The Economical Use of Plastic Pipe for Corrosion Control

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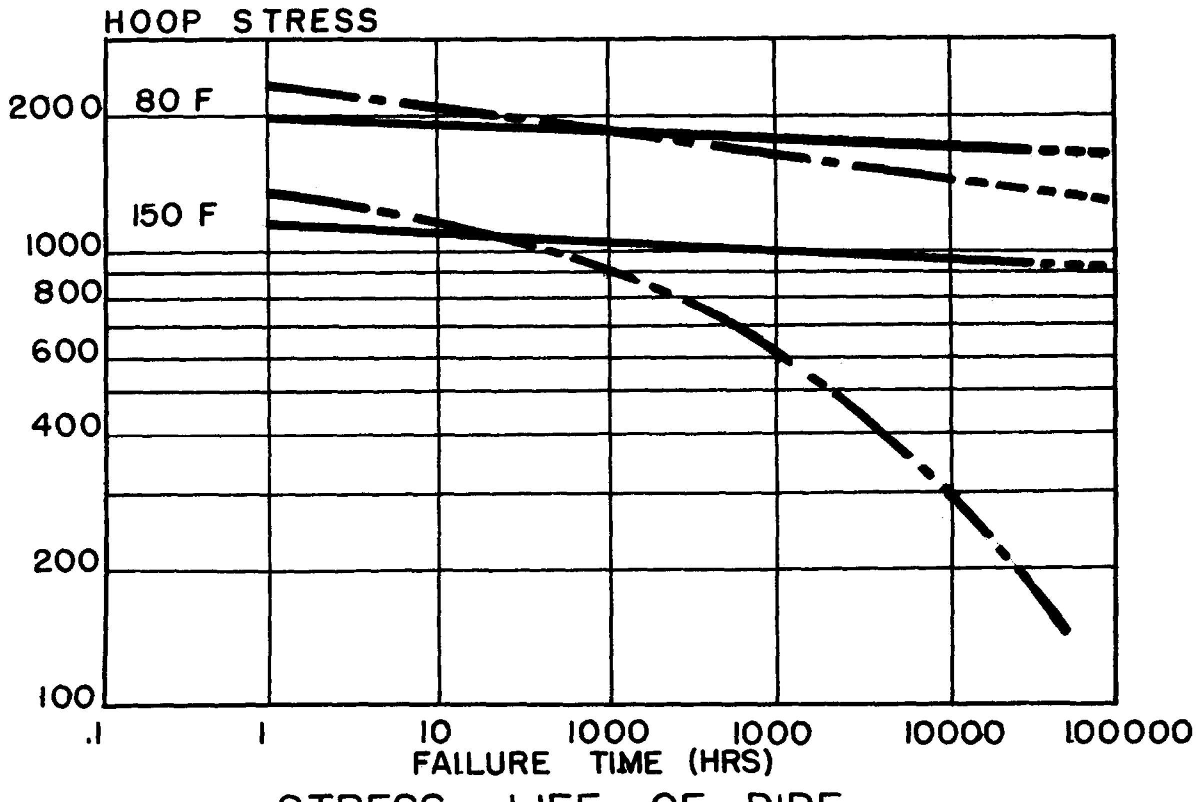
In the early days of the plastic pipe industry, manufacturers had few, if any, standards to use as guides. Consequently, published information by different companies on basically the same material often varied greatly. Fortunately, the last few years have seen great strides made by such organizations as the American Gas Association, Commercial Standards, National Sanitations Foundation, and the Thermoplastic Pipe Division of the SPI. Along with these organizations the larger manufacturers, such as Allied Chemical, Rexall, DuPont, and Phillips Petroleum are continuously working to feed more information, and even better thermoplastic materials into a mushrooming industry.

It is the purpose of this paper to treat a few of the more important aspects of plastic pipe standards and ratings, along with recommended installation procedures, and uses.

WORKING PRESSURE

It was early evident that some method must be universally adopted to determine long term load bearing properties of plastic pipe. Since all plastics have one characteristic in common, that is, a reduction in allowable stress or conversely working pressure, with time, the plastics industry has selected 100,000 hours as an arbitrary "life." It is this life for which an allowable hoop



STRESS LIFE OF PIPE
Fig 1

stress must be determined. This is done by exposing pipe samples to a constant internal hydrostatis pressure and measuring the time to failure, while maintaining a constant temperature of 20° C. Enough samples must be ruptured to definitely determine a trend for the hoop stress-time curve. Tests are generally conducted over a 10,000-hour period. The curve is then extrapolated to 100,000 hours, and will generally appear as shown in Fig. 1.

One-half of the ultimate stress indicated at 100,000 hours has been designated as a safe design stress level. This design stress is then used in the ISO (International Standards Organization) or the Barlow Formula, to compute working pressure. The ISO Formula is shown below:

$$H.S. = \frac{\left(\frac{I.D.}{T} + 1\right) P}{2}$$

Where H.S. = Indicated Hoop Stress
I.D. = Inside Diameter of Pipe
T = Wall Thickness
P = Internal Pressure

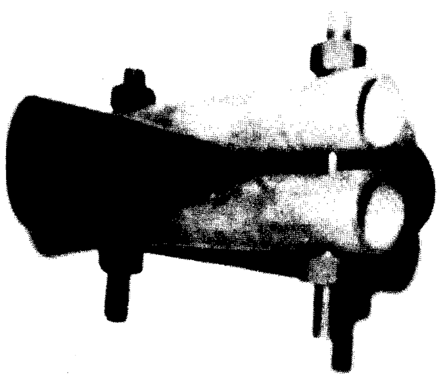
It should be noted that the vertical axis in Fig. 1 is hoop stress, rather than working pressure as such. This is general practice so that working pressures can be determined for all sizes and wall thicknesses of pipe, through the use of either the ISO or Barlow formula.

Unfortunately, one such curve will not suffice to cover all possible situations, since temperature is a large factor in the service life of plastics. Most manufacturers now furnish these curves at temperatures up to 150°F.

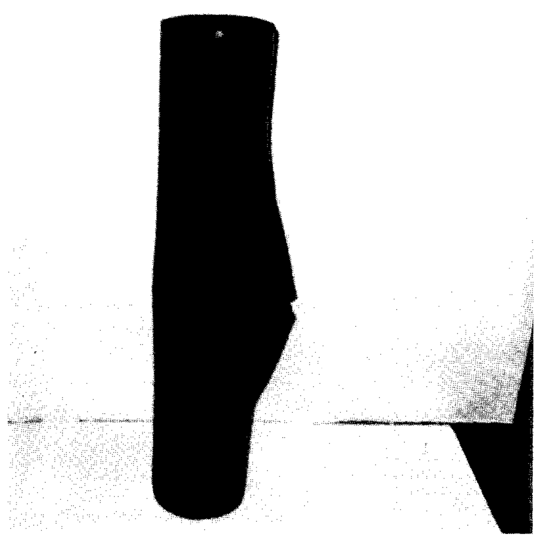
While working pressure must definitely be high enough to handle the intended service conditions, the author believes it to be one of the lesser considerations to be dealt with when specifying plastic for a particular job.

ENVIRONMENTAL STRESS CRACKING RESISTANCE

Environmental stress cracking, or E.S.C., is the susceptibility of thermoplastic resins to crack or craze under the action of outside agents. E.S.C. can occur in various ways; from aromatic hydrocarbons within the fluid being transported, action of the soil, or even ultra-violet rays from the sun. E.S.C. resistance is expressed in hours, because of the nature of the tests to determine the material's resistance to E.S.C. The ASTM standard procedure is to place several specimens under a bending stress and immerse them in a hot reagent bath. The length of time at which one-half of the specimens show signs of failure is E.S.C. resistance. This rating, while appearing to be an ironclad standard, should be used in a comparative sense only, since this is an accelerated test. For instance, most tests for



PINCH OFF CLAMP
Fig 2



TYPICAL RUPTURE
Fig 3

E.S.C. resistance are concluded at 1500 hours if there is no evidence of failure. An E.S.C. rating of less than 1500 hours does not mean that a plastic pipe will fail at a specified length of service. It means, simply, that it is more likely to fail under equal conditions than a higher E.S.C. rating pipe.

If a pipe will withstand 200 psig at 150°F., and then fails due to stress cracking, the pipe is expensive at any price.

DUCTILITY

Ductility is another property of plastics that is frequently overlooked. A highly ductile material such as ultra-high molecular weight polyethylene can offer many advantages, the most important of which is impact resistance. A well known fact is that materials of all kinds are handled and used more severely in the oil field than in any other industry. Many times a plastic of high ductility has been flattened for one reason or another, and then "rounded out" with a hammer and put into service. Fig. 2 is an illustration of this ability. Fig. 3 shows a typical rupture test on a highly ductile material.

Closely allied with ductility and impact strength is notch sensitivity. Scratches or abrasions on a highly notch sensitive plastic pipe are very detrimental, and can cause some "unexplained" failures.

CREEP

Creep is deformation under load, after the initial elastic deformation. Generally speaking, the more ductile materials exhibit a greater resistance to creep, or a better "memory." That is, they return to their original shape more readily.

As an illustration of material susceptible to creep, assume the following conditions:

A heater-treater discharges at a temperature of 100°F., and a pressure of 40 psig, into a 125 psig working pressure pipe. For some reason the temperature control pin sticks and the temperature increases to 160°F., and immediately drops back to 100°F. This increase in temperature will cause the pipe to balloon slightly. A creep resistant material will return to its original size and shape with no detrimental effects. However, a non-creep resistant plastic will not, producing the following results:

(1) a thinning of the wall section, effectively reducing working pressure.
(2) an increase in size, which immediately causes problems with replacement in case of trouble.
(3) deformation is likely to occur over relatively long sections of the pipe, increasing replacement expense.

It might be difficult to understand how any of the above considerations taken singly could have much effect on the economics of using plastic pipe. However, any property that might cause needless failure and expense should be examined and weighed before choosing a plastic.

The uses of plastic pipe become more widespread every day, and it is being used to carry every type of fluid found in the oil field.

CRUDE OIL

Probably the first plastic line in the oil field was used as a crude oil gathering line. Manufacturers and users alike were convinced that plastic pipe was the answer to paraffin problems. However, this is not completely true. Plastic pipe will retard paraffin build-up, because of its lower thermal conductivity when compared to steel. Some build-up will always occur from high melting point paraffins. Therefore, this problem should still be considered closely from an economical standpoint before a decision is made to use plastic in place of steel. In other words, in the long run, is it more economical to hot oil a steel line every six months, or continuously inject paraffin solvents into a plastic line?

CASINGHEAD GAS

In the Permian Basin, plastic pipe is fast becoming the standard for gas-gathering systems. This is true for several reasons:

(1) Normally well head pressures are quite low, below 100 psig.
(2) In many cases, gases to be handled are quite sour.
(3) In most areas of the Basin, soil conditions warrant some sort of outside protection from corrosion.

In most systems, thin-wall plastics can be used with a two-fold advantage. In the first place, thin-wall pipe is much more economical, and in the second place, will develop less pressure drop than a thicker walled, smaller inside-diameter pipe.

The actual design of a gas gathering system can be quite exacting, since most systems consist of two-phase flow. Since flow characteristics between steel and plastic differ greatly, and little information is available on two-phase flow in plastics, most of the larger manufacturers now provide technical aid to assist in the design of these systems.

SALT WATER

With the advent of no-pit orders and extensive waterflooding, the oil patch is using plastic pipe at an even greater rate. Plastic pipe is being used in all phases of floods and disposal systems, from low pressure gathering lines to downhole liners for high pressure injection. In high pressure injection lines, plastic and steel work hand-in-hand, with the plastic providing corrosion protection, while the steel supplies working pressure. An economical design of water handling systems is not nearly so strenuous as for wet gas, since pressure drop curves are readily available from most manufacturers.

INSTALLATION OF PLASTIC PIPE

Since plastic pipe is by its very nature a relatively soft material, and is susceptible to mechanical damage, it should never be laid on top of the ground. In addition, some plastics are vulnerable to attack by ultra-violet light, as previously mentioned. Heat from the sun would also be a factor to be considered.

Ditching for a plastic pipe need not be strenuous in the case of grading, since the pipe's inherent flexibility will allow it to follow the contours of an uneven ditch. However, care should be used in rocky areas. At least two inches of padding should be provided, with the same amount of cover before the ditch is backfilled.

Particular attention should be paid to creek crossings, road crossings, etc. It is advisable to provide a steel conduit to protect the plastic from outside damage.

The location of a plastic line should be well marked so that future ditching operations will not endanger the pipe.

In an application where expansion and contraction might present problems, adequate care must be exercised to assure that the plastic will not pull apart, nor expand to such an extent that it forces itself out of the ditch. This can easily be done, with expansion joints and/or slack loops.

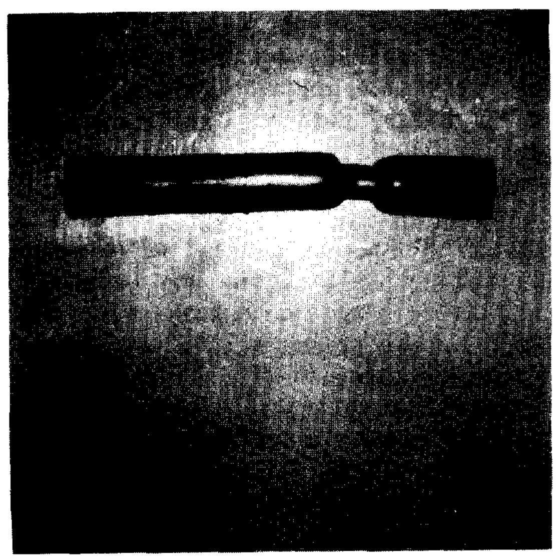
Planning the installation of a plastic line with particular attention to the ideas already mentioned can maximize the cost advantages already possible with plastic pipe.

JOINING OF PLASTIC PIPE

There are basically three methods of joining plastic pipe. These are by insert fittings, solvent weld, and heat fusion. Generally, insert fittings are associated with the installation of merchant pipe for sprinkler systems, stock water lines, etc., and are of little interest here.

The solvent weld joint is made by applying a solvent to the pipe, to actually dissolve it. Before the solvent can evaporate, the pipe is inserted into the mating collar. The joint is then allowed to stand for 24-48 hours to "set" before putting into service. The author's opinion is that the solvent weld joint, although in no way comparable to the heat fusion joint, can be used most satisfactorily in oil field applications, when care is taken in making the joint, and provisions are made for expansion and contraction.

The heat fusion joint was developed for use with such resins as acetals, polypropylenes, and polyethylenes. These materials cannot be solvent welded as can be PVC, ABS, and CAB. The heat fusion joint is made by actually melting the plastic, forcing it together to form a monogenous weld, and allowing it to cool. No "setting time" is required. There is little room for error with



TENSILE TEST OF JOINT
Fig 4

this type joint, and the joint is actually stronger than the pipe itself. Special equipment is necessary for this joint, but is readily available for rent in almost every location. At least two plastic pipe manufacturers maintain this equipment for customer use at a very reasonable cost. Figure 4 illustrates a tensile test of a heat fusion joint. The tensile stress was great enough to severely neck the pipe itself, while the joint remained undamaged.

COST SAVINGS

There are definite cost advantages to be had when specifying plastic pipe for corrosive service, in initial costs, installation costs and long range savings. Initial costs of even the most expensive and high quality plastics are competitive with other materials. Pipe made of the better resins will average 34 to 36 cents per foot in 2-in. diameter Schedule 40 sizes. Some of the more economical resins will cost in the range of only 22 to 25 cents per foot in the same sizes.

Installation costs, including delivery, stringing, and joining, vary greatly, but are always very reasonable. Many believe the solvent joint to be more economical. The author contends that laying costs per foot is at a minimum when using the fusion joint in connection with coilable pipe, and cites a case in point. A recent line was laid just north of Odessa, Texas, using coilable pipe and the fusion joint. Length of the line was 3000 ft. and was 2-in. Schedule 40 pipe. Total laying time from tie-in to tie-in was one hour and ten minutes. Total installation cost per foot was less than 1.5 cents per foot. Even though coilable pipe is generally more economical, straight lengths can also be installed economically. Recently, one man with a helper heat-welded 8700 feet of 2-in. Schedule 40 in 32-foot lengths in a 9-hour period.

Steel pipe in corrosive services needs protection, whereas almost all plastics are corrosion proof. When used within pressure and temperature ratings, it is not unreasonable to assume that plastic pipe will endure indefinitely.

SUMMARY

It is hoped the above information will aid producers in some small way to make more realistic use of available thermoplastics in corrosive services.

In choosing a plastic, consider all properties of the material, such as ductility, E.S.C resistance, notch sensitivity, etc. All of these have a definite bearing on long term economics. One $100.00 repair job can easily pay the difference between a cheaper resin and a higher quality one.

Then, check installation procedures and cost with your contractor and/or manufacturer. As mentioned before, some manufacturers supply necessary equipment for this operation at, or near, cost.

Inquire, also, about delivery time for pipe for replacement or additions.

With the above information in mind, engineers will be able to make a better choice of plastic for any particular application. Remember, selection of plastics should be done with your thinking cap on!