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Polypropylene Reduces FGD Cost and Improves Operation Flexibility

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ABSTRACT

Recent rapid escalation in the cost of certain metals has driven up the cost of alloys historically used in the construction of FGD vessels. This cost escalation has been compounded by the demand for alloys created by CAIR for new FGDs, which has also put demands on the market for alloys such as 2205 and C-276.

RWE Power was planning to build two new super critical 1,100 MW units at their BOA station located near Cologne, Germany. The BOA plant was being designed to burn local lignite coal. RWE has 10,000 MWs of FGDs on lignite coals and is therefore very experienced with various construction materials utilized in the manufacture of FGDs, their limitations, and life cycle cost.

RWE's experience with FGD systems burning lignite has shown that both carbon steel/rubber lined and flaked glass lined vessels have a defined life, especially since the BOA design criteria calls for > 70,000 ppm of Chlorides in the slurry. Up until now only metal vessels have life of plant expectancy. However, the recent rise in the cost of alloys typically used in FGD vessels has led to the application of a new design system for FGD vessel construction. For the new BOA plants, RWE selected the patented Bekaplast FGD vessel technology developed by the Steuler Company. The Bekaplast FGD vessels utilize a concrete shell with a polypropylene (PP) liner

Experience gained over the course of 25 years, during which Steuler utilized the most diverse corrosion protection materials in flue gas scrubbers, led to the development of a technically advanced and economically viable Bekaplast manufacturing concept.

The main advantage of using polypropylene is that this material does not require additional protection. The surface is smooth and without pores, which prevents the formation of caking deposits or incrustations. The service life of this material is virtually unlimited.

Bekaplast makes use of the advantages of polypropylene as mechanically anchored linings in concrete scrubber constructions. Thanks to its outstanding chemical, thermal and mechanical resistance properties as well as its exceptionally high resistance to abrasion, polypropylene is also employed as a mechanically anchored corrosions protection lining in concrete scrubber constructions.

Steuler utilizes its PP lining system, which has been field-proven with over 30 years experience in the chemical industry. It consists of large-format thermoplastic sheets having a thickness of 5 to 8 mm. Conical knobs are welded onto the reverse side. These large knobs create a permanent, inseparable mechanical bond between the plastic lining and concrete construction. In this case, the service life of the materials is also virtually unlimited. Damages caused by the absorption of media, the formation of deposits or chemical changes in the surface can be effectively ruled out. Spray piping systems, and linings for the scrubbers and components, such as sieve boxes for example, are manufactured out of the same material and round off the protection system. Today there are six FGD systems in operation and one in construction with the Bekaplast system

The BOA plant is currently under construction and the first unit is scheduled to begin commissioning December 2008 for unit 1 and January 2009 for unit 2.

The paper will discuss the construction techniques used in the Bekaplast system, why the properties of PP lend them selves to FGD systems, and the advantages that the system has over other materials of construction.

INTRODUCTION

Recent rapid escalation in the cost of certain metals has driven up the cost of alloys historically used in the construction of FGD vessels. Cost escalation in the United States has been compounded by the demand for alloys created by The Clean Air Interstate Rule of 2005 (CAIR) requiring retrofitting about 100,000 MW of FGDs. This, plus 20,000 MW of new FGDs in Germany and the number of projects underway in China, has added to the market demand for steel and alloys such as 2205 and C-276.

RWE Power in Germany is building two new super critical 1,000 MW units at their BOA station located near Cologne. The BOA plant is designed to burn local lignite coal. RWE has 10,000 MWs of FGDs operating on lignite coals and 14,000 MW of FGDs on bituminous-fired plants, and is therefore very experienced with various construction materials utilized in the manufacture of FGDs, their limitations, and life cycle cost.

RWE's experience with FGD systems burning lignite has shown that both carbon steel/rubber-lined and flaked glass-lined vessels have a defined life, especially since the BOA design criteria calls for >70,000 ppm of chlorides in the slurry. Until now, only alloy metal vessels have matched plant life expectancy. However, the recent rise in the cost of alloys typically used in FGD vessels has led to the application of a new design system for FGD vessel construction. For the new BOA plants, RWE selected the patented Bekaplast™ FGD vessel technology developed by the Steuler Company. The Bekaplast™ FGD vessels utilize a concrete shell with a polypropylene (PP) liner.

Experience over the course of 25 years with PP for FGD applications, during which time Steuler utilized the most diverse corrosion protection materials in flue gas scrubbers, led to the development of a technically advanced and economically viable Bekaplast™ manufacturing concept.

Steuler utilizes its demonstrated PP lining system that is based on over 30 years experience in the chemical industry. In this case, the service life of the materials is also virtually unlimited. Damages caused by the absorption of media, the formation of deposits or chemical changes in the surface can be effectively ruled out. Spray piping systems and linings for the scrubbers and components, such as pump screens for example, are manufactured out of the same material and round off the protection system. Today there are six FGD systems in operation and one in construction with the Bekaplast™ system.

The BOA plant is currently under construction and the first unit is scheduled to begin commissioning January 2010 for Unit 1, and July 2010 for Unit 2.

The Material Polypropylene

Corrosive chloride compounds in the flue gas place very exacting demands on chemical resistance properties in the scrubbing vessels. In addition to the chemical loads, severe mechanical loads are also encountered, particularly as a result of abrasion by finely dispersed solid materials. Other flue gas or slurry components such as sulfur compounds, fly ash and other solids, pH, and temperature also impact the selection of materials used to construct FGD systems.

The surfaces and components of steel and concrete vessel type construction utilized until now required extensive and costly protective measures. Considering the service life and durability of subsequently applied protection systems are clearly limited, this is an expensive and time-consuming procedure.

Steuler's technology makes use of thermoplastic material for FGD applications: Spray headers, pump screens and linings for concrete scrubbers made of polypropylene. The PP consists of physically connected macromolecules that are developed in the polymerization process.

Characteristic properties of PP are:

- Low density (0.90 g/cm3)
- Balanced stiffness / toughness relation
- Very good chemical resistance
- Excellent acoustic dissipation
- Easy to handle

In contrast to duroplastic and elastomer material, thermoplastics have a temperature range in which they could be formed, e.g., by extrusion, injection molding and proven welding process.

Some general physical properties of thermoplastics are shown in Table 1.

Table 1

General Physical Properties of Some Thermoplastics

Material	Density Kg/dm3	Thermal Expansion Mm/mK	Tension OzB N/mm2	Temperature Ranges	Chemical Resistance	Fire Classification
PE	0,95	0,20	11	up to 140° F	fulfilled	B2
PP	0,90	0,15	32	up to 210° F	fulfilled	B2
PPS	0,95	0,15	32	up to 210° F	fulfilled	B1
PVDF	1,78	0,12 - 0,18	55	up to 300° F	fulfilled	B1

Welding operations are carried out in accordance with the guidelines established by the German Association of Welding Division (DVS). Steuler uses the following welding procedures:

* Heated tool butt welding
* Ultrasonic welding
* Hot gas extrusion welding
* Hot gas draw welding

In FGD applications PP has the following important characteristics:

* Continuous operation at flue gas temperatures of 212ºF (100°C) does not impact the properties of PP.
* Flue gas temperature excursions between 212º F and 248º F for one hour or less do not impact the properties of PP.
* Continuous operating temperatures above 248ºF (120°C) could be critical for the material, as changes in the molecular structure can appear.
* Loss of strength or sagging starts at a temperature of about 329ºF (165°C). The PP will not fail suddenly; it will take some time until the heat has creeped into the entire thickness of the sheet or the pipe.
* The thermal decomposition of PP-H starts at a temperature of about 572ºF (300°C). PP will inflame at about 680ºF (360°C).

FGD Applications of PP

PP Spray Levels

Experience gained over the course of 25 years led to the development of a technically advanced and economically viable manufacturing concept for the spray levels. The large dimensional components will be produced entirely out of PP.

The main advantage of using PP is that this material does not require additional protection. The surface is smooth and without pores, which prevents the formation of incrustations. The service life for this material is virtually unlimited.

The only concern expressed by some operations for using PP material as the primary material for FGD vessel construction would be limits on operating temperature. Concerns regarding operating temperature can be addressed by installing emergency quench systems to protect the vessel in case of a boiler trip. This is a normal design feature since PP is a normal component of mist eliminators, and would require the same quench protection system. Quench systems are also required when FRP headers or glass or rubber-lined vessels are used.

The scope of delivery in addition to the manufacturing, delivery, and final assembly on site also includes the complete engineering, as well as the preparation of all construction and manufacturing drawings.

Stability calculations, considering stress in longitudinal, circumferential and radial direction, coming from the internal overpressure, from the pipe flexing as well as thermal expansion, are also included in Steuler's scope of supply.

Main Benefits of PP Spray Levels:

* Smooth, non-porous surface
* Standardized construction
* Short installation time
* No modification of PP surface
* Cost effective
* Maintenance free

PP Pump Screens

Steuler offers complete screen system fabrication, including delivery and installation of PP pump screens. Single screens for each suction nozzle separate or combine elements to cover the span between the pumps and are also provided.

Concrete / Bekaplast™ Scrubbers

Steuler utilizes its special lining system known as Bekaplast™, which has been field-proven for over 30 years in the chemical industry. It consists of large-formatted thermoplastic sheets with a thickness of 5 to 8 mm. Conical anchor knobs are welded onto the reverse side. These large knobs create a permanent, inseparable mechanical bond between the plastic lining and concrete construction. While the concrete structure is being built, the sheets are attached to the inner formwork, then cast into place together with the walls and ceiling. Even complex constructions can be executed with great speed and reliability.

Bekaplast™ is available in the material grades PP, PE, PVC, and PVDF. The standard sheets are equipped with 256 anchor knobs per m^2 Bekaplast™ and are produced in Steuler's Workshop. The sheets will be delivered to the site prefabricated according to size and shape of formwork and installed onto inner formwork. The lining grows together with erection of the concrete structure. After removing the formwork, the lining will be welded gastight and can be checked repeatedly by spark testing.

Thanks to its outstanding chemical, thermal and mechanical resistance properties, as well as its exceptionally high resistance to abrasion, Bekaplast™ PP is also employed as a mechanically anchored corrosion protection lining in concrete scrubber constructions.

Since the concrete structure and the lining are erected in one operation, this method offers significant advantages in terms of time. The finished structure may be exposed to loads immediately, and is operational right away. With this system, elaborate pre-treatment measures normally required for retrofit applications of customary corrosion protection linings, as well as health protection measures due to the use of dangerous chemicals, are unnecessary.

The conversion of process engineering plants to a concrete construction method also eliminates the necessity of elaborate prefabrication procedures and costly substrate pretreatment for large-scale absorption towers.

Even complex constructions can be executed with great speed and reliability.

Materials of Construction

In the lignite coal region of the Rhine River there are a total of 39 FGD plants built by various technology suppliers. The Niederaussem and Weisweiler plants went into operation in 1988. Thirty-seven of the FGD vessels are steel with rubber linings, and two are made of roll cladded plates of Alloy 59 (C-276).

Since the start-ups, various rubber-lining systems and their service life have been found to be as follows:

Type of Rubber Lining	Lining thickness	Operating hours
Chloroprene	1 layer — 4 mm	15,000
Chlorbutyl	1 layer — 4 mm	up to 60,000
Brombutyl	1 layer — 4 mm	up to 80,000
Butyl	2 layers — 8 mm	up to 100,000
Brombutyl	1 layer — 6 mm	>120,000

In the case of new rubber linings or if lining repairs need to be made, only brombutyl rubber with a 6 mm thickness (without vulcanization) is used. Any FGD system that requires rehabilitation and has headers made of steel with rubber lining or FRP are replaced with PP headers.

A number of other materials have been successfully used to construct wet FGD systems in different applications including:

- Acid Brick-Lined Carbon Steel
- High Nickel Alloy Clad Carbon Steel
- Fiberglass-Reinforced Plastic (FRP)
- Resin Coated Carbon Steel (flake glass-lined)
- Polypropylene (Bekaplast™)

One of the key design considerations for selection of materials of construction is the chloride concentration at which the FGD system will operate during its life. Table 2 presents a list of construction materials and the maximum annual chloride concentration at which the system can operate. Table 2 also shows the amount of wastewater a 600 MW FGD system will produce when firing an eastern bituminous coal. Wastewater treatment cost is a major consideration for owners. If a plant needs to install a brine concentrator and a wastewater treatment plant, it could add $30,000,000 to a 600 MW plant to reduce the chloride concentration from 50,000 to less than 12,000 ppm.

Table 2

Materials of Construction

Materials of Construction	Design Chloride Limits (ppm)	GPM Wastewater
317LMN Stainless Steel (S31726)	8,000	287
Duplex 2205 Stainless Steel (S32205)	12,000	141
Super Duplex 255 Stainless Steel (S32550)	20,000	115
Super Austenitic 6% Mo Stainless Steel (N08367)	40,000	57
C-276 (N10276)	>50,000	46
Carbon Steel/Glass Lined	>50,000	46
Carbon Steel/Rubber Lined	>50,000	46
Concrete/Tile Lined	>50,000	46
Concrete/PP Lined	>50,000	46

The selection of materials of construction is based on the following criteria:

* Resistant against chemicals
* Resistant against vapor diffusion
* Resistant against abrasion
* Long life
* Easy to apply (impacts quality control and quality of labor to install)
* Easy to repair in a short time
* Investment costs

The above materials do not have the same service life qualities nor do they have the same cost. In the United States, glass-lined and rubber-lined vessels are not widely accepted. In Germany, most bituminous-fired utility boilers use rubber-lined vessels. However, lignite boilers use a greater variety of materials such as alloys and polypropylene. Lignite FGD systems must operate at an exit gas temperature of 158ºF, while bituminous FGD systems have an exit temperature of about 133ºF. This higher operating temperature results in vapor diffusion through rubber and glass products, which shortens their operating life.

The most significant difference between construction materials such as rubber and glass liners are:

* Glass and rubber-lined vessel have a lower initial capital cost than an alloy vessel.

* All glass and rubber-lined vessels have a defined operating life: 5, 10 or 15 years depending on the material and operating conditions. At some point in their life, they may require a major outage for major repairs or replacement.

* Glass and rubber-lined vessels require some outage periods for routine maintenance.

* Owners have to make a selection of materials based on their life cycle cost evaluations.

One of the most significant impacts today on the cost of FGD construction has been the rapid escalation in cost of construction material, especially alloys. The most common stainless steels and alloys used in the construction of FGD systems are 2205, 317L, and C-276 which use nickel and chrome. Table 3 shows the change in cost of these materials since 2003. In addition, the devaluation of the US dollar has impacted the price of imported materials and fabrication. These factors have led to an increased use of tile-lined concrete vessels in the United States. At the present time Babcock Power has contracts for 4,200 MW of FGDs using tile-lined concrete vessels, 4,110 MWs of 2205 vessels and 1,330 MWs of glass-lined vessels. We assume this mixture is similar to other vendors' orders.

Table 3

Material Price Changes (Percentage)

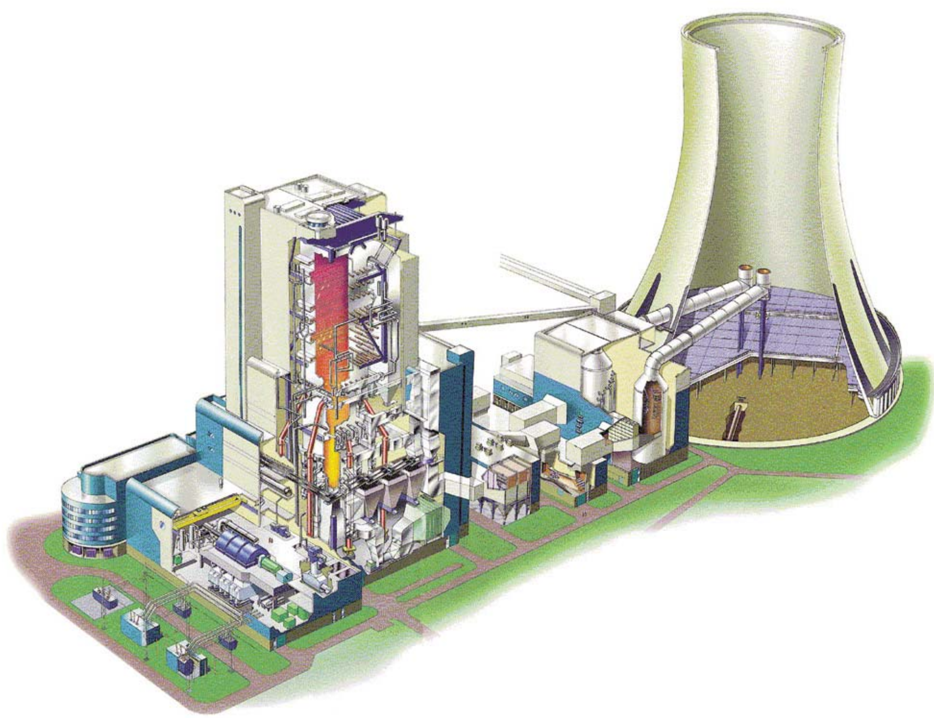
	10/01/03	05/01/07	06/01/07
Steel Scrap	Base	120.7	80.7
Nickel	Base	394.1	398.0
Hot Rolled Coil	Base	82.70	83.6
Hot Rolled Plate	Base	124.09	135.8
Molybdenum	Base	291.30	378.26
Chrome	Base	91.53	103.39
Vanadium	Base	190.91	227.27
Manganese	Base	90.00	125.00
Tungsten	Base	333.33	333.33
Copper	Base	344.71	317.40
Aluminum	Base	90.07	84.84
Euro/USD (EURO.EUR)	Base	-14.10	
Yen/USD (JAPANESE YEN.JPY)	Base	8.03	
Baht/USD (THAI BAHT.THB)	Base	-16.89	
Won/USD (South-Korea Won.KRW)	Base	-18.71	
Cad/USD (Canadian Dollar.CAD)	Base	-17.18	

The volatility in material cost led Babcock Power to investigate other materials that were being used to construct FGD systems. In discussions with RWE in Germany, RWE stated they were building two new large supercritical lignite fired boilers using a concrete vessel lined with PP. These units will fire local lignite with the following design features:

Design Features of Lignite Fired Boilers

Calorific value kJ/kg	Ash content %	Water content %	Sulfur content %
7,800 — 10,500	1.5 — 8.0	50 — 60	0.2 — 0.5

BOA Technical data:	
Gross capacity	1,100 MW ea.
Net power generation	965 MW
Net el. Efficiency (LHV)	> 43%
Lignite feed rate	820 t/h
Steam parameters	3987 psi/1112°F
Height of cooling tower	656 ft
Height of boiler house	564 ft



The air pollution control system for these plants consists of an ESP followed by a forced oxidation wet FGD system. The optimized FGD system would operate at chloride levels up to 70,000 ppm to minimize wastewater. RWE evaluated the life cycle cost of glass-lined, rubber-lined, alloy and PP-lined FGD vessels. Since both glass and rubber-lined vessels have defined operating life and may require two or three major replacements over the life of the plant, they were eliminated as economic construction options. RWE's alternatives were alloy and PP. During the evaluation period some of the alloys under evaluation doubled or tripled in price.

Based on their 25 year history of using PP in FGD systems, the requirement to operate the system with chloride concentrations up to 70,000 ppm, and the uncertainty of the cost of alloys, RWE elected to use Steuler's Bekaplast™ with a concrete shell and PP liner for the absorber vessel and drain tanks. They also selected PP spray headers and screens.

RWE selected PP vessels and spray headers based on the following criteria:

* Cost savings
* Wear resistance
* Resistance to caking
* Reduced repair cost
* Long service life

United States Market Conditions

At the present time there are about 50,000 MWs of FGDs in design or construction in the United States. The same market conditions that led RWE to look at alternative construction materials in Germany exist in the United States. The escalation in metals cost is not entirely driven by the FGD market, however; CAIR requirements have created a considerable demand.

A recent paper presented by Burns & McDonald provided the following table indicating the cost of alloy FGD systems. Table 4 highlights the escalation of various materials and components over the past four years when evaluating the cost of construction materials required for a wastewater treatment plant.

Table 4

Construction Material Pricing

Source: Burns & McDonald

Materials of Construction	Material Costs ($/ft)	Erection Costs ($/ft)	Installed Costs ($/ft)
317 LMN Stainless Steel (S31726)	$ 19	$ 39	$ 58
Duplex 2205 Stainless Steel (S32205)	$ 25	$ 39	$ 64
Super Duplex 255 Stainless Steel (S32550)	$ 48	$ 39	$ 88
Super Austenitic 6% Mo Stainless Steel (N08367)	$ 45	$ 39	$ 84
C-276 (N10276) (wallpaper)	$ 70	$ 47	$ 117
C-276 (N10276) (solid)	$ 98	$ 51	$ 148

Babcock Power was asked to look at a 600 MW FGD system burning an eastern bituminous coal designed to operate at 50,000-ppm chloride to minimize the wastewater discharge system. Using recent cost data for our existing projects and the data from the Burns & McDonald paper, we conducted an evaluation of alternative materials and construction techniques for this FGD application. The materials evaluated included C-276, rubber-lined carbon steel vessels, concrete tile-lined, and concrete PP-lined.

C-276 was eliminated due to the cost, and no detail designs were prepared. Designs and cost estimates were prepared for the concrete tile-lined, carbon steel glass-lined, and concrete PP-lined systems. Both the concrete tile-lined and the carbon steel glass-lined systems had FRP spray headers, and the concrete PP-lined system had PP spray headers.

Prior to starting work on the concrete PP-lined system, Babcock Power reviewed the designs of the BOA project with RWE and visited the Bekaplast™ FGD system in Mason City, Iowa. The Bekaplast™ FGD at Mason City is located on a cement kiln exhaust. This FGD went into service in February 2005 and handles the equivalent of an 80 MW coal fired boiler. The vessel is 23 feet in diameter and 88 feet tall. The flue gas SO_2 concentration is 1120 ppm or 2.16 lbs/MMBtu. Based on our visits with RWE and Mason City, a joint design for a 600 MW Bekaplast™ FGD was made with Steuler.

A comparison analysis of the capital costs of the three construction options (including material and labor) showed the Bekaplast™ FGD vessel and components were 28.8% less expensive than a concrete tiled system, and 10% less then a carbon steel glass-lined system.

CONCLUSIONS

Market conditions and material cost escalation require the industry to look at new construction materials. Polypropylene is currently being used for several FGD designs, and one of the largest FGD vessels in the world is currently under construction using this technology. PP is a definite option that needs to be considered as a construction material with the Bekaplast™ construction method.

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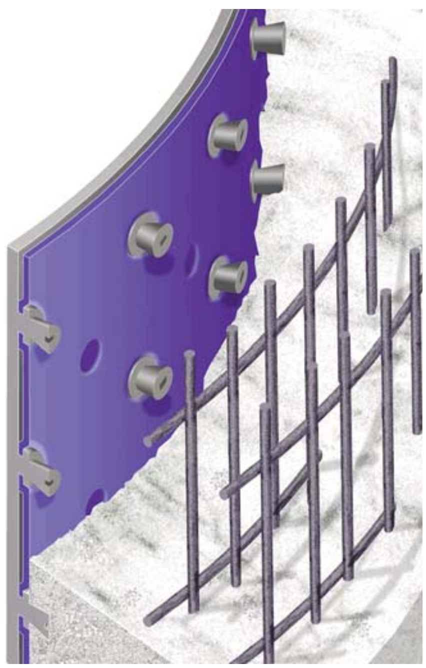
Recycle Pump Screens Made From Polypropylene



Bekaplast™ FGD Vessel Construction