SECTION 6
SAFETY PROBLEMS

In the two previous sections reviews were made of historical data (OPSO and NTSB reports) and of systems analytic techniques (fault tree analysis) as they relate to distribution pipeline system safety. In this section, eight specific safety problems are identified and discussed. These topics can be categorized under three main headings according to which phase of loss of system control is considered:

A. Prevention
   1. Assessment of pipeline conditions
   2. Corrosion
   3. Damage by outside forces
   4. Plastic piping

B. Detection
   5. Odorization

C. Correction/Mitigation
   6. Emergency plans
   7. Valving and rapid shutdown

The eighth topic, Master Metering, does not fall within any of the above.

The seven problem areas are all connected with leakage, or loss of gas from the system, in the manner shown in Figure 6-1. Once leakage occurs one of the three necessary conditions exists for an undesired event, such as fire or explosion. The other two, presence of oxygen and a source of ignition, are not normally found within the confines of the distribution piping system.

Failures that result in escape of gas can also be classified in terms of system design parameters:

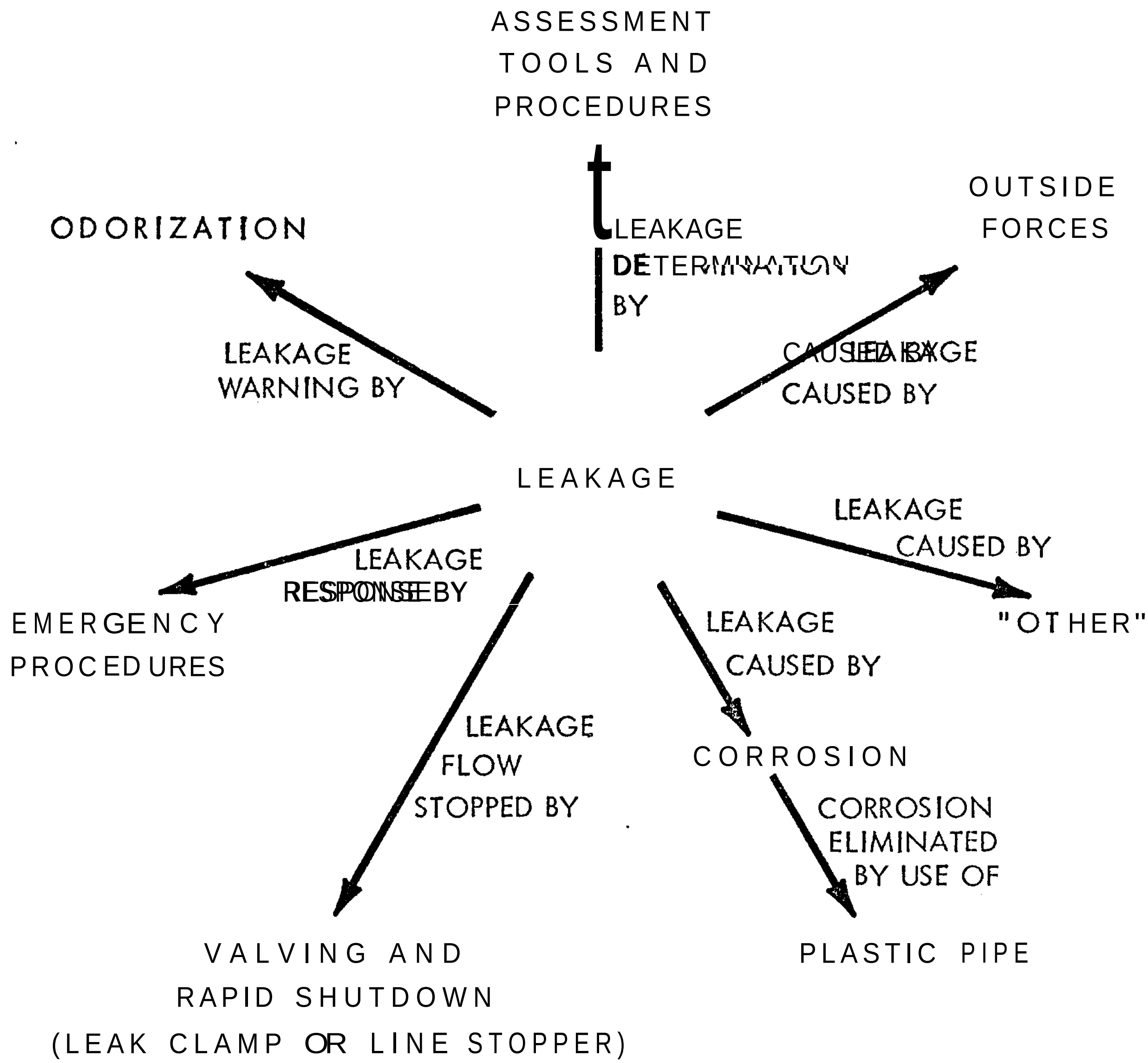

Figure 6-1 Relationship of Safety Areas

Type I - Failures experienced while the system is functioning within its designed operational and environmental parameters. These are usually due to deterioration, as from corrosion, decomposition due to aging, mechanical wear, etc.

Type II - Failures caused when one or more operational or environmental parameters 'exceeds system design values. Examples here are pipewall rupture due to excess internal gas pressure, external forces or loadings caused by earth subsidence, earthquake, nearby explosions, earth-moving machines, etc.

Type I failures generally indicate a degradation of the condition of a system from its original "as-new" state. The origin of Type II failures is not always simple to identify. Among the many possible causes are original inadequacies of design, poor construction practices, insufficient maintenance procedures, as well as acts of man and nature.

6.1 ASSESSMENT OF PIPELINES

Pipeline assessment and leak surveys address the major problem of gas systems, that of leakage and potential leakage points. There is a relatively large amount of ongoing research and technique improvement being performed in this area. Basic research is performed by institutes and educational facilities. Gas companies on an individual basis, and collectively through the AGA, are investigating new equipment and improvements in operations and techniques. Inspection equipment is being developed and improved by supplier manufacturing companies and companies involved in survey service to the gas utilities. The purpose of this section is to briefly note the equipment and techniques currently used by the gas industry and to discuss the application of nondestructive testing and new developments for pipeline evaluation. The main topics include pipe location, leak detection, pipeline measurements procedures, nondestructive testing, and new equipment and procedures.

6.1.1 Pipe Location

Pipe locators, while they do not constitute an assessment method, are often used by gas companies to update maps, reduce excavation damage, or as a preliminary step for subsequent pipe inspections. The mainstay of the industry is the metal locator, but recently a new radar method has been developed.

Metal locators utilize a radio frequency transmitted to the underground pipeline and a receiver to pick up the signal from the pipeline to determine the location. They are used in inductive and conductive modes and can also determine pipe depth. They are limited to finding metallic items and applicable to electrically continuous pipelines.

The radar method uses signal pulses directed downward as an antenna unit is moved over the area of interest. When part of the pulses are reflected back to the antenna from underground objects, the signal travel time is converted to a depth scale. These signals must be interpreted to denote the underground features but many including cast iron, steel, copper, clay, or plastic pipe, cables and conduit in additional to bedrock boulders, voids, and pavement thickness can be pinpointed or determined. The units are relatively new and their development and use are being furthered by the Columbia Gas System and Geophysical Survey Systems, Inc.

6.1.2 Leak Detection

Leak detection is performed as a normal operation by gas systems, using a number of methods including vegetation surveys, gas and sound detectors, and odorization equipment and instruments.

A vegetation survey denotes gas leakage by its effect on vegetation. Natural gas removes oxygen and water from the soil which over a period of time results in withered or stunted grass, trees or shrubbery. The method is fast, economical, efficient, and requires no instruments, but is limited to certain seasons and areas where sufficient Vegetation exists. It relies heavily on the perception and experience of the individual conducting the survey.

The gas detectors that are used to denote concentrations of methane in air include 'hydrogen flame ionization units, combustible gas detectors and infrared units. Flame ionization units are very sensitive and are capable of detecting methane concentrations of a few parts per million. They are most applicable for over-the-line surveys to detect leakage in trace amounts but the process is not conducive to detection of large concentrations of methane. Very small hand-held units are available for use in walking surveys and some units have been installed in vehicles with external probes for mobile operation. Infrared units have about the same sensitivity and use as flame ionization units except for portability. Generally the units are heavier and more delicate so their use, which was primarily in mobile survey units, is in a stage of being phased out and replaced by flame ionization units.

Combustible gas indicators detect gas in air as a percent of volume They are small, portable, and generally have two scales; one for gas percent of Lower Explosive Limit (0 to 5% gas in air) and the other for total gas by volume (0 to 100%). The equipment is most applicable for checking confined spaces such as building areas, valve boxes, and manholes or can be used to pinpoint leak'locations through the barhole technique.

Sound detectors amplify or convert the sound waves propagated by gas escaping to easily heard audible signals signals. Units capable of amplifying sonic waves and units which convert ultrasonic waves are available. The units are good for above ground structures but not applicable to underground gas pipelines.

The techniques regarding odorization discussed here are instruments which determine the level or concentration of odorant in a gas stream. Problems of the odorant additives themselves and their lessened effectiveness due to reactions with soil or pipe are discussed later in this report. Odorizing agents are required to be added to gas in distribution systems so that the gas is detectable at 1/5 of the LEL. Methods to verify this requirement include the use of an odorometer and other equipment which measures the concentration of odorizing agents in the gas stream. These latter units include titrators and the Odotron.

The odorometer is a combustible gas indicator which mixes varying amounts of the gas stream with air. The mixture is sniffed by the operator until a noticeable gas smell is observed. The instrument is then used to determine the volume of gas in air. Although portable and easy to use, they rely on the sense of smell of the operator.

Tritrators verify that the proper concentration of odorant is in the gas stream. They can determine the total sulphur content or specific sulphur forms by the use of filters and separate titrators. The known sulphur contents are then equated to the regulation requirements by data which shows that a certain concentration of sulphur or sulphur compounds allows the gas to be detected by smell at 1/5 of the LEL or below.

The Odotron is a registered trademark of Heath Consultants Inc. for a piece of equipment developed by a joint effort of Heath, the Institute of Gas Technology and the AGA. It is a gas chromatograph which responds to the sulphur compounds that contribute to the odor of natural gas. The output of the equipment is a chart recording profile of each odorant constituent with the area under each curve proportional to the amount of sulphur present. This can be related to odor intensity on the average human nose by background data on odorant sense tests.

6.1.3 In-Place Pipeline Measurements

A number of in-place measurements of pipeline parameters are available and used by utilities. The degree of access to the pipeline; - no access, external access or internal access - often determines whether and when the techniques will be used. Topics discussed here include electrical measurements, coating inspection, wall thickness and flaw indicators, pressure testing and borescopes.

Pipeline Electrical Measurements

A majority of pipeline leaks are due to galvanic action corrosion. The susceptibility to and occurrence of this type corrosion can and is defined or controlled by electrical measurements such as soil resistivity, pipe-to-soil potential and line currents.

Low soil resistivities are conducive to corrosion due to easier electron flow. The soil resistivity can be calculated by measuring the current flow and voltage drop over a specified section of earth, but generally, portable instruments such as a Vibroground are used.

Pipe-to-soil potential is a term used to signify the electrical potential between a pipeline and a copper sulfate electrode in contact with the soil. Measured potentials can be used to determine "hot spots" and areas of damaging stray currents. It is possible to use a connection at one point on the pipeline and use long test wires in order to move the electrode at intervals over the pipeline to obtain readings. A second method is to obtain a reading between pipeline and a reference electrode at one point and then use a second electrode to obtain a reading between the two electrodes. The two electrodes then are leap-frogged along the pipeline and polarities and voltage magnitudes are noted. The results from both these methods are often plotted on a graph with potential as the ordinate versus pipeline length as the abcissa. The two electrode leap-frog method may give erroneous readings where pipe joints have impaired conductivity.

Line current measurements are applicable to large corrosion areas on long electrically continuous pipelines. This is an approximate method of calculating the current flowing along a pipeline, using voltage drop measurements between test leads on the pipe and nominal pipeline resistance obtained from published resistance tables.

Coating Inspection

Coating inspections are made to locate holidays or holes in coatings where corrosion is liable to occur. One method is the Pearson Technique wherein an audiofrequency current is induced into the pipeline. Two men wearing conductive shoe cleats that are connected electrically to an audio receiver then walk in tandem over the pipeline. One man carries the receiver which gives a signal when a holiday is encountered. A 20 to 25 foot separation is maintained between the men, and the electrical connection between the two is a single insulated wire conductor. Holiday pinpointing is done by shortening the distance between the men or moving one man off to the side of the pipe.

Another holiday locator operates on a principle similar to metal locators. A signal is induced onto the pipeline and will be siphoned off at coating faults. A man walks along the pipeline with a receiver and notes locations where the received signal strength is abruptly reduced. These areas indicate an electrically conductive spot between pipe and soil such as a coating fault or grounding. The units are portable but require considerable knowledge of the pipeline and interpretation by the operator.

Wall Thickness and Flaw Indicators

Wall thickness and flaw indicators require as a minimum, access to either the internal or external wall of the pipe. The external wall requires pipe excavation while internal access requires excavation and opening of the pipe.

Once excavated, pipes are visually examined almost as a matter of course to locate corrosion or deterioration. Also, pit gages or mechanical measuring tools are often used to note the depth and size of corrosion which has occurred.

Instruments available to check wall thickness or degradation include units based on ultrasonic and eddy current principles. The ultrasonic units can use cleaned areas of the internal or external wall while the eddy current instrument generally uses the internal wall. The ultrasonic equipment used most is the pulse-echo method where the transducer induced pulse is reflected back to the same transducer from flaws or interfaces. Both flaws and thickness can be determined. The pulse amplitude assesses the void and time between pulses determines its depth. Ultrasonic resonance units are also still in use. Flaws are determined with these units by tuning the signal so that propagated and reflected signals are in phase. The units do require two separate transducers, they are slower in operation than pulse-echo types, and are more applicable to thickness (corrosion depth) measurements. The eddy current units can detect cracks, seams, laps and changes in metal structures. Changes in impedance are recorded during inspection and compared to the results from a test standard to determine the defect or wall thinning in the pipe under inspection.

Pressure Testing

Pressure testing by either hydrostatic or gas pressurizing is much used in the gas industry. The gas pressurizing method is probably used more in distribution systems because the pressures are fairly low and no dry out after testing is required. In this method a pressure at some value above normal operating pressure is applied to a sealed segment of the pipeline. Sources of leaks are found by pressure decay methods, sonic detectors, or application of bubble testing solutions.

Borescopes

Borescopes can be used to aid visual inspection of the interior of pipeing. The standard borescope is a rigid tube with an arrangement of mirrors and lenses to transmit the image. A fiberscope is also available which is a somewhat flexible inspection device since fiber optic bundles are used to transmit the image. These units are easy to use but depend on visual acuity of the observer and are usually limited in length to about 30 feet for borescopes and 10 feet for fiberscopes.

6.1.4 Documentation and Procedures

The daily operations of a gas utility result in the collection of information and data useful for assessing and making decisions concerning the safety aspects of the system. Leak reports and mapping are universally used by most gas companies. Leak reports convey data on leak causes, surrounding environment of the pipe and the repair made. Collection and summaries of leak reports over many years often allow specific pipeline segments to be identified as leakage prone, and can aid in repair/replace and maintenance decisions. Maps, in addition-to defining the physical layout of a pipeline system, its components, sizes, and materials can also be used as the summarizing medium of leak reports. All leaks and repairs made can be noted on maps for a concise view of events and occurrences in the underground plant. The maps also are important for leak surveys, denoting locations to reduce outside force dig-ups, and component location during emergencies.

6.1.5 Nondestructive Testing

The development of testing methods for materials, parts and assemblies without destroying them has advanced the ability to detect inhomogeneities, discontinuities, and thicknesses of in-use piping. The purpose of this section is to present a very brief description of nondestructive testing methods and their application to in-place evaluation of pipelines. Table 6-1 identifies the methods and presents comparative information on the principles of operation, properties sensed, use and the more notable qualifications, advantages and disadvantages. Also, each method is discussed below to note its operation, main capability,. greatest deficiency and best application to pipeline assessment.

Ultrasonic

Ultrasonic testing uses the transmission and reflection of ultrasonic sound waves through an item to detect either subsurface or surface flaws. The sound waves used are above the upper limit of the human ear

Table 6-1 NDT Method Evaluation

	PRINCIPLE OF OPERATION	PROPERTIES SENSED OR MEASURED	TYPICAL USE AND FLAWS DETECTED	DISTRIBUTION SYSTEM MATERIALS APPLICATION	INTERPRETATION LIMITATIONS AND REQUIREMENTS	OPERATOR SKILLS REQUIRED	SPECIAL CONSIDER-ATIONS	ADVANTAGES	DISADVANTAGES
ULTRASONIC	Vibrations above 20,000 cps are introduced into sample. Waves are reflected or scattered by dis-continuities.	Irregularities in acoustic Impedance.	Thickness measure-ment. Denotes cracks, pits, discontinuities, porosity, and delami-nations. Surface and subsurface flaws.	Any continuous medium with frequency transmission characteristics.	Considerable inter-pretation of results required. Size and severity of flaws obtainable by data reduction a com-parison to known data.	High experience and technical knowledge level needed for obtaining good results. and to interpret signals.	Access to one wall required. Coupling trans-ducer to test item.	Good sensitivity. Needs access to only one side. Flaw size and depth accurately determined. Permanent record.	Only small area is scanned. Possible to miss some flaws. Reference standards required. Operator dependent.
ACOUSTIC EMISSION	Test item is stressed. Flaws emit measurable frequency emission.	Wave forms from a crack undergoing plastic deformation.	Detection end location of flaws. Denotes cracks, and possibly pits, os related to occurence of plastic deformations.	Any solid medium with macro-cracks and frequency transmission characteristics.	Data reduction needs to resolve location and severity of flaw. Does not indicate size of flaw.	Nominal experience for field testing. Experience required for data reduction.		Good survey technique. Excavation of pipe may not be required.	Does not determine size of flaw. Contact with pipe required. Stressing of test item required.
RADIOGRAPHY X-RAY & GAMMA RAY	Penetrating ray. as X-ray or Gamma are transmitted through sample. Shadows caused by discontinuities are recorded on film on the other side of the sample.	Variations in thick-ness, density, or composition of test sample.	Thickness measure-ment. Denotes cavities, voids, cracks, porosity, non-metallic inclusions, and foreign particles. Surface and subsurface flaws.	Any continuous medium.	Indicates location and size of flaw and approximations of severity. Film comparison to known reference films required to assess severity.	Experience required for operation end testing methods. High experience and technical knowledge level required to interpret films.	Safety due to radiation hazards.	Visual analysis of buried defects. Permanent record. Detects internal flaws. Good penetration of most structural metals and materials.	
EDDY CURRENT	A-C coil induces fields and current in two samples. Analysis of currents indicates physical differences.	Variations In electrical conduct-ivity a magnetic permeability.	Material properties. Denotes surface finish, discontin-uities, cracks, seams, loss of material, and material irregularities. Surface thws to 1/40 deep.	Metallic only. Best fur non-ferrous metals.	Indicates location and size of flaw. Type of flaw deter-mined from data reduction. Automatic comparison to known sample.	Nominal experience for operation of equipment. Experience required for data reduction.		Adaptable to high-speed testing. Moderate cost. Permanent record. Good for non-ferrous metals.	Conductive materials only. Reference standards required. Shallow penetration. Readings influenced by more than one variable.
SONIC	Vibrations below 20,000 cps are introduced into sample. Waves are scattered, reflected, or attenuated by discontinuities and transmitted by good test sample.	Irregular conditions in low frequency acoustic impedance or natural modes of vibration.	Material properties. Denotes disbonds, delaminations, cracks, voids, changes In tinuities.	Any continuous solid. Limited by geometry.	Locates flaws. Size and severity not determined. Some data reduction required.	Highly experienced personnel not required.		Simple in use. Easily automated.	Geometry sensitive. Locates flaws only. Size and severity not determined. Poor resolution or definition.
MAGNETIC FIELD	Magnetic field induced into test sample. Flaws detected by per-turbation in flux paths.	Variations in magnetic field flux at the surface of the test sample.	Material irregularities. Denotes cracks, seams, laps, voids, porosity, and inclusions. Excellent for surface flaws and good for sub-surface flaws.	Metallic only. Ferromagnetic materials only.	Indicates location, size and severity of flaws. Data reduction requires experience comparison to known data files.	Technician quality personnel required for field testing. Highly experienced personnel for data reduction.		Good sensitivity to flaws and pits. Discriminates between types of flaws. Permanent record.	Ferromagnetic materials only. Reference standards or data file needed. Not suited for general corrosion wall thinning.

response which corresponds roughly to 20 KHz. Frequencies in the 100 KHz to 1 MHz range are commonly used. Higher frequencies provide resolution for smaller flaws since they correspond to shorter wave lengths. Ultrasonics can be used in three definite modes; the pulse-echo, the resonance technique, and the through-transmission method. Of these, the pulse-echo technique is more applicable to pipelines since it requires only one transducer and access to only one side of the pipe wall.

Ultrasonic methods have the capability to determine the size and depth of many types of flaws, both surface and subsurface, in many types of materials. They do require access to a smooth clean area on the pipe wall and a coupling medium of transducer to pipe. Care must be taken in use to cover all areas of the pipe since flaws can be missed if the transducer is not placed directly over the flaw. They have excellent possibilities for assessment of pipelines because detected flaws can be identified sufficiently to determine their potential hazard.

Acoustic Emission

Acoustic emission results from energy released as a material is stressed and undergoes deformation and fracture. This energy propagates in wave form through the material and can be detected by sensitive transducers.

Fatigue cracks and weld cracks have been located with this method. The severity of the flaws are noted by monitoring the rate and intensity of pulses, which increase with the rate of crack growth and extent of the crack. Flaw locations are determined by measuring the relative time of arrival of the emission signal at two locations on the pipeline.

The acoustic emission method can locate and determine the approximate severity of flaws in buried pipelines without requiring major excavations. It does not permit determination of flaw size, nor has it yet been applied to all types of flaws. It is a good survey tool for pipelines to locate areas needing further investigation to eliminate potential problems.

Radiography

Radiography is commonly used for weld inspections during new pipeline construction. Basically, a film is placed on one side of the pipe wall and a radiation source on the other side. Differences in attenuation of the radiation due to voids, cavities or thicknesses cause varying degrees of film exposure which can be interpreted by trained individuals. Reference to known data file radiographs for flaw assessment is often needed. Radiography can locate, identify and determine the size of defects but narrow cracks are difficult to detect and it may not denote the significance of the defects with respect to serviceability. It does require exposure of the pipe so it is best suited to construction inspection and special conditions with regards to pipelines.

Eddy Current

Eddy current testing is a method of evaluating material characteristics or locating surface or subsurface flaws in electrically conductive materials. A primary coil with a varying electromagnetic field induces electrical currents in the item being tested which creates a secondary electromagnetic field.. The secondary field is affected by flaws and characteristics of the test item. The secondary field can be sensed by an independent sensor or by its effect on the primary coil. Generally, eddy current results are compared to the results of testing a test standard specimen to determine flaws. It is considered best for nonferrous metals, but can be used on ferrous materials with magnetic saturation. Its best use for pipelines appears to be inspections for specific type flaws or conditions such as graphitizaticn of cast iron.

Sonic Testing

In sonic testing, the test body is caused to vibrate in its natural frequency mode. Two methods of inducing vibration are by striking the object or by excitation by a transducer driven by a variable frequency generator. Common detectors are microphones or vibration transducers.

For pipelines, sonic methods can be used for detection of leaks by inducing sounds and using receivers. Also, vibration waves can be induced into the ground or pipe and transducers further down the pipe are used to pick up the signal. Wave propagation depends on the homogeneity of the pipeline such that cracks, crevices, corrosion pits, or graphitization should cause attenuation and be detected. Flaw size or severity is not determined so this is best used as a survey tool for locating flaws which require further investigation.

Magnetic Field Perturbation

Magnetic field perturbation methods have the capability of rapid scanning to find the location, size and severity of flaws. They can detect both surface and subsurface flaws in ferromagnetic materials. A magnetic field is induced in the item being inspected and flaw detection is based on the variation in the magnetic reluctance of the pipe caused by the presence of a flaw. The results of the inspection are not directly readable but can be accurately interpreted by trained individuals. It is not applicable to general corrosion or wall thinning detection but versatile for locating other types of defects such as corrosion pits, crevices, voids, and cracks in pipelines.

6.2 CORROSION

Corrosion accounts for considerable expenditures of time and funds by gas utilities. Steel is, and will continue to be for some time into the future, the predominant material in the underground plant, and consequently, corrosion will remain as a major cause of pipeline leaks. In 1973 corrosion accounted for 46% of all leaks repaired, as noted on the OPSO Annual Report. Being time-dependent, the more common corrosion leaks tend to develop slowly such that they are often found by leak surveys and repaired before becoming a reportable type incident. This is somewhat substantiated by inspection of the OPSO Leak Reports which shows that corrosion accounted for only 15% of these failures.

The main steps taken for corrosion mitigation have been coatings and cathodic protection. While corrosion still occurs on pipes with these protective measures, data does show that occurrences are fewer than on pipelines which are bare or have no cathodic protection.

Research and investigation into corrosion have been an on-going concern of gas companies for many years. The work of individual gas companies is exemplified by numerous articles on corrosion. The AGA has funded corrosion research at Battelle. The National Association of Corrosion Engineers (NACE) has on-going programs of research, specification preparation and dissemination of information throughout the industry. Further, many corrosion consulting and service companies have developed procedures and techniques for abating corrosion. Coating materials and techniques as well as equipment to inspect pipes have been developed by manufacturers and producers.

OPSO has also been active in the corrosion problems of pipelines. A primary action has been the issuance of regulations for cathodic protection. Another effort of the OPSO was a study program of "Ferrous Pipeline Corrosion Processes, Detection, and Mitigation" performed by Mechanics Research Inc. Briefly, this study investigated many different forms of corrosion from both the theoretical and practical standpoints. A survey of 373 operating companies was made to determine the occurrences of corrosion and procedures and methods being pursued for corrosion control. Of the 373 companies, 159 responses were from gas distribution companies with the remainder from gas storage, gathering and transmission companies, petroleum transmission and distribution, and water companies. Thus, the results of the above study are related to the problems of gas distribution and very applicable to this report. Much of the discussions which follow are summarizations of that corrosion study.

The deterioration of underground plant is due to a number of types of corrosion which have been identified and noted under various headings defining where it occurred, causative factors involved or the type of failure.

The major cause of corrosion was found to be galvanic action pitting of the pipe external wall. A few categories of corrosion noted in the report are:

Uniform corrosion	Pitting
Crevice corrosion	Galvanic
Stray current	Stress corrosion cracking
Intergranular corrosion	Hydrogen stress cracking

The mechanisms and factors involved in the above types of corrosion vary considerably and are affected by several environmental parameters. Higher temperature generally increases the rate of corrosion. Most corrosion increases with time except uniform corrosion, where corrosion products may block access of corrodents. Solutes in the soil, within certain ranges for particular metals, increase susceptibility to certain types of corrosion. Moisture in the soil acts as an electrolyte and increases corrosion by lowering soil resistivity. The chemical properties (acidity or alkalinity) affect the progress of corrosion and micro-organisms in the soil can also degrade some coatings or reduce compounds in the soil to generate by-products conducive to particular corrosion.

A considerable amount of research is going into corrosion control and several methods are used. Emphasis on corrosion research by gas companies has been in areas of stray currents, coatings, environmental effects on corrosion resistance and coatings, and anode composition. Often specific forms of corrosion can be mitigated by material selection or material property specifications. For pitting, the main problem of distribution systems, little can be done by the selection of particular steel compositions. The application of inhibitors on the pipe exterior is seldom'used because its effectiveness with regard to pipelines is still unknown and application is based on empirical data.

Coating of the pipe exterior is an often used method. Coal tar, thin film plastics and asphalt are used most for major portions of the pipe and at joints or appurtenances.

Cathodic protection has been used for many years and is now required except under non-corrosive conditions. These systems must usually be tailored to the particular pipeline in order to obtain the proper balance of electrical conditions. The needed current densities can depend on many environmental conditions as well as coatings and the pipe itself. Soil resistivities are particularly important when designing a cathodic protection system. Sacrificial anodes are used often with many companies preferring Magnesium anodes but impressed current is also used. Generally it is found that cathodic protection is more effective on coated pipes. The two complement each other well since the coating reduces the current required to protect the pipe and corrosion would primarily occur at coating holidays.

The methods used to assess the cathodic protection on a pipe include measurements of electrical parameters and records of leak occurrence. The measurements made include the pipe-to-soil potential, current flow between pipe and soil, and the current flow in the pipe itself. These were discussed previously under the pipeline assessment section. Also, the plot of cummulative leaks has been discussed as a means to evaluate corrosion control by indicating where cathodic protection has been effective. For all of the methods, a criterion of acceptibility must often be established for each individual utility. Specifications have been established for the electrical measurements but even these often must be slightly modified to suit particular pipelines and their environment.

Leak history is used by the majority of utilities and is the factor principally considered for determining action as to replacement or abandonment of corroded pipe. The pipe-to-soil potential, visual inspections at bell holes, and electrical current measurements rate high as the most used pipeline surveillance methods for corrosion.

A few other general problems associated with corrosicn were mentioned in the study. One of these is a lack of training of- corrosion consultants.

A number of training programs are available but since corrosion control is more an art than a science, it is difficult to grade or certify corrosion specialists. It was also found that many small piping systems are seldom controlled and are often subject to interference by stray currents caused by electrical grounding to water pipes. Mechanical damage by outside forces often damages coatings, which eventually results in a corrosion leak. Finally, it was found that cathodic protection was sometimes improperly used either due to lack of knowledge or personnel errors.

6.3 OUTSIDE FORCES

Outside forces are the largest problem of gas utilities in causing reportable leak incidents. In 1973, the OPSO Leak Reports showed outside forces to be the cause of 68% of all leaks. From the Annual Reports, outside forces accounted for only 13% of all the repaired leaks in 1973. The damage done by outside forces, while not a large overall cause of leaks, usually results in dangerous ones. While they are attributed to many causes including landslides, washouts, earth movement, etc., by far the major "outside force" cause is pipeline damage due to excavation equipment. The problem is not. limited to gas pipelines, for other organizations operating buried waterlines, sewer lines, and electric and telephone cables have a high incidence of dig-ins.

One response to this problem has been the recent revision to the regulations regarding pipeline marking. An amendment issued in March 1975, included distribution mains in the requirement for permanent markers. Marker locations are denoted along with standardized sign wording and minimum letter size. The exceptions for buried pipelines in class 3 and 4 locations allow considerable latitude and probably will help push along programs established by law for preventing interference with underground pipelines.

Studies have been conducted by individual gas companies and the AGA into the causes and means to prevent damage to pipelines. One study entitled, "Analysis of Causes and Determination of Possible Means for Prevention of External Damage to Pipelines," was performed by Battelle for the AGA on transmission lines. This report showed that some of the reasons why damage did occur to pipelines included the following:

- Equipment operator negligence, misjudgment or carelessness.
- Inadequate physical markers to accurately locate or alert equipment operators of the presence of a pipeline.
- Company pipeline patrol was not effective in detecting earth moving jobs. This is somewhat correlated to frequency of patrol which tends to indicate that lines with more frequent patrols have fewer dig-ins.
- Lack of communication between company and excavators as to the importance for notifications of intent to dig.

A few of the more recent attempts to reduce outside forces have been by 1) establishing good means of communications between utilities and excavators, 2) establishing laws which provide penalties for improper excavation, and 3) studies of outside forces. The items to be discussed include the one-call system, utility location and coordination council, proposed laws, and a study on outside forces.

6.3.1 One-Call System

The one-call system uses one telephone number to be called by a contractor planning to excavate, to inform all participating utilities and operators of underground facilities of the proposed excavation. These programs were pioneered by utility companies to assist contractors so that as a minimum, the utilities would be aware of any excavation near their facilities. Contractors in many areas are legally required to notify operators of underground facilities prior to start of work. The problem to them, however, is almost formidable simply because often there is no way to be aware of all who should be contacted. One example is Michigan where the MISS DIG program is in effect. Michigan's lower peninsula has

34 gas and oil companies, 44 electric companies and 45 telephone companies operating with non-uniform or overlapping boundaries. Couple this with water and sewage systems and facilities of private companies and it becomes very difficult for a contractor to comply. The problem is even further complicated by the need to reach the proper individual or department within the companies contacted.

Thus, a method by which a contractor can call one number and designate his excavation spot, letting others determine who is involved and then notifying them, can be beneficial. The key to success is to have all operators of underground facilities participating in the program.

In general, it can be stated that the majority of the operational problems of these programs have been largely resolved so that specific areas or states can tailor programs to suit their needs. There are currently at least eighteen major one-call systems operating in the country. A central notification station is established and provided with recording and computer equipment. Reports of proposed excavations are teletyped to major utilities and telephoned to smaller participants. The area served is divided into small sections by grids or using existing township or county divisions so that some discrimination can be made at the center and only those who may be affected by the excavation will be notified. Costs involved are shared by the participants.

The assessment of effectiveness of these programs is difficult partially because they are relatively new and because of such unknowns as:

- The amount of excavation in any one year which would have affected a utility.
- The number of dig-ins which were prevented.
- The number of important notifications the utility would have received without the one-call system.

An idea of the effectiveness can be noted by the number of requests for location received each year. Implementation of these programs has generally resulted in a 2 to 3 times increase in requests for location.

Also, most utilities in one-call systems have noted a decline in the total number of dig-ins on a per year basis. One company involved in a one-call system started in 1972 has indicated a 16% reduction in dig-ins in 1974 compared to 1973. However, there is an involved cost associated with this. The manhours spent locating distribution lines increased about 50% which for the gas company meant that two persons had to be added to the staff for the purpose of locating and marking pipelines for damage prevention.

A few points required to make these programs effective are:

- Participation by all operators of underground facilities.
- Proper and quick response by all utilities and agencies notified.
- Dissemination of information so excavators are aware of and use the system.
- Adequate subdivision of the area so that the number of applicable notifications remains as a good percentage of total notifications received.
- The program is established to the extent that the contractors can rely on it.

6.3.2 Utility Location and Coordination Council

A Utility Location and Coordination Council was established within the American Public Works Association (APWA) in 1974. The establishment of this council was partially intended to fulfill a recommendation of the NTSB and to fill the need for a centralized group to organize and direct material to utility companies.

This council will disseminate information to help the establishment of coordination councils at the state and local level. They intend to set-up guidelines for organizing a coordination council and standardized procedures for operation. While workable procedures for councils have been proven, the problem of educating and presenting the information to all agencies still remains. The future goal is establishment of local utility coordination committees or one-call systems at all areas where they are needed. Such efforts will improve the safety of working conditions, reduce the number of dig-ins, reduce accident severity, minimize public inconvenience, and promote cooperation between all parties involved in construction, excavation and regulation or operation of underground facilities.

6.3.3 Proposed Laws

It has been pointed out that pipeline damage does occur on lines even where notification has been made and the line was marked. Therefore, laws have been enacted by some states and proposed in others to provide that certain requirements be met and to invoke penalties if they are not met. It has been pointed out that damages occur in spite of laws passed, so that it appears the damage control programs initiated by utilities are more beneficial in reducing damage. However, the law does focus attention on the problem and can provide means by fines or loss of license to stop contractors with bad dig-in records.

A Model Statute proposed by the OPSO has been submitted to regulatory, governmental and industry agencies for comment and guidance for legislation. The intent is to obtain inputs for revisions of the statute so that a viable statute may be eventually published. Local governments could then enact, in total or in part, the requirements of the statute to satisfy local needs. A few of the provisions of the statute are:

- Utility location information will be filed by underground facility operators at a central location.
- Persons engaged in excavation or demolition work must present a written notice of work to be performed to the central location prior to start of work.

- Pipeline or utility line operators will be notified of intended excavation or demolition prior to start of work.
- Operators will respond to notices by identifying or marking buried lines.
- Work near the lines will be performed so as to avoid damage.
- Damage which occurs will be reported.
- Enforceable penalty provisions for violations.

6.3.4 OPSO Study on Outside Forces

OPSO is now finalizing a contract for a study to evaluate the effectiveness of programs for the prevention of damage to pipelines by outside forces. This study will investigate all the facets and causal conditions of outside force damage to pipelines. The promotion of statutes and coordination councils will be investigated and their effectiveness evaluated along with investigations into pipeline marking and locating methods. Also, discussions will be held with a wide cross section of organizations associated with outside force damages including the gas industry, other utilities, contractors, labor oganizations, public work groups, manufacturers, professional groups, and regulatory agencies. The results of this study will provide greater insight into the outside force problem and potential solutions in the form of conclusions and recommendations.

6.4 ODORIZATION

Odorization of natural gas in distribution lines, which is now mandatory, has been in use for a number of years to give warning of the presence of gas. Some natural gas is odorless while others contain natural odorants. In some cases the gas must be completely odorized while in others the natural odorant is supplemented so that the gas is detectable at 1% gas in air by volume. Used properly, in addition to providing a warning of the presence of gas, odorants allow use of the general public to assist in leak detection. Some assessment of the value of odorization may be derived from the OPSO Leak Reports which show that many leaks are reported by the public and by customers.

Several problems of odorants such as which odorant to use, how much to use and how to inject it into the gas stream, have largely been overcome by the gas utilities either by individual investigations or collectively through the AGA. Producers of odorants have assisted by development of compounds and blends to obtain better and more effective odorants. Equipment for odorant injection has been developed and improved upon over the years. Manufacturers and organizations have likewise developed equipment for measuring or assessing the odorant in the gas stream. Development is continuing in this field to improve upon the gains made to date, since the value of odorization is well acknowledged.

The mechanics of odorization and its use appear to be well managed by most utilities. However, articles and failure reports have indicated two problems which do need some investigation. One problem is odor attenuation as the gas permeates soil under some conditions. The second is the failure of individuals to recognize the odor as a warning of natural gas possibly due to olfactory fatigue or lack of education. Attention to these problems has been given by the AGA which over the years has sponsored considerable research into odorants. One of the more recent trends has been towards developing odorants that are not removed from the gas. as it permeates through the soil.

There also exists a third problem with odorization of natural gas which bears indirectly on safety. This third problem stems from the use of sulphur based odorants. These sulphur compounds have detrimental effects on some industrial processes. Since the removal of odorants from gas is inconvenient and costly, there is a tendency to want to keep the gas stream as pure as possible during the long distance transmission stage. The development of non-sulphur odorants would alleviate this problem and be a beneficial alternate.

The **OPSO** has also been active in the odorization of gas in both transmission and distribution lines. Through there are still many conflicting views, OPSO recently revised the regulations to require odorization of much of the gas carried in transmission lines. A second action was the sponsoring of a study entitled "Study of the Properties of the Numerous Odorants and of Their Effectiveness in Various Environmental Conditions to Alert People to the Presence of Natural Gas", which was performed by IGT. The purpose of this study was to survey gas utilities and available research to determine and make recommendations to resolve some odorant problems. The remainder of this section on odorization contains excerpts from the above study.

To be effective, natural gas odorants must have an odor which is distinguishable from most other odors and which the public associates with gas. Most commercial odorants are based on sulphur compounds, which have what is considered a "gassy" smell and generally most companies consider them to be satisfactory. The more commonly used compounds for odorants include tertiary butyl mercaptan (TBM), isopropyl mercaptan (IPM), normal propyl mercaptan, secondary butyl mercaptan, thiophane (tetra hydothiophene-THT) dimethyl sulfide (DMS), diethyl sulfide and methyl ethyl sulfide. Each has particular characteristics such that, while usable individually, they are generally better when blended.

Odorization goals vary in minor degrees from one company to the next, but there are several common to all companies. Regulations are a common requirement but generally the odorization is based more on meeting company needs. First, gas is odorized to be detectable when it is escaping from a leak. However, the odorant must not be toxic or harmful to people or piping materials, it should be relatively insoluble in water, and the products of its combustion must not be harmful or corrosive. Secondly, the intent is to warn of leaks only when safety is concerned. Over-odorization can lead to a situation where extremely minor leaks are reported, which overpowers the capabilities of the utility to respond and makes odorization counterproductive. Odorizing programs are therefore a balance of many factors, including cost and availability of odorants.

One reason for the variety of odorizing practices is the differences in the gas purchased by distribution companies. Some companies receive gas with natural odors or where odorants have already been added, while others receive gas with no odor. It is therefore important to know what is being received in order to know what to add to attain proper odorization. Most of the common odorants are used to some extent to provide or supplement existing gas odor, with the mercaptans or mercaptan blends being used the most

The two main types of odorizing equipment used are the evaporation and liquid injector odorizers. Evaporation types are simple, lower in cost, and comprise the majority of the odorizers in use. The liquid injection types are somewhat more complex, have more components and are more expensive, but have more capability and are used on larger installations. Liquid injector types, though fewer in number, odorize larger volumes of gas than evaporation types. Generally, the companies feel the liquid injection types have better overall operation and are satisfactory. The evaporation types are satisfactory due to simplicity, but need improvements in achieving odorizing control.

Odor level monitoring is in many ways slightly subjective in that it must eventually be referenced back to an average human sense of smell. The two more general methods of odor measurement are 1) those which use the sense of smell directly and 2) those which determine the sulphur content of the gas stream, which then can be related to its odor.

The sense of smell is used in conjunction with odorometers to determine if the gas is properly odorized. Of the two types, the gas in air volume by flowmeter measurement was used more than the combustible gas indicator type. Another type of check involves gas sniff tests at various locations in the system by employees. Room tests are also used but they are more of a research rather than control method. Another method is to keep track of all leaks reported by the public and determine the size of the leaks reported. Fewer than average calls may indicate insufficient odorant while excessive calls may indicate over-odorization.

Titrators are used most often to indicate the sulphur compound concentrations in the gas stream. They can be used to selectively titrate different classes of compounds. This information can then be compared to data which shows that certain concentrations of compounds result in proper odorization of the gas. Titrators can be used to monitor gas flow and the results then used to adjust the odorant-injection rate. Other equipment used includes gas chromatographs or other special equipment with sulphur-selective detectors.

The fading of odor from gas has been looked at from many standpoints. Chemical reaction of odorants with piping materials has been known to occur, as well as adsorption on pipeline walls and deposits. Odorant adsorption can also occur due to solubility in liquids in the gas stream. New piping also presents problems of odor retention in the gas. Most of the above problems are recognized and can be corrected by spot checks and supplemental odorization. The problem noted as needing research was fading of odor by adsorption of odorant by soil. Here studies have shown that it is not so much the odorant as all the field variables encountered which affect the fading. The variables include type of soil, moisture content of soil and gas, and other lesser variables. It is a recognized problem and one odorant characteristic which needs improvement.

6.5 PLASTIC PIPE

Over the past 20 years, the use of plastic pipe in gas distribution systems has increased considerably, with the most dramatic increase taking place in the past 5 years. In 1974, plastic pipe accounted for about 13,000 of the approximately 25,000 total miles of pipe installed, which amounts to over 50% of plastic pipe usage. The majority of the plastic use was in pipes of 2 inch diameter or less. Two of the major reasons for its use are a) the noncorrosive characteristics of plastic and, b) the economies to the user for both direct burial and insertion techniques for refurbishing deteriorated installations. The extent and increase of plastic use is seen in the table below.

Table 6-2. Plastic Pipe Use

Year	% Plastic	Million Feet Installed
1966	12	---
1967	13.5	---
1968	16.5	---
1969	19	---
1970	21	46
1971	25	55
1972	31	57
1973	42	81
1974	51	71 (Est.)
1975	57 (Est.)	---

The percentage of plastic pipe has continued to increase even though the amount of pipe installed may decrease due to possible slow downs in construction as noted for the year 1974. It is thought throughout the industry that plastics will continue to be used at a rather high rate in future years for both new and replacement installation.

The advantages of plastic pipe include installation adaptability and corrosion resistance. Plastic pipe is adaptable to plowing in methods including continuous pulling of pipe or continuous planting of pipe. It is also used for insertion into existing pipe. Further, the lightness of plastic and its ability to be coiled facilitates handling and installation. The non-corrosive characteristic of plastic may be the prime reason for its use. Recently enacted regulations concerning cathodic protection on steel piping, or proving that corrosion is not occurring, may have actually accelerated the use of plastic. Obviating the need for cathodic protection and the subsequent record keeping and inspections can add to the economic advantages of plastic.

The more notable disadvantages of plastic pipe are:

- Location after burial. Tracer wires or tapes must be buried with plastic pipe to trace it by conventional metal locators.
- More susceptible than steel pipe damage by excavation equipment.
- Susceptibility to creep, cold flow and deformation under load.
- Temperature limitations regarding lower heat resistance due to thermal degradation and heat distortion, and brittleness at low temperatures.

The introduction of plastic pipe into gas distribution systems at such a high rate has brought new problems to the industry. First, the plastics industry has been developing new and improved materials at such a rate that the materials used today are not the same as those used earlier.

Secondly, materials were often being used that were sufficiently new that their complete characteristics, particularly with regard to aging, were not known. This is further complicated because some plastic compounds are considered proprietary formulations by their producers. Other new problems include the need for new standards and specifications, new installation and inspection methods, the unknown resistance to in-use loads, and after burial location problems.

A large amount of research has been done on these problems by individual gas operators, the AGA, Battelle, ASTM, ASME, Plastic Pipe Institute and the Technical Pipeline Safety Standards Committee. In addition, plastic producers and independent testing laboratories have performed investigations and research on plastic pipe. The work of individual gas utilities is evidenced by the wide coverage of articles in pipeline periodicals and journals. Recently the OPSO initiated a study to be performed by the Toups Corporation, entitled "Pipeline Industry's Practices Using Plastic Pipe in Gas Pipeline Facilities and the Resulting Safety Factors." Much of the information contained below is a summarization of that study.

6.5.1. Plastic Materials in Use

The particular plastic materials which have been used or are currently in use for gas piping are:

ABS	Acrylonitrile-Butadiene-Styrene
CAB	Cellulose-Acetate-Butyrate
PVC	Polyvinylchloride
PE	Polyethylene
PB	Polybutylene
RTRP	Reinforced Thermosetting Resin Pipe

Of all the materials installed in the past, PE has the greatest percentage of use and RTRP has the lowest. ABS and CAB were some of the original plastics introduced into the gas industry and are in use in older systems but not newer ones. Results of a questionnaire sent to gas companies shows that in 1974: PE was used by 96 percent, PVC was used by 26 percent and ABS and

CAB were not being used. Many companies use both PE and PVC. PB has only recently been included in ASTM D2513 and as yet is not being installed in significant amounts.

6.5.2 Characteristics of In-Use Plastics

The characteristics of in-use plastic pipe are related to the resins and compounds used for pipe and fittings. A few of the basic points that have been considered and evaluated for acceptability of use in the gas piping are:

- Aging resistance
- Chemical resistance
- Failure behavior
- Impact resistance
- Joining - ease and reliability
  - Plastic to plastic
  - Plastic to metal
- Long term strength
- Permeability
- Temperature resistance

Over the time period of plastic use in gas systems these items have been considered by gas operators, producers, and technical committees. Generally, the result has been that the superior materials are still used while inferior products have been eliminated through gained experience. Most companies purchase pipe to specifications and some perform testing to verify compliance. Overall there appears to be a need for increased technical evaluation of plastic pipe selection to match the specific design, construction and operating requirements to the various plastic pipe characteristics.

Additives used in plastic pipe generally provide coloring, increased resistance to ultra-violet rays and anti-oxidant protection. Also, some additives are used in particular compounds to ease or facilitate processing or to improve aging characteristics. Few users of pipe specify or require certification of additives.

6.5.3 Problems Identified with Plastic Pipe

From leakage data and reports and a review of the literature, the problems identified with plastic pipe include damage by outside forces, locating after burial, and damage from electrical sources including close proximity to electrical services, lightning conducted by tracer wires and static electricity.

The plastic pipe study identified additional problems from questionnaire responses of 40 gas companies. Many of the additional problems, while potential safety problems are more relatable to the day-to-day problems of constructing and maintaining a system. The items noted in the report are:

- Improper construction - this was noted as one of the major problems of plastic pipe use by gas companies. Corrective measures include better construction specifications, training, and inspection.
- Dimensional problems which included both sizes and out-of-round pipe. This can create joints of inferior quality. Corrective action entails greater quality control and pipe coiling specifications since some of the set taken and pipe ovalness has been traced to the coiling process.
- Transition fitting failures have been noted by many companies but are rated as infrequent or minor. The failure causes or results were noted as shear at stiffeners, pullouts, stress cracks and leaks.
- Joint failures were noted in solvent and epoxy joints. They were traced to pipe brittleness and faulty installations.
- Joint trenching by several utility companies was identified by the gas utilities as a reoccurring problem. Generally the damage to plastic pipe was due to improper backfilling, lack of coordination between utilities, insufficient utility separation and construction damage.

6.5.4 Installation and Inspection Methods

The installation and inspection methods for construction of gas systems covered in the plastic pipe report included pipe laying-in techniques, joints, protective sleeves, transition fittings and non-destructive testing methods.

Installation techniques include standard laying in an excavated trench and new methods of plowing in. For standard ditching operations, it is imperative to provide clean, smooth, trench bottoms and to cover the pipe with a select backfill free of sharp rocks or pavement fragments. The plowing-in method involves pulling a ripper through the ground and simultaneously pulling a section of pipe through the hole made by the ripper. The straight pull method has the potential for pipe damage from cuts and scratches due to rocks or other material being wedged between the pipe and soil as the pipe is being pulled. This has been learned from experience in pulling steel pipe and noting the rock damage to coatings. Generally, there is no way to inspect for damage after this type of installation, other than by excavating. The feed-in method from a coil is more satisfactory in that the pipe is laid into the opening behind the ripper. This eliminates the soil friction problem so that longer lengths can be continuously laid, eliminates the rubbing of pipe against soil, and reduces the potential for cutting or scratching of the pipe. A few problems noted with plow-in methods are: possible cuts and scratches, no visual inspection after installation, tracer wire breaks, and stretching of the pipe.

The joints used in construction include solvent cement, butt fusion, socket fusion, compression fittings, and adhesives. The solvent cements are used for PVC, CAB, and ABS pipe, the fusion joints for PE and PB, compression fittings for all plastic and adhesives used niainly for RTRP. For all joints,cleanliness , strict following of procedures and directions, and good workmanship are important. In general, the study determined that all the above joining methods when used properly, provide satisfactory joints.

One problem yet to be worked out is which joint to use depending upon pipe diameters and wall thicknesses. Research would be required to determine the best joint for particular pipe parameters and also to standardize joining procedures and develop less complex joining techniques.

Transition fittings were developed to allow connection of plastic to steel pipe. The problems generally attributed to them probably stem from attaching a flexible item to a rigid item. Protective sleeves over transition joints have eliminated many failures. The main problems noted with these fittings have been improper installation, workmanship, and external loadings from earth settlement.

Protective sleeves can be used around pipes to take the load where support is removed such as at a bell hole or trench excavation. Sleeves are used to limit the bending of the plastic pipe, reduce bending and shear stresses in the pipe due to inadequate backfilling, provide protection from mechanical damage, and reduce stresses at fittings. The main problem associated with sleeves is that they were not used or were improperly applied; In these cases, the imposed loads on the gas piping were not distributed and failure of the piping occurred.

Once piping has been laid and jointed, an inspection of pipe should be performed. Visual inspection is often used, sometimes in conjunction with a pressure test and bubble check. Of the nondestructive testing methods available, ultrasonics was considered to be more adaptable to plastic pipe joints than x-ray, microwave and others. Research *is* needed for development of plastic joint testing equipment based on ultrasonic principles which are 95% reliable, lightweight, and easily used by one man.

6.5.5 In-Use toads Investigation

The in-use loads on plastic pipe whether inherent, internally applied or externally induced can cause failures. These can be either ductile or brittle in nature, with brittle failures being more sudden and potentially more catastrophic. At present, it is difficult to predict the mode of failure over long periods of time for the most-used pipeline plastics. Reports by gas companies indicate that more have had brittle fractures than ductile failures. Research performed also indicates that brittle fractures will occur at lower pressures than ductile fractures. Values of fracture toughness of materials are heeded to determine hoop stress versus pipe diameter for selecting plastic pipe for new designs. The means to assess potential failures of installed pipe is by continued leak investigations and evaluation of each plastic failure in terms of failure mode and material failures.

Most structural failures of plastic pipe are attributed to external loadings caused by soil stresses and other induced loads. The soil stresses can be due to vertical soil pressure or soil movements while the other induced loads are often attributed to heavy construction equipment, road loads and traffic vibrations. Generally, the best corrective action for induced loads is a specification for backfilling and the fill material.

Another commonly induced load on plastic pipe is the squeeze-off technique. The pipe is squeezed to shut off the flow of gas through the pipe and has been found to be useful as temporary pressure control measures to permit repair or replacement of sections of failed or damaged pipelines or to facilitate construction of new pipelines. The pipe squeezer consists of two rounded metal bars and a mechanical or hydraulic means for forcing the two together. Proper procedures including maintaining a minimum squeeze gap, use of round smooth squeeze bars, and locations of squeeze points, are required if the pipe is to be reused. The main problems with this method of gas control relate to some pipe having to be replaced due to damage, and the unknown long term effect on pipe which has been squeezed-off and returned to service. A further safety problem for gas employees is the static electricity generated by the squeezing-off procedure.

6.5.6 Plastic Pipe Locating Methods

Locating buried plastic pipe is a problem to gas companies. In order to make use of standard metal locators in either conductive or inductive modes, tracer wires or tapes are buried along with the pipe. The tracer wires can be placed alongside the pipe, taped to the pipe, or above the pipe. Usually, the tracer tape is placed above the pipe. Tracer wires can be bare or covered, the covered being preferred from a corrosion standpoint. Tracer tapes are usually aluminum foil encased in plastic. A few problems noted with tracer wires are that it can present a path for lightning or stray voltage sources which can damage the pipe, corroded or cut tracer wire which is difficult to locate and tracer tape also requires special operations for installation. Corrective actions regarding tracer wires would be to establish regulations requiring coated wire of a minimum size.

A more recent development in locating plastic pipe is the use of a downward looking radar. A transmitter generates a short pulse which is transmitted into the ground. Reflected pulses from underground discontinuities are detected by a transducer and transformed into a readout indicating substructure and their depth.

6.6 EMERGENCY PLANS

All pipeline operators are required by regulation to have written emergency procedures. Further, they are required to acquaint appropriate operating and maintenance employees with these procedures and must establish liaison with appropriate public officials, including fire and police, with respect to the procedures. Finally, the operators must establish educational programs for customers and the public in recognizing and properly reporting gas emergencies.

As of this time, there are no regulations which identify exactly what must be contained in the written emergency plan. Rather the regulations are a performance type which allow the utilities wide latitude in preparing plans which best fit their particular system. Plans can therefore emphasize or be adjusted to suit specific problems or special operations of the system. Utility size, location, and standard operations can affect the emergency plan as well as the pipeline parameters such as materials, components, age and operating pressures.

Emergency plans have received considerable attention recently, most notably in the pipeline failure reports published by the NTSB. As was indicated in Table 4-10 in Section 4 of this report, emergency plans were cited in many cases as contributory to occurrence of the accident or of resultant damage due to improper preparation or execution of an emergency plan. A few of the more important procedural or emergency plan problems noted in NTSB investigations are:

- No written emergency plan of written procedures for operations being performed.
- Insufficient liaison between gas employees and firemen at an incident, or failure to inform public officials.
- Inadequate personnel training.
- Failure to shut-off the flow of gas.
- Insufficient educational programs for customers and the public to recognize and report gas emergencies.
- Equipment or special tools not available at the scene.
- Communication lines overloaded or emergency calls not handled properly.
- No carry through of evacuating people, checking buildings for gas, shutting down, or locating the leak.

The above items and others have been incorporated into several NTSB recommendations. Generally it has been these investigations and recommendations and the experience and data gained by OPSO which has allowed a proposed rulemaking to be drafted.

The proposed rulemaking, which amplified the requirements of emergency plans, was published in the Federal Register, Vol. 40, No. 59, on March 26, 1975. The revisions provide more detailed imformation which can assist operators in preparing plans. The revisions, while defining some minimum items to be included, still leave sufficient latitude for operators to tailor the plans to meet their needs. Basically, the proposed rules would require emergency plans to identify emergency calls, indicate how at least two means of communication are provided, the response to each type of emergency and how proper action and equipment are to be applied. The training and monitoring of employees in emergency procedures is added, as well as the requirement for advance planning of gas utilities with public officials. The educational programs have also been broadened to make them more comprehensive with respect to geographical areas covered and languages to be used. Comments by interested individuals on the proposed rule modification will be used by OPSO to determine extent, additions or deletions which should be made to emergency plan regulations.

Another development concerning emergency plans are Addenda 10 and 11 of the ASME Guide for Gas Piping. The OPSO proposed rule and the Guide are consistent with one another. The guide presents a number of items and considerations which would be useful to be contained in an emergency plan. In addition to stating what should be contained it specifies possible solutions in handling emergency situations.

Overall, the importance of emergency plans has been recognized by both industry and governmental agencies. It is also recognized that it is impractical to try to define detailed procedures for all types of emergencies. So many variables can be introduced that it becomes necessary for the procedures to be flexible, Yet, by preplanning and having specific courses of action in mind, the reaction time can be reduced, which in many cases may prevent some fatalities or damage.

The approach taken to date, that of amending and emplifying existing regulations seems to be the best method of applying the results of failure analysis and experience gained to the problem. In a step-wise fashion, the plans of all utilities will be up-graded to be more comprehensive and useful to them without creating undue hardships by requiring extensive manuals to be prepared. Also, since detailed procedures may be inherently impractical from the standpoint of covering all types of emergencies and the needed continuous updating, the trend for employee training is interesting. The beneficial result of employee training was commented upon at the 1975 AGA Distribution Conference. Two similar failures of a pipeline supplying three interconnected systems were compared for response. One response was prior to training, while the second response was subsequent to having written shutdown plans and study sessions. In the first case shutdown took 40 hours while in the second case it took only 5 hours. In this example, it must be emphasized that the system was not out of control for the full 5 hours. Leak control from notification to isolation required almost 2 hours with the remaining time being spent in switching over a complex system to reduce effects to customers. Also, while several other factors were involved in these incidents, the benefits of training were evident. Other cases were also noted where the lessons learned from training in one area were easily applied to other situations.

Generally, it appears that improvements in emergency response will be accomplished by planning that identifies hazards, provides specific actions and methods for response, and concentrates on training and education. Of these, maintaining a well trained staff will probably provide the greater benefit.

6.7 VALVING AND RAPID SHUTDOWN

Valving, rapid shutdown of failed systems, and telemetering of information to central locations to detect failures, are topics which have been considered and investigated as to their application to distribution systenis. Most notably these topics came to attention in NTSB investigations of pipeline failures. It was noted in several cases that actual shutdown of gas flow was not performed in an expeditious manner, and situations existed where pressure or flow measurements if telemetered to a central office could have forewarned of the potential danger that was building.

. The above methods of control have been effectively used on transmission pipelines but their application to distribution systems is neither simple nor easily achieved. A transmission line is usually a single long pipeline which operates on a relatively constant flow basis. Distribution systems on the other hand are often looped and interconnected, may have several gas input stations in the system, and can have wide fluctuations in flow determined by consumer usage patterns. To shut down a section of distribution pipeline may involve a series of valves. Rapid shutdown and telemetry information can only be used in selected sections of systems or must take into consideration many variables. Rapid shutdown of distribution systems is probably most useful as automatic shutoff equipment on service lines, since the fluctuations in gas flow in distribution mains can be so wide as to not allow any meaningful setting of shutoff equipment. Telenietered data would be most useful if obtained at a gate station, but if the system has more than one gate station, then information from all stations must be compared and correlated to obtain valid results.

A large amount of work has been done by many organizations on these control methods for distribution systems. Manufacturers have been developing automatic shutoff valves for service lines and gas utilities have been installing them in selected pipelines. Telemetry equipment development has been pushed by private industry and installed in limited fashion by some utilities. Valves have long been installed to sectionalize distribution systems and now some valves, which then receive specified periodic maintenance, are required to be designated as key valves to be used in emergency situations. However, the exact 'locations of valves must still be left to the discretion of the gas operator as to spacing, to allow accounting for pressure, flows, line sizes, and other local conditions.

Studies have also been conducted on these control methods. Recently the AGA made a study of rapid shutdown in distribution systems and a report is expected to be published shortly. Also, OPSO initiated a study entitled, "Rapid Shutdown of Failed Pipeline Systems and Limiting of Pressure to Prevent Pipeline Failure Due to Overpressure." This study performed by Mechanics Research, Inc. (MRI) investigated all types of liquid and gas pipeline systems. Several excerpts from this report were used in the following discussions of sectionalization valves, automatic service shutoffs, and telemetry.

6.7.1 Sectionalization Programs

Distribution systems are valved so that the whole system can be sealed. That is, valves are installed upstream of regulator stations so that flow of gas to whole systems can be curtailed. Also each service line has a shutoff valve to isolate the distribution system from the customer's piping. Both the inlet(s) and all of the outlets of each system are valved to allow total isolation of the distribution system.

In addition, valves are installed in the distribution mains to allow control of subsections of a system. These valves can reduce the time required to shut a section of main in an emergency. The recent report by MRI shows that the manual closing of sectionalizing valves is the most frequent method used to control escape of gas in distribution systems. Other frequent methods are saddles and clamps, stoppers, and pipe pinchers. Saddles and clamps are more of a repair method while stoppers and pipe pinchers perform the same function as a valve except their use often includes some damage to the pipe. The report goes on to show that although valves are the most used method, they are frequently not used where interruption of service would result. This is a conflict which the report indicated as needing further investigation to clarify the use made of sectionalization valves by distribution companies.

A few advantages of using shutoff valves to stop gas flow are:

- Rapid shutdown represents a potential safeguard against errors in judgment.
- Safeguards against unknown paths of gas migration through soil.
- Can present a simple follow-through procedure for emergency conditions. Reduces the need for judgment or evaluation by the gas employees at the scene.
- The times required to locate and close valves are less than other typical methods of controlling the escape of gas.

A few of the disadvantages noted with regard to sectionalization valves are:

- The true value of shutting down a system has not been proven.
- Inconvenience and possible hardships to customers.
- Weather conditions can affect valve operation.
- Many valves can be a potential problem with vandals shutting off gas to customers.
- Special locks or wrenches to insure only authorized operation of the valves often places emergency personnel in the position of not having the proper tool.
- There is an associated risk involved with starting up a system which has been shut down.
- If gas has migrated considerably or collected in areas, subsequent closing of valves may not prevent an explosion.
- Other actions such as checks for gas migration, evacuation, elimination of ignition sources, and others are often still required in addition to closing of valves.
- Costs on the order of 20 to 30 dollars per customer are the expected average due to shutdowns. This can be significant if service to a large number of customers is curtailed.

A cost/benefit analysis based on installing and using valves placed at 0.1 mile intervals was performed in the MRI study. The analysis showed that rapid shutdown by manual sectionalizing valves cannot be recommended from a cost/benefit approach wherein the criterion for justification is that the estimated benefits equal or exceed the costs. One problem encountered is the considerable uncertainty in the estimated benefits from rapid shutdown. This led to the recommendation that there is a need for improved gas escape control practices used by gas distribution companies in responding to notification of a leak. This was based on accident reports which showed failure to (a) determine limits of gas migration, (b) evacuate and control public access to areas of gas concentration, and (c) close valves which were available and which would have effectively reduced time to stop escape of gas.

6.7.2 Automatic Service Shutoff Valves

Automatic service shutoff valves are designed to close when the flow of gas in a service line exceeds a specified rate. Their point of installation is at' the service tap on the distribution mains. Thus, they can protect the complete service line but this does mean that they are generally buried and relatively inaccessible. These devices have only been recently introduced to the gas industry and are still under development and trial use by gas operators. A few of the current devices on the market are:

Gas Phase	Mueller Company
Donkin Flow Limiter	UMAC
Autovalve	Continental Industries
Follett Safety Valves	Follett Valves

An industry survey by MRI resulted in the following information:

- Some companies have had good experience with the devices while others have had bad experiences.
- False closure of the valves was the major complaint.
- False closures were traced to faulty installations, dirt in the line, too fast start up of a new line, and several unexplained reasons.
- Several reports were made where the valve closed correctly after severing of a service line.
- Most companies that have tried the devices are continuing to use them. In some cases, use is limited to special applications where higher risks of severed service lines are involved.

The principal advantage of the device over other gas escape control methods is the automatic shutoff of escaping gas. Further, the valve designs are such that they are inexpensive. Some valves are designed into the service tap so that the cost from the manufacturer is $1.25 to $1.50 over the cost for a conventional tee. Thus, they represent a potentially beneficial. safety device for the gas industry if the disadvantages are overcome. A few noted by the gas industry are:

- False closures and sticking in the closed position when a new service is turned on. Repairs in these cases can involve excavation of the street to replace or remove the device.
- Selection of the proper flow for closure. The flow must be selected so that seasonal uses or additional appliances added to the service do not trip the valve. Thus, there is a tendency to select the equipment for larger flows to preclude false closures. In these cases, small leaks or partial breaking of service lines may not trip the valve.

- Lack of background information. The ability of the equipment to sit for many years and still be operable under the proper conditions is not known. The affects of aging, contamination and others must be checked by trial use. Aging may cause the device not to work or could cause the device to be more susceptible to pressure fluctuations or street vibrations. Contamination may stop a valve from seating properly or be incapable of being reset.

6.7.3 Telemetering

Telemetering refers to the sensing of some pipeline parameter and transmission of that signal to some distant station. Telemetering has long been used on transmission lines to transmit pressure of flow data from distant parts of the line to a central location. This allows the line to be better controlled and problems along the line can be noted sooner. This type of system has been used by distribution systems to assist in managing and controlling load fluctuations and has been considered for possibly noting line failures with large amounts of escaping gas.

Currently, distribution systems supplied by more than one district pressure regulating station must be equipped with telemetering or recording pressure gauges to indicate the gas pressure in the system. Systems supplied by a single regulator station are not specifically required to have telemetry or gauges. Rather, the operator is to determine the need taking into consideration the number of customers supplied, the operating pressures, capacity of the installation, and other conditions.

Recording gauges are probably used more than telemetering devices although one municipal company contacted was using telemetering to control the pressure throughout their system. Sensors at the outer limits of the system noted the pressure and information was transmitted back to the regulating station. In this system the control for the regulators was established to maintain a pressure at the system outer limits. By this means, during periods of slack demand, the pressure throughout the total system was reduced.

The consequences of this resulted in less gas escape through any existing leakage areas in the system.

. The NTSB recommended the use of telemetry as a method of noting significant pipeline failures during investigation of the Clinton, Missouri incident, December 9, **1972.** (Reference **NTSB-PAR-74-3).** In this case, a recording chart at the border station which supplied Clinton, Missouri with gas registered a large, unexpected increase in the flow of gas. The utility was unaware of the increase because the station was unmanned. A 4-inch high pressure cast-iron main had cracked and before it was controlled, subsequent events included deaths and buildings demolished. If the information from the recording gauge had been telenietered to a central manned location, it is possible that two things may have occurred. First, it could have been apparent that a serious failure had occurred and secondly, emergency procedures could have been started earlier with the knowledge that it was a serious failure. This has led the NTSB to recommending telemetering of distribution systems-to insure prompt warnings of significant system failures.

The NTSB report discussed monitoring of pipeline systems, some points of which are noted below:

- Complex systems are difficult to monitor in a manner which will detect system failures.
- Small systems with one feed may be very conducive to system failure detection by telemetered information.
- The magnitude of the failure will largely determine detection by telemetered information. Flow or pressure will have to change noticeably to be detected, a condition generally associated with breaks in main piping.
- The type of reduction used in the distribution system must be considered with regard to the information which should be telemetered.

6.8 MASTER METERING

Master metering refers to the situation where a distribution company delivers gas to one meter from which many customers can be served. Piping beyond the meter often belongs to someone other than the distribution company, can be buried or be above ground, and is in itself a small distribution system. These installations are prevalent in mobile home parks, recreational facilities, building complexes and apartment buildings.

The problem that occurs here is that the distribution company does not own the piping and therefore may not include it in the leak surveys or reports to the OPSO. In many cases, the owners of the piping are not aware of the DOT/OPSO regulations or how to comply with the regulations. Installation of the piping is often performed by a plumbing contractor who follows a plumbing code which in some cases may not meet OPSO regulations, the most notable divergence being in the requirements for cathodic protection. The number of master meter installations is not now known but could be determined through the records of distribution companies. Other unknowns are the number of miles of piping involved, their age and condition, and the number of individual customers served by master meters. This could represent a number of installations and owners which are applicable to OPSO regulations but for which no method of informing them or surveying their piping is available. A few items needing resolution are:

- A definition of master metering to delineate the boundaries of the problem.
- The number of these installations in this country should be determined with a follow through of determining miles of piping involved and customers served.
- Identification status for owners of master meter installation to resolve concurrence to OPSO regulations.

- Methods for OPSO and regulatory agencies to provide direction and control over such installations. This may require coordination between building inspections, contractors, the OPSO, and other government agencies.
- Methods to resolve local and regional codes to be consistent with state and OPSO regulations.

From the above, it can be seen that the problem is largely undefined at this time. A study should be performed to resolve the issues. This study would:

- Determine miles and customers on master meters.
- Determine type of piping used and the corrosion prevention applied.
- The physical characteristics of the systems in terms of age, components, etc.
- Records and leak surveys which are maintained and performed.
- Perform leak surveys on selected systems for assessment.

SECTION 7
PROBLEM EVALUATIONS AND SOLUTIONS

7.1 METHODOLOGY

For each of the problems noted and discussed in this report, specific studies have been made with resultant conclusions and recommendations. Many of those studies have included a survey of distribution companies to determine the reliance placed on current procedures and technologies and the degree of use. The surveys also often uncovered specific areas that utilities considered to be lacking and needing more research or which are considered to be unaddressed at this time.

The methodology used for evaluation was to review the final results of many reports and incorporate them here. The findings, conclusions, or recommendations could then be evaluated against the identified safety problems derived from leakage data and NTSB reports. Since not all of the results from the numerous reports surveyed could be included, a selection was made of those most pertinent or promising for increasing the safety of distribution systems. Also, to achieve a standard report format, many findings had to be extracted or rephrased, but sources are identified so that the search for backup data may easily be accomplished. Also, the study results have been grouped according to the safety problems and comments added to include pertinent and new developments.

7.2 RESULTS OF STUDIES AND INVESTIGATIONS

This section presents the results from studies and investigations into safety problems of gas distribution pipeline systems. It is a compilation of findings, conclusions and recommendations from several reports which are grouped by safety problem topics.

The important conclusions and recommendations from the "Study to Evaluate the Tools and Procedures for Assessing the Safety of Existing Gas Distribution Systems" are as follows:

- The OPSO reporting requirement has provided a good tool for assessing and improving the safety of gas distribution systems. Analysis of the data must be continued with consideration given to determining trends of interest. Since fatalities and serious injuries focus attention on the gas industry and the effectiveness of regulations, written reports should be made on all incidents with fatalities. Also, better resolution of the "other" category on leak reports is needed.

- Corrosion pitting accounts for a large number of leaks and is extremely difficult to locate in buried pipes. Also, measurements to prove that cathodic protection is effective or corrosion is not occurring are needed. Further investigations should be made to upgrade the electric measurements and techniques used for locating hot-spots, holidays, pipe-to-soil potentials and electrical currents.

- No commercial equipment is currently available for in-situ inspection for graphitization of cast iron pipes. Much of the cast iron pipes are still usable and because they are often located in older business districts, a method for their inspection should be developed.

- The methods of gas detection including both odorization and gas sensitive instruments are currently the most effective techniques for controlling the safety of distribution systems. Odorization allows use of the public at large for gas detection. The periodic use of gas detectors is important since they are used to locate existing faults and the intent is to find the leaks while still small or before they progress to an accident.

- For near term future, the nondestructive techniques which appear to have the most promise are acoustic emission and ultrasonics. Acoustic emission can be used to note the location and severity of flaws, but not actual size. Ultrasonics is adaptable to most materials and can distinguish between types of flaws and assess the size of flaws.

The important findings on corrosion identified in the study, "Ferrous Pipeline Corrosion Processes, Detection and Mtigation", are as follows:

- It probably is not possible to eliminate all corrosion leaks. Rather, the corrosion control program must be established to be consistent with the useful life of a pipeline,
- Pipelines fail predominantly by localized attack in the form of pits generally initiated by some inhomogeneity of the environment or pipe material. The corrosion rate can be fairly low, but many factors do influence corrosion including temperature, soil resistivity, the chemical species of the soil , moisture, texture, and microbiological metabolism products.
- Welds appear to be particularly susceptible to corrosion, but the effects of welding conditions and metal inhomogeneities are little understood.
- Coating on pipe is a widely used method of corrosion control with thick organic coatings being preferred. However, no perfect coating material exists and coating processes and construction techniques do not prevent all holidays. Physical damage to the coating is the most common circumstance for leaks and improperly applied coatings are second.. The need for inspection during construction and at subsequent periods is obvious.
- Cathodic protection, while effective, is not a panacea. Many items can reduce the effectiveness of cathodic protection, such as shielding by the pipeline coating. Also, the proper application of cathodic protection often includes many judgmental considerations and the methods of verifying cathodic protection are imperfect. Electrical measurements made may not actually indicate what is occurring at the pipe itself and the verifying criteria cannot be used under all conditions.

- Record systems should be improved to allow the correlation of leaks to as many environmental conditions or other parameters as possible. These records may then be more useful for predicting leaks as well as guidelines for new construction,

- The economies of corrosion control have not been sufficiently detailed. The selection of coatings and cathodic protection systems are often made on guidelines not correlated to the pipe lifetime.

- The process of corrosion mechanisms are not thoroughly understood at this time and need investigation. Most literature on corrosion is too complicated to be used by the utilities. Corrosion research directed towards pipelines and dissemination of this information in easily understandable terms is needed. Short courses and seminars are needed to train individuals in corrosion control and there appears to be a need for ways to judge the qualifications of corrosion engineers.

The major results of investigations into and solutions for reducing outside force damage to pipelines from several sources are listed below:

- Many of the programs to reduce outside force damage such as Utility Coordination Committee "one call" systems and the proposed statutes are sufficiently new that their effectiveness is difficult to determine. However, once included as a viable procedure, there is an overall reduction in outside force events.

- The operational problems associated with setting up "one call" or coordination councils have been largely resolved and should now allow tailoring to suit local needs.

- Proposed model statutes to provide penalties for excavation damage, or if certain requirements are not met, have not been universally accepted by states. There seems to be a hesitancy in enacting such legislation.

- Good communication by companies and excavators, swift and accurate pipeline markings by operators, and education of excavators seem to hold the most promise for reducing pipeline damage.
- Further investigations into outside forces are needed and are being performed as exemplified by a recently awarded OPSO study.

The primary results obtained from the "Study of the Properties of the Numerous Odorants and of Their Effectiveness in Various Environmental Conditions to Alert People to the Presence of Natural Gas" are as follows:

- Present-day odorants are accepted and considered satisfactory by most gas utilities with regard to odor and persistence.
- Odorant fading is rated as a problem but could be minimized by greater use of TBM blends, Fading due to soil contact needs investigation and improvement.
- Most commercial odorants can be harmful to some industrial processes because of the sulphur compounds. Odorants without sulphur compounds could be a useful development.
- The majority of odorizing equipments are usable or satisfactory. The main problem is trying to maintain a set odorization rate over a range of gas flows.
- Odor monitoring equipment and procedures could use some improvements. Odorometers rely heavily on the observer's sense of smell. Leak call records cannot be correlated directly to proper odorization of gas. Instruments to measure sulphur compound concentrations are more expensive, complex and require trained personnel. Further, their results must still be referenced to the human sense of smell. Overall, while improvements and more correlative data is needed, the equipment to assess odorization of gas is available.

- Educational programs aimed at the general public in recognition and proper reporting of gas odors must be maintained and expanded.
- Regulations on odorization should not be too specific. The performance language method allows leeway and a workable system for the gas industry.

The primary results obtained from investigation into plastic pipe and the study entitled "Pipeline Industry's Practices Using Plastic Pipe in Gas Pipeline Facilities and the Resulting Safety Factors" are noted below:

- The formulation, extrusion, and molding techniques have been improved through the years and are considered to be effective in producing high quality gas pipe.
- Material selection processes, which are based on experience must be continually updated, but are effective as evidenced by the large numbers of successful plastic pipe installations.
- Quality control, while good, can be improved upon.
- Investigations are needed in testing of plastic compounds and components particularly as regards aging, specific failure modes, and assembled components.
- Distribution construction receives a lesser level of emphasis than transmission lines and better installation standards and field inspection are needed for distribution systems.

- Joining of large diameter pipes and effects of odorants are two areas to be investigated for RTRP.
- A questionnaire response indicated that the major problem areas of plastic pipe are dimensional tolerances, brittle failures, out-of-roundness, pressure test failure, transition fitting problems, joining failures, and stress cracking. Improper construction practices due to workmanship are also prevalent and increasing as a problem. Other lesser problems were poor extrusion, improper material selection and unsatisfactory matnrial performance.
- To improve quality control, pipe and fitting producers should certify compliance to ASTM D-2513 and ASTM D-2517. Further, a number of recommendations were made for revisions of these standards for inclusion of quality control requirements, increased testing, and more clear, concise terminology.
- More information on plastic pipe performance is needed. The annual report form should be modified to allow leaks by materials to be identified. Another alternative is for companies, on a volunteer basis, to provide information on leak repairs and replacement of plastic pipe.
- Consideration should be given to regulations for plastic pipe installation as to replacement of damaged pipe and backfill requirements.
- Standards should be developed for sleeves, transition fittings and for installations over bell holes and open trench spans.
- Further investigations are needed into the temperature limitations of plastic pipe. Research should be performed to develop plastic

pipe usable up to 140°F or to develop casings which would limit the temperature in metal casings to 100°F.

- o Good nondestructive instruments are needed for field inspections of joints.
- o Research is required into test programs for transition fittings and plastic pipe compounds for fracture toughness.

The two main problems noted as a result of investigating emergency plans in this study are first, that in order to be useful to the utility they must be tailored to the particular system and secondly, if available, they often are not followed. The solution to the first problem is that after considerable failure analysis and experience is gained in distribution systems, it becomes apparent that certain specific items are needed in every emergency plan. Thus, the approach of amending regulations as needed to include additional items appears to be a good method to ultimately attain useful, comprehensive emergency plans for each utility. To obtain better use of emergency plans, training is essential. Training programs of employees have been proven to be beneficial and probably hold the most promise for expedient hazard control.

The important results and recommendations from the study entitled "Rapid Shutdown of Failed Pipeline Systems and Limiting of Pressure to Prevent Pipeline Failure due to Overpressure," are as follows:

- o Rapid shutdown systems can reduce accident effects from product discharged.
- o The implementing of rapid shutdown cannot be justified by a cost/benefit analysis where the basis is that the benefits must exceed the costs.
- o The use of frequent sectionalizing valves can represent a considerable fraction of the pipeline installation costs while automatic service shut-offs can represent a small fraction.
- o The risks in not shutting down a failed gas distribution system are greater than the risks of shutting down, but a good comparison cannot be niade.

- Emergency action and hazard control appear deficient in several gas distribution accidents. Further investigations and regulation are required in this area.

- Some gas distribution systems lack adequate overpressure protection, but the true problem is what pressure limit to establish for pipes which are weakened, corroded, or otherwise deteriorated.

- More information should be obtained on serious accidents reported to the OPSO. This could include a number of items to be added to the leak report form.

- Automatic shutoff devices should be required on all new and repaired service lines for particular pressure and flow rates which should be determined by further investigation. Additional data should be obtained on the devices regarding operating experiences and fouling by contamination.

The investigation into master metering installations indicated generally that this is largely an unknown area. It is important because these installations should conform to regulations to provide safety to the public and at the same time, the possibly large number and small sizes of these units indicates that special situations or requirements may have to be established to allow conformation to regulations.

7.3 EVALUATION OF STUDY RESULTS

In this investigation, it has been determined that several problems have been identified that affect the safety of gas distribution systems. Further, these problems have been or are under investigation to determine solutions. The result is a series of articles and study reports with widely scattered results and conclusions which are difficult to assess as to importance. One intent of this study was to see if any particular results, conclusions, or recommendations were repeated in several reports. A few results were noted to be comparable in two separate reports, but only comments on data reporting appeared in a number of reports. This could be because the reports surveyed covered widely divergent investigation areas such that the solutions can be expected to be somewhat narrowly aimed or unique.

The one item commented upon most was data gathering by the OPSO Annual and Leak Report forms. In most cases, greater detail is desired or comprehensive information is wanted on specific types of incidents, but overall the reports seldom wanted the same item of information. If all the recommendations on greater detail were taken collectively, the report forms used by OPSO would have to be extensively modified and expanded. The increased mass of data collected by such revisions could actually make data analysis almost unwieldy. Probably the best suggestion made was to work with a few selected gas companies and from these companies obtain very detailed information on specifically desired subjects. Inquiries sent to the gas industry could possible determine the best way to establish such a data collection system.

From the overall safety standpoint, corrosion and outside force damage rate as the largest leak cause problems of gas utilities. The most important secondary cause of incidents was emergency handling as related to notification and the means to control the hazard. Thus, it would appear that emphasis by industry and agencies should be in these areas.

Although the main safety problems are identified, it is still difficult to evaluate the relative worth of variously proposed solutions. The method chosen to select the conclusions and recommendations for this study was to note a few of the more pronounced or commonly mentioned results from previous work and also to take each of the identified problem areas and identify what is currently being done, the trends in development, and the needs for future research and investigations.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

This section presents some general conclusions and recommendations regarding the main topics of this report. They have been derived primarily from the results of studies that have been made into the specific problem areas. The format used is to define each problem area, the findings on current solutions and deficiencies, the trends in development, and future needs for investigation and research.

Data Reporting

The Annual and Leak Reporting format on an overall basis provides sufficient information for regulatory use. However, whenever it is used as a base for specific detailed studies, greater depth of information is usually desired. To increase the content of the above forms would increase the burden on the gas utilities and provide too much data for digestion, but for resolution of specific problems, some small data base, highly detailed information is required. Examples are failures of plastic pipe by age and material or miles of plastic pipe replaced by age and material. This might best be obtained from a few gas utilities, possibly on a voluntary basis.

It should also be mentioned that the reporting forms were established when little information had been obtained by a central agency on all the various distribution systems. The question exists as to whether some data (e.g., pipeline miles by decade of construction) changes significantly from year to year as to require annual reporting. On the other hand, data items such as size of leaks or more detail on incidents involving deaths could provide greater insight for OPSO.

The recommendations regarding data reporting are:

- The reporting formats be re-evaluated in the light of the current needs of OPSO and the ability to assist in verifying compliance to regulations
- Provisions be made to obtain very detailed information on leakage from a limited data base through liaison or voluntary cooperation of OPSO and a few selected utilities or periodic use of the new OPSQ regional field office staffs.
- A written leak report form should be required of each incident involving death independent of size of the company such that focus can be applied to the causative factors and provide direction for increasing safety.

Assessment of Pipelines

The current assessment methods used by gas distribution cannot be judged inadequate as evidenced by the number of leaks found in any one year and the very low percentage which require leak reporting, much less become catastrophes. To assess the systems, a large number of various equipments, techniques and procedures are available. The more effective methods including gas detectors, odorization, and leak reporting are all based on leakage which is already occurring.

The development trends have been along the line of adapting non-destructive testing methods to on-line evaluation of pipelines. Acoustic emission has been shown to be effective in locating and assessing flaws. Ultrasonic methods are known to be useful in noting sizes and depths of flaws For the future, emphasis should be on increased use and improvements of existing assessment methods and development of acoustic emission and u trasonic applications to pipelines.

Specific recommendations on assessment of pipelines include:

- The development of new procedures and equipment for assessing pipelines should be pursued with the industry and manufacturers taking the lead. Non-destructive testing should be emphasized.

- The OPSO, through its regional field offices, should make assessment surveys on selected pipelines. First, this allows an evaluation to be made of survey and equipment effectiveness and secondly, as new pieces of equipment are developed and tried by OPSO, they can be phased into wider use in the gas industry with knowledge of involved problems, costs, and increased effectiveness/safety.

Corrosion

Corrosion leaks currently account for the largest number of repaired leaks noted on the annual reports.

The current methods of lessening the toll on pipelines by corrosion have been to increase the miles of pipeline under cathodic protection and to make more electrical measurements around pipelines to determine corrosion-susceptible pipelines.

Trends have included avoiding the corrosion problem in many cases by switching over to increased use of plastic pipe. Also, improvements have been made in coatings for steel pipe and new installations of steel pipe are coated and cathodically protected.

The needs for the future include improvements in techniques and better guidelines for determining the occurrence of active corrosion and assessing the adequacy of applied cathodic protection. Also, an overall better understanding of the corrosion process is needed.

It is recommended that the OPSO promote investigations into cathodic protection monitoring methods and equipment either singly or in concert with research currently being solicited by the AGA. To remain consistent with the establishment of regulations for cathodic protection, ultimately the methods, criteria and equipment to locate small "hot spots" and verify protection effectiveness along the total pipe surface will have to be defined.

Outside Force

Outside force accounts for the largest number of leaks as reported on the leak report form. The current trends to reduce outside forces have been along the lines of better communication between excavators and operators of underground facilities. This has been enacted through Utility Location and Coordination Committees and One-Call systems. Also increased and improved marking of pipelines has been promoted for reduction of this problem.

Additional studies of outside forces are being conducted and should provide more insight into the problem.

In view of the current OPSO study into the outside force problem which is to be a detailed investigation, recommendations at this point would be academic. However, from the conclusions it does appear that more emphasis should be placed on ULCC, One-call systems, and education of excavator and less emphasis on statutes.

Odorization

Odorization acts as a warning of the presence of natural gas and allows the public-at-large to assist in leak detection.

The present day odorants, odorizing equipment and odor monitoring equipment are generally accepted and considered satisfactory by most gas utilities although improvements can be made.

Odorant fading and definite recognition of specific odors by the public as leaking gas are the two main problems of odorization.

Odorant fading within the pipelines can be reduced by greater use of TBM blends. Fading due to soil contact needs more research and development.

Educational programs for the public on recognition of odors and proper reporting of gas leaks must be maintained and expanded.

From a regulatory point of view, odorization is well covered and no recommendations are made here. However, more research into non-fading and non-sulphur base odorants should be pursued along with improvements and greater dissemination of educational material for the general public.

Plastic Pipe

Plastic pipe is currently being used for more and more gas distribution installations. While corrosion free, it is known to be more susceptible to outside force damages. Much of the information on plastic pipe performance is sketchy and more data is needed.

The trends in plastic pipe have been towards improvements in materials and processes for production of high quality pipe. A few of the problems noted with plastic pipe have been dimensional tolerances, brittle fractures, transition fitting and joining failures, pressure test failures and stress cracking. Also, improper construction due to workmanship is prevalent and increasing as a problem.

For the future, the quality and uniformity of plastic pipe can be improved upon by revisions to specifications for more quality control requirements and testing and clearer terminology. Further research and investigations are needed in the areas of developing plastic pipe usable up to 140°F, nondestructive testing instruments for field inspection of joints and testing methods for transition fittings and plastic pipe compounds.

It is recommended that the results of the OPSO sponsored study be objectively considered particularly with regard to specifications, tracer wires and obtaining in-service data on plastic pipe failures. Also of note would be a review of the regulation because if SubPart H, paragraph 192.375 is read from a narrow viewpoint, it appears that plastic service lines are exempt from needing tracer wires.

Emergency Plans

Emergency plans must be tailored to suit the needs of particular distribution systems. It has been noted that often the emergency procedures are acted upon either late or not at all when controlling a hazard.

Current trends have been to slowly upgrade the contents of emergency plans and provide more training of personnel. This is probably the best avenue for the future also, with more training probably providing the greater benefit.

It is recommended that OPSO maintain its present posture on emergency plans, that of periodic regulation amendments which upgrade the requirements and will provide adequate plans tailored for the individual utility. With emergency plans which involve human reactions, use and experience considerably outweigh scientific or engineering disciplines. Periodic review of emergency plans and observance of training programs should provide the needed verification of regulations.

Rapid Shutdown and Valving

Rapid shutdown of a failed pipeline system can reduce accident effects and hazards from the product discharged. Distribution systems are valved, some designated as emergency valves, for controlling the gas flow in the system. However, where distribution systems are complex and looped, cost/benefit analysis does not justify implementing rapid shutdown systems or addition of sectionalizing valves in distribution systems.

The current trends have included development and trial use of automatic service shut-off valves and improved emergency action and hazard control. This also holds true for the future. Automatic service shut-offs should be installed in special conditions and their performance monitored to establish their reliability and effectiveness.

Also more development of automatic control equipment is needed for future use but better emergency reaction is needed for existing systems.

Rapid shutdown has the problem of being an idealized solution; that is, equipment is always desired which will activate and render a system totally safe if any failure within the system occurs. Thus, there is a tendency to promote it as the solution to almost all gas explosion incidents without considering the costs and problems involved to apply it. As such, it may have gained too much attention compared to expected benefits and so overshadows other problems of gas systems

It is recommended that the OPSO sponsored study on rapid shutdown and the AGA report, when available, be used collectively and if required, a completely updated study be made into rapid shutdown and telemetry for distribution systems. This will establish:

- The limits or applicability to distribution systems.
- A cost/benefit analysis.
- A detailed effectiveness analysis.

The intent here is that any subsequent investigations into gas incidents would no longer recommend solutions that are infeasible economically and of marginal benefit in the real world situation. Application of systems safety analysis in this area should lead to a practical appraisal of the priority that should be accorded this topic.

Master Metering

Master metering exists, but its scope or conformance to regulations seems to be an unknown. This could be determined by an investigation which could also identify methods for regulatory agencies to provide direction and control over such installations.

It is recommended that a study be conducted into master meter systems along the lines of the DOT/Municipal System survey with requirements to perform and obtain the following:

- A definition of these systems in terms of number of systems, customers served and piping parameters (age, miles, sizes, etc.)
- Selected systems should be surveyed to obtain an insight into the integrity of the systems.
- Determinations be made as to how these systems should be handled and controlled to verify compliance to federal regulations.

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