ISO 17025 ACCREDITED LABORATORY
ExcelPlas

Technical Note EP-48

How to Choose/Specify a High Quality PVC-EIA Liner

PVC-EIA liners and covers are made by alloying PVC with a solid plasticizer called Elvaloy® which has a ketone-ethylene-ester (KEE) structure. Since PVC-EIA liners use a solid (non-migrating) KEE plasticizer they are flexible yet highly resistant to hydrocarbons, chlorine, oxidation, ozone, UV light and weathering effects. There are more than a dozen different commercially available PVC-EIA liners from various manufacturers worldwide.

Unfortunately the Technical Data Sheets (TDS) for commercial PVC-EIA liners generally only list physical/mechanical properties and so-called 'index tests' but do not list those critical properties that enable designers, installers and asset owners to choose the liner/cover with the best durability and long-term performance. This makes it impossible to use technical data sheets to rank or make a comparative assessments of different PVC-EIA liners in terms of stability and durability.

Typical properties for PVC-EIA liners/covers found on most manufacturer's data sheets are simply mechanical tests results such as tensile, tear and puncture while the durability tests that designers expect/require are lacking. Important properties such as thermal stability, UV stability, type and level of KEE plasticizer, type and level of other (lower cost) plasticizers, type and level of white pigment, type and levels of fillers/extenders etc. are not disclosed.

In contrast the GRI GM-13 specification for HDPE liners lists durability tests such as OIT, HP-OIT, Stress Crack Resistance, Oven Ageing and UV Ageing endurance/challenge tests. However no similar specification currently exists for PVC-EIA liners.

The robustness and durability of PVC-EIA is a function of:

-the type and level of Elvaloy® KEE plasticizer added

-the types and levels of liquid plasticizers added

-the type and level of heat stabilizer/s added

-the level of other additives such as fillers and pigments

KEE exhibits a significantly higher molecular weight (MW) than conventional monomeric liquid plasticizers which greatly reduces plasticizer migration in PVC geomembranes. It has been reported by the FGI that KEE has a MW of 100,000 Dalton to more than 260,000 grams/mole or 500 times greater than the molecular weight of traditional liquid plasticizers There are three main types of KEE plasticizers that are used in PVC liners namely:
Elvaloy™ 741 - Standard Grade with hardness of 70 Shore A
Elvaloy™ 742 - Softer Standard Grade with hardness of 55 Shore A
Elvaloy™ High Performance (HP) grade which has an even higher molecular weight than the standard grades but at the expense of greater hardness and lower flexibility.

ExcelPlas Labs have developed the following test matrix and scorecard for determining the quality and expected durability of PVC-EIA liners (see table below).

Durability/Quality Scorecard for PVC-EIA Liners

Property	***Test Method***	***Value***	***Score out of 10***
Thermal Stability			
Congo Red Induction Time (CRIT) at 200 deg.C	ISO 182-1	> X mins	Value!
Plasticizer Type and Levels			
KEE Polymeric Plasticizer Levels by NMR	ASTM D8154	> X % (w/w)	Value!
Monomeric Plasticizer Levels by Solvent-extraction/GC/HPLC-MS	ASTM D7083	< X % (w/w)	Value!
Weight Av. Blended Phthalate-based Plasticizer Molecular Weight (MW)	ASTM D2124	> 400 g/mol	Value!
UV Stability			
Quantitative Additive Analysis (QAA) for type & levels of AO, UV absorbers and UV stabilizers such as HALS (low-basicity hindered piperidine derivatives)	ASTM D7210/D6042, D6953 mod.	> X % (w/w)	Value!
Pigment Levels/Quality			
Titanium Dioxide Level	ASTM D5630	> X % (w/w)	Value!
Titanium Dioxide Grade/Purity by XRD	ASTM D3720	< X% anatase	Value!
Titanium Dioxide Dispersion	ISO 18553	X rating	Value!
Filler Levels/Quality			
Calcium carbonate (and other fillers) type and level	ASTM D5630/ ASTM C1365	< X% $CaCO_3$	Value!
Chlorine Resistance			
Resistance to stress cracking in **0.1 wt.%** chlorine solution for 1 week at 23 deg.C	ASTM D1693	> X hrs	Value!
Resistance to stress cracking in **1.0 wt.%** chlorine solution for 1 week at 23 deg.C	ASTM D1693	> X hrs	Value!
TOTAL SCORE			**X**

Notes:

KEE = Ketone-Ethylene-Ester polymeric plasticizer
NMR = nuclear magnetic resonance
GC = gas chromatography
HPLC = high performance liquid chromatography
MS = mass spectrometry
MW = molecular weight
XRD = x-ray diffraction

The above table is based on the following testing regime used by ExcelPlas Labs to determine the quality and durability of PVC-EIA liners:

• Heat Stabilizer levels using the Congo Red Induction Time (CRIT) test at 200 deg.C. The Congo Red induction time measures the time in minutes until the heat stabilizer is exhausted which then causes the PVC to release acidic hydrogen chloride. The longer the induction

time, the more heat stabilizer is add to the PVC-EIA liner and the better the long-term field stability and heat ageing resistance.

• KEE plasticizer levels by NMR since difference levels of KEE polymeric plasticizers are used by different manufacturers. Since KEE plasticizers are costly some manufactures use less KEE and instead blend with cheaper monomeric plasticizers. Unfortunately monomeric plasticizer migrate from the PVC over time and leave it brittle.

• Level of monomeric (i.e. cheaper) plasticizers by solvent extraction and HPLC.

• Quantitative Additive Analysis (QAA) by GC/HPLC-MS to determine level of additives such as antioxidants and UV stabilizers in particular HALS.

• Bent-Strip Stress Crack Testing (ASTM D1693 mod.) and Bend-back (180 deg.C deadfold test) after 1 week immersion in 0.1% and 1% chlorine solution to determine present of microcracking and chlorine resistance.

• Bend Back (180 deg.C deadfold test) at -30 deg.C to determine low-temperature flexibility and tendency for star-cracking.

The weathering data in the datasheets for PVC-EIA liners is generally based on exposure times such > 8000 hrs in a carbon-arc weatherometer (ASTM G153) or > 19,000 hrs in a xenon-arc weatherometer. However neither of these two listed properties provide quantitative metrics that can be used to assess the relative weathering performance of the liner in the way that GM-13 gives the % retention of HP-OIT after QUV exposure. Furthermore 1 or 2 years of accelerated weathering is not practical when assessing the best PVC-EIA for a given project. Therefore to assess the weathering resistance of PVC-EIA one can instead use chemical analysis to determine the type/level of UV screening pigments (e.g. titanium dioxide), the type/level of UV absorbers (e.g. hydroxyphenylbenzotriazole and hydroxybenzophenone classes of compounds) and the type level of Hindered Amine Light Stabilizers (HALS). This data in combination can inform and predict the expected level of UV resistance of the formulation.

• The GRI GM-13 specification for HDPE liners forbids the use of fillers or extenders however in PVC formulations it is common to add calcium carbonate or kaolin. Some Asian made PVC-EIA liners contain rather high and unregulated levels of such fillers to cheapen the product. Therefore the type and level of mineral filler in the PVC-EIA liner/cover is an important parameter that affects the quality and durability of the liner/cover. The type and level of mineral fillers in the liner are measured using gravimetric ashing to determine ash content followed by XRD analysis to determine minerology of the filler/s.

Further Reading

Scheirs, J. '*A Guide to Polymeric Geomembranes*' Published by John Wiley and Sons (2009) pp. 139-148.

DuPont™ Elvaloy® Resin for PVC Modification
https://www.youtube.com/watch?v=zrCIUZx1O1M