve: Slam shut valve is installed in series with active regulator.
- Active Monitor regulator : A monitoring regulator is installed in series with active regulator.
- Non return valve is used to prevent flow in the reverse direction.

6.3.5 Installation of valves

Block valves install in transmission lines, distribution system and service lines at intervals and at locations.

- Valves are installed above ground and above highest flood level.
- Valves are installed in accessible locations of the systems in order to reduce the time to shut down a section of main in an emergency.
- A valve is installed on the inlet piping of each regulator or station controlling the gas flow in the system. The distance between the valve and the regulator or regulators should be sufficient to permit the operation of the valve during an emergency, such as a large gas leakage or fire in the station.

6.3.6 Location of meters and regulators

Meters or regulators have been installed or located in easily accessible and ventilated place and the distance should be at least five meter far and invisible from any source of heat or ignition such as hearth, furnace, electric heater or open flame of any sort.

6.3.7 Safety distance of pipeline

The following safety distances of pipeline have been maintained for all pressure pipelines to be operated above 150 Psig or above pressure of all high pressure pipeline which is shown in Table 6.1.

Table 6.1 Safety distance of pipeline

Pipe size	Pressure 150 Psig to 350 Psig	Above 350 Psig
Up to 20ò	2.00 Meter	2.50 Meter
Above 20ò	3.00 Meter	3.50 Meter

6.3.8 Controlling Hazards

Some control measures to prevent hazards are as follows:

- Marking hazards with signs, flags, lights, alarms, barricades, fences, labels, placards or other materials.
- Providing personal protective and other safety equipments to workers.
- Using engineering controls to reduce the impact of hazards.

Whenever possible, hazards should be eliminated. If elimination is not possible, other control measures should be used to protect workers.

6.3.9 Prevention of eddy current

Insulating joints (IJ) have been used at station inlet and outlet of RMS to protect eddy current producing from transmission and distribution network that may damage the RMS.

6.3.10 Leak detector

Pipe line leak detectors should be used in the gas system. Generally odorant is used to detect the line leakage. A leak detector is suggested for the proposed RMS.

6.3.11 Fire Extinguisher

There is a provision of fire extinguisher in the RMS premises for controlling of small fires due to leakage of gas.

6.3.12 Protection against corrosion

Natural gas pipelines are laid below the ground surface. These pipelines are susceptible to corrosion by various subsoil environments. As the pipelines are growing old, it is becoming more difficult to protect them from the damage caused by corrosion. Major cause of the supply interruptions is leakage in the pipeline due to corrosion. To control corrosion of pipeline combined system of coating and cathodic protection should be used. Within one year of construction of pipeline, cathodic protection is applied to the pipeline in accordance with BS CP 1021 or American National Association of corrosion Engineers code RP 01-72 as far as practicable.

A safe and leak free pipeline network is essential for uninterrupted gas supply to the power plant. For this reason a Cathodic Protection (CP) station is recommended for the 0.5 km 4" DN ×500 psig pipe line network of the power plant RMS within one year of the construction of the pipeline.

6.3.13 The lighting arrangement

The lighting arrangement for the RMS area should be explosion proof and suitable for hazardous area. Lighting fixtures are mounted on a pole above the suitable height for proper illuminations.

6.3.14 Major activities of a Project

The major activities of a gas facilities project are pipeline routes survey, Clearance from DOE, Design and Drawing, procurement of materials, construction, fabrication and installation, testing, Tie-ins with live line and Commissioning.

Hydrostatic test

Hydrostatic test is performed after mechanical completion of the pipeline. For hydrostatic test, water is poured into the pipeline section. Then the pipeline is pressurized by injecting small amount of water through hand pump. As per API standard minimum hydrostatic test pressure should be 1.5 times of design pressure.

Commissioning of pipeline and facilities

Commissioning is the flowing of natural gas through the newly constructed pipeline for first time. Pipeline, valves, fittings, meters and regulators are checked and rectified if necessary before Commissioning.

CHAPTER 7

POSSIBLE VARIATION IN DESIGN

RMS Inlet pressure, gas flow rate, gas composition, heating value and compressibility factor has a strong effect on selection of equipment size and material type. Ultimately, design of the RMS will be affected for variation of all these factors.

In this chapter the above mentioned subjects are discussed in designing a regulating and metering station.

7.1 Change the inlet pressure

The inlet pressure of the RMS is considered within 400 psig to 500 psig. Putting the minimum and maximum inlet pressure in the equation 3.1, 3.10 and 3.11 the size of the pipe, regulator and meter are shown in Appendix P.

From the Table P.1, P.2 and P.3 (Appendix P) it is seen that the pipe and equipment size will be decreased with increase of the inlet pressure for the maximum flow rate.

In the proposed design, the minimum inlet pressure is taken in sizing all equipments for the maximum flow rate. Therefore, no change is required in the design of the proposed RMS.

7.2 Change of gas composition and properties

The RMS which is required to be designed for supplying conditioned gas suitable for delivery to the power plant, will get natural gas from the transmission system connected at present with all major gas fields of the country. Since the system will receive gas from multiple sources, it is not possible to indicate very precisely the composition of the gas. The expected composition of the gas will be generally within the range which is shown in Table 7.1.

Table 7.1: Natural gas composition analysis report

Composition of natural gas	
Components	% Mole
Nitrogen	: 0.20-0.356
Carbon dioxide	: 0.20- 0.45
Methane	: 95.00-97.50
Ethane	: 1.50-2.20
Propane	: 0.30-0.50
Butane	: 0.16-0.20
Pentane	: 0.044-0.190
Hexane	: 0.090
Heptane+	: 0.062

Properties of natural gas	
Particulars	
Specific gravity (Air =01)	: 0.57-0.60
Specific heat ratio	: 0.60-0.75
Density at std. condition	: 0.7132 kg/m3
Compressibility factor, Z	: 0.98-0.9978
Higher Heating value (BTU/SCF)	: 950-1050
Lower Heating value (BTU/SCF)	: 915-940

(Source: Department of Petroleum and Mineral Resources Engineering, BUET, Dhaka)

7.2.1 Change of heating value due to composition change

Taking the worst situation of gas composition, the lower heating value is 915 BTU/SCF. Therefore, the fuel consumption of the power plant will be 11 MMSCFD (Chapter 4).

If lower heating value increases, fuel consumption of the power plant will be decreased. The fuel consumption of the power plant will be 10.5 MMSCFD for 940 BTU/SCF. This value will also affect the design of the RMS. Considering the fuel consumption of heater and decrease of the power plant efficiency, the proposed RMS has been designed for the flowing capacity of 12 MMSCFD.

7.2.2 Change of specific gravity due to composition change

In first stage regulating unit, pressure cuts from 500 psig to 200 psig and in second stage pressure cuts from 200 psig to 60 psig. In this situation putting the different value of specific gravity (S.G) in the equation no. 3.10 and 3.11, the size of the regulators are summarized in the following Table 7.2.

Table 7.2: Regulator sizing calculation

Sl No.	Regulating stage	S.G	C_g Value	Calculated size (inch)	Selected size (inch)
1	First stage regulating unit	0.57	1757	2	2
2		0.58	1775	2	
3		0.60	1803	2	
4	Second stage regulating unit	0.57	3142	3	3
5		0.58	3175	3	
6		0.60	3224	3	

From the above data it is seen that the calculated results for different values of specific gravity are similar to the selected sizes of the proposed RMS.

7.2.3 Effect on filter separator sizing due to change of composition and properties

Putting the different values of gas compressibility factor in the equation 3.7, the sizes of the separator are summarized in the following Table 7.3.

Table 7.3: Separator sizing calculation

q_{gas} (MMSCFD)	T (°Rankine)	p (psia)	Z	K_l	D(ft)	L/D
12	520	514.7	1.00	0.167	3.099	1.936
12	520	514.7	0.98	0.167	3.068	1.955

(Minimum length (height) for vertical separator should be 6 ft (Kumar,1987), So L/D = 6/D)

All of the length verses diameter ratio do not satisfy the design consideration. Length verses diameter ratio should be between 3 to 8 (Kumar,1987).

For Length, L = 6 ft = 72 inch

Maximum L/D ratio = 8, So L/D = 8 or 72/D = 8 or Diameter, D = 9 inch.

Therefore, a vertical filter separator of size 9 inch (dia)x 6 ft (length) is required for the proposed RMS.

The recommended size of the filter separator is similar to the above mentioned size.

7.2.4 Effect on heater sizing due to change of composition and properties

Putting the maximum and minimum value of specific density (ρ_n), specific heat (C_p) of natural gas and the following data in the equation 3.14, the required heat for preheating the natural gas are computed and summarized in the Table 7.4.

Required data:

q_n = Gas flow rate (max) = 12 MMSCFD = 12524 nm^3/h

P_i = Inlet pressure of natural gas = 500 Psig = 514.73 Psia = 35.7451 bar (abs)

P_o= Outlet pressure of natural gas = 60 Psig = 74.73 Psia = 5.190 bar (abs)

Maximum inlet temperature of gas = 20 °C (68° F)

Minimum outlet temperature of gas = 18 °C (64 °F)

Table 7.4: Heat capacity calculation

q_n (nm3/h)	ρ_n (Kg/m3)	c_p (kCal/Kg°C)	Heat capacity			
			Heat capacity (kcal)	Heat capacity (kw)	Efficiency (%)	Input heat of heater (kw)
1	2	3	4	5	6	7 = (5/6)
12524	0.57	0.60	56967	66.25	85	78
12524	0.58	0.70	67627	78.65	85	93
12524	0.60	0.75	74956	87.17	85	103

From the above table it is seen that the calculated result of required heater for maximum and minimum value of specific density (ρ_n), specific heat (C_p) is similar to recommended heater capacity for the proposed RMS. Therefore, the selected capacity of heater is acceptable.

7.2.5 Effect on material type due to change of gas properties

The gas composition, properties and environmental factors are also affecting in selection of material type. Raw natural gas may contain high qualities of sulfur and carbon dioxide (sour gas). Sour gas is extremely corrosive, therefore, special pipe material has to be used. In this case, the supplied gas is sweet and line quality gas. Therefore, the material of line pipe and equipments are used usually steel or cast iron. Steel pipes are both covered with a special coating to avoid corrosion and they are protected by cathodic protection.

Considering the safety and environmental aspects, the pressure rating and materials of the proposed RMS have been selected steel as per maximum allowable operating pressure in accordance with ANSI and API codes and standards.

CHAPTER 8

COST ESTIMATION OF PROJECT

Cost estimation is an essential part of a project. The costing of this project is consists of a 0.5 Km×4"DN×500 psig inlet pipe line of RMS, a 0.3 Km×12"DN×65 psig outlet pipe line of RMS and one gas regulating and metering station having capacity of 12 MMSCFD.

8.1 Material costs

The detailed break-up of equipment and materials costs of both in local currency and foreign currency are explained in Table 8.1.

Table 8.1: Cost Estimation of RMS Materials

Item Name	Specifications	Overall material		Local	Foreign	Total Price (Taka)
		Quantity	Unit	Unit Price (Taka)	Unit Price (Taka)	
Meter	Type :Turbine Class : ANSI 150 Size :12" DN Rating : G-4000 Connections :Flanged 12"x12"	2	No		8,20,300	16,40,600
Pressure Regulator	Type :Pilot-operated Mode of Operation : Active/Monitor Class : ANSI 300, Size : 2" DN Pr. range :150-600 psig	4	No		1,72,300	6,89,200
Pressure Regulator	Type :Pilot-operated Mode of Operation : Active/Monitor Class : ANSI 300, Size : 3" DN Pr. range :0-75 psig	4	No		2,50,200	10,00,800
Slam shut valve	Class : ANSI 300 Size : 3" DN Pr. range :150-600 psig	2	No		86,400	1,72,800
Slam shut valve	Class : ANSI 300 Size : 4" DN Pr. range :0-75 psig	2	No		94,000	1,88,000
					Sub total (a)	**36,91,400**

Table 8.1: Cost Estimation of RMS Materials (Contôd)

Item Name	Specifications	Overall material		Local	Foreign	Total Price (Taka)
		Quantity	Unit	Unit Price (Taka)	Unit Price (Taka)	
Valve	Type : Ball valve (Full bore) Class : ANSI 300 Size : 4" DN	15	No		12,300	1,84,500
Valve	Type : Ball valve (Full bore) Class : ANSI 300 Size : 6" DN	2	No		26,250	52,500
Valve	Type : Ball valve (Full bore) Class : ANSI 300 Size : 8" DN	2	No		51,250	1,02,500
Valve	Type : Ball valve (Full bore) Class : ANSI 150 Size : 12" DN	8	No		90,500	7,24,000
Valve	Type : Ball valve (Full bore) Class : ANSI 300 Size : 1/2" DN	51	No		13,000	66,300
Valve	Type : Ball valve (Full bore) Class : ANSI 300 Size : 1" DN	15	No		31,000	4,65,000
Safety Relief valve	Type : Spring Loaded Class : ANSI 300 Size : 1" DN	1	No		46,500	46,500
Safety Relief valve	Type : Spring Loaded Class : ANSI 150 Size : 1" DN	1	No		42,300	42,300
Non-Return valve	Type : Check Valve Class : ANSI 150 Size : 12" DN	1	No		1,44,100	1,44,100
Liquid Separator	Type :Liquid Separator Class : ANSI 150 Size : 12" DN Capacity :12 mmscfd at 80 psig with max 100 mbar pressure drop	1	No		6,89,700	6,89,700
					Sub total (b)	**25,17,400**

Table 8.1: Cost Estimation of RMS Materials (Contôd)

Item Name	Specifications	Overall material		Local	Foreign	Total Price (Taka)
		Quantity	Unit	Unit Price (Taka)	Unit Price (Taka)	
Filter Separator	Type :Liquid Separator Class : ANSI 300 Size : 4" DN Capacity :12 mmscfd at 80 psig with max 100 mbar pressure drop	2	No		5,97,700	11,95,400
Heater	Type :Water Bath, Heat duty :100 KW, Class : ANSI 300 , Connections :Flanged 4"x4" DN Pressure range: Upto 1460 psig,	1	No		24,14,000	24,14,000
Mechanical Chart Recorder	2 (Two) Pen, Pressure Range:0~100 Psig, Temperature Range:0~150 F	1	No		51,350	51,350
Gas Flow Computer (FC)	Multi-stream	1	No		17,41,000	17,41,000
Gas Chromatography (GC)	On Line gas Chromatography	1	No		41,79,000	41,79,000
Pressure Gauge	Type : Bourdon Tube Connection Size : 1/2" NPT-M Pressure range : 0-600 psig Dial Size :150 mm	19	No		1,900	36,100
Pressure Gauge	Type : Bourdon Tube Connection Size : 1/2" NPT-M Pressure range : 0-400 psig Dial Size :150 mm	3	No		1,800	5,400
					Sub total (c)	**96,22,250**

Table 8.1: Cost Estimation of RMS Materials (Contôd)

Item Name	Specifications	Overall material		Local	Foreign	Total Price (Taka)
		Quantity	Unit	Unit Price (Taka)	Unit Price (Taka)	
Pressure Gauge	Type : Bourdon Tube Connection Size : 1/2" NPT-M Pressure range : 0-100 psig Dial Size :150 mm	4	No		1,850	7,400
Temperature Gauge with Thermo well	Connection Size : 3/4" NTP(M) Range : 0-150 F Dial Size : 100 mm	3	No		2,500	7,500
Thermo-well	Type : TXC Connection Size : 3/4" NPT-M U-Length : 10"	1	No		900	900
Insulating Joint (IJ)	Class : ANSI 300, Size : 4" DN	1	No		15,600	15,600
Insulating Joint (IJ)	Class : ANSI 150, Size : 12" DN	1	No		38,000	38,000
Reducer	Sch-40 Size : 4"x3"	17	No		500	8,500
Reducer	Sch-40 Size : 4"x2"	2	No		700	1,400
Reducer	Sch-40 Size : 3"x2"	2	No		500	1,000
Reducer	Sch-40 Size : 6"x4"	4	No		800	3,200
Reducer	Sch-40 Size : 6"x3"	2	No		750	1,500
Reducer	Sch-40 Size : 8"x6"	2	No		1,000	2,000
Reducer	Sch-40 Size : 8"x3"	2	No		1,200	2,400
Reducer	Sch-40 Size : 12"x8"	2	No		1,500	3,000
Equal Tee	Sch-40 Size : 4"x4"x4"	9	No		600	5,400
Equal Tee	Sch-40 Size : 6"x6"x6"	2	No		1,500	3,000
Equal Tee	Sch-40 Size : 12"x12"x12"	5	No		5,000	25,000
Elbow	Sch-40 Size : 4"x 90	14	No		500	7,000
Elbow	Sch-40 Size : 6"x90	2	No		1,000	2,000
Elbow	Sch-40 Size: 12"x90	2	No		7,000	14,000
					Sub total (d)	**1,46,800**

Table 8.1: Cost Estimation of RMS Materials (Contôd)

Item Name	Specifications	Overall material		Local	Foreign	Total Price (Taka)
		Quantity	Unit	Unit Price (Taka)	Unit Price (Taka)	
W/N Flange (RF)	Class: ANSI 300 Size : 4"	41	No		2,100	86,100
W/N Flange (RF)	Class: ANSI 300 Size : 3"	12	No		700	8,400
W/N Flange (RF)	Class: ANSI 300 Size : 2"	8	No		500	4,000
W/N Flange (RF)	Class: ANSI 300 Size : 6"	4	No		2,500	10,000
W/N Flange (RF)	Class: ANSI 300 Size : 8"	4	No		5,000	20,000
W/N Flange (RF)	Class: ANSI 150 Size : 12"	24	No		10,000	2,40,000
12" M.S Seamless Pipe	API 5L G-B	30	Meter	32,300		9,69,000
8" M.S Seamless Pipe	API 5L G-B	5	Meter	29,000		1,45,000
6" M.S Seamless Pipe	API 5L G-B	20	Meter	2,100		42,000
4" M.S Seamless Pipe	API 5L G-B	35	Meter	1,200		42,000
3" M.S Seamless Pipe	API 5L G-B	5	Meter	1,150		5,750
2" M.S Seamless Pipe	API 5L G-B	2	Meter	700		1,400
4" Gasket	ANSI 300	41	No	200		8,200
3" Gasket	ANSI 300	12	No	170		2,040
2" Gasket	ANSI 300	8	No	150		1,200
6" Gasket	ANSI 300	4	No	400		1,600
8" Gasket	ANSI 300	4	No	500		2,000
12" Gasket	ANSI 150	24	No	1,000		24,000
1/2" MS Nipple	Pressure rating :Upto 3000 psig	51	No	100		51,000
1" MS Nipple	Pressure rating :Upto 3000 psig	15	No	100		15,000
Plug & Socket 1"	Pressure rating :Upto 3000 psig	15	No	200		3,000
Plug & Socket 3/4ò	Pressure rating :Upto 3000 psig	4	No	200		2,000
					Sub total (e)	**14,10,690**

Table 8.1: Cost Estimation of RMS Materials (Contôd)

Item Name	Specifications	Overall material		Local	Foreign	Total Price (Taka)
		Quantity	Unit	Unit Price	Unit Price	
Plug & Socket 1/2"	Pressure rating :Upto 3000 psig	51	No	50		2,550
SS Fittings 1/2" NPT x 3/8" OD	Pressure rating :Upto 3000 psig	26	No	2,000		52,000
SS Fittings 1/4" NPT x 3/8" OD	Pressure rating :Upto 3000 psig	26	No	1,100		28,600
Sensing Tube SS 3/8 "	Pressure rating :Upto 3000 psig	60	Meter	50		3,000
Stud bolt & Nuts 7/8"x6(1/4)"	Pressure rating :Upto 3000 psig	196	No	200		39,200
Stud bolt & Nuts 7/8"x5(1/2)"	Pressure rating :Upto 3000 psig	80	No	110		8,800
Stud bolt & Nuts 7/8"x4(1/2)"	Pressure rating :Upto 3000 psig	288	No	110		31,680
Stud bolt & Nuts 5/8"x4(1/2)"	Pressure rating :Upto 3000 psig	64	No	110		7,040
Stud bolt & Nuts (3/4)"x4(3/4)"	Pressure rating :Upto 3000 psig	48	No	110		5,280
Stud bolt & Nuts (3/4)"x4"	Pressure rating :Upto 3000 psig	64	No	110		7,040
Condensate tank	Capacity :500 Gallons	1	No	6,00,000		6,00,000
Sub total (f)						**7,85,140**
Sub total (a+b+c+d+e+f)						**1,81,73,680**

Item Name	Specifications	Overall material		Local	Foreign	Total Price (Taka)
		Quantity	Unit	Unit Price (Taka)	Unit Price (Taka)	
4" M.S Seamless Pipe	API 5L G-B	500	Meter	1,200		6,00,000
Total (RMS Materials Cost +Pipe Line Cost)						**1,87,73,680**

8.2 Land acquisition and requisition

Acquisition is the permanent possession of land. Eight meter wide strip land is required for the pipeline route. Pipeline is laid along the acquisition land. Requisition is the temporary possession of land for the construction period only. Fifteen meter wide strip at the other end of acquisition land and along the pipeline route is requisitioned. After completion of pipeline construction requisition land is handed over to the original land owner. Requisition land is used to provide working space for construction crew and equipments.

8.2.1 Land acquisition

The location of the proposed power plant RMS is at Sreepur in Gazipur district. A 0.5 km 4" DN ×500 psig pipe line can be constructed to transmit gas to the power plant (Appendix N). The RMS is in the premises of the power plant area. Fifty (50) decimals land is required for RMS and One hundred (100) decimals land is required for pipe line. Therefore, total one hundred fifty (150) decimals land should be acquisitioned. Cost of the land is Taka 1(one) Lakh per decimal. The cost of one hundred fifty (150) decimals of land has been considered at Taka 150 Lakh.

8.2.2 Land requisition

One hundred eighty five (185) decimals land is required for requisition for 0.5 km 4" DN pipe line. Cost of this land is Taka 716/decimal/year. For this project assumed one year construction period. The cost of One hundred eighty five (185) decimals of land is Taka 1,32,460 Lakh.

8.3 Costing of the project

The costing of this project is concerned with Pre construction expenditure, Construction cost, Equipment and materials cost, Transport and vehicles cost. The summary of the project costing is shown in Table 8.2.

Table 8.2: Capital Cost

SL No.	Description	Cost (Taka)		
		Local	Foreign	Total
1	Pre construction Expenditure			
	Land Acquisition	1,50,00,000	0.00	1,50,00,000
	Land Requisition	1,32,460	0.00	1,32,460
	Soil & subsurface investigation	20,000	0.00	20,000
	Survey	10,000	0.00	10,000
	EIA	20,000	0.00	20,000
	Engineering Design	100,000	0.00	100,000
2	Construction Cost			
	Civil construction	10,00,000	0.00	10,00,000
	Construction of pipeline & other facilities (500m @Tk 650)	3,25,000	0.00	3,25,000
	Installation & Fabrication	5,00,000	0.00	5,00,000
	Testing & Commissioning	46,500	0.00	46,500
3	Equipment & Materials Cost			
	Line Pipe	6,00,000	0.00	6,00,000
	RMS Equipment & Materials	18,27,330	1,63,46,350	1,81,73,680
	Pre-shipment inspection (1% of foreign cost)	0.00	163,464	163,464
	Landing (7 % of foreign cost)	0.00	11,44,245	11,44,245
	CD/VAT (45 %of foreign cost)	0.00	73,55,858	73,55,858
4	Supervision	3,60,000	0.00	3,60,000
			Total	44,951,207
			Adding 10 % Contingency	4,495,121
			Total Cost	49,446,328

(Note: Land acquisition and requisition cost have been calculated on the basis of TGTDCL rate and the quantity of land has been fixed as bare minimum base on the Natural Gas Safety rule 1991. Civil construction work have been prepared on the basis of PWD standard and rate. Cost of material and equipment have been calculated on the basis of TGTDCL rate.)

From the above estimation and calculation it is found that the total cost of the project is Taka 494.463 Lakh.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1. Conclusions

Based on the objectives of this project to design an ideal gas Regulating and Metering Station and cost estimation of the project, the following conclusions are made from this study.

- Gas flow capacity, maximum inlet pressure and outlet pressure of the RMS are 12 MMSCFD, 500 psig and 60 psig respectively for uninterrupted gas supply to the 50 MW power plant.
- In this project work, fluid characteristics, process data, gas safety rules, International codes and standards (ASTM, ASME ANSI, API) have been followed for proper design.
- All the equipments of Regulating and Metering station have been selected and arranged as per internationally recommended standards (IGE TD 9, AGA 7 and API) maintaining the entire requirements for filtering, regulating, metering to prevent various operational difficulties and measurement error.
- The pipe and fittings have been chosen in such a way that turbulence can be avoided or made minimum.
- Meter type and size have been selected considering variation of flow rate and pressure to measure the gas volume accurately because the revenue earning for the company is related to measurement.
- The RMS has been proposed to be well furnished with modern flow computer for gas measurement and online gas chromatograph for continuous gas analysis for smooth, quantitative and accurate measurement of gas flow.
- Variation in different variables such as inlet pressure, specific density, specific heat, compressibility factor and heating value within the allowable limit do not require any change in the proposed design.
- The cost estimation of the project has been calculated on the basis of preconstruction expenditure, construction cost, material cost etc. The total cost of the project is estimated as Tk. 494.463 Lakh.

9.2 Recommendations

- A Regulating and Metering station should be designed to meet the present and future demand under variable gas flow and pressure conditions and decreasing efficiency of the power plant.

- The RMS should be kept under a SCADA system for remote controlling of the system such as the valves, regulators and also for monitoring the status of flow rate and pressure for the case of operation as per international practice of the gas industry.

- After construction of the pipe line of RMS, cathodic protection (CP) system should be installed in the pipeline network and RMS for safe and leak free network in accordance with the requirements of British standard specification code BS CP 1021 or American National Association of Corrosion Engineers code RP 01-72.

- RMS equipments, piping and inlet outlet direction of gas flow should be painted as per colour coding of pipes and equipments.

- Before commissioning of the pipeline and RMS, both the pipeline and RMS should be tested by means of standard hydrostatic test for ensuring the safety and integrity of the pipeline and RMS.

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APPENDIX A : TERMINOLOGY

Active/Monitor Regulator - A regulator that is in service performing a control function.

Backpressure Regulator - This is a device that controls and responds to changes in its upstream/inlet pressure. Functions the same as a relief valve in that it opens on increasing upstream pressure.

British Thermal Unit (Btu) - The quantity of heat required to raise one pound of water from 59°F to 60°F.

C_1 - A term used in a sizing equation. It is defined as the ratio of the gas sizing coefficient and the liquid sizing coefficient and provides a numerical indicator of the valve's recovery capabilities.

Capacity, Flow - The amount of a specified fluid that will flow through a valve, specific length and configuration of tubing, a manifold, fitting, or other component at a specified pressure drop in a fixed period of time. (scfh, gpm, m^3/h(n), lpm, pph)

C_g (Flow Coefficient) - A term used in gas and steam valve sizing equations. The value of C_g is proportional to flow rate and is used to predict flow based on physical size or flow area.

Control Line - The external piping which connects the regulator actuator or pilot to the point on the main line where control is required.

Critical Flow - The rate at which a fluid flows through an orifice when the stream velocity at the orifice is equal to the velocity of sound in the fluid. Under such conditions, the rate of flow may be increased by an increase in upstream pressure, but it will not be affected by a decrease in downstream pressure. Critical flow occurs when P_2 is approximately 1/2 of P_1.

Critical Velocity - The velocity at critical flow. Also called sonic velocity.

.

Downstream - Any site beyond a reference point (often a valve or regulator) in the direction of fluid flow.

Hunting - A condition where a regulator's outlet pressure slowly fluctuates on either side of a set point.

Lockup Pressure - Increase over set point when the regulator is at no-flow condition.

m^3/h(n) - meters cubed per hour (normal); measurement of volume rate of a gas at atmospheric pressure and 0°C.

m^3/h(s) - meters cubed per hour (standard); measurement of volume rate of a gas at atmospheric pressure and 60°F.

Monitor: A general term for an instrument used to sense the magnitude or status of one or more variable.

Maximum Allowable Operating Pressure (MAOP) - The maximum pressure that the system may be operated at as determined by its components, taking into account function and a factor of safety based on yield of parts or fracture.

Pilot (Amplifier) - A relatively small controlling regulator which operates the main regulator. They are used to increase accuracy.

Pressure Reducing Regulator - A valve that satisfies downstream demand while maintaining a constant reduced pressure. As the pressure decreases, the valve opens to increase flow.

PSIA - pounds per square inch, absolute - The pressure above a perfect vacuum, calculated from the sum of the pressure gauge reading and the (local or ambient) atmospheric pressure (Approximately 14.7).

PSIG - Pounds per square inch, gauge. The pressure above atmospheric pressure. Near sea level the atmospheric pressure is approximately 14.7 pounds per square inch.

Rangeability - The ratio of maximum rated capacity to the minimum controllable flow within the specified accuracy band.

Repeatability: Repeatability is a meterôs ability to replicate the same reading each time, given that the same flow conditions exist.

Retention time: The amount of time a liquid stays in a vessel is called retention time. The retention time assures that equilibrium between the liquid and gas has been reached at separator pressure. The retention time in a separator is determined by dividing the liquid volume inside the vessel by the liquid flow rate.

Set point: An input variable that determines the value of the output variable.

Standard Pressure: The standard base pressure is generally recognized as 14.73 psia or 1.0136 Bara.

Standard Temperature: The standard base temperature is generally recognized as 60 degrees F or 15.5556 ^{o}C or 520 degree Rankine.

SCADA : Supervisory Control and Data Acquisition system is the overall system ï the combination of software and hardware.

Sonic Velocity - The speed of sound for a particular gas at a given inlet pressure and temperature.

Transducer: A device that receives information in the form of one or more physical quantities and converts the information and produces an output signal.

Transmitter: A device that responds to a process variable through a sensor and has an output, which varies in relation to the process variable.

Vent - An opening in the regulator spring case to allow atmospheric pressure access to the diaphragm, thus allowing free movement of the diaphragm during operation.

A piping and instrumentation diagram- A piping and instrumentation diagram/drawing (P&ID) is a diagram in the process industry which shows the piping of the process flow together with the installed equipment and instrumentation.

APPENDIX B : CODE AND STANDARDS

Gas Regulating and Metering Station designed and manufactured in accordance with the latest edition of the following Codes and Standards :

a) Mechanical :

Equipment will generally be mechanically designed in accordance with the relevant Institute of Gas Engineers (IGE) codes and the following principal codes of practice:

IGE Codes :

IGE/TD/9, IGE/GM/1.

ASME

Section V : Non-destructive Examination
Section VIII : Pressure Vessels, Div. 1
Section IX : Welding and Brazing Qualifications

ANSI

ANSI B.16.5 : Flanges and Flanged Fittings

ANSI B.31.8 : Gas transmission and distribution piping system

API

API RP 1104 : Welding Specifications
API RP 520 : Parts 1& 2 Design and Installation of pressure Reliving Systems in Refineries
API RP 521 : Guide for pressure relief and depressurizing Systems
API 5L : line pipes
API 6D : Pipeline Valves

ASTM

ASTM A 36 : Structural Steel
ASTM A 106 : Seamless Carbon Steel Pipe
ASTM A 105 : Forging, Carbon Steel for Piping Components
ASTM A 435 : Straight Beam Ultrasonic Examination of Steel Plates for Pressure Vessels

b) Instrumentation :

Instrumentation will generally be in accordance with the applicable section of the following principal codes of practice:

AGA Report No 3 : Orifice metering
AGA Report No 7 : Turbine metering
AGA Report No 8 : Super compressibility compensation
ISA A 5.1 : Instrument Symbols and Identification
API RP 550 : Manual on Installation of Refinery Instrument Control System
API RP 521 : Guide for Pressure Relief and Depressing System
BS 1041 : Code for Temperature Measurement.
BS 1042 : Method for Measurement of Fluid in pipes.
BS 1259 : Intrinsically safe Electrical Apparatus and Circuits.
BS 5345 : Part- 1; Section, Installation and Maintenance of Electrical Apparatus & circuits.
BS 5490 : Specification for degree of protection provided by enclosures.
BS 5501 : Part 1, Electrical apparatus for potentially explosive atmospheres.
BS 2765 : Thermo well.
BS 4161 : Gas Meters.

c) Electrical

I.E.C. : International Electro technical Committee

d). Civil Engineering

Civil design will be performed in accordance with British Standard and Bangladesh Regulations.

APPENDIX C : GAS COMPOSITION ANALYSIS REPORT

Table C.1: Composition analysis report

Components	% Mole	% Wt
Nitrogen	: 0.356	0.592
Carbon dioxide	: 0.236	0.617
Methane	: 96.241	91.577
Ethane	: 2.202	3.928
Propane	: 0.464	1.215
i-Butane	: 0.173	0.596
n- Butane	: 0.086	0.296
i-Pentane	: 0.052	0.224
n-Pentane	: 0.036	0.153
Hexane	: 0.090	0.448
Heptane+	: 0.062	0.354
Total	100	100
Molecular weight	: 16.860 gm/mol	
Specific gravity (Air =01)	: 0.582	
Density at std. condition	: 0.7132 kg/m3	
Higher Heating value	:1043.4991 BTU/SCF	
Lower Heating value	: 915.7936 BTU/SCF	

(Source: Department of Petroleum and Mineral Resources Engineering, BUET, Dhaka)

APPENDIX D : GAS GENERATOR DATA SHEET

Table D.1: Gas Engine Technical Data Sheet

Particulars	Value	Units
Engine mechanical output	8660	KW
Generator electrical output	8425	KW
Thermal overall efficiency	42	%
Generator efficiency	97.3	%
Specific energy consumption	7590	KJ/Kwh+5%
Lower heating value (LHV) of Fuel	36.0	MJ/Nm^3
Generator power factor	0.8	
Exhaust gas emission, NO_2 , level at 5% O_2	500	$mg/\ Nm^3$
Exhaust gas temperature	415	^0C
Minimum gas feed pressure to Engine inlet	50	Psig
Gas feed temperature to Engine inlet	20	^0C

Fuel type : Natural gas

Gas feed quality to Engine inlet: Clean and dry gas without any free droplets of moisture and particle size normal 5 micron.

Mole percent of methane: 70%

(Source: Rolls-Royce, 2006)

APPENDIX E : UNIT CONVERSION

Table E.1: Unit conversion

Particulars	Relation	Remarks
1 barg	14.505 psig	
1 atm	14.73 Psig	
14.73 Psig	101.560 KPa	
1 Kg	14.22 Psig	
14.22 Psig	2.2046 lb	
1 Barrel	42 Gallons	
1 Gallon	3.8 Litres	
1 Nm^3	37.32566 Nf^3	
1 sm^3	35.3147 sf^3	
1 Btu	1055 Joules	
1 Btu	0.252 Kilocalories	
1 Joule	0.00024 Kilocalories	
1 meter	3.0487 feet	
1 feet	0.328 Meter	
1 hector	0.01 Square Kilometer	
1 Acre	0.0040469 Square Kilometer	

APPENDIX F : G-RATING FOR TURBINE METER

Pipe Size			Measurement Range (m^3/h)	High Frequency	2 x Low Frequency	Overall Length	Pressure Rating
mm	inch	G-rating	Qmin-Qmax	(Hz)	(Pulse/m^3)	(mm)	
50	2"	G40	13-65	200-400	10	150	ANSI 150 DIN PN 10/16
		G65	10-100		10		
		G100	16-160		1		
80	3"	G100	16-160	200-300	1	240	ANSI 150 DIN PN 10/16
		G160	25-250		1		
		G250	20-400		1		
		G400	32-650				
100	4"	G160	25-250	200-300	1	300	ANSI 150 DIN PN 10/16
		G250	20-400		1		
		G400	32-650		1		
		G650	50-1000		1		
150	6"	G400	32-650	100-200	1	450	ANSI 150 DIN PN 10/16
		G650	50-100		1		
		G1000	80-1600		0.1		
		G1600	130-2500		0.1		
200	8"	G650	50-1000	75-150	0.1	600	ANSI 150 DIN PN 10/16
		G1000	80-1600		0.1		
		G1600	130-2500		0.1		
		G2500	200-4000		0.1		
250	10"	G1000	80-1600	75-150	0.1	600	ANSI 150 DIN PN 10/16
		G1600	130-2500		0.1		
		G2500	200-4000		0.1		
		G4000	320-6500		0.1		
300	12"	G1600	130-2500	75-150	0.1	600	ANSI 150 DIN PN 10/16
		G2500	200-4000		0.1		
		G4000	320-6500		0.1		
		G6500	500-10000		0.1		

(Source: Instromet, 2001)

APPENDIX G : TURN DOWN RATIO

Table G.1: The turn down ratio of RMS Equipments.

Equipment Name	Turn down ratio	Remarks
Turbine meter	20:1	As per AGA report 7
Orifice meter	3:1	As per AGA report 3
Regulator	5:1, 4:1,3:1	As per Catalogue
Filter Separator	5:1	As per Catalogue
Liquid Separator	5:1	As per Catalogue
RMS	12:1.8	As per maximum and minimum flow rate
Power Plant Generator Bank	6:1	As per gas consumption of the power plant

(Source: AGA report 3 and 7, Fisher Control, Rolls-Royce, Shanghai Fiorentini)

APPENDIX H : PIPE SCHEDULE

Add three inches to the actual inside diameter; divide this by the wall thickness; the schedule number can then be identified by the following Table H.1

Table H.1: Pipe Schedule

Pipe Schedule	Calculated value	Remarks
30	40 to 50	
40	29 to 39	
60	25 to 29	
80	20 to 23	
100	16 to 18	
120	13 to 15	
140	11 to 13	
160	9 to 11	

(Source: Mc.Allister, E.W,1998, Pipe Line Rules of Thumb Handbook)

APPENDIX I : PRESSURE RATING FOR VALVE, REGULATOR AND FITTINGS

Table I.1: Pressure Rating

Class	PN	
	Bar	Psi
150	20	290
300	50	725
400	64	928
600	100	1450
900	150	2176
1500	250	3626
2500	420	6092

PN = Nominal Pressure

(Source: API Specification 6D, 1994)

APPENDIX J : GAS CAPACITY OF SEPARATOR

The Separator size can be selected by using the following Figure J.1

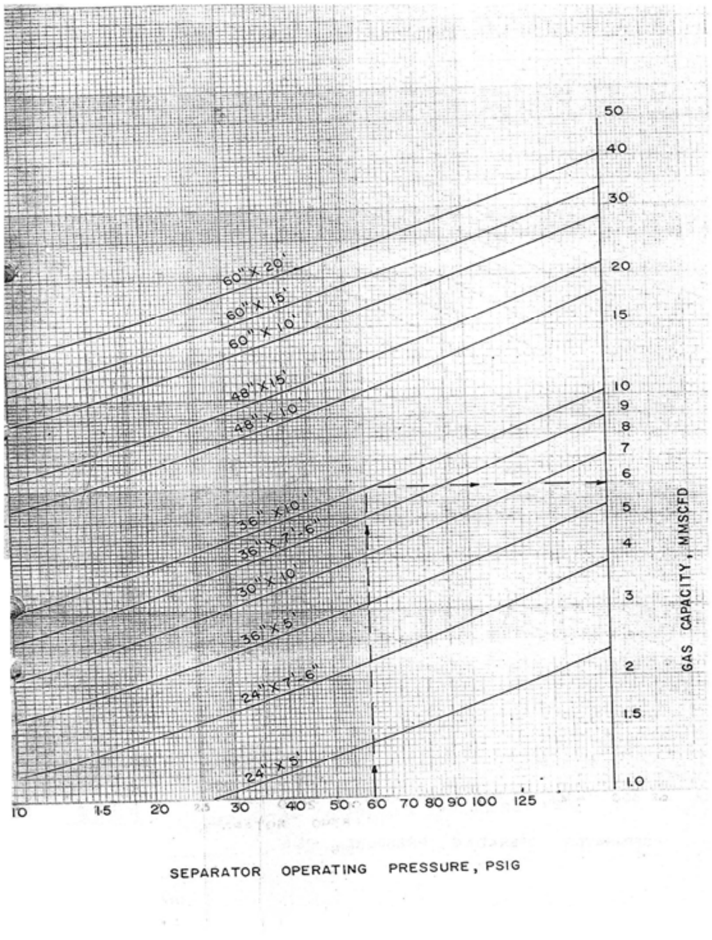

Figure J.1: Gas capacity of vertical L.P. Separator

(Source: C. Richard Sivalls, P.E, 1987)

APPENDIX K : SETTLING VOLUME OF VERTICAL SEPARATOR

The settling volume of vertical separator can be determined by the following Table K.1

Table K.1: Pipe Schedule

Sl No.	Vertical Separator Size (Diameter x Height)	Settling volume, bbl
1	24 inch x 5 ft	0.65
2	24 inch x 7.5 ft	1.01
3	30 inch x 10 ft	2.06
4	36 inch x 5 ft	1.61
5	36 inch x 7.5 ft	2.43
6	36 inch x 10 ft	3.04
7	48 inch x 10 ft	5.67
8	48 inch x 15 ft	7.86
9	60 inch x 10 ft	9.23
10	60 inch x 15 ft	12.65
11	60 inch x 20 ft	15.51

(Source: C. Richard Sivalls, P.E, 1987)

APPENDIX L : STANDARD VALUES FOR NOISE

The Environmental Quality Standards for Bangladesh (DoE, 1991) have been set noise guide noise for industrial sites in Bangladesh. According to standard, noise level should not exceed 75 dBA in the daytime and 70 dBA at night.

Table L1 : Standard Values for Noise

Area Category	**Unit**	**Standard Valve**	
		Day Time	**Night Time**
A	dBA	45	35
B	dBA	50	40
C	dBA	60	50
D	dBA	70	60
E	dBA	75	70

(Source: DoE Report,1991)

APPENDIX M: MATERIAL SYMBOLS

APPENDIX N: COLOUR CODING OF PIPES AND EQUIPMENTS

Table N.1: COLOUR CODING OF PIPES AND EQUIPMENTS

A)	**Transmission Line Block Valve Assay**			**Colour**
	1	Above ground valves	:	Signal Red
	2	Above ground pipes	:	White Enamel (Epoxy)
	3	Valves Handle	:	Black
B)	**Metering and Regulating Stations**			
	1	Inlet Valves	:	Signal Red
	2	By pass Valve	:	Signal Red
	3	Sensing/Impulse Valve	:	Signal Red
	4	Drain Valves	:	Bright yellow
	5	Vent Valves	:	Bright yellow
	6	Outlet Valves	:	Azure Blue
	7	Regulators/Meters	:	Gray
	8	Skid	:	Black
	9	Pipes	:	Aluminium
	10	Instrument Air Pipes	:	Rose
	11	Vessels (Scruber/Heater)	:	Aluminium/Gray

(Source: Planning Department, TGTDCL, Dhaka)

APPENDIX O

(Source: TGTDCL Annual Report, 2007-2008)