# A Novel Continuous Kynar® PVDF Foam Concentrate and Application Developments

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***Abstract***

Kynar® PVDF and Kynar Flex® PVDF have long been used for many extrusion applications. The need for lighter weight, more flexible product has been of interest for some time, but the lack of the ability to foam PVDF for continuous products has always been an issue. Several batch processes for producing PVDF foam articles currently exist, but filling the need for continuous articles such as plenum rated wire, tube, pipe, film, and stock shapes has continued to be a challenge. Research organizations and industry experts have made several failed attempts to be able to develop a robust foaming mechanism and process for PVDF resins. Finally, Arkema has developed a suitable chemical foam concentrate as well as a robust processing method for many continuous Kynar® PVDF applications of infinite length.

***Introduction***

Kynar® PVDF and Kynar Flex® PVDF have long been used in diverse markets for chemical processing, electricity & electronics, high purity, transportation, and architectural coatings. Properties such as chemical resistance, electrical insulation integrity, weathering performance, flame retardance, abrasion resistance, and mechanical strength even at high temperatures have led to many industrial end use applications. Applications include plenum rated wire, cable jacketing and primaries, fluid handling (chemical, pharmaceutical, food, and potable water), outdoor coatings, fuel exploration, and transportation design. Kynar® PVDF is known to be a tough, durable semi-crystalline engineering thermoplastic which offers a unique balance of performance properties.

Kynar® PVDF resins are well known for superior chemical resistance to water, strong acids, oxidants, halogens, aromatic & aliphatic solvents, and mixtures of such. Beyond chemical resistance, Kynar® PVDF resins also meet NFPA 262 requirements for low smoke and flame performance.

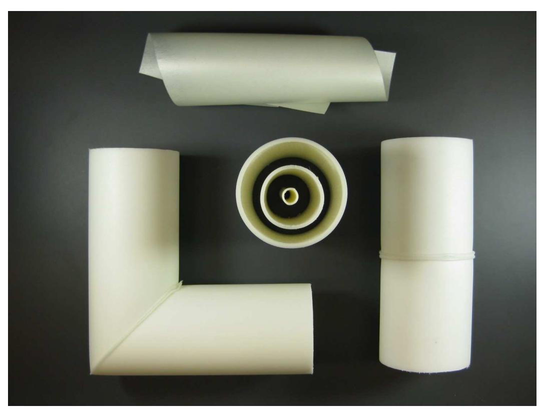

**Figure 1: Samples of Kynar® Foam including film, tube, pipe, and welded pipe**

There has been a growing need to develop a foam PVDF product in order to reduce part weight and improve flexibility. There have been several unsuccessful attempts by research organizations and industry to make a useable, stable continuous foam product that maintains the integrity of the PVDF polymer's superior properties. The lack of earlier continuous foam development arises with the relatively higher cost of PVDF resin compared to other polyolefins and the effort required to technically evaluate different foaming techniques and processes. The key to developing a continuous foam process is to understand the material properties required to make good foam, understand the nature in which to produce foam, and develop the technology to process the foam product.

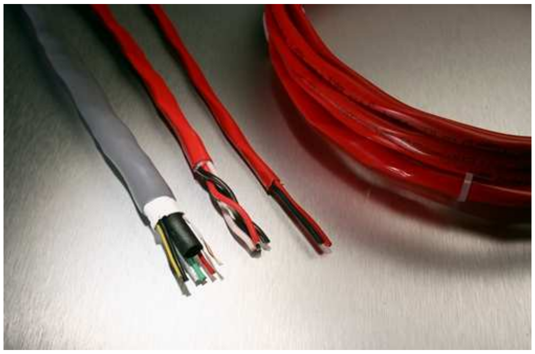

**Figure 2: Kynar® Foam plenum rated wire and cable jacketing**

PVDF has a specific gravity of 1.78 g/cc. Using the newly developed foaming technique the specific gravity can be reduced to 1.25 g/cc for many applications. The specific gravity has also been reduced as low as 0.90 g/cc for select stock shape applications. In this case, Kynar® PVDF can be made to float on water.

***Process Summary***

There are two common ways to continuously manufacture foamed products. Both techniques require a blowing agent, which is simply a gas that is dissolved and distributed in a polymer during a softened or molten state.

The most expensive and complicated is the use of physical blowing agents. Physical blowing agents, or PBA, are gases that do not react chemically in the foam process and are inert to the polymer matrix. PBA's are typically injected as a liquid or gas into an extrusion process and often require a tandem extruder to blend the two phases. As can be understood, this process requires specialized extruders and gas injection systems.

The lower cost and less complicated technique is to use chemical foaming agents. Chemical foaming agents, or CFA, are masterbatch blends that react with heat which gives off a gas to the polymer matrix. The CFA typically consists of a carrier resin, chemical compound, and a nucleating agent. The CFA can be in powder or pellet form which is commonly added as a dry blend before processing, similar as a color concentrate would. This process typically does not require specialized extrusion equipment, but does have an additional cost to produce the CFA as a secondary operation.

Arkema has chosen to develop CFA technology for Kynar® PVDF and Kynar Flex® PVDF. This is the best initial option based on the needs of the market place because it does not require specialized equipment or capital expenditures. The CFA was developed by Arkema Inc. based off of a proprietary blend of materials. This concentrate has been designed to work efficiently with both Kynar® homopolymer and Kynar Flex® copolymer resins for a variety of closedcell foam applications. This CFA, Kynar® 2620 FC, has proven to be very efficient for making foamed tube, pipe, film, rod, and sheet at laboratory scale, Figure 1, as well as commercial wire and cable jacketing, Figure 2.

***Kynar® PVDF Resin Selection***

The foaming of Kynar® PVDF resin can be accomplished using a wide variety of grades available in homopolymer and copolymer families.

***Processing Conditions***

As mentioned earlier, Arkema chose to develop CFA technology for processors to limit the need of capital expenditures for new equipment. The foaming process with Kynar® 2620 FC does not require a specialized extruder or screw and can be processed using standard tooling and Kynar® and Kynar Flex® PVDF resins.

***Application Development***

Initially the foam concentrate and processing technology was developed in order to create lower weight and more flexible products. After foaming several types of products, the new development unveiled other improved properties that users have come to enjoy. The foamed product properties not only include weight reduction and improved flexibility, but also improved strip ability, reduced shrink back, ease of cutting, thermal and acoustic insulation, increased compressibility, and improved dielectric constant. Most importantly, the same superior barrier, chemical resistance, weatherability, temperature resistance, and smoke/flame properties have been observed as well.

A large market for PVDF is in piping systems. Most recently Arkema Inc. has developed the technology to produce foam core structures. Figure 3 is an example of a foam core pipe which has a total density reduction of 40%, despite having a solid layer of Kynar® PVDF on the inside and outside of the pipe, in green color. This market relies on welding in order to build the systems. Welding may include butt fusion for pipe to pipe welds or socket fusion for pipe to coupling welds. It has been demonstrated that foamed products can be welded both to foam or pure Kynar® PVDF articles via common welding techniques.

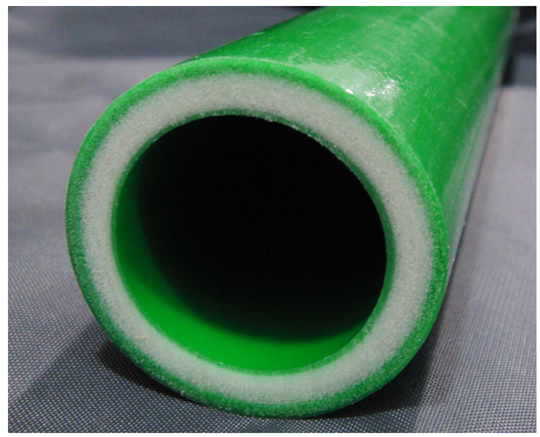

**Figure 3: Kynar® Foam Core Pipe**

The wire and cable industry is excited that the foamed jacketing material exhibits a 50% improvement in dielectric constant and a 20-40% reduction in shrink-back properties. The low shrink-back characteristics insure optical integrity of the fiber optic cable during temperature fluctuations.

***Results***

Physical testing has been conducted on various samples of Kynar® foamed products. The results in Chart 1 show that with a reduction in weight by foaming Kynar Flex® PVDF maintains good mechanical properties. As can be seen in this chart, Kynar Flex® which is foamed 6-8 weight percent is equivalent in tensile strength to unfoamed, solid polypropylene. Other common fluoropolymers in an unfoamed, solid state exhibit a tensile strength around 14 MPa, Kynar Flex® can be foamed to nearly 40 weight percent and still be a stronger material.

Of course all of the data in Chart 1 represents Kynar Flex® copolymer grades. The homopolymer grades would exhibit approximately 25% greater tensile strength properties.

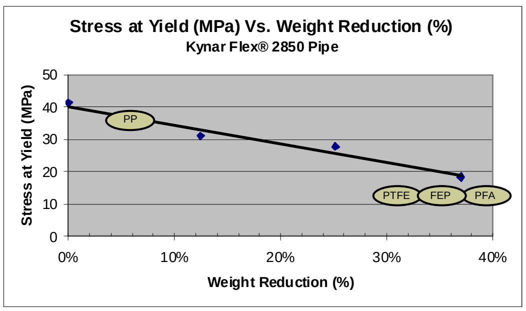


**Chart 1: Yield Strength versus Weight Reduction of Kynar Flex® 2850**

As shown in Chart 2, a reduction in modulus is favorable to segments in the market place where a more flexible product is desired.

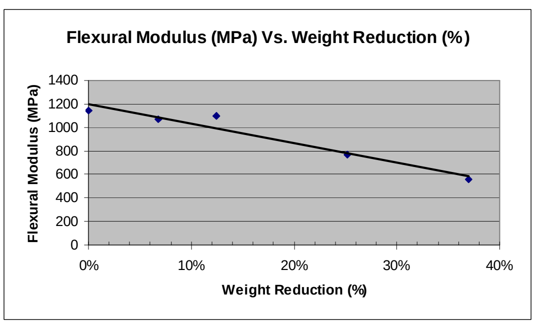


**Chart 2: Modulus versus Weight Reduction of Kynar Flex® 2850**

Often, many markets are over engineered for the final applications. Kynar® foam allows a new avenue to tailor a product for a lighter weight option which still meets the application demands. For example, Chart 3 shows a lighter weight option for low pressure pipe applications. For low pressure piping applications that are less then 0.69 MPa (100psi) a 40% foamed product is still significantly strong to handle process fluids.

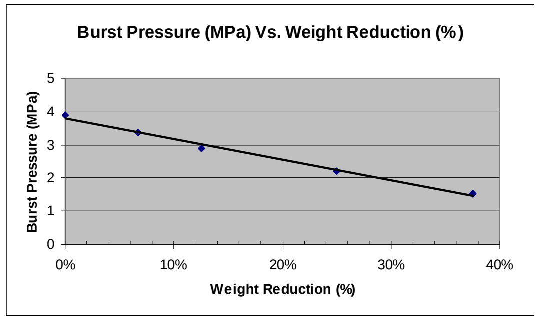


**Chart 3: Burst Pressure versus Weight Reduction of Kynar Flex® 2850**

## *Conclusion*

The research center at Arkema Inc. has spent several years designing a foam concentrate to use with the wide variety of Kynar® PVDF homopolymers and copolymers commercially available. The result is Kynar® 2620 FC foam concentrated masterbatch. In conjunction with the development of the concentrate, the research team has also internally developed the processing technology for many extrusion articles which has successfully been transferred to final component suppliers. This foam concentrate pellet can be pre-blended directly with the Kynar® PVDF resin or fed like a color concentrate. This technology has been used for commercially produced wire and cable and has been successfully proven to be viable at the laboratory scale and commercial trial scale for tube, pipe, film, sheet up to 30-50% density reduction.