Single Ply Roofing

INSIDE:
- EPDM Roof System Performance Update
- KEE Standard for Roofing Membranes
- Thermoplastics
- Drying Effects on a Moist Cementitious Deck
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

<table>
<thead>
<tr>
<th>Physical Requirements</th>
<th>D 6754-02</th>
<th>D 4434-96</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type III</strong></td>
<td><strong>Type IV</strong></td>
<td></td>
</tr>
<tr>
<td>Thickness, min., mm (in.)</td>
<td>0.79 (0.031)</td>
<td>1.14 (0.045)</td>
</tr>
<tr>
<td>Elongation at break, min., %</td>
<td>15</td>
<td>--</td>
</tr>
<tr>
<td>Tearing strength, min., N (bf)</td>
<td>335 (75)</td>
<td>200 (45.0)</td>
</tr>
<tr>
<td>Retention of properties after heat aging</td>
<td>999 999 999</td>
<td></td>
</tr>
<tr>
<td>Hydrostatic resistance, min., MPA (ps)</td>
<td>3.5 (500)</td>
<td>33 lbf 33 lbf</td>
</tr>
</tbody>
</table>

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 inter-polymer). 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

---

![Thickness Test Results](image)
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
reactive or degrading to either PVC or Elvaloy®, the increase in
does not allow for any weight loss. Since water is not chemically
softening of the membrane under warm exposure.
membranes can promote over plasticization and
affinity for lightweight plasticizers. Consequently, exposing KEE
High molecular weight KEE and PVC polymers have a natural
flexibility, some liquid plasticizers may be used during processing.
Although KEE formulations do not rely on liquid plasticizers for
membranes are vulnerable to liquid phthalate plasticizers.
important to the overall performance of all roofing membranes.
Adhesion of the coating to the reinforcement, hydrostatic resis-
tance, fungus resistance, and abrasion may all contribute to the
“design service life” of a membrane roofing system, but are con-
spiciously 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 contami-
nants 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 creat-
ing 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 weather-
ing 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 require-
ments, 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 for-
mulated and engineered KEE membrane can perform or provide a
“design service life” at 70% of the 45 mil norm for PVC mem-
branes 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 perfor-
ance of KEE membranes and the subsequent publication of
ASTM D 6754-02.

Figure 4

Water Absorption Test Results
ASTM D 471 for 166 Hours at 158°F

About the Author

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 roof-
ing 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 lead-
ership, product development, marketing, and strategic visioning to
guide a nationwide team of sales, technical, and manufacturing representa-
tives. 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.