The Polyurethane Foam Book

Chapter Five: Fire and Foam

by David B. South

One of the major reasons I love Monolithic Domes is that they are as close to fireproof as a building can be. Yet they have urethane foam -- the world's best insulation as a major component. But, as Paul Harvey would say, "let's hear the rest of the story."

When I first started in the foam business, I was told that urethane foam was as good as fire proofing. It was rated noncombustible or non-burning. I demonstrated this by taking a piece of foam, setting it on fire with a match or torch and watching it self-extinguish the minute the flame was taken away. The flames on the foam instantly went out. This is especially true if the surface of the foam sample was previously burned, creating a char that protects itself.

A sales pitches I used in selling my first large foam jobs was telling prospective clients that they could cancel their fire insurance on their potato storages. I told them that the foam would protect the metal building so that fire couldn't hurt it. Now, where did I get such information? In 1970, it was a common misconception and part of the sales patter promoted by urethane foam supply companies.

As it turned out, those companies were using ASTM (American Society for Testing and Materials) tests that urethane could easily pass. One of the tests was ASTM 1692-T*. Basically, that test was performed by clamping a piece of urethane foam in a stand and putting a flame under an edge of the sample for a few seconds. The flame was then moved away, and the lit sample self-extinguished. Because urethane foam easily passed this test, it was designated "self-extinguishing or non-burning."

In early 1970, I performed a number of similar experiments: I set blocks of urethane foam on fire, then took the fire away, and the samples flamed out immediately. I concluded that the self-extinguishing tests were valid. But foam doesn't have any large amount of fire retardants and would not pass any of the fire tests used today. As I eventually learned, those early fire tests were not of the real world, and so wrong conclusions were drawn.

The real world caught up to us quickly. I started spraying urethane foam in Southeast Idaho in 1970. One of my very first jobs was lining the inside of a van body off a two-ton truck. This van body was used as a boiler house for a concrete company. We sprayed two inches of foam on the van's inside. We did this to keep the boiler equipment located within from freezing. But a small area of the van's wall, behind some piping, was missed. One night the pipe next to the missed spot froze, and the operator of the concrete plant proceeded to thaw out the pipes with a propane torch. The torch set some of the foam on fire. He slapped it out with his hand and thought "that was interesting."

The operator had been in on some of our discussions and had heard that urethane was virtually fire proof; so he went ahead and put the torch back on the pipes. Suddenly the whole inside of the van caught on fire and totally burned the interior insulation. The fire was so hot that it melted many of the metal parts and destroyed everything within the van body. It lasted less than five minutes, but the operator felt lucky to get out.

*ASTM D 1692 and D 1692T. "Rate of Burning [or] Extent and Time of Burning of Cellular Plastics Using a Specimen Supported by a Horizontal Screen." ASTM discontinued these standards in 1978 with no replacement.

At that point we decided to reassess this so-called non-burning, self-extinguishing theory. It was

very obvious that foam did burn, and it only self-extinguished when it was all gone.

Fact: urethane foam is, far and away, the world's best insulation. So, lining a van with it turns the inside of the van into a reflector oven. Urethane does not burn anything but hot. You cannot start it on fire with out hot heat. But once it starts to burn in the reflector oven, the temperature rises astronomically. In literally an instant, the fire grows very hot, and the hotter it gets, the hotter and faster it burns. We discovered, quite by accident, something the fire industry also learned: so-called self-extinguishing foam does, in fact, burn very well. We later learned about other foam fires around the United States and in other countries, similar to our van fire. Some involved large structures.

As it turns out, a urethane foam that does not create a fire hazard under certain conditions simply does not exist. This is not because foam burns so well. It is because foam insulates so well.

Nevertheless, most modern urethane foams do not burn very well. Most of these are called "UL rated" or "Class I" foams and have a flame spread of less than 25. (Flame spread rating is explained in the Appendix.) But even these more highly fire-retardant foams can be a fire hazard. Again, that's not because the foam burns -- most won't burn but very little when isolated. The hazard exists because foam is such a superior insulation.

Because of this superiority, urethane foam, left exposed as a lining of a building, helps create a reflector oven in the building's interior. So, the heat from a fire started within the confines of the building has no place to go. The heat radiates from the fire to the foam and back to the fire, again and again. The temperature rise is phenomenal! An Upjohn engineer told me that a normal house burns at about 3500 F -- maximum temperature. Fire temperatures within a urethane foam lined metal building will hit 10,000 F within 30 seconds.

It matters little if urethane is most fire-retardant or least fire-retardant; if a fire gets going in a building lined with exposed urethane, the foam accelerates the fire. This is because urethane foam will not absorb any significant amount of heat. Obviously, this is more of a problem if the walls and the ceiling are both insulated than if just the ceiling is insulated. It is even more of a problem if the building contains flammable materials. In any case, those so called noncombustible foams turned out to be a very serious fire hazard. The urethane industry had advertised the foams as self-extinguishing or nonburning. After a number of fires, the Federal Trade Commission stepped in and sued major urethane suppliers. The FTC and the suppliers came up with a consent decree: the urethane suppliers would fund new testing and stop promoting foam as nonburning or self-

extinguishing.

Factory Mutual Insurance and Underwriters Laboratories also got into the act. They devised more appropriate tests and determined that the only way to protect foam from fire in any circumstance was to use a thermal barrier. Originally the approved thermal barriers were 3/4 of an inch of plaster or 1/2 inch of sheet rock over the urethane foam. Since then, a number of other products have been tested and approved as fire barriers.

The Appendix includes a description of the Factory Mutual test. Anyone who has a fire barrier and wants to test it can do so either with a full scale Factory Mutual corner test or a small scale corner test, that is now also being administered by some of the other testing labs. The point is, urethane is such an exceptional insulation it creates its own fire hazard by being such a super insulation. On the other hand it also acts as a fire barrier.

Here are examples of urethane as a fire hazard and as a fire barrier.

Urethane as a Fire Hazard

Example -- Sugar Beet Storage

In 1972 Toppenish, Washington, we insulated a huge, rigid-frame, metal building used for sugar beet storage. It was 120' wide by 400' long, with a 28' height at the eaves and a center height of approximately 45'. It had a 60'x 20' doorway as the entrance in one end. For insulation, we sprayed 3 inches of urethane over the entire interior surfaces -- ceiling and walls.

During the first year of storing sugar beets, the owners discovered the heat given off by the sugar beets was more than anticipated and the beets needed more ventilation.

The next summer while the building was empty, a crew of men was told to cut additional vents in the structure. While cutting the opening for the first vent, they were extremely careful about fire. They chipped the foam off the metal for an area considerably larger than the vent, and they put wet burlap on the foam surrounding the area to be removed. Then using a cutting torch, they removed a section of the building to provide space for the ventilator.

As the workmen continued from vent to vent, they found that the urethane would ignite but would very quickly self-extinguish -- there didn't seem to be a problem. They continued cutting and growing more and more sure of themselves. Soon, they stopped carrying water or wet burlap up the scaffold. They simply climbed up, scraped the foam back the best they could and cut a vent opening. At this point, the workers assumed that the foam would not burn, and if it did burn a little, it would not be a big deal.

On the last vent they cut at the rear of the building, enough fire was created to start reflecting. It began reflecting against the ceiling, girts and beams of this metal building's side walls. Suddenly, there was enough heat for the fire to self propagate, and it spread very, very rapidly. The men rushed down the scaffold and ran for the door. Remember: the door, a 60-foot-wide opening at the other end of the building was 400 feet away. The workmen barely made it. By the time they reached the door, fire and smoke were already out the door, ahead and over them, and visibility was virtually zero.

The fire burned the urethane foam on the inside of the building. Men on the site estimated that the fire burned for three or four minutes -- five minutes tops -- and then went out. In less than five minutes, the foam burned off and the entire building collapsed. The fire went out before the fire department could react! There are dozens of such stories of foam catching fire within a metal building totally encapsulated with exposed urethane foam. In nearly all cases, the fire burned the foam off and extinguished itself in just a very few minutes. But during that few minutes, heat melted aluminum and totally destroyed a steel structure. The beams curled up and the building caved in. This is a quick way to destroy a building.

Example -- Potato Storage

Many potato storages have died of this same phenomenon, including a potato storage at Pleasant Valley near American Falls, Idaho. This potato storage was an all-metal Quonset half-round building, about 300 feet long. At the front of the building, men working with a cutting torch on some bent door hinges started the fire. They had sixteen hinges, damaged in a truck accident, to repair and were working on the last hinge.

At this point, the workers may have grown tired and possibly a little careless. Sure enough, they created enough fire to begin the reflection process and start the building on fire. It roared down the length of the building, gaining momentum all the way. When the fire hit the far end, it literally blew the wall at the end of the building into the field. In other words, the temperature rise was comparable to a low grade explosion.

Most of the 1970's fires involved earlier, less fire-retardant urethane foams. While not highly fire retardant, these foams had an insulation value that held in the heat, causing the temperature to rise high enough to vaporize all combustibles.

Example -- Potato Processing Plant

This potato processing plant, near Rexburg, Idaho, was a metal building sprayed with the most highly fire-retardant foam available at that time. It had a flame spread of less than twenty-five, as do most urethane foams available today. The fire was started by thieves stealing gas from a truck. Evidently, they had been smoking while stealing the gas and set the truck on fire.

The fire spread so quickly that the thieves left their gas can and siphon tube and ran from the building. Here again, the flame shot through the building in just a few minutes. Its high heat

destroyed equipment within the building and, of course, set fire to all the combustibles -- including a couple of trucks and a tractor. All burned furiously for a considerable time. After the initial flash, the foam extinguished very quickly. Areas over the vehicles were totally destroyed, but in much of the building the foam was charred less than 1/4 of an inch. This is quite characteristic of foams rated Class I. In any case, the basic structure was damaged beyond repair, all of its contents totally lost. Had the urethane been covered with plaster or sheet rock, the fire would have been very localized, and a fire department would probably have had time to limit its destruction.

Example -- Auto Dealership

In 1972, during my first year of business in Twin Falls, Idaho, I made a trade with a Chevrolet dealer. I sprayed the inside of his garage with urethane foam for a new Chevrolet pickup truck.

By 1973, I knew about fire problems with foam. I contacted the garage owner and said, "I'm really sorry but I misinformed you. The foam will burn and will burn very rapidly; you may lose your building and all its contents. We must spray plaster on the inside surface to protect the foam from fire and to protect you from loss."

The owner said that he had already heard about the fire possibilities from the local fire marshal, but that his foam was fire-proof. He had proved it by taking a piece off the building and testing it. He set a torch on it, and it wouldn't burn. It would char a little, but go out once the flame was removed. I tried explaining that it was not the chemical composition of the foam that made it a fire hazard but its super-insulation value. I failed to get the message across.

About five years later, a worker in the body shop area accidentally set the facility on fire. He dropped a gas tank near another worker cutting with a torch. Needless to say, the fire went through the car dealership in just a few minutes. Fortunately, there were enough openings for all employees to escape. In an estimated four to five minutes, fire had spread throughout the facility; all was a total loss. Again, it was not that the foam burned so well as much as its ability to intensify the fire within.

An exposed urethane lining in a building is not a joke. No one, under any circumstances, should leave large areas of a building's interior covered in exposed urethane foam. The risk of fire is too large to be ignored.

Urethane as a Fire Barrier

Urethane foam is an excellent fire barrier when used on the exterior of a building. There are numerous examples of urethane foam roofs saving a building from fire. Burning brands* and debris can lay on a urethane roof for a considerable time before burning through. The urethane insulated roof will simply char. If there is no external heat source, the fire will go out. It requires a lot of heat to keep urethane foam burning. Where heat can radiate into the atmosphere, urethane makes a superior fire barrier.

***Note:** In the fire industry, burning brands are large embers that may blow from building to building, setting them ablaze. For testing, the fire industry uses a burning brand made of a 12-inch square block of burning oak; its placed on the material being tested.

Example -- Mattress Factory

In Twin Falls, Idaho, before we worried about heat sinks, thermal barriers and the like, we insulated a common wall in a mattress factory. We sprayed one inch of urethane foam on a metal wall to protect the office area from losing heat into the furniture storage area. One night, the storage area caught fire. As you can imagine, flames in the stored mattresses caused the fire to burn for a long time. The Fire Marshall told me that the fire burned against the common wall for more than an hour before they could cool it. He said it was phenomenal to him that the heat did not come through the common wall. But rather than letting it come through, the wall's urethane insulation reflected the heat back into the storage area. The Fire Marshal declared that he knew of no other material (other than concrete) that could hold a fire back for the length of time they

needed to extinguish it.

Since then, I have found that the best fire doors consist of a urethane foam core sandwiched between two metal sides. The metal takes care of the surface combustion, and the insulating urethane foam prevents the temperature from raising to the point of combustion on the nonburning side of the door.

Review: Urethane foam is a thermoset. Thermosets cannot be heated and changed back into their original liquid form. When urethane burns, it does not liquefy and run as many other plastics (thermal plastics) do. The urethane either burns very hot (such as an exposed building lining) or it doesn't burn well at all. There is no danger of urethane foam smoldering. The real fire danger from urethane comes from its insulation value, since it increases the temperature within a fire area. A fire barrier such as sheet rock prevents foam from burning by "soaking up" the heat.

Urethane foam is not much of a fire hazard while it is being sprayed. In other words, nothing combustible out-gasses from it. Various solvents used to clean the gun may be combustible, but the urethane foam itself is virtually noncombustible.

Example -- Spud Truck

Once, working within our shop that -- admittedly -- was too full of stuff, we began spraying a liner inside the bed of a spud truck. A heap of plastic sheeting, previously used as masking, lay on the floor. A welder working in an adjacent area somehow started that pile on fire. Our spray foam applicator saw the fire; using his foam gun, he sprayed it out faster than you could have with a fire-extinguisher. In other words, he sprayed right over the flames, encapsulated them and almost instantly drowned the fire. I use this example to illustrate that urethane foam has fire hazards, but not necessarily the usual kind.

Urethane foam components, by themselves, are not a fire hazard and can be shipped without fire hazard labels. Burning Isocyanate (as a separate chemical) gives off very toxic fumes. Great care should be taken not to breathe these toxic fumes. The chemical by itself will not support combustion. However, if you are disposing of empty Isocyanate drums by removing the tops, do not cut the tops with a cutting torch in a confined area. In fact, it is best if you don't use a cutting torch. There are can-opener type top removers for barrels that are far better than a torch. No matter how often this is said, some people use a torch. If you do use torches on barrels, make certain that you do not breath the smoke generated by the burning of the Isocyanate. It will make you sick. That smoke is a first cousin to Phosgene gas -- the gas used on troops in Europe during World War I. Here's a caution to remember: never burn organics. Even wood smoke can kill you. It is far better to dispose of chemicals as recommended by the manufacturers than to release them into our environment.

During the mid 1970s, we sprayed more than a million pounds of foam per year. Because of our involvement in this industry, we tried to find information on every urethane foam fire. It was amazing how information gets distorted in the retelling of a story. I found a lightning rod salesman trying to convince people that lightning caused most foam fires. I met an electrician telling people that it was wiring. The fact is, most of the fires were caused by a large amount of heat or quick heat -- something like a cutting torch or a burning truck.

Nevertheless, there is nothing yet made that will insulate a building as well as urethane foam. But when used on a building's interior, it must be covered with a thermal barrier.

It is absolutely vital that fire be prevented during the construction process. After the building is totally lined with urethane but before fire barriers are in place, a fire can be devastating. Caution must be exercised in not allowing a fire to start.

Pictured are results of a substantial fire that burned nearly an hour against a Monolithic Dome. Three wood structures and 300 gallons of transformer oil fueled it. Wind blew directly from the fire end of the dome -- the worst possible case for the dome. As the photo shows, approximately one third of the Airform burned off the dome. The foam under the Airform suffered various degrees of damage -- from almost none to substantial where majority of the flames burned. In a small area, the fire totally burned the foam off the concrete, exposing it completely. This was the area in which the transformer oil burned for more than an hour, while high winds blew directly onto the dome. **Note:** Foam held the fire back for a considerable time; then the nonflammable concrete ended any possibility of flames burning through to the material inside. The dome's interior surface never even got warm, and its contents remained totally unaffected by the fire.

The picture shows exposed concrete where the foam burned off and a few spots with sacrificial steel -- a light network of rebar, tightly tied against the urethane and covered with a small amount of concrete. Sacrificial steel is used to tie heavier ties into the main steel of the structure. In other words, if the foam is taken off this type of bulk storage structure, the fitting is of no consequence other than cosmetic.

Outline of the wood building against the Monolithic dome. When the char from the 2 x 4's was cleaned off, it left the outline of the wood structure. You can see where the foam was burned totally off the concrete, exposing rebar hangers and bases. This is the area of the 300 gallons of transformer oil that was totally consumed.

A closeup view of the most damaged area and the carcass of transformer and foam burned off building. In the condition in which this fertilizer bulk storage dome survived the fire, it did not lose any of its functionality. Bringing it back to its original form would have required sandblasting or scraping away the old foam, spraying new foam, covering the new foam with a liquid coating to tie it into the Airform, then for cosmetic reasons coating the entire structure with the same color.