The Selection, Fabrication, and Application of Flexible Thermoplastic Materials for Oil Field Tank Liners

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INTRODUCTION

Before going into detail on the mechanics of a successful, flexible oil field tank liner, perhaps it would be wise to explain what we mean when we refer to a flexible oil field tank liner.

Perhaps the simplest way to explain what we're talking about would be to say that a flexible oil field tank liner is simply a big plastic bag which is pre-fabricated to fit a given tank. The bag is impervious, and holds the liquid to be contained. The shell of the tank is used merely as a structural support for the plastic bag.

The liner is not attached or adhered to the tank except at the circumference of suspension at the top of the tank, at the clean-out opening, and at piping connections.

Thus, it is possible to fabricate a flexible, one-piece plastic liner which will completely isolate the internal surface of the storage tank from the fluid to be contained. As long as the liner remains intact, the tank will remain virtually leak-proof and free of corrosion attack from the fluid being handled.

THE SELECTION, FABRICATION, AND APPLICATION OF FLEXIBLE THERMOPLASTIC MATERIALS FOR OIL FIELD TANK LINERS

The task of producing a completely impervious and economical flexible oil field tank liner installation can be broken down into three main categories:

(1) Proper Material Selection

(2) Proper Fabrication Techniques

(3) Proper Field Installation Procedures

Each of these facets of the problem should be given careful consideration. Failure to do so will result in premature failure of the liner, or in unsuccessful attempts to get the liner to hold fluid at all.

PROPER MATERIAL SELECTION

There is a wide variety of flexible, thermoplastic, synthetic films commercially available which, at first glance, would seem suitable for use as an oil field tank liner.

Time does not permit a detailed resumé of of each of the candidate thermoplastic films available. Suffice it to say that upon detailed evaluation most of the industrial synthetic films can be eliminated for one good reason or another.

Of the several remaining films from which one might choose, there is one particular material which seems to possess more of the desirable attributes we're looking for; that material is a plasticized (or flexible) polyvinyl chloride film. But plasticized polyvinyl chloride film means a lot of things to a lot of people. This versatile synthetic material is used to make hundreds of different products. For instance, it can be used to make baby pants, shower curtains, rain-coats, inflatable toys, automobile seat covers, furniture upholstery, swimming pool liners, flexible garden hose, electrical wiring insulation, oil field tank liners and so on, ad infinitum.

The key to the versatile applicability of plasticized PVC film lies in two very important words. Those words are properly compounded.

The various manufacturers of polyvinyl chloride film and sheeting perform many important compounding operations on the polymer before molding, extruding, or calendering the finished product.

By virtue of this selective compounding, certain physical and chemical resistance properties can be enhanced to meet specified service; but these same compounding techniques used to enhance one or more properties of a product made from PVC film often result in a sacrifice of performance in other properties.

This important influence of compounding on the physical and chemical properties of finished products based on polyvinyl chloride resins must be very carefully controlled. It would do no good to compound a very highly oil-resistant PVC film, for instance, if in so doing we sacrificed the stress cracking resistance for the basic film.

Therefore, when we say "properly compounded" we mean a compound of PVC film that is formulated for optimum performance in the characteristic under discussion, without serious sacrifice of other basic characteristics.

Therefore, by carefully defining the conditions of fabrication, installation, and service exposure that an oil field tank liner must withstand, it is possible for the manufacturer to properly compound a flexible polyvinyl chloride film that has the optimum physical and chemical properties to suit the service. Of course, the whole procedure entails extensive laboratory and field testing under actual service conditions before satisfactory performance can be demonstrated. Only then can we say the PVC film has been properly compounded.

It would be a waste of time to itemize the complete list of oil field service exposure conditions that a properly compounded PVC tank liner film must withstand. We all know what its like inside an oil field salt water tank, a produced fluid receiving tank, or a crude oil stock tank. We know it's tougher than the back end of a shooting gallery inside one of those tanks.

We can deduce that the PVC lining film must have not only the physical properties to withstand such rugged service, but also, must have the chemical resistance properties to withstand the degenerating effects of all the solid, liquid, and gaseous compounds that are common to crude oil production.

The properties of one such PVC film, compounded for oil field tank liner service, are illustrated in Fig. 1 and Table I.

Figure 1 illustrates an important point regarding the service life of plasticized synthetic films. The ability of a given plasticized PVC film to withstand the deteriorating effects of a given fluid for a given time is dependent on the rate at which the fluid (or other degenerating condition) extracts plasticizers from the film. When sufficient plasticizers have been extracted, the film will undergo serious shrinkage, and will become stiff, brittle, and easy to crack even at elevated temperatures.

The PVC tank lining film of Fig. 1 demonstrates a very low rate of plasticizer loss with time even when exposed to hydrocarbon liquids which would attack improperly compounded PVC films at a very vigorous rate.

Figure 1 and Table I are graphic evidence of the vital importance of proper compounding in the design and selection of a flexible thermoplastic, synthetic film for oil field tank liner service. Actual field installations of the finished product add the clincher.

PROPER FABRICATION TECHNIQUES

The next step, after establishing with reasonable certainty that a properly compounded PVC film for oil field tank service can be designed, is to determine if this paritcular film can be fabricated into a one-piece, completely impervious tank liner.

The basic material is calendered by the film manufacturer, and is wound into rolls of specified length, width, and thickness. In so doing, it is imperative that the film be calendered without pin holes or holidays. In other words, it must be produced with zero defects. These rolls of properly compounded, perfectly calendared film represent the raw material from which the fabricator must make his tank liner.

A tank liner is a three dimensional object. The liner fabricator must start with flat sheets of flexible PVC film, and construct a three-dimensional cylindrical tank liner. This process requires that several flat pieces of film, cut to pattern, be seamed together in a given shape so that the integral liner will not leak. The completed liner might be fitted with an extended clean-out box, special piping sleeves, a deck cover, and other appurtenances. This presents a tedious task of cutting, fitting and sealing, which must also result in a finished product with zero defects; all seals must be completely impervious.

This important function can be accomplished by careful layout coupled with the use of production-tooled electronic thermal sealing equipment.

Fortunately for our choice of tank liner materials, flexible PVC film can be compounded to produce uniform thermal sealing characteristics. If this were not true it would be very difficult to produce a completely impervious, three-dimensional tank liner.

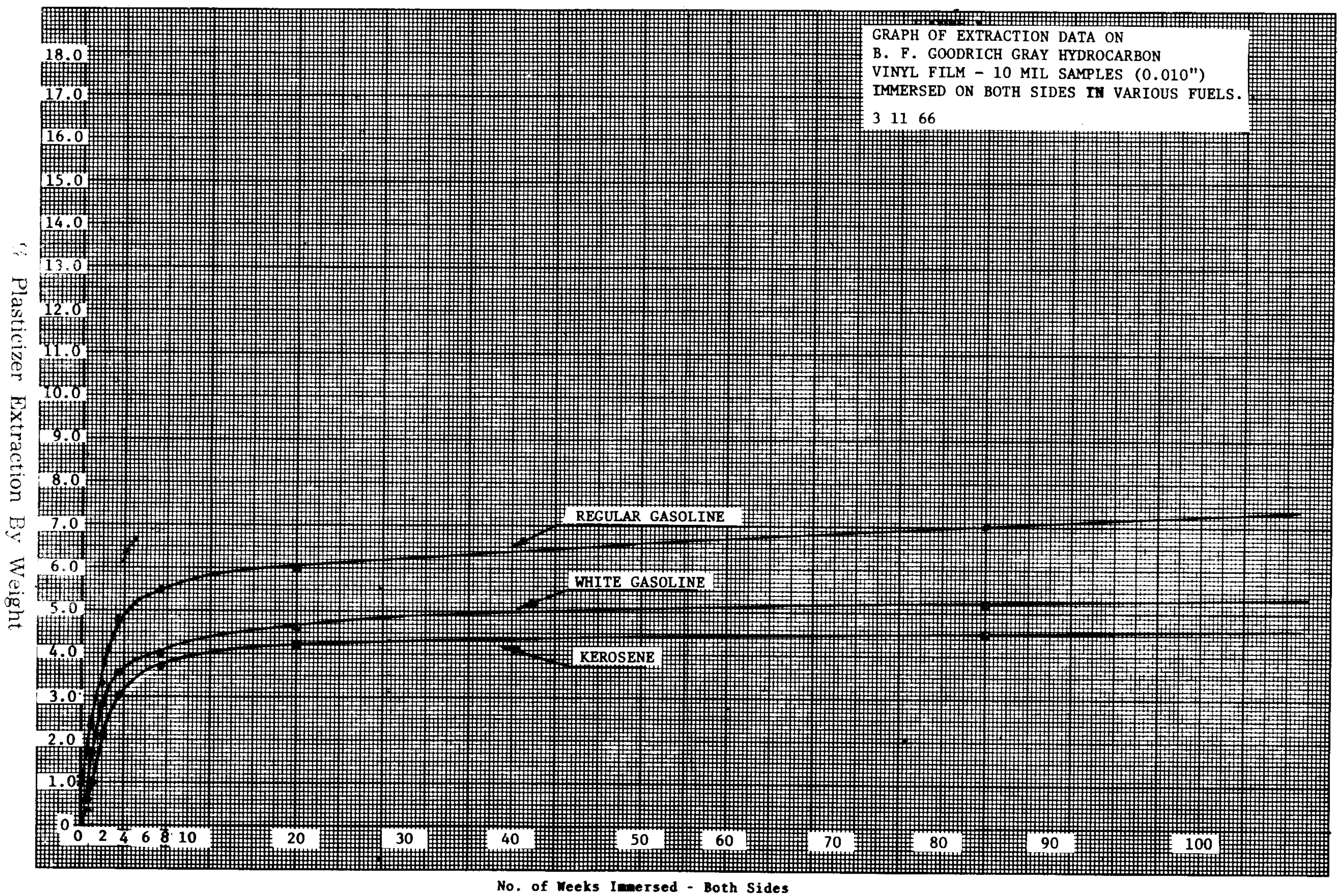
GRAPH OF EXTRACTION DATA ON
B. F. GOODRICH GRAY HYDROCARBON
VINYL FILM - 10 MIL SAMPLES (0.010")
IMMERSED ON BOTH SIDES IN VARIOUS FUELS.
3 11 66
REGULAR GASOLINE
WHITE GASOLINE
KEROSENE
% Plasticizer Extraction By Weight
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
0 2 4 6 8 10
20
30
40
50
60
70
80
90
100
No. of Weeks Immersed - Both Sides

FIGURE 1

TABLE 1

LABORATORY TEST RESULTS
30 MIL HYDROCARBON VINYL TANK LINING FILM

IDENTIFICATION: 64-03-2630-90

Physical Test		Original Film	Aged in Crude Oil (Both Sides Immersed)	Units
Tensile (ASTM D-882:B)	Long.	3150	3350	PSI
	Trans.	3112	3225	PSI
Elongation (ASTM D-882:B)	Long.	345	425	Percent
	Trans.	475	394	Percent
100% Modulus (ASTM D-882:B)	Long.	1825	1575	PSI
	Trans.	1525	1560	PSI
Graves Tear (ASTM D-1004-49T)	Long.	377	316	Pounds/inch
	Trans.	344	298	Pounds/inch
Elmendorf Tear (ASTM D-689-44)	Long.	190	187	Grams/mil
	Trans.	210+	210+	Grams/mil
Hardness - Shore (Durometer "A")		94	90	Scale reading
Hydrostatic Resistance		135	114	PSI
Water Extraction (Distilled)		0.377	---	Percent
Crude Oil Immersion:				
	Long. Shrinkage		-3.00	Percent
	Trans. Shrinkage		+2.50	Percent
	Extraction		+1.742	Percent

NOTE:

After three months complete immersion in Crude Oil (both sides of film immersed) there is no significant change in flexibility or in dimensions. There is a slight increase in weight indicating a slight absorption of oil.

The significant fact to recognize is that long-term extraction tests (see accompanying graph of extraction tests) indicate that virtually all the plasticizer extraction that is going to take place occurs in the first six to ten weeks of immersion. The hydrocarbon vinyl film after that remains virtually inert to the test fluid. The extraction of plasticizers by most crude oils (other than those highly aromatic in character) would occur at a significantly lower rate than that of the hydrocarbon fluids used in the laboratory tests and from which the long-term extraction data was determined for the graph.

Further, since only 10 Mil thick samples were used in the long-term laboratory immersion tests (in order to accelerate the tests), one can anticipate far less gross effects on the 30 Mil thick material which will be immersed on one side only (as in a crude oil stock tank liner). Actual field installations are bearing this out every day.

Thermal sealing of all seams permits complete fusion of two adjoining pieces of PVC material wtihout pin holes, holidays, air bubbles, or capillary channels which would pass fluid. This uniform degree of impermeability could not be achieved if the tank liner film had to be sealed together with adhesives, pressure sensitive tapes, mastics, solvents, or other foreign materials.

Again, proper compounding of the PVC film permits the application of film handling and fabrication techniques which result in the tough, impervious liner we need before we could even begin to think about hanging one in an oil field tank.

PROPER FIELD INSTALLATION PROCEDURES

Assuming that we have now manufactured a properly-compounded PVC tank liner that will hold produced oil field fluids, the task remaining is to get the liner in the tank in one piece. Again we must strive for zero defects in the completed job. This can be achieved in the field by carefully recognizing and following certain precautions and protective measures during the course of the liner installation.

At the introduction of this paper, the statement was made that the steel (or wooden) shell of the tank is necessary only to give structural support to the plastic bag. This is quite literally true. The tank holds the bag, and the bag holds the produced fluid. If we do the whole job properly, the tank and the fluid to be stored will never meet in intimate contact.

From the above statement, one can infer that the tank itself doesn't necessarily have to be liquid tight. As a matter of fact it's probably advantageous if the tank itself is a leaker, especially at the bottom. If this advantage is not already clearly evident, it should be before we're finished.

Since the tank is the rigid structural member used to support the bag, all we have to do is prepare the tank shell so that it cradles the liner in such a manner that there is virtually no chance of punctures, abrasions, or tears occurring due to the liner contacting the tank shell under fluid pressure.

Obviously, the tank to be lined must be thoroughly and minutely inspected. All burrs, sharp projections, and cracks must be removed or covered with protective cushioning. Any opening through the tank structure into which the liner might be extruded under fluid pressure must be covered with protective cushioning. Such places need not be made liquid tight, but they must be covered up.

The tank does not require internal sand blasting. As a matter of fact, it doesn't necessarily have to be meticulously cleaned. A clean tank, however, is generally (though not always) a safer tank in which to work, and it also facilitates visual inspection of the internal surfaces.

The type of internal protection required for the liner is of course slightly different for the different types of oil field tanks encountered. Steel, bolted tanks must be stripped with protective vinyl padding over all internal bolt heads and bolt channels in the staves. The bottom of the bolted tank is completely covered with a thick protective padding. Clean blow sand is an ideal bottom cover in West Texas and New Mexico. In areas where there is no natural blow sand available on the location, other types of padding can be used: fiber matting, re-enforced rubber, rigid vinyl (or urethane) foam, etc. In any event, all internal bolting, bolt channels, and protruding metal objects are completely covered to offer permanent protection to the flexible liner.

All welding beads in steel, welded tanks are carefully inspected, ground smooth, and coated with epoxy patching adhesive where necessary. The condition of the bottom of a steel welded tank determines whether protective padding is needed. Very often it is not needed in a welded tank.

Wooden tanks are caulked and padded internally as necessary to provide permanent liner protection. One other precaution on wooden tanks must be taken: the outside hoops must be kept tight if there is any tendency for the wooden staves to shrink and open gaps into which the liner could extrude under liquid load.

The crucial step in installing one-piece flexible oil field tank liner lies in handling the liner, during the actual installation, without imparting mechanical damage. At no other time will the liner receive rougher mechanical abuse than while it is being hung and fitted to the tank. This is where good, tough physical properties pay off. Working within the confines of close quarters inside the tank with 500 or 1000 lbs of folded-up vinyl film requires considerable foot traffic, pulling, twisting, stretching, etc.

Such handling required to unfold and hang the liner in the tank will impose a variety of mechanical stresses on the liner that should never be equalled in normal service.

There are several methods by which the liner can be hung, or suspended, from the top of the tank. Of course, the method used depends, too, on the type of tank.

Steel, bolted oil field tanks provide a very simple and effective method for securing the liner. All we do is unbolt the deck of the tank at the top chime. The liner is then pulled out over the top chime of the tank and cushioned between two continuous strips of neoprene tank rubber. Holes are punched for the chime bolts, the deck is put back in position and bolted down. The liner thus is securely gasketed between the deck and the top chime of the tank, completely fluid tight.

Steel, welded tanks necessitate another method of suspending the liner, since we can't very well remove the tank deck. In this case, the liner is hemmed at the top. Inside the hem, we insert a curved steel tubing ring of suitable metallurgy. In most cases, rigid 1/2-in. galvanized conduit will do very well.

The welded tank deck is drilled on the outside periphery in several points. Through these drilled bolts we insert J-bolts of proper metallurgy for the service. The steel conduit ring with the hemmed liner attached is suspended on the J-bolts. The bolts are tightened through the deck, and the ring and liner are pulled up snug against the deck. Neoprene gasketing can be used to snug the liner against the deck with proper cushioning.

Extended clean-out openings, fabricated to required tank dimensions are electronically sealed onto the liner. The clean-out opening on the liner is carefully fitted to the clean-out opening on the tank. A cover strip is cut for the clean-out plate, and the clean-out flange on the liner is gasketed between the clean-out flange on the tank and the clean-out cover plate.

Piping connections can be installed as suits the desires of the design engineer. Piping sleeves of suitable dimensions can be fabricated onto the liner to fit flanged or grooved nozzle connections on the tank. Standard bolted oil field tank flange connections can be made by properly gasketing the liner between the tank and the inside half of the tank flange. Proper attention to gasketing and sealing of all flanges and flange bolting can assure completely fluid-tight joints for all piping connections.

Following installation, the internal surface of the liner and all piping connections are visually inspected for improper seals, gasketing, and material defects. Any accidental mechanical damage to the liner can be repaired with a solvent weld patch which, when properly applied, effects complete fusion and closure of the defect.

If the liner is not completely impervious, it will pass through the defect in the liner following final installation when fluid is introduced to the tank. If the tank is fluid tight, then liquid will be trapped between the liner and the tank, and will tend to equalize with the liquid level in the liner.

But, if the shell of the tank **is not** fluid tight, liquid will pass to the outside through the defect in the tank shell. A visible leak on the outside of the tank shell will occur. We will, thus, have visible evidence that the liner **is not** holding. This is a desirable method of operating a tank containing a flexible liner. If the liner is not holding, we need to know that fact **immediately** before the corrosive liquid attacks the tank steel.

Therefore, several weep holes should be opened up in or near the bottom of the tank shell to permit liquid to drain out if the flexible liner does not hold for some reason.

This is a most infallible method for determining that the liner is holding as designed. If, at any time during the service lift of the tank liner a leak occurs, it immediately becomes visible and remedial steps can be taken to locate and repair the source of leakage before the tank shell is damaged.

If installation and maintenance procedures have been properly performed, the weep holes in the tank will stay dry, providing daily evidence that the flexible liner is doing the job for which it was designed.

CASE HISTORIES

In the last analysis, however careful the material selection, fabrication, and installation techniques, the only criterion by which to judge success or failure of the flexible oil field tank liner is by field performance over reasonable periods of time under various operating conditions.

Failures of record must be evaluated as closely as possible so that a determination, with reasonable certainty, can be made of the basic causes of the failure. Thus, if the basic premises are reasonably correct, the success ratio of all succeeding installations can be improved; this has proven to be the case.

The first successful attempts to put flexible liners in oil field tanks were made on produced salt water collection and storage tanks, mostly of the steel, bolted type of construction.

Recognition was given to the fact that, even though some hydrocarbon compounds would accumulate in the tank with time, a high percentage of the fluid in the tank would be "just salt water". The general feeling was that a highly oil-resistant film was not necessary for such produced salt water tank service. Field performance indicated that this attitude was not completely justified. Although a large majority of these non-hydrocarbon salt water tank liners are still in service after five years, there were several untimely failures. These failures were directly attributable to typical hydrocarbon attack on the film: shrinkage, embrittlement, loss of impact strength, stress cracking due to loss of plasticizers from the film.

The development and application of a properly compounded, oil-resistant vinyl film brought about a very sharp decrease in the number of failures, along with the promise of extended service life from the liner even in the presence of large concentrations of raw crude and natural gas. Such performance of the film permitted installation of the liner to be extended to crude oil stock tank storage and receiving tank storage at moderately high operating temperatures (180°F maximum continuous for the type of film under discussion here).

Subsequent troubles have been limited in number, and are mostly traceable to defective electronic seals which are detected by quality control procedure during fabrication, and/or mechanical damage imparted to the liner during installation. Improvements in factory production, quality control, and in field equipment and procedures for installing the liner have been effective within the last two years in achieving a very high success ratio.

Many problem tanks have been effectively protected by the installation of a flexible, one-piece vinyl liner without having to resort to extensive steel repairs and tank rebuilding procedures before other corrosion and/or leakage protection methods could be applied.

Production and maintenance histories on many oil field installations have established the economic justification and anticipated long service life of a <u>properly</u> <u>compounded</u>, <u>properly</u> <u>fabricated</u>, <u>properly</u> <u>installed</u> flexible oil field tank liner.