ABSTRACT

One of the most difficult sales to make involves selling someone with the mind set of - they know it all. Patience must endure or one will find one’s self under the bed reciting the Greek alphabet.

Even though dinosaurs are claimed to be extinct, sightings from time to time within the pipeline industry do occur. It seems that every company has at least one and when spotted exhibits an attitude of disbelief, faulty paradigms, false safety and security condition of their pipeline(s), and of course the old proverbial - we’ve never done it that way attitude. Additionally, possible loss of future revenues may dominate perceived reality.

Pigging technology today appears to be advancing exponentially and what we mean by technology is not so much the hardware side but the application side. This paper will address the application side of pigging and discuss rules of thumb for liquid and dry pipeline cleaning and the effectiveness of their respective results.

We will discuss topics such as: pig types, urethane durometer usages and types, recommended pig velocity, liquid cleaning verses dry mechanical cleaning, types of pipeline contaminates, suspected causes, maintenance, advantages and disadvantages of various pipeline cleaners on the market, and suggested pigging procedures for natural gas lines.

These topics will be discussed in an order of usable procedures that will hopefully guide you to a successful, economical, practical, safe, cost-effective, and reliable data retrieval for your in-line inspection program and may even prepare and arm your integrity team against the inevitable office dinosaur.

KEYWORDS: Durometer, polyurethanes, dry pigging, liquid pigging, black powder, pipeline cleanliness, and liftoff.
PARADIGMS:

What is it that we really know or understand about pigging a pipeline? Are our dynamics such that we are in such a hurry to meet government and company requirements that the completion goal date is more important than the procedures to secure accurate pipeline information?

If just running any type of mechanical pig through your pipeline at any speed and getting it out in one piece constitutes a clean or good run and now you’re ready for the MFL tool, then the answer to both questions is not much and yes respectfully. Pigging, of any type, requires planning and decisions that should be assisted by pig manufactures and/or qualified pipeline cleaning service companies. Specialty of others can be an excellent degree of assistance and knowledge. After all, the goal is too pre-clean so as to minimize sensor liftoff of the ILI tool.

Technology today allows for a proven product in pig manufacturing to assist companies in achieving maximum results whether mechanically dry pigging or liquid cleaning using mechanical pigs. Mechanical pigs have come a long way from bails of hay wrapped with barbwire (the squealing sound of the wire on the pipe wall sounded like a pig, thus the name), too today’s formulated polyurethanes.

POLYURETHANES:

There are many types of polyurethanes but this paper will only discuss castable elastomers. For more on various types of polyurethanes read: “What Polyurethane? Where? Selecting The Right Polyurethane for Various Applications” by Dr. Ronald W. Fuest, Uniroyal Chemical Company.

Mixing and pouring together two liquids, a prepolymer and a curator make castable urethanes. There are basically two chemical structure types of polyurethane prepolymers:

1. MDI (methylenediphenyl diisocyanate)
2. TDI (tolylenediisocyanate)

The most common used polyurethane today by most pig manufactures is TDI and this paper will focus on this type when referencing polyurethanes. The curative and the prepolymer when mixed together cause a chemical reaction forming the castable urethane. Each manufacturer has their own ratio mixture, other additives, and process that differentiate them from each other in the market.

Some advantages of polyurethane:

1. Non-brittle
2. Elastomeric memory
3. Abrasion Resistance

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Some disadvantages:

1. Breakdown in high temperature, 220°-225°F
2. Moist hot environment (hydrolysis in the presence of moisture and elevated temperatures)
3. Certain chemical environments dissolve urethane, (Very strong acids & bases, aromatic solvents: i.e. toluene, ketones, methanol, & esters)
4. UV exposure > 6 months as a rule. (covered and stored inside prolongs life)

**DUROMETER:** (ref: www.matweb.com “Material Property Data”)

Plastics are mostly measured by the Shore (Durometer) test or Rockwell hardness test. The Rockwell test is usually for “harder” elastomers such as nylons, polycarbonate, polystyrene and acetal. Shore hardness uses the Shore A or Shore D scale as the preferred method of testing for rubbers/elastomers (polyurethanes). The Shore hardness is measured with an apparatus known as a Durometer thus the name used to denote softness/hardness of urethanes in pig part manufacturing. Durometer Shore test only indicates the indentation made by the indenter foot upon the urethane. Other properties such as strength or resistance to scratches, abrasion, and/or wear are not indicated. Durometer is expressed by a number system. The higher the durometer number the harder the urethane. TDI urethane is good in the range from 50A to 90A. These durometer ratings are associated by various color codes depending on the manufacturer i.e. yellow denotes 65A, green 75A, and red 85A. Combinations of each can be incorporated in a pig design to maximize desired conditions and/or results. The rule of thumb is, the harder the durometer the better scraping capability and softer the durometer the better the sealing characteristics. In all hereafter pig types and conditions the durometer of the polyurethane plays an important roll in your choice of needs. Build a relationship with your pig supplier and pipeline service company to best assist you.

**PIG TYPES**

Pig types and functions are as numerous as people’s opinions on politics. As a rule, most pigs, of any type, are a standard designed length to diameter ratio 1.5 times the OD of the pipe, i.e. 24” pig is 36” in length. This is why the lowest ell bend of 1.5d is important. If your line has less than 1.5d ells then consideration may be required to replace with greater radius ells if your trying to get to the point of making the line piggable for ILI tools. Rule is - greater radius is better. Of course, if you just want to sweep the line then poly pigs and some unibody types can maneuver in less than 1.5d ells. Pig types are of three basic designs: poly foam, unibody urethane, and steel mandrel.

**POLLY FOAM TYPE**

Polly open cell polyurethane foam types are usually made the full OD of the pipeline requiring most concerns for various internal diameters nonlimiting. Polly Pigs have the ability to negotiate short radius ells and bends, miter bends, tees, multi-

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dimensional piping, and reduced port valves. Foam pigs come in various densities determined in pounds of urethane per cubic foot but most common are ranges from 2-lbs/ft³; 5-8 lbs/ft³; and 9-10 lbs/ft³. These densities are usually color coded: yellow for 2-lbs, red for 5 lbs, and scarlet or blue for 10 lbs depending on each manufacturer but most follow these rules.

Polly’s are the least aggressive of the pig design family. They are great for sealing and light abrasion removal and can reduce in diameter up to approximately 35%. Length can be increased to allow maneuverability through large tees, some older designed Orbit valves, and other type gate valves.

Wire strip brushes, nose pull rope, transmitter cavity, and jetting ports can be incorporated in each density and type of poly foam pigs. Assorted selections of various configurations (polly criss cross, polly criss cross wire brush, bi-directional, bullet shape, and bare swab), of each density are as numerous as there are requirements so check with your manufacturer’s representative and pipeline cleaning service companies for help in design to meet your requirements.

UNIBODY:

Popular are the single body cast polyurethane pigs designed to be more aggressive than polys but more forgiving than the steel body mandrel type. Effective in removing liquids from wet gas systems and liquid pipelines and help control paraffin build up in crude oil lines, separation of refined products, pipeline commissioning, and product evacuation. The unibody design can also maneuver in less than 1.5d radius ells and bends and are usually but not limited to a multi-disc cup configuration. The multi-disc designed in a bullet concave nose type or bi-directional type can have wire brushes attached along with other aforementioned configurations and add-ons. The unibody cast polyurethane with hollow shaft can handle up to a 20% reduction in pipe ID. These pigs can be casted from various durometer strengths-discussed further under “Durometer” above.

STEEL MANDREL:

Steel body mandrel type pigs are the most aggressive type available made by any manufacturer. This is not the pig to use first if you have an old pipeline that has never been pigged but if you do, make sure you have an electronic transmitter attached with long lasting batteries. You will need the transmitter signal to locate the pig if it becomes lodged in the pipeline a.k.a. “a stuck pig”. The configuration of the steel body allows for multiple designs for multiple usages.

Steel body mandrel pigs are built around a steel constructed mandrel. Three basic designs: cleaning pigs, batch and gauging, and conical cup are usually available. This paper will only discuss the cleaning pig type.

Cleaning pigs can be made with all disc, disc with scraping cups, disc with conical cups, with any combination of all, and all types with various kinds of wire brushes and scraper urethane blades. Any of the cast polyurethane products can be made from various durometer material strengths.

Polyurethane disc are cast and molded to the desired diameter of your pipeline. There are basically three types of discs, sealing disc, scraping disc, and slotted disc. The sealing disc is usually thinner, ≤ 1-inch and is designed for low to medium scraping

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2 Girard Industries, Houston, TX, Literature-“TURBO Series"
characteristics but high on liquid sealing. The softer the urethane material (durometer type), the better the sealing but worse the scraping functions. The scraping disc is usually > 1-inch in thickness and compared to the description of the sealing disc functions just the opposite. Sometimes a combination of both types is required. Slotted disc or feathered type disc are generally used on multi-diameter pipelines. Special design maybe required for each pipeline condition. Considerations of pipeline length and pipe wall roughness to be pigged will also determine the type required for each type. When all multi-type disc are used the pig can also be used as bi-directional.

Just like the disc, cups come in two basic types: scraper cups and conical cups. Scraper cups are as the name implies but allows for greater surface forces to be exerted on the pipe walls especially in less than oval shape pipe while maintaining its ability to seal. These cups can reduce on average 15-20% of design diameter. Conical cups allow for maximum sealing with minimum scraping too remove solids. This type is normally seen on gauging plate pigs and multi diameter and out of round pipelines. These types of cups can reduce up to approximately 30-35% and maintain adequate seal. Again, conical and scraper cups can be made in various durometers.

HOW TO GET STARTED:

Your company has made ready a given pipeline to be smart pigged, launchers and receivers have been designed with smart pig capabilities, and then installed. When all main line block valves are full flow and all ells and bends have been classified 1.0d; 1.5d etc, the line is piggable.

ILI tool companies require that data on all ells, types of ells, bends, other types of bends, wall thicknesses, ovality, and pipeline cleanliness be known before running their tool. Generally, either the ILI companies or other caliper companies will offer a caliper pig to be run first to retrieve this data. There are two types of caliper tools, a single-channel tool and a multi-channel tool. Most new construction uses single-channel on short sections of pipe to check the ovality, but by far, the multi-channel tool is required before most ILI tool runs. The multi-channel tool (as noted by multi-channel) gives multiple data points, welds, taps, valves, types of nineties, bends, direction of bends, wall thicknesses, and other data - all in the o’clock position with pipeline linear footage location. The single-channel only records anominallies on the linear footage with no o’clock position capabilities.

The ILI tool companies have different tolerances for different tools and you will need to discuss required data for each. Once tolerances are known and approved by an ILI company, a date is scheduled to run their dummy tool, then the ILI tool. This all sounds simple and it should be, however, unexpected internal conditions on most pipelines may open Pandora’s box even before the caliper tool is run. Most pipeline companies discover their pipeline is contaminated with solids and debris and needs cleaning during the installation of launcher/receiver and/or block valve replacement.

ON-LINE OR OFF-LINE:

Once the decision to clean a pipeline is made, you need to evaluate whether this line is to be cleaned on-line or off-line. **On-line** is defined as operating the pipeline under normal conditions while cleaning and **off-line** with the pipeline out of service and depressurized. As a rule, off-line cleaning can be twice as expensive as on-line cleaning
and not to mention loss of gas revenues. In general, the extra costs are due to several factors: slower pig runs, generating more man hours, more cleaning runs, continuous nitrogen and air to propel the cleaning trains, and the fuel cost to generate that propellant over the duration of cleaning. An exception would be, if natural gas at low pressure were used to propel the pig cleaning trains instead of nitrogen and compressed air. The downside is the cost to recompress the gas and place it downstream or the lost revenue to vent to atmosphere and/or flare. In either option, expect a cleaning program of a pipeline section less than 100 miles long to take 4-8 days of actual cleaning runs. Of course this depends on the cleanliness condition of the pipeline.

On-line cleaning allows the pipeline company to continue to operate and service their customers with uninterrupted service while cleaning their pipeline. This cleaning procedure is quicker, safer, and less costly than off-line, as a rule. The general rule-of-thumb - velocity for any size diameter pipeline is (>4-ft./sec.) but (<15-ft./sec.). See rule-of-thumb calculation for pig speeds. See Figure C. It is not that at velocities greater than 15-ft./sec. cannot be used, but experience and pig manufacturers studies have shown and indicate, at that elevated speed, hydro-plaining of the pigs will occur, in the presence of liquids, which causes greater blow-by leaving greater volumes of liquid and entrained solids in the pipeline. Of course the object is to remove the solids and minimize free liquids in the pipeline. Special cleaning procedures must be designed with your Cleaning Service Company to counteract this concern.

WHAT IS CONSIDERED CLEAN?

This is a great question and the answer is, it depends on the Pipeline Company. First of all, there is NO industry standard. Cleanliness can mean internal conditions that minimize or eliminate ILI sensor liftoff. However, the industry from a proposal request must tell the Cleaning Service Company bidders to propose a given amount of cleaning runs for all to be on an even playing field. Our experience has shown that three liquid cleaning runs are minimum. Usually the third liquid cleaning train removes the greatest amount of solids and extra sequential runs are for polishing. Fewer runs can be achieved but the concern is always the probability to remove too much, too fast, resulting in possible plugging of pipeline and/or receiving equipment used to separate the liquid/solids from the gas. The rule is to remove the pipeline contaminates a layer at-a-time by using a combination of the right liquid cleaner in a diluent and the right choice of pig type as mentioned in the pig type section of this paper. Pipeline Cleaning companies, in conjunction with many customers; have set a standard of four cleaning runs with a final cleaning run solution solids percent at 6% by volume or less. Some pipeline companies say 10%v or less and the pipeline is considered clean for smart pigging. However, 6%v or less is the norm. Other factors such as pig condition and residual of solids on pigs combined with the field test percent assist in a combined Pipeline Company and Cleaning Service Company’s agreed upon satisfactory cleaning performance. Another advantage of liquid cleaning is the residual liquid remaining in the pipeline after cleaning. Usually a 1-mil inch, (0.001 inch) or less, will assist in minimizing chatter on the caliper tool run. Measures are available to lesson the 1-mil volume and should be discussed with the Pipeline Service Company.

If you are cleaning a pipeline for hydro testing and have requested from your State or governing authority the approval to discharge the water on the ground and/or
back into the water source, i.e. a river, different final water specifications are required. Carbon purification may be required. Check with your State regulatory group for requirements.

FALSE PARADIGMS:

But you say we only have clean treated gas, therefore, our pipelines should be clean. Consider this, if glycol dehydration is upstream of your system, it is safe to say you have free liquid triethylene glycol (TEG) in your pipeline not to mention various types of lubricants, scavengers, flow promoters, corrosion inhibitors, methanol, hard hats, wooden skids, pig bars, chill rings, welding rods, and electric grinders. Dr. John Smart III and assisted by this author has written a paper to be introduced in San Diego, California in 2006 titled: “Possible Glycol Corrosion in Nominally Dry Gas Pipelines”. In this Dr. Smart discusses the theory that liquids will travel short distances through the pipeline close to the point of introduction but TEG vapor will travel greater distances than originally thought. The rule of thumb is, you lose 1 pound of liquid glycol per MMSCF of gas treated. My twenty-one years of experience in gas processing of Coastal Chemical has shown that most field dehydration units are neglected and actual TEG losses average between 3-6 pounds of TEG per MMSCF treated. Triethylene glycol weighs ~9.36 pounds per gallon and is usually acidic when it leaves the glycol dehydrator. This is because all glycols (EG, DEG, TEG, TTEG) in the presence of H2S, COS, CS2, RHS, CO2, O2, and water, in the gas stream, naturally become acidic. Once acidic, a pH less than 7.0, the glycol starts digesting the dehydrator unit components causing free iron loss absorbed in the glycol, causing stabilized foaming, then large amounts of glycol carryover into the pipelines. In this author’s opinion and experience, the iron carryover greatly accelerates the formation of long chain polymers (shoe polish looking substances), and contributes to black powder fouling. Using mass balance calculations see Fig. A. Hydrogen sulfide (H2S) at 1 part per million (ppm) (0.25 grains per 100 cubic feet is 4 ppm) in a continuous gas stream of 10 MMSCFD, if all converted to iron sulfide (FeS), will produce over 800 pounds of iron sulfide in a year. Thus, even pipeline quality gas has the potential to cause internal problems. Even a 1-mil inch (0.001 inches) film buildup of iron oxides can produce quantum amounts of solids.

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3 Smart III, John Dr. and Randy L. Roberts, John Smart Consulting Engineers and Brenntag/Coastal Chemical Co., L.L.C. Paper introduced at San Diego, CA Corrosion Conference 2006 “Possible Glycol Corrosion in Nominally Dry Gas Pipelines”

4 Ballard, Don, Coastal Chemical Co., L.L.C., “How To Improve Glycol Dehydration”, page 14

5 Huntsman Corporation, Houston, TX, Product Bulletin, 1995: Ethylene Glycol, Diethylene Glycol, Triethylene Glycol, page 9

6 Manning, Dr. William P., Coastal Chemical Co., L.L.C., Houston, TX, and Wood, Harold S., Maloney-Crawford, Inc., Tulsa, OK “Design Guidelines For Glycol Dehydrators” page 1

7 Kensell, Wendell W., Matthew Hall Engineering, Inc., PetroEnergy 84 Workshop, “Design And Operate Glycol Units, To Save Money”, page 7 & 8

8 Roberts, Randy L., Coastal Chemical Co., L.L.C., Personal Experience, Tyler, TX, 1984-2005

9 Baldwin, Richard M., Southwest Research Institute, May 1998, GMRC, TECHNICAL ASSESSMENT, ‘Black Powder In The Gas Industry” page 6-4

10 Parnell, Dave, MS/Chemical Eng. CBI/TPA, Dallas, TX, “Personal Conversation” Plano, TX 12/6/03 & recently 11/21/05
Since most ILI companies only guarantee 90 percent or less accuracy on their tools capabilities, less free iron on the pipe walls will assure gathered data is more accurate.

CLEANING A PIPELINE:

There are two types of pipeline cleaning programs and the terminology of cleaning is in whom you ask. One type is referred to as mechanical cleaning (the running of mechanical pigs dry) and is the one most mentioned when asked, “Do you clean your pipelines?” ILI tool companies and pig manufacturers, for obvious reasons, have pushed this type because it’s cheaper and anybody can run mechanical pigs. However, cleanliness is relative and subjective. Most debris is in the 4 to 7 o’clock position due to gravity and in most cases, if mechanically dry pigged, will only displace the debris from the 6 o’clock position to 360 degrees around the pipe wall. When the pig arrives with minimal solids in front of it, a possible false assumption is made that the line is not that dirty. Even if more mechanical pigs are run, the solids (black powder), iron compounds, and other organic and inorganic compounds can be broken-down to sub-micro particles causing downstream nuisances. Examples are: plugged meters, fouled turbine/compressor filter elements, customer’s equipment, etc. Again, the more one mechanically dry pigs, the smaller the particles become. If the solids are iron compounds (iron sulfides, iron carbonate, iron oxides, etc.) these particles and sub micro-particles will be pressed by the pig’s disc and cups, at pipeline pressure, into any pipe wall anomalies and/or pitting which may interfere with the magna-flux readability of actual pipe wall metal loss areas.

LIQUID CLEANING WITH SURFACTANT BASE CLEANERS

To achieve greater solids removal from pipelines with fewer pig runs liquid cleaning, referred more commonly to as chemical cleaning, is becoming the industry standard. Liquid cleaning in tandem with the use of mechanical pigs will remove a greater volume of debris with fewer runs. Liquid cleaning by definition means the use of liquid cleaners mixed in a diluent (water, diesel, methanol, IPA, MEK, etc.), to form a cleaning solution, pushed through a pipeline using mechanical pigs. Most cleaning companies will use a calculated volume of liquid to coat the interior walls of a given diameter pipe, X-number of miles in length, using 10 to 20 percent of that volume as pipeline cleaner.

There are various manufacturers of cleaners. However, a careful choice of designed pipeline cleaners should be based upon the following characteristics:

1. Neutral pH,
2. Permeating and penetrating capabilities,
3. Original design parameters of the cleaner,
4. Its case histories.

OTHER LIQUID CLEANER TYPES

Pipeline acid cleaners that dissolve solids could form harmful gases and be detrimental to pipe-wall metals. These types should be evaluated before making your decision. Other liquid cleaners that dissolve iron sulfide MUST have water in them in order to facilitate the reaction. The most common of this type has an active ingredient called THPS (tetrakishydroxymethylphosphonium Sulphanate), formulated with an
ammonium ion or organic phosphonate to speed up the dissolution.\textsuperscript{11} THPS is well known as a highly effective biocide for a variety of water treatment applications including oilfield. However, in those applications THPS was used in ppmv quantities and only lately is being used in percentages to dissolution FeS\textsuperscript{+}. THPS dissolves certain iron sulfides by chelation avoiding the production of any insoluble byproducts and any significant hydrogen sulfide. Rhodia Incorporated continues to state in their laboratory findings “that they are not sure of the fate of the sulfide component of scale but one theory is that it might be incorporated in the complex, possibly attached to the iron atom.” Test have shown that 1000 ml of 20\% concentrate of formulated THPS solution will dissolution approximately 120 grams of iron sulfides (two types tested: trolite [FeS] and pyrite [FeS\textsubscript{2}]).\textsuperscript{12} In other words, one gallon of 20\% of neat THPS dissolves approximately one pound of iron sulfide. For reference see figure A “Mass Balance Calculations” converting 1.0 ppm of H\textsubscript{2}S to FeS in a 10 MMSCFD gas flow requiring 847 gallons of the aforementioned solution to dissolve the iron sulfides. THPS is environmentally friendly and is completely rapidly deactivated in the presence of free oxygen and contact with high pH products; ie: corrosion inhibitors.

Another liquid cleaner is a gel type. Gels are very good carriers and rely on mechanical pigs to disassociate solids from the pipe walls with few of the aforementioned characteristics. Unit price in itself can be deceiving. For example, one gallon of neat liquid cleaning product of Company A priced at $20.00 per gallon may do the work of three gallons of a $10.00 per gallon product by Company B. The old adage, “Cheaper is better”, does not always hold true in choosing pipeline-cleaning products. And remember, the more one uses, the more one has to dispose/recycle. There are premixed solutions on the market today, but after careful scrutiny one needs to take under consideration its aforementioned characteristics and its shelf life. Once blended and total receipt of full volumes are accepted, whether used or not, you have purchased it. In other words, pre-blended cleaner(s), once blended, is yours. There is some concern on the premixed products as well as THPS products that downstream neutralizing of odorants of ethyl or methyl-mercaptans may occur. In some cases THPS is suspected in causing the formation of arsine gas when arsenic is present in the pipeline.

Liquid cleaning basically consists of two types of cleaning products, liquid and gel with distinct physical property advantages/disadvantages between both. We use the term liquid cleaning because the term chemical cleaning conjures up the impression of acids and caustics. Even though inhibited acids maybe required at special conditions, most liquid cleaners are surfactant base and gel’s viscosity base. Both types require different cleaning procedures, number of personnel and amount of equipment for the project, and the disposal/recycle cost concerns of spent cleaners and solids. Disposal and recycling, considered off-pipeline cost, either by the Cleaning Services Company as an added value or the Pipeline Company its self, is an issue that must be discussed as an overall total package cost in choosing a contractor. Sometimes the off-pipeline cost can

\textsuperscript{11} Corrosion 2002 Conference, paper 02030, page 1, 2, Rhodia Inc. “THPS for Dissolving Iron Sulfides Downhole & Topside-A Study of The Chemistry Influencing Dissolution” Gilbert, Grech, Talbot, Veale, Hernandez

be equal to or more than the actual on-pipeline (pipeline cleaning program) cost. Off-pipeline cost consist of cleaning of contractor’s equipment, cleaning of frac tanks, disposal of urethane pig parts, and any third party confined spaced service charges to complete the aforementioned.

**PIPELINE EFFICIENCY**

When all is said and done in preparation for running the ILI tool(s), one of the great side benefits of liquid cleaning your pipeline is the possible increase in operation efficiency. Actual field test done before and after cleaning have shown that liquid cleaning increased gas capacity with less horsepower due to less pipeline pressure required. Increased gas throughput with less horsepower required can result in increased revenues both with more gas being sold, less horsepower means less fuel (less gas shrinkage) which also reduces less maintenance on compression units. Another stated benefit is that gas control may start to see their computer modeling balancing out.

With the stated benefits, who can not afford to properly clean their pipelines? Liquid cleaning should more than pays for itself.

**CONCLUSION**

In conclusion, the pigging process consisting of the aforementioned cleaning applicability, running a gauging plate pig, a caliper pig, pipeline construction corrections if required, the ILI dummy tool run, (optional with approval of ILI Company), and finally the ILI tool run itself.

The overall objective is to retrieve data integrity conditions of your pipeline. To maximize truer conditional data results, we believe, improving the internal condition by liquid cleaning the pipeline before trying to mechanically/electronically retrieving data, greatly increases the chances of a more reliable and truer ILI tool performance. Cleaner pipelines yield truer data from your ILI tool run.

Your pig manufacturer and/or a good qualified pipeline cleaning Service Company can assist your company in directions that may save you time and frivolous expenses toward meeting your objectives. Let their knowledge and experience prepare and protect you from the perceived known, dinosaur in the office.

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13 Pipeline & Gas Journal March Issue 2008, “Cleaning Gas Pipeline For Inspection Also Increases Flow Efficiency For A Time” Al Michini, PE, Michael Mori, PE, NW Pipeline/SLC, UT and Randy L. Roberts, N-SPEC® Pipeline Services/Coastal Chemical Co., LLC a Brenntag Company
**Figure A:**
MASS BALANCE CALCULATIONS:
Pipeline Specifications:
- 4 ppm H₂S
- < 3% CO₂
- <7 pounds/MMSCF Water
- 1.0 MMscfd

**H₂S (Hydrogen Sulfide: molecular weight: [H₂: 2 + S: 32 = 34])**
(1.0 MMscfd / 379.5 scf/mol) x 1.0 ppm H₂S (0.000001) x 34 mol wt. H₂S =
~ 0.09 pounds of H₂S/day

**FeS (Iron Sulfide: molecular weight: [Fe: 56 + S: 32 = 88])**
(1.0 MMscfd/379.5 scf/mol) x FeS formed from 1.0 ppm of H₂S in the gas (0.000001) x 88 mol wt. FeS =
~ 0.232 pounds of FeS/day

10 MMscfd
10 MMscfd x 0.232 lbs. FeS/MMscfd x 365 days/year =
~ 847 pounds of FeS per year

NOTE: Rule of Thumb: ~ 0.1 pound of H₂S in the present of Fe converts to ~ 0.23 pounds of FeS or for every 1.0 pound of H₂S converted to FeS, 2.3 pounds of FeS is formed.

**Figure B:**
ESTIMATED Iron Oxides 1-mil INCH BUILDUP CALCULATIONS:

1-mil Inch = 0.001 inches = 0.0000833 feet
d = ID of Pipe in Feet
Estimated Mass Density of Iron Oxide-Rust (Fe₂O₃): ~ 319 Pounds Per Cubic Foot
Fe₂O₃ specific gravity: 5.12

**FORMULA:**
\[(d^2 \pi)(1 \text{ mil-foot}) (\text{ft./mile})(\text{Miles of Pipe}) (\text{Pounds of FeOx per ft}^3) = \text{Estimated pounds of iron oxide per given length of pipe}\]

Example: 30" OD Pipe, Wall Thickness: 0.344", 50 Miles in Length, 1-mil inch buildup.

\[(2.443\text{ ft. ID})(\pi)(0.0000833\text{ ft}.) (5,280 \text{ ft./mile})(50 \text{ miles})(~ 319 \text{ Pounds FeOx/ft}^3) = ~ 53,839 \text{ Pounds of Fe₂O₃}\]

**Figure C: Rule-of Thumb “Pig Velocity”**
\[S = \text{MPH}\]
\[\text{Gas Line: } S = \frac{(41 \times \text{MMSCFD})(\text{Gas Temp F}^\circ + 460^\circ)}{\text{PSIA (Pipe Diameter ID)}^2}\]
Pipe ID in inches

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14 Parnell, Dave, MS/Chemical Eng. CBI/TPA, Dallas, TX, “Personal Conversation” Plano, TX 12/6/03 & recently 11/21/05