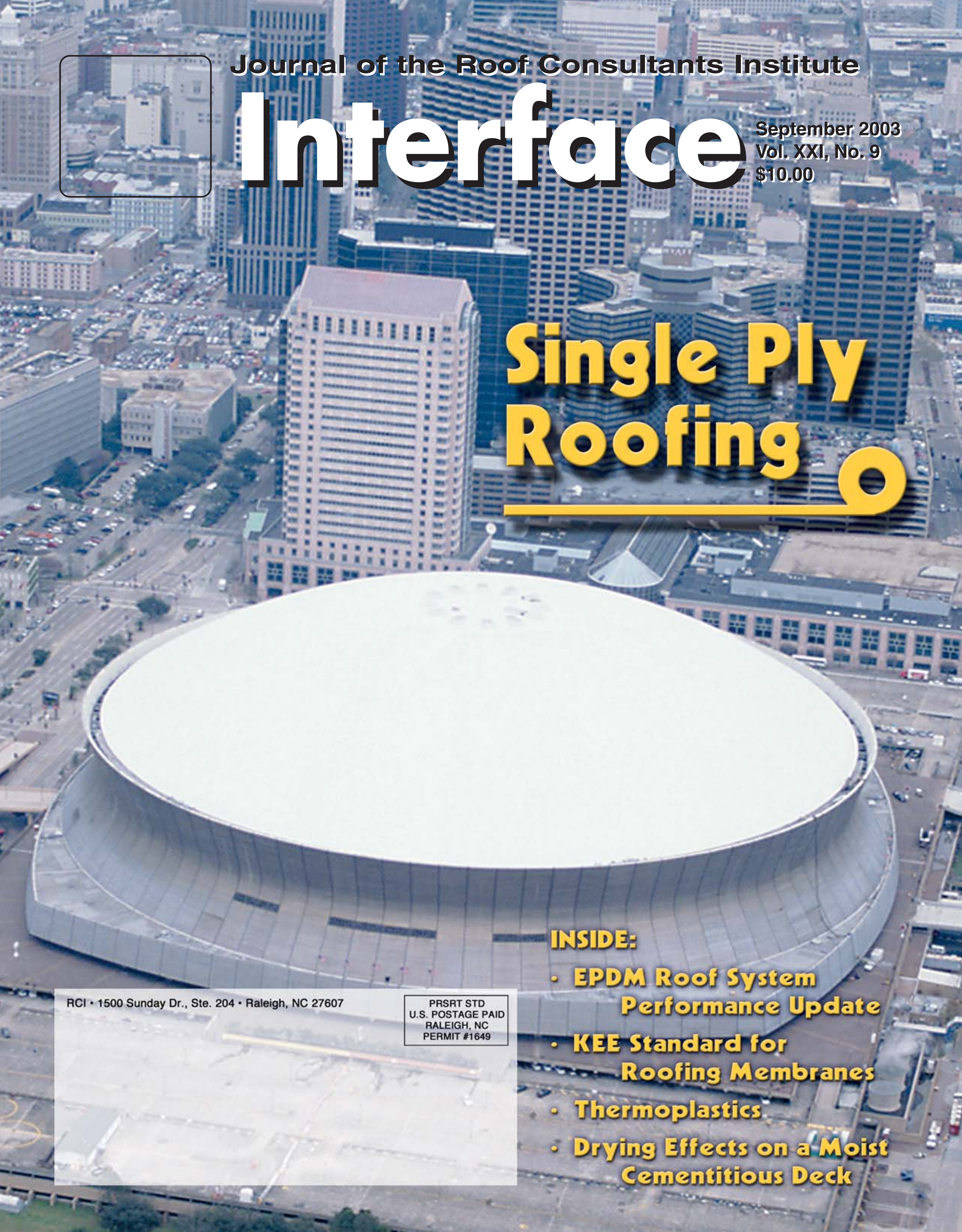

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A KEE Standard for Roofing Membranes

By Jerry Beall

In March of 2002, ASTM, the American Society for Testing and Materials, assigned a number to the new Standard Specification for KEE Sheet Roofing.

The new ASTM D 6754 is the exclamation point to the 15-year saga associated with its development. The journey began in the late 1980s as an effort to assure the roofing industry that it is possible to manufacture a "vinyl" roofing membrane less than 45 mils thick that is capable of meeting or exceeding the performance expectations of some thicker membranes.

Prior to the adoption of D 6754-02, the only official option for evaluating and/or characterizing vinyl membranes was ASTM D 4434. ASTM published the D 4434 Standard in 1985, the first consensus standard for single ply membranes. It was the result of a consensus procedure among roofing industry professionals which characterized PVC sheet roofing. The development of the document came at a time when PVC membranes, as roof coverings, were recovering from the stigma associated with early failures. The D 4434 Standard Specification established a nationally-recognized definition for PVC roofing membranes.

Section 4.1 of ASTM D 4434-96 defines the applicable material as follows:

> *The sheet shall consist of poly (vinyl chloride) resin in amounts greater than 50% of the total polymer content suitably compounded with plasticizers, stabilizers, fillers, pigments, and other ingredients to satisfy the physical property requirements and accelerated durability tests.*

The standard was an attempt to list physical properties that would characterize a "good" PVC roofing membrane. Although internal reinforcements, resistance to heat aging, and resistance to ultraviolet light were significant considerations, the industry gravitated toward elevating the 45 mil minimum thickness as a prerequisite toward the consideration of a vinyl membrane's viability. And even though the D 4434 was later modified in 1991 to include minimum 36 mil heavily reinforced vinyl membranes, the 45-mil paradigm held.

During the past 17 years, ASTM D 4434 has been the benchmark standard for the competitive evaluation of vinyl membranes. Although invaluable in its own right for establishing minimum characteristics for a particular segment of PVC membranes, it was not necessarily applicable to all vinyl roofing membranes. There were a variety of vinyl roofing membranes in existence at the time it was adopted in 1985. In addition to "liquid" monomeric materials, solid polymers such as vinyl acetate, nitrile, and chlorinated polyethylene were also being used as alternative modifiers for vinyl membranes. Was it appropriate to lump all the variable fabric, compounding, and production technologies available under

Physical Requirements	D 6754-02	D 4434-96	
		Type III	Type IV
Property			
Thickness, min., mm (in.)	0.79 (0.031)	1.14 (0.045)	0.91 (0.036)
Thickness over fiber, min., mm (in.)	0.15 (0.006)	--	--
Breaking strength, strip, N (lbf)	1175 (265)	--	--
Breaking strength, grab, min, kN/m (lbf/in.)	--	35 (200)	48 (275)
Elongation at break, strip, min., %	15	--	--
Elongation at break, min, %			
Machine direction	--	15*a*	25*a*
Cross-machine direction	--	15*a*	25*a*
Tearing strength, min., N (lbf)	335 (75)	200 (45.0)	400 (90.0)
(1 h at 212 ± 5^2F) Lineal dimension change, max., %	1.3	--	--
(6 h at 176 ± 2^2F) Lineal dimension change, max., %	--	0.5	0.5
Fabric adhesion, min., N/m (lbf/in.)	225 (13)	--	--
Retention of properties after heat aging:			
Breaking strength, strip, min., % of original	90	90	90
Elongation at break, strip, min., % of original	90	90	90
Low-temperature bend after heat aging	-30 ± 2°F	--	--
Low-temperature bend	-30 ± 2°F	-40°F	-40°F
(D 471) Change in weight after exposure in water, max, %	0.0, +6.0	--	--
(D 570) Change in weight after immersion in water, max, %	--	± 3	± 3
Factory seam strength, min., N (lbf)	1780 (400)	--	--
Seam strength, min, % of tensile or breaking strength	--	75	75
Hydrostatic resistance, min., MPa (psi)	3.5 (500)	--	--
Static puncture resistance	99 lbf	33 lbf	33 lbf
Dynamic puncture resistance	10 J min	20 J min	20 J min
Accelerated weathering test after 5000-h xenon arc light exposure	--	*	*
Cracking (7x magnification)	none	none	none
Crazing (7x magnification)	none	none	none
Accelerated weathering test after 5000-h fluorescent light exposure	--	*	*
Cracking (7x magnification)	none	--	--
Crazing (7x magnification)	none	--	--
Fungi resistance	--		
Sustained growth	no growth	--	--
Discoloration	none	--	--
Abrasion test, min., cycles	1500	--	--

a For reinforcing fabric only; elongation of PVC material shall be the same as Type II, Grade 1.
* *either xenon or fluorescent / Kee standard specifies both*

Figure 1

one universal standard for thermoplastic vinyl roofing membranes? The adoption of ASTM D 4434 had an unintended consequence of doing just that.

The technology used to produce those membranes, defined within the D 4434, is a simple process that begins with a high molecular weight PVC resin but extends it and makes it flexible with a lower molecular weight liquid plasticizer. The challenge for this process is to produce a material that remains flexible, even though the lightweight plasticizers tend to drift away from the PVC polymer over time and exit the sheet. Certain environments can accelerate this process, leaving a membrane prone to *in-situ* shrinkage and stiffening. A minimum polymer thickness is required to function as a reservoir to prolong the time it takes for liquid plasticizers to migrate to the surface and erode away.

The original acronym used to differentiate KEE technology from conventional vinyl technology was EIP (ethylene interpolymer). The few associated with the development and introduction of EIP roofing membranes in the early 1980s contended that thicker isn't necessarily better, better is better! The EIP acronym and its associated performance record began to catch on and were eventually recognized by the NRCA by definition in the *NRCA Low Slope Guide*. In the late 1980s and early 1990s, additional manufacturers introduced new membranes under the EIP banner.

Was the difference between EIP and PVC technologies significant enough to warrant the development of a separate standard? The American Society of Testing and Measures was petitioned to take a look and agreed to evaluate EIP roofing membranes. The subcommittee for the development of a standard specification for Ethylene Inter-polymer Sheet Roofing was formed in 1987.

EIP was the original acronym used to differentiate membranes manufactured using a hot melt vinyl coating technology with DuPont Elvaloy® as the foundation for the vinyl compound. Elvaloy® is a flexible terpolymer containing ketone, ethylene, and ester monomers, all within the backbone of the polymer. Simply put, it is a high molecular weight, solid, and flexible thermoplastic polymer. *PVC* resin is added to and alloyed with the Elvaloy to impart a few of its more desirable properties such as strength and flame retardancy. Elvaloy® and PVC are completely miscible and become a single-phase polymer when mixed. They disperse within each other and, since both polymers are high in molecular weight, they will not migrate away from each other when properly alloyed. Their affinity for each other ensured membrane flexibility in severe environments that would otherwise accelerate the loss of liquid plasticizers in conventional PVC membranes.

Realizing that EIP coating technology utilized Elvaloy® instead of PVC as the backbone for the polymer matrix, the title for the standard was changed to better reflect the chemistry. The standard's title was subsequently changed to "Ethyl Vinyl Acetate Carbon Monoxide Terpolymer Sheet Roofing." Subjecting the roofing industry to *EVACMTPR* as an acronym would have been cruel.

In 1997, the standard's title was changed again as the subcommittee refined its understanding of the chemistry and technology associated with the manufacturer and processing of Elvaloy. Ketone Ethylene Ester (KEE) was eventually agreed upon as the appropriate acronym to describe the chemical backbone of the polymer. Hence, the proposed ASTM Specification for a KEE Sheet Membrane was defined, but stood in contrast with the conventional definition and description for a PVC sheet membrane within ASTM D 4434.

3.3 Polymer Content: In this specification, polymer content shall be defined as polymeric materials, which are in the solid state at room temperature and are high (greater than 50,000) in molecular weight. Other ingredients known to the art of polymer compounding, such as certain waxes, stabilizers, and other additives, while polymeric in nature, are not considered to be part of the base polymer system.

4.1 The sheet shall be formulated from the appropriate polymers and other compounding ingredients. The KEE polymer shall be a minimum of 50% by weight of the polymer content of the sheet.

Since the proponents of KEE sheet membranes were about to challenge the "thicker is better" paradigm that evolved from the D 4434, and since it takes a consensus among committee members to move the process along, satisfying all the concerns raised by the committee took time.

There were two KEE issues that stood in stark contrast to the ASTM D 4434 PVC standard. Although KEE membranes exceed the majority of the physical property requirements of the D 4434, they were significantly "thinner" than 45 mil and exhibited a higher water absorption characteristic.

Apart from the technical discussions on how to statistically analyze and display the data assembled, thickness and water absorption were the most significant objections toward adoption of the standard within the subcommittee. The KEE proponents were asked to "prove" that thickness and water absorption (as historically defined within ASTM D 4434) were not appropriate mandates for performance.

How Thick is Thick Enough

Depending upon the internal fabrics or reinforcements, initial impact resistance may be improved with the additional mass when testing new membranes. But most roofing membranes anchored to liquid phthalate technologies are known to be prone to loss of flexibility due to plasticizer migration. This has been, and will continue to be, a factor affecting *in-situ* performance of PVC roofing systems.

A true KEE membrane by definition doesn't have to be thick to achieve desirable membrane attributes or to prolong the migration of liquids out of the sheet. KEE will not migrate, and the sheet will stay flexible. The membrane strength attributes come from the fabric, not its thickness. If the fabric is engineered properly, then the purpose of the coating is to protect

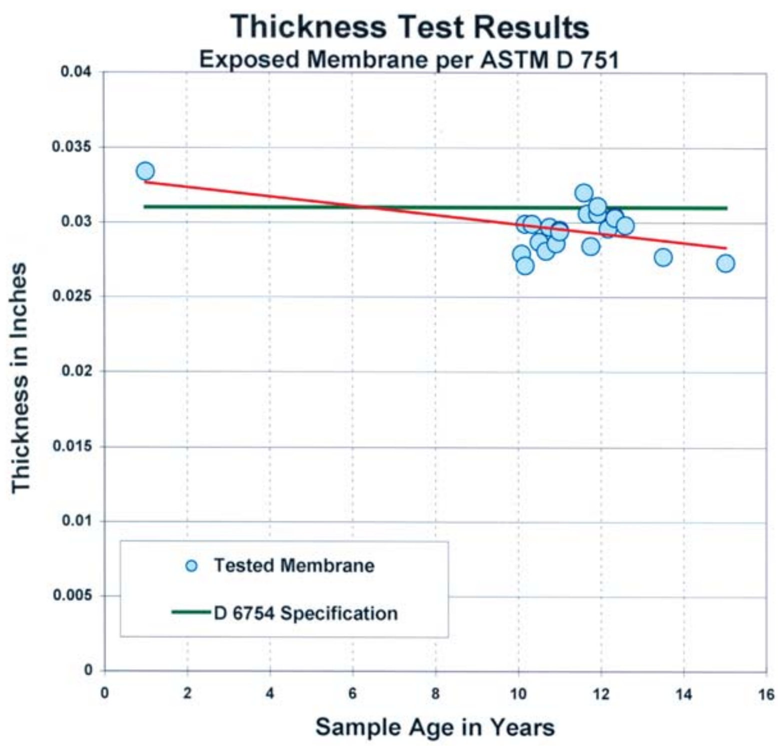

Figure 2

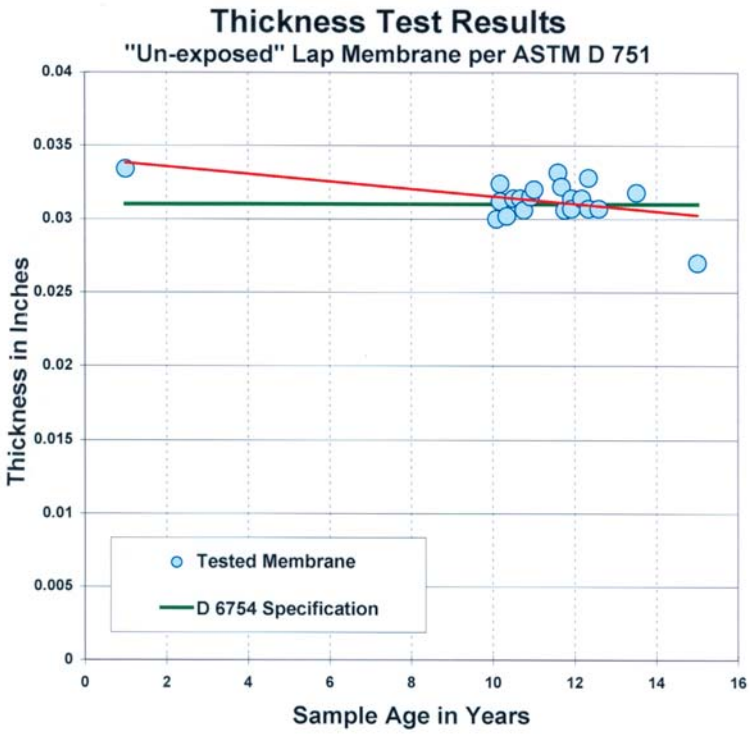

Figure 3

the fabric's inherent attributes.

Although the D 4434 standard prompted the adoption of a 45-mil standard within the industry, the trend over the past 15 years has been for many manufacturers to promote even thicker materials, ranging from 0.050 to 0.100 inches. Curiously, the increase in thickness rarely yields a corresponding increase in physical properties such as the tear and tensile of the sheets.

Is it a coincidence that the increase in thickness shadows the rise in the tenure and liability associated with commercial roofing warranties over the past 15 years? Maybe ASTM D 4434 actually offers a plausible explanation for the alignment between thickness and warranties.

"Design service life is defined as the designated time period of intended system performance."

Water Absorption

Water Absorption is the second issue to examine when comparing D 6754 to D 4434. KEE membranes have the proven ability to endure and sustain performance within the hostile rooftop environment. However, when "immersed" in a high temperature water bath, they exhibit "water absorption" characteristics higher than PVC membranes defined within the context of D 4434. In addition to variable fabric densities within the membranes, different polymers exhibit a different affinity to water. KEE is significantly different from PVC. Properly compounded KEE membranes, as defined within the context of ASTM D 6754, may appear to have increased "high temperature" water absorption characteristics, yet they are proven to excel as waterproofing membranes. ASTM D 4434 allows for membranes to experience a 3% weight gain or a 3% weight loss after the water absorption test. The new D 6754-02

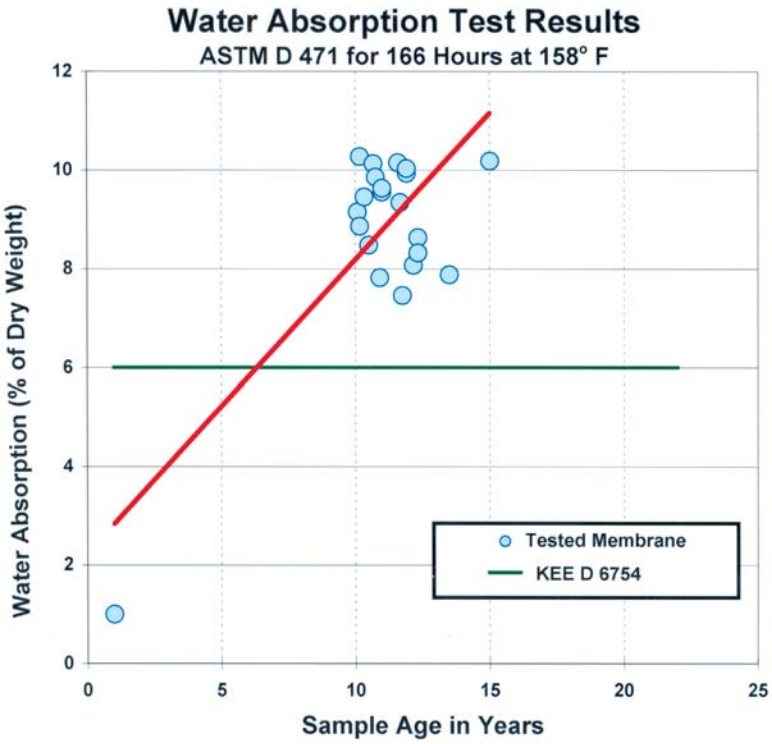

Figure 4

does not allow for any weight loss. Since water is not chemically reactive or degrading to either PVC or Elvaloy®, the increase in water take up for KEE roofing membranes when evaluated at a high temperature doesn't translate into a performance factor.

There are a few additional tests and property limits recognized within the KEE standard that should not only characterize minimum values for KEE membranes, but should be considered essential to the overall performance of all roofing membranes. Adhesion of the coating to the reinforcement, hydrostatic resistance, fungus resistance, and abrasion may all contribute to the "design service life" of a membrane roofing system, but are conspicuously absent in the D 4434 Standard Specification for PVC Sheet Roofing.

KEE membranes are also characterized by excellent chemical resistance. The rooftop environment is one of contamination. In addition to direct exhaust exposure, areas of ponding water can accumulate all forms of fallout. Even seemingly benign contaminants such as oils, greases, and fats can accelerate the aging process for PVC membranes by accelerating plasticizer loss. Since properly formulated KEE membranes begin with flexibility creating a permanent-phased polymer, they're not prone to having their flexibility extracted.

All roofing systems have some hidden Achilles tendon. KEE membranes are vulnerable to liquid phthalate plasticizers. Although KEE formulations do not rely on liquid plasticizers for flexibility, some liquid plasticizers may be used during processing. High molecular weight KEE and PVC polymers have a natural affinity for lightweight plasticizers. Consequently, exposing KEE membranes to phthalates can promote over plasticization and softening of the membrane under warm exposure.

To address the committee's concerns, a ten-year history of performance for KEE membranes was assembled and presented to the subcommittee. The history included a certifiable sampling of roof systems over ten years old in Florida, Ohio, Denver, Wisconsin, and Texas. This sampling was supported by a 1997 study and evaluation of KEE roofing systems by Exterior Research & Design, LLC.

Samples of the ten-year-old membranes were presented to the committee, evaluated against the proposed KEE standard for new materials, and subsequently found to be in excellent condition. They all retained over 90% of their original physical property requirements, including thickness. Many of the 10-year-old samples were exposed to additional accelerated weathering tests, including QUV and heat aging. The committee eventually concluded that the results from immersing a 1-inch by 2-inch sample of membrane in a 158˚F water bath for seven days, as described within the D 4434, wasn't an appropriate test method for the characterization of a KEE membrane. One-side water absorption evaluation, similar to EPDM requirements, was selected as a more appropriate test method.

Properly compounded and engineered KEE membranes have a proven performance record. Physical properties that had generated the greatest concern, specifically thickness and water absorption according to conventional evaluation of "PVC," were determined to be of no consequence with respect to performance.

ASTM D 6754-02 Standard for KEE Sheet Roofing specifies a minimum thickness of 0.031 inches. When the first KEE membrane was commercialized in 1979, the model building codes required a minimum thirty mils for most forms of sheet roofing. This new standard clearly recognizes that a properly formulated and engineered KEE membrane can perform or provide a "design service life" at 70% of the 45 mil norm for PVC membranes produced, according to the criteria in D 4434.

The permanence of the phased polymer structure within the KEE coating, the coating's adhesion to the base fabric, and superior resistance to UV, chemical, and microbiological attack are all attributes that have contributed to the historical performance of KEE membranes and the subsequent publication of ASTM D 6754-02. ■

About the Author

Jerry Beall

Jerry Beall's career in the roofing industry spans more than 30 years, stemming from a 10-year chapter as a journeyman with Roofers' Local #88, and then developing into work in technical service, commercial roofing sales, estimating, and project and technical management. Today, as national sales and technical manager for FiberTite® Roofing Systems by Seaman Corporation, Jerry uses his field experience and interest in leadership, product development, marketing, and strategic visioning to guide a nationwide team of sales, technical, and manufacturing representatives. Jerry enjoys engaging the industry in discussions related to the design, engineering, application, and sales of different roofing systems by giving presentations to audiences that include members of AIA and RCI, as well as roofing contractors and building owners.