

## Amino Foam Chemistry

CfiFOAM's resins are part of the family of amino/furan resins consisting of phenol, urea and melamine coupled with an aldehyde. Amino resins are thermosetting plastic materials produced by reacting compounds containing amine groups ( $\text{NH}_2$ -) with an aldehyde such as formaldehyde.

According to the literature, amino resins are typically produced by addition of an amine-containing group, urea, for example, to an aldehyde such as formaldehyde under basic conditions, yielding a combination of monomethylol, dimethylol and trimethylol-substituted urea. Due to the presence of a tertiary blend of compounds, UF resins are sometimes referred to as "tripolymer" resins. The second stage of resin production is condensation of the addition products in the presence of an acid catalyst. When the condensation step is carried to completion, the resins are fully cured polymers containing methylene linkages. So for resin manufacture, the condensation reaction is stopped short of completion, leaving partially cured polymers/monomers/oligomers in the resin with linkage groups available for further crosslinking. Once the condensation phase is completed, the pH is adjusted to a modestly high level for shelf-stability reasons prior to the resin being spray-dried and packaged. Another name for these resins is "convertible" resins, meaning they can be further converted into higher polymers via self-polymerization reaction.

There are three mechanisms for curing these convertible resins described in literature:

1. Heat-curing, often done in glue applications such as plywood, MDF and fiberglass insulation preparation where large ovens thermally cure the final product.
2. Catalyst-curing, a favorable alternative to heat-reaction for ambient-cure applications such as building insulation.
3. Self-curing without heat or catalyst, done in some glue applications, but taking days or even weeks to cure.

Foam installers reconstitute the powdered resin with water and also prepare a dilution containing, among other things, a blend of acid catalyst(s) and anionic surfactants. As the name implies, the foaming catalyst concentrate is not a **co-reactant** to the resin, rather it is a **catalyst** which causes the resin to continue to react with itself, resulting in a fully-cured, infusible resin. Careful selection is made of the acids and surfactants. Phosphoric acid, for instance, is commonly used because it is a relatively mild acid containing phosphorous, a fire

retardant that can help impart intumescent properties to foams. Boric acid is also chosen for similar reasons and for its reputation as an insect repellent. For surfactants, proper choice is key to achieving good foam properties. A combination of alkyl and aromatic sulfonic acids are described as being suitable, the final combination of which can impact compatibility of the surfactant with the polymerized resin, affecting long-term foam stability, along with properties such as foam friability.

So, amino foams are similar to polyurethane foams in that they are 2-component liquids metered to a foam gun. The chemistries differ, though, in that amino resins are comprised of a convertible resin and a catalyst/surfactant while the spray polyurethane foams contain functional reactant groups in each chemical stream in addition to catalysts, surfactants, fire retardants and other ingredients.

For polyurethane foams, comparative chemical ratio of the two liquid streams is very important due to the need to balance the stoichiometric ratio of functional groups in the 2 streams. Off-ratio foam can lead to un-reacted -OH groups resulting in incomplete polymer formation, or, on the other hand, can result in unreacted isocyanate groups which eventually would react with atmospheric moisture. In either instance, foam physical properties are significantly impacted by off-ratio liquids. General consensus is for chemical ratios to be within 1-2% for spray polyurethane foams, with rigid temperature control needed to achieve optimum results.

By contrast, amino resin chemistry is a bit different. Balancing the ratio of the two chemical streams is not driven by the need to balance the ratio of functional reactant groups as much as it is providing the proper concentration of catalyst needed to drive the condensation reaction of the convertible resin to completion in an appropriate time-frame. For amino foam-in-place applications, nucleation and formation of the foam bubbles is a physical phenomenon rather than a chemical mechanism as is the case with polyurethane foams. As such, in addition to catalyzing the resin reaction, the catalyst stream must also contain the proper amount of surfactant and water to allow for formation of sufficient bubbles with proper strength to achieve formation of high quality foam.

A deficiency of catalyst, or resin-rich blend, can cause the resin to cure slowly rather than quickly. The downside result of grossly deficient catalyst would be un-reacted resin migrating through the wall substrate resulting in glassy-looking stains of tacky material. If the material is not removed, cross-linking of the resin would eventually occur on the wall surface resulting in a stain that's very difficult to remove. Further, insufficient catalyst level may also result in insufficient bubble formation, resulting in foam with too-high density or the need to add additional nucleation sites in the foam gun, by virtue of adding more stainless steel scrubbers. So, foam yield could suffer as well from having insufficient catalyst.

By contrast, an excess of catalyst, or a catalyst-rich blend, can result in an accelerated resin reaction. From a foam installation standpoint, the foam could achieve its initial "set" time before the wall cavity is filled. Based on practical experience, this situation is not unmanageable. However, an excessive amount of surfactant could lead to too many foam bubbles being formed, resulting in foam with too-low density which can lead to excessive foam shrinkage. Grossly excessive amounts of acid catalyst could result in acid-rich foam

with potentially corrosive properties. While studies have shown that properly made foam with neutral pH does not cause corrosion of metal, an exhaustive study of the corrosive properties of acid-rich foam on both wood and metal has apparently not been performed. Lessons can be taken from foams with similar chemistry. Phenolic roofing foams, for instance, came under intense scrutiny when it was found that leaking roof membranes resulted in rainwater leaching acid catalysts from the foam onto metal roof decks, resulting in premature corrosion of roof structures. Acid-rich foams can also be irritating to building occupants, not only from potential irritation caused by emissions of trace acid compounds from foam via moisture migration, but potentially from acid-catalyzed hydrolysis of the polymer resulting in emissions of low molecular weight moieties. While much of this concern has been alleviated through advancements in amino chemistry, clearly the need exists to exercise caution when both blending and metering the resin and catalyst streams.

So, how close does the ratio need to be in order to produce satisfactory foam and avoid the pitfalls of resin-rich or catalyst-rich foam? The amount of catalyst and surfactant is most often described as the minimum amount needed to achieve satisfactory reactivity and/or foam physical properties. This is the basis by which CfiFOAM's products are formulated as are other amino resin systems. One source more specifically describes the preferred amount of acidic curing catalyst as between 0.1 to 12% based on the weight of the amino resin. CfiFOAM's products are within this range, albeit toward the upper half of the range for foam stability reasons. Lower catalyst quantities may suffice for adhesive applications such as wood-glue, but experience verifies that catalyst levels between 5-10% are needed for foam-in-place insulation to have the necessary robustness and stability to flow through wall cavities at the broad range of temperatures encountered in construction applications.

To answer the ratio question, a catalyst level of 10% as a percentage of amino resin would require a 10% difference in liquid ratio between the resin and catalyst streams to impart a 1% change in catalyst concentration level. A 20% ratio differential results in a 2% catalyst change. So, from a catalysis standpoint, the accuracy in ratio can be within +/- 20% without causing detrimental effects or without falling outside the preferred amount of acidic curing catalyst. From a foam stability standpoint, freshly-produced foam that is either 20% high in resin or surfactant level is difficult to visually detect without the use of flow-monitoring devices such as flow totalizers or flow meters. Certainly foam insulation with 20% excess catalyst would likely shrink more than foam with 20% excess resin over time, but the initial results would be difficult to discern. From practical experience, a ratio accuracy of +/- 5% has been found to be acceptable. A differential of +/-10% would, in all likelihood, be acceptable as well, given the numerous variables that change from jobsite to jobsite such as the type of substrate, ambient temperature, water chemistry, product temperature, etc.

So, as a manufacturer of foam-in-place insulation, CfiFOAM believes that a ratio accuracy of +/- 5% will yield consistent, high-quality foam with sufficient margin of error for changes in local conditions. Importantly, CfiFOAM firmly stands behind the need to regularly monitor liquid flow-rates by using flow meters or flow totalizing meters. Further, the need is imperative for monitoring fresh foam density to make certain water chemistry variations, liquid temperatures and foam gun set-up are accounted for. If these variables are properly accounted for, good results will normally be obtained within a 5% tolerance range.