CORROSION AND PIPE PROTECTION

FBE evolves to meet industry need for pipeline protection

Epoxy resin veteran recounts companies, people who developed powder coatings business in U.S. market

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Fusion bonded epoxy (FBE) coatings have revolutionized the pipe coating industry.

The coatings provide corrosion protection for pipeline systems used in the production, transportation, and distribution of oil, gas, water, and petroleum products. FBE is used to coat the interior and exterior of pipe and field-weld joints, as well as the interior of tubing and fittings.

FBE coatings were introduced by 3M Company in the late 1950s. 3M's initial product, Scotchkote 101 (1959), was based on a solid EPON[1] resin cured with dihydrazide. This first product provided excellent corrosion resistance but was somewhat brittle, resulting in a tendency to chip during handling and to crack on bending. This limited the market to small-diameter pipe. 3M developed improved formulations, and went on to be the first to coat pipe as large as 48 in. diameter.

Shell's Union Technical Service Laboratory played an important early role in this process. In the 1960s, Shell generated interest in EPON resins for FBE coatings by developing and making available to its customers several starting point formulations, practical processing methods, and performance data.

Joe Manasia, a chemist at Shell's Union Technical Service Laboratory, was an ardent believer in the merits and potential of EPON resin powder coatings for underground hydrocarbon transmission pipelines. In 1963, Manasia and co-worker Roy Allen set out to develop a more flexible, rapid-curing, corrosion-resistant powder coating. They developed three promising systems, all based on Shell's EPON resin 1004, with different curing agents:

- Benzopherone tetracarboxylic dianhydride (BTDA)
- Trimellitic anhydride (TMA)
- Dicyandiamide (dicy).

The BTDA system was the fastest curing, with best overall performance of any anhydride system, but it was deemed too expensive to compete with existing systems.

The dicy system showed good performance, but was too slow curing for 2.5 to 6-in. diameter pipes, which were the target market. Pipe in this diameter range did not have enough heat capacity to cure the coating without post baking, which added to production costs.

The TMA system provided excellent chemical and physical properties, could be formulated at a competitive price, and seemed to have potential to open markets for coating pipe 2.5 to 6 in.

diameter. This system was selected for extensive testing. Laboratory tests showed the TMA-based coating provided:

- Toughness and flexibility to withstand rough handling during transportation and bending in the field during installation
- Excellent corrosion resistance
- Good heat resistance – "burnback" of the coating during welding was only one inch
- Good chemical resistance to alkali, acid, and a range of solvents.
- Rapid cure – 30 seconds when electrostatically sprayed on pipe heated to 425 to – 475°F.

Early field tests. Despite even the best laboratory test results, any new corrosion protection system must be field tested to determine performance under operating conditions, both below and above ground. Shell's Dennis Neal recalls that Shell Pipeline personnel, particularly Ed Karraker, Lloyd Nelson, and Harold Layne, helped arrange in-ground testing of Shell's TMA system in about 13 different locations, representing different service and soil conditions.

The first test was on 56,000 ft of 6-in. pipe installed in Puerto Rico, in the winter of 1965 – 66. Pipe was coated on the inside and outside at the H. C. Price Co. plant in Philadelphia with EPON resin powder supplied by Armstrong Products Co. An EPON 1004/TMA powder was used on the exterior, and an EPON 1004/BTDA powder on the interior. Pipe was prepared in the conventional manner. It first passed through a burn-off oven to remove grease and mill lacquers, then cleaned with a wheel-type, grit-blasting 'achine, and heated at 425° to 475°F.

Epoxy powder coating was applied to the hot pipe by electrostatic spray. The pipe's heat was sufficient to melt and cure the coating in less than a minute. Pipe was then water-cooled and inspected for imperfections, which were repaired on the spot. Roy Allen, who accompanied Dennis Neal on the Puerto Rico test, formulated a two-component, ambient-temperature curing, solventless EPON resin coating to cover the weld joints. The two components were packaged in kits for convenient use in field application.

Another test installation of the EPON 1004-TMA coating was made in Bermuda in September 1966, on 7,000 ft of 6-in. aluminum pipe that would carry aviation fuel. Coating was applied to the exterior only. No internal coating was required. This was an interesting application because the pipe sections were swaged together, not welded. The longest test section was 64,000 ft of 4-in. pipe laid in Lea County, New Mexico, in the spring of 1966.[2]

Commercial development. 3M and Napko were pioneers in developing and promoting FBE coatings, particularly for large-diameter pipe. Shell promoted its EPON-TMA technology to some of its customers, with an eye toward commercial development. Neal, a technologist in the Head Office Resins Department, headed the market development and in-ground testing of the TMA system for oil and gas transmission pipe. Neal and Manasia went out as a team explaining formulations, compounding techniques, and related application methods to a number of companies, including:

- Armstrong Products Co., Warsaw, Indiana
- Napko (now Dupont Powder Coatings), Houston, Texas
- Cook Paint and Varnish Co. (now Lilly Industries) Kansas City, Missouri
- Mobil Finishes (now Jotun)[3]
- Hysol (now Dexter Corp.).

Armstrong, Napko, Cook Paint, and Mobil embraced the technology, and manufactured EPON 1004/TMA powders. 3M declined to accept the Shell TMA technology, feeling they were well along on in their own research and development of FBE coatings.

Of the companies that were given the Shell TMA technology, Napko was the first to take action. Napko already was supplying two-component solvent-based EPON resin interior coatings for large-diameter gas transmission pipe. Joe Rench, Napko's Executive Vice President, recognized the potential for an improved exterior coating for large diameter pipe – one that could be easily applied, withstand shipping and field handling, and provide long-term corrosion protection. He also was convinced that successful marketing required a good applicator.

Midwestern Welding Co. Ltd. was one of Napko's customers for solvent-based epoxy internal pipe coatings. Midwestern operated five internal pipe-coating plants across the U.S., at least two of which were equipped to coat the interior of large diameter gas transmission pipe. One was at Gadsden, Alabama (opened in 1960 next to a Republic Steel plant), and the other at Steelton, Pennsylvania (opened in 1964 next to a Bethlehem Steel plant).

In the mid 1960s, Midwestern Welding formed a subsidiary, Midwestern Coating Corp., to build and operate external FBE pipe-coating plants, first at Gadsden, and then at Steelton. These first Midwestern plants were modest operations. Rench considered Midwestern a good company to work with, to develop markets for large-diameter, FBE-coated pipe.

In 1969, Midwestern designed and built new pipe coating lines at Gadsden, Alabama, to coat up to 30-in. diameter pipe; and at a new plant at Steelton, Pennsylvania, to coat up to 42-in. diameter pipe. These were the maximum pipe sizes produced by Republic Steel Co. at Gadsden and by Bethlehem Steel Co. at Steelton. Napko supplied the FBE coating used by Midwestern. This was a two-coat system – a solvent-based epoxy-phenolic primer, and an EPON 1004-TMA powder topcoat.[4]

The plants operated on a "trolley" system. Pipe was carried on a trolley, first to a large soaking oven to bring it up to desired temperature; then to the next station where it was sprayed with a solvent-based primer; then to a Ransburg electrostatic spray-powder coating station. Coated pipe was post baked for 10 minutes at 400°F, mainly to cure the prime coat, even though primer and powder coats were cured simultaneously.

In 1970, Neal was released from Shell to work for Midwestern Coating Corp. as executive vice president. Ron Carlson, an engineer formerly at Shell's Union Technical Service Laboratory, had been Midwestern's sales manager since late 1967. Al Seigmund was Napko's "man" at the Steelton plant supervising FBE application.

Midwestern Coating supplied 24-in. and larger-diameter coated pipe to such companies as Tennessee Gas, El Paso, and Transco. The entire 28-in. Explorer product pipeline from Houston to Tulsa, in which Shell was the major partner, was coated at Gadsden. Altogether, about 150 mi of 20 through 42-in. pipe was coated successfully at the Steelton plant until 1972, when an explosion terminated operations. The plant was not immediately rebuilt, but by this time the technical and commercial feasibility of coating large-diameter pipe with FBE had been established. Neal left Midwestern, but Carlson continued on, developing markets for epoxy pipe coatings, and assisting in the construction of a new FBE coating plant at Steelton a few years later.[5]

While marketing FBE coatings for large-diameter pipe, Carlson saw the "weak link" at weld joints. He began developing a method for applying FBE to field girth welds, the area where two sections of pipe are welded together during construction. Soon thereafter, Carlson established Commercial Resins Co. to continue development of girth-weld coating equipment. The goal was to coat pipelines with FBE from end-to-end, including field construction welds and fittings.

In the late 1960s, Joe Manasia and Jim Todd developed a more user-friendly formulation based on EPON 1004, cured with dicyandiamide ("dicy"). This system cured fast enough to coat large-diameter pipe, 16 through 48 in., without requiring a post cure.

Unlike the smaller-diameter pipe on which Manasia and Todd tried dicy-cured epoxy powders earlier, larger diameter pipe has thicker walls with a higher heat capacity, and is processed slower. The EPON resin 1004-dicy system provided an excellent balance of corrosion resistance and physical properties, particularly better flexibility, compared with TMA-cured systems. Proprietary epoxy resin-dicy systems, modified with accelerators, additives, and improved pigments are the principal FBE pipe-coating systems in the 1990s.

3M followed a different path to commercialization. Rupert F. Strobel, business manager, Corrosion Protection Products at 3M Company[6] recalls 3M's development and commercialization of FBE coatings dating back to 1959 – 1960. The Electrical Products Division, which produced vinyl insulating tape for the electrical industry, began selling vinyl tape to operators for wrapping pipeline weld joints.

At the time, the standard external coating for oil and gas lines was a thick coating of hot coal tar. With vinyl tape, 3M was supplying product for about one foot of every 40-ft pipe section. Supplying product for the other 39 feet presented a technical and marketing challenge. 3M perceived that a complete vinyl tape system would not replace coal tar, so they looked for new technology.

Fig. 1. In 1960, when there was no commercially available equipment to apply powder to pipe, 3M built this pipe-coating machine to apply its Scotchkote 101 epoxy powder. *Photo courtesy Rupert F. Strobel, 3M Co.*

Fig. 2. Crews install the first pipeline coated with 3M's Scotchkote 101 for

Pioneer Natural Gas Co. in New Hope, New Mexico, in 1960. *Photo courtesy Rupert F. Strobel, 3M Co.*

A group at 3M, which had been working on epoxy molding powders, learned of the Gemmer patent. This patent described a fluid-bed method of applying thermoplastic powder coatings to heated metal products. This technology seemed potentially applicable to pipe coating. 3M had experience with a solid dihydrazide curing agent for epoxy resins, and decided to try the system for pipe coatings. They first tried making an epoxy powder by dry-blending the resin, curing agent, pigment and filler. Like other researchers, they found this unsatisfactory.

The 3M group then migrated to a 2-roll rubber mill. As the solid epoxy resin was milled and the temperature increased to soften the resin, the powdered dihydrazide, fillers, and pigment were added. Shortly thereafter, the mixture was taken off the mill, cooled, and ground. 3M found this first (dihydrazide) FBE powder had a major drawback: it required a post bake to cure properly.

While experimenting with different catalyst systems, Strobel accidentally discovered the answer. He had dipped a hot piece of 2-in. pipe into a fluid bed of epoxy powder and was holding it in one hand with a pair of pliers on his way to place it in an oven for post bake, when someone stopped him to ask a question. As he went on his way after answering, he noticed that the coated pipe looked different. He touched it and found it had gelled (partially cured) in that short time. Before placing it in the oven, he looked at it again. This time, it had fully cured. Now 3M had a potentially viable epoxy powder pipe coating which could be cured rapidly with the pipe’s residual heat, no post baking required.

In less than a year, 3M developed their Scotchkote 101 epoxy powder. There was no commercially available equipment to apply powder to pipe, so 3M built their own (Fig. 1). The first commercial application was made in February 1960 at Briner Rustproofing Co. in Albuquerque, New Mexico. The job was for a Pioneer Natural Gas Co. 2-in. diameter gas feeder line to New Hope, Texas. The pipe is still in service (Fig. 2.)

That was the beginning, but as is the case with so many new developments, 3M found they were about 10 years ahead of their time. Strobel recalls pipeline people wondering whether "that paint" was going to be as tough as coal tar coating. To demonstrate the FBE pipe coating’s toughness, 3M representatives would beat the coating off the coal tar enamel-coated pipe with a piece of pipe coated with Scotchkote 101. The coal tar enamel flew off; the Scotchkote coating remained intact.

3M began to receive orders for Scotchkote 101, to coat small-diameter pipe. Their first coating machine could only coat up to 4-in. diameter pipe. Interest developed slowly for specialty uses. For example, pipeline contractors liked FBE-coated pipe for driving pipe under streets, to avoid tunneling-related expenses.

Pipeline contractors gradually came to appreciate the properties of epoxy powder-coated pipe, but wanted the same coating on the weld joints. 3M wanted to develop and build equipment to flame-spray epoxy powder on the weld joint, and worked with a Minneapolis-based welding equipment company to this end (Fig. 3). The method was not entirely satisfactory. For one, there was a problem achieving satisfactory cure. Secondly, when pipeline contractors looked at the capital investment and the complicated technology, they decided to continue using tape on the joints.

Fig. 3. In an attempt to respond to pipeline contractor needs, in the early 1960s 3M worked with a Minneapolis- based welding equipment company to design and build equipment to flame-spray epoxy powder on weld joints. *Photo courtesy Rupert F. Strobel, 3M Co.*

The flame-spray effort produced some revolutionary venturi technology, which made it practical to pump powder from a fluid bed to the coating chamber of a pipe-coating machine. The new design pumps operated hour after hour; whereas most other pumps (at this time) plugged up after a few hours. 3M donated this technology to the industry.

In 1961, Banister, a Canadian company, built an FBE pipe-coating plant in Canada and shipped it to Warren, Ohio. This was the second FBE coating plant in the United States. Rupert Strobel helped start up this plant using Scotchkote 101. Pipe was sandblasted, heated, and run through a powder chamber. The early powder coating chamber, called a "cloud chamber," was just an air chamber filled with powder. The powder was augured into a materials-handling blower. Then, it was distributed in the chamber by a series of vacuum cleaner type hoses leading to flattened funnels that applied powder in a circular pattern over the pipe. This first plant could coat up to 6-in. diameter pipe (Fig. 4).

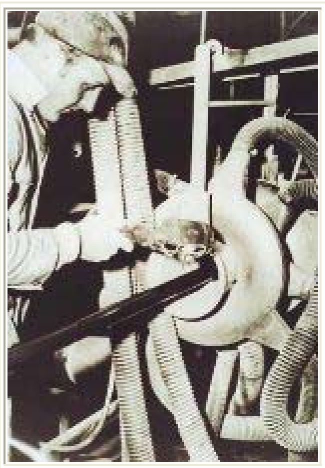

Fig. 4. Pipe emerges from the "octopus" air blower-coating chamber, used at Banister's Warren, Ohio, FBE pipe-coating plant, in the early 1960s. *Photo courtesy Rupert F. Strobel, 3M Co.*

3M next worked with H. C. Price Co., coating pipe up to 12-in. diameter. Harold Price started out as a welding contractor for cross-country pipelines. The company became general pipeline contractors, and got into the pipe-coating business with mastics and concrete in the early 1950s. Price started coating pipe with FBE supplied by 3M in 1962, at a new plant in Philadelphia. 3M had convinced Philadelphia Electric Co.'s Gas Division to use FBE-coated pipe for their household gas distribution lines. Price first applied FBE using the 3M "cloud box" method.

About a year later, Price was the first company to apply FBE by electrostatic spray, using a new Ransburg electrostatic-spray system (Fig. 5). The 3M venturi technology, from the flame-spray pump development, was used to feed the spray guns from a fluid bed. Electrostatic-spray guns were positioned at holes in the side of a fiber drum to coat heated pipe as it passed horizontally through the drum. H. C. Price developed improved coating processes, and was the first company to use flame spraying to patch "holidays" in FBE-coated pipe.

Fig. 5. H.C. Price was the first company to apply FBE to pipe by electrostatic spray, using a Ransburg electrostatic spray system. *Photo courtesy Rupert F. Strobel, 3M Co.*

Price was a major FBE pipe-coater for many years. The company built a plant in Orrville, Ohio, to coat large-diameter pipe, up to 36 in. This plant closed after a few years. Price also operated a plant in Galveston, Texas, for a while. After several joint ventures and acquisitions, the derivative of H. C. Price Co. became a part of Bredero Price Co., a Bredero-Shaw Group Co., the largest pipe-coater in the U.S.

In 1965, 3M introduced Scotchkote 202, a more flexible coating based on a solid EPON resin, and cured with methylenedianiline. By this time, 3M was making FBE on a 60-in. rubber mill. The resin was banded on the mill. Curing agent, pigment, filler, and flow-control agents were milled into the warm, semi-solid resin. The sheeted mixture was taken off the mill, cooled and ground to a fine powder in a hammer mill.

3M wanted to show the pipeline industry that 3M's epoxy powder coating and application process was feasible for coating large-diameter pipe. Working with Joe Ashlok, owner of Surfcote Company, 3M built a line at Surfcote's Houston plant to coat 16-in. pipe. This was the prototype for a commercial electrostatic spray pipe coater.

In 1970, 3M built the coating machines, supplied the powder, and supervised powder application to 400 mi of 48-in. pipe for the Trans Alaska (Alyeska) pipeline. Rupert Strobel was operations manager and Dick Eikos was engineering manager on the project. Pipe was coated at three locations – Prudhoe Bay, Fairbanks, and Valdez.

Girth welds. When the first large-diameter, FBE-coated pipe was laid in 1967, girth welds were protected on the exterior with either a spray applied, two component, solvent-based epoxy coating; a-brush applied, 100% solids, two-component epoxy coating; or merely wrapped with specially designed tape. Marion Frank and Leonard Choate of Tennessee Gas Transmission Co. asked Ron Carlson, then marketing manager for Midwestern Coating and owner of Commercial Resins Co., to design equipment to apply FBE coatings to construction welds.

The first machine designed by Carlson to coat field girth welds with FBE used an electrical induction heating device, engineered by Dr. William Hughes at Oklahoma State University, and a powder application device that resembled a scorpion wrapped around the pipe. The first field trial of the equipment was conducted on a Tennessee Gas Transmission Co. pipeline in Mississippi in 1969. Tennessee Gas encouraged Carlson to perfect the system, and provided opportunities for field trials on their construction projects. During the next two years, Commercial Resins developed a sturdy, practical machine to apply FBE to field welds. Operators liked the results, and started specifying FBE for girth welds during construction, as well as on pipe at coating plants.

In 1975, Commercial Resins Co. started work on a prototype unit to coat internal girth welds with FBE. In 1976, they tested a model on three miles of 20-in. pipe in Louisiana. The company soon developed a commercial, remote-controlled machine that traveled through the completed line on a self-propelled chassis, applying FBE to interior girth welds.[7] A 24 and 30-in. Tennessee Gas pipeline laid in the Gulf of Mexico in the fall of 1977 is believed to have been the first large-diameter pipeline coated internally and externally with FBE. It also was the first to have the girth welds coated internally and externally by Commercial Resins.

In 1999, there were three major U.S. suppliers of fusion bonded epoxy powder coatings:

- 3M Company – Scotchkote
- Dupont Powder Coatings (Napko, then Herberts-Obrien) – Nap-Gard
- Lilly Industries (formerly Cook Paint and Varnish) – Pipeclad.

In 1999, about 10 companies applied FBE coatings to oil and gas pipe in the U.S.; there were again about that many outside the U.S. The number of applicators is growing. A few other companies make and apply FBE to their own pipe, mostly internal coating for down hole oil-well pipe. PLG

Acknowledgment

This article is an edited excerpt from a book entitled, "Fifty Years of EPON[1] resins: A History of the Epoxy Resin Business," in preparation by John G. Dickerson. Copyright to the book is held by J. G. Dickerson.

Literature Cited

[1] EPON is the registered trademark of Resolution Performance Products, LLC.

[2] Details of laboratory and field tests were published in a paper presented by Dennis Neal at The Conference on Corrosion and Protection of Pipes and Pipelines, Great Britain, 1968.

[3] Mobil Finishes was acquired by Valspar in 1984. In 1999, Jotun, a Norwegian firm, acquired the (Mobil) Valspar "Mobilox" powder-coating business and licensees.

[4] Napko discontinued the solvent-based primer system in the late 1970s, despite its superior performance. It was replaced with a one-coat epoxy powder marketed as Nap-Gard MarkIV. In 1992, Napko (then Herberts-O'Brien) introduced a two-coat (primer and top coat) epoxy powder system which provides higher-temperature performance, and greater resistance to water penetration.

[5] In 1974, Shaw Co. constructed a new FBE plant just up the river but still on the Bethlehem Steel complex at Steelton. Shaw operated this plant, which coated 20 to 42-in. pipe, until 1993, when the plant was purchased by Dura-Bond Co., McKeesport, Pennsylvania.

[6] Based on interviews with Rupert Strobel before he retired from 3M in 1998.

[7] This development is described in detail in an article "Internal Joint Coating Machine," by John Pfeiffer when he was with Commercial Resins Co., published in *Pipeline Magazine,* March 1978. Pfeiffer is now president of Commercial Coating Services.

The author

John G. Dickerson, Jr., has 40 years' experience in the chemical industry. After receiving a BS degree in chemical engineering from the University of Maine in 1944, he joined Shell Chemical Co. in San Francisco. His involvement with epoxy resins began in 1947, when Shell signed a patent cross-licensing agreement with Devoe and Raynolds Co., which had just developed epoxy resins in the U.S., and was introducing them to the coatings industry. In 1959, Dickerson was appointed Sales Development Manager-Resins for Shell, with responsibility for developing new markets for EPON resins in the U.S. In 1962, he was assigned to Shell International Chemical Co. in London, where he headed resin marketing activities outside the U.S. He later returned to the U.S. and became Marketing Services Manager for Shell's Plastics and Resins division in Houston. He retired in 1983.

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