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FLOW MEASUREMENT - THE NEXT TEN YEARS

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"To Accomplish Great Things, We Must Not Only Act But Also Dream, Not Only Plan But Also Believe." - Anatole France

1. GLOBAL OUTLOOK

The global economy, the political events in the Middle East, Eastern Europe, the European Community's (EC) unification, the Commonwealth of Independent States (CIS) and the USA's regulatory atmosphere continues to drive the energy industry. Until the global recession ends the demand growth in most industrialized nations will remain flat.

As a result, this decade will be the most challenging for the petroleum and natural gas industry. Though oil and gas remains among the world's biggest businesses, consolidations, restructuring, "rightsizing" and layoffs permeates the global community. The global recession has accelerated these changes, particularly in the upstream sector.

The requirements for success are challenging - a clear vision complemented by strategy, corporate structure and required systems (Figure 1). For mature industries, functional excellence and competitive cost leadership are goals required for survival.

Today even the best-managed companies are transforming their cost structures, and companies that fail to do likewise probably won't survive as independent companies. More consolidations can be expected in this decade for companies that do not adapt to the economic realities of a mature business.

For example, the effort to overcome the political, technical, and commercial obstacles for adequate energy supply to Eastern Europe and the CIS may pose one of the biggest entrepreneurial challenges of this century. Going or not going into these markets is a decision that could make or break global integrated companies.

The cultural differences, the lack of a free market infrastructure, the legal system and the political risks are significant issues. Protection of investment, free profit distribution in hard currency, operating management and other issues frequently call for joint ventures to minimize risk associated with a single project. Expansion of these markets will occur only when experience meets expectations over time.

Progress will emerge slowly. Patience is needed as much as capital, if not more. The culture shock of moving to a free market system is enormous for both sides of the equation.

At today's oil prices, the investments required over the next decade is a formidable challenge. The sums needed are not likely to be met out of cash flows alone. Also, increasing production in the regions mentioned above will involve leading edge western technology combined with excellent management skills for increasingly complex projects.

East Asia is also a major player on the energy scene. Its decisions and choices affect the global community. Obviously, the presence of Japan within the region is the primary factor in this development.

As energy consumers, the USA and Western Europe remain at the heart of the world energy drama. While they continue to exert great influence, many of the levers of power are now found in the Middle East, South America, Northern Africa, East Asia and, in the next century, the CIS.

Competition among the sources of energy will grow as a result of environmental legislation, market forces and capital investments (Figure 2). The future energy situation can be stated simply - Energy demand will continue to grow steadily with the economies of the world. Alternative energy sources will be developed as a result of economics <u>and</u> the environment.

Concerns about the environmental impacts of the energy industry - on the daily life of neighboring communities or, on a grand scale, in global climatic effects - is no passing fashion. The necessity of choosing between competing fuels based on their environmental credentials is with us to stay. Taking these views means, among other things, that the science underlying these environmental beliefs needs to be sound and comprehensive.

Due to these global pressures, the future for flow measurement and quality assurance is bright.

2 UPSTREAM SECTOR

With declining prospectivity, companies are reducing and retargeting exploration budgets, consolidating E&P operations, shifting their efforts towards the CIS, South America and Asia, and taking an increasingly stern view of E&P performance. The cash flow demands for most CIS projects are matched by their profitability - big and bigger. The peculiarity of the CIS crude oil reserves is their concentration in gigantic and large fields. In the EC and North America, it takes at least five years after exploration efforts are initiated to bring new production online.

The production facilities of the future will be cleaner, sophisticated, and more capital-intensive. Emissions to the air and water will be significantly reduced, and efforts will be made to eliminate solid wastes.

Sophisticated computer control systems will be used to instantly and continuously monitor wells and protect the environment. Information will be stored on several different systems (relational data bases) linked via networks. Support software will be task oriented with a user-friendly front end to perform low level systems work. All data and operating manuals will be accessible via computer (laptop, personal, workstation).

E&P personnel will be highly trained, reflecting the increasingly complex nature of their jobs. Regional training centers will be an integral part of international companies.

Crude Oil

Basins for conventional exploration of crude oil are well drilled in the United States (USA) and Canada. An accelerated decrease in the USA domestic production will occur due to the maturity of the producing fields and environmental pressures. The USA currently imports 57% of their crude oil needs.

The North Sea will experience significant growth through 1995. After this period, the prodigious North Sea activity will level off and gradually migrate to a mature region.

In the crude oil supply picture there exists an interesting dichotomy. Greater than anticipated growth in key national economies - USA, Japan, and Germany - will boost petroleum demand and cause a supplier driven pricing scenario. The International Energy Agency (IEA) estimates a lack of spare production capacity in the global oil market in the near term. As a result, crude oil prices will rise sharply with the economic growth of these key national economies.

Natural Gas

The international gas industry has undergone an extremely dynamic evolution over the two decades. This evolution was spawned by energy policies oriented towards supply diversification, crude oil substitution, environmental concerns, and in the USA - regulatory restructuring of the transmission segment.

The worldwide demand for natural gas is projected grow rigorously over the next decade. Conversion of power generation plants, home heating systems, mass transportation vehicles and fleet vehicles are projected as a result of environmental regulations and alternative energy pricing structures.

Natural gas is believed to be more environmentally friendly than crude oil. Whether or not the science behind this belief is sound, there seems little doubt that gas as a source of energy will become increasingly acceptable and, where economics permit, preferable to other fuels.

2. DOWNSTREAM SECTOR

In recent years, refining capacity for the key industrialized nations has remained at a constant level. Since 1984, USA refining capacity has declined slightly due to environmental legislation - the Clean Air Act (CAA), and the Clean Water Act (CWA), and the global decline of sweet crude oil. As product demand increases and additional refineries permanently close their doors, capacity utilization rates, now at 87%, will increase to 90-95%.

Refiners can't or won't add capacity, due to the capital investments and the resulting cash flow crunch associated with compliance to the CAA and CWA. Capital investments required by the CAA alone is currently estimated to be approximately 40-50 billion USD by 1995. This cash flow drain will not increase capacity and will consume most if not all short term profits. Joint ventures, toll processing and a migration by some refineries to niche markets will be necessary to survive in the North American market.

As a result, the USA will have to import additional volumes of finished product to keep up with demand. These imports will be required to comply with the CAA Reid Vapor Pressure (RVP) gasoline requirements, benzene limits, gasoline oxygenate requirements, and by 1995 the reformulated gasoline specifications. In addition, new regulations will require low sulfur diesel fuel for all "on-road" vehicles.

Refineries of the future will be cleaner, sophisticated, and more capital-intensive. Emissions to the air and water will be significantly reduced, and efforts will be made to eliminate solid wastes. These complexes will be enormous in size to offset the environmental investments associated with the waste heat recovery systems, waste water treatment systems, vapor recovery systems, air emissions' scrubbing system, CAA gasoline specifications, and so forth.

Instant and continuous monitoring via sophisticated computers will ensure optimization of yields and protection of the environment. Hydrocarbon management systems will emerge to maximize the raw materials needed to meet short term market demands for finished products.

Crude oil quality is emerging as a key to efficient and effective refinery operations. The refiner must receive a consistent crude slate to optimize yields, conform to product specifications, meet the market demands, and comply with the environmental limitations. All crude oil is not created equal in the eyes of the refiner.

Refinery personnel will be highly trained, reflecting the increasingly complex nature of their jobs. In-house training centers will be an integral part of refining complexes.

3. TRANSPORTATION SECTOR

The transportation industry will undergo significant expansion, contraction and regulatory changes over the next ten years.

Current and future customers still want the same things that yesterday's customers wanted, namely, a quality transportation sector which provides reliability and security of supply. But they may have uncomfortable perceptions regarding supply reliability, and/or pipeline capacity reliability.

The transportation business will be accelerating towards computerized transfers of commodities, pipeline movements, tariff billings, pipeline scheduling and supply contracts/agreements. One analogy is that of the international banking industry and its dependence on computerization to conduct daily business.

In highly populated nations, the need for high discrimination line integrity systems will be fierce. Densely populated regions should not be subjected to the uncertainty of eighty year old systems not being monitored for dynamic leak detection. Regulations requiring internal inspection and possibly hydrotesting on a set time interval are probable if the leak detection technology has not met the needs of the general public.

The industry has only scratched the technology surface that can provide the kinds of service customers will pay for. Technology is the key that starts the economic engine. Willingness to work together globally is the engine. The resources that we apply to the task is the fuel that runs the engine and makes all things work.

One thing is for sure, the oil, natural gas, refined products and chemical industry isn't going anywhere without pipelines. But even more than that, the industry must demonstrate to the customers that we can get the commodity to the right place at the right time and the least cost. Dr. Edward Deming would probably agree that the challenge awaits those who wish to pursue progress and viability.

Oil Systems

The oil transportation sector will undergo the most significant pains (Figure 3). As domestic production in the USA continues to accelerate its decline, the grid demographics will be redefined towards imported crude movements. Older onshore domestic crude oil pipeline grids will be eliminated and replaced with independent operators or truck gathering alternatives. Offshore pipelines will grow only when the pricing structure meets the capital investments required for deep water operations. New batched crude oil pipeline systems and modifications to existing domestic pipelines will be justified to satisfy the appetite for imported crude oils.

The refiners' sensitivity to crude oil quality assurance (QA) will be amplified due to refinery design, environmental regulations, market demands, product specifications and economics. The transportation industry will need to address these customer concerns with clear vision, a creative atmosphere and mutual agreement on acceptable performance levels.

Natural Gas

Overall, the natural gas transportation systems will be expanding in all industrialized nations (Figure 4). In the USA, Canada, North Sea, Western Europe, the CIS, the Middle East and the Mediterranean significant pipeline projects are currently planned and/or underway to satisfy the growing demand for natural gas. The environmentally friendly fuel is anticipated to replace petroleum based products in power plants, heating systems, government and/or commercial fleet vehicles, and mass transportation systems (buses).

Recent regulatory revisions by USA's Federal Energy Regulatory Commission (FERC) will focus the transportation companies to invest in basic infrastructure, cost control, and operating issues.

Natural gas quality will become a significant issue in Europe. To a lesser extent, gas quality will be sensitized in North America. The difference is the age of the grids and the customers' requirements. In North America, the customers have not required stringent gas quality specifications.

Refined Products' Systems

With the uncertainty associated with refined products markets, existing pipeline systems will support the application of drag reducing agents (DRAs) and localized capital expansions (Figure 5). The auto mileage improvements required by the CAA should offset the economy's demand growth. To add to this complexity, the market will be regionalized with respect to economic growth.

By 1995, North America will have transported RVP limited gasolines, benzene limited gasolines, oxygenated gasolines and reformulated gasolines through almost <u>every</u> products pipeline without a significant increase in capital facilities. A formal RVP assurance program is now regulated during the control period. QA programs will be required to ensure that <u>no</u> "off-spec" product enters the pipeline or is received unknowingly by the customer.

Checmical Systems

With the cycles associated with sophisticated chemicals, existing pipeline systems will grow at a rate directly with the global economy (Figure 6). Again, the market will be regionalized with respect to economic growth.

Online analyzers will be required to ensure that <u>no</u> "off-spec" product enters the pipeline or is received unknowingly by the customer. The move towards ISO 9000 certification will occur over the next five years for chemical transportation systems.

4. QUALITY ASSURANCE & IT'S IMPORTANCE

Quality assurance is a requirement for any viable company. Zero defects to outside customers is a prerequisite in a competitive environment. The aspect of crude oil, natural gas, refined product, and chemical online QA analyzers brings fear and heart palpitations to all senior pipeline management personnel (Figure 6). The issues of increased capital investment, operating and maintenance costs, training costs, additional personnel and ISO 9000 certification are real concerns in today's business climate.

However, QA will also reap benefits. By applying statistical quality control (SQC) to equipment performance, the maintenance costs and risks will be minimized. By investing in equipment which has a record of quality performance, minimum operating and maintenance costs will be achieved. This plateau does not occur at the lowest capital investment level. Other returns are the minimization of store stock inventory for equipment which hardly ever breaks, standardization of equipment, and training costs.

5. FLOW MEASUREMENT TECHNOLOGY

Instrumentation is selected based on its technical and commercial specifications. Usually the selection process considers only the instrument's capital cost and not the full cost of ownership over the its lifetime.

The full cost of ownership consists of the initial capital, commissioning, training, spare parts, maintenance and calibration costs for the lifetime of the equipment. The full cost is several times the initial capital investment and should be the deciding factor in equipment selection.

The technical selection - accuracy, repeatability, drift, ease of calibration as well as reliability indirectly affects the cost of ownership.

Proper installation and application of flowmeters are two of the most significant parameters in the measurement chain. These parameters influence the factors mentioned above and are neglected in most assessments. The misapplication of any device brings the wrath of field personnel on the operating company's engineering staff --- as it should! More effort is required by the user community to match their expectations with reality. The selection, installation, operation and maintenance of quality equipment, if properly performed, is almost never discussed by operating personnel.

Modularization of discrete instrumentation is a key to success in the future (Figure 7). While some users have proposed the combination of all measurement instrumentation into a single control, computing, totalization, and communications device, this is obviously incorrect. Discrete functions will persist in order to satisfy performance, security, auditability and technology requirements.

6. PRIMARY FLOW DEVICES

The future vision of primary flow devices is clear and defined. The vision consists of "smart" flowmeters, new flowmeters, and in situ calibration or central calibration technology for both incompressible and compressible fluids (Figure 8).

Installation Effects

The problems associated with installation effects of flowmeters have been with us a long time. Pragmatic solutions have evaded our industry due to our limited insights into the "real" flow field.

Experiments over the last ten years has shed light on increasing our insights. In the USA, Canada and EC, scientists have recently conducted installation effects research on turbine, orifice and ultrasonic flowmeters. This data measured the meter's performance as a result of interation with the near term flow field. With this insight, postulates have been proposed and are planned to be validated or revised within the year.

With the application of microchip technology into smart transmitters, sophisticated flow computers, personal computers, Computational Fluid Dynamics (CFD), thermal anemometry (TA) probes (i.e., hot wire, hot film, x-wire), Laser Doppler Velocimetry or Anemometry (LDV/LDA), characterization of flow meters in real time, high pressure gas piston provers, ultrasonic flowmeters, coriolis flowmeters, videoimagescopes, etcetera, large steps toward lowering the flow measurement uncertainty is possible. These "new" tools are providing significant advances in the refinement of existing metering equipment as well as the birth of new technology.

The advent of LDV/LDA technology has provided a tool to perform three dimensional flow field measurements. This technology is capable of measuring three non-orthogonal velocity components simultaneously, resolving from those three independent orthogonal velocity components, and then computing the mean velocity vector, the time averaged Reynolds stress tensor, and other items associated with those values. In this manner, variations in the flow field (upstream and downstream of flow conditioners, flow meters, fittings, etc.) can be documented. The next step involves comparing these measurements to Computational Fluid Dynamics (CFD) predictive models such as Creare's FLUENT code. Through these comparisons the optimum turbulence model can be identified. The final results should have a predictive model which approximates the decay of distorted flow fields through flow conditioners and flow meters.

A fundamental understanding of the effects of upstream flow conditioning on flowmetering is essential for significant improvements. Recent LDV/LDA and TA probe research is attempting to provide a thorough understanding of the complex flow field. The LDV/LDA, or TA probe are tools which provide us with the needed insight to the microscopic flow field. Studies at NIST Gaithersburg (Mattingly and Yeh), Texas A&M (Morrison et. al.), NIST Boulder (Brennan, et. al.), SwRI (Morrow, Park et. al.), NOVA Husky (Karnik, et. al.), CERT (Gajan et. al.), NEL (Reader-Harris, et. al.), Gasunie, K-Lab (Wilcox et. al.) and others have recently measured mean velocity profiles and turbulence structure associated with upstream flow conditioning effects.

The optimum turbulence model does not currently exist for CFD installation effects' applications. Hopefully, existing and planned turbulence structure measurements and installation effects research will provide future scientists with the needed insight for this development. Irrespective of this limitation, CFD technology will still be utilized to maximize the experimental pattern efficiency and to provide sensitivity analyses.

The goal of current orifice research programs is to focus on the effects of various installation conditions for natural gas applications. Since significant deviations from the Law of Similarity cause measurement errors, the main goal is to identify and quantify the error associated with these flow disturbances.

Present industry standards provide installation specifications for pipe length requirements and flow conditioner location upstream of flowmeters. Current upstream effects research has focused on assembling experimental data for evaluation of straight length requirements stated in the respective standards.

Flow Conditioners

All flowmeters are subject to the effects of velocity profile, swirl and turbulence structure approaching the meter. The meter calibration factors or empirical coefficients calculated from the discharge coefficient equations are valid <u>only</u> if similarity exists between the metering installation and the experimental data base. These parameters should not be significantly different from those at the time of meter calibration, or from those which existed in the empirical coefficients of discharge data base. Technically this is termed the Law of Similarity.

Many piping configurations and fittings generate disturbances with unknown characteristics. Even a simple elbow can generate very different flow conditions from "ideal" or "fully developed" flow. In reality, multiple piping configurations are assembled in series generating complex problems for standard writing organizations and flow metering engineers. The problem is to minimize the difference between "real" and "fully developed" flow conditions on the selected metering device thus maintaining the low uncertainty required for fiscal applications. For clarity, we will refer to this as "pseudo-fully developed" flow.

A method to circumvent the influence of the fluid dynamics (swirl, profile and turbulence) on the meter's performance is to install a flow conditioner in combination with straight lengths of pipe to "isolate" the meter from upstream piping disturbances. Of course, this isolation is never perfect. After all, the conditioner's objective is to produce a "pseudo-fully developed" flow.

In general, upstream piping elements may be grouped into the following categories -

* those that distort the mean velocity profile but produce little swirl

* those that both distort and generate bulk swirl

Flow conditioners may be grouped into three general classes based on their ability to correct the mean velocity profile, bulk swirl and turbulence structure (Figure 9).

The first class of conditioners is designed to primarily counteract swirl by splitting up the flow into a number of parallel conduits. This class of conditioners includes A.G.A. radial tube bundles, A.G.A. hexagonal tube bundles, ISO 5167 tube bundles, AMCA's honeycomb and the Etoile.

The second class of conditioners is designed to generate an axisymmetric velocity profile distribution by subjecting the flow to a single or a series of perforated grids or plates. The profile is redistributed by use of the blockage factor or porosity of the flow conditioner. This class of conditoners includes the Sprenkle, Zanker and Mitsubishi designs.

The third class of conditioners are designed to generate a "pseudo-fully developed" velocity profile distribution through porosity of the conditioner and the generation of a turbulence structure. The turbulence structure is generated by varying the radial porosity distribution. This class of conditioners includes the Sens and Teule, Bosch and Hebrard, K-Lab and Laws designs

In the next two years, additional research into the third class of flow conditioners should result in a significant decrease in the uncertainty associated with installation effects and velocity profiles for "real" field installations. The adoption of existing conditioner designs, or the refinement of these devices, or the creation of a new design will occur at the termination of this research.

Smart Flowmeters

With the application of microchip technology, large steps towards lowering flow metering uncertainties are possible due to the advent of sophisticated flow computers, personal computers, characterization of flow meters in real time, etcetera. These "new" tools are providing significant advances in the refinement of existing metering equipment as well as the birth of new technology.

The application of Statistical Quality Control (SQC) techniques is viable today. By using serial meters of differing technology, it is possible to monitor the performance of each flowmeter separately as well as the ratio (or difference) of the two meters. The user should be able to discern when one of the devices is in need of repair. Additionally, each meter should be equipped with predictive performance software as a function of Reynolds number or other appropriate correlating parameters. The objective is to discern systematic bias shifts between the devices at a level that is acceptable to the economic value of the commodity transferred between the parties.

Ultrasonic Flowmeters

For incompressible fluids, the ultrasonic flowmeter is fast approaching the performance levels of custody transfer flowmeters (CTMs). Tests are currently being conducted in the USA on the application of a new platform of ultrasonic flowmeters for line integrity purposes. For liquid systems, preliminary results indicate +/- 0.3% agreement with CTMs without the installation of flow conditioners.

If additional tests confirm this performance, the installation of flow conditioners upstream of ultrasonic flowmeters should lower the uncertainty by minimizing the installation effects on its' performance. In other words, it is better to have a flat, repeatable velocity profile, for ultrasonic flowmeters rather than a fully developed one.

For compressible fluids, tests conducted by Gasunie and Daniel Industries indicate the viability of this technology to natural gas applications. To date, additional development effort is needed in the electronic packages associated with these devices. The future looks promising.

Coriolis Flowmeters

One of the most unique flowmeters introduced in the last decade is the coriolis meter. This device measures the total mass as a function of the rotational forces exerted on a specially configured tube.

Mixed results have been reported to date. However, it appears that this device will be viable in sizes up to 100mm. Velocity profile, velocity of sound, mechanical installation, and vibration are known to adversely affect the meter's performance.

There is evidence that the coriolis meter may prove to be the future custody transfer meter for direct mass measurement of LPG and similar viscosity fluids. However, the problem of providing a dynamic mass prover for calibration under operating conditions presents a stumbling block. Currently, tests are being conducted by an API Working Group to determine the feasibility of a SVP and density meter combination as a suitable transfer package.

In Situ Calibration

In situ calibration of incompressible fluids has been performed successfully since the 60s. The challenge of the measurement community is the calibration of compressible fluids such as natural gas.

Verifying the accuracy of flowmeters in specific compressible fluid applications has been one of the desires of the user community. Shop tests of orifice meters and turbine meters with various upstream configurations have been conducted for several years to aid in the design of high volume metering facilities. The question posed by the user community is - "Can the operator ensure the parties involved in the fiscal transfer that the measurement station is adequately described by the tested design?".

In response to the North American community's request, the Gas Research Institute (GRI) has initiated funding for assessment of in situ calibration devices - sonic nozzles, master meters and piston provers. These tests, planned for 1993, will be conducted at GRI's MRF facility.

In situ calibration of flowmeters now appears feasible with the advent of the gas piston prover.In the last decade, high pressure gas piston provers were introduced to the natural gas community. The application of this device was inspired by the chemical industry's development for highly compressible polymer grade ethylene systems in Europe and North America. At this same time, the liquid small volume prover (SVP) demonstrated the acceptability of double chronometry interpolation techniques for turbine meters. Through the pioneering efforts of Gasunie, Shell, Amoco, DSM, Ruhrgas and Ogasco, a modified SVP approach was developed for chemical, CO_2 and natural gas applications.

The piston prover has been used as a primary standard to prove a turbine meter or a master turbine meter installed in series with an orifice meter. This arrangement ensures calibration under normal operating conditions - velocity profile, instrumentation, etcetera. Additionally, wet gas will not alter the performance of the piston prover as long as the flowing conditions are not lower than the hydrocarbon dew point. Small amounts of fine solids will have no effect unless the bore of the calibrated section or the piston seals are damaged.

At this time, the high pressure gas piston prover is being successfully applied by Gasunie, Shell USA, Amoco USA and Ruhrgas for fiscal applications and/or laboratory flow standards. Gasunie has replaced their "bootstrapping" method with the piston prover. Shell USA has applied this technology to chemical and CO_2 systems since 1984 to identify out of tolerance metering facilities. Amoco USA has operated an Ogasco design for the calibration of small turbine meters in a coal degasification project since 1990.

Potentially, the piston prover offers the best opportunity for successful field calibration of flowmeters on multiple component natural gas streams. However, the measurement community needs; additional research, an established gas piston prover design, and certification standard. The additional research needs will be assessed with the GRI activities for 1993. In answer to the need for standards, the API Committee on Gas Measurement (COGM) has recently established a Working Group to address the global community input and concerns.

7. SECONDARY DEVICES

Secondary devices consist of instrumentation which is not a part of the primary flow device such as smart transmitters, chromatographs, viscometers, moisture analyzers, densitometers, etcetera (Figure 10).

The future vision of secondary devices is also clear. This vision consists of advancement in "smart" transmitters, field calibration standards, online viscometers and QA analyzers, portable analyzers and density meters for both incompressible and compressible fluids.

Smart Transmitters

Smart transmitter experience has proven the adoption of these devices is justified due to lower the full cost of ownership. There are few improvements to be made in the type and application of smart transmitter technology except for the digital transmission issue.

Smart transmitters have exhibited twice the mean time between failures than previous analog transmitters. The actual failures proved to be dependent on installation conditions rather than on manufacturers' construction. The devices should be positioned to minimize vibration, rapid temperature changes, blockage and corrosive/erosive conditions.

Digital means of communications are available but not standardized at this time. The short term performance level for smart transmitters using analog outputs is ± 0.10% of full span. Internal tests have indicated digital output techniques would provide a short term performance of ± 0.05% of reading. This is a signifcant improvement!

Field Calibration Standards

With the advent of smart transmitters, field calibration standards have been required to improve. Using SQC and corrective software, field standards will improve in the next five years due to market forces. After all, if the transmitter is good for 0.05% of reading, why can't the field standard be at least twice as good?

Other Instrumentation

Other secondary instrumentation will be required for efficient and effective operations.

Improvements in viscometers have occurred to address moderately viscous fluids. When used in combination with a densitometer, the calculation of real time Reynolds numbers are possible. This leads to the possibility of meter factor footprinting as a function of Reynolds number for flowmeters. Other viscometer applications include pipeline interfacial mixing, batch cutting and power optimization.

Online and portable QA analyzers are emerging at a fast pace. Graebner RVP offline analyzers were required to comply with the CAA gasoline requirements. Additional analyzers are being evaluated for oxygenate analysis. Other QA measurement applications will arise as the industry adopts a proactive approach to quality in operations.

8. OPERATIONAL ENHANCEMENTS

Several operational enhancements are attainable in the next ten years. The objective is increased performance through intelligent capital investment which is offset by lower operating and maintenance costs (Figure 11).

Flowmeter Applications

Flowmeters will be selected not only on short term performance but also long term performance, training costs, SQC software, frequency of calibration and calibration technology.

The increasing use of liquid ultrasonic meters will occur in refineries and chemical plants. The uncertainty and performance is approaching CTMs. The current performance combined with its non-intrusive design will be difficult to match with other devices. Twill be possible to calibrate and inspect flowmetering devices on process units prior to plant turnarounds.

The life of the orifice meter has been extended as a direct result of "smart" transmitter technology and new flow conditioner designs. This meter will continue to be preferred on certain fluids because of its lower sensitivity to density determination errors.

Extended Calibration Intervals

Operational enhancements are needed in extending the calibration intervals of the associated primary and secondary equipment (flowmeters, flow computers, smart transmitters, chromatographs, etc.), required physical inspection intervals (i.e.,videoimagescopes, etc.), required certification of field standards on specified intervals, and statistical footprinting of field devices and standards.

Line Integrity Systems

The detection of leaks in pipelines presents a number of technically challenging problems. Compounding the technical difficulty of leak detection is the environmental and safety concerns. The leak detection response rate must be sufficiently fast and of a high resolution.

As a practical matter, pipelines cannot afford to install CTMs every 200 kilometers. Therefore, the number of monitoring points should be minimized by the resolution and response of the device.

Changes in temperature between monitoring points can result in significant changes in fluid and pipe volumes. Also, operating conditions such as batched operations, elevation differences, and dynamic transients pose unique problems.

Leadership

To succeed, Measurement Teams will need to establish and maintain free and open communication. The Team will need to achieve seamless communications across all organizations and through all necessary levels of those organizations (hourly field personnel to senior management). The objective of the effort and the important steps necessary to achieve that objective will be communicated clearly along with the requirements. Leadership should be perceived as competent, credible, and sharing a unified direction toward a stated purpose by all customers.

Technology transfer and optimization of individual skills should be an ongoing effort by all members of the Team.

Loss Control Targeting

The following targets for annual loss control performance has been established by Shell Pipe Line Corporation's (SPLC) Measurement Team -

* 0.03% major crude pipelines
* 0.02% refined products systems
* 0.10% crude gathering systems
* 0.10% LPG pipelines
* 0.10% chemical & CO_2 pipelines

The Team should aggressively promote the following measurement philosophies -

* Manage the business by being proactive towards loss prevention

* Conformance to the requirements (tariff & contractual obligations, federal & state regulations, measurement standards, and customer established requirements)

* Document measurement problems or nonconformances (troubleslip system)

* Maintain 5 year evergreen plan covering performance levels, personnel training, and capital investments

* Establish a daily loss control on large tank farms & key transportation systems

Innovation and Creativity

An important part of SPLC's strategy is the establishment of the Targeted Loss Unit (TLU) Program. SPLC operated systems are divided into over one hundred separate loss units (or measurement systems) to monitor their performance. The majority of loss units operate within acceptable Statistical Quality Control limits and require no attention. The TLU Program maximizes the effectiveness of our efforts by focusing our fiscal and manpower resources. Working as a team, HO Measurement and field personnel select ten loss units -

commonly referred to as the "Ten Most Wanted". Manpower and fiscal resources are then directed towards identifying the "root cause" for their performance. The list is "rolling" in nature. When a targeted loss unit's problems are defined and corrected, it is removed from the list and replaced by the next loss unit in line.

The SPLC's Team is challenged by the breadth of operations which covers crude oils, refined products, LPGs, chemicals and CO_2 measurement applications. Measurement is a technically demanding, complex, state of the art field with significant impact on the profitability of any transportation system. Technology, research and testing of hardware, instrumentation and flow standards are ongoing efforts due to this state of the art field. Innovation, creativity and realistic assessment capabilities are required traits of any quality measurement organization to adapt new technology with an acceptable level of risk. This blend was the key to establishing new levels of performance in SPLC while maintaining low operating costs.

Measurement Information Systems

As an example, innovation and creativity in the field of measurement is being applied through the use of laptop computers for measurement ticketing, proving reports and analysis techniques (Figure 12).

A goal of any large transportation system is to minimize monthly losses (Figure 13). A program to monitor the daily loss performance for tank farms and key transportation systems is critical to attain loss prevention. Expansion of this concept is currently underway. SPLC has established a corporate goal - accurate daily loss performance for all large transportation systems and storage facilities within the next five years.

Innovation and creativity by the SPLC Team resulted in computerized automation of monthly loss control reports thereby eliminating redundant effort throughout the organization. The report package is layered to provide management with overview information, and measurement specialists with two levels of detailed information. This approach places the required information in the necessary format for the appropriate individual.

Certification of Technicians

With the complexity of future technology, the need will occur for certification of measurement and laboratory technicians.

Eventually the ISO 9000 philosophy will provide market distinction and enhanced profitability for companies with visions.

Application of Quality Concepts

Measurement personnel has always applied quality concepts. This approach is natural in problem solving dynamic systems. The following discussion presents SPLC's application of quality concepts to its measurement mission.

Customer Focus. SPLC operates transportation systems for a multitude of owners and focus on our customers' requirements has always been a high priority. A summary of our measurement performance is presented annually to the various owners who provide feedback on our performance and mutual agreement on the requirements.

Prevention. As mentioned above, the Team identified the need for daily loss control on large tank farms and key transportation systems. Most systems identified are now monitored daily resulting in early detection and prevention of significant losses.

Problem Solving. Measurement is a technical field and requires problem solving skills by all participants. The Team exhibited this process individually and jointly in areas of limited knowledge/experience (cross training). Innovative problem solving is shared by all Team members through quarterly newsletters, technical awareness bulletins and annual Team meetings.

Continuous Improvement. The Team is by nature on a continuous improvement path. Constant assessment of competitors, technology, culture, loss performance, training requirements and staffing needs are a part of the Team's culture. A positive competitive atmosphere within the Team members promotes continuous improvement.

Measurement. As previously mentioned, SPLC operations are divided into over one hundred separate loss units (or measurement systems) to measure their performance. Statistical data bases are archived for each loss units monthly performance from 1985 to the current month's business. Individual charting of data, meter factor analysis, measurement ticket analysis are all done on a monthly basis to assure proper statistical control (Figure 14). In addition, daily loss performance is computerized (with manual entry) to provide preventive measurement.

9. SUMMARY

We have attempted to provide a vision of the measurement community's direction for the next ten years. The technological advances will be fast and fierce. Companies should be positioned to take advantage of these opportunities through a strategy, structure, systems and people. The elements to success in the next ten years will be flexibility, proper corporate cultures, innovation and creativity, maximization of current capital investments, and prudent capital investments.

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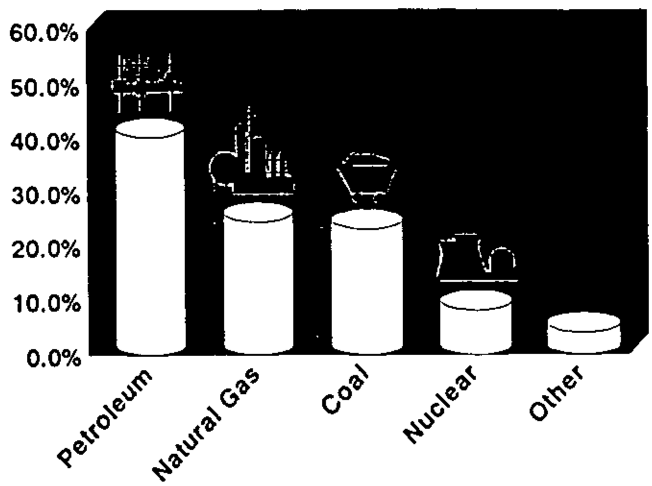
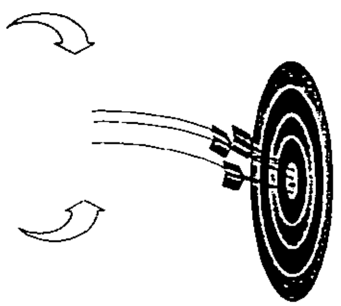
USA Sources of Energy



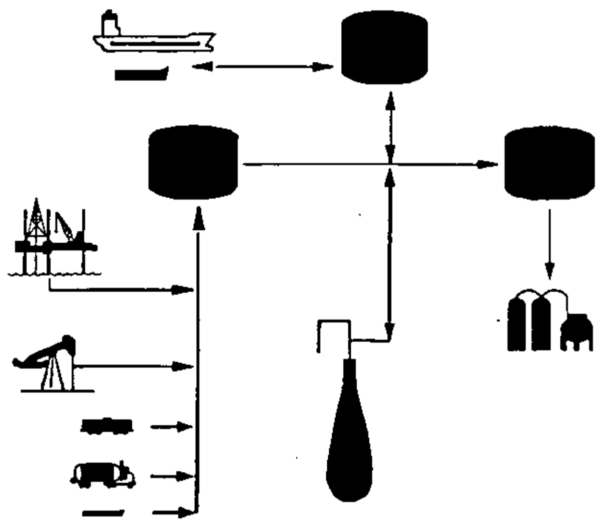
Requirements for Success

Clear Vision

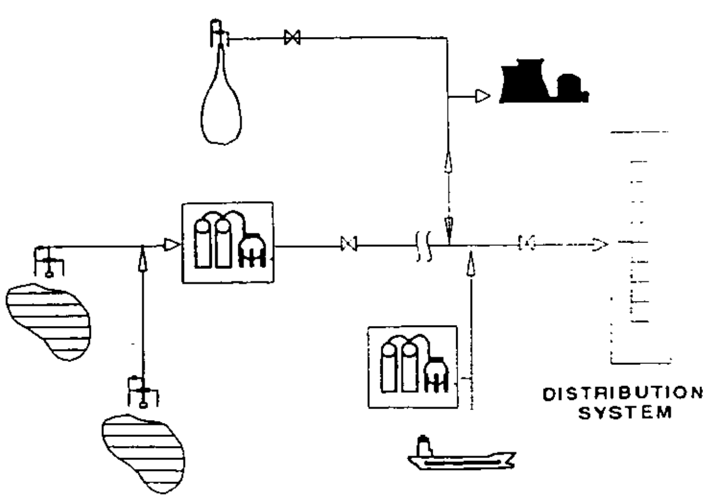
People
Strategy
Structure
Systems



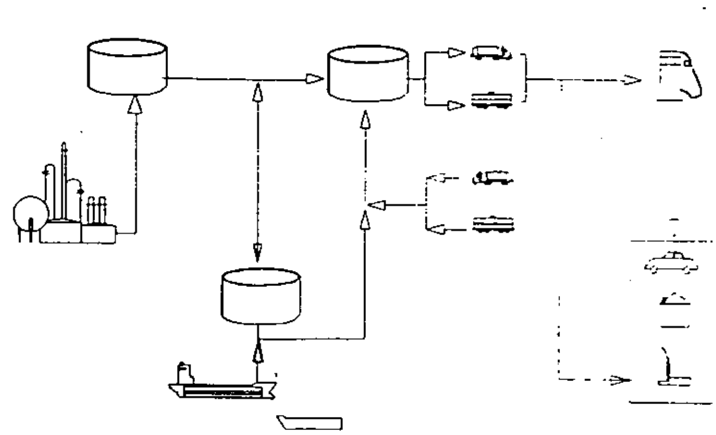
CRUDE OIL SYSTEM



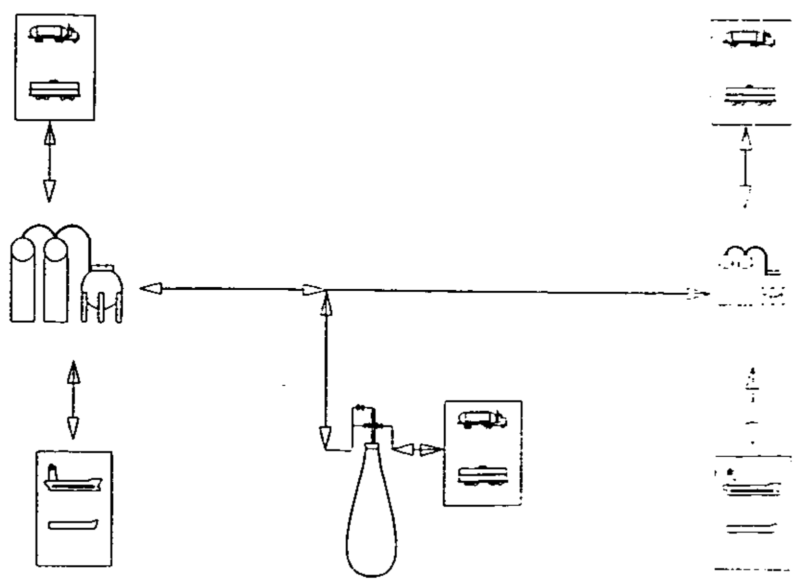
NATURAL GAS SYSTEM



REFINED PRODUCTS' SYSTEM



CHEMICAL SYSTEM



PRIMARY FLOW DEVICES
Future Direction

- Installation Effects
- Flow Conditioners
- Smart Flowmeters
- Ultrasonic Flowmeters
- Coriolis Flowmeters
- In Situ Calibration

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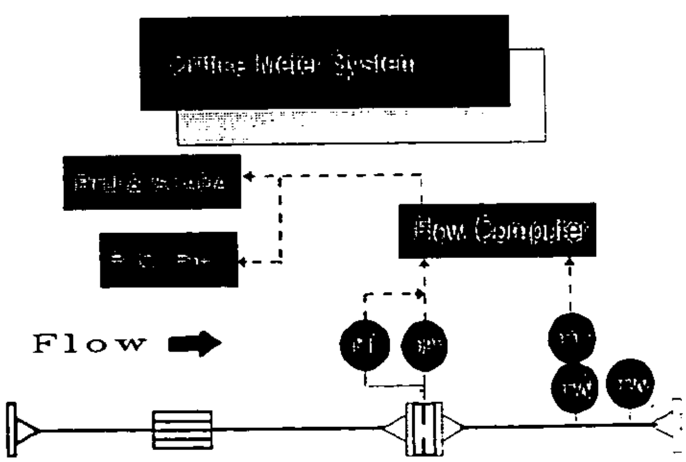

Classification of Flow Conditioners

Type	Class	Head Ratio	Cost
Tube Bundles			
Radial	I	1	Lo
Hexagonal	I	1	Lo
Etoile	I	1	Med
AMCA Honeycomb	I	1	Med
Mitsubishi	II	2	Lo
Zanker	II	6	Hi
Sprenkle	II	15	Hi
Laws	III	2	Med
K-Lab	III	3	Med
Sens & Teule	III	5	VHi
Bosch & Hebrard	III	5	VHi

SECONDARY DEVICES
Future Direction

- Smart Transmitters
- Field Calibration Standards (dP, P & T)
- Online Viscometers
- Online QA Analyzers
- Portable QA Analyzers
- Portable Densitometers

OPERATIONAL ENHANCEMENTS
Future Direction

- Flowmeter Applications
- Extended Calibration Intervals
- In Situ Calibration
- Line Integrity Systems
- Loss Control Targeting
- Measurement Information Systems
- Certification of Technicians
- Allocation Metering

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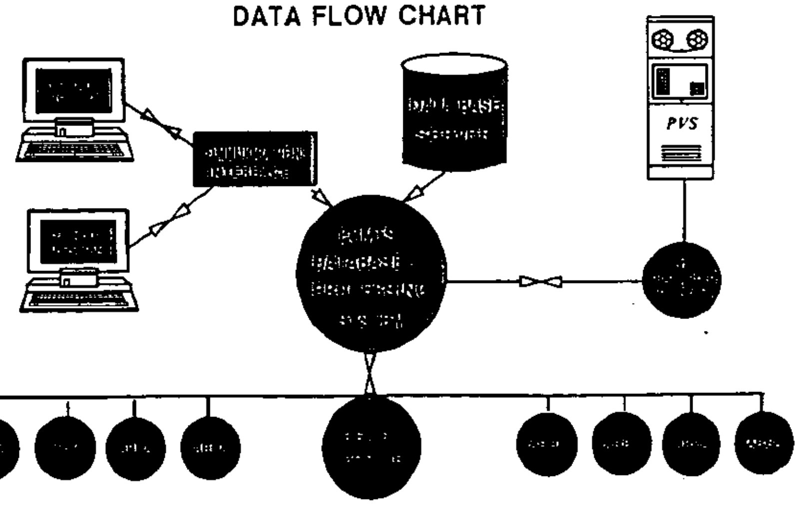
ECMTS PROJECT
DATA FLOW CHART



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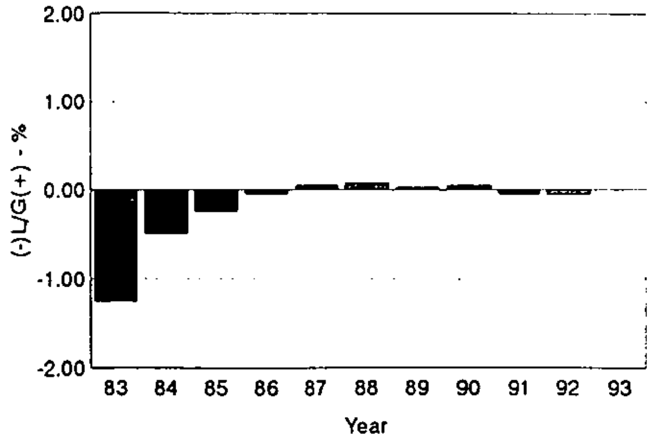
Ethylene Pipeline

Annual Loss Control Performance



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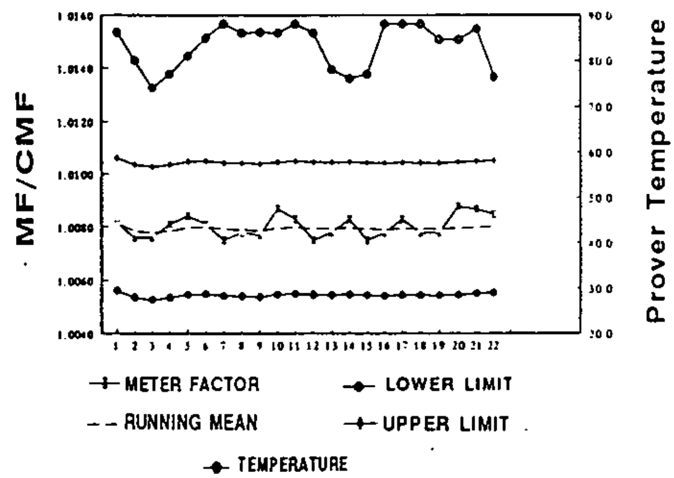
METER FACTOR CONTROL CHART

LACT METER - Noncompensated : Meter 002



References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.