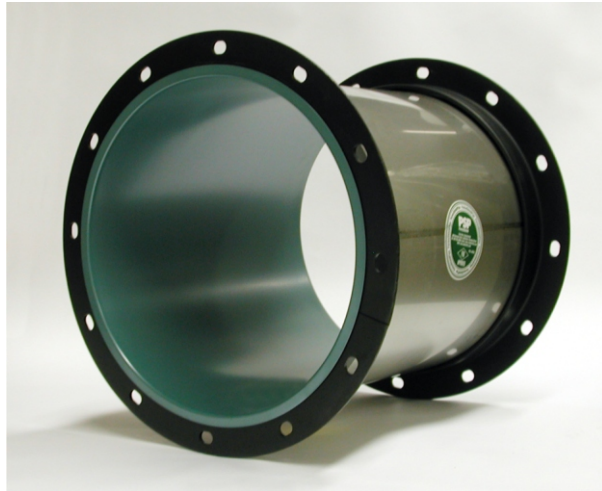


Advances in Wastewater Odor Control Duct Technology



Fluoropolymer Coated Stainless Steel Duct Surpasses Fiberglass Reinforced Plastic Duct In Ease Of Installation, Performance And Safety

Vince Rocca

Premise

Engineers and operators of wastewater facilities can benefit from the use of stainless steel duct internally coated with a high corrosion resistant fluoropolymer barrier resin, in lieu of FRP (fiberglass reinforced plastic) thermosetting duct. The combination of extreme corrosion resistance, Factory Mutual Research (FM) smoke and fire ratings, ease of installation and overall low installed cost has led many municipalities to install fluoropolymer coated stainless steel instead of vinyl ester or epoxy resin glass reinforced plastic duct.

Background - Challenges In Wastewater and Odor Control Facilities

Wastewater treatment facilities are sites where corrosive, flammable and toxic chemicals and by-products are used and generated. Odor Control has become the most pressing air quality problem in the wastewater processing industry. Vent duct lines not only convey malodorous fumes, but also a witches-brew of hazardous by products. Virtually every part of the wastewater collection system, from pumping to lifting stations, to force mains and drop structures can produce and release objectionable odors. Airborn hydrogen sulfide is the most prevalent odorous compound present at wastewater sites, but additional odorous organic chemicals, such as methyl mercaptan and dimethyl disulfide, can also be present.

Wastewater chemical vapors can also include: chlorine (Cl_2), hydrogen chloride (HCl), hydrogen sulfide (H_2S), ozone (O_3), sulfuric acid, sodium hydroxide, methane and digester gas. All of these components can be corrosive to carbon steel, galvanized steel, and even some plastics. Plant designers are challenged to employ the best materials possible for safety, yet stay within budget constraints.

Codes And Standards

Given the ever-changing body of rules and regulations, wastewater facilities must be as flexible as possible to meet existing and anticipated proposed regulations. Sometimes it seems that an alphabet soup of government agency acronyms and abbreviations governs almost everything in a wastewater facility.

A growing number of odor control facility designers are focusing on exhaust systems as an area where improvements can be made. This paper will focus on the use of fluoropolymer coated stainless steel duct as a viable option to fiber-

glass reinforced plastic (FRP) duct. Fluoropolymer coated stainless steel was first used in the semiconductor industry in the early 1990's, but is now finding increased use in numerous industries, including pharmaceutical, photovoltaic, and wastewater, where corrosive gases are present.

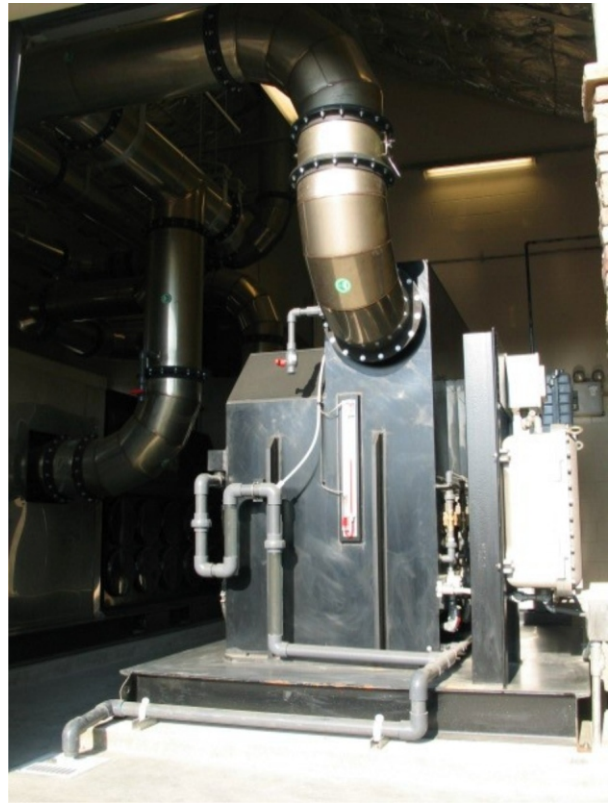
Enacted in 1998, the EPA's ruling 40 CFR imposed strict standards, with the goal of reducing industrial emissions of hazardous air pollutants. "The agencies rule was intended to reduce emissions of a number of air toxins and hazardous air pollutants (HAPs), including methylene chloride, methanol, toluene, and HCl. It was estimated at the time that the ruling would reduce air toxins by approximately 24,000 tons or 65% from contemporaneous levels."

To meet these regulations, many facilities have installed caustic scrubber systems to remove emissions, as well as older technology flare stacks and various other air pollution devices. In some forward thinking municipalities, flammable "digester gas" is collected and routed via the pipe/duct system to be burned as a fuel in steam generating boilers.

The increased use of scrubbers and other devices has resulted in the need for advanced duct materials that can carry these hazardous and flammable pollutants to vapor collection and destruction systems (or digester gas systems) without compromising plant safety. As a result, more plants are installing fire-safe and corrosion resistant fluoropolymer coated stainless steel duct and pipe.

Fiberglass Reinforced Plastic (FRP) vs Fluoropolymer Coated Stainless Steel

Fiberglass Reinforced Plastic (FRP) has been a construction material that met the needs of a variety of applications for over half a century. Since its inception during WWII, it has seen use in electronics (aircraft radomes), the oil field, and chemical and wastewater applications. FRP duct is manufactured by a winding process that employs epoxy resins reinforced with continuous glass filaments. The resins used are thermosetting (they undergo irrevers-



Fluoropolymer duct connected to a Calgon Carbon "Phoenix" unit specifically designed for odor control at a wastewater lift station. (Photo courtesy of Fab-Tech, Inc.)

ible chemical reactions as they cure) resulting in good chemical and temperature capability, while the filament reinforcing makes the duct components mechanically stronger than non-reinforced thermoplastics. Thermosets include all two-part resins such as epoxy, polyester, vinyl ester and phenolic.

Fiberglass pipe and duct have been used for years in the wastewater and chemical industries for a variety of services, from transporting feed and waste chemicals to being the material of construction for process vent systems. However, in wastewater facilities, we now see more stringent design and regulatory criteria evolving for vent duct systems. When comparing FRP duct to fluoropolymer coated stainless steel duct, there are significant differences in flammability, smoke generation, corrosion resistance, cost and speed of installation... all in favor of coated stainless steel.

Fire and Smoke

Prior to the appearance of fluoropolymer coated stainless steel duct, the common materials of duct construction for venting corrosive vapors and fumes were galvanized steel, coated metals, polyvinyl chloride, polypropylene and FRP. Today, wastewater sites are high cost, complex and technologically advanced facilities. Federal, state and local codes and regulations set high standards for flame spread and smoke generation in case of a fire. These guidelines have been accepted and embraced by facility owners and underwriting insurers, who all are looking for best practices and materials to safeguard not just their property and physical structures, but their most valued asset - the employees working inside these structures.

E-84 Test

Continually changing codes and fire regulations stress the use of lower flame spread and smoke generation indices for components used in industrial buildings, including exhaust duct materials. An important test frequently referenced is the Steiner Tunnel test (ASTM E-84), a method to quantify flame spread and smoke density and is a mandated test for many laboratory building materials. The test consists of a 25' vented tunnel, lined with firebrick, with the test material mounted to the top of the chamber. At one end of the chamber, a test sample is subjected to a high-energy flame for ten minutes. Flame spread is determined visually through windows built into the tunnel, and an optical cell mounted at the tunnel exhaust measures smoke density. The findings of the E-84 test for fire and smoke on fiberglass duct and fluoropolymer coated stainless steel duct will be examined and evaluated below.

Fire

When examining fiberglass reinforced plastic duct, flammability is dependant upon the resins used in the fiberglass matrix, as well as the fire retardant agents added. The most commonly used resin is fire retardant brominated bisphenol-A vinyl ester. In addition, antimony trioxide, antimony pentoxide or APE 1545 antimony oxide (up to 5%) can be added. When reviewing the flame-spread values resulting from

the ASTM E-84 test, as reported in Factory Mutual Research documentation, we find that the flame spread value for vinyl ester fiberglass duct ranges from 15 to 20₂. Using the same methodology, Factory Mutual Research reports flame-spread values for fluoropolymer coated stainless steel duct approved for use in clean-rooms range from 0 to 10. One type (Perma-Shield Pipe model PSP[®]) registered a perfect score of "0" for flame spread.

Smoke

Sometimes in a conflagration, it is not just fire and heat that can cause extensive damage - the tremendous amount of generated smoke billowing through a building can contaminate labs, electronic equipment, the entire complex... not to mention the deadly effect on employees and the general public living in close proximity to the wastewater site. Not to mention corporate embarrassment and public infamy as your building makes the 6 o'clock news. It is critical that duct materials not generate or contribute smoke when exposed to fire conditions. Comparing E-84 and Factory Mutual ratings for fume and/or smoke exhaust duct systems we find that the Smoke Generation index for vinyl ester fiberglass duct ranges from 275 to over 375₂. Smoke Generation index for fluoropolymer coated stainless steel duct ranges from 15 to 35₂.

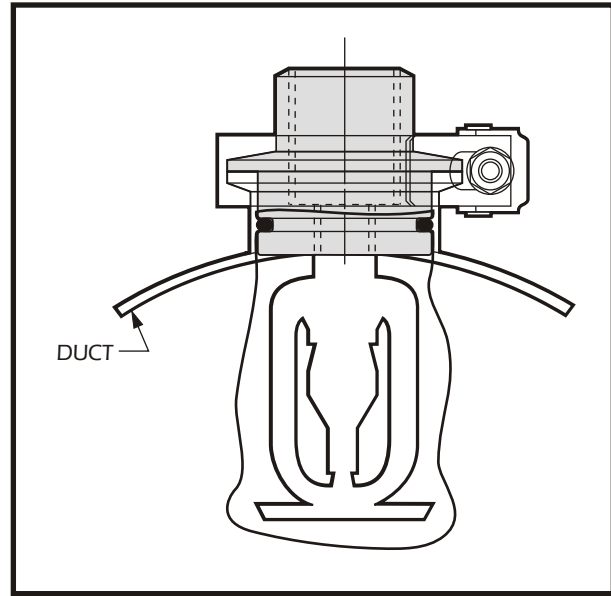
The most striking difference between Fiberglass Reinforced Plastic duct and fluoropolymer coated stainless steel duct is the smoke development of each. When exposed to flame, FRP duct generates large volumes of thick black smoke, several hundred times the value of fluoropolymer coated stainless steel. "Flame retardant vinyl ester resins are used by many industries for applications requiring good thermal resistance. The current flame-retardant technology is dependent on brominated vinyl ester, which generates high levels of smoke and carbon dioxide."³ This high smoke generation level, therefore, does not qualify FRP duct as a true "Class 1" rated system, while the fluoropolymer coated stainless steel is "Class 1" rated. A "Class 1" rating means that the duct and connector materials have a flame-spread rating of not over 25 without evidence of continued progressive combustion and a smoke-developed rating of not over 50. To

safely use FRP duct (with a smoke generation rating of over 50) in certain facilities, internal sprinklers (that is, sprinklers inside the exhaust duct) must be used.

The Cost To Sprinkle

Most resins used for FRP duct (except a few modified phenolic resins) will burn rather easily. Because of this, many building codes and insurance companies mandate duct made of stainless steel or other noncombustible materials. In some instances, fiberglass and other combustible duct materials may be used but require the use of internal sprinklers to prevent the spread of fire. As stated in the National Fire Protection Association's Standard 318. "3-3.6: Exhaust duct systems shall be constructed of non-combustible materials or protected with internal sprinklers in accordance with 2-1.2.6. Exception: Ducts approved for use without automatic sprinklers." The NFPA standard continues with a hierarchy of material preferences, "3-3.6: Considering fire protection issues only, duct materials listed in descending order of preference are: (a) metallic, (b) approved coated metallic or nonmetallic not requiring fire sprinklers, (c) combustible with internal automatic sprinkler protection."⁴ Note: "although most NFPA standards are not laws, they are widely accepted industry standards with considerable legal standing. Failure to comply with them can potentially put manufacturers in serious liability."⁵ Factory Mutual (FM) approved stainless steel duct internally coated with a fluoropolymer satisfies this requirement without the use and costs of an internal sprinkler system.

Besides adding significant costs to a project, sprinkled duct has an entire sub set of additional problems to consider and resolve. "In some instances, the special materials of construction cause a ripple effect in special requirements. For example, some acid resistant duct materials are considered flammable by code authorities and insurance underwriters. As a result, the duct systems constructed of these materials require fire suppression systems, usually in the form of sprinklers. The sprinklers, being exposed to potentially corrosive exhaust, require special treatments and coatings to protect them and special installation connections (typically, flexible



To meet code requirements, non "Class 1" duct requires the use of internal sprinklers, which adds significant costs to an exhaust duct system as compared to a fluoropolymer coated unsprinkled system.

metallic hose) and arrangements to allow them to be removed for inspection and service. Since a sprinkler discharge inside the duct system will fill the ducts with water, the ducts need to be supported in a manner that could withstand the weight of the duct if it were filled with water. In addition, the duct needs to have drainage access in the event that the sprinkler system activates. The effluent from this drain will probably need to be treated as hazardous waste. And finally, the discharge connections of the duct need to be arranged to trap water in the duct so that a sprinkler discharge does not flood the expensive and delicate process machinery served by the system."⁶ These problems can be completely avoided by using fluoropolymer coated duct, approved by Factory Mutual for use without an internal sprinkler system!

Who is Factory Mutual And What Role Does It Play?

When selecting duct for corrosive exhaust applications, it is critical to choose a product that is rated by Factory Mutual (FM) an affiliate of FM Global, an insurance company devoted to reducing commercial and industrial property losses and maintaining the continuity of its policy-

holders' business operations. The insurer's extensive research is often used to help set new industry standards, develop new products and advance loss-prevention practices.

Manufacturers of fluoropolymer coated stainless steel duct use FM Research's services to earn the FM Approval mark, certifying the performance of their products. Fluoropolymer coated stainless steel duct is regulated and approved by FM Research Standard Number 4922. With fluoropolymer coated stainless steel duct, structural integrity is maintained in the event of a fire. With extremely low flame and smoke characteristics, these systems will not burn or melt or generate large quantities of smoke, an extremely important issue in the odor control environment. They are inherently safe when they arrive on site.

Corrosion Resistance

Corrosive fume exhaust and pipe should be just that... corrosion resistant. The choice of materials for the corrosive vent exhaust system is a function of the science and processes employed within the building or lab. It is the role of the design engineering firm, working in conjunction with the architect and client, to choose the highest performing, safest, yet cost effective materials of construction.

A fluoropolymer is a polymer that contains atoms of fluorine. It is characterized by a high resistance to solvents, acids, and bases. Fluoropolymers were discovered by happenstance in 1938 by Dr. Roy J. Plunkett as he was working on freon (for the DuPont corporation) and accidentally polymerized tetrafluoroethylene. The result was PTFE (polytetrafluoroethylene), more commonly known as Teflon®. This material had the lowest coefficient of friction of any known solid and was inert to virtually all chemicals known. Its corrosion resistivity (in almost all applications) exceeds even that of glass (borosilicate and enameled glass-steel) and exotic alloys such as Hastelloy, Niobium, Tantalum and Titanium.

Fluoropolymer coated stainless steel was born out of necessity in the early 1990's to solve a specific need in the semiconductor industry - plastic and fiberglass products just were not

providing the needed safety and performance. The first shipments of coated stainless steel duct were eagerly placed into service at an IBM semiconductor chip plant in Essex Junction, Vermont, to replace failing FRP duct.

When compared to fiberglass reinforced plastic (FRP), polypropylene (PP) and polyvinylchloride (PVC), the superiority of fluoropolymer coated stainless becomes obvious. Based on published data, fluoropolymer coated stainless steel (coated SS) far surpasses other materials in chemical resistance and the robust stainless steel tubing does not burn, collapse or leak. Fluoropolymer coated stainless steel has been tested in over 400 chemical applications, and proven superior to both FRP and plastics when tested for corrosion resistance, concentration and upper temperature limit.

In evaluating the level of corrosiveness of a given application, it is vital to consider the entire range of chemicals that the duct system will be exposed to. Even more important is to consider the potential of combinations. **"It is also important to evaluate complex systems with several different types of process streams (e.g., reactor, storage tank, relief stream) discharging into a common header. Where vents from several sources are combined, it is necessary to carefully consider all possible interactions between the different streams in terms of both chemical reactivity and flammability."** ⁷ It's reassuring to know that Dr. Plunkett's creation (the fluoropolymer) has a wide corrosion resistant envelope to handle almost any chemical situation.



First used in the semiconductor market, coated stainless steel duct has gained acceptance in numerous other industries. No UV or external coating is necessary on 300 series stainless steel. (Photo courtesy of Fab-Tech, Inc.)

Fluoropolymer coated duct is 300 series stainless steel that is coated with a fluoropolymer barrier coating system, then heated and "baked" to form a chemical and mechanical bond with the stainless substrate. Duct thickness depends on airflow specifications and is governed by SMACNA (Sheet Metal and Air Conditioning Contractor's National Association) guidelines, however, heavier-gauge duct is available.

One manufacturer has developed a fluoropolymer barrier coating with proprietary resin technology that assures superior adhesion to the stainless steel - resulting in a coating that will not delaminate. Most manufacturers complete the manufacturing cycle with a thorough inspection - making sure that every inch of every component is both visually inspected and electrically spark-tested for any voids. Check with your selected supplier to confirm that they have a certified Quality Control program in place to guarantee that you receive a defect and pinhole free surface.

Installation Safety and Cleanliness

New wastewater facilities, are increasingly becoming "cleaner and greener" in design and operation. Increased awareness of harmful attributes of certain materials, such as asbestos, lead and fiberglass, are causing plant owners to re-evaluate materials used on site.

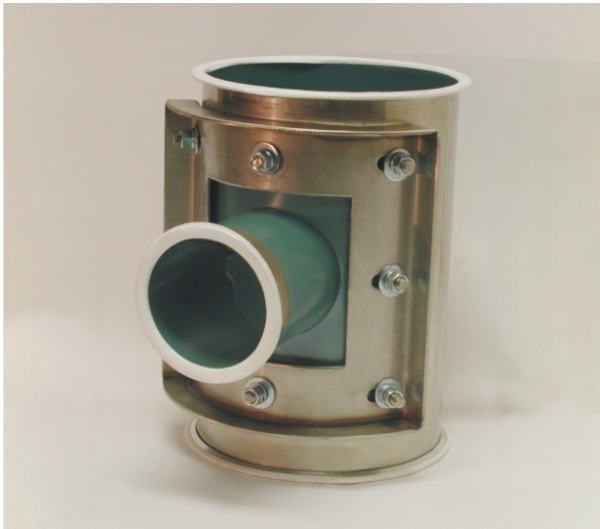
Cutting and grinding FRP produces large quantities of dust. The glues and adhesives used usually have a strong malodorous smell. And FRP resins and adhesive can outgas as they cure and even after they have cured. Working with fiberglass poses potential hazards to the health of construction workers and any employees in the FRP work area. "The risk of exposure to resin, hardener and mixed epoxy is greatest when they are liquid. As epoxy cures, the chemical ingredients react to form a non-hazardous solid. As it solidifies, epoxy and its components are less likely to enter the body. Skin contact is the most common means of exposure to resins and hardeners. Even minor skin contact, if repeated often enough, can cause chronic health problems. In rare cases, with prolonged or repeated contact, the skin can absorb harmful epoxy ingredients. Exposure by inhaling vapors is unlikely, because

epoxy products evaporate slowly. However, the risk increases when ventilation is inadequate or when the products are heated. Sanding partially cured epoxy produces airborne dust, which increases your risk of exposure by skin contact, inhaling or ingesting. Although epoxy is firm enough to sand within two hours, it may not cure completely for up to two weeks. Until then, the dust can contain unreacted hazardous components." Installation and modification of fluoropolymer coated stainless steel duct is a clean process, with none of the problems as found with FRP. Coated stainless steel duct can be cut and shortened without damaging the fluoropolymer barrier coating. In addition, items such as saddle taps (a "tee" nozzle inserted into a straight run) or accessories such as test or instrument port can be added to a coated duct section without fear of damage to the coating.

Joint Technology Differences

Joints on FRP duct are traditionally accomplished by means of a labor intense "butt and wrap" procedure. Duct ends are ground smooth, exposed ends are sealed with catalyzed resin, and the duct or fitting is "battered-up" and overlaid with several layers of resin and reinforcing fiberglass. Adhesive curing at an ambient temperature of 70°F would take at least 24 hours, so electric heating blankets must be used to accelerate the needed time to cure each joint. Even with the use of a heating blanket, cure time for a joint could take over one hour. Work site temperatures below 69°F or above 90°F, as well as high humidity, can adversely affect the adhesive, the curing of a fiberglass joint or the overall integrity of the connection. Adhesive resins must be stored and mixed at the right temperature, and the two parts must be mixed in the exact ratio to prevent "crazing".

One of the hardest steps in joining FRP pipe and duct is the procedure of affecting the required internal joint. In sizes 24 inches and above, a person has to get into the pipe or duct to the point of the joint, and apply an interior corrosion wrap. "3.03 PIPE JOINTS A. Butt and Wrap Joints: Prior to joining, ends shall be ground smooth. All dust and debris Must be fully removed. Ends shall be resin-coated to prevent corrosion, in pipe 24" Diameter and above an



Modifications to fluoropolymer coated stainless steel duct is an easy task. Above is a straight section of duct with a field installed saddle tap kit attached. (Photo courtesy of Fab-Tech, Inc.)

interior corrosion wrap is required. The joint should be of equal strength as the pipe. A butt and wrap sequence and thickness chart should be shown on the fabrication drawings. The laminate sequence for each size duct should be supported by a separate section in the design calculations." Making connections with fluoropolymer coated stainless steel duct is quick and easy. Standard "van stone" rotating flanges are bolted together, sandwiching a PTFE gasket between them. One manufacturer has added to their product line an "EZ" clamping system - using a patented and FM approved one bolt clamp connector. Available on 4 inch through 14 inch diameters, no joining system is quicker or easier.

Whether it's flange or EZ clamp style joints, the installation labor savings in joining fluoropolymer coated stainless steel duct versus butt and wrap fiberglass FRP duct, is significant. Most mechanical contractors who have worked with both systems have claimed that coated stainless steel duct can be installed in half the time of FRP. And the labor savings increase as the diameters get larger. FRP duct then requires the internal corrosion wrap and lengthened time to "heat cure" each joint. Coated stainless steel duct is not affected by ambient temperature or humidity. If FRP duct is assembled using flanges, this will add greatly to the per foot cost

of the fiberglass system, as hand laid-up FRP flanges are very expensive.

Cost / Value

A common misconception among engineers and facility designers is that fluoropolymer coated stainless steel is substantially more expensive than FRP alternatives. Although it is more expensive per foot than standard FRP, it is important to compare it against the resin and service type of FRP duct and to include the evaluation of the lower installation cost. On a recent wastewater project in the state of Washington, fluoropolymer coated stainless steel duct from Fab-Tech was selected instead of the specified fiberglass duct because the client municipality realized a huge savings over budgeted costs. The price differential of comparing Fab-Tech's fluoropolymer coated stainless steel to FM approved FRP was less than expected. When factoring in the installation labor savings, the total installed cost of Fab-Tech's PSP[®] duct was below that of fiberglass duct!

Conclusion

In the past, wastewater sites have used fiberglass, plastic, stainless steel and even expensive PTFE lined carbon steel pipe to handle corrosive vent applications. This paper has attempted to present several key points differentiating fluoropolymer coated stainless steel duct from FRP duct, and listing areas where it excels - it is more corrosion resistant, has a lower flame spread, generates far less smoke, is easier, cleaner, safer and less time consuming to install, and is a better dollar value than fiberglass. And the 300 series stainless steel exterior never needs painting or an ultraviolet protective coating.

Fluoropolymer coated stainless steel duct has proven itself in tough, aggressive service for nearly two decades and is the first choice for an entire industry (semiconductor) to handle corrosive vent exhaust. It meets all the required design and operating criteria for extreme service when applied and installed according to the parameters for its intended use. If corrosion, fire and smoke safety are a concern, fluoropolymer coated stainless steel could be the ideal solution. Professionals who design, build or maintain wastewater and odor control facilities that contend with corrosive

and hazardous vapors can benefit greatly by doing additional research into this revolutionary product.



A sixty inch fitting being readied for shipment to a Rahway, New Jersey pharmaceutical mid-scale organic facility. Fluoropolymer coated stainless steel duct saved both time and money when introduced as a value engineered alternative to furan FRP. (Photo courtesy of Fab-Tech, Inc.)

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