The Next Advance in Heat Welding of Thermoplastic Single Ply Roofing

Double Weld Technology Sets a New Standard For Wind Uplift Performance

By Brian Whelan, Paul Peterson, and Paul Larson

History of Hot Air Welding

PVC (polyvinyl chloride) or vinyl roofing was first introduced in Europe in the 1960s and later in the United States in the mid-1970s. One of the advantages of PVC membrane is that the overlaps can be welded by solvent or heat.

One Swiss manufacturer of PVC roofing and waterproofing promoted the advantages of hot-air welding, while solvent welding was recommended by a few German PVC manufacturers. Solvent welding uses a strong solvent such as THF (tetrahydrofuran) to fuse the seams together and was initially faster than heat welding. Solvent welding was phased out in the mid-1980s due to performance and safety issues. With solvent welding, the quality of weld was greatly affected by workmanship, temperature, and humidity conditions. There were also cases where the solvent actually damaged the PVC membrane, causing the roof to fail prematurely. Meanwhile, hot air welding machines continued to improve over the decades. Today, there are two primary suppliers of automatic hot air welding equipment for roofing in Europe and North America: Leister, located in Sarnen, Switzerland; and Sarnafil, located in Canton, Massachusetts. In both instances, the machines are designed and built in Switzerland.

Today's automatic welders are the result of significant research and development (see *Photo 1*). State-of-the-art electronics maximizes productivity while maintaining consistent quality. With almost four decades of successful installations, hot air welding has proven to be the most reliable method of seaming thermoplastic roofing and waterproofing membrane overlaps. This includes single ply products entering the U.S. market in the 1980s, such as CSPE Hypalon and CPE (chlorinated polyethylene) as well as polyolefin (TPO), utilizing hot air welding, in the 1990s.

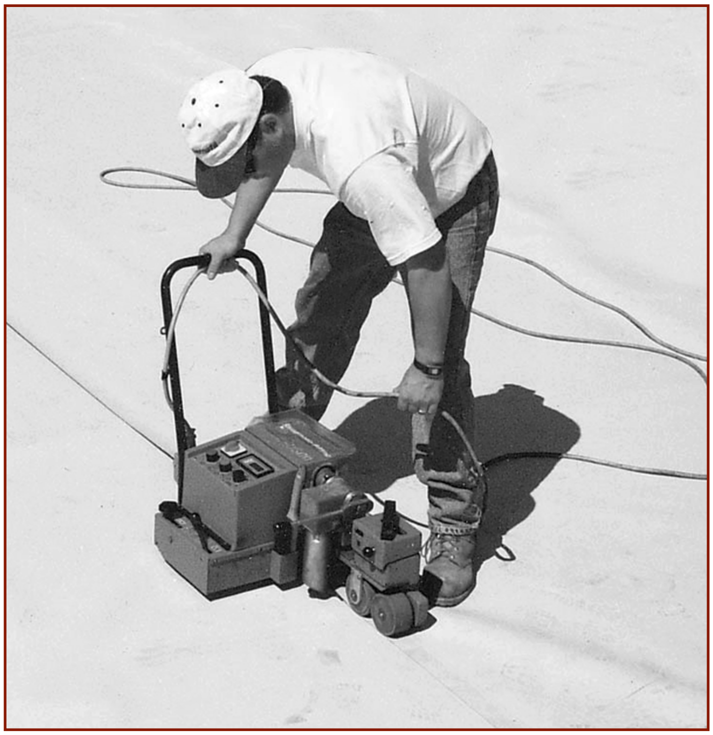
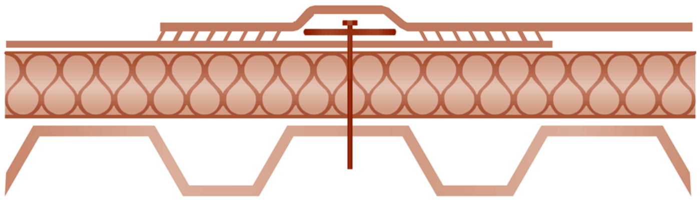


Photo 1: Automatic hot air welder in action.

Testing of single welded seams, according to ASTM D 413 (Type A, 180° peel) of various roof membranes shows different peel resistance and modes of failure (see table below).

	AVE. SEAM PEEL RESISTANCE	MODE OF FAILURE	SEAM FAILURE
PVC membrane	41 lbf/in.	• Rupture of membrane • Pull through of scrim	No seam failure
Polyolefin membrane	30 lbf/in.	• Delamination within layers of polyolefin • Scrim pull through polymer	No seam failure

 © International Institute of Building Enclosure Consultants (IIBEC)



DOUBLE WELD IN LAP

Figure 1: Cross section of double weld system.

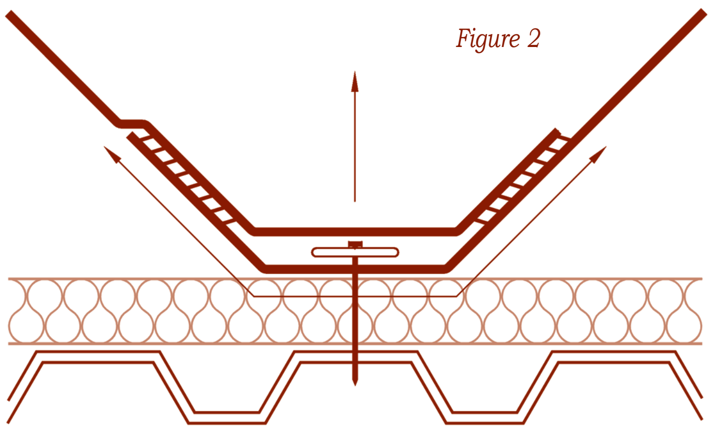
Enter Double-Weld Technology

Until recently, the goal was to create a consistent, 1 to 1-1/2" wide, watertight weld. Two single ply roofing membrane manufacturers (Omnova and Sarnafil) recently obtained patents that define methods of creating a double weld in the membrane overlap. Sarnafil has created a patented kit that attaches to a Sarnamatic automatic welder and creates the double weld in one pass.

There are many reasons why creating a weld on both sides of the fastening system is advantageous for the building owner:

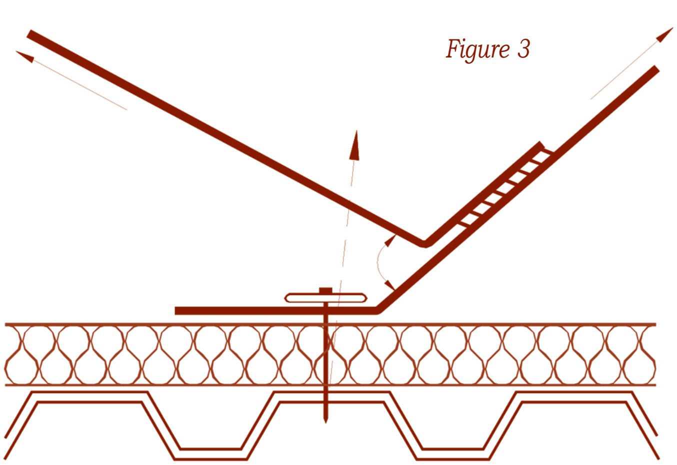
- The compressive strength of the substrate is not a factor in long-term performance of uplift resistance. Loss of compression of the plate/screw/membrane assembly is critical to the performance of single weld lap attached systems. This is especially important with today's insulation products.
- Under wind loading (see *Figure 2*), the fastener and polymer batten strip are pulled in a perpendicular direction to the deck. This results in higher withdrawal resistance and is the ideal situation for maximizing fastener performance.
- The double weld allows maximum fastener densities (spacings), increasing contractor productivity.
- The double weld eliminates the possibility of fastener backout and rocking (see *Figure 3*).
- The double weld stops the sheet from being put into a tear mode (see *Figure 4*), which is typical of lap-attached systems.
- The inner weld absorbs the wind uplift pressure, eliminating stress on the critical waterproofing weld (see *Figure 2* vs. *Figure 3*).
- Wind uplift forces exerted on an in-seam mechanically attached single welded system combine peel and shear forces onto the weld, while double-welded seams are subjected to shear force only. Membrane seams will typically provide significantly better resistance to shear loads than to peel forces.
- During the double welding process, a slight air pocket is formed, making it easier for the operator to visibly determine the location and width of each weld.
- Because of its symmetrical wind loading, a

Figure 2



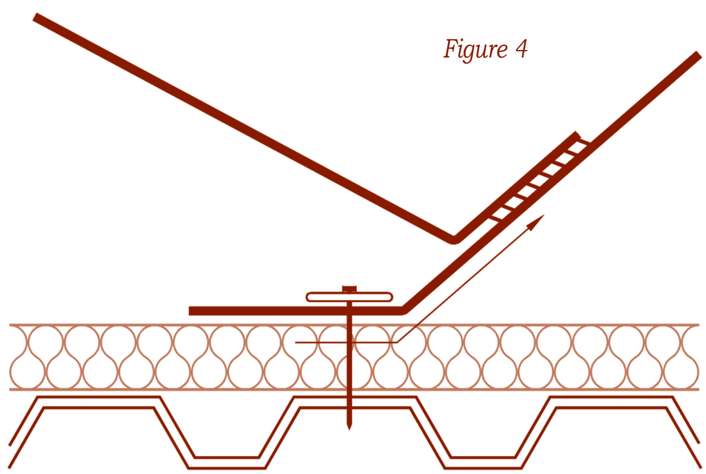
DOUBLE WELD

Figure 3



SINGLE WELD

Figure 4



SINGLE WELD

Figures 2, 3, and 4: Cross sections during wind uplift conditions.

© International Institute of Building Enclosure Consultants (IIBEC)

double weld system can withstand repeat high wind loads, not just an individual event as is typical with a lap-attached system.

The patented Polymer Batten strip also has its advantages. It absorbs the load and can then return to its original shape without deformation, unlike a metal plate or batten which will reach a point under loading where it will deform permanently. The Polymer Batten strip will also not rust or deteriorate. It also creates a straight line, which is desirable for consistent double welding.

The results of the wind uplift tests are listed below.

Static Pressure Wind-Uplift Testing

All roof membranes were installed over 1.5" polyisocyanurate insulation labeled 20 psi, Grade II over a standard Wheeling type BW36 22 gauge primed roof deck. Tensile strength testing on deck confirmed ultimate strength of 96,815 psi, which conforms to ASTM A 1008 Grade 80. Forty-five mil TPO and 48 mil PVC were used. The test panel is 12.5' x 24.25' in size. Testing was conducted in compliance with Factory Mutual's standard 4470. Test samples of 12.5' x 24.25' were exposed to increments of 15 psf of pressure for one minute until failure occurred.

Unfortunately, tests like those conducted by Factory Mutual do not allow for damage to the roof system assemblies to be noticed until a complete failure occurs, defined as loss of attach-

	Description According to FM Standard	Pass	Failed PSF	Time	Comments/Failure Description
Test #1	6.5', PVC, fastened 12" o.c., #15 Fastener, XPN Plate, Single weld	90 psf	100 psf		Membrane tear and pullover of plates
Test #2	6.5', PVC, fastened 12", o.c., #15 Fastener, Polymer Batten, Double weld	105 psf	120 psf	4 sec.	Fastener pullout. Rail pull over fastener.
Test #3	6.5', TPO, fastened 12", o.c., #15 Fastener, XPN Plate, Single weld	75 psf	90 psf	3 sec.	Interlaminate delamination
Test #4	6.5', TPO, fastened 12", o.c., #15 Fastener, Polymer Batten, Double weld	90 psf	105 psf	7 sec.	Fastener pullout
Test #5	10', PVC, fastened 12", o.c., #21 Fastener, ML Plate, Single weld	75 psf	90 psf	59 sec.	Membrane pullover plates
Test #6	10', PVC, fastened 12", o.c., #21 Fastener, Polymer Batten, Double weld	105 psf	120 psf	10 sec.	Fastener Pullout
Test #7	10', TPO, fastened 12", o.c., #21 Fastener, ML Plate, Single weld	75 psf	90 psf	12 sec.	Interlaminate Delamination
Test #8	10', TPO, fastened 12", o.c., #21 Fastener, Polymer Batten, Double weld	75 psf	90 psf	51 sec.	Interlaminate Delamination. Rail pull over fastener.

	Description – Head to Head Comparison	Pass	Failed PSF	Time	Comments/Failure Description
Test #9	6.5', PVC, fastened 12", o.c., #15 Fastener, XPN plate, Single weld	90 psf	90-105 psf		Membrane ruptured around plate
	6.5', PVC, fastened 12", o.c., #15 Fastener, Polymer Batten, Double weld	90 psf	105 psf	22 sec.	Fastener pullout after failure of single weld

	Description – Bring load to zero psf between increments	Pass	Failed PSF	Time	Comments/Failure Description
Test #10	6.5' PVC, fastened 12", o.c., #15 Fastener, XPN plate, Single weld	75 psf	90 psf	13 sec.	Membrane tear & fastener pullout
Test #11	6.5' PVC, fastened 12", o.c., #15 Fastener, Polymer Batten, Double weld	90 psf	90 psf	123 sec.	Rail pullover fastener

© International Institute of Building Enclosure Consultants (IIBEC)

ment. In Tests #1, 2, 3, 4, 5, 6, and 9, a clear PVC or TPO membrane was welded in place outside the seam overlap as a window of observation (see *Photo 3*).

The window of observation showed some interesting results. On single weld tests, fastener and plate rocking were observed typically at 30 psf for both 6.5'- and 10'-wide PVC and TPO membranes. Membrane slippage (from below plate) started to occur at 60 psf with 6.5'- and 10'-wide PVC and TPO membrane applications. Permanent bending of stress plates occurred at 75 psf with 6.5'- and 10'-wide PVC and TPO membrane applications.

Through the windows of observation, it was obvious that the fastener and plate assembly was damaged and lost preload (clamping to insulation) at low levels, questioning the products' ability to resist multiple medium-to-high loads. On double weld tests, no damage was observed to the polymer batten and fastener until failure occurred.

Test #9 was a head-to-head comparison of single weld and double weld polymer batten systems on the same test panel. The 6.5'-wide PVC membrane was held down with the same fasteners at the same spacing and densities (see test panel layout in *Figure 5*). Both systems had the same 5.5" overlap. Both attachment methods passed 1 minute at 90 psf.

Photo 2: Wind uplift table.

Photo 3: Window of observation.

The single weld plate and screw-attached system failed on the way to 105 psf. The polymer batten and double-weld system not only withstood the additional load from the extra square footage (due to the single weld failure), it held an additional 22 seconds at 105 psf – a clear indication that the double weld system is a superior wind performer.

Two additional tests (#10 and #11) were conducted to see what would happen if the pressure was brought down to zero between repeating 90 psf pressure increments. This would better represent how wind really works and how the roof system resists numerous severe wind events. The single weld system failed at 13

 © International Institute of Building Enclosure Consultants (IIBEC)

Page 10
1/3 Page Ad -
Vertical
2.24w X 9.5h
4-Color
Chemlink
Pick-up from
3/03, Page 30

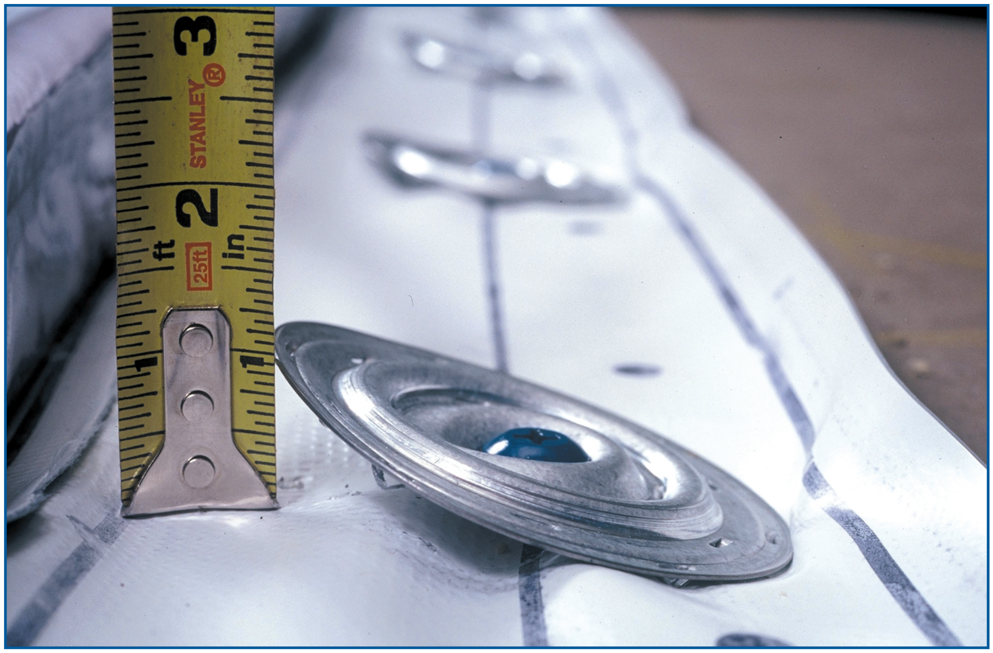


Photo 4: The 3-1/2"-round, 20-gauge metal plate is permanently deformed, as the membrane shows slippage and the fastener is rocking.

seconds. During the first 90 psf increment, the double-weld system failed three seconds into the third cycle of 90 psf.

More dynamic testing is needed, but the current testing confirms that the double weld system is a more reliable wind performer than single weld systems and can withstand repetitive wind events. A single weld system is susceptible to losing wind uplift resistance after a large single wind event. The compressive strength of the substrate is much more critical for the long term performance of a single weld system. No damage was observed to the same substrate below the Polymer Batten strip.

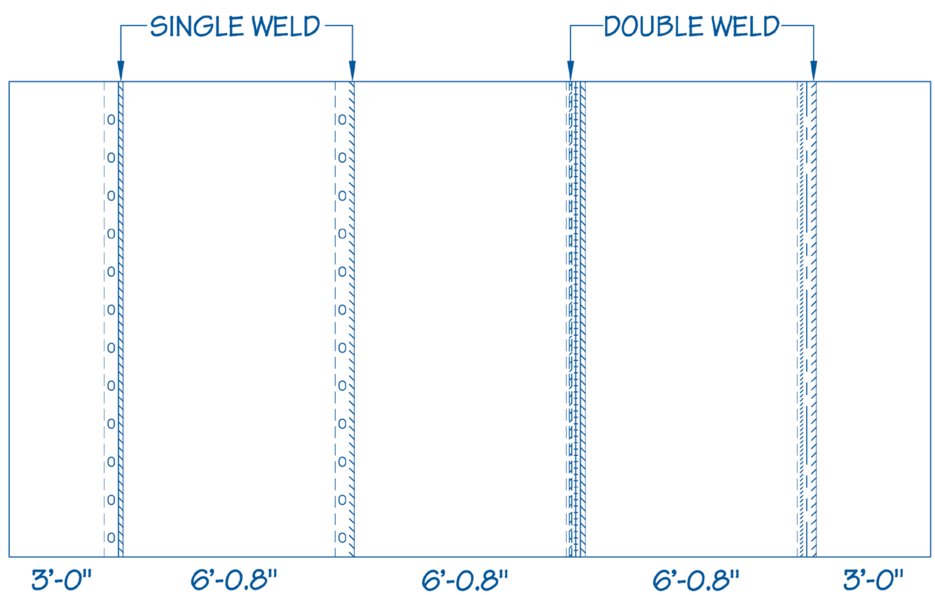


Figure 5: Test panel layout.

 © International Institute of Building Enclosure Consultants (IIBEC)

PVC vs. TPO

In this testing, PVC provided better overall wind uplift performance than TPO. Delamination of TPO membranes (both 6' and 10') was a common mode of failure due to poor interlaminate strength (see *Photo 6*). The interlaminate strength of the single ply membrane is critical to long term wind performance, especially with a single weld system. This testing is based on a small sample of membranes, and no conclusions should be drawn, as products vary from manufacturer to manufacturer.

6.5 Foot Wide vs. 10 Foot Wide Membranes

In all cases, the double weld system provided superior wind performance to single welded systems. Almost the same results occurred between 6.5'-wide double weld (failed at 4 seconds and 120 psf) and 10'-wide double weld (failed at 10 seconds at 120 psf). Testing confirms the 10'-wide membrane attachment system can be designed to provide the same wind uplift results as 6.5'-wide membrane applications.

Single Weld vs. Double Weld Economics and Experience

Millions of square feet of PVC membrane attached with polymer batten strips and double welds in the membrane overlap have been successfully installed in North America in 2002.

Contractors have confirmed that as much as 15 to 35 percent labor savings have resulted from going from a standard 6.5 foot-wide membrane to a 10 foot-wide membrane. Time studies have indicated the polymer batten strip is slightly faster to install than loose plates and screws. The polymer batten also helps the contractor consistently hit the top flutes of the steel deck. Large #21 fasteners are needed with 10'-wide membrane to obtain an F.M. I-90 rating at 12" o.c. The #21 fasteners cost an average of 55% more than #15 fasteners; however, this is offset by the requirement for fewer fasteners (1 every 9.5 sf at 10' wide vs. 1 every 6.0' sf at 6.5' wide). Time studies show double weld takes the same amount of time as consistent single welds. The double-weld system, whether installed in a 6'- or 10'-wide membrane overlap, builds a better wind performing roof at virtually the same cost as a single weld system. ■

Photo 5: Damage to insulation.

© International Institute of Building Enclosure Consultants (IIBEC)

This will reduce the risk of fastener rocking and backout and improve wind performance, especially important for wider membranes.

2. The type of deck and deck attachment are critical to the roof system performance. Be sure to specify ASTM A 1008 Grade 80 if called for in the roof system's FM listings, as well as a minimum deck attachment pattern (refer to FM's Loss Prevention Data Sheet 1-28). Alternatively, ANSI/SPRI FX-1-2001 may be used to confirm the fastener and deck's suitability for a particular system (refer to FM's Loss Prevention Data Sheet 1-29).
3. Single weld systems should utilize substrates that will resist permanent crushing and loss of fastener pre-load (clamping action).

Photo 6: Delamination and membrane tear.

Recommendations

1. Wind uplift calculations should be conducted for each project, and roof systems should be designed to resist wind loads calculated. Where possible, specify the double-weld system.

4. Confirm with the manufacturer that its roof system will resist repeat wind events, not just one. Look at the wind speed coverage in the manufacturer's warranty. How does the wind speed coverage compare to local code requirements?
5. Factory Mutual and others should look at 4470 wind uplift testing protocol to determine if consistent incremental sta-

Page 12
Half Page Horizontal
4-Color
Exterior Research & Design
New
Remove this border.

 © International Institute of Building Enclosure Consultants (IIBEC)

tic loading or cyclic loading back to zero between loading increments is more realistic. Manufacturers are producing roof systems to meet or beat a test. Little attention is directed to creating a system that can resist *repeated* high wind loads (wind events).

6. More dynamic testing (such as that used in Europe) is needed to evaluate the performance of mechanically attached single ply roof systems.

Reading Materials:

Below are additional reference articles about double-welding.

1. Baskaran, A. and Liu, K., "Double Weld Technology: Wind Fatigue Effects on the Seam Strength of TPO Roofs," *Roofing, Siding, Insulation,* January 2001.
2. Baskaran, A. and Xu, G., "Wind Uplift Rating of TPO Systems: New Data Confirm the Theory of Double-Sided Weld Technology," *Interface,* January 2001.
3. Russo, M., "Make Room for the Wide Weld," *Roofing, Siding, Insulation,* August 1998.

About the Authors

Brian Whelan

Brian Whelan joined Sarnafil in 1980. For the last seven years, he has been the vice president of Sales and Marketing. He also spent three years as technical services director and six years as the General Manager of Sarnafil Services. Whelan is the co-owner of two U.S. patents and two patents pending regarding hot-air welding of thermoplastic seams and profiles. He has a degree in Architectural Technology and is a graduate of Harvard University's Business School PMD program. Whelan is a member of SPRI (Single Ply Roofing Institute) and was one of the organization's original members. He is also a member of RCI, CSI (Construction Specifiers Institute), and RICOWI (Roofing Industry Committee on Weather Issues). He has participated in many ASTM committees on roofing and waterproofing. Prior to joining Sarnafil, Mr. Whelan was a project manager at Simpson, Gumpertz & Heger, a Massachusetts-based engineering/consulting company. He lives in Canton, Massachusetts, with his wife, Mary Kay, and their two daughters.

Paul Peterson

Paul Peterson brings over 20 years of technical experience to the roofing industry. He joined Sarnafil in 1986 as a field technical representative, inspecting roofing projects during and after completion by authorized applicators, and providing on-site training to new installers. For the last five years, Peterson has played a pivotal role in Sarnafil's product development, becoming an expert in hot-air welding techniques, membrane testing, fastening, and adhesive technology. His experience has given him a keen understanding of roof assemblies, their components, and how they work best together. Paul lives in Raynham, MA, with his wife, Joanne, and their children. He enjoys horses, camping, and traveling to job sites across the U.S., especially those with good fishing nearby.

Paul Larson

Paul Larson is an Account Executive with ITW Buildex, Itasca, IL, where he has been involved in the roofing industry and uplift testing for over 10 years. He has a mechanical engineering degree from the University of Iowa, and his MBA from the Kellogg School of Management. Paul is also an Associate Director and the Assistant Technical Committee Chair at SPRI.

Halliburton Agrees to Asbestos Settlement

Halliburton (NYSE: HAL) has reached an agreement in principle that, when consummated, will result in a global settlement of all personal injury asbestos and certain other personal injury claims against the company, including some 300,000 pending claims.

Under the proposed agreement, the settlement will be implemented through a pre-packaged Chapter 11 filing of DII Industries, LLC (DII, formerly Dresser Industries, Inc.), and Kellogg Brown & Root, Inc. (KBR), both subsidiaries of Halliburton Company.

After final and non-appealable court approval, up to $2.775 billion in cash and 59.5 million shares of Halliburton stock with a net present value expected to be less than $100 million will be paid to a trust for the benefit of the present and future asbestos and certain other personal injury claimants.

Halliburton Company has 82,000 employees at more than 400 locations worldwide and had $13 billion in revenue in 2001. Founded in 1919, Halliburton is one of the world's largest providers of products and services to the petroleum and energy industries. The company serves its customers with a broad range of products and services through its Energy Services Group and Engineering and Construction Group business segments.

This is the largest asbestos settlement since Owens Corning's in 1999.

— www.halliburton.com

© International Institute of Building Enclosure Consultants (IIBEC)