BASICS OF HIGH PRESSURE MEASURING AND REGULATING STATION DESIGN
Class #1010.1

Thomas G. Quine
President
Northstar Industries, LLC
126 Merrimack Street
Methuen, MA 01844

INTRODUCTION

This presentation is intended to illustrate the recommended steps for implementation of successful projects; from preliminary engineering to project data books and commissioning. In addition, the key components and ideal P&ID are reviewed in detail to define the technical components of M&R facilities. These principles can be applied to measurement and control projects, LNG projects, and LPG projects.

When considering current design practices for M&R facilities, it is useful to view the current drivers in the industry, which can then be viewed on an annual basis. For example, a resurgence of gas fired generation is predicted along with a continued emphasis on bi-direction facilities between major pipes.

The strategy presented involves the following disciplines: performing through preliminary engineering, performing final design, procurement, the qualification of installers, construction, testing, commissioning, training and documentation.

This presentation focuses on the following items:

- Developing a project perspective
- Establishing a sound baseline from which to proceed
- Examples of actual designs
- Typical design deliverables
- Conclusion

DEVELOPING A PROJECT PERSPECTIVE

In order for an employee to properly understand the process of implementing successful projects in the gas distribution and transmission area, it is important to place this process in the context of six – sometimes conflicting – areas, which are:

- **Codes and Standards**
- **Sound Engineering Practice**
- **Company Practice**
- **Community Standards**
- **Permitting Requirements**
- **Departmental Interactions**

Codes and Standards

Relevant codes and standards must be understood and applied to the process. For example, Title 49 CFR, Section 192 instructs the natural gas engineer in the decision making and design processes. The engineer must become the company expert in these matters and take responsibility for interpreting these codes.

Sound Engineering Practices

It's incumbent on the project manager or engineer to base all calculations and assumptions on accepted engineering practices. This means that the system in place is analyzed by the accepted formulas and methods. In matters of uncertainty, the engineer is encouraged to seek advice and reach solutions based on a solid foundation of well documented engineering. In this way the engineer participates as a team member, and helps refine the process.

Local Community Standards

The design must meet local conditions for frost, wind, snow, and rain. It must also meet community and customer standards for noise, aesthetics, building codes and gas characteristics.

Company or Industry Standards and Practices

Current practice should be applied so as to give the design consistent appearance. If company standards are not being applied, the engineer should become a training resource in clarifying the standards to operating personnel. If standards are not adequate, the engineer should take a leadership role in fixing them.

Permitting and Work Requirements

Often restrictions are placed on operating companies by permitting agencies that are unplanned and unbudgeted. Typically, these permits involve environmental construction standards, OSHA requirements, emission requirements, noise requirements, and mechanisms for extra work on contracts.

Understanding Company Interdepartmental Interactions

It is critical for the successful engineer to fully understand and appreciate the company's method of justifying and adding new customers during the course of day to day operations.

Too often, departments within companies conflict regarding department needs:

- **The Executive Group** is balancing stockholder, employees, the Board of Directors, and customers.
- **The Business/Marketing Group** is charged with processing new requests for interconnects and negotiating the Interconnect Agreements.
- **The Engineering Department** is mandated to estimate costs, design safe systems, specify installation of facilities and support other areas as needed.
- **The Service Department** has many service calls, meter exchanges, and installations to balance.
- **The Distribution Department** is maintaining and installing depending on daily needs.
- **The Corrosion Department** is protecting the integrity of the system.
- **The Gas Supply and Production Group** is balancing firm, best offers, and dual fuel loads, peak shaving transportation and order 636.
- **The Measurement and Control Group** is balancing accuracy, safety and cost.
- **The Financial Group** is processing invoices and ordering new equipment, billing and bottom line budget.

Clearly, there are many conflicting interests within the company itself that make the design and implementation process even more challenging. Each department has a unique role that, when property administered, can be a vital resource to the company.

DEVELOPING DESIGN CRITERIA

General

In order to accomplish a project, the company must apply a sound methodology to the problem. Design criteria must be established, codes and standards need to be applied, calculations must be made, cost effective equipment must be selected, a project must be designed in its entirety and qualified installers must be instructed on what to do by means of drawings and specifications. After installation, the facility must be operated and maintained properly with the engineers support and company personnel.

Companies often make the mistake of processing gas requests from the office, thereby isolating themselves from the customer.

The best marketing tool is often a well-informed team set up to meet the client's needs. The engineer should make an appointment with the marketing representative from the gas company and visit the new customer's facility.

The following design criteria need to be estimated before beginning final design:

1. What is the customer's name and address and who is the site engineer?
2. Who is the manufacturer of the equipment items and what is the input rating of each piece of equipment?
3. What is the minimum and maximum flow rate of the new load?
4. What is the required gas pressure for each piece of equipment?
5. What is the MAOP of the burner train or service regulator?
6. Is there a gas or electric pilot?
7. What is the MAOP of the distribution system feeding the facility?
8. What is the minimum and maximum pressure that can be expected during design load?
9. What is the minimum and maximum that can be expected for the load?
10. Based on the MAOP, what ANSI rating or flanges are required?
11. What grade and wall thickness of pipe is required?
12. What method of regulation is appropriate?
13. What type of overpressure is required?
14. Is preheating required?
15. If yes, how many BTU's?
16. Will this location be part of the SCADA system?
17. What type of isolation valves is required?
18. Does the customer have any unusual aesthetic or noise concerns?
19. Is filtering required?
20. What is the maximum velocity of the gas pipe?
21. What are the cathodic protection requirements?
22. What is the actual cost of the project?
23. Is it economically justified?

After answering as many questions as possible about the design criteria and becoming familiar with applicable codes and standards, the engineer must complete the design by sizing the pipe, selecting and sizing metering and regulation devices, and selecting the method of overpressure protection.

The American Gas Association provides excellent guidelines to the gas engineer in selecting measurement devices and designing their piping configurations for optimum design.

It is incumbent upon the engineer to utilize all existing resources for information on design.

Performance curves and sizing calculations must be reviewed in making the proper choice for pressure and flow control and overpressure protection devices.

Industry Accepted Options for Metering

Diaphragm – Displacement
Rotary – Displacement
Turbine – Inferential
Orifice – Inferential
Ultrasonic - Inferential

Industry Accepted Options for Regulating

Self Operating
Pilot Operating
Control valve with Pneumatic Controllers
Control Valves split range control

Industry Accepted Options for Overpressure Protection

Wide Open Monitor
Working Monitor
Shutoff Valve
Internal relief
Separate Relief Devices

Having completed all of the above, the design criterion for the project is completed. It is then likely that the customer's input will be needed on several occasions, and the local building inspector may need to offer clarification on certain particulars.

At this point, customer personnel should have given their input as to what features they would like to see in the new design, and pertinent company standards and O&M procedures have been reviewed and applied to the job. The corrosion department has been consulted, and the impact that the gas supply system will sustain from the load has been evaluated. All AGA practices on metering/regulating and purging of new systems have been reviewed, and all the relevant codes applied. The calculations for pressure drop, stresses, and equipment sizing are complete and in a permanent file. At this time, it is now important to help the purchasing department by preparing accurate data sheets for acquiring necessary equipment for a project.

The engineer must then communicate the fabrication and installation details of the system in drawings and written, technical specifications. These specifications should include a qualified welding procedure and X-ray, or other non-destructive testing requirements. Details on pressure testing and special installation requirements on equipment should also be included in the specifications

A request for as-built drawings and records of the test can be made at this point.

The site plan allows for proper separation and access, and the piping and instrumentation diagram demonstrates redundancy, ease of maintenance and operations, and overpressure protection.

- A firm or interruptible gas supply must be available and a tap point along an existing pipeline must be developed.
- A natural gas pipeline must deliver gas to the facility.
- Gas filtering must take place.
- Custody transfer metering must take place.
- Cathodic protection facilities must be incorporated in the design.

At least two sites must be developed for the project.

A. The side tap location

B. The custody transfer measurement and control site feeding the facility.

(In some cases, the metering area is located at the side tap area).

Codes and Standards

The design should be in compliance with the following:

Title 49, Part 192	Minimum Safety Standards for Gas Lines
ANSI B16.5	Steel Pipe Fittings
ANSI B16.11	Forged Steel Fittings, Socket Welding & Threaded Fittings
ANSI Z223.1	National Fuel Gas Code
API 5L	Specification for Line Pipe
API 6D	Specification for Pipeline Valves
API 1104	Welding of Pipelines and Related Facilities
ASME B31.3	Chemical Plant & Petroleum Refinery Piping
ASME B31.8	Gas Transmission & Distribution Piping Systems
ASME Section VII	Boiler and Pressure vessel Code
NEMA ICS 1	Industrial Controls
NEMA ICS 6	Enclosures for Industrial Controls
NFPA 70	National Electric Code
	Local Building Codes

Code Highlights (49 CFR Section 192)

Materials

The subpart instructs the engineer that the steel pipe is qualified for use only if it was manufactured with a listed specification.

API standard 5L is an approved specification for steel pipe which allows the engineer to review in a cookbook fashion the specific grade, well thickness, length, end type, and testing and documentation requirements as well.

Subpart B also instructs the engineer that each length of pipe, valve, fitting and component must be marked by the manufacturer to indicate size, materials, manufacturer, pressure rating, temperature rating, type, grade and model. Technical specification for steel pipe can easily be put together using API-5L.

Pipe Design

This subpart instructs the engineer of how to calculate for required wall thickness and grade of pipe for a particular application.

Design of Pipeline Components

This part informs the engineer that the only qualified components can be used in design 1. For example: API-6D qualified valves must be utilized and ANSI or MSS-SP-44 flanges incorporated as well. The standards enable the engineer to write specifications for pipeline components.

Welding of Steel in Pipelines

This section of DOT 192 requires companies to have qualified welding procedures as a part of its permanent O&M. It also describes qualifying individual welders to work with your procedure according to API 1104.

Customer Meters, Service Regulations and Service Lines

Subpart H instructs the engineer on the allowable location and required protection of meter sets.

In order to properly design, a thorough understanding of code requirements is necessary. It is recommended that a design manual be implemented in order to ensure that all steps are covered and consistent design is occurring.

Civil/Structural Design

Each site will be designed to allow for required building separation and yard piping for proper drainage. Grading design will be carried out from topographical survey information. Finished elevations and slopes will be coordinated with plant personnel in order to maintain consistency at the site.

Boreholes may be required to determine sub surface geotechnical conditions. These borings are included in the engineering scope of work. Foundation design will be based upon the results of this investigation. The buildings will be supported on grade beams with spread footings or standard foundations.

The boiler buildings and gas regulation building can be of the prefabricated type. The regulator building will feature skylights that will act as relief panels in the event of a major leak or explosion. The location of the buildings would be typically shown on the conceptual layout. The spacing between buildings will allow good accessibility around the site, will meet area classification requirements for electrical designation, and will provide an adequate distance for protecting of each building from adjacent buildings for fire rating purposes.

Mechanical/Piping

All gas piping will be designed for the pressure rating and noise characteristics desired. Flanges will be ANSI rated for the intended service. The general arrangement of valves and piping will allow good access for adjustment and maintenance purposes. Gas can first pass through a filter to minimize containment of abrasion during the meter's and regulator's service life. Prior to regulation at the site, the gas stream will first be metered then heated in a shell and tube heat exchanger. The heat transfer medium will be a water/glycol mixture that has been heated by a boiler. The water/glycol flow rate will be controlled so that gas discharge from the station will be a nominal temperature required.

Gas regulation will be carried out via two redundant pairs arranged in parallel. Gas will first pass through a wide open ball valve configured as a monitor regulator. The attached operator will move the ball valve to the appropriate controlling position to maintain regulation should a failure occur to the main regulator that is regularly located immediately downstream. The main gas regulator will be normally controlled to the proper pressure. The regulators will be sized such that each one can pass the maximum station flow at an inlet pressure and a design discharge pressure. The parallel regulator pipes will be stacked one above the other, side by side. Each run can be isolated and vented to permit servicing of valves and instruments. Before entering the pipeline, the gas will pass through the station isolation valve.

Custody Transfer Metering

There are two portions of gas measurement that must be considered in order to obtain accurate custody transfer metering. There is volumetric measure of natural gas, which is compressible fluid, and there is energy content of natural gas in British Thermal Units. It is known from Charles Law and Boyles Law that the pressure and temperature of the gas determines the number of molecules of gas in a cubic foot. Because of this fact, the concept of a standard cubic foot was developed in order to convert the amount of gas being transferred to a common base value. Most people consider the base condition to be atmospheric pressure at a temperature of 60ºF. As pressure increases, the amount of molecules in the standard cubic foot increases. As temperature decreased, the amount of molecules increases. To further complicate matters, natural gas is not an ideal gas. It has been determined that, as pressure increases, gas behaves in a manner such that it compresses more than expected. The concept of super compressibility was created to describe this phenomenon. The American Gas Association has published a great deal of detailed data to guide the engineer to the proper calculation of these factors. It is generally recognized that in order to properly calculate the super compressibility of gas, a flow computer is required as well as the gas properties.

Constituents such as CO_2, N_2, specific gravity and BTU ate commonly input into flow computers for real time calculating.

Energy Content (Therm Billing)

At its inception, natural gas energy content was less important to custody transfer applications than the amount of cubic feet that were delivered. Gas is commonly delivered between 1000-13000 BTU's per cubic foot in the United States. Over the last 20 years, the price of gas has increased in order of magnitude. Because of this concept the therm was introduced. As opposed to buying standard cubic feet, most pipeline corporations bill according to therms.

A therm is defined as 100,000 BTU's of energy.

In order to properly calculate the amount of BTU's per cubic feet, most people recognize that several constituents should be available, such as BTU, N_2, and CO_2 content of the gas.

This information can be obtained from a chromatograph or a therm titrator.

Shared Measurement

One definition of good measurement is a single meter that two parties agree upon.

In one example a single auto adjust signal is split after the SER by using a 7003NS splitter.

The splitter can handle the 0-1000HZ signal.

A high-speed input can receive the split signal and separate inputs for pressure, temperature, and gas composition that allows an RTU to perform a calculation for corrected volume.

Electrical Design

Electrical power design can be 120/240V, single phase, from a utility pole at the corner of the site. Buried conduit can be used to bring the power cable to the main panel in the data acquisition building and for all power control and instrument cable between buildings.

Electrical design for the regulating building should be for Class 1, Division 2, and Group D for 10 feet from the outside wall and Class 1, Division1, Group D inside each regulator and metering building. The data acquisition building and boiler building should be designed as non-hazardous areas.

Buried conduit design can be PVC coated rigid steel. Exposed conduit can be galvanized rigid steel. Buried gas piping should be designed with cathodic protection.

A ground grid system should be developed for the station. The system should be designed to tie in all buildings including all electrical equipment, motors, duct lines and station fence. The system design can consist of a grid of buried conductors with galvanized ground rods.

Area Classification Plan

A common error seen at many natural gas facilities is the misapplication of Section 500 of the National Electric Code. This section instructs the engineer in the appropriate electrical equipment and seals that should be utilized in various classified areas.

It is incumbent upon the engineer to classify these areas properly prior to proceeding with final design of the facility.

The location of non-hazardous equipment in Class I, Division I, or Division II areas would be considered a serious violation of the code.

The first step in any electrical design of a gas facility should be the creation of an area classification plan. Having developed this plan, the engineer can properly apply the requirements of Section 500 of NEC 70.

In addition to Section 500, the engineer would be aware of the application of Section 400 as it relates to intrinsically safe circuits. With the increased use of frequency output auto adjust turbine meters; the requirements of Section 400 are critical. The engineer is instructed to provide clearly labeled isolated circuits so as to prevent a surge on the "Safe" circuit.

Odorant Design

Odorization is performed by LDC's for two reasons: code compliance and public safety. The odorant injection into the gas stream is the only safety warning agent that the gas industry has to alarm the general public in the event of leaks. Tighter regulations, and increased litigation in recent years, have increasingly placed odorization in the spotlight.

No longer is it acceptable to simply odorize using differential-pressure-driven devices that do not provide remote SCADA monitoring of odorization system performance. Modern odorizers can provide 24-hour remote monitoring capabilities of both system performance and actual injection rate. It is critical to maintain consistent, adequate odorization throughout the distribution system in order to protect the public, ensure compliance and avoid costly litigation.

At the same time, it is also important (and code required) to design the system to prevent unnecessary odors and odor releases around the station.

Things to specify when designing an odorization system include:

- Size storage tank for maximum of one fill per year.
- Utilize ASME rated pressure vessels (Preferably ASME 250).
- Fill tanks directly from the bulk supplier's trailer or from pressurized DOT rated cylinders. Avoid transferring from drums- they are not pressure vessels!
- Tank connections should be all top connections and should include vapor connection, liquid fill connection, relief valve (with locking ball valve for isolation), liquid withdrawal dip tube, blanket pressure connection, and level indication (avoid site glasses; they can be source of leaks).
- Utilize good quality stainless steel valves, tubing and fittings.
- Minimize pipe thread connections and other potential sources of leaks.
- Select a pumping system with an integral odorant meter that provides real time measurement (temperature compensated!)
- Utilize a pump that prevents leakage should internal components fail and that will handle the entire range of flows through the station. Consider future load growth.
- Design tubing to allow for close loop purging and priming of all system tubing. Consider the use of filters, scrubbers, flares and vapor compressors when depressurizing for fills of maintenance.
- Select a system with a controller separate from the RTU or SCADA system.
- Utilize a controller that is Class I, Division I rated. System performance can then be noted while standing directly at the unit.
- Select a controller that in itself will provide information on odorant usage, pump performance, and real-time system conditions. The controller should communicate with the SCADA system to provide alarm information, instantaneous odorization rate, daily summaries of odorant injected, and remote shut off capabilities.
- Monitor many points in the distribution system continuously with distinct Odor Level Test to establish and ensure adequate injection rate.

Controls Design

The configuration can consist of meters for flow measurement, followed by heat exchanger and then parallel runs for pressure regulation.

The control design is based on a process controller mounted in a freestanding rack located in the data acquisitions building. This process controller will calculate the flow from the turbine meters. This controller will perform pressure or flow control as requested.

Design of the local operator interface with the process controller, including monitoring flow and assigning a set point for the working pressure regulator, will be via a keypad on the controller front or laptop for changing parameters.

The controller can be designed to monitor alarm conditions, including LEL, smoke/heat, and UV fire. The occurrence of any of these alarm conditions can be designed to illuminate a local visual device in the data acquisition building. The exact condition in alarm can be viewed locally or remotely.

The process controller will monitor the outlet temperature of the heater and position a temperature control valve via a control function to control the heater outlet temperature to an operator assignable set point. This function can also be performed with pneumatic temperature controller.

A plant instruction manual should include a section giving specific direction to the use of the operation of this installation.

The software to be provided and installed (by vendor) in the process controller should include capability for both custom programming and general take station control (M&R package). In general, the standard M&R will be used, unaltered, whenever possible.

The process controller hardware and software are intended to be suitable to allow this process controller to act as an RTU in a SCADA network. The process controller itself is furnished with an integral modem intended for dedicated phone line communication to the dispatch area or radio interface.

ENGINEERING DELIVERABLES

The following is a typical list of items, which are required in the installation of facilities in the natural gas industry.

- Drug and Alcohol Compliance
- Engineering Calculations
- Design Criteria
- Process Flow Diagram
- P&IDs
- Site Plot/Grading Plan (2)
- Foundation & Support Details (2)
- Yard Piping Plan & Details (2)
- Piping Plans & Elevations\
    - Regulator Building (1)
    - Heater Building (1)
    - Metering Building (1)
- Grounding, Conduit, Hazardous Area Plan (1)
- Electrical Arrangement & Conduit Plan (2)
- Cable Schedules, Routing, Terminations (4)
- Instrument Installation Details
- Final Instrument List
- Control System I/O List
- Process Controller Custom Operating Descriptions
- Final Configuration Software Printout
- Bill of Materials (2) Gas Glycol/Water
- Construction Specifications-Mechanical, Civil, Structural, Electrical, Controls
- Material/Instrumentation Data Sheets
- Installation Test Reports
- Cathodic Protection Details
- Operations Manual (1)
- Geotechnical Boreholes and report
- Civil, Cultural and Environmental Surveys
- Permit Applications and Adjudication
- As Built Drawings
- Electrical Power to Site
- Telephone to Site
- Permits
- Telephone Company Interface

CONCLUSION

One of the best marketing tools for a company is a successful team project.

In order to implement a successful project, the company must present a team that is able to provide an inexpensive, cost efficient, properly billed, reliable and safely delivered product. This can only be achieved by:

- **Marketing**
- **Engineering**
- **Gas Supply**
- **Production**
- **Service**
- **Measurement Control**
- **Corrosion**
- **Finance**
- **Inventory Control**
- **Administration**

All of these disciplines must understand their respective roles in this process.

The employee has the unique role of presenting himself or herself as a resource for the entire company to utilize, particularly in the area of evaluating options for growth.

It is incumbent upon the employee to understand and communicate his/her individual role in this process to further company success.

Ideas need to be expressed with positivity and boldness. It is important to remain available for consultation, and if the right answer is not on hand, always be prepared to get it. Listen to the input from operators of the equipment; valuable design input is readily available from them.

Listen to the needs of other departments, and especially the customers.

Express a willingness to be a company resource and personal success will be achieved. In the process, the company will achieve team success by adding new customers effectively and keeping the ones it already has.