NUKOTE COATING SYSTEMS

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COMPARISON OF NUKOTE COMPOSITES WITH TRADITIONAL LINING SYSTEMS

INTRODUCTION

This comparison is provided for use by Nukote Coating Systems International Distributors, Qualified Applicators and the End-users to facilitate their general analysis and comparison of the various products available in the market. The data compared and our comments on the general strengths and weaknesses of each product type included in this comparison were compiled from published industry articles, manufacturer's specific product data sheets and general industry knowledge related to each distinct product type. Any references to specific manufacturers, or their specific brand or trade name products, are provided solely in comparisons of the various products from published information available in the public domain. It is the hope of the authors that this document be used as a tool to assist in proper product selection for each end-users specific needs, which can vary greatly in each instance.

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DEFINITION OF SYNTHETIC MEMBRANE LINER SYSTEMS

The common definition of a flexible membrane lining system is; "a continuous plastic or rubber sheeting used to cover the sides and/or bottom of ponds, pits, and lagoons for the purpose of containing liquids and preventing seepage". These lining systems are readily available in a wide range of product types, each with unique properties and physical characteristics designed to provide specific benefits to the user. Conversely features that are beneficial in one respect can be detrimental in another, hence the quandary posed to the Specifiers in determining which product is most suitable for their needs. These membrane liner products are currently the system most commonly specified when designing a system to provide long lasting barriers for such applications.

A wide variety of liner materials are being manufactured and marketed today. These materials vary considerably in physical and chemical properties, methods of installation, cost and interaction with various chemicals. The base "polymers" used makes the available variations even greater because of the differences from each supplier related to their unique compounding, manufacturing, seaming and installation techniques and requirements. Choosing the correct flexible membrane liner material is no easy task today for many industries, especially those in the waste containment field.

For Specifiers, the primary focus should be to "design by function". Specific project requirements will determine the proper liner to be utilized. Rarely will the lowest priced material be the "best" liner for the job. Compromises are usually made if price is the primary decision making criteria rather than performance and design life. Price should be the decisive factor only when more than one material meets all of the project requirements.

Recognizing that there are numerous types of synthetic lining materials on the market today, analysis of the most widely utilized materials in this application type is appropriate. Comparing every liner system in the market is simply not feasible, instead a comparison of these systems generically, by polymer group will provide for a simpler decision making criteria without the sales hype generated by individual brands. Every lining system in the market will fit into one of five generic polymer categories. Each of these generic polymer categories has their own strengths and weaknesses. By understanding these strengths and weaknesses, individual decision makers will be able to determine the most suitable liner system by type for their specific project needs, only then should individual brands be considered and compared and a final supplier selected.

WHAT IS A POLYMER?

Polymers include chemically different compounds such as plastics, rubbers and even some of the proteins. The word "polymer" means "repetition of structural chemical units, such as linear chains". These polymer chains can align themselves in different ways. In some cases they intertwine like strands of spaghetti forming amorphous structures, while in others they align themselves in parallel crystalline structures. The "crystalline level" or "semi crystallinity" has a marked effect on derived physical properties. An amorphous polymer (lower crystalline level) may be a very viscous liquid in the extreme state while a highly crystalline polymer may be very hard or rigid. This level of crystallinity is what essentially determines the basic physical properties of every lining system marketed today.

CLASSIFICATION OF POLYMERS IN THE LINER INDUSTRY

As noted above, all membrane type liners can be consolidated into four basic product groups that will provide similar general characteristic properties due to their polymeric type, those being;

1) Synthetic Thermoset Rubbers (Neoprene, EPDM, Butyl)
2) Compound Thermoplastics (PVC, CPE)
3) Crystalline Plastics (HDPE)
4) Thermoplastics Elastomers (Chlorolsulphinated Polyethylene)
5) Thermoset Elastomer Composites (Polyurea Geo-textile Composites)

Note that the generic product types listed adjacent to the product group classification are just a few of the lining materials available within each group, however, these are the materials most commonly specified in liquid containment applications. Each of these materials has unique properties that translate to specific strengths and weaknesses. Become familiar with these advantages and disadvantages and make any final liner selection based on the individual material that best meets the specific technical requirements of any given project.

Bear in mind that there is no single material that will work best in every different project application. Additionally note that all brands within each product group are not equal and vary greatly at all levels from and the final specified thickness can greatly effect the installed products performance properties. The individual comparisons and data utilized in this document were taken from commonly used brands at a standard thickness which is noted on each test or comparison utilized, which may or may not be relevant to a specific projects performance requirements.

1. Synthetic Thermoset Rubbers

Common Synthetic Thermoset Rubbers, i.e. Neoprene, Butyl and EPDM were the first generation of amorphous polymers widely used as liner materials.

Known Strengths:

1. Excellent fiber memory and performs well under thermal cycling in the warmer temperature ranges (when exposed to temperatures from 20ºC and higher provides high elongation properties when under tension returning to their original shape and size when tension is released). This characteristic is desirable in applications where thermal cycling is common; however the products do not perform in the same manner when the ambient temperatures fall to the lower end of the temperature scale.

2. Good chemical resistance properties at ambient or slightly elevated temperatures.

Known Weaknesses:

1. Complicated application process requiring pre-wash, priming and closing of seams (dependent on roll width availability there are typically more lineal meters of seams than total square meters of area lined). Seams are where liner systems fail and failure of even a few seams translates to total failure of the system.

2. Poor dimensional stability performance over time causing seams to open as base grade settles or moves.

3. Poor thermal cycling when subjected to constant temperature fluctuations, especially when lower temperature ranges are present.

4. Poor performance in direct ultraviolet exposures (products loses physical properties after even short duration exposures to direct ultraviolet)

5. Life span is limited with common manufacturer warranties less than five-years.

Summary

This product was the pioneer in synthetic liner membrane products and like most pioneers newer products (designed to address its known weaknesses) are readily available and at competitive prices making this product somewhat obsolete in terms of this application type. The complicated application process, known weaknesses and lack of significant benefit over other products make it an infrequently specified product as a liner membrane system.

2. Compound Thermoplastics

Common compound thermoplastics, Polyvinyl chloride (PVC) and Chlorinated polyethylene (CPE) are heat formed products that gain their strength from their semi-crystalline chemical chain structure. For the purpose of this document we are utilizing PVC products only as they are much more commonly specified within this application type than CPE.

Known Strengths:

1. Good initial physical and ultraviolet resistance properties. PVC is a versatile thermo plastic when formulated with additional materials, such as plasticizers and other modifiers. There is a wide choice of plasticizers (both the traditional liquids and polymeric) that can be used in conjunction with PVC sheeting, depending upon the application and service conditions under which the PVC membrane will be used.

2. With the correct additive materials this product can provide good chemical resistance properties in containment applications.

3. High flexibility and durability after installation (prior to long term ultraviolet exposures).

Known Weaknesses:

1. Complicated application process requiring pre-wash and heat welding of all seams and dependent on roll width availability there are typically more lineal meters of seams than total square meters of area lined. Seams are where liner systems fail and failure of even a few seams translates to total failure of the system.

2. Poor elongation and thermal cycling performance in lower temperature ranges.

3. Typical application is via mechanical attachment only causing slow installations and potential failure points at attachment locations.

4. Carbon black is added to prevent ultraviolet attack of the PVC polymer. The carbon black causes the absorption of solar energy (when left exposed), raising the membrane temperature to a high level, causing migration of the plasticizer making the PVC less flexible. Plasticizer loss during service is the key source of PVC degradation. A soil or other suitable cover material used to bury the liner protects it from ultraviolet exposure and reduces the rate of plasticizer loss.

5. Life span is limited with manufacturer warranties common at seven-year maximum

Summary

PVC liners are typically not suitable for prolonged exposure to sunlight (UV). If specified in exposed applications, the expected life span will be for two to three years (could be less or more depending on climatic and chemical environment). PVC needs to be buried with 1’ of topsoil for reasonable UV protection. Most manufacturers require this before warranting their installed products in liner applications. Some manufactures offer UV resistant liner products but the price is at a premium which is not commonly acceptable in the market.

PVC liners are formulated with plasticizers and biocides. Plasticizers are what make an otherwise rigid PVC film flexible. Plasticizers continuously migrate from PVC causing it to stiffen and eventually become brittle. This typically doesn't present a problem in installations unless the PVC liner is in direct contact with another substance that has an affinity for the plasticizers and "robs" them at an accelerated rate. This has been noted to happen in applications on concrete (for example).

Biocides protect PVC plasticizers (which are most commonly phthalate based) from microbial attack. Without biocides, plasticizers will be consumed by soil borne microbes leaving the geo-membrane brittle. Biocides found in PVC can be toxic. When a non toxic grade PVC is made available it usually does not include a biocide, therefore this grade typically doesn't survive more than few years.

3. Crystalline Plastic

The most common Crystalline Plastic product marketed as a liner system is High Density Polyethylene (HDPE). Its desirable properties are derived from its high crystallinity within the chemical chain.

Known Strengths:

1. HDPE has been widely used as a membrane liner because of its good chemical resistance properties that better fit the requirements for hazardous waste disposal sites in spite of known disadvantages.

2. Strong resistance to permeation

3. Long historical track record

4. Common material with many suppliers in all geographic locations

Known Weaknesses:

The principal weaknesses of HDPE are derived from the same source as its principal strengths, i.e. its high crystallinity levels. In fact the high crystallinity accounts for almost all of its recognized problems today.

1. HDPE has a high coefficient of thermal expansion, causing stress in the seam areas.

2. The polyethylene commonly used today in the liner market is generally a medium density polyethylene, but many producers still refer to it as high density when in fact the densities are moderate and performance properties reflect this lower density level.

3. Unprotected clear polyethylene degrades readily on outdoor exposure. The addition of 2-3% of carbon black can produce improved protection from ultraviolet attack. The carbon black causes the absorption of solar energy when left exposed, raising the membrane temperature to a high level causing migration of the plasticizer making the HDPE less flexible. Plasticizer loss during service is the key source of HDPE degradation. A soil or other suitable cover material is commonly used to bury the liner protects it from ultraviolet exposure and reduces the rate of plasticizer loss.

4. Polyethylene membrane liners are made by sheet extrusion processes. The width of the sheet can be as much as 6-10 meters and the wider the roll size the lower quantity of seams to close. Larger widths are desirable but not available in most locations increasing seam quantities and future failure points at the same time.

5. HDPE product thickness varies typically from 1.0mm to 2.5mm. With HDPE thicker is better but thicker sheets are very stiff in comparison to the other membranes described in this document and thinner HDPE sheets are more difficult to field seam due to temperature sensitivity and are also punctured easily. Larger roll sizes and thicker sheets are desirable yet difficult if not impossible to

handle and install. Smaller rolls sizes and thinner sheets are easier to handle yet more difficult to seam and offer less impact and puncture resistance. Unfortunately this product most often gets specified at small roll widths (causing a lot more seaming) and thinner thicknesses (making it more difficult to seam and seaming is already difficult) and thus fails consistently in less than 5-years and often much less.

6. The benefit of many supply sources for this product are also a weakness in that many unqualified suppliers specify this product at incorrect thicknesses to provide adequate performance using properties derived from tests of thicker membranes. This product is too often specified incorrectly and as a result fails consistently.

7. Life span is typically less than five years with manufacturer warranties reflecting this fact

Summary

HDPE has a long historical record of application in liquid containment projects and provides good chemical resistance properties when properly installed. The product is very seldom properly installed, especially in third world countries and in many cases the project is sold on the features and benefits of wide roll and heavy thickness data but installations are performed using small rolls and thinner thicknesses.

HDPE is almost impossible to repair without the use of an expensive extrusion gun. All welds on environmental grade HDPE liners are field welds which greatly increase installation and third party field quality control costs. HDPE is almost never pre-fabricated in a controlled factory setting. HDPE is a very stiff "flexible" liner with a high coefficient of thermal expansion often requiring special design considerations. HDPE is prone to environmental stress cracking (ESCR) due to a crystal lattice structure. Environmental stress cracking is similar to taking a dark colored credit card and bending it until a fracture plane appears as a white crease.
HDPE has virtually no surface friction unless heavily textured. Puncture resistance properties require that a minimum 1.5mm thickness be specified for most applications.

HDPE is supplied to the job site in rolls that are the same width as it is produced. Because of the stiffness of the material it would be very difficult to prefabricate panels and then fold them as is done with other flexible membranes. The product is unrolled at the job site and each sheet is seamed to the adjacent one using either an extrusion welding technique or some other type of heat seaming such as a heated wedge, double wedge etc. Seam integrity is very dependent on operator skill.

If using the extrusion welding process, the beaded material used to cap the overlapping sheets must be of the same resin type as the original sheeting to assume a homogeneous seam. HDPE cannot be solvent welded. The product is more difficult to seam when compared to other membranes, although it appears easy when viewing the process in the field. Inspection of completed seams will show that most appear satisfactory but what is not apparent is that the act of melting the polyethylene during any of the installation processes has caused a realignment of the crystals, in effect producing a polymer having different properties along the seam area than found in the center of the sheet. This melting and cooling process builds in stresses which can produce cracks in the liner with time.

When repairs are required after the installation crew has left the site, then all the heavy seaming equipment must be brought back in to correctly make the repairs. Various suppliers of this product have placed a heavy emphasis on improving seam methodology but the result remains that this product is more subject to environmental stress cracking than other membrane liner systems.

4. Thermoplastic Elastomers

This product group is a modified HDPE product which derives it strengths from both crystalline and amorphous chemical chains. Chlorolsulphinated Polyethylene is made from high density polyethylene but with additive modifications (chlorine, sulfur and scrim) to address the known disadvantages of common HDPE. The chlorine interrupts or reduces the crystallinity common to normal HDPE producing an amorphous, elastomeric material. Since the crystallinity is the source of strength in HDPE products and the addition of chlorine with this modification reduces this inherent strength along with the reduction in crystallinity, a small amount of sulfur is then added to regain the strength lost while providing a much more flexible liner material. The finished liner product is manufactured in layers with the Chlorolsulphinated material on both sides of a polyester scrim. The product encases the scrim by bonding to itself through the openings between the fibers. Without the scrim reinforcement these products do not provide satisfactory dimensional stability, tensile or tear strength.

Known Strengths:

1. Good tensile, tear and dimensional stability while providing flexibility (reinforced imbedded scrim versions only).

2. Resolves some of the known weaknesses of HDPE in this modified version of the same product

3. Fair chemical resistance properties

Known Weaknesses:

1. Seams and the common weaknesses and potential failure points that this entails (highlighted above under all other sheet membrane products summaries).

2. Ultraviolet exposure instability as noted above in many of the other sheet membrane products. This product has the same issues with carbon black migration as HDPE and EPDM.

3. Poor chemical resistance to any mixture containing hydrocarbons

Summary:

This product does not provide good overall chemical resistance especially to hydrocarbons which readily swell and weaken it. The material continues to cure or vulcanize over time, its tensile strength continues to increase but its ability to accept repairs decreases proportionately. Special preparation and bonding agents are often required on older installations. The product is expensive when compared to others and typically exhibits somewhat lower physical property characteristics. Its unit weight per square meter is high increasing freight costs. The modifications made to improve on common HDPE have created a plethora of problems requiring further modification or mediation during installation.

5. Thermoset Elastomeric Composites

This product group derives its unusual high properties (not just a singe physical property but high levels are averaged across all properties) from both crystalline and amorphous chemical chains.

Polyurea Geotextile Composites are the latest product to enter the market which does not represent a modification of an existing polymer to improve on known weaknesses. The outstanding features of these composites provide a clear alternative to traditional lining materials used in containment of potable water, waste waster or other liquid containment systems.

Within this document we are comparing Nukote Polyurea Composites by brand name, as they are our brand and we pioneered this technology, which has become the buzz word in containment applications on both concrete and directly over compacted soils in composite form for both primary and secondary containment applications.

Known Strengths:

1. Excellent range of high physical properties including tensile, elongation, impact resistance, etc., compared to other products that are high in one area and low in another.

2. Excellent chemical resistance against a range of chemicals and PH levels and the product comes in varying grades that can be utilized when and where needed dependent on a projects unique requirements

3. Excellent temperature stability in both high and low ranges providing for good thermal cycling and recovery in all temperature ranges not just in warm to high ranges

4. Excellent Ultraviolet Resistance providing long term use without the requirement for cover maintaining higher percentages of physical properties on aging

5. Fast Application Times application speeds per crew in common containment over compacted soil is achieved at speeds of 1500 to 3000 square meters per day

6. Seamless Applications regardless of size there will be zero seams over the entire application reducing thousands of potential failure points over seamed product applications

7. Life Spans of up to 20-years warranted and insured for both supply are apply are provided

Known Weaknesses:

1. Short historical track records are common to products that are cutting edge technologies. These products have been used in this application type for slightly less than 10-years with zero failure occurrences yet the newness of the system is a perceived weakness by some Specifiers

Summary:

This remarkable technology offers a range of containment applications limited only by your imagination, for example:

The product is used as a liquid barrier in huge projects on offshore reclaimed land applications placed at -1 meter below grade and then filled and drained keeping unwanted chlorides from affecting landscaping while at the same time keeping fertilizers from contaminating marine life habitats.

Another common application is with secondary containment burms containing potential petrochemical spills from seeping into groundwater.

Another common application is in potable water reservoirs and in canals or wadis providing cost effective long lasting containment without the need for concrete or other expensive solutions.

Nukote polyurea sets fast (almost instantly), while providing very high elongation, tensile strength, impermeability, temperature resistance, chemical resistance, impact resistance and other desirable physical properties. The products can be applied at any temperatures and work in process temperatures from -40C to +150C. The products ability to provide high ranges of all properties is unique in the industry. Their ability to maintain these properties over long durations (even in direct ultraviolet exposures) combined with strong thermal cycling capability, while being economical and repair is unmatched by other coating and lining systems in the market.

Nukote Polyureas are applied over selected Geotextile fabrics and meshes creating a reinforced seamless liner system of any size fast and simply on site. The selection of fabric and Polyurea utilized is defined by the end user and their specific requirements including design life. Pricing is affordable and cost effective when compared to the other systems available on the market.

Scores heavily over preformed or other lining systems due to its flexibility and the strong physical properties provided. Traditional synthetic linings have either a very rigid nature and cannot accommodate movement from any cause, whether by settlement or otherwise, are susceptible to fracture and provide little thermal cycling capability or they are very flexible providing good thermal cycling but little impact or tear resistance. Nukote Polyurea Composites have strong elastomeric properties combined with strong hardness levels providing the desirable features of HDPE, PVC and others in a singe product, which is seamless, reinforced with Geotextile fabric that can expand and contract with the substrate and still provide high impact resistance, tear resistance and impermeability levels.

Nukote Polyurea is applied to Geotextile fabrics using state of the art plural component equipment, eliminating the potential for human error. The Geotextile fabrics themselves are lightweight and compact thus are easy to handle and apply. The products can be applied at any thickness (vertically, horizontally and even overhead) without any layering, sagging or other negative features common to other lining systems. Most failures occur at seams and/or joints. Nukote polyurea composite products, due to their 100% seamless, monolithic nature, completely avoid these historic failure points.

The strong properties of Nukote products, when combined with its elastomeric, seamless nature are not to be ignored when selecting a suitable lining system. The added benefit of having 100% insurance backed warranty (that can not be provided by other systems) makes the decision to use these products simple.

See Attached General Method Statement for installation methods, general physical properties, etc.

See Attached Comparison Charts to other liner systems

DESIGNING WITH SYNTHETIC LINERS – PHYSICAL PROPERTIES

The design process should include full consideration of all aspects of expected performance. Designing is much more than specifying a liner based on thickness as is being done more often than not today. A full evaluation of physical performance is recommended to obtain the most appropriate liner for your individual site. It is not an easy task to compare reinforced membranes to un-reinforced membranes. The following is a review of some physical test data that can help you specify your liner requirements.

1. Strength in Tension - Strength in tension measured in one direction:

HDPE produces a curve with a yield point in the range of 15 to 20 percent elongation. At the yield point it starts to "neck-down" in a localized area until the polymer chains are highly oriented and they resist further elongation. The strength in any other direction is very poor. For this reason, tear strength and puncture resistance are also very poor after the HDPE starts to neck-down. This can be demonstrated by taking a stretched test specimen, placing it on a soft surface and pushing a ballpoint pen into the surface of the specimen. It will easily penetrate completely through the membrane where it has been stretched. After it has been punctured, it can be torn very easily. This factor is particularly important where differential settling is encountered. Polyurea composites perform much better in such situations.

2. Biaxial Strength

Strength in tension measured in two directions at the same time; Stress imposed on flexible membrane liners in actual service is often in two directions rather than the one measured by typical stress-strain test. HDPE fails at relatively low elongations when stressed in two directions. The elongation at failure is also dependent on the thickness of the membrane. This is further evidence supporting the need for a minimum of 1.5mm to 2mm thickness requirement for HDPE membrane liners. Polyurea composite failure elongation factors are far greater than those provided by HDPE. The higher elongation provided by Polyurea and Polyurea composite is very meaningful for liners for ponds or landfills. The stress applied to the liner by the tons of liquids or solids it supports would far exceed the strength of any liner if it were not supported by the soil underneath. To avoid rupture and failure of the liner, it must be able to accommodate the movement caused by any differential settling of the soil without exceeding the failure elongation of the liner. The high elongation of Polyurea composites provides a big safety factor compared to HPDE.

C. Environmental Stress Cracking**:**

Crystalline and semi-crystalline polymers, such as HDPE, can develop stress cracks when exposed to certain conditions while under stress. Some of these conditions include chemicals that only attacked these polymers when they are under stress. This problem is generally labeled as environmental stress cracking. HDPE is known to be sensitive to a variety of chemicals of which the most common types are soaps and detergents. Environmental stress cracking is receiving a great deal of attention. Several organizations are researching and trying to explain the cause of this phenomenon. What is clear at this time is that any liner specified should provide the highest range of elongation and tensile strength possible to alleviate or mediate this phenomenon.

D. Coefficient of Thermal Expansion:

The amount of expansion or contraction that occurs when a membrane is heated or cooled is expressed as its coefficient of linear thermal expansion. It is determined by accurately measuring the dimensions of a test section at two different temperatures and calculating the percent change/degree F or C. HDPE has a very high coefficient of thermal expansion. This means that a liner on a 150 meter burm will expand slightly less than 2 meters on a day when the temperature starts at 29ºC and the black liner gets up to 70ºC in the early afternoon sun. To accommodate this much expansion, the liner develops large undulations or waves on the burms and exposed side slopes. Besides providing a poor appearance, this results in severe stress in the region between the exposed membrane and the membrane that is below the liquid level which expands very little. This high linear expansion also placed limitations on when seaming can be done. Seaming on hot sunny days can result in split seams or the liner lifting away from the corners at the top of the side slopes as the liner contracts during cooling in the evening.

Summary

The designer should consider all of these factors along with the unique requirements of the specific project to correctly determine which product is most suitable for their needs.

DOCUMENT SUMMARY

Attached to this document are some comparison charts that provide side by side published physical properties data from the most prevalent lining systems marketed today within each of the polymer groups summarized in this document. The data utilized in this document was derived from individual manufacturers published data sheets and general product descriptions. When viewing this data bear in mind that the published data is at a specified 1mm membrane thickness when in most cased EPDM and HDPE should be specified at 2mm thicknesses or higher to adequately be specified in this application type. The data is published in this manner to show higher values for elongation and other factors (in many cases) when actual values will vary. Additionally many values for properties that should be reported are not published, to avoid bringing attention to weaknesses in the product and make it more saleable.

In all cases products that perform well will have a high range of properties, not just one or two high values, for instance having high elongation does not directly translate into a products suitability as a liner (very high elongation usually means other required properties such as tensile, puncture resistance; hydrostatic resistance, etc. are not up to the application for which they are attempting to be specified). The best solution is a liner that has high marks in all areas that specifically relate to the requirements of the individual project.

The most prevalent specification in liner membrane systems is HDPE. The reasons for this can principally be attributed to the long historical track record of the HDPE product (regardless of the high failure rate and short derived life span) and the sheer quantity of companies marketing the products. I.E., HDPE has been around a long time and there are a lot of people selling it. Since this is the most common specified product we have provided a lot more direct comparison information in the above summaries than with other products that are simply not specified commonly in this application type.

We are rightfully proud of our Nukote Polyurea Geotextile composite system and in some cases this document will reflect this. We do not apologize for this, but want it known that we are aware and quite frankly can find no reason to make our statements anything but true in this regard. We believe that our products can meet the needs of most project applications considering or requiring the use of membrane liner systems and feel that from the positions of performance, price, warranty and suitability we frankly have no peers. We are sure that our competitors will beg to differ and acknowledge their right to do so.

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COMPARISON OF SYNTHETIC MEMBRANE LINERS SYSTEMS					GENERAL FEATURES COMPARISON		
ITEM	CHARACTERISTIC	STR (EPDM)	CT (PVC)	CP (HDPE)	TE (HYPALON)	TEC (NUKOTE COMPOSITE)	PRINCIPAL NUKOTE BENEFIT
1	SOLD CONTENT 100%	N/A	N/A	N/A	N/A	YES	NUKOTE PRODUCT IS 100% SOLD AND VOC FREE
2	MONOLITHIC NO LAYERS	N/A	N/A	N/A	N/A	YES	NO LAYERING REGARDLESS OF DFT EVEN FOR REPAIRS OR REMEDIATION
3	SEAMLESS 100%	NO	NO	NO	NO	YES	NO SEAMS PERIOD THE ONLY PRODUCT IN THIS COMPARISION WITHOUT THIS FATAL FLAW
4	APPLICATION SPEED	VERY SLOW	VERY SLOW	VERY SLOW	VERY SLOW	VERY FAST	1500 TO 2000 SQUARE METERS PER DAY COMPLETION LEVELS FOR NUKOTE COMPOSITES
5	APPLICATION COMPLEXITY	COMPLICATED	COMPLICATED	COMPLICATED	COMPLICATED	SIMPLE	SINGE APPLICATION STEP USING STATE OF THE ART EQUIPMENT ELIMINATES ERRORS/FAILURES
6	APPLICATION METHOD	MANUAL	MANUAL	MANUAL	MANUAL	EQUIPMENT	APPLICATION VIA PLURAL COMPONENT EQUIPMENT ELIMINATES ERRORS/FAILURES
7	MOISTURE SENSITIVITY	ADVERSE ADHESION EFFECT	ADVERSE EFFECT PRE-WELDING	ADVERSE ADHESION EFFECT	ADVERSE ADHESION EFFECT	HYDROPHOBIC 100% INSENSITIVE	MOISTURE HAS NO EFFECT ON ADHESION CURING OR APPLICATION OF NUKOTE PRODUCTS
8	ADHESION TO CONCRETE	NO CHEMICAL BOND	NO CHEMICAL BOND	NO CHEMICAL BOND	NO CHEMICAL BOND	> 3. 5MPa	NUKOTE BOND STRENGTH TO CONCRETE IS EQUAL TO FAILURE LEVEL OF CONCRETE SUBSTRATE
9	ADHESION TO METALS	NIL	NIL	NIL	NIL	> 20 Mpa	NUKOTE BOND STRENGTH TO STEEL SUBSTRATES IS EXCEPTIONAL
10	CHEMICAL RESISTANCE	MODERATE	GOOD	GOOD	MODERATE	EXCELLENT	NIUKOTE IS RESISTANT TO ALKALINE OR ACID CHEMICALS IN MOST SOLUTION UP TO 30% CONCENTRATION LEVELS

COMPARISON OF SYNTHETIC MEMBRANE LINERS SYSTEMS					GENERAL FEATURES COMPARISON		
ITEM	CHARACTERISTIC	STR (EPDM)	CT (PVC)	CP (HDPE)	TE (HYPALON)	TEC (NUKOTE COMPOSITE)	PRINCIPAL NUKOTE BENEFIT
11	SOLVENT RESISTANCE	POOR	POOR	POOR	MODERATE	EXCELLENT	NUKOTE IS RESISTANT TO MOST SOLVENTS AND OTHER SOLUTIONS CONTAINING HYDROCARBONS
12	ULTRAVIOLET RESISTANCE	VERY POOR	POOR	VERY POOR	POOR	GOOD	NUKOTE IS UV RESISTANT COLOR WILL FADE BUT PROPERTIES WILL BE MAINTAINED
13	CO EFFICIENT OF THERMAL EXPANSION	VERY HIGH	HIGH	VERY HIGH	HIGH	LOW	HIGH VALUE CREATES STRESS ON THE SEAMS AND REDUCES FABRICS ABILITY TO MOVE WITH GRADE CHANGES CAUSING FAILURES
14	REPAIR AND MAINTENANCE	COMPLICATED	COMPLICATED	COMPLICATED	COMPLICATED	SIMPLE	CLEANING BY STEAM OR HIGH PRESSURE WATER THEN CHEM WIPE THEN APPLY PRODUCT TO ACHIEVE SPECIFIED DFT MONOLITHICALLY
15	APPLICATION AT CRITICAL AREAS	VERY DIFFICULT	VERY DIFFICULT	VERY DIFFICULT	VERY DIFFICULT	SIMPLE	PENETRATIONS, TERMINATIONS, SEAMS ALL IN THE SAME SIMPLE APPLICATION PROCES INCLUDING TERMINATING AND BONDING TO ADJACENT SUBSTRATES
16	WARRANTY WITH INSURANCE BACK	NO	NO	NO	NO	YES	AIG SUPPLY AND APPLY WARRANTY TO 1M USD PER FAILURE OCCURRENCE OFFERED BY NUKOTE AND ONLY NUKOTE OF ALL SUPPLIERS
17	WARRANTY TERM	5-YEARS	7-YEARS	7-YEARS	7-YEARS	20-YEARS	LONGER DURATION OF WARRANTIES DESIRABLE

COMPARISON OF SYNTHETIC MEMBRANE LINERS SYSTEMS						PHYSICAL PROPERTIES @ 1MM THICKNESS COMPARISON		
ITEM	**PROPERTY**	**TEST METHOD**	**STR (EPDM)**	**CT (PVC)**	**CP (HDPE)**	**TE (HYPALON)**	**TEC (NUKOTE COMPOSITE)**	**PRINCIPAL NUKOTE BENEFIT**
1	TENSILE STRENGTH PLI	ASTM D-683	50	97	88	-	426	NUKOTE VALUE MUCH HIGHER HYPALON NOT PUBLISHED
2	BREAK ELONGATION %	ASTM D-882	500%	400%	350%	15%	429%	ELONGATION VALUE MUST BE COMPARED WITH OTHERS I.E. TENSILE, TEAR, DIMENSIONAL STABILITIY (BEST RANGE OF PROPERTIES IS DESIRABLE NOT A SINGE HIGH OR LOW VALUE
3	TEAR STRENGTH PLI	ASTM D-624	9	10.5	30	80	755	NUKOTE VALUE MUCH HIGHER
4	PUNCTURE RESISTANCE PSI	ASTM D-4833	35	-	52	24	92	NUKOTE VALUE MUCH HIGHER PVC NOT PUBLISHED
5	RESISTANCE TO OZONE	ASTM D-1149	PASS	-	-	PASS	PASS	CRITICAL FACTOR IN EXPOSED APPLICATIONS NOTE THIS TEST IS 7-DAY EXPOSURE ONLY SOME NOT PUBLISHED
6	LOW TEMPERATURE IMPACT	ASTM D-746	-45C	-29C	-75C	-40C	-50C	COMPARABLE IN THIS TEST METHOD USED
7	MOISTURE VAPOR TRANSMISSION	ASTM E-96-80	2% MAX	2% MAX	-	-	1% MAX	NUKOTE VALUE MUCH LOWER (BETTER) SOME NOT PUBLISHED
8	WATER ABSORPTION %	ASTM D-741	8% MAX	2% MAX	-	-	2% MAX	NUKOTE AND PVC VALUES MUCH HIGHER OTHERS NOT PUBLISHED
9	HYDROSTATIC RESISTANCE PSI	ASTM DF751 (A-1)	-	120	-	250	448	NUKOTE VALUE MUCH HIGHER HDPE NOT PUBLISHED
10	DIMENSIONAL STABILITY % CHANGE	ASTM E-96	1% MAX	3% MAX	2% MAX	-	7% MAX	NUKOTE VALUE MUCH HIGHER
11	ABRASION RESISTANCE	TABOR ABRASION C17 WHEEL 1000 G 1000 REVS	-	-	-	-	10 GRAM LOSS MAX	NUKOTE VALUE HIGH OTHERS NOT PUBLISHED
12	SHORE D HARDNESS	ASTM D2240-81	-	-	-	-	48	NUKOTE VALUE HIGH OTHERS NOT PUBLISHED