HIGH-PERFORMANCE ANTICORROSION COATINGS

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SUMMARY

High-performance anticorrosion coatings are applied to steel and concrete structures to provide protection from corrosive environments. Generally, the coatings are separated into two major markets:

- Industrial maintenance or protective coatings applied to structures in the oil and gas, petrochemical, paper mills, and power generation industries, as well as to bridges and water and waste treatment plants. Most of these coatings are applied to structures that are "on shore," but some are applied to offshore oil and gas rigs.

- Marine coatings applied to commercial ships, including freight carriers, tows, cruise ships and others

The same types of coatings tend to be used in each market, and tend to be based mainly on epoxy, urethane, ethyl silicate, and to a lesser extent, acrylic, vinyl and chlorinated rubber binders. Epoxies account for around 40% of the global market; these coatings are noted for very good chemical and abrasion resistance and for excellent adhesion. Urethanes, accounting for 15-20% of consumption, display excellent color and gloss retention, and good abrasion resistance and flexibility. Ethyl silicates are used mainly as binders for zinc dust; these inorganic zinc coatings form excellent primers, providing superior corrosion resistance to the surface. Vinyls and chlorinated rubber coatings provide good corrosion protection and are easily applied. Often, combinations of coatings are used. As an example, the primer may consist of an inorganic zinc coating, while the intermediate coat is epoxy and the topcoat is urethane. Alkyds, which are polyesters modified with fatty acids or oils, are used in environments that are subject to little, if any, corrosive elements. Alkyds are still favored by many contractors because of their easy applicability, and are sometimes used on structures that have limited remaining service lives. Good growth is expected for coatings that are based on waterborne acrylics, especially in the United States, as environmental regulations become more stringent.

Heavy-duty coatings, applied to substrates subject to highly corrosive environments, account for about two-thirds of the total market. The other one-third consists of lighter-duty coatings applied to such areas as the interiors of industrial buildings and structures located in dry rural environments. However, architectural coatings, applied to residences, office buildings and the like, are not included. The value of the industry is much higher if one includes the value of surface preparation (cleaning the steel substrate to enhance adhesion prior to coating) and application operations. The cost of the coating material itself often amounts to only 10-20% of the installed cost of the coating. Coatings manufacturers have been stressing the life cycle concept to users over the past 20-25 years, pointing out that it is less expensive in the long term to use high-quality (and usually more expensive) coatings that have relatively long service lives; thus, savings in touch-up, repair and downtime costs can be realized over the lifetime of the structure. Unfortunately for the coatings industry, this message is becoming more difficult to sell; with the downsizing in the corporate world, many facilities have eliminated corrosion engineers and other coatings personnel who understand the value of maintenance painting.

Worldwide consumption of anticorrosion coatings in 2007 was about 1.5 billion liters (1.8 million metric tons) with a value of about $6.25 billion. In terms of sales on a dollar basis, the market has been growing at about 10% in recent years, but some of the increase is attributable to the continuing decline in the relative value of the dollar. The breakdown on the 2007 applications is as follows:

Table 1

World Market for High-Performance Anticorrosion Coatings—2007

	Sales		Expected 2007-2012 Growth Rate (percent)	Remarks
	Millions of Dollars	Millions of Liters		
Marine	3,500	644	5-7	The market was very strong in 2004-2008, especially in China, the Republic of Korea and Japan. Shipbuilding will probably peak in the next few years, but maintenance will increase. The value of coatings has risen in recent years as new antifouling paints have been replacing lower-cost, but environmentally harmful, tin-containing coatings.
Industrial Maintenance (onshore)	2,350	803	3-5	The market was strong in 2004-2008 due to global oil and gas drilling and production activity. Also there have been expansions in high-value infrastructure, especially in China and other parts of Asia.
Industrial Maintenance (offshore)	400	55	5-7	The market was very strong in 2004-2008 due to high oil and gas prices and drilling activity. Oil exploration will probably peak in the next few years, but gas production will continue to grow.
Total	6,250	1,502	5%	

SOURCE: SRI Consulting.

The markets in the three major industrialized regions of the world—the United States, Western Europe and Japan—are mature, and most growth is in the lesser developed world, especially China.

Table 2

Consumption of High-Performance Anticorrosion Coatings by Major Region
(millions of liters)

	United States	Western Europe	Japan	China[a]
1985	200	215	176	na
1988	210	220	151	na
1992	220	215	183	na
1995	230	225	178	na
1998	235	225	180	na
2001	220	207	181	na
2004	225	200	178	248
2007	235	230	188	300
2012	255	255	200	400

a. Excludes bulk cargo container coatings. In 2007, consumption was about 200 million liters.

SOURCE: SRI Consulting.

Comparing the three major industrialized regions, ship coatings are important in Japan, but much less so in the United States and Western Europe.

Table 3

Consumption of High-Performance Anticorrosion Coatings by Market and Major Region—2007 (percent)

	United States	Western Europe	Japan	China
Marine Uses[a]	20	30	59	24
Industrial Maintenance				
Oil and Gas Exploration, Production and Transmission[b]	18	13	11	18
Petrochemical Plants (including oil refineries and chemical plants)	13	12	5	14
Bridges and Other Infrastructure	12	13	16	5
Water and Sewage Treatment Plants	10	9	2	1
Public Utilities	8	11	5	1
National Defense and Space	7	2	0	2
Food and Beverage Processing Plants	4	6	< 1	1
Pulp and Paper Mills	2	2	< 1	1
Primary Metals and Mining Operations	2	2	0	1
Cargo Containers	<1	<1	0	31
Other Processing Uses (including textiles)	4	<1	2	1
Total	100%	100%	100%	100%

a. Includes coatings used in the construction, repair and maintenance of ships.

b. Includes onshore and offshore operations, and storage tanks.

SOURCE: SRI Consulting.

Most of these markets should grow at moderate rates in the next five years in the United States, Western Europe and Japan. Some of the faster growing segments in these regions should be the following:

- Water and wastewater treatment pipes and equipment, which is an area that is in need of considerable rehabilitation because of aging and neglect, and also because of the U.S. Clean Water amendments that have led to the generation of more corrosive wastewater
- Oil and gas exploration and production, a sector that is on the upswing because of the recent increase in oil and gas prices
- Marine coatings for repair of ships that are being operated at high utilization rates because of high freight rates
- Intumescent coatings, which are thin-film decorative finishes that provide a degree of fire protection when exposed to high temperatures

There should be much higher growth rates in other areas of the world. Consumption of anticorrosion coatings in China has been growing quickly. As an example, China has been aggressively increasing its presence in merchant vessel shipbuilding; in 1990, the country accounted for about 2% of the industry, and by 2007, this percentage had grown to nearly 20%, with further increases expected. Much of the growth has been at the expense of Western European shipyards. Practically all cargo containers are now made in China, consuming about 200 million liters of coatings per year.

Estimated regional 2007 consumption of high-performance anticorrosion coatings for industrial maintenance is as follows:

Table 4

World Consumption of Industrial Maintenance Coatings—2007[a]

	Millions of Liters	Percent
China	196	23
United States	185	22
Western Europe	160	19
Japan	76	9
India	55	6
Korea, Republic of	34	4
Middle East	30	3
Thailand	24	3
Taiwan	18	2
Eastern Europe, Africa, Latin America	15	2
Malaysia	14	2
Singapore	10	1
Pakistan	10	1
Australia	7	1
Vietnam	7	1
Indonesia	7	1
Other	10	1
Total	858	100%

a. Includes coatings applied to onshore and offshore structures and excludes marine vessels. Excludes coatings used on cargo containers and architectural and lower-performance coatings used on structures.

SOURCE: SRI Consulting.

Well over 80% of the global shipbuilding industry (large consumers of marine coatings) is now located in Asia. The following table shows how the industry has changed in the last fifteen years:

Table 5

World New Shipbuilding[a]
(percent)

	1990	1995	2000	2004	2007
Korea, Republic of	22	27	39	39	36
Japan	43	41	38	38	31
China	2	4	5	10	19
Western Europe	18	17	11	7	8
Other	15	10	7	6	6
Total	100%	100%	100%	100%	100%

a. Includes mainly merchant vessels, and excludes naval vessels and pleasure boats, which are more likely built in their home markets.

SOURCES: *World Fleet Statistics*, Lloyd's Register; SRI Consulting.

However, shipbuilding accounts only for about 40% of consumption of marine coatings. Ship repair is much more important in the United States, Western Europe and Singapore. The table below summarizes the global marine paint market by country.

Table 6

World Consumption of Marine Coatings—2007[a]

	Millions of Liters	Percent
Korea, Republic of	123	19
Japan	108	17
China[b]	104	16
Western Europe	70	11
Singapore	60	9
United States	50	8
Middle East	25	4
Taiwan	18	3
Philippines	18	3
India	15	2
Vietnam	12	2
Malaysia	8	1
Indonesia	7	1
Thailand	6	1
Australia	5	1
Pakistan	3	<1
Sri Lanka	2	<1
Other[c]	10	2
Total	644	100%

a. Includes coatings applied to marine vessels. Excludes any coatings applied to offshore structures.

b. Excludes consumption of architectural and lower-performance coatings used on houseboats, fishing vessels and others, as well as coatings used to repair some large vessels. Estimated 2007 consumption of all marine coatings was about 180 million liters.

c. Including Eastern Europe, Africa and Latin America.

SOURCE: SRI Consulting.

There are numerous manufacturers of anticorrosion coatings, with at least 100 in the United States alone. Many companies provide specialized products to small geographical areas and/or markets. Akzo Nobel is the leading supplier in the world, with an estimated 6% market share in the United States, 28% in Europe and a growing presence in Asia. Other leading producers are PPG, RPM and Sherwin-Williams in the United States and PPG, Jotun, Hempel and Sika in Europe. In Japan, Chugoku Paint (26% market share) and Nippon Paint (24%) are the leading suppliers, followed by Kansai Paint/NKM Marine Coatings (20% of the total) and Dai Nippon Toryo (10% of the total).

Merger and acquisition activity increased in 2005-2007 after a lull in the early 2000s. PPG has significantly increased its presence in the anticorrosion coatings market with the acquisition of Ameron and SigmaKalon. In 2007, Akzo Nobel acquired ICI, which mainly focuses on decorative and container coatings, but also has some presence in the North American anticorrosion coatings market. Some of the motivations of acquiring companies are to

- Increase raw material purchasing power.
- Spread research and development costs to more environmentally acceptable products over greater output.
- Acquire environmentally compliant technology.
- Take advantage of production and distribution economies of scale. As an example, the leading producer of marine coatings, Akzo Nobel, produces anticorrosion coatings at eighteen locations and maintains over 300 stocking locations throughout Europe, North America, the Middle East, Africa, Australia and Southeast Asia. Products are made to the same global specifications.
- Increase presence in rapidly growing areas. For example, some Western producers are acquiring coatings companies in China and India.

Sales of the leading 2007 suppliers are estimated as follows:

Table 7

Major World Suppliers of High-Performance Anticorrosion Coatings—2007 (millions of dollars)

	Sales Revenue		
	Protective	**Marine**	**Total**
Akzo Nobel Coatings (global)	320	1,100	1,420
PPG[a] (global)	390	390	780
Hempel (global)	150	500	650
Jotun Protective Coatings (global)	250	400	650
Kansai Paint (Asia)	238	112[b]	350
Chugoku (mainly Asia)	9	508	517
Nippon Paint (Asia)	187	160	347
RPM (mainly North America)	330	small	330
Sherwin-Williams (mainly North America)	300	small	300
Dai Nippon Toryo (Asia)	150	9	159
KCC (Asia)	43	110	153
Tnemec (North America)	75	--	75
Asian Paints/Berger International	50	20	70
Sika (mainly Europe)	55	--	55

a. Includes results of SigmaKalon, which was acquired in January 2008.

b. Includes results of joint venture with NKM Coatings.

SOURCE: SRI Consulting.

Many suppliers of anticorrosion coatings in the industrialized world have established or will establish satellite operations in developing countries.

The return on sales (before taxes) of an average producer of anticorrosion coatings is 5-10%. The cost of goods sold is 60-70% of the selling price; 75-80% of this amount is attributed to the cost of raw materials. Selling, general and administrative costs (including research and development) are 20-30% of the selling price. Generally, margins for coatings operations are higher in North America than elsewhere in the world.

Most of the current research effort in anticorrosion coatings is focused on the development of coatings that meet more stringent environmental standards dealing with emissions of volatile organic compounds (VOCs). The VOC regulations for industrial maintenance coatings were recently tightened in the Northeast United States and became very strict in Southern California starting in 2006. Europe is in the process of establishing continent-wide standards with a VOC Directive implemented in 2007. Complying high-solids coatings, having at least 60% solids content, are already being used, primarily in the form of two-package epoxies and urethanes. The industry has been using additional quantities of solventless epoxies and urethanes. Complying waterbornes are also being developed, and interest has been growing rapidly in acrylic-based waterbornes. Both types of compliance coatings are more difficult to formulate and apply than conventional low-solids coatings. Other R&D projects are directed toward the following:

- Coatings for potable water supplies that must contain low levels of toxic leachable compounds
- Coatings for oceangoing vessels that limit the buildup of microorganisms on the hull but do not contain any biocide that presents potential hazards to the environment
- Coatings that contain little or no toxic heavy metal pigment (lead- or chromate-based) or potentially hazardous organic solvent such as ethylene glycol–based ethers and esters, methyl ethyl ketone, methyl isobutyl ketone, toluene, xylenes and chlorinated solvents
- Coatings for concrete containment structures (such as those built around storage tanks) that resist migration of any spilled chemical into the concrete

INTRODUCTION

High-performance anticorrosion coatings are used to protect metal and concrete structures, tanks, pipes and processing equipment from deterioration caused by exposure to corrosive environments, including acid rain. These coatings are used chiefly in chemical plants, oil refineries, public utility works, pulp and paper mills and other facilities; in addition, anticorrosion coatings are used to protect ships, offshore oil drilling rigs and production platforms, and other structures used in marine environments. This report does not cover light-duty coating systems used to protect industrial structures, such as office buildings or warehouses, and does not include coatings used to repair railroad cars, airplanes, general machinery and equipment, and other goods; these coatings are grouped with original equipment manufacturer (OEM) finishes under appropriate product finish categories.

High-performance anticorrosion coatings are used for new construction as well as maintenance and repair. Their main function is to provide protection against corrosion, with aesthetics of lesser concern. Usually they are applied outdoors, sometimes under adverse weather conditions. The structures they protect are located in environments that are subject to adverse conditions such as wet or humid climate, abrasion, and/or chemical fumes. Generally, these coatings are relatively high-cost systems that are formulated to provide protection to substrates for at least five years before repair or recoating is required. Users of these coatings are willing to pay for this high performance to extend the service lives of their capital equipment and to maximize the intervals between expensive repair and refurbishing operations. Also, high-performance coatings provide an extra measure of protection to structures that contain potentially hazardous materials or are part of the public infrastructure (e.g., highway bridges). For cargo tanks on ships, coatings not only prevent corrosion but also prevent contamination of cargo and allow easy cleaning and inspection.

The demands on an anticorrosion coating can be numerous. It must

- Prevent serious damage to the structure even though there may be abrasion damage or breaks in the coating
- Be noncontaminating or inert to materials with which it is in contact
- Exhibit good adhesion to the substrate, even after exposure to extremes in temperature or other environmental conditions
- Have a pleasing appearance
- Possess good resistance to seawater or other corrosive environments
- Be applied economically and easily
- Present few or no toxicity concerns

The impact of corrosion is enormous; one study estimated the breakdown of direct costs in the United States as follows:

Table 8

U.S. Estimated Cost of Corrosion Prevention

Corrosion Prevention Measure	Item or Task	Estimated 1998 Cost (billions of dollars)
Protective Coatings	Cost of applying organic coatings	93.8
	Cost of organic coatings	6.7
	Cost and processing of annealing and galvanizing steel	1.4
Corrosion-Resistant Metal and Alloys	Cost of materials and application	7.7
Stainless Steel	Cost of materials and application	7.3
Cathodic and Anodic Protection	Cost of materials and application	2.2
Engineering Plastics and Polymers	Cost of materials and application	1.8
Corrosion Control Services	Professional consulting and contracting	1.2
Corrosion Inhibitors	Cost of materials and application	1.1
Research, Education and Training		neg
Total		123.2

SOURCE: www.corrosioncost.com

Another study estimated corrosion costs by industry as follows:

Table 9

U.S. Estimated Direct Costs of Corrosion by Industry

Sector	Industry	Estimated 1998 Direct Costs of Corrosion (billions of dollars)
Utilities	Drinking water and sewer systems	36.0
	Electrical utilities	6.9
	Gas distribution	5.0
Transportation	Motor vehicles	23.4
	Ships	2.7
	Aircraft	2.2
	Hazardous materials transport	0.9
	Railroad cars	0.5
Infrastructure	Highway bridges	8.3
	Gas and liquid transmission pipelines	7.0
	Hazardous materials storage	7.0
	Waterways and ports	0.3
Government	Defense	20.0
	Nuclear waste storage	0.1
Production and Manufacturing	Pulp and paper	6.0
	Petroleum refining	3.7
	Food processing	2.1
	Chemical, petrochemical and pharmaceutical	1.7
	Home appliances	1.5
	Oil and gas exploration and production	1.4
	Agricultural	1.1
	Mining	0.1
Total		137.9

SOURCE: "Corrosion Costs and Preventative Strategies in the United States," Publication No. FHWA-RD-01-156, Federal Highway Administration.

The authors of the second study noted that their findings only covered a portion of the U.S. economy, and determined the total cost by extrapolating the cost numbers to the entire U.S. economy. A total cost of corrosion of $276 billion was estimated, which was approximately 3.1% of the nation's GDP in 1998. The indirect corrosion costs (i.e., the costs incurred by other than owners and operators as a result of corrosion) are conservatively estimated to be equal to the direct cost; giving a total direct plus indirect cost of $552 billion (i.e., 6% of the GDP). Large indirect corrosion costs include (1) lost productivity because of outages, delays, failures, and litigation; (2) taxes and overhead on the cost of the corrosion portion of goods and services; and (3) indirect costs of nonowner/operator activities.

The National Association of Corrosion Engineers (NACE) believes that about one-third of this amount could be avoided with broader application of corrosion-resistant materials and use of corrosion control techniques. In the United Kingdom, the corrosion of major structures and equipment through inadequate protection costs an estimated £10 billion per year, or 5% of the GNP. An estimated 60% of the expenditures for maintaining the North Sea production platforms is spent for corrosion control. Agip S.p.A., the Italian oil and gas exploration subsidiary of Eni, estimates that it spends about $0.40 per barrel of oil produced on corrosion control. However, much of this expenditure is for corrosion-resistant metals, with much less spent for coatings. Antifouling paints are applied to the hulls of all oceangoing vessels. Without the coating, organisms attach on the ship bottom that add significant drag to the vessel. A fouled hull costs up to 40% more in fuel costs than a clean hull, or roughly $450,000 per year. Without the coating, ships would have to be dry-docked at more frequent intervals. The estimated savings in dry-docking costs are about $800 million per year.

Anticorrosion coatings can also be applied to cement, even though cement, largely a mixture of inorganic materials, cannot corrode. Coating concrete facilitates cleaning by allowing easy removal of oil and grease in warehouses and other structures, disinfection of food processing facilities, and radioactive disinfection of nuclear plants. Also, concrete is coated for safety, such as increasing slip resistance on flooring that is subject to oil and grease spills, and for containment of spills in storage areas. One of the more critical applications for concrete coatings is in the food processing industry, where floors must be easy to clean and disinfect, impervious and nonabsorbing, washable and nontoxic. A damaged floor can reduce efficiency, cause personal injury, and lead to unpleasant and unhygienic working conditions. The high cost of reinstalling a floor, in terms of disruption, inconvenience, and loss of production, makes it important to get the proper initial installation. This requires a thorough understanding of the environment, the best possible design, the choice of the most suitable product for the job and using appropriate installation procedures.

Total world consumption of anticorrosion coatings was about 1.5 billion liters, or 1.8 billion metric tons, worth about $6.25 billion in 2007. Total consumption of all coatings worldwide is roughly 35 billion liters, with a value of $70 billion. Thus, high-performance anticorrosion coatings represent 4% of the total volume of coatings, but about 9% of the total value.

PRODUCTS

RAW MATERIALS

Coatings are composed of four types of raw materials: resins or film formers, pigments (including extender pigments), solvents and additives. Film formers, the backbone of the coating system, serve to bind the pigment particles to the surface of the substrate. Resins that commonly serve as binders include alkyds, acrylics, vinyls, epoxies, polyesters and urethanes.

Pigments are finely ground, insoluble, dispersed particles that provide aesthetic qualities such as color and opacity; more importantly, they are added to anticorrosion coatings to improve impermeability. Commonly used pigments for aesthetics include titanium dioxide, iron oxides and carbon black. For enhanced corrosion protection, zinc dust can be added; this material is “sacrificed” in nature (a galvanic couple is established between the zinc and the steel surface; zinc tends to oxidize first, thus protecting the steel). Other anticorrosion pigments include zinc chromates and lead silicochromate. Use of these pigments has declined significantly in recent years because of toxicity concerns.

Extender pigments, such as calcium carbonate, mica, talc and clay, are included in coating formulations to reduce costs and enhance certain properties. In recent years, glass flake has been added as a filler to aid in the buildup of a barrier resistant to corrosive substances, especially as a coating for the bottom lining of storage tanks.

Solvents are volatile organic liquids used to disperse or dissolve the film-forming constituents; they also reduce the viscosity of the formulation (making it easier to handle and apply) and modify the setting rate, drying time, flow properties and flammability characteristics. Typically, aliphatic and aromatic hydrocarbon, alcohol, ester and ketone solvents are used. In some formulations, most or all of the organic solvent is replaced with water to make a more environmentally acceptable coating.

Additives facilitate the production, application and performance properties of the coatings. Commonly used additives are surfactants, plasticizers, thickeners, antifoaming agents, flow-control agents and pigment-dispersing agents.

COATINGS

The coatings used in high-performance anticorrosion applications are classified by type of binder. The principal binders, listed in order of importance, are epoxies, urethanes, ethyl silicates, vinyls, chlorinated rubber, acrylics and silicone-modified alkyds. Each has advantages and disadvantages (see Table 10); the selection of binder will depend on the desired physical properties and chemical resistance of the coating.

Table 10

Principal High-Performance Anticorrosion Coatings

	Advantages	**Disadvantages**
Acrylic	Environmentally acceptable when water-based Excellent gloss and color retention Rapid dry time Will not support mildew growth	Poor resistance to acids and strong solvents (although newly developed resins have improved resistance) Not suitable for immersion service
Alkyd	Easy to apply Low initial cost Good durability, gloss and color retention in mild environments Single package, easy application Good tolerance to poorly prepared surfaces Thin films Wide choice of raw materials and properties	Unsuitable for immersion service or corrosive atmospheres Limited heat resistance Embrittles with age Thick films have slow cure
Chlorinated Rubber	Fast drying and recoat times Very good overall resistance to acids, alkalies and oxidizing agents Low water vapor transmission Does not support mold and fungus growth Dried film is nonflammable	Limited solvent resistance Softens when exposed to certain acids and oils Requires good surface preparation Low solids content
Epoxy (two-component)	Very good chemical and solvent resistance Tough and abrasion-resistant Easy to apply Excellent adhesion Good flexibility Can be high-solids, waterborne, solventless or conventional solvent-based	Consists of two components that require mixing prior to application Prone to chalking and yellowing upon exposure to sunlight Limited heat resistance (95°C) Less tolerant to temperature extremes during application than other systems Difficult to recoat because of very inert surfaces Two-component systems must be applied with more specialized equipment by better-trained painting staff
Ethyl Silicate	Excellent corrosion resistance (when used as a binder for zinc to form inorganic zinc coatings) Excellent solvent resistance Extreme heat resistance (400°C) Fast drying	Must be topcoated for good resistance to strong acids or caustic substances Requires very good surface preparation
Silicone	Excellent heat, UV, electrical and water resistance Can be used to modify properties of other binders	Poor abrasion resistance and hardness Expensive
Urethane (one-component moisture cure or two-component)	Outstanding color and gloss retention, and yellowing resistance (if aliphatic isocyanate is used) High surface hardness and abrasion resistance High gloss; exhibits “wet look” Excellent chemical and solvent resistance Excellent film flexibility	Usually requires two packages Limited heat resistance (95°C) More expensive than most other coatings Uses isocyanate curing agents, which are potential health hazards Hard to recoat (surface must be abraded prior to recoating)

Table 10 (concluded)

Principal High-Performance Anticorrosion Coatings

	Advantages	Disadvantages
Urethane (continued)		
	Properties/costs can vary widely, depending on raw material mix (can use acrylic-, polyester-, polyether-, epoxy-, vinyl-, or alkyd-based polyols and aromatic or aliphatic isocyanates to tailor properties)	
Vinyl	Good durability, flexibility and toughness Excellent resistance to many chemicals and saltwater; preferred coating in acid environments Better weathering properties, recoatability and flexibility than epoxies Near foolproof application	Requires excellent surface preparation Poor resistance to aromatic hydrocarbons, ketones and esters Lower solvent and heat resistance than epoxies Low solids content; environmentally unacceptable in certain areas

SOURCE: SRI Consulting.

Generally, straight alkyds are not considered high-performance anticorrosion coatings because of their relatively poor chemical resistance; they are used widely as decorative topcoats in noncorrosive industrial environments. These coatings remain popular because of their ease of application, but they are gradually losing market share in the light-duty protective coatings market to waterborne systems. Many of these basic binders can be modified to provide a balance of properties. Table 11 lists some of the more important modified binder systems.

Table 11

Major Modified Binder Systems Used in High-Performance Anticorrosion Coatings

Coal Tar Epoxies	Made from coal tar and epoxy resins; often used for water-resistant linings. Have a long track record of providing excellent service in dams, canals and other similar structures at a relatively low cost. Coal tar supplies added moisture resistance. Can be formulated for high film build (10 mils per coat). One disadvantage to these coatings is that they are supplied only in dark colors, so application and inspection is more difficult.
Epoxy Esters	Made from a combination of an epoxy resin with a fatty acid. Compared with alkyds, epoxy esters display better adhesion and chemical resistance, but are more costly and exhibit less gloss and color retention after exposure to sunlight.
Modified Epoxies	Epoxy resin mixed with coumarone-indene resin, xylene resin, toluene resin, terpene phenol resin, dicyclopentadiene resin and others. Modified epoxy coatings have light color and are used to replace coal tar epoxy coatings with competitive properties and with less toxicity. Generally, these form thick films that are often applied over substrates contaminated with rust, oils or other matter. Often called “epoxy mastics” or “surface tolerant epoxies.”
Organic Zinc-Rich Coatings	Formulated using epoxy, urethane, vinyl or chlorinated rubber binders and zinc dust pigment. More tolerant of surface preparation conditions and easier to topcoat than inorganic zinc-rich systems.
Phenolic-Modified Alkyds	Improved gloss retention and water and alkali resistance compared with straight alkyds.
Silicone-Modified Alkyds	Made by substituting up to 30% of the alkyd resin with a silicone intermediate. Possess greater durability, gloss retention and heat and moisture resistance than straight alkyds.

SOURCE: SRI Consulting.

Table 12 shows that certain coatings are more effective than others at resisting breakdown upon exposure to corrosive conditions.

Table 12

Estimated Service Life of High-Performance Anticorrosion Coatings[a]
(years)

Coating System	Saltwater Immersion	Mildly Corrosive Environment	Moderately Corrosive Environment	Severely Corrosive Environment
Water-Based Acrylic Primer/Topcoat	na	16.5	12	9
Epoxy Primer/High-Build Epoxy Topcoat	6	18	12	9
High-Build Epoxy Primer/High-Build Epoxy Topcoat	7.5	19.5	13.5	10.5
Epoxy Waterborne	na	18	12	9
High-Build Epoxy Primer/Acrylic Urethane Topcoat	na	16.5	10.5	7.5
Inorganic Zinc/Epoxy Mastic/Polyester Urethane Topcoat	na	31.5	22.5	16.5
Inorganic Zinc/Epoxy Mastic/Acrylic Urethane Topcoat	na	30	21	15
Inorganic Zinc Primer/Waterborne Acrylic Topcoat	na	24	16.5	12
Zinc-Rich Urethane Primer/High-Build Acrylic/ Urethane/Acrylic Urethane Topcoat	na	30	21	15

a. Substrates are prepared to a Steel Structures Painting Council (SSPC) standard "SP-10 commercial blast" level prior to painting. Estimated service life is defined as the time between initial coating and when 5-10% of the coating has failed and active rusting of the surface is present (ASTM-SSPC No. 4 standard).

SOURCE: Gordon H. Brevoort, Michael F. McLampy and Kirk R. Shields, "Updated Protective Coating Costs, Products, and Service Life," presentation at the National Association of Corrosion Engineers (NACE) Annual Conference and Corrosion Show, April 1996, Denver, Colorado.

TECHNOLOGY

PRODUCTION OF COATINGS

The formulation of coatings is usually a batch operation since many of the finished products are custom made. The basic steps are as follows:

- **Mixing.** The resins, pigments and additives are mixed with appropriate solvents.
- **Dispersing.** High-speed dispersers and sand mills are used to separate, wet and stabilize the pigment and extender pigment particles.
- **Adjustment.** The mixture is adjusted or thinned with solvent and tested for viscosity, color and other properties.
- **Packaging.** The coating is then strained and put into containers.

APPLICATION OF COATINGS

The first step in the application process is surface preparation, to ensure that the surface is receptive to coating adhesion; good substrate preparation is as important as selecting a high-quality coating. The best results are obtained when the surface is blasted with steel shot or ceramic abrasive (grit) to remove oils, corrosion and any other contaminants. Blasting also increases the substrate surface area by abrading or roughening the surface. If a substrate is being repaired and is not badly deteriorated, a fresh coat can be applied to the topcoat; shot or grit blasting down to bare metal is not necessary.

Cleaning is sometimes performed with wire brushes in cases in which blasting equipment is not available, access to the job is limited or the repair job is too small to warrant the use of power equipment.

Industry has been increasing its use of high-pressure water blasting (pressure of about 35,000 psi) to eliminate the need for abrasives and the generation of dust and noise.

Coatings can be applied by using spray equipment, rollers or brushes. Spray equipment, which atomizes the paint particles and directs them under pressure toward the substrate, is used in most cases, since application is rapid and easy. However, using rollers or brushes reduces consumption of coating material since less is lost as a result of overspray. Rollers are most suitable for coating large, flat areas, while brush application is preferred for small areas and odd shapes.

The reactive epoxies and urethanes are applied in two-package systems in which the resin and curing agent are mixed just prior to use. The mixture has a “pot life” during which the coating can be effectively applied before significant gelation occurs. Plural-component spray equipment, which mixes the two components prior to atomization, is available but is cumbersome to use.

Many coatings are applied in multicoat layers: primers are formulated to maximize adhesion to the steel surface and provide good corrosion resistance; intermediate coats are applied to build film thickness and to provide a barrier to moisture and aggressive chemicals; and topcoats provide impermeability, weatherability and a pleasing appearance. Often, a complete coating system will entail the use of a variety of binders; for example, coatings suppliers often recommend the following coating system for steel that is in poor condition and that will be exposed to corrosive conditions:

- Blast-clean the surface
- Apply 3 mils of inorganic zinc primer
- Apply 4-5 mils of epoxy intermediate coat
- Apply 2 mils of urethane topcoat

This coating displays excellent corrosion protection, as well as good gloss and color retention.

Some coatings can be applied as thick film, single-component systems. These include epoxy mastics and coal tar epoxies, both of which form strong, impervious barriers to chemicals and moisture. Alkyd coatings that contain lead pigments were used as barrier coatings but have largely been replaced by the epoxies, which have a much longer service life and much shorter drying time. The advantages and disadvantages of multicomponent coatings are summarized below.

Table 13

Principal High-Performance Anticorrosion Coating Systems

	Advantages	**Disadvantages**
Three-Coat Systems (primer, intermediate, topcoat)	Fast drying/curing Less chance for pinholing Each layer has special function Good mechanical properties	Labor intensive Low solids
Two-Coat Systems (primer, topcoat)	Fewer layers Layers still have distinct functions Higher solids	More brittle More thixotropic (film thickness tends to be uneven)
One-Coat Systems (direct-to-metal)	One layer Can be solvent free	More brittle Chance of weak spots Short potlife, compromise in function

SOURCE: SRI Consulting.

OVERVIEW OF THE INDUSTRY

STRUCTURE OF THE INDUSTRY

The high-performance anticorrosion coatings industry can be divided into the following five segments:

- **Suppliers of Raw Materials.** This category supplies raw materials such as resins, curing agents, pigments, solvents and additives. Many of these products are manufactured and sold by a relatively small number of companies.

- **Coatings Producers.** There are a number of producers of high-performance anticorrosion coatings, with many providing specialized products and services to small geographic areas.

- **Specifiers/End Users.** This segment includes private firms or government agencies that have the responsibility for determining which types of coatings will be used.

- **Applicators/Contractors.** This category covers those who are responsible for applying the coating. At least 1,000 companies in the United States apply maintenance coatings on a contract basis. According to the Steel Structures Painting Council (SSPC), an estimated 70% of the anticorrosion coatings in the United States is applied by contractors, rather than by companies using employee painting crews. The average facility pays outside painting contractors an average of $1.5 million per year. The average contractor has revenues of about $7.4 million per year, performs 82 painting jobs, and employs 96 workers at peak season.

- **Inspectors.** Inspectors are hired by the end user to ensure that coating operations by contractors conform to specifications. They will also periodically inspect coated structures to determine when repair/touch-up operations are necessary and assess the causes of any coating failures. The importance of this function cannot be overemphasized. Documentation must be meticulous and extensive to resolve disputes in case of coatings failure. Some of the leading inspectors are KTA-Tator in North America (about 250 employees) and Corrpro (fifty offices worldwide). These relatively large companies offer a wide variety of services besides inspection, including coating maintenance programs, testing and evaluation, project management, failure analysis and expert testimony.

There are many producers of anticorrosion coatings. The technologies are well established and capital requirements are relatively low. Many smaller producers thrive by servicing a narrow geographical area. The top four producers of anticorrosion coatings account for about 60% of the market. The global leaders are listed in the following table:

Table 14

Major World Suppliers of High-Performance Anticorrosion Coatings—2007 (millions of dollars)

	Sales Revenue		
	Protective	**Marine**	**Total**
Akzo Nobel Coatings (global)	320	1,100	1,420
PPG[a] (global)	390	390	780
Hempel (global)	150	500	650
Jotun Protective Coatings (global)	250	400	650
Kansai Paint (Asia)	238	112[b]	350
Chugoku (mainly Asia)	9	508	517
Nippon Paint (Asia)	187	160	347
RPM (mainly North America)	330	small	330
Sherwin-Williams (mainly North America)	300	small	300
Dai Nippon Toryo (Asia)	150	9	159
Kumgang Korea Chemical (Asia)	43	110	153
Tnemec (North America)	75	--	75
Asian Paints/Berger International	50	20	70
Sika (mainly Europe)	55	--	55

a. Includes results of SigmaKalon, which was acquired in January 2008.

b. Includes results of joint venture with NKM Coatings.

SOURCE: SRI Consulting.

Total global size of the anticorrosion coatings industry is about $6.25 billion per year.

United States

At least 100 companies supply the U.S. high-performance anticorrosion coatings market. However, the five largest companies generated about 60% of total 2007 sales of about $1.4 billion. These companies are listed in Table 15 by market share.

Table 15

Major U.S. Suppliers of High-Performance Anticorrosion Coatings—2007

Company	Market Share (percent)	Remarks
RPM	18	See profile.
Carboline Company		
Rust-Oleum (industrial)		
Sherwin-Williams	17	See profile.
PPG	13	See profile.
Akzo Nobel (includes International Paint)	8	See profile.
Tnemec	5	See profile.
Sika	2	See profile.
ICI-Glidden	2	Acquired by Akzo Nobel in 2008.
Jotun	2	See profile.
Hempel	2	See profile.
Other Suppliers	31	
Benjamin Moore		
Wasser		
Miscellaneous		
Total	100%	

SOURCE: SRI Consulting.

RPM

RPM, based near Cleveland, Ohio, entered the anticorrosion coatings market in 1985 with the purchase of Carboline and a subsidiary, Wisconsin Protective Coatings, from Sun Company for $60 million. At that time, Carboline had sales of about $85 million, mainly of high-performance coatings for the construction, chemical, utility, bridge, pulp and paper, offshore, nuclear and petroleum industries. Wisconsin Protective Coatings' products are noted for their performance in extremely harsh conditions, especially in tank lining applications. In 1990, RPM acquired Kop-Coat (based in Pittsburgh, Pennsylvania), a leading manufacturer of coatings for water and wastewater treatment plants, for $35 million. At the time, annual sales of Kop-Coat were about $55 million. In 1991, RPM acquired the European operations of Rust-Oleum ($20 million in sales) and in 1992, the Martin Mathys operations ($24 million); the addition of these companies raised sales in Europe to $75 million per year. Also in 1991, RPM opened a business office in Singapore in anticipation of serving this growing marketplace. In Japan, a joint venture with Shinto Paint and Sumitomo Corporation (Japan Carboline) sells heavy-duty coatings.

RPM also owns Briner Paint Co. (Corpus Christi, Texas) and Sentry Polymers (Freeport, Texas). Briner is a leading supplier of coatings for high-temperature applications like furnace stacks, while Sentry specializes in secondary containment and flooring. Carboline assimilated the Briner product lines into its own portfolio.

In 1993, with the acquisition of Stonhard, Inc., RPM entered the market for industrial and commercial flooring and related products. Stonhard had annual sales of about $125 million in North America, Asia and Europe in 2007. The company has about 10% of the global polymer flooring business.

In 1994, RPM acquired the U.S. operations of Rust-Oleum for $175 million. Sales of the acquired company were about $150 million at the time, with consumer corrosion protection coatings accounting for about two-thirds of sales and industrial maintenance coatings accounting for most of the remainder.

RPM's strategy is to expand into technologies or geographic areas that exhibit promising growth. To expand the company's international distribution network, RPM acquired interests in Poland, China, Singapore and South Africa. The company started a manufacturing and distribution base in Poland in 1997. International sales have risen significantly in recent years, and now represent more than 25% of total corporate sales. Corporate sales have steadily increased during the past fifteen years, except during the recessionary 2000-2002.

In 2007, corporate sales were $3.3 billion, with the industrial sector accounting for 64% of RPM sales and the consumer portion 36%. From 2003 to 2007, corporate sales grew at a compounded average rate of 11.2% annually, with organic growth accounting for 8% of the total and mergers and acquisitions making up the remaining 3.8%. Historically, RPM has found that the consumer sector remains steadier than the industrial market, but the potential for upside is much greater with industrial sales. In 2004, RPM's sales mix was 54% industrial and 46% consumer.

During 2005-2007, there was considerable pressure from rising raw material prices on margins. RPM finds it easier to raise prices in the industrial sector than in the consumer sector where there is a concentration of buyers that are determined to keep retail prices at low levels. It takes about three months to raise prices in the industrial business compared with about nine months in the consumer sector. Carboline can bid on projects with higher prices, and if it finds it is losing too much business to competitors, readily decrease its prices, but on the consumer side, there is less dynamic interaction in the marketplace.

For almost fifty straight years until 2000, RPM achieved annual increases in sales and earnings, mainly through an aggressive acquisition program. The management of an acquired company is always retained; RPM claims that it has never lost an entrepreneur who has joined the company through acquisition. From time to time, RPM divests companies; usually, it sells companies that have product lines that have gone from niche markets to commodities.

Carboline offers a managed services program to provide technical guidance ranging from a simple coatings recommendation to facility-wide corrosion audit and comprehensive protective coatings program. The company's Maintenance Audit Program (MAP) combines on-site, total facility corrosion surveys and analysis with a comprehensive coatings maintenance program and planning schedule. Currently, Carboline employs about 130 sales engineers in the United States and Canada. It supplies coatings from three plants that serve seven major distribution centers and 22 warehouses.

In 2006, Carboline acquired the certain assets of Nu-Chem, an international provider of fireproofing products for structural steel. Nu-Chem specializes in intumescent coatings for the petrochemical and offshore markets.

In recent years, Carboline has introduced the following products:

- Carboxane 2000, which is based on polysiloxane technology.
- Carboline's 600 series which are epoxy-based coatings cured with phenalkamines.
- A/D Firefilm, a new generation of thin-film intumescent coatings.

- Galoseal WB, a water-based acrylic adhesion promoter that replaces polyvinyl butyral primers, which can no longer meet VOC regulations.
- Plasite 4555, a 100%-solids fast-cure reinforced epoxy lining for food-grade cargos.
- Carbocoat 8215, a quick-dry alkyd enamel with corrosion inhibition, which can be applied direct-to-metal.

In 2005-2007, RPM's industrial businesses showed good growth, which has offset the decline of some consumer businesses, which have been adversely affected by the housing slowdown. Generally, the Carboline and Tremco businesses tend to lag the general economy by about six months. The chemical and power plants and aerospace sectors have shown good strength, with growth of about 10% in recent years. Generally, RPM products are high quality and high priced with little price elasticity. RPM has seen governments refocusing on high-end, long-lasting products for infrastructure which benefits the Carboline and Stonehard businesses.

In 2007, Carboline announced the acquisition of the Marine & Industrial Assets of Finnaren & Haley, a national supplier of marine, industrial and architectural products. The marine and industrial coatings include a full line of new construction and maintenance coatings that are specified, sold and applied to U.S. government vessels, tugboats, barges, work boats and other shipyard customers/owners. Key customers are located throughout the United States. Finnaren & Haley marine coatings are also included as specifications for Army new construction, maintenance and for the Army Corps of Engineers. Sales are less than $10 million per year.

Total anticorrosion sales in 2007 were estimated at $330 million, with 75% in North America. This figure does not include any sales of Stoncor, a supplier of polymer flooring, which were about $115 million (6% of the global flooring industry), or any of Fibergrate, a supplier of fiberglass-reinforced structures.

Sherwin-Williams

Sherwin-Williams is the largest supplier of architectural coatings in the United States, with a market share of 35-40%. Coatings are sold mainly through a network of company-owned stores throughout the United States and to mass merchandisers. The company also manufactures and distributes maintenance coatings in its stores, as well as necessary application equipment. The remaining portion of Sherwin-Williams consists of the sale and marketing of industrial coatings (mainly sold directly to consumers) and automotive refinishes (mainly sold through about 145 separately owned stores). Total company sales were over $8 billion in 2007, with net income of more than $700 million. In recent years, Sherwin-Williams reports that sales of its industrial maintenance and marine coatings division have been growing.

It is estimated that Sherwin-Williams' 2007 sales of anticorrosion coatings were about $300 million. The maintenance coatings sales staff includes about 140 sales-service representatives and corrosion engineers. However, the key strength to the Sherwin-Williams strategy is distribution. Most of its industrial maintenance sales are alkyds and latexes used in relatively light-duty applications, such as office buildings and warehouses. These coatings do not require high levels of technical support; it is easy to sell large volumes of these coatings through retail stores. The stores cater to the contractor for both architectural and industrial maintenance sales—contractors account for an estimated 80-90% of Sherwin-Williams' store business. Besides an attractive inventory, the stores offer credit terms and training to these painters. Currently, Sherwin-Williams has approximately 3,200 stores in North America, which is almost 25% higher than the number in 2002. The closest competitor is ICI-Glidden (acquired by Akzo Nobel in early 2008), which has 660 stores in North America. It is believed that the contractor market will continue to grow in the architectural coatings sector, as more consumers are tending to hire outside help for painting instead of doing it themselves.

In late 1995, Sherwin-Williams acquired Con-Lux Coatings, a manufacturer of coatings for tanks, high-temperature use and severely corrosive environments, and Pratt & Lambert, a large manufacturer of architectural coatings. Pratt & Lambert mainly sells architectural coatings, but also markets maintenance coatings through its Southern Coatings subsidiary. In late 1999, Sherwin-Williams acquired General Polymers of Cincinnati, Ohio, which is a leader in supplying coatings for industrial flooring.

In 2004, Sherwin-Williams acquired Duron, Inc., which mainly produces and markets architectural coatings, but also sells about $20 million per year of maintenance coatings. Duron, based in Beltsville, Maryland, is a major regional coatings manufacturer and retailer serving the professional and do-it-yourself (DIY) markets in the eastern United States, and operates 230 company-owned stores. Duron stores and manufacturing facilities continue to supply Duron-brand products.

In 2004, Sherwin-Williams and three partners (B&H Coatings, Teijin Twaron and TechFab) announced the development of polyurea-based construction technology designed to provide resistance to the effects of explosions, a technology the company said represents “a potentially important development in defending against terrorism in the United States and abroad.” The technology involves the use of prefabricated reinforced polyurea panels that elongate and stretch, acting as a safety net to contain blast pressure and flying debris. Potential uses include new construction and retrofitting of existing structures in embassies, military installations, waterworks, nuclear plants or any place that might be subject to a terrorist attack. Compared with other construction technologies, prefabricated reinforced polyurea panels require less material, are easier to install, are less expensive to use, and can be shop-applied, thus assuring more consistent quality and less concern over worker and environmental factors.

In 2007, Sherwin-Williams introduced an ultra-high-solids epoxy coating that contains fluorescing optically active pigments, which allow tank lining applicators to check the coating instantly for discontinuities and verify uniform coverage and proper film thicknesses. After application, the coating is inspected with an ultraviolet light; any discontinuity or improper film thickness will appear dark compared with the fluorescing coating.

Some of the recently introduced product offerings include the following:

- “Hi Build” water-based catalyzed epoxy for institutional and commercial facilities
- Self-cross-linking alkyd primer with low VOC and low odor
- Fluorokem fluoropolymer urethane, which provides long-lasting protection to extreme exposures
- Fast Clad Epoxy coating with improved edge protection and faster cure time compared with conventional epoxies for pipeline coating repairs

PPG

In 2006, PPG acquired Ameron, a relatively large producer of marine and protective coatings. PPG was already active in the North American and European anticorrosion coatings market with sales of around $75 million, including the operations of Keeler & Long, which specializes in coating sales to nuclear plants and other utilities.

The former Ameron operation, based in Alpharetta, Georgia, has anticorrosion coating manufacturing plants in the United States, the Netherlands and the United Kingdom. The company has jointly owned operations in Mexico (Amercoat Mexicana) and Saudi Arabia (Oasis-Ameron, Ltd.), and it has numerous licensees throughout the world, including Argentina, Australia, Brazil, Canada, India, Indonesia, Republic of Korea, Malaysia, New Zealand, Peru, the Philippines, Singapore, Taiwan, Thailand, Trinidad and Venezuela. In addition to supplying coatings, the company offers complete turnkey contract management services, including plant surveys, specification of suitable products and supervision of coatings applications.

The former-Ameron's largest coatings market is the marine industry. It supplies tank linings, topside coatings and antifouling compounds, as well as field service to shipping and cruise companies and to the military. In the early 1980s, most of Ameron's marketing efforts were focused on coatings for new construction and facilities maintenance. By 1990, the company had made significant inroads into offshore oil and gas, utility, pulp and paper, concrete protection, wastewater treatment, food processing and other industries.

Recent financial results for Ameron's protective coatings and linings segment are shown in Table 16.

Table 16

Financial Results for Ameron Inc., Protective Coatings Division

	Sales (millions of dollars)	Income Before Taxes and Interest (millions of dollars)	Income Before Taxes and Interest (percent of sales)	Income Before Taxes and Interest (percent of assets employed)
1990	118.7	3.6	3.0	4.6
1991	134.3	5.5	4.1	8.0
1992	139.9	4.8	3.4	6.9
1993	137.8	1.5	1.1	2.2
1994	134.2	13.3	9.9	20.6
1995	130.5	3.2	2.5	4.5
1996	142.6	10.1	7.1	9.4
1997	190.7	16.8	8.8	14.0
1998	214.0	3.2	1.5	1.9
1999	199.4	9.2	4.6	6.2
2000	186.8	7.1	3.8	4.8
2001	188.8	9.8	5.2	7.4
2002	183.3	9.1	5.0	6.5
2003	190.3	9.3	4.9	5.7
2004	199.6	4.5	2.3	2.6
2005	209.8	5.6	2.7	3.3
2006[a]	152.2	5.3	3.5	na

a. Includes nine months of operations before the business was sold.

SOURCE: Ameron Inc. annual reports.

It is believed that about half of the company's sales are in the United States.

In 1995, Ameron consolidated its coatings operations in Little Rock, Arkansas, in order to reduce costs and improve efficiencies. Also in 1995, Ameron began marketing a siloxane-epoxy coating ("PSX technology") for anticorrosion coatings to compete with epoxies and urethanes. PSX coatings have the corrosion resistance of epoxies, but better weatherability. PSX coatings can be applied over a zinc primer to give a finish with properties comparable to a three-coat zinc primer/epoxy intermediate/urethane topcoat, but only two coats are needed, so there are considerable savings in labor. Thus, applicators save labor costs and can finish many jobs in two days instead of three. This is an increasingly important consideration due to the trend toward minimizing downtimes.

In late 1996, Ameron acquired the Devoe marine coatings business from ICI for $350 million for a company with annual sales of about $500 million and a slightly negative income, caused by the squeeze on margins resulting from escalating raw material prices. With the acquisition, Ameron became the leading supplier of marine and offshore coatings in North America. In addition, Ameron continued to manufacture and sell Devoe coatings to industrial maintenance markets in Europe, the Middle East and parts of Africa.

In 1997, Ameron acquired the maintenance coatings business of Valspar (sales of $18 million in 1996) in exchange for its product finishes business (sales of $16 million) and $2 million in cash. Also, in 1997, Ameron paid $46 million for the industrial paints businesses of Croda International, a UK-based manufacturer of specialty chemicals, coatings, inks, cosmetics and toiletries. The business included Mebon (the anticorrosion coatings business of BP) and HPG Industrial Coatings (the anticorrosion and plastics coatings segment of Herberts in the United Kingdom). Croda actually bought only the marketing rights from Manders and HPG, and dispersed manufacture of the paints to its existing sites. The only factory complex that was acquired was the Mebon site in Huthwaite. With the acquisition of Mebon and HPG, Croda had about 20% of the United Kindgom's anticorrosion coatings market.

Sales for Ameron's Coatings Division increased in 1998 as a result of the acquisition of Croda, but income dropped considerably because of the steep decline in volume and pricing of coatings sold to the offshore platform and marine markets. Activity in these sectors is closely tied to the price of oil. The downturn in the Asian economy also had a negative effect.

In mid-1999, Ameron started to expand marketing efforts in Brazil and China by appointing two licensees that could provide product to local businesses using Ameron technologies. Also, the company expanded distribution of proprietary fire-protection coatings (Amergard™ and Steelguard™) in Europe.

In 2001, sales to the U.S. marine and offshore markets increased, while European operations benefited from higher sales of fire-protection coatings, sales into Eastern Europe and the former USSR and strong demand for pipe coatings in the Middle East.

In 2002, Performance Coatings & Finishes' sales decreased by $5.4 million because of general economic conditions in the United States and Europe. Market demand remained weak throughout 2002 as major markets such as offshore, rail, industrial and petrochemical continued to be adversely affected by weak economic conditions.

In 2003, the industrial sector was generally soft worldwide, while the marine and offshore markets were improving. Performance Coatings & Finishes' sales increased by $7 million because of the appreciation of foreign currencies relative to the U.S. dollar. Sales in local currencies by operations outside the United States were relatively flat, while sales of protective coatings in the United States declined because of continued sluggishness in the chemical, industrial and marine markets. Industrial markets in Europe were similarly flat, but international demand for offshore and marine coatings improved in 2003.

In 2004, Ameron introduced a high-solids (87%), low-VOC (<150 grams per liter) surface-tolerant, user-friendly and universal-use general epoxy coating. The high solids content makes the coating especially attractive for quick build and, because of the universal nature of the coating, fewer products are required for major construction projects. Also in 2004, Ameron introduced an epoxy-based coatings line for the sizable industrial flooring market, which includes concrete flooring for areas such as manufacturing and warehouse facilities. A thin-film intumescent coating for fire protection of steel in high-rise buildings, currently marketed in Europe, completed Underwriters Laboratories' certification testing and was introduced in the United States early in 2004. Another development is an environmentally friendly tin-free, antifouling coating with a low copper release rate for the marine industry and ABC® Release, a silicone-based, non-biocide-containing elastomeric release coating designed to minimize fouling of ship hulls.

In 2004, the Performance Coatings & Finishes Group had higher sales because of the appreciation of foreign currencies relative to the U.S. dollar. However, the group posted lower profits, and continued to suffer margin pressures and weak market conditions. Sales increased in Europe because of increased sales of fire protection coatings, and in Australia and Asia because of sales of coil coatings. Sales declined in the United States, in part because of lower offshore oil and gas exploration and production activity. Both U.S. and European operations continued to struggle against weak demand for high-performance coatings used in chemical and industrial markets because of an apparent reluctance to increase spending on industrial infrastructure in North America and Europe. The U.S. offshore market also remained weak, but the marine market was solid.

In early 2005, Ameron opened a new branch in Pusan, Republic of Korea, to sell marine and offshore coatings. Han Jin, Ameron's existing Republic of Korea licensee, started manufacturing for Ameron under a toll manufacturing agreement.

Performance Coatings & Finishes' sales increased in 2005 due to improved market conditions in the United States, higher selling prices, higher shipments of lighter-duty product finishes by Ameron's Australian and New Zealand operations, and favorable foreign currency exchange rates. Ameron's European coatings operations had essentially flat sales as lower shipments to the Middle East and lower intumescent sales due to timing of product introductions offset selling price gains in Europe. The relative strength of the euro and the British pound constrained exports of Ameron's European operations, and sales of marine coatings declined, primarily due to the loss in the middle of 2004 of a contract to supply coatings to the U.S. Navy. The U.S. coatings market improved in 2005-2006, in part due to the rebuilding of the chemical, oil and industrial infrastructure along the U.S. Gulf Coast.

In 2007, PPG acquired Champion Coatings, based in Houston, Texas. Champion is a producer of coatings applied to marine vessels, rail and overland transportation equipment, offshore oilrigs, bridges, large buildings, and heavy industrial applications.

In 2008, PPG acquired SigmaKalon (see the **Western Europe** section), a large producer of architectural and anticorrosion coatings. As a result, PPG became the second-largest producer of anticorrosion coatings in the world, with annual sales of about $780 million. The Protective and Marine Coatings business now accounts for about 10% of total PPG coatings sales.

Tnemec

Tnemec, "cement" spelled backwards, was founded in the 1920s to supply coatings mainly to nearby oil fields. Today, Tnemec holds the position of the largest privately held company in the United States that specializes in industrial coatings for new construction and maintenance. Tnemec manufactures over 100 architectural and industrial coatings—from premium epoxies and polyurethanes to specialized fluoropolymer and polyurea products formulated specifically for extreme durability, enduring performance and enhanced aesthetics. Manufacturing facilities are in Kansas City, Missouri and Baltimore, Maryland, with warehouses in eight other locations in the United States. Tnemec has technical representatives in the United States, Canada, Puerto Rico, the Dominican Republic and the Czech Republic.

With sales of about $110 million per year and 260 employees, the firm derives 70% of its revenues from industrial maintenance, 25% from architectural and 5% from industrial OEM coatings. Tnemec's strategy for sales is to concentrate its marketing efforts on the specifier as opposed to the applicator of the coatings. Tnemec specializes in interior and exterior coatings for water storage tanks, and claims its products are used to coat about 75% of the water tanks in the United States. The key to success in selling coatings to the water and wastewater treatment market is to obtain the necessary approvals to meet specifications—for example, Tnemec was one of the first companies to obtain ANSI/NSF Standard 61 certification for coatings used in direct contact with drinking water. The acquisition of Chemprobe in late 1999 extended its product range to water-repellent products for concrete, masonry and wood. It also deals in specially formulated containment coatings as well as anticorrosive products for the food and drinks industry, power generation, pulp, paper and chemical industries.

In 2000, Tnemec introduced StrataShield Advanced Floor Technology into the industrial flooring market, including specially designed thin-film epoxies, urethanes, decorative laminates, chemical-resistant novolacs and trowel-applied mortars.

In 2004, Tnemec introduced a one-component, moisture-cured, micaceous iron oxide, zinc-filled perimeter steel primer, which offers triple corrosion protection for perimeter and structural steel. The first barrier is a moisture-cured urethane film. The second layer of protection uses micaceous iron oxide inside the urethane to create a platelet barrier. Moisture vapor that manages to penetrate the first two lines of defense reacts with zinc pigments, resulting in an oxidation process that causes the zinc to fill any voids the vapor used to infiltrate for added moisture protection. The use of the system allows less surface preparation and/or less costly steel reinforcement or replacement.

Western Europe

At least thirty companies supply the Western European market; the leading suppliers are listed in Table 17 and profiled following the table. The top six companies generated approximately 80% of this market's total 2007 revenue, compared with 65% in 1995. Total size of the Western European anticorrosion coatings market was about $1.4 billion in 2007.

As in the United States, there is little integration into coatings raw material production. Akzo Nobel formerly had a sizable coatings resins business but sold it to Nuplex in late 2004. The leading 2007 suppliers of anticorrosion coatings in Western Europe are:

Table 17

Major Western European Suppliers of High-Performance Anticorrosion Coatings by Market Share—2007
(percent)

Akzo Nobel	28
PPG	22
Jotun	12
Hempel	10
Sika	7
Other Suppliers[a]	21
Tikkurila	
W. & J. Leigh	
CIN—Corporaçao	
Miscellaneous	
Total	100%

a. Listed in descending order of approximate market share.

SOURCE: SRI Consulting.

Of the large suppliers, Akzo Nobel is the only one that is truly European-wide, with anticorrosion coatings activities in most countries. The other companies tend to specialize in certain geographic areas or markets such as PPG (formerly SigmaKalon, (in Benelux and France [marine coatings] and France [onshore protective coatings]), Jotun (Scandinavia—marine and offshore coatings) and Sika (Germany—protective coatings). In the United Kingdom, Akzo Nobel, Leigh and PPG together claim around 60-70% of the onshore and offshore protective coatings market, followed by Tikkurila (all onshore) and Hempel and Jotun (all offshore).

Akzo Nobel

Akzo Nobel is a large diversified chemical company with headquarters in the Netherlands. Total sales of the company in 2007 were 10.2 billion euros, split about 65% in coatings and 35% in chemicals, after divesting the pharmaceutical business in 2007. Earnings before interest, taxes, amortization and depreciation (EBITDA) for the coatings group were 143 million euros, for a margin of 9.4%. Akzo Nobel is now the largest producer of paints and coatings in the world; sales will increase even more in 2008 with the acquisition of ICI, which had coatings sales of 3.3 billion euros. Akzo Nobel is the global leader in architectural (decorative), protective and marine, powder and general industrial coatings. Revenues for the Marine and Protective Coatings Division were reported at 1.251 billion euros in 2007. Divisional sales are estimated among the segments as follows: Marine Coatings about 700 million euros, Protective Coatings were about 200 million euros, with other coatings (Aerospace Coatings and Yacht Coatings) accounting for the remainder.

Akzo Nobel became a major factor in the anticorrosion coatings industry with the 1998 purchase of Courtaulds, a major manufacturer of fibers, paints and various specialty chemicals. Courtaulds was also a large manufacturer of powder coatings, container coatings, coil coatings and yacht paints. In 1998, the Courtaulds Coatings & Sealants Group had sales of $573 million for anticorrosion, aerospace, powder, coil, container, architectural and other coatings. Operating profit was $13 million, with an 18% return on capital employed and a 9.5% return on sales. In the 1990s, Courtaulds had expanded its presence in East Asia; roughly 30% of its coatings sales came from this region by 1998.

Akzo Nobel continues to use the well-known International Paint name for its marine coatings business and International Protective Coatings name for the industrial maintenance sector. The group is also a major supplier of industrial maintenance coatings and focuses on six market sectors:

- Offshore and onshore oil and gas—from fabrication and equipment manufacturing to drilling production, refining and distribution
- Power generation, which most recently includes wind turbines where Akzo Nobel has a strong position
- Refining and chemical processing
- Pulp and paper plants
- Steel bridges and infrastructure
- Fireproofing

The company also is a supplier to the water, mining and paper industries in some regions. It began supplying marine coatings around 1900 and employs professional teams of supervisors that are based near local shipyards and dry-docks to service the business and assist yards, contractors and owners. Anticorrosion coatings are produced at eighteen locations and available from over 300 stocking locations throughout Europe, North America, the Middle East, Africa, Australia and Southeast Asia. Products are made to the same global specifications.

Sales and earnings for the marine coatings business were depressed in much of the world throughout the 1990s and early 2000s. However, sales and earnings have grown in the Asia Pacific region, mainly as a result of the increase in shipbuilding and ship repair. Akzo Nobel continues to expand operations in this region.

In late 1999, Akzo Nobel opened a major new $5 million product development facility in the heart of the global shipbuilding market on Koje Island, Republic of Korea. The laboratory occupies an area of 8,500 square meters. In 2001, Akzo Nobel started operating a new $17 million plant in Houston, Texas. The facility has updated manufacturing capabilities, with six production lines, and features greater productivity and environmental safety. The company notes that the improved batch size flexibility of the plant will improve customer service.

In 1999, Akzo acquired the Chartek® line of intumescent fireproofing coatings from American Textron Corporation. The products were developed for mission reentry vehicles in the 1970s for the NASA space program. The coatings are now used on offshore oil and gas platforms to mitigate the effects of potentially deadly fires. The product line continues to grow in the 2000s.

In May 2002, Akzo Nobel announced an agreement to acquire the worldwide marine and protective coatings business of NOF Corp., Japan, a purchase that included the marine and protective activities of U.S. Paint Corp. in the United States and NOF Europe. Total sales of the acquired group were 35 million euros in 2001. In October, Akzo Nobel strengthened its position in the Republic of Korea market by increasing its shareholding in the joint venture with DPI to 60% and by acquiring the marine coatings factory from its partner.

In 2002, International Paint introduced Interswift® 655 antifoulant which combines the patented copper acrylate self-polishing copolymer (SPC) technology of Intersmooth® Ecoloflex with the rosin-based controlled-depletion polymer technology of Interspeed® 340. This results in a high-solids, tributyltin-(TBT-) free antifoulant with surface tolerance and a relatively high-volume solids content, together with the SPC attributes of polishing rate control, control of biocide release, and reduced leached layer size. Controlled polishing rate and biocide release allow tailored specification design with optimum dry film thickness. The coating is functional for up to 36 months in service for the vertical sides and up to 60 months for the flat bottom. International Paint offers a “Hull Roughness Penalty Calculator” for ship owners, which shows how roughness extrapolates into added power requirements and fuel consumption. The owner can input variables (like the ship type, cost and consumption of fuel, and anticipated operating time before dry-docking) into the model to determine the potential costs for various types of coatings. The company notes that with container ships becoming larger and faster, the need to keep ships’ hulls as smooth as possible becomes ever greater.

In 2003, Akzo Nobel sold its Nordic industrial maintenance coatings operations to Tikkurila Coatings. The company launched Interfine® 979 polysiloxane technology for nonbiocidal antifouling, and experienced sales growth of the Chartek® fireproofing material.

In 2004, Akzo Nobel opened a state-of-the-art research and development laboratory in Felling, United Kingdom, and one in the Republic of Korea. The existing Felling R&D building was transformed into a Technology Center, and the existing Newtown Ferrers laboratory was upgraded. These improvements are part of a $10 million upgrade of the company’s global R&D facilities.

Like other coatings companies, Akzo Nobel has been very active in developing more environmentally acceptable coatings. It offers “Ecotech” coatings for industrial maintenance and marine applications which are environmentally friendly coatings that are either waterborne or high solids, and contain no isocyanates, coal tar pitch, red lead, zinc chromate, lead chromate, aromatic amine and low-molecular-weight aliphatic amine curing agents, ethoxy ethanol, chlorinated solvents, or free phenol. Coatings contain no more than 340 grams of VOCs per liter (which meets the new Ozone Transport Committee [OTC] requirements in the United States). International Paint now offers coatings based on acrylic polysiloxane (U.S. Patent 6,281,321), which have been used on a number of high-profile projects around the world, including British Airways London Eye, Barcelona’s iconic Hotel Arts, Singapore’s Changi Airport extension, Vancouver’s Broadway Station project, the Ganghui Plaza in Shanghai, and the Melbourne Gateway in Australia, as well as roller coasters, bridges, stadia, and office buildings in a wide variety of countries.

In October 2004, the technical alliance between Akzo Nobel and Nippon Paint in the marine field in Asia Pacific was dissolved, ending a 27-year association, although transferred technology can continue to be used (Nippon Paint’s Ecoloflex technology is used in Intersmooth, and International Paint’s Intersleek biocide-free silicone coating technology is used in Nippon Paint’s Ecolosilk). International Paint started supplying the Asian marine market directly in November 2004 from its Republic of Korea coatings plant, which has capacity of 50 thousand metric tons per year. International Paint supplies its full range of shipbuilding, drydocking and seastores products and supply services to both local customers and foreign flag vessels. All products are supplied from the company’s central warehouse near Kobe, or from regional depots.

In 2004, International Paint opened a Central Distribution Center (CDC) to serve its U.S., Canadian and Central American customers. The 55,000 square foot facility, located in Houston, Texas, now warehouses and distributes the full line of protective and marine coatings and Chartek fire protection products to sixteen smaller distribution stations that service customers in three countries. In 2007, International Paint opened a new distribution center in St. Louis, Missouri, to service the North Central United States. The company now has about thirty warehouses all over the United States. Akzo Nobel is especially strong in the U.S. Gulf Coast, primarily as a supplier of offshore coatings. It also has a strong presence in Canada and Mexico.

Like other anticorrosion coatings suppliers, International Paint offers a turnkey maintenance coating service (“Interplan”), which offers in-depth analysis and assessment. Recommendations incorporate the life and age of the plant, the environment, the condition of existing coatings, and budgetary constraints. The plan establishes a historical record and facilitates long-range planning, estimating and budgeting. Also, International Paint maintains a “Dataplan” which details the coatings’ performance on 170,000 dry-dockings and shipbuildings since 1977.

In 2006, International Paint increased prices for marine coatings, reacting to a dramatic new raw material cost base. In 2005, the price of oil increased by nearly 50%, resulting in a consequent 20% price rise for key solvent groups for marine products. In addition, prices rose even higher for zinc (increase of over 50% in 2005), copper (40%) and aluminium metals (over 20%).

In 2006, revenues from the Marine & Protective Coatings unit were about 1.1 billion euros ($1.5 billion), which was 26% higher than in 2005. Double-digit volume growth and internal cost savings offset high material prices in the marine coatings business. Akzo anticipates that the protective coatings market should grow with continued strength in the oil and gas market, as well as continuing installations of power stations and wastewater treatment facilities. Marine coatings will continue to benefit from increased production of natural gas tankers.

In mid-2007, Akzo Nobel’s International Paint business officially opened its new 7.3 million euro R&D Technology and Administration Center at Felling, Gateshead, in the United Kingdom. The facility is part of International’s ongoing development plans and follows a previous R&D investment at the site completed in 2004. It will serve International Paint’s worldwide Marine, Protective and Yacht Coatings businesses and is now in one central location, replacing previous laboratory facilities which had evolved around buildings dating from the 1920s. In mid-2007, International Paint announced plans to expand and modernize its R&D facility in Houston, which allows the company to develop and test new environmentally friendly products in the United States, where environmental laws tend to be the most stringent.

In recent years, International Paint has introduced a new fire protection product, Interchar®, based on technology created for NASA, and a silicon- or fluoropolymer-based foul-release coating, Intersleek®. Also in 2007, International Paint announced a partnership with Lloyd’s Register to offer shipyards in China step-by-step advice on how to meet the requirements of the new Performance Standard for Protective Coatings (PSPC), which were adopted by the International Marine Organization in 2006. The partnership offers a “gap analysis,” which estimates the extra costs that a shipyard will incur to meet the new IMO standards. The new regulations can add up to 10% onto the current costs.

In 2007, Akzo Nobel acquired Ceilcote from KCH Group for about 12 million euros. Ceilcote specializes in supplying anticorrosion coatings to the petrochemical and power industries for both new and maintenance projects. Ceilcote is based in Cleveland, Ohio, with manufacturing and administrative personnel. Total employment is about 35.

In 2007, the Marine business grew significantly due to strong volume growth, in particular in Asia. The Protective Coatings business also grew as well in all regions. Akzo Nobel is now the largest manufacturer of marine and protective coatings in the world with over 20% of the global $6.25 billion market.

In early 2008, International Paint announced that it received the Lloyd's Register IMO PSPC (Performance Standard for Protective Coatings) Type Approval for Intershield® 300, an abrasion resistant, aluminum pure epoxy coating.

PPG (SigmaKalon)

SigmaKalon was formed upon the 1998 merger of Sigma Coatings and Kalon, members of Petrofina and Total, respectively. The subsequent merger with Elf created the current international giant oil and chemicals company TotalFinaElf. In 2003, Bain Management Capital acquired SigmaKalon for approximately $1.15 billion. In 2007, PPG purchased the business from Bain for about $2.2 billion. PPG paid about 8.8 times earnings before interest, taxes and amortization (EBITA) of the operation, indicating that the 2007 EBITA was $250 million.

SigmaKalon is the fourth-largest coatings company in Western Europe and Sigma Coatings is the part of the company that specializes in marine and protective coatings. Prior to the merger in 1998, Sigma Coatings had sales of about $700 million and Kalon had sales of around $750 million. Sigma specialized mostly in industrial coatings, with marine and anticorrosion coatings accounting for about 35% of the total coating sales. Kalon specialized more in decorative coatings, with sales in protective coatings estimated at around $50 million per year, mostly in France.

Total sales of SigmaKalon were about $3 billion in 2007 and $2.6 billion in 2006, compared with $1.6 billion in 2001. Operating income in 2001 was $106 million. Total 2006 sales of marine and protective coatings were $440 million; decorative coatings sales account for about $1.9 billion, with other industrial coatings accounting for the remaining $240 million. SigmaKalon is the third-largest global supplier of marine coatings and the fourth-largest supplier of protective coatings. The geographical breakdown on its 2004 sales are as follows:

Table 18

Sales of SigmaKalon—2004
(percent)

	Marine Coatings Sales	Protective Coatings Sales
Europe	50	63
Korea, Republic of	20	7
South America	--	6
Other Asia	29	24
Other	1	--
Total	100%	100%

SOURCE: SigmaKalon 2005 Company Presentation.

PPG noted that the acquisition would improve its global scale in coatings with raw material procurement and new technology opportunities. The company announced the following motivations behind the acquisition:

- Strengthen its European industrial coatings presence
- Supplement growing global marine and protective coatings businesses

- Grow positions in Eastern Europe and Asia
- Add channels through its distribution footprint

In 1998, SigmaKalon built a plant in China to manufacture marine coatings. The costs of moving the marine coatings operations to Asia were recouped almost immediately due to the lower logistics costs. The protective and marine coatings business operates one facility each in Belgium, China, Indonesia, Republic of Korea, and Malaysia. In Japan, SigmaKalon partners with Shinto Paint in the marine coatings business.

In 2000, Sigma started to offer SigmaPrime, a universal epoxy primer, suitable for application to virtually any part of a ship, including ballast tanks, underwater hull, decks, superstructure, cargo holds, cargo tanks, and on internal surfaces. It can be applied to any kind of metallic surface, including mild steel, aluminum, stainless steel, galvanized steel, or blasted surfaces. Any type of topcoat can be used, including epoxy, alkyd, chlorinated rubber, urethane or acrylic. The benefits to coating applicators are reduced inventory, increased user familiarity, improved production speed, and less waste.

Like all other manufacturers of marine coatings, Sigma started offering TBT-free alternatives for antifouling in the early 2000s. Sigma AlphaGen antifouling products are based on a proprietary binder (believed to be vinyl pyrrolidone) that slowly releases cuprous oxide biocide, and that are effective for up to sixty months. Sigma Marine Coatings maintains a Color Network that is able to provide one thousand colors in four marine paint coating types (alkyd, acrylic, epoxy and urethane) in the major ports of the world, ready for shipment.

In 2002, Sigma Coatings announced the launch of AlphaTrim, a new-generation, cost-effective, tin-free antifoulant coating in the AlphaGen series designed to meet scheduling requirements up to 36 months. Sigma says the new coating is fully compatible with most existing antifouling systems and can upgrade a conventional or TBT self-polishing antifoulant coating. The polishing rate of Sigma AlphaTrim is designed for deep-sea operating vessels with operational speeds of 15-25 knots and operational rates of 70-90%. Complementing the system is SigmaSeal, which is claimed to completely seal in existing TBT-containing antifoulants, thus avoiding the need for expensive removal by grit blasting and providing a cost-effective, user-friendly route to tin-free upgrade. Sigma Glide is a TBT-free, biocide-free, self-polishing antifoulant applied to vessels that sail at a speed of at least five knots. At that speed, the antifoulant coating starts dislodging; at fifteen knots, the hull is free of all foreign matter. Some relevant SigmaKalon patents on self-polishing copolymers cover hydrolysable polyorganosilylated carboxylate monomers and polymers with precisely controlled content of silicon (EP 1 380 611), trialkylsilylated carboxylate monomers (EP 1 389 214) and copolymers based on trialkylsilyl esters of ethylenically unsaturated carboxylic acids (EP 1 263 819).

In 2003, Sigma established facilities for producing marine coatings in Asia, with operations in the Republic of Korea, Indonesia and Malaysia, thus becoming the fourth Western firm to enter this market (besides International Paint, Jotun and Hempel). Also in 2003, Sigma became the first major supplier of ship coatings to begin operations in Nigeria to supply the oil and marine industries.

In early 2004, Sigma started partnering with Samsung Fine Chemicals to provide industrial maintenance, marine, coil and general industrial coatings in the Republic of Korea. The company is known as Sigma Samsung Coatings, and is one of the leading suppliers of coatings to the Korean shipbuilding industry. The partners will continue to serve their separate customer bases, but will combine manufacturing facilities and technical support.

In early 2005, SigmaKalon announced that it was relocating the marine, protective coatings and decorative businesses in the United Arab Emirates and Oman under the management of one team located in Dubai. Also in 2005, Sigma's U.S. production facility was ruined by Hurricane Katrina; the company continued to service customers through arrangements with other producers.

In 2006, SigmaKalon opened a new R&D Center in Kunshan, China, which services its marine and protective coatings business in northern Asia. The $1 million center employs 28 professional chemists. Its equipment can reproduce the harshest conditions in marine and petrochemical environments. SigmaKalon has been active in the Chinese market since 1990. In 1998 a dedicated protective and marine coating manufacturing plant was opened in Kunshan, and expanded for the second time in 2006 to a capacity of 35,000 metric tons per year.

Jotun Protective Coatings

Jotun Group manufactures and markets decorative, marine, protective (i.e., industrial maintenance) and powder coatings. The company is headquartered in Norway, began operations in 1920, and began to do business outside of Europe in the early 1960s with the start-up of a factory in Libya in 1962. Jotun now has more than thirty factories outside Norway, primarily in the Middle East, Southeast Asia and Europe. About 70% of company sales are from outside of Norway, with one-third of global revenues from sales in Asia. The group is made up of some fifty wholly owned or joint venture operations in 33 countries, with 3,400 of the group's 4,500 employees working outside Norway. The worldwide production and sales network, with both fully owned and joint venture facilities in the rest of Europe and also in the Persian Gulf, Southeast Asia, South Africa and Australia, gives Jotun access to international oil and gas projects. It has about 250 personnel supporting the marine coatings business.

Jotun Group, with total sales of $1.5 billion in 2007, is divided into four main divisions: Decorative, Paint, Coatings and Powder Coatings. The Coatings division, established in 2003, focuses on marine and protective coatings, with its main activities in Europe and northeast Asia, which are home to the largest shipping markets and environments. Other operations are in the United States, Australia, Singapore and South Africa. The Paint Division is responsible for sales of decorative, marine and protective coatings in the Middle East and Southeast Asia.

In the early 1990s, the company began viewing the European market as too mature and competitive, and therefore focused growth plans in Asia. In 1991, it built a new $12 million facility in Singapore, which increased production by a factor of three, to 14 million liters per year. It has also built a plant in the Republic of Korea, and has a joint venture in Japan with NOF Corporation, and another in Thailand. In 1995, Jotun strengthened its presence in Saudi Arabia by acquiring a 40% share in Red Sea Paints. Jotun now has the capability to make its own binders in Saudi Arabia.

In late 1998, Jotun opened a new paint factory in Thailand capable of making 40 million liters of paint annually. The new facility replaced an existing smaller unit. The cost was announced at around $40 million, representing the biggest investment in company history.

In early 1999, Jotun acquired the worldwide marine coatings business of Valspar, which had sales of about $25 million per year. Valspar continues to manufacture paints for Jotun in its Garland, Texas plant.

Also in 1999, Jotun entered a partnership with NOF Corp. of Japan to produce NOF-developed silyl acrylate and silyl methacrylate antifouling ship coatings, using copper compound as a biocide. With the arrangement, NOF raised its capacity for making antifoulant coatings from 2 thousand metric tons per year to 3.5 thousand metric tons per year.

The year 2000 was difficult for Jotun, with sales and profitability falling compared with 1999. In 2000, Jotun acquired Products Research Service (PRS), a regional manufacturer of marine, protective and industrial coatings based in Belle Chasse, Louisiana. PRS markets coatings in the Gulf of Mexico region and operates production facilities in Belle Chasse and warehouses and sales offices in Lafayette, Louisiana; Houma, Louisiana; and Houston, Texas. Jotun was motivated to acquire operations in the United States to increase its presence at engineering companies serving the oil and gas sector, since about 80% of the specifiers working in these companies are based in the United States. Jotun believes that acceptance and approval of its products in the region will improve its potential to sell to affiliated operations in the Middle East and Asia.

Sales picked up again in 2001 principally because of the boom in shipbuilding in Southeast Asia and improvement in the global oil industry resulting from the increase in oil prices; however, operating margins dropped a further 15% to a level of 3.5% of sales. Global marine coating sales accounted for about 50% of Jotun’s sales and were about $320 million in 2001; protective coating sales were about $120 million.

In 2001, Jotun announced an expansion program of its U.S. operations, including a series of investments at its Belle Chasse, Louisiana, manufacturing and laboratory complex, with production expanded to offer a broader product range designed specifically for the U.S. market. Jotun introduced “Multicolor” which allows tinting marine and protective coatings closer to the customer, thus improving efficiencies. In the United States, Jotun has already tinted over 500 thousand liters of coatings using Multicolor machines specially developed for industrial coatings. Also in 2001, Jotun opened a plant capable of making 5 million liters of architectural, anticorrosion, and marine paints per year in Yemen. This facility, Jotun’s ninth in the Middle East, cost $15 million.

In 2002, Jotun A/S and NKM (joint venture between Kansai Paint and BASF-NOF Coatings of Japan) formed the SeaStar Alliance to serve the world marine and offshore coatings market. SeaStar Alliance, which has more than 20% of the global marine market, provides a global presence that ensures that products and services are readily available wherever a ship is being built or drydocked, supported by numerous coatings advisors approved by either FROSIO (Norwegian professional council for education and certification of inspectors of surface treatment), NACE or similar organizations.

Jotun developed “SeaQuantum” TBT-free self-polishing antifouling coating in conjunction with NKM. SeaQuantum hydrolyses in water, thus helping to minimize hull roughness throughout the lifetime of the coating. Because the surface becomes increasingly smooth as the coating wears, there are major financial benefits when it comes to operating a vessel, as the fuel consumption is reduced because of the reduced friction. Jotun offers five versions of “SeaQuantum” that are designed for specific use conditions, depending mainly on the speed of the vessel and its propensity to fouling. The product has been applied to nearly 2,000 vessels since 1993.

In 2003, Jotun relocated some of its Middle Eastern paint production to Dubai, United Arab Emirates, where it manufactures architectural, anticorrosion and powder coatings. Production capacity is now 60 million liters per year, with tank farms and silos with more than one thousand metric tons of raw material capacity. Industrial coatings are used for gas and water pipes, for the new airport in Dubai and by the flourishing ship repair industry, which is centered at the huge dry dock facilities in Dubai. In addition, there are shipbuilding facilities for yachts, leisure boats and small warships. The thirty-year-old Rashidiya facility was closed. Jotun now employs about 1,100 personnel in the Middle East.

In 2003, Jotun sold its cathodic protection and pipe antifouling businesses to Cathelco in return for ownership of a 10% share of Cathelco. Cathelco, with about £7.5 million turnover, is the leader in the marine antifouling pipe market with a record of 8,000 installations on ships of all sizes over a period of more than forty years. It developed an impressed current cathodic protection (ICCP) system now fitted to around 4,000 vessels. Jotun has been supplying ICCP hull protection systems to shipbuilders and operators of oil rigs since the 1960s.

In 2003, Jotun noted that global shipping enjoyed high levels of activity but the marine coatings market suffered because of excess production capacity. Major players attempted to strengthen their positions by capturing market share, resulting in squeezed margins and poor profitability. Because of a sharp downturn in the European marine coatings market in 2003, Jotun streamlined its organization in Europe, including the restructuring of operations in Spain. Jotun continues to strengthen its position in Asia and decrease its involvement in Europe to reflect the new realities of the shipbuilding and repair industry, since Asia now accounts for over 80% of ships being built and over 50% of ship repairs.

In late 2004, Jotun announced the development of "Hardtop Flexi," an impact-resistant polyurethane formulation that is currently unequaled in its flexibility, and also matches the highest levels of color and gloss retention expected of polyurethane topcoats.

In 2004, Jotun announced that it planned to invest $2.5 million in an industrial paint plant in Duque de Caxias, Rio de Janeiro (Brazil), to be started in December 2005. The new development was prompted by the new offshore oil construction projects by the Brazilian state-owned oil and gas company Petrobras. Jotun supplied 500 thousand liters of paint over two years at one installation through the Fels-Setal-Technip consortium. Jotun's new plant had an initial capacity of 5 million liters per year, with plans to reach 10 million liters within three or four years. In the first stage, 80% of production was directed at exports, although the group intended to supply 50% to the domestic market. Jotun will concentrate on the offshore, industrial and marine sectors in Brazil.

In late 2004, Jotun announced the development of new antifouling paints called "SeaForce" that contain unique, nontoxic plasticizers to keep most antifoulants from becoming brittle and losing effectiveness over time. The company also introduced "Jotuncote Universal," a universal primer designed to reduce the number of products required by applicators. In turn, the painting process is simplified in that paint volumes, thinners, cleaning and downtime, waste, manpower needs and logistics complexities are all reduced.

Like most coatings producers, Jotun is concentrating the activities of its 160 R&D personnel on the development of environmentally friendlier production processes and products. Work is concentrated on water-based technology and solvent reduction, and a recent joint $2 million project with Statoil focused on the creation of new and improved products for offshore anticorrosion treatment that reduce or eliminate health hazards. In one project, the joint research effort decided that it would be more economical and more environmentally acceptable to coat an oil drilling platform scheduled to last 25 years with unsaturated polyester instead of a more traditional coating.

In 2004, the marine and protective coatings sectors experienced increased sales and volumes over 2003, but earnings were down, primarily because of a sharp increase in raw material prices, which were not totally offset by higher selling prices.

In early 2005, Jotun formed a joint venture with HAS Group, based in Yemen. The $5 million joint venture started production in mid-2005 in a 5 million liter-per-year facility. In Oman, Jotun produced 10 million liters of decorative and anticorrosion paint in 2004 in a facility with 15 million liters of capacity. Jotun announced that it also was planning a joint venture in India.

In early 2005, Jotun projected that revenues would increase by 20% over the previous year in the United Arab Emirates because of the booming construction markets. Between 60% and 65% of the company's business in the Middle East is in architectural decorative paint, 20% is in protective coatings and the rest in marine paint. The Middle East, which includes the Gulf States, Jordan, Syria, Egypt and Iran, is now the company's main focus. However, the company notes that despite the fact that large projects continue to be launched, international competitors have flooded the market in a bid to secure a slice of the business, to the detriment of local suppliers. The Middle East experiences lower margins than other regions because of larger increases in raw materials and building materials prices.

In 2005, Jotun introduced Jotashield Flex, which it claims is the only elastomeric paint with stretch and retract properties capable of accommodating the expansion and retraction of masonry due to temperature fluctuations. It is ideally suited to exterior concrete protection where it can prevent hairline cracks.

In 2006, Jotun increased its annual plant capacity in Thailand from 16 million liters to 35-40 million liters. The company also opened a new paint manufacturing plant in Zhangjiagang outside Shanghai, China. The $30 million factory has the capacity to produce 70 million liters annually. Jotun paints and protects about 10,000 vessels annually, representing 20% of the world's merchant fleet. In China the Jotun Group now has two companies—Jotun Cosco Marine Coatings Co. and Jotun Coatings (Zhangjiagang) Co., headquarters is in Shanghai.

In 2006, Jotun Coatings started supplying coatings to Kashagan in the Caspian Sea, the world's largest offshore oil field, as well as to other projects in Italy and Turkey. Also, Jotun announced that it was building a new plant for marine and protective paints in Pusan, the Republic of Korea, with a capacity of 40 million liters per year at a cost of $37 million. It will replace the existing plant with a capacity of 18 million liters per year, which was built in 1982. Construction is scheduled to be completed in January 2009.

In 2006, Jotun experienced record sales due to strong demand for coatings in the marine sector, and in the energy and construction industry, especially in the Middle East and Southeast Asia. Sales of marine coatings were $360 million in 2006 and sales of protective coatings were $225 million. Both sectors grew by 10% in 2006-2007.

Jotun had another record year in 2007 due to high levels of worldwide activity in shipbuilding, oil and gas projects in the North Sea and elsewhere, and a highly active construction industry in the Middle East. In 2007 the Jotun Group had an operating income of more than $1.6 billion, which was $200 million higher than that of 2006. Jotun's profit before tax was $140 million. Jotun has benefited from the strong underlying economic growth worldwide and has a solid market position in Scandinavia, the Middle East and Southeast Asia. In the Middle East and Southeast Asia, revenue increased by more than 18% in 2007.

Jotun is expecting good growth in the wind power industry using waterborne coatings. High-quality coatings must be used especially on windmills located offshore due to the high costs of maintenance and repair.

In early 2008, Jotun started production at a new $25 million facility in Ranjangaon, India, with capability of producing 50 million liters of decorative, protective and marine coatings, and 5 thousand metric tons of powder coatings. In 2007, Jotun sold about $25 million of industrial paint, mainly marine and protective coatings, mostly in the southern part of India. The company is aiming for a market share of about 8% in the country in 2010.

Hempel A/S

From its beginning in 1915, Hempel has developed a strong presence in anticorrosion coatings for the industrial and construction sectors. The company is a leading European supplier of marine coatings, with its main production plants in Denmark and Spain. It also produces protective coatings for petrochemical plants, bridges, steel structures and general civil engineering projects. Hempel has a strong presence in China, the Republic of Korea, Singapore and the Persian Gulf area, where it produces and supplies coatings for the marine, petrochemical, pipeline and refinery sectors for both new construction and maintenance applications. Hempel is also very active in coatings for wind turbines and considers itself to be the worldwide leader in this market. Hempel also produces container, decorative and yacht coatings. Most of the container coatings activities are in China, where it has a joint venture with Hempel Hai Hong (Kunshan). Most decorative coatings are sold in the Middle East, with sales of yacht coatings being focused on Europe and Australia. Altogether, Hempel has over 25 plants, forty sales offices and 150 distribution centers throughout the world. The company's R&D centers for marine paints are located in Denmark, Spain, Singapore and China, while those for protective paints are in Singapore, Denmark and the United States. The company continues to be privately held by the original founder's trust.

Hempel has an alliance with Dai Nippon Toryo to manufacture, sell and cross-license marine coatings. The alliance has a market share of both the European and the global marine coatings markets of 15-20%. It is the fourth-largest supplier of marine coatings in the world, behind Akzo Nobel, Jotun/NKM alliance and Chugoku.

In early 2000, Hempel opened a new state-of-the-art 107,000 square foot production facility in Conroe, Texas, which more than doubled its production capacity in the United States. The Conroe complex features manufacturing innovations designed to reduce VOC emissions and other environmental hazards, and also to minimize potential health hazards to all employees. The factory, which is International Standard Organization (ISO) 9001 certified, is designed to manufacture high-quality liquid coatings for the marine and heavy-duty industrial markets, including the rail, offshore, bulk cargo container, pipeline, chemical and hydrocarbon processing industries.

In May 2001, Hempel inaugurated an "innovation center" in Denmark in order to strengthen its R&D in marine and protective coatings. For some time, Hempel has been active in developing water-based coatings, including some based on epoxies, for the marine market, as well as TBT-free, high-solids alternatives for antifouling.

Global sales in 2002 were 570 million euros. The company built a 6 million euro plant in Kluang, Malaysia, to serve the Southeast Asian market. The latest internal and external environmental protection technologies have been incorporated in the plant, which had an initial output of 7 thousand metric tons per year, expandable up to 26 thousand metric tons per year. Total employment in the plant is about sixty. About 80% of output is exported.

Also in 2002, Hempel opened a research and development center at its Singapore site and introduced two new TBT-free, fiber-containing antifoulant coatings, Oceanic and Olympic, to meet new market requirements caused by the IMO regulations for antifouling paints. Oceanic is a cost-effective, self-polishing antifoulant coating with high-volume solids that can be specified for up to 36 months on vertical bottoms and 60 months on flat bottoms. The high-solids formulation (56% solids) contains mineral fibers for increased elasticity and increased binder loading. Olympic is an economical, self-polishing antifoulant that can be specified for up to 36 months. The binders in the antifouling paints are zinc/copper carboxylates modified with synthetic rosin, which is believed to have better resistance to oxidation and produce higher-quality, more consistent coatings than natural rosin. Hempel claims that its antifoulant coatings can be applied without first applying a tie-coat during recoating of an existing antifouling coating. These coatings complement the Globic line, which was introduced in the late 1990s. Globic coatings are reinforced with fibers to improve the strength of the coating and its resistance to impact. Once the ends of fibers are exposed by erosion, they break off at the surface, maintaining a smooth profile on the ship bottom, thus reducing friction and increasing fuel economy.

In late 2003, Hempel announced that it was shutting down some European capacity because of poor profitability, the rapid decline of the European shipbuilding industry and the difficulties in logistics in supplying 19,000 products from multiple locations. The Pinneberg, Germany plant closed in mid-2004, and there were personnel reductions in the plants in Spain and Denmark, as well as the closure of thirteen warehouses. The reduction in output was partially offset by increases in production facilities in Portugal, France and Malaysia, which are more cost-efficient.

In 2003, after some slow years, Hempel experienced growth in its container and marine coatings businesses. Renewed optimism and the recovery in world trade provided full order books for Hempel and a heavy increase in cargo transport, primarily from Asia to the United States and Europe. About 97% of Hempel's container business is in China, where the company has three factories. Local Chinese advisers maintain close professional contacts with container producers, while other Hempel staff in the rest of the world maintains close contacts with European and U.S. ship owners.

In recent years, the marine coatings sector faced increased competition and rising raw material prices. Ship owners and managers continued to increase pooled purchasing power and establish joint purchasing pools, a trend that has continued to grow. Hempel will introduce a global customer management concept in the future, concentrating services and logistics in key ports along the major shipping lanes, which is aimed at establishing an integrated and transparent partnership with the customers. The Asian market for marine paints continues to grow, with more complex vessels being built, such as LNG carriers and large container ships. Also in 2003, Hempel phased out all use of tributyltin (TBT) antifoulants.

In September 2003, Hempel launched Hempadour Uniq 4774, a universal epoxy primer, specially developed to suit the large Republic of Korea yards looking to reduce the number of different products in use. From as many as 25 different paint products necessary for a single vessel, Hempel is now offering a two-component paint that satisfies requirements throughout the vessel, thus reducing cleaning, waste, and labor. Benefits of the system include less cleaning, waste and potential for errors.

Hempel regards China as a major opportunity. It established its first regional office in China as early as 1958. In 1992, Hempel formed a joint venture with China Merchants Holdings (International) Co., Ltd., one of China's biggest industrial groups, called Hempel-Hai Hong. Hempel contributed a global brand and a strong worldwide network as well as advanced technology and management skills while China Merchants provided extensive local knowledge and a good market presence for marine, container and industrial coatings. All paint produced in China is sold domestically, and most of the 700 professionally trained staff have a Chinese background. Hempel-Hai Hong has three factories, seven offices, and thirteen stock points that can deliver Hempel products to any new building or repair yard in China or Hong Kong within 48 hours. The company has 140 qualified professional coating advisers in China, forty certified by FROSIO (the Norwegian surface coating institute). The three production plants in China have gained ISO 14001 certification for environmental protection and OHSAS 18001 for employees' Occupational Health and Safety standards.

In 2003, Hempel started changing from a country-based, product-oriented organization into a client-focused, service-oriented "one company" structure to better serve customers within markets and improve services among various business areas. Like other suppliers of anticorrosion coatings, Hempel offers service-level agreements that can range from basic service to major, turnkey involvement. As an example, Hempel will deliver the precise product, regardless of where the vessel is docked at any port in the world. Also, Hempel offers seminars and expert consultancy in evaluation of ships, offshore installations and infrastructure construction. In 2003, Hempel Service Academy advanced from being a purely internal education facility to being an external competence provider.

In mid-2004, Hempel announced price increases for many products of 5-15% because of sharply increasing prices for oil, and many paint raw materials, such as epoxy resins, which were up by as much as 30%. In addition, the prices of metals, particularly zinc and copper, were also under pressure. In addition, the paint industry faces increasing demands from both federal and local authorities regarding raw material testing and registration.

Sales of Hempel grew by 9% in 2004 to 214 million liters because of rapid Asian growth, not only in marine coatings, but also coatings for bridges, cranes and containers. European shipyards benefited from the boom in Asia and managed to pick up extra business as globalization continued. However, operating profits fell by 23% because of higher raw material prices and several one-time charges.

In early 2005, Hempel began expanding its operations in the Middle East to increase sales from the $70 million generated during 2004.

- The company expanded its largest regional plant at Dammam, Saudi Arabia, which is also the third-largest Hempel facility in the world. The plant was debottlenecked and new machinery was installed to add 5 million liters to its current total capacity of around 30 million liters per year. The output of the plant is now about 65% decorative paints, 33% protective coatings, which are widely used by oil and gas companies and power stations, and marine paints. Total sales of the plant are about $45 million annually. The plant, which began operations in 1973, was originally set up to provide protective coatings for Saudi Aramco.

- In Kuwait, the company built another plant with annual capacity of about 20 million liters. The existing Kuwaiti plant was the company's second-largest in the region, producing 12 million liters annually. Most output is higher-end decorative products.

- In the United Arab Emirates, Hempel built a facility with 10 million liters of capacity per year to supply mainly marine and protective paints. The existing UAE plant at Sharjah had capacity of 6 million liters per year, with most used at drydocks in Dubai. The company has another plant making marine and protective paints in Qatar, with capacity of 5 million liters per year, which supplies coatings to the country's energy and infrastructure markets. At the end of 2004, Hempel did not renew a 25-year license to produce paints at a site in Bahrain.

- Hempel built a factory in Syria with an initial annual capacity of 5 million liters, with plans to double capacity.

In 2005, Hempel created the Hempel Radargram, which gives a perfect snapshot of any epoxy coating based on eight performance values that describe all important features in terms of application and protective performance, including volume of solids, certification, maximum/minimum recoating intervals, abrasion resistance, surface preparation grades, submerged performance, application method, and chemical resistance. For example, for chemical resistance, "chemical tank (service)" rates a ten on a scale of ten, while "saltwater tank (ballast tank)" is given a five. The Radargram is easily accessible at http://www.hempel.com/Internet/inecorporatec.nsf/vHEMPELDOC/16C4E6CE34340FF4C1256EBB003C62BB?OpenDocument where a large selection of the most commonly used Hempel epoxy products is listed. A click on one of the products immediately draws up its product profile by a sweep of the radar display.

In 2006, Hempel had a record year, with coatings revenues of 755 million euros and operating profits of 61 million euros. The Protective Coatings business was up by 30% with strong sales to the oil and gas and wind power segments. The company's marine segment benefited from continued higher worldwide growth rates in 2006 with a 12% increase in sales due to considerable demand throughout the year with order books full at yards across Asia and Europe. However, profit margins decreased due to higher raw material costs for copper, zinc and crude oil. Hempel introduced several new antifouling products, including Globic NT (based on nanocapsule technology) and Hempadur Fibre 4760 (highly durable fiber-reinforced epoxy ballast tank coatings), as well as Hempaxane 55000, a polysiloxane-based topcoat. The Protective segment experienced strong performance in China, due to economic growth and investment in the country's infrastructure. Growth in the United States was again driven by success in the oil and gas sector, with several major jack-up rig projects completed during the year. Further growth in the North American protective coatings market is expected.

In mid-2006, Hempel opened a new production plant in Vietnam, near Ho Chi Minh City, with a capacity of 3 million liters per year. The plant will produce anticorrosion coatings; the Vietnamese market is growing quickly, with the marine coatings market expected to grow by 30% per year.

In 2006, Hempel and Dai Nippon Toryo agreed to expand their partnership. Dai Nippon will promote Hempel's anticorrosive paints in the Middle East, including for liquefied natural gas plants constructed by Japanese engineering firms. It will supply paint from Hempel's manufacturing bases at such locations as Saudi Arabia and Kuwait.

In January 2007, Hempel acquired Germany-based Lacor, a national and international supplier of protective coatings and industrial paints.

In 2007, Hempel's Protective segment exceeded the increase in the global protective market, delivering a healthy growth of more than 30%, which was similar to the growth in 2006. Most of this growth has been driven by increased demand in Asia and Europe. In 2007, the Marine segment increased net sales by 8%. The largest growth was in Asia, with slower growth in the larger U.S. and European markets. The effects of higher raw material prices, and the fact that many fixed contracts were mainly U.S. dollar based, put margins in the Marine segment under pressure.

The Container segment continued its good performance with high activity levels and record volumes. The Yacht segment saw double-digit growth in a relatively steady market.

Sika (formerly DuPont Protective Coatings)

In late 2006, DuPont sold its Protective Coatings product lines and related assets to the Sika Group, a leading Swiss company supplying specialty chemicals markets. Financial details of the sale were not disclosed.

DuPont became the world's third-largest coatings company, effectively doubling its coatings sales to around $3.8 billion in 1999 when it acquired Herbert's, formerly part of Hoechst. DuPont became a major supplier of anticorrosion as well as automotive, industrial and powder coatings in Europe. Previously, DuPont had some minor activity in anticorrosion coatings from its site in Mechelen (Belgium). In the United States, DuPont had been selling maintenance coatings for a number of years. Obviously, as a major producer of chemicals, it consumed a high quantity of protective coatings for protection of its assets. The company offers its maintenance service program to other manufacturers, where DuPont assumes total responsibility for the preparation, application, inspection and maintenance of coatings for a facility.

The high-performance coatings activities are headquartered in Vaihingen (Germany) under Permatex Protective Coatings with annual sales of around $40 million. Sika offers the whole spectrum of anticorrosion coatings for steel construction, plants and pipe/tank protection in the oil and gas, chemical and public sectors. Stocking points include Vaihingen; Turin, Italy; and Beaune, France, with Shanghai recently added to service the Chinese market. The company does not produce marine coatings.

DuPont/Permatex, like most German-based companies, has been particularly active in Eastern Europe, with one key acquisition of part of Lacufa AG in the former German Democratic Republic. About one-third of DuPont’s sales of anticorrosion coatings are outside Germany; sales in the former USSR and Eastern European countries are relatively strong.

Permatex Protective Coatings introduced a new coating for drinking water service that is completely free of solvents and bisphenol F. This is believed to be the first such coating meeting these environmental standards.

Sika Protective Coatings makes products designed to protect concrete, steel and other materials from corrosion, water, fire and environmental forces. Sika employs approximately 150 former DuPont Protective Coatings employees, primarily located at Vaihingen.

In January 2008, Sika acquired the commercial and industrial flooring business of Valspar, which had revenues of about $17 million in 2007. The business, based in North America and employing 25-30 people, produces and markets epoxy and polyurethane flooring materials.

Japan

Over twenty companies supply the Japanese high-performance anticorrosion market, with the top five sharing about 80% of the total market in 2007, as shown in Table 19. The leading companies also offer contractor services.

Table 19

Japanese Suppliers of High-Performance Anticorrosion Coatings by Market Share—2007
(percent)

	Marine Coatings	Protective Coatings	Total	Remarks
Major Suppliers				
Chugoku Marine Paints	43	2	26	
Nippon Paint	25	22	24	
NKM Marine Coatings	17	--	10	
Dai Nippon Toryo (DNT)	2	22	10	
Kansai Paint	--	22	10	Marine paint included with NKM Marine Coatings.
Other Suppliers	13	31	21	
Shinto Paint	--	X	X	
Shinto Sigma	X	--	X	
Kanae Paint	X	--	X	Marine paint for coastal ships.
Tohpe Paint	--	X	--	
Daido Paint	--	X	--	
Kawakami Paint	--	X	--	
Atomix	--	X	--	
Rock Paint	--	X	--	
Japan Carboline	--	X	--	Equally owned by Shinto Paint, Sumitomo Corporation and Carboline.
Roval	--	X	--	Zinc-based anticorrosive coatings.
Total	100%	100%	100%	

SOURCE: SRI Consulting.

Many Japanese marine coating suppliers have technical affiliations with major European coating firms in order to promote TBT-free shipbottom coatings to the global market. Nippon Paint started a technical affliation with Courtaulds (now International Paint, a part of Akzo Nobel) in 1993, but ended the association in October 2004. In 1995, Kansai Paint formed an alliance with Tikkurila to market marine coatings in the Baltic Sea area. In 1999, NOF reportedly began licensing tin-free antifouling paint from Jotun, and Dai Nippon Toryo started cross-licensing marine paint technology with Hempel. In 2001, NOF (currently BASF Coatings) and Kansai Paint established a joint venture (NKM Marine Coatings, formerly NOF Kansai Marine Coatings) for the marine coating business, and NOF's alliance with Jotun has been integrated into this joint venture. Toray Industries is a distributor of moisture-curing urethane paints manufactured by Wasser in the United States.

According to the Japan Paint Manufacturers Association, the marine coatings classification includes coatings for new ships and repair, and structural coatings includes coatings for bridges, civil engineering, plants, marine structures, water gates, metal towers (for electric), large pipes, and large pools, and excludes bulk cargo container coatings (almost negligible in Japan) and some construction parts coated by the factory. The value of coating shipments by producers was around ¥61 billion ($528 million) of marine coatings and ¥45 billion ($389 million) of heavy-duty maintenance coatings in 2007.

Chugoku Marine Paints

Chugoku Marine Paints is the leading supplier of marine paints in Japan. The company was first authorized by the Japan Industrial Standard (JIS) in 1954 to produce marine coatings. In fiscal 2007 (fiscal year ended March 2007), annual consolidated sales were ¥88.2 billion ($760 million), which was up 60% from fiscal 2004. Sales in 2008 are expected to reach ¥102 billion ($879 million). Profits from sales in 2007 were ¥4.85 billion ($42 million), and are expected to reach ¥6 billion ($52 million) in fiscal 2008. Sales of marine coatings accounted for 58% of total corporate sales. Sales of marine coatings to other Asian countries have been increasing, and sales of all coatings now account for 33% of total sales. Sales to other regions (mainly Europe and the United States) accounted for 10% of total sales in 2007.

The company continues to be the leading supplier of marine paints in Japan, especially for new ships. Chugoku supplies marine paints to more than twenty countries and has manufacturing facilities in Singapore, China, Malaysia, the United States and the Netherlands (all of these are 100% subsidiaries). The plant in Malaysia was built in mid-1992, cost $81 million, has a capacity of more than 700 metric tons of paint per month, and is now Chugoku's second-largest facility in Southeast Asia. The company has built an important R&D center in Singapore. In China, Chugoku manufactures marine paints in Shanghai and Guangdong Province; total capacity of both plants is 140-150 thousand metric tons per year. The Shanghai plant also makes container coatings, and is hoping to reach a market share of 35%. Other marine paint manufacturing joint venture facilities are PT Chugoku Paints Indonesia (54.57% share), and Chugoku Samhwa Paints, Ltd., Republic of Korea (50%). Chugoku also has a sales office in Dubai in the Middle East.

Chugoku currently markets two types of tin-free antifouling coatings; one is based on hydrolytic silyl polymer technology, silicone elastomers and zinc polymer, and the other is based on zinc acrylate polymer. Chugoku also markets biocide-free elastomer coatings. The company also developed electroconductive polymers, which were expected to be used in antifouling coatings, but are currently mainly used for "heat-generating" coatings, which are applied to road signs in colder regions of Japan to melt the snow on the signs. Chugoku also markets underwater curing coatings for coating marine structures.

Nippon Paint

Nippon Paint is one of the two largest paint manufacturers in Japan, with a size comparable to Kansai Paint. Like Kansi, Nippon has an extensive product line in every major segment of the coatings market. Sales of industrial maintenance and marine paints are estimated to account for about 10% of its total consolidated sales. Annual consolidated sales in fiscal 2007 were ¥226 billion ($1.9 billion), with profits after tax of ¥7.5 billion ($64 million). These figures are expected to increase to ¥260 billion ($2.2 billion) and ¥7.7 billion ($66 million), respectively, in fiscal 2008. Sales of protective coatings were around ¥100 billion ($860 million) in 2007. Marine paints are marketed by Nippon Paint Marine, which had sales of around ¥16 billion ($138 million) in 2007 as consolidated sales.

Nippon Paints has been establishing itself in overseas markets mainly through its own subsidiaries and affiliates rather than licensing or sales agreements. Nippon Paint has subsidiaries and joint ventures worldwide. In Asia, paint manufacturing subsidiaries are located in seven countries; among them, PT Nipsea Paint and Chemicals (Indonesia), Nippon Paint Singapore and Nippon Paint Malaysia produce heavy-duty coatings and/or marine paints. Marine paints are supplied from Japan, China, Taiwan, Singapore and the Republic of Korea (outsourced through a second party).

Nippon Paint has developed and marketed tin-free antifouling paints based on hydrolyzing copper acrylate polymers to replace TBT-based paints from early stages. Nippon Paint also markets silicone elastomer–type paints as nonbiocide systems, using technology obtained in part from International Paint. The company licensed some of its paint manufacturing technology to International Coatings in 1993, and expanded sales of the tin-free antifouling paints worldwide through the marketing channels of International. However, the alliance was dissolved in October 2004. Nippon Paint now markets through its own global sales network.

Aiming to more aggressively promote its marine coatings business worldwide, Nippon Paint restructured its marine coatings company, Nippon Paint Marine Coatings Co., Ltd. (NPMC), with capital investment by Wuthelam Holdings in April 2004. Nippon Paint plans to expand its overseas business network centering on the new NPMC by using manufacturing, sales, service and logistic networks possessed by its NIPSEA corporate group, while establishing new bases at key stocking locations in Europe, America and the Middle East. Nippon Paint also intends to manufacture and supply worldwide marine coatings and paints for shipbuilding as well as maintenance and repair of ships. It will also provide technical services to customers for new buildings and repair of ships in and outside Japan. With the aim of achieving more than ¥20 billion in marine sales by fiscal 2010, Nippon Paint aims to sharpen its competitive edge in the Asian market and secure a market share among the top three companies in the international marketplace. For research and development, Nippon Paint will continue to handle basic research, while the new NPMC will be in charge of applications, development and improvement.

Nippon Paint Marine Coatings and the marine paint division of the German paintmaker Wilckens Farben GmbH signed a cooperation agreement in October 2005. The companies will mutually use all production facilities and service networks in Europe and Asia, and develop a common worldwide marketing strategy for marine paints.

In early 2008, Nippon Paint announced the formation of a new firm, Nippon Paint Marine, based in Zhangjiagang, China, which will be capitalized at $4 million and be fully owned by Nippon Paint Marine Coatings Co. The new company will be capable of producing 1,000 metric tons of paint a month and is expected to start operations in February 2009. The monthly production capacity will eventually be expanded to 2,000 metric tons. Currently, Nippon Paint consigns production of paints for ships to a local Chinese firm and sells them through its own subsidiary in Shanghai, which was set up in 2004. With the new arrangement, Nippon Paint hopes to triple its sales of paints for ships in China from one billion yen in 2007 by fiscal 2010.

In addition, the company is aiming to increase global sales of marine coatings from ¥18 billion in fiscal 2007 to at least ¥23 billion in fiscal 2010.

Dai Nippon Toryo

Dai Nippon Toryo is the largest industrial maintenance coatings producer in Japan, and the third-largest Japanese coatings manufacturer, following Kansai Paint and Nippon Paint. Consolidated sales were ¥78 billion ($669 million) in fiscal 2007, and are expected to increase to ¥81 billion ($698 million) in fiscal 2008. Pretax profit from sales in 2007 was ¥1.37 billion ($11.8 million). About 20% of sales are for industrial maintenance coatings. The company has an especially large market share in heavy-duty coatings for large structures and bridges. Sales stagnated in the early 2000s, reflecting the reduction of the government budget for public works as well as flat demand for architectural coatings. Dai Nippon has had little involvement in the marine coatings market because it was at one time affiliated with Chugoku, and upon separation, each company was allocated certain businesses; however in 1998, Dai Nippon established a cross-alliance with Hempel’s Marine Paints in manufacturing and sales for marine, bulk cargo container and plant maintenance paint, both domestic and overseas, including the Middle East. The company was formerly part of a leading manufacturer of electric cells and first offered anticorrosion coatings using lead-based technology. Dai Nippon offers other corrosion protection services and products besides paints. In October 2006, Dai Nippon acquired a coatings division of Nitto Chemical, which produces coumarone resins, epoxy coatings and epoxy coal tar coatings.

Dai Nippon has supplied coatings to Asia Pacific countries since 1970. Heavy-duty coatings for the Asian market are supplied from its wholly owned subsidiary in Singapore (DNT Singapore, which acquired Tanabe Chemical Singapore in 2007). Other manufacturing subsidiaries and affiliates in Asia include Thai DNT Paint and Tanabe Chemical Malaysia. The company has technical affiliations with many overseas companies, including those in Central Paints Industrial, Taiwan (fluorinated coatings, automobile coatings, protective coatings for bulk cargo containers) and P.T. Tunggal Djaja Indah, Indonesia (anticorrosion coatings).

Kansai Paint

Kansai Paint, established in 1919, has been a pioneer in the Japanese paint industry. In the 1950s, the company began to license synthetic polymer technology from overseas companies. In the past thirty years, it has been expanding its presence in overseas markets either by establishing joint ventures or by licensing technologies. The company now also manufactures mainly automobile and industrial paints at Asian subsidiaries in seven countries—Taiwan Kansai Paint, Kansai Paint Singapore, Thai Kansai Paint, Sime Kansai Paint (Malaysia), Kansai Nerolac Paints (India), PT Kansai Paint Indonesia and several subsidiaries in China.

Kansai Paint has been one of the largest manufacturers of coatings in Japan, comparable in size to Nippon Paint, with annual consolidated sales of ¥231 billion ($2.0 billion) and profits after tax of ¥13.3 billion ($114 million) in fiscal 2007, which are expected to increase to ¥260 billion ($2.2 billion) and ¥14 billion ($121 million) in fiscal 2008, respectively. Sales of the marine and protective coatings segment accounted for 4% of total consolidated sales in fiscal 2008 (about ¥10 billion [$88 million]). Total sales of marine and protective coatings through subsidiaries were about two to three times this amount, consisting mainly of container coatings sold in China through an agreement with COSCO (Chinese Ocean and Steamship Corporation) and marine coatings sold through the NKM Coatings joint venture with BASF Coatings (formerly the Marine Paint Division of NOF Corporation).

Kansai has actively increased its participation in non-Japanese markets. In 1994, Kansai entered into an agreement with Kemira’s subsidiary Tikkurila to produce marine paints in Europe. Tikkurila has marketed these paints in Finland, Sweden, the Baltic states and Russia. Also, in 1994, the company entered into an affiliation with Renner Herrmann in Brazil, and in 1996, with Twin Aces in the Philippines. During the 1990s, Kansai reached an agreement with COSCO in China to build two new plants to make container and marine paints in Shanghai and Tianjin with a capacity of 80 thousand metric tons per year. COSCO is reported to be the world’s largest freighter line, with 400 agencies in and around the country. In 2007, a new joint venture operation with COSCO started production of container, marine and protective coatings in Zhuhai with a capacity of 96 thousand metric tons per year.

Like other producers, Kansai is developing more environmentally acceptable coatings to replace coal tar epoxies, chlorinated rubbers, vinyls and tin antifouling compounds.

Kansai has introduced tin- and copper-free antifouling marine paints. In October 2001, Kansai merged its marine coating business with NOF (now BASF Coatings), which has advanced technology for TBT-free antifouling coatings, to form NOF Kansai Marine Coatings. The joint venture was renamed NKM Coatings after BASF acquired the NOF coatings business in 2005. NKM continues its global alliance with Jotun; the group continues to market its TBT-free systems based on zinc acrylate polymer, silicone elastomers and hydrolytic silyl acrylate polymer, as well as conventional cuprous oxide with chlorinated rubber. Sales of NKM Coatings were ¥1.2 billion ($10.3 million) in 2007.

China

Marine coating plants are located in the coastal areas, such as Dalian, Qingdao, Shanghai and Guangzhou. Most coatings applied to large oceangoing ships are supplied by large multinationals, such as International Paint (Akzo), Chugoku, Hempel, Kansai Paint, Jotun, PPG and Korea Chemical (KCC), with local presence in China. The price of these functional coatings is fairly similar to the international price. On the other hand, coatings for fishing boats are generally supplied at low prices by domestic coating manufacturers, such as Shanghai Kailin, Guangzhou Pearl River, Guangzhou Supe Chemical and others.

China is the world leader in the construction of bulk cargo containers. These containers generally are used for about ten years before they are scrapped, and coatings are formulated to last for the duration of service. China dominates the market for container coatings (more than 90% globally), and consumes roughly about 200 million liters of coatings per year. Major suppliers of bulk cargo container coatings in China are Chugoku, Hempel, Kansai Paint and Korea Chemical (see also the **China *Container coatings*** section).

The market for protective (industrial maintenance) coatings is shared by multinational and domestic companies. Major Chinese anticorrosion coating producers are shown below.

Table 20

Major Chinese High-Performance Anticorrosion Coating Producers—2008

Company and Plant Location	Marine	Container	Protective
Akzo Nobel Group			
Akzo Nobel Protective Coatings (Suzhou) Co., Ltd.			
Suzhou, Jiangsu			X
International Paint Shanghai			
Shanghai	X		
China Haohua Fine Chemical Corporation			
na	X		X
CMP Group	X	X	X
Chugoku Marine Paints (Shanghai) Co. Ltd.			
Shanghai			
Chugoku Marine Paints (Guangdong) Co. Ltd.			
Guangzhou, Guangdong			
COSCO Kansai Paints & Chemicals Co., Ltd.	X	X	X
COSCO Kansai Paints & Chemicals (Shanghai) Co., Ltd.			
Shanghai			
COSCO Kansai Paints & Chemicals (Tianjin) Co., Ltd.			
Tianjin			
COSCO Kansai Paints & Chemicals (Zhuhai) Co., Ltd.			
Zhuhai, Guangdong			

Table 20 (continued)

Major Chinese High-Performance Anticorrosion Coating Producers—2008

Company and Plant Location	Marine	Container	Protective
Dao Nuo Heavy-Duty Coatings			
Tianjin	X		X
Euronavy (Beijing) Heavy Anticorrosion Coatings Co., Ltd.			
Beijing	X		
Guanghui Chemical Industry Co., Ltd.			
Changzhou, Jiangsu			X
Guangzhou Pearl River Chemical Industry Group Ltd.			
Guangzhou, Guangdong	X		X
HEMPEL-Haihong (China) Co., Ltd.	X	X	X
HEMPEL-Haihong (Kunshan) Co., Ltd.			
Kunshan, Jiangsu			
HEMPEL-Haihong (Shenzhen) Co., Ltd.			
Shenzhen, Guangdong			
HEMPEL-Haihong (Yantai) Co., Ltd.			
Yantai, Shandong			
Jiangsu Lanling Chemical Group Ltd.			
Changzhou, Jiangsu	X		X
Jotun Group			
Jotun Paints (Zhangjiagang) Co., Ltd.			
Zhangjiagang, Jiangsu	X		X
Jotun COSCO Marine Coatings (Guangzhou) Co. Ltd.			
Guangzhou, Guangdong	X		X
KCC			
KCC (Kunshan) Co., Ltd.			
Kunshan, Jiangsu	X	X	
KCC (Guangzhou) Co., Ltd.			
Guangzhou, Guangdong	X	X	
Nippon Paint Marine (Shanghai) Co., Ltd.			
Shanghai	X		
Qingdao Haijian Chemical Co., Ltd.			
Qingdao, Shandong	X	X	X
Qingdao Jinneng Special Anticorrosion Coatings Co., Ltd.			
Qingdao, Shandong	X		X
Shanghai Coatings Co., Ltd.			
Kailin Paint Manufacturing Company			
Shanghai	X		X
SigmaKalon (Kunshan) Co., Ltd.			
Kunshan, Jiangsu	X		X
Tianjin Beacon Paint & Coatings Co., Ltd.			
Tianjin			X

Table 20 (concluded)

Major Chinese High-Performance Anticorrosion Coating Producers—2008

Company and Plant Location	Marine	Container	Protective
Tianjin Dagang Oilfield Puhai Chemical Co., Ltd. Tianjin			X
Wuyi Beacon Antirust Paint Co., Ltd. Wuyi, Hebei			X
Xiamen Sunrui Marine Coatings Co., Ltd. Xiamen, Fujian	X		
Yangzhou Maydos Jin-ling Special Paint Co., Ltd. Yangzhou, Jiangsu			X

SOURCE: SRI Consulting.

Republic of Korea

The leading suppliers of high-performance anticorrosive coatings in the Republic of Korea are listed below.

Table 21

Republic of Korea Suppliers of High-Performance Anticorrosion Coatings—2008

Company and Plant Location	Marine	Protective
Chokwang Jotun Ltd. Gyeongnam	X	
Chugoku-Samhwa Paints Ltd. Gyeongnam	X	
KCC Corporation Ulsan	X	X
International Paint (Korea) Ltd. Busan	X	
Nippon Paint Marine (Korea) Co., Ltd. (outsourcing) na	X	
Sigma Samsung Coatings Ltd. Ulsan	X	
Other (PPG, Noroo, Kunsul)		X

SOURCE: SRI Consulting.

KCC Corporation (formerly Kumgang Korea Chemical) is the largest paint company in the Republic of Korea. Total 2006 sales were valued at 1,909 billion won ($2.0 billion), and net profit was 842 billion won ($849 million). Sales increased to 1,937 billion won ($2.08 billion) in 2007. Coating sales for domestic shipments were 485.5 billion won ($515 million) and overseas shipments were 356.5 billion won ($379 million). Anticorrosion coatings (including containers) are about 10% of the total sales of KCC Corporation. The major marine coating plant is in Ulsan. KCC Corporation has overseas plants in Singapore (built in 1992) and in Kunshan, China (2002). The Singapore plant produces container coatings and architectural coatings, and the Kunshan plant produces container coatings and coil/precoated metal coatings.

Rest of Asia/Middle East

The leading suppliers of high-performance anticorrosion coatings in the rest of Asia and the Middle East are listed below.

Table 22

Suppliers of High-Performance Anticorrosion Coatings in the Rest of Asia/Middle East—2008

Company and Plant Location	Marine	Protective
Australia		
Jotun Australia Pty. Ltd. Melbourne, Victoria	X	X
Bahrain		
Berger International na	X	X
India		
Akzo Nobel Coatings India Pvt Ltd. Bangalore	X	X
Asian Paints Ltd. Various	X	X
Jotun India Pvt Ltd. Pune	X	
Kansai Nerolac Paints Ltd. Various		X
Indonesia		
PT Chugoku Paints Indonesia Jati Uwung, Tangerang	X	
PT Hempel Indonesia Bekasi, West Java	X	

Table 22 (continued)

Suppliers of High-Performance Anticorrosion Coatings in the Rest of Asia/Middle East—2008

Company and Plant Location	Marine	Protective
Indonesia (continued)		
PT Internal Paint Indonesia Bekasi, West Java	X	
PT Jotun Indonesia Bekasi, West Java	X	X
PT Mowilex Cengkareng, Jakarta	X	X
PT Pacific, Pabrik Tjat dan Tinta Tanjung Priok, Jakarta	X	
PT Pan Oceanic Paint Timur, Jakarta	X	X
PT SigmaKalon Indonesia Jakarta	X	
PT Tiara Gaya Arga Kencana Bandung, West Java		X
Other	X	X
Kuwait		
International Warba Coatings Paint Mfg. Co. Kuwait	X	
Malaysia		
Berger International na	X	X
Chugoku Paints (Malaysia) Sdn. Bhd. Pasir Gudang, Johor	X	
International Paint Sdn. Bhd. Johor Darul Takzim	X	
Jotun (Malaysia) Sdn. Bhd. Persiaran Perusahaan, Selangor	X	X
SigmaKalon Malaysia Shah Alam Selango	X	
Sime Kansai Paints Sdn. Bhd. Klang, Selangor		X

Table 22 (continued)

Suppliers of High-Performance Anticorrosion Coatings in the Rest of Asia/Middle East—2008

Company and Plant Location	Marine	Protective
Saudi Arabia		
Jotun Saudia Co., Ltd.		
Jeddah	X	X
Rantinjat Saudia Co., Ltd.		
Jeddah	X	X
Red Sea Paints Co., Ltd.		
Jeddah	X	X
Sigma Paints Saudi Arabia Ltd.		
Damman	X	X
Singapore		
Berger International	X	X
Chugoku Marine Paints (Singapore) Pte. Ltd.	X	
DNT Singapore Pte. Ltd.	X	
International Paint Singapore Pte. Ltd.	X	
Jotun (Singapore) Pte. Ltd.	X	
KCC Singapore Pte. Ltd.	X	
Nippon Paint Marine (Singapore) Pte. Ltd.	X	
Taiwan		
Asia Industries Ltd.		
Taoyuan	X	X
Taiwan Kansai Paints Co., Ltd.		
Kaohsiung	X	X
Yung Chi Paint & Varnish Mfg. Co., Ltd.		
Kaohsiung		X
Thailand		
Berger International		
Samut Prakan	X	X
Jotun Thailand Limited		
Amphur Muang, Chonburi	X	
TOA-Chugoku Paints Co., Ltd.		
Bangpakong, Chachengsao	X	
Turkey		
Jotun Boya San. Ve. Tic. A.S.		
Istanbul	X	

Table 22 (concluded)

Suppliers of High-Performance Anticorrosion Coatings in the Rest of Asia/Middle East—2008

Company and Plant Location	Marine	Protective
United Arab Emirates		
Berger International Dubai	X	X
International Paint (Gulf) LLC Dubai	X	
Jotun Abu Dhabi Ltd. Abu Dhabi	X	
Jotun UAE Ltd. Dubai	X	
Vietnam		
Haiphong Paint Joint Stock Company Haiphong	X	
Jotun Paints (Vietnam) Co. Ltd. Binh Duong	X	
Vinashin Paint Co., Ltd. Binh Duong	X	
Yung Chi Paint & Varnish (Vietnam) Co., Ltd. Bien Hoa	X	X
Yemen		
Jotun Yemen Paints Ltd. Aden	X	

SOURCE: SRI Consulting.

Jotun and International Paint have established marine paint subsidiaries in most of these regions. Chugoku Marine Paint opened a sales office in the United Arab Emirates in 2004 to meet increasing marine paint demand, with the coating supplied by its Singaporean subsidiary.

Asian Paints is India's largest paint company and the third-largest paint company in Asia today, with a turnover of Rs36.7 billion ($850 million). Marine and protective coatings overseas are mainly supplied by its 50% subsidiary, Berger International, which has manufacturing plants in East Asia (Malaysia, Thailand, Singapore, China), the Middle East (Bahrain, UAE), and the Caribbean (Barbados, Trinidad & Tobago). Berger International's sales are 38% in the Caribbean, 36% in the Middle East and 26% in East Asia. Total 2006 sales were $99 million.

Demand for protective coatings for petrochemical plants, such as ethylene cracker plants, is growing in Saudi Arabia and other Middle Eastern countries. Marine coatings use is growing as well in the Middle East.

MERGERS AND ACQUISITIONS

There was considerable merger activity in the coatings industry in the late 1990s. Most notably, Akzo Nobel acquired Courtaulds in 1998, thus becoming the largest manufacturer of coatings in the world. Other acquisitions in the anticorrosion coatings industry included Euridep (subsidiary of Total) by Kalon in 1996, Devoe and Croda Mebon by Ameron (1996 and 1998, respectively) and Herberts by DuPont in 1999. In addition, Total and Fina merged in 1999; a consequence of the deal was the combination of the coatings businesses of Kalon and Sigma into SigmaKalon (the high-performance coatings business was still called Sigma Coatings).

Merger and acquisition activity declined considerably in 2000-2005, with only one other major transaction: in 2003, TotalFinaElf divested SigmaKalon to Bain Management. There was an increase in activity starting in 2005, mainly as profitability and outlook in the anticorrosion coatings industry improved. Some of the recent, more notable mergers and acquisitions in the anticorrosion coatings industry were:

- In 2000, Jotun acquired Products Research Service (PRS, based in Louisiana), a producer of marine and protective coatings.
- In 2000, Berkshire Hathaway, a financial holding company, acquired Benjamin Moore.
- In 2001, Dudick (Cleveland, Ohio) acquired DuPont’s “Cor Max” product line, including secondary containment products for corrosive environments, mainly based on epoxy coatings and polysulfide elastomers.
- In 2001, NOF and Kansai Paint merged their marine coating businesses to form NOF Kansai Marine Coatings.
- In 2002, Akzo Nobel acquired NOF’s marine and aircraft coatings businesses in the United States and Europe (U.S. Paint and NOF Europe).
- In 2002, Akzo Nobel announced the acquisition of a Daihan Paint and Ink plant in the Republic of Korea that produces marine coatings.
- In 2003, Bain Management acquired SigmaKalon for $1.15 billion.
- In 2004, Sherwin-Williams acquired Duron, Inc., which mainly produces and markets architectural coatings in the United States, but also sells about $20 million per year of maintenance coatings.
- In 2005, the NOF paint business was acquired by BASF Coatings, and NOF Kansai Marine Coatings was renamed NKM Coatings.
- In 2006, PPG acquired the coatings business of Ameron, a leading supplier of anticorrosion coatings based in the United States, for about $115 million. Sales of the division in 2005 were about $210 million. Also, PPG acquired Protec, a manufacturer of automotive refinish, light industrial and protective coatings based in Australia and New Zealand.

- In 2006, BASF acquired the Degussa construction chemicals business, which includes Relius wind turbines, marine and protective coatings, as well as powder and other industrial coatings.

- In late 2006, DuPont sold its Protective Coatings business to Sika Group, a Swiss-based producer of specialty chemicals.

- In 2006, Dai Nippon Toryo (DNT) acquired a division of Nippon Steel Chemicals that makes coatings, and founded Nitto Chemical Ltd., which produces epoxy and epoxy coal tar coatings.

- In 2007, PPG acquired Champion Coatings, a manufacturer of rail, marine and other protective coatings based in Houston, Texas.

- In 2007, 3M acquired E Wood Holding, a UK manufacturer of protective coatings for oil and gas pipelines, for £40 million.

- In 2007, Akzo Nobel acquired Ceilcote, a supplier of protective coatings based in the United States, for about 12 million euros, and ICI, including its protective coatings business.

- In 2007, Caroline (subsidiary of RPM) acquired the Marine and Industrial Coatings sector of Finnaren & Haley, based in Conshohocken, Pennsylvania.

- In 2007, Hempel acquired Lacor, a supplier of protective coatings and industrial paints based in Germany.

- In 2007, PPG acquired SigmaKalon from Bain Capital for $2.2 billion. SigmaKalon’s sales in 2006 were about $2.6 billion.

- In 2007, the Stonhard Group of RPM acquired Star Maling, a Norwegian manufacturer of protective and marine coatings. RPM also acquired Tor, a UK supplier of fire retardant and antigraffiti coatings for the building maintenance market. Sales are $45 million annually.

Motivations for mergers and acquisitions include the following:

- Stagnating markets in some areas, leading regional producers to expand geographically

- Low margins, caused by rising costs of materials and fierce competition

- Economies of scale, especially in purchasing

- Costs of environmental compliance, which are ideally amortized over larger units of production

- Acquisition of technology

- Desire of private individuals or families to sell out to larger interests if there is no succession plan

- Acquisition of smaller firms by larger companies to complement their existing product lines or geographical areas

OPERATING CHARACTERISTICS

Research and Development

All successful producers of high-performance anticorrosion coatings maintain strong applied research and technical service programs to develop products that satisfy the requirements of a number of end users. In turn, each end user can have a variety of requirements. For example, an offshore drilling rig may be coated with two or three different types of coatings, each formulated to provide certain properties. Coatings for the immersed surfaces must be more corrosion-resistant than those for the topside; the splash zone (part of the rig that is exposed to the water-air interface) is especially susceptible to corrosion. On the other hand, the topside surfaces should be coated with a more aesthetically appealing and UV-resistant finish. Producers of the coatings must also adjust formulations to allow easy application under different conditions (e.g., ambient temperature and humidity, level of surface preparation).

Major coating manufacturers usually do not perform basic research on raw materials used in high-performance anticorrosion coatings unless they are backward-integrated into resin production (as is PPG). Instead, most depend on their raw material suppliers for information on essential properties and how to use them in specific formulations. Often, raw material suppliers (mainly of resins) and coatings producers establish cooperative projects to develop new technologies.

In general, technical development in the industrial coatings sector tends to be incremental, as proven technology is difficult to displace. A new coating formulation typically is subjected to accelerated lab testing followed by field testing before it can be sold on the general market. The ultimate field performance of a coating is determined by end users and independent agencies with experience in conducting field tests and interpreting data. Thus, there may be a lengthy time period between product development and the market acceptance of a product; therefore, coating manufacturers must make a strong long-term commitment to applied research.

The Steel Structures Painting Council (SSPC) has estimated the cost for a company to develop antislip coatings for elevated steel beams to conform to OSHA standards (issued on August 13, 1998) as follows:

Table 23

Estimated Cost for Developing and Testing New Antislip Coatings
(dollars)

	Four or Fewer New Products	Five or More New Products
Initial Formulation	10,000-20,000	40,000-80,000
Preliminary Laboratory Testing	10,000-20,000	40,000-80,000
Formulation Refinement	10,000-15,000	40,000-80,000
Full-Scale Laboratory Testing	10,000-25,000	60,000-100,000
Field Testing	10,000-20,000	20,000-40,000
Health, Safety and Environmental Review	5,000-10,000	20,000-40,000
Quality Control Program Development	5,000-10,000	80,000-120,000
Introduction to Market (including end-user support)	10,000-15,000	10,000-15,000
Total	70,000-135,000	310,000-555,000

SOURCE: *Journal of Protective Coatings & Linings*, February 1999, p. 109.

The coating manufacturer must respond rapidly to the changing performance requirements or application conditions of individual end users. If the coating manufacturer does not have a suitable product in stock that meets customer requirements, it is expected to be able to formulate one or make adjustments to an existing product in a reasonable period of time.

Much of the current research effort in anticorrosion coatings is directed toward the development of coatings that will meet more stringent environmental standards dealing with emissions of volatile organic compounds (VOCs). These efforts are discussed in the **GOVERNMENT REGULATIONS** section. Another driver in the market is the demand for higher productivity. Some of the other research programs of producers of high-performance anticorrosion coatings are described below.

- Development of more surface-tolerant coatings that can be applied over surfaces that cannot be subjected to abrasion blasting because of costs, difficult logistics or environmental restraints. For example, a surface-tolerant coating would be applied over a floating roof in a petrochemical plant that cannot be blasted unless taken out of service. These coatings are claimed to give good adhesion even over surfaces contaminated with oil, moisture or rust. There continues to be strong pressure to minimize labor costs and structure downtime.

- Development of coatings that treat rust by inhibition or by conversion to a more dense and stable film.

- Development of more rapid simulation test methods to evaluate coating performance and choose the appropriate coating for a specific project.

- Development of systems that reduce application times such as one-coat, high-solids finishes. Already, there are systems that require only a two-coat application instead of three coats. Owners of large capital investments want their assets to return to service quickly, so there is considerable interest in fewer coats with less downtime.

- Development of systems that cure at lower temperatures to allow year-round outdoor painting. For example, municipalities prefer to have water tanks taken out of service and painted in the winter when demand for water is less. For application in colder climates, paints should cure or dry at temperatures around 0°C.

- Development of antifouling coatings to meet the regulations forbidding TBT.

Interesting developments in connection with environmental performance and monitoring include:

- Fatigue-monitoring coatings based on the piezoelectric effect produced by a lead zirconate pigment, which generates an electric current when stressed.

- Self-healing coatings (i.e., coatings in which reactive materials encapsulated in inert shells are added during manufacturing). Corrosion, crack growth, mechanical damage or chemical attack ruptures the capsules, releasing the ingredients, which react and become part of the coating. The ingredients may include epoxies and amines (in separate capsules) that react with each other or alkyd resins that react with the ambient air.

In Europe, almost 200 companies support the Paint Research Association, which conducts research for and offers analytical services to the coatings industry. Some of the recently funded research projects have directly impacted the high-performance anticorrosion sector, particularly in the formulation of high-performance, waterborne anticorrosion coatings.

In some cases, there have been cooperative R&D efforts between governments and industry. The Dutch environment ministry has sponsored a "Hydrocarbons 2000" project that has subsidized several projects, such as the replacement of chlorinated rubber coatings and the development of coatings containing low levels of organic solvents.

In the past, the coatings industry would use long-term testing of coatings to prove their reliability. However, these practices are no longer feasible because of the need to introduce new products more quickly to meet the rapid changes in environmental and safety legislation.

In China, most high-performance anticorrosion coatings are produced by foreign producers or by joint ventures of foreign and local companies. However, local Chinese producers and research associations are becoming more involved in the research and development of these products.

Manufacturing

As mentioned earlier, production of coatings is by batch process because of the number and variety of finished products. Many products may be differentiated by color only. For most companies, the average batch size is 4 thousand liters or less. One large producer manufactures maintenance coatings at three locations in the United States; it has over 100 tanks available for mixing batches, which range from 250 gallons (950 liters) to 10,000 gallons (38,000 liters) in size. The higher-volume latex coatings are usually made in large automated processing lines, but solventborne paints must be made in smaller allotments, as they require more care in processing than latex-based coatings. For example, moisture must be excluded from urethane coatings and the release of organic solvents into the atmosphere must be minimized. Also, fillers and pigments must be ground in ball mills before they are added to solventborne coatings to maximize dispersibility.

The economies of scale of operating large, centralized production facilities are often rather minimal. Most companies prefer to operate smaller plants in geographically diverse locations to provide timely service at lower distribution cost to local markets. Additional shifts are often added during peak demand seasons. Quality control during production is important and is usually accomplished by a well-staffed and well-equipped laboratory on the production site.

In September 2001, Akzo Nobel opened a new $17 million plant to make maintenance and marine coatings in Houston, Texas. Six new thin-film manufacturing lines were installed, with dispersers, mills and letdown tanks (i.e., mixing tanks that disperse pigments and fillers that have been previously ground) dedicated by color and chemistry. Four new packaging lines using fill-by-weight technology were also installed with a new small production area, where batches from 70 to 250 gallons are manufactured. The equipment and control technology in these mixers is identical to the larger units, allowing for easy batch scale-up with minimum production charges. The mixing tanks are all computer monitored, gathering up to ten variables of manufacture (such as temperature, blade speed and material weight) every fifteen seconds to aid in quality control. All raw materials are added automatically by weight. Dry materials in the new plant are delivered by "supersacks"—large bags typically between one-half and one metric ton each—and liquids by bulk line or tote tank. Each mixer and letdown tank also has an internal washing system that reduces solvent emissions to the atmosphere and hazardous waste generated from tank cleaning. An above-ground tank farm stores 22 different resins and solvents ready for bulk delivery into the factory. The stainless steel transfer lines are purged after every transfer, reducing waste and eliminating a possible source of spillage.

Major producers of high-performance anticorrosion coatings utilize a variety of polymer systems in their coating formulations. These polymers are often purchased from outside sources; however, a captive production capability provides pricing leverage against outside suppliers, and also allows the producer to pursue its own polymer development effort.

Marketing

In the United States, there are three channels of distribution of industrial maintenance coatings:

- Direct sales
- Distributors
- Manufacturer's representatives

The Steel Structures Painting Council (SSPC) estimates that U.S. anticorrosion coatings are purchased by the following users:

Table 24

U.S. Purchasers of Anticorrosion Coatings[a]
(percent)

Painting Contractors	40
Metal Fabricators	16
Facility Owners	13
Shipyards	9
Manufacturer's Representatives	8
General Contractors	4
Other	10
Total	100%

a. Percentages based on dollar volumes.

SOURCE: *A Survey of the United States Industrial Maintenance Coatings Market: Phase Two*, Steel Structures Painting Council, October 2001, p. 10.

Most facility owners have established long-term relationships with coatings suppliers—the SSPC estimates that over 90% of the facility owners report doing business with the same coatings supplier(s) for more than four years. About 60% of the jobs solicit bids from at least three coatings suppliers.

The most important attributes in the selection of coatings suppliers by facility owners were estimated by the SSPC as follows:

Table 25

Important Attributes for the Selection of a U.S. Supplier of Anticorrosion Coatings[a]

Product Performance/Application/Durability
Price/Cost
Technical Service/Specifications
Availability/Delivery Efficiency
Salesman Proficiency/Attitude
Warranty/Accountability

a. Listed from most important to least important.

SOURCE: *A Survey of the United States Industrial Maintenance Coatings Market: Phase Two*, Steel Structures Painting Council, October 2001.

In 2000, the website www.paintsquare.com was initiated, which provides coatings specialists a number of services:

- **Hiring.** Employers can post advertisements for help wanted and receive resumes.

- **Supplying Technical Information, with a Keyword Search to Find Relevant Technical Articles.**

- **Locating Suppliers, Including Contractors, Consultants, Equipment Manufacturers or Coatings Manufacturers.** The buying guide can be searched to develop a list of vendors, with links to their storefronts for complete information about their products, services and locations. Users can develop lists of qualified contractors by entering criteria of selection and acquiring a list of contractors who match. Coatings applicators can find rental equipment by searching on geographical area and type of equipment needed.

- **Finding Bargains in PaintSquare's Marketplace to Find Used Equipment or Excess Paint.** Suppliers can post a description and photo of used equipment or excess paint and provide a hyperlink and contact details to get inquiries from interested buyers.

- **Getting Prices.** Buyers can check on the price and availability of products or services by sending e-mail inquiries or requests for quotation using the messaging functions in the procurement hotline and in the buying guide.

In Western Europe, the major portion of high-performance anticorrosion coatings is supplied either to qualified painting contractors or directly to end users. A small portion is sold through dealers/jobbers. The share of coatings sold directly to applicators is estimated to be approximately 60%, with the exact percentage depending on the individual country and end-use segment. The contractual chain from the coating supplier to the end user in the case of new construction may include contractors and subcontractors, so that the coating supplier has difficulty in contacting the owner, or in some cases the consulting engineer, in order to interest him in higher-performance coatings that cost more but last longer. Usually, the painting contractor is mostly interested in the lowest price. Therefore, most of the coating suppliers put a considerable effort into convincing owners and consultants to think in terms of life-cycle costs. With large owners, the argument seems to be increasingly accepted but the negotiation usually starts all over again for each new structure. For maintenance work, the contact with the owners is more straightforward and high-performance coatings are more readily accepted.

In the marine sector, the majority of paint jobs are conducted by painting contractors, which have a strong influence on the choice of paint producer for new vessels.

In Japan, most manufacturers of high-performance anticorrosion coatings are primary dealers with in-house sales subsidiaries situated by region or by market segment. Other secondary dealers/jobbers are also used for distribution throughout Japan. These suppliers provide decentralized stock points, and in some cases technical service as well. Delivery from the dealer/jobber can be more cost-effective than direct delivery from the manufacturer.

To increase customer acceptance of their high-performance anticorrosion coatings, some companies supply additional products and services, such as the following:

- **Guarantees.** In some cases, the coating company will warrant the performance of a coating for a certain period of time and be responsible for any required recoating. Guarantees are usually issued only on large projects in which a reputable applicator or contractor is used. Oftentimes, when there is a coatings failure, there are lengthy and costly disputes between coatings manufacturers, contractors, consultants and owners over responsibility. Meanwhile, the affected structure will continue to deteriorate, leading to even greater costs for remediation. In a novel "no blame guarantee" approach, a Steel Protection Guarantee Company (SPG) was established in 1999 by several insurance companies that underwrites the cost of any coatings failures associated with a public works project in the London area.

- **Maintenance Service Programs.** Essentially all coatings suppliers offer programs wherein they assume total responsibility for preparation, application, inspection and maintenance of the coating for a facility. Thus, the plant management is relieved of the burdens and risks associated with in-house coating programs. In recent years, these programs are believed to have lost popularity, as many plant management teams, facing ownership changes through divestitures, prefer not to invest in long-term maintenance programs.

- **Application Equipment.** Items such as spray guns, rollers, blast equipment and support sundries are supplied.

- **Partnering.** The raw materials supplier agrees to sell or license key feedstocks to a select coatings manufacturer to develop technologically unique products. The raw materials manufacturer benefits by gaining extensive support to develop contractor acceptance. The coating manufacturer gains by selling a superior coating that eclipses the competition. Superior products command higher prices, giving the coating manufacturer an incentive to market these custom feedstock formulations.

  Other types of partnering are used. Coating manufacturers can team up with contractors; these relationships can be beneficial if highly specialized coating materials are used in which special application or preparation skills are required. In sales partnering, a distributor gains outside product lines and markets them to its existing customer base. At the same time, the coatings supplier expands its distribution into additional geographic regions and/or end-use markets.

  To succeed, partnering requires trust, a long-term commitment, proprietary respect, shared control and communication.

- **Expert Support Personnel.** Corrosion engineers can survey an existing plant or structure and anticipate the nature and severity of corrosion problems. They can recommend the proper coating system and a program of preventive maintenance, and also provide training to the plant staff.

- **Widespread Distribution Network.** Sherwin-Williams provides paints and accessories to industrial maintenance customers (as well as other users) through 3,200 company stores in North America. Benjamin Moore sells maintenance coatings through its independent, licensed retail outlets. The company notes that these coatings cannot be sold by mass merchandisers, so there is less competition than in the consumer market. However, high-performance maintenance coatings require strong selling expertise, so Benjamin Moore has invested in training seminars and computer software programs. The company's service may be especially attractive to smaller manufacturing facilities in rural areas that are not serviced by large paint manufacturers.

- **Electronic Commerce.** Companies are now offering product data sheets, material safety data sheets, and guideline specifications on their Internet sites. Some companies are allowing customers to track the status of their orders over the Internet. Internal business documents can be rapidly transmitted at all times of the day, thus streamlining procedures. Business-to-business e-commerce makes it possible for many companies, often competitors, to form an alliance to provide a limited source over the Internet for buyers. To date, however, the business-to-business approach has not proven to be commercially successfully in the industrial marketplace, and does not seem attractive in the coatings industry because of the high number of products available, many of which are made on a custom basis. Most suppliers now have extensive Internet services for customers, where a vast amount of information is available, including ordering and stocking information, specifications, technical data, VOC calculators, contact lists, news and others.

  Some companies are now selling coatings exclusively over the Internet. National Paint Industries/ Blue Water Marine Paint (http://www.nationalpaintsupply.com) operates its own retail website for industrial maintenance and marine coatings, complete with pricing and availability. The firm also offers automotive and swimming pool finishes. It claims to offer lower prices than larger manufacturers, with full warranties. Products include epoxy coatings, industrial enamels, acrylic enamels, waterborne enamels and high-gloss urethanes, which are stocked in two warehouses totaling over 100,000 square feet. Progressive Epoxy Polymers (http://www.epoxyproducts.com) offers epoxies and urethanes from multiple vendors.

- **Assured Global Quality Standards.** Some suppliers offer a "fingerprinting" service, which allows a user the ability to monitor product composition to make sure there is no significant deviation in quality among batches. Such a service will ensure that suppliers cannot unscrupulously ship substandard product after winning contracts, and will improve the standardization of products that can be used anywhere around the world. The marine coatings industry has adhered to standards owing to the global nature of the business, but the maintenance coatings sector is prone to modifications and substitutions in formulas to meet local conditions.

  The International Organization for Standardization recently issued its ISO Standard 12944, "Paints and Varnishes—Corrosion Protection of Steel Structures by Protective Paint Systems," which helps determine how long a coating should last before requiring maintenance. Environment and coating selection are among the factors considered in the standard. ISO 12944 gives an indication of how long a coating might be expected to last before "reasonable" maintenance will be required in various environments ranging from indoor dry, through rural to aggressive industrial and marine situations. The standard covers short-, medium- and high-durability situations.

Cost Structure and Profitability

Manufacturing

The production of high-performance anticorrosion coatings is not capital-intensive. The major portion of the production cost is attributed to the prices paid for raw materials. The Steel Structures Painting Council (SSPC) estimates that the average producer spends 57% of its raw material purchases on resins, 19% on solvents, 13% on pigments and 11% on additives.

A cost breakdown for an average U.S. producer of high-performance anticorrosion coatings in recent years is shown in Table 26.

Table 26

Average U.S. Producer Cost Structure for High-Performance Anticorrosion Coatings (percent)

Revenue	100
Less: Cost of Goods Sold[a]	60-70
Gross Margin on Sales	30-40
Less: Selling, General and Administrative Expenses[b]	20-30
Return on Sales (before taxes)	5-10

a. Includes cost of raw materials, utilities, labor, overhead, property taxes, insurance and depreciation. The cost of raw materials probably accounts for 75-80% of this total.

b. Includes research and development.

SOURCE: SRI Consulting.

Thus, the two largest factors in manufacturing these coatings are the raw material and the selling, general and administrative expenses. On a percentage basis, an increase or decrease in these two costs has a greater effect than other expenses.

The following table presents representative figures on cost structure and profitability for Western European producers of anticorrosion coatings:

Table 27

Costs and Profits of Western European Producers of High-Performance Coatings as a Percentage of Paint Sales—2007 (percent)

Raw Materials and Packaging	50
Marketing and Selling	15
Production	9
Warehousing	6
Transport and Distribution	5
R&D	2.5
General and Administration	2.5
Total Costs	90%
Profits	10
Total	100%

SOURCE: SRI Consulting.

During 1999-2002, on average, European resin prices were relatively steady except for epoxies, which fell by as much as 10%; lesser-valued pigments dropped by between 6% (e.g., titanium dioxide) and 15% (lithophorone) in price while the higher-priced pigments remained steady. Solvent price levels varied—for example, hydrocarbons, alcohols, esters and glycol ethers were quite stable. By 2003, the situation had changed significantly. Key raw materials used in anticorrosion coatings including zinc, epoxy resins, titanium dioxide and solvents steadily increased in price in late 2003 and 2004. For example, zinc prices rose by over 30% and epoxy by 15-20%. Solvent prices increased steadily as the price of a barrel of oil rose to about $55 per barrel before retreating later in the year. Xylene, isopropyl alcohol, toluene and n-butyl acetate prices were up by 30-46% in October 2004, compared with October 2003. Marine coatings were impacted by the price of copper, which is used extensively in marine antifouling products. Copper prices in China have increased significantly in recent years, from around $2 per kilogram in 2003 to over $6 per kilogram in 2007. The marine coatings producers are rather insignificant buyers since most copper is used in construction and electrical applications, so they cannot leverage their purchasing power. However, the ability to raise prices has been limited since contracts with many shipbuilders are made three years in advance. Finally, steel prices have risen significantly in recent years, which increased the cost of steel containers for packaging.

In general, coatings manufacturers have failed to keep up with the rising costs of raw materials. In 2006, rising crude oil prices led to the cost of solvents increasing by 15-20%, with resins and binding agents rising by about 15%. Pigments and additives rose by 8-10%. Taking a longer view, the collective feedstocks in coatings rose about 40% during 2000-2006, but prices of coatings rose only by about 10% in the same time period. Other costs, such as transport, logistics and staffing, have also risen.

Historically, the industry has always been reluctant to raise prices because of intense competition. As a result, there continues to be significant pressure on the profitability of coatings producers. Generally, the high-performance coatings industry is characterized by relatively low margins on sales, but relatively attractive returns on assets. Profitability tends to be cyclical.

Application

Thirty years ago, steel would be erected on-site with millscale (corrosion) present, which would be allowed to weather until it started to detach and then the structure was painted. On large plants/structures this would be basically a continuous process which, once started, never stopped. Coatings used at the time were suitable for this purpose. Generally, the binders used were alkyds, chlorinated rubbers, or vinyls, and anticorrosive pigments such as red lead and zinc chromate were used. The realization of the potentially harmful effects of these pigments, as well as improvements in factory abrasive blast cleaning and alternative coatings technologies changed much of this procedure. Steel could be economically fully cleaned in the factory and long-life coating systems applied. Epoxy or silicate zinc-rich coatings, together with high-build epoxies, allowed resistance to handling damage that could never be achieved with the conventional resins systems. The rapid application in the factory sped up the construction process, as well as allowing application to be undertaken in a relatively controlled environment, hence allowing a better quality application to be achieved.

Many factors can affect the cost of applying a high-performance anticorrosion coating. For example, the degree of surface preparation and type of coating used will depend on the application conditions, condition of the substrate and level of protection required. A recoating operation may require blasting down to bare metal or may entail a mere touch-up of the topcoat.

The more severe the environment, the more durable the coating system should be. The Steel Structures Painting Council (SSPC) defines four distinct atmospheric service environments as follows:

- **Moderate Environment**—industrial and chemical, subject to moderate external corrosion
- **Offshore Environment**—facilities and structures built in and above seawater
- **Severe Environment**—heavy industrial and chemical plant area subject to aggressive external corrosion
- **Severe/Seacoast Environment—**within five miles of coast/seawater and in the presence of heavy industrial plants subject to aggressive external corrosion

For a moderate environment such as a rural, dry area, no coating or a single-coat system may be adequate, depending on the substrate. For a severe seacoast environment, a three-coat high-performance coating would be more appropriate.

The International Organization for Standardization ISO Standard 12944 describes short-, medium- and high-durability situations. The high-durability range for all environments is currently defined as more than fifteen years before major maintenance (Standard Ri3 defined by ISO 4628). When defining high durability as more than fifteen years, ISO 12944 includes a comment that systems can be selected either on the basis of their track record or accelerated laboratory testing that is specified in the standard, although such tests are often inadequate and track records may not be applicable as well, as there are probably few paints being sold today that are identical to those sold fifteen years ago. The standards are currently being revised to reflect more realistic conditions, as there is little evidence currently to suggest that it is realistic to expect the time to first major maintenance in most aggressive environments to be greater than fifteen years.

Cost of the coating operation depends in part on where the application is performed; it is usually less expensive and more effective to perform surface preparation and coating application to new steelwork in shops and fabrication yards prior to field assembly. Access to trained, reliable personnel is often more of a problem in the field as opposed to shops and fabrication yards. Extensive training is required to ensure that people are aware of the hazards associated with the materials and to ensure that application procedures are properly followed. Weather conditions often delay on-site painting. As a result, there has been a trend toward greater in-shop painting in recent years. Sometimes it is necessary to apply the intermediate and/or finishing coats on the construction site, but the primer can be applied at the shop or fabrication yard.

The cost of applying a coating to a chemical plant structure several stories high will be greater than that for a small tank at ground level. Sometimes a more durable and expensive coating will be applied to inaccessible areas. Previously painted steelwork is generally repainted on-site, with the notable exception of marine vessels, which must be dry-docked before recoating.

The cost of the coating material is generally less than 20% of the total installed cost. The cost of surface preparation can be as high as 80% of the total, as in the case of treating an existing structure that is heavily corroded and must be cleaned to the bare (white metal) surface. It is usually advantageous to apply a long-lasting coating to avoid extensive recoating operations subsequent in the life of the structure. As an example, the costs of applying a more expensive, long-lasting, ultra-high-solids coating were compared with those of using a traditional low-solids-based system:

Table 28

Long-Term Life Cycle Costs of Conventional vs. Durable Tank Coatings on U.S. Navy Surface Ships[a]
(dollars per tank coated)

	Conventional Low-Solids Coating	Durable Ultra-High-Solids Coating
Blasting	68,000	68,000
Paint Cost	3,322[b]	5,120[c]
Application Equipment	120	960
Operator Training	20	44
Labor for Application and Touch-Up (13 workers, 10 hours per day, labor rate of $25/hr)	42,250	35,750
Dehumidifier Rental	3,250	2,750
Miscellaneous Sundry Costs	7,500	7,500
Initial Painting Costs	124,462	120,124
Subsequent Touch-Up Maintenance Coating Operations		
5 Years	25,000	25,000
10 Years	124,462[d]	25,000
15 Years	25,000	25,000
Total[e]	298,924	195,124

a. Case assumes that 25 tanks will be coated; total costs are divided by 25 to estimate per-tank cost.

b. Assumes paint has 67% volume solids, is applied at an average thickness of 0.254 micron, is applied with a 30% loss factor and costs $6.60 per liter.

c. Assumes paint has 98% volume solids, is applied at an average thickness of 0.432 micron, is applied with a 30% loss factor and costs $11.89 per liter.

d. Case assumes that the less durable coating will fail in ten years and require a total repainting operation with costs comparable to those of the initial painting.

e. Figure ignores the time value of money.

SOURCE: Mark Schultz, and Eric Bosanac, "The Evolution & Benefits of Ultra-High Solids," Presentation at 2008 Paint and Coatings Expo, January 2008, Los Angeles, California.

There was some savings in the initial application of using the ultra-high-solids system since fewer working days were required to apply the system. The recommended film build was reached quicker when using the higher-solids coating.

Table 29 shows estimated lifetime costs for different coatings used on a bridge in Japan. The fluoropolymer-based coating has a very high installed cost due to the high price of the coating, but is more economical in the longer term since it eliminates the need for periodic recoating. In one study, the cost of applying a fluoropolymer coating to a bridge in Japan was compared with that of the traditional chlorinated rubber coating. The chlorinated rubber coating must be replaced every eight years due to failure, while the fluorourethane coating was still performing well after 21 years. The actual lifetime costs for the fluorourethane system could not be determined because its longevity exceeds the time span of the test.

Table 29

Relative Costs of Chlorinated Rubber and Fluorourethane Coating

Coating System/ Process	Cost (dollars per square meter)	Initial Cost Ratio	Life of Coating (years)	Cost per Year (dollars per square meter)
Chlorinated Rubber				
Surface Preparation	10.08	1.00	--	--
Coating System	15.53	1.00	--	--
Scaffolding, Staging	27.48	1.00	--	--
Total	53.09		8	6.64
Fluorourethane				
Surface Preparation	10.08	1.00	--	--
Coating System	35.08	2.26	--	--
Scaffolding, Staging	32.98	1.20	--	--
Total	78.14	1.47	>21	<3.72
Life Cycle Cost Ratio				0.56

SOURCE: Winn Darden, "Developments in Fluoropolymer Resins for Long Life Coatings," Presentation at 2007 International Coatings Expo, October 4, 2007, Toronto, Ontario.

The following table shows application costs for three types of coatings used in North Sea offshore installations. Owners are continually looking for economies in all segments of offshore construction and as far as coatings are concerned fewer coats for equivalent corrosion protection is highly attractive. Coating B, although more expensive on a material basis, has a lower applied cost since only two layers are needed rather than the normal three with the more conventional coatings. These coatings are gaining in importance in the North Sea and elsewhere.

Table 30

Application Costs for High-Performance Anticorrosion Coatings Offshore in the United Kingdom North Sea—2001

Coating System	Thickness (mils)	Cost (dollars per square meter) Material	Labor and Equipment	Total
A				
Zinc Epoxy Primer	3			
Epoxy Intermediate	2 x 5	7.00	24.00	31.00
Urethane-Epoxy Topcoat	2			
B				
Organic Epoxy Primer	3	7.40	19.20	26.60
Epoxy Polysiloxane Intermediate	5			
C				
Zinc Epoxy Primer	3			
Glass-Flake High-Solids Epoxy Intermediate	14	8.25	22.35	30.60
Urethane-Epoxy Topcoat	2			

SOURCE: SRI Consulting.

The example shown in Table 30 gives only the installed cost; additional calculations can be made for spot repair and recoating operations. For example, a structure in a moderately corrosive environment may be expected to have a thirty-year life. The following coating operations would typically be required:

- Year 0 Original coating
- Year 8 Spot repair of rusted areas using wire brush and touch-up with coating
- Year 12 Maintenance repair (remove rusted areas with hand tool and apply primer and topcoats)
- Year 18 Full recoating (blast down to bare metal and apply entire three-coat system)
- Year 26 Spot repair and touch-up

Many experts believe that the most effective route to long-term, low-cost protection is to make sound plans at the time of new construction. Some users of structures coated with anticorrosion coatings have changed their philosophies from using the best available technology to “good enough technology,” where costs and speed of processing are prime criteria. The “good enough technology” philosophy with functional requirements has given room for innovation and has opened the door for new technologies. One coatings company estimates that the cost of paint represents only 0.1% of the total investment cost of a structure, and points out that a decrease of 30% of the cost of the paint will represent only a 0.03% savings in the total cost. The consequences of not applying a high-quality, long-lasting coatings can include the following:

- Maintenance cost can be up to ten times the cost of initially installed paint cost
- Paint failure in a severe environment may lead to the need for costly steel replacement

- A significant coatings failure can have a negative effect on health, safety and environmental considerations

- Downtime for reapplication of coatings or asset replacement can be quite costly

Generally, the owner establishes the design life of the plant based on the cost of capital and return on investment (ROI). If the plant has a design life of twenty years, the coating system should provide protection to assure that components will perform for twenty years. This does not necessarily mean that the paint system will not fail. In fact, if properly designed, the coating system will have failed, but the components would still be functioning and creating profit for the owner. If the coating system is perfect at the end of twenty years, it probably means that the system was overdesigned, and capital was expended unnecessarily. If the system fails after five years for a plant with a twenty-year design life, expense dollars will be relatively high, reducing the operating margin. A coating system for a plant with a ten-year design life should be selected based on a lower initial investment, that is a coating system that is less expensive and provides protection for less time. A life-cycle cost analysis should be performed when making the initial coating selection, but instead, coating systems are often selected based on the best available products without regard for capital cost and ROI.

Recoating and repair operations can often be delayed and, as a result of the delay, corrosion damage will increase, making subsequent repair work more costly. Thus, the life-cycle cost will increase. One company estimates that major painting repairs are five to ten times more costly than spot repairs, and structural steel replacements cost about ten times more than major painting repairs. Still, it is often difficult to get management to embrace the idea of the preventative approach, so maintenance coating often is not a priority item in company budgets. However, in some cases, painting is regarded much more seriously. For offshore maintenance work, the costly transport of supplies and incidentals needs to be taken into account, and on bridge painting, the cost of traffic coning has been shown to be as great as, if not more than, repaint costs. In the case of offshore oil well platforms, the opportunity cost during equipment failure or production shutdowns is enormous, so many units begin coating maintenance when only 3-6% of the coating is failing. Shell Oil estimates it costs $7-15 per square foot to recoat offshore platforms compared with $2-3 per square foot of onshore structures. In the North Sea, coating offshore typically costs ten times more than coating onshore. A paint job on a typical structure costs about $1 million and takes a six-man crew about one year to complete. Therefore, there is a strong incentive to reduce labor costs by developing single-coat systems to replace the conventional multilayer coatings.

In some cases, preparation costs have increased significantly in recent years because of the need for applicators to provide systems for containing all of the debris generated when stripping paint off existing structures. For example, when restoring old bridges, the U.S. Environmental Protection Agency (EPA) requires that all paint containing lead pigments must be captured to prevent contamination of waterways. Elaborate booths must be installed and moved throughout the application. After painting, the debris must be disposed of as hazardous waste. Some experts note that the costs for repainting many structures are comparable to those for initially building them. In some cases, it is more cost-effective to erect a new bridge rather than refurbish an existing one that has been coated with lead-based paint. In the United States, the lead-related worker safety regulations became effective in 1992-93, resulting in a doubling of the associated costs (including blast cleaning, painting, disposal of hazardous waste and required worker training).

Generally, a relatively high-priced coating material will have a longer service life than a less expensive coating, thus saving the end user touch-up and repair costs, as well as plant downtime costs over the life of the structure. Also, coatings manufacturers developed “surface-tolerant” coatings in the 1980s that can be applied over surfaces that are only marginally cleaned; these have become very popular with applicators since they allow considerable savings in substrate preparation. More recently, overcoating sealers have been introduced that tolerate contaminated surfaces and permit application of a suitable topcoat to extend protection without abrasive blasting. These coatings are usually solvent-free epoxies and moisture-cured aluminum-pigmented urethanes.

A comparison of the costs for various high-performance maintenance coatings is given in Table 31.

Table 31

Typical 2004 U.S. Costs for High-Performance Anticorrosion Coatings[a]

Coating System	Recommended Dry Film Thickness (mils)	Theoretical (cents per square feet)	Spray (cents per square feet)	Roller (cents per square feet)
Acrylic Primer (water-based)	3.0	14.5	20.7	16.1
Acrylic Topcoat (water-based)	3.0	13.4	19.1	14.9
Alkyd Gloss Topcoat	2.0	5.9	8.4	6.6
Alkyd Primer	2.0	6.4	9.1	7.1
Alkyd Silicone	2.0	11.5	16.4	12.8
Coal Tar Epoxy Standard	8.0	11.9	17.0	13.2
Coal Tar Epoxy C200	8.0	15.2	21.7	16.9
Epoxy Thin Film, 100% Solids, Solvent-Free	5.0	6.8	10.9	7.6
Epoxy Clear Sealer, 100% Solids Solvent-Free	2.0	3.9	5.6	4.3
Epoxy Ester Primer	1.5	3.5	5.0	3.9
Epoxy Ester Topcoat	2.0	7.2	10.3	8.0
Epoxy High-Build Primer (two-part)	4.0	10.0	14.3	11.1
Epoxy High-Build Intermediate (two-part)	4.0	11.0	15.7	12.2
Epoxy Mastic (high-build)	5.0	12.0	17.1	13.3
Epoxy Phenolic Primer	5.0	17.3	24.7	19.2
Epoxy Phenolic Topcoat	5.0	19.0	27.1	21.1
Epoxy Primer (two-part)	2.0	5.0	7.1	5.6
Epoxy Topcoat (two-part)	2.0	6.9	9.9	7.7
Epoxy Waterborne (two-part)	3.0	19.2	27.4	21.3
Hot Dip Galvanizing	4.0	8.2	na	na
Latex Emulsion, Primer	2.0	5.5	7.9	6.1
Latex Emulsion, Topcoat	2.0	5.4	7.7	6.0
Urethane Primer (one-component)	2.0	7.2	10.3	8.0
Urethane (aliphatic isocyanate, acrylic polyol, two-component)	4.0	11.6	16.6	12.9
Urethane (aliphatic isocyanate, acrylic polyol, two-component, high-build intermediate/topcoat)	4.0	20.4	29.1	22.7
Urethane (aliphatic isocyanate, acrylic polyester polyol, two-component)	2.0	15.0	21.4	16.7
Urethane Elastomer (solvent-based)	20.0	91.0	130.0	101.1
Urethane Moisture-Cured Aluminum	2.5	9.5	13.6	10.6
Urethane Moisture-Cured Clear Sealer	2.0	7.6	10.9	8.4
Urethane Primer (moisture-cured, contains aluminum pigment)	2.5	9.5	13.6	10.6
Vinyl Ester	20.0	74.0	105.7	82.2
Zinc-Rich Inorganic	3.0	13.4	16.1	14.9
Zinc-Rich Moisture-Cured Urethane	3.0	13.1	18.7	14.6
Zinc-Rich Organic	3.0	14.9	21.3	16.6

a. Figures reflect approximate market prices for coating materials in the United States in 2004 as supplied by U.S. paint and coatings manufacturers. Application labor, equipment and coating loss are not included. The coating loss during application by spray is approximately 40% and by brush or roller is about 10%.

SOURCE: L. Brian Castler, et al., "Comparative Painting Costs," *Planning and Specifying Industrial Protective Coating Projects*, Steel Structures Paint Council Publication 04-10, 2004, p. 18.

The protective coating costs for bridges in Japan, in 2007 are shown in Table 32. As coating bridges requires skill and preparation for items such as steps for painters, costs include significant labor costs and preparation costs.

Table 32

Japanese Application Costs for High-Performance Anticorrosion Coatings—2007

	Recommended Usage (gram per square meter)	Yen per Square Meter	Cents per Square Meter
Modified Epoxy Primer	240	204	176
Nonsolvent Epoxy Ester Primer	300	600	517
Tar Epoxy Primer	180	108	93
Nonsolvent Tar Epoxy Primer	300	411	354
Alkyd Topcoat	110	52	45
Chlorinated Rubber Topcoat	200	110	95
Fluorinated Topcoat	140	524	451
Polyurethane Topcoat	140	183	158
Silicone Topcoat	140	326	281
Silicone Alkyd Topcoat	110	116	100

SOURCE: SRI Consulting.

GOVERNMENT REGULATIONS

Most of the current research in anticorrosion coatings is directed toward the development of coatings that meet more stringent environmental standards dealing with emissions of VOCs. Historically, the industry has been highly motivated to use high-solids or waterborne coatings as a means to reduce worker exposure to organic solvents, and to reduce fire hazards in tanks and other confined areas. Using higher-solids coatings is also desirable since films can be built faster than with lower-solids coatings, thus reducing labor costs.

Air pollution regulations are tightening. The heavily populated areas of California (the San Francisco Bay Area and the Southern California coast) restricted industrial maintenance coatings to a maximum of 420 grams of VOCs per liter (3.5 pounds per gallon) starting in 1987. (Rules on high-temperature maintenance coatings [e.g., those used on substrates exposed to temperatures above 200°C] were more lenient—650 grams per liter (5.3 pounds per gallon). Other specialty coatings [e.g., pretreatment primers, metallic pigmented coatings and dry-fog coatings] also had more lenient standards.) Subsequent proposals in the early 1990s to lower the standards to 340 grams per liter (2.8 pounds per gallon) were delayed because of lawsuits covering maintenance and certain other coatings, from a group of coatings manufacturers. The lawsuits were based on the premise that low-VOC coatings do not perform as well as most finishes that contain higher VOC levels; thus, structures need to be repainted more often. As a result, during the life of the structure, total consumption of coatings is increased, along with total VOC emissions.

The U.S. government started regulating anticorrosion coatings as a result of the 1990 Clean Air Act Amendments. The EPA developed control technique guidelines (CTGs) for various industries that set limits on VOC emissions from coatings, particularly in areas that exceed certain levels of lower-atmospheric ozone (which is produced by the reaction of sunlight with nitrogen oxides and hydrocarbons). CTGs address the control of emissions of 189 compounds that are classified as hazardous air pollutants (HAPS) by the 1990 Clean Air Act Amendments; the list includes some key raw materials used by the coatings industry such as methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), glycol ethers, toluene, methanol, 1,1,1-trichloroethane, methylene chloride and xylenes. For the shipbuilding and ship repair industry, best available control measures (BACM), based on CTGs, were developed in conjunction with national emission standards for hazardous air pollutants (NESHAPs). Both programs focused on establishing allowable VOC levels (although not all VOCs are HAPs, it was assumed that by decreasing solvent emissions, both VOCs and HAPs would be reduced). In 1994, standards were established for the marine industry, establishing the VOC ceiling for general coatings use at 340 grams per liter. The limits for specialized coatings were higher; for example, antifoulants have a ceiling of 400 grams per liter.

The U.S. EPA started reviewing the Architectural and Industrial Maintenance (AIM) coatings market in the early 1990s. The EPA intended to use the “reg-neg” process, by which regulations are developed through negotiations between industry and government representatives. However, the process was discontinued in 1994 when one group of industry representatives could not reach a compromise. In 1998, the EPA finally issued its regulations for AIM coatings requiring that all coatings manufacturers and applicators be in compliance with the ceiling of 450 grams per liter of VOCs for general industrial maintenance coatings (VOC limits for certain coatings used in specific applications may be higher) by August 1999. The delay allowed industries time to introduce approved products and various governments time to eliminate a number of conflicting state regulations. Coatings companies can elect to sell products with VOC levels that exceed the AIM level if they elect to pay an exceedance fee. There have been no changes to these regulations since they were first imposed, but the EPA is currently reviewing the limits.

The states are allowed to impose stricter regulations. In mid-1999, the regulatory body in Southern California (the South Coast Air Quality Management District—SCAQMD), which tends to be in the forefront in enacting environmental legislation, proposed that general industrial maintenance coatings contain no more than 250 grams of VOCs per liter in 2002 and 100 grams of VOCs per liter starting in 2006 (the standards for specialty maintenance coatings were also to be reduced). In 1996, the average VOC levels of solventborne industrial maintenance coatings sold in California were 313 grams per liter, while the VOC levels of waterborne industrial maintenance coatings were 170 grams per liter, so the industrial maintenance industry in 1996 could not even meet the 2006 standards with most existing waterborne coatings. Opponents to the measure point out that the 2006 regulations would require reformulation costing about $250,000 per product, and that smaller producers would be faced with onerous financial burdens.

In 2001, SCAQMD issued its final rules, setting a limit of 250 grams of VOCs per liter in 2004, with further reduction to 100 grams per liter starting in mid-2006. Most other urban regions in California adopted the 2004 standard, but not the 2006 level. In the eastern United States, the Ozone Transport Committee (OTC) makes recommendations on environmental policy for thirteen states, including New England plus Pennsylvania and New Jersey. Six states/regions (New York, New Jersey, Pennsylvania, Delaware, Maryland and the Washington D.C. metropolitan area) lowered VOC limits for industrial maintenance coatings to 340 grams per liter in 2005. Some of the OTC’s six other member states in New England are also expected to approve the new rules. The EPA is currently considering the revision of the AIM rule to make it more consistent throughout the United States.

Even manufacturers of waterborne industrial coatings are continuing their developmental efforts. Currently, the VOC level of most waterborne acrylic industrial maintenance coatings is 150-250 grams per liter. Industry is developing new polymers to meet the 100 gram-per-liter limit. A survey of industrial maintenance coatings use in California was conducted again in 2001 and found that about 30% of the coatings met the 250 gram-per-liter level and about 10% met the 100 gram-per-liter level. A subsequent survey conducted in 2005 found that 54% of the coatings met the 250 gram-per-liter level and 23% met the 100 gram-per-liter level.

In recent years, however, there have been some changes in regulations aimed at easing the burden on the coatings industry, including the industrial maintenance sector. In 2003, the EPA reclassified methyl ethyl ketone (MEK) as a non-HAP and no longer considered to be a toxic air pollutant. However, MEK emissions will continue to be subject to reporting under the Toxics Release Inventory legislation and will continue to be regulated as a VOC. In late 2004, the EPA decided to classify tertiary-butyl acetate as a non-VOC solvent; thus, coatings manufacturers do not have to include its presence in a formulation when calculating VOC levels. Also in 2004, the SCAQMD agreed to consider regulating coatings on the reactivity of solvents rather than establish VOC content requirements. In the case of alkyds, mineral spirits, often used as the principal solvent, exhibit low VOC formation while other solvents, such as ketones or glycol ethers, display high VOC formation. Therefore, solventborne alkyds would theoretically contribute less to ozone formation than emulsion acrylics (which are formulated with glycol ethers). Also, it must be remembered that the solids content of solventbornes is considerably higher than that of waterbornes (approximately 73% vs. 55%), so less solventborne is needed to achieve a given film thickness. No timetable has been set for any decision.

Most producers believe that about 15% of the coatings used for high-performance anticorrosion applications are waterbornes as of 2007. Even in the extremely environmentally conscious state of California, use of waterbornes in general industrial maintenance coatings was estimated at less than 10% in 1996, 13% in 2000 and 33% in 2004.

In 2007, SCAQMD announced that it was considering the imposition of fees on coatings products, including architectural and industrial maintenance coatings, and industrial coatings, as well as associated solvents sold in the district. SCAQMD has indicated that the fee schedule would favor low-VOC and ultra-low-VOC products, with higher fees being charged for the higher-VOC products. The small container exemption schedule may also be eliminated.

In Europe until recently, VOC regulations have generally been more lenient than in the United States; however, regulations concerning potentially toxic compounds (e.g., aromatic solvents and liquid epoxy resins) are more stringent. Most European VOC regulations tend to vary from country to country, covering paint production facilities and fixed painting operations such as factory-coated equipment and coil coatings. Generally, regulations in Scandinavian countries have been the strictest, followed by Germany, the United Kingdom and the Netherlands. Other countries (e.g., France and Italy) have fewer regulations. In most areas, a maximum level of solvent emissions is allowed per area of painted surface (the “bubble concept”). Coatings systems that have more solvent in one layer and less solvent in other layers are allowed if the combined emissions are in compliance. The guidelines generally stipulate a percentage reduction based on a particular base year. In Scandinavia, VOC emissions from coatings operations have been reduced considerably with the use of waterborne coatings. There has been a strong trend to use waterborne coatings despite their greater cost and difficulties in application. Norway now demands that a user must evaluate if there are alternative products or chemical compounds that lead to a reduction in health, safety and environmental (HSE) risk for the company and user. The alternative must be used unless the applicator can document that there would be an unreasonable increase in cost or inconvenience. In the United Kingdom, legislation covering isocyanates has been tightened, leading to substitution with alternate coatings. There have been discussions in Scandinavian countries to limit the use of isocyanate-based coatings. As of yet, no legislation has been enacted, but some producers have begun offering nonisocyanate coatings as substitutes.

To unify regulations on a continent-wide basis, the European Council of the European Union adopted a VOC Directive, the so-called Solvent Emissions Directive (SED), in March 1999, which affects a wide range of solvent uses and that will further increase the pressure to implement new coating technologies. The VOC Directive was first formulated in 1991 but progress in its adoption was delayed while the Integrated Pollution Prevention Control (IPPC) Directive was being approved, with the objective of limiting emissions of organic solvents. The IPPC Directive was adopted in September 1996 and covers, among other things, emissions of VOCs from installations that have a solvent capacity of more than 150 kilograms per hour (or 200 metric tons per year).

The VOC Directive proposed emission limits for various processes and sought to cut the 1997 level of VOC emissions from solvent-using installations by 57% by October 31, 2007. This obligation can be met via abatement techniques or solvent substitution (e.g., through environmentally friendly coatings), but the manner by which this is achieved is largely left to the member states themselves. The recommended VOC limit is 250 grams per liter but different countries calculate the VOCs in different ways; thus, a VOC-compliant paint in Austria may be rejected in France. (As an example, in the United States, VOCs are measured by determining the weight loss after the coating is heated to 104ºC, while the European Union measures VOCs by the vapor pressure of the coating. A high-solids or solventless coating will usually display higher VOCs by the former method since reactive diluents will be counted as VOCs.)

The differences in environmental legislation among countries were expected to diminish with the adoption of the Solvent Emissions Directive but, in practice, differences will continue to exist into the near future. Eventually the SED will force installation of solvent abatement equipment or mandatory use of waterborne products. Solvent abatement systems are expensive with high operating costs, and may not be satisfactory long-term solutions, as exhaust emissions of CO_2 and SO_2 will be restricted in many countries.

The European coatings industry is quite concerned over the European legislation known as Registration, Evaluation, and Authorization of Chemicals (REACH), which requires toxicity evaluations of about 70,000 substances. All chemicals sold in quantities of one ton or more per year have to be registered (actually all new chemicals introduced since 1981 have already had to be registered). All chemicals sold in volumes of at least 100 tons per year are subject to toxicity assessment by national authorities. An authorization is required for all substances that pose threats as carcinogens, mutagens, reprotoxics, bioaccumulating materials, or endocrine disrupters.

It is expected that the major effects of REACH on the coatings industry will be as follows:

- Fewer raw materials available since suppliers will be unwilling to spend money and time registering all products, especially small-volume products. An estimated 50 thousand euros will be required to register a small-volume chemical and one million euros will be spent for a large-volume chemical.

- Producers will lose confidentiality of product formulations.

- Many small paint formulators will close due to the burdensome administrative costs.

- Many non-European coatings producers will be affected by the legislation due to the globalization of coatings consumers.

- Even non-European suppliers of raw materials will be subject to REACH regulations if they wish to export to the EU.

- Products made in the EU will become less competitive in the global marketplace and become more prone to displacement by imports.

Generally, VOC concerns in Japan are much less than in the United States and Europe. There are no severe restrictions concerning VOC emissions from paint. However, the government established a system for industries to disclose the solvent release, which is called Pollutant Release and Transfer Register (PRTR), in 2001. The legislation requires the disclosure of emissions of 345 chemicals, of which 139 are believed to be used in the coatings industry. The system is to some extent similar to TRI (Toxic Release Inventory) in the United States. Coatings companies are becoming more sensitive to solvent emissions from a corporate image standpoint. Some coatings companies have developed high-solids, 100%-solids and waterborne anticorrosion coatings for marine and industrial maintenance coatings to reduce worker exposure levels to potentially toxic solvents. The use of high-solids or 100%-solids coatings for inside-tank applications is increasing because of safety and hygiene concerns. Also, there is a trend of moving away from using strong aromatic solvents (toluene- or xylene-based) to less-toxic aliphatic solvents.

In 2007, a revised Air Pollution Control Law was passed that targets a 30% reduction in VOCs from stationary sources effective in 2010 compared with levels in 2000.

The Republic of Korea is starting to enact VOC legislation as well, but controlling solvent emissions is still not an issue in other Asia Pacific areas. Building of offshore platforms is mainly focused in Southeast Asia. With increasing regulations in the industrialized world, applicators of marine and bulk cargo container coatings are tending to move operations to the less industrialized countries to avoid complying with VOC regulations and to take advantage of lower labor costs.

In developed countries, VOC compliance can be achieved by using either waterborne or high-solids coatings with at least a 60% solids content. However, either technology presents considerable challenges to the coatings formulator and/or user. Table 33 summarizes the major advantages and disadvantages of these technologies.

Table 33

High-Solids and Waterborne High-Performance Anticorrosion Coatings

	Advantages	Disadvantages
High-Solids Coatings	More surface-tolerant than waterbornes Can be formulated into highly durable coatings using epoxy, urethane or zinc binders Better track record than waterbornes	Less surface-tolerant than conventional solventbornes Often difficult to achieve sprayable low-viscosity properties Relatively poor flow properties Usually relatively short pot life Often contain low-molecular-weight oligomers that are potentially hazardous to worker health Slow drying times Overspray is a problem Higher film builds than conventional coatings
Waterborne Coatings	Fairly good dried film properties Very low organic solvent concentration	Requires excellent surface preparation Must be applied under moderate conditions (above 5ºC and less than 85% relative humidity)
	Low odor	Low-solids content requires multiple applications
	Low flammability No need to stock thinning and cleaning solvents Generally, pose lesser health and safety concerns	Cost more than solvent-based coatings
	Appearance like latex paint	Subject to poor early water resistance—the coating degrades upon exposure to rain and high humidity
	Faster drying and recoating than solvent paints at moderate climatic conditions	Poor durability in immersion or highly corrosive environment

SOURCE: SRI Consulting.

For high-performance formulations, high-solids coatings have been more successful than waterborne coatings. Waterbornes account for only about 10% of the total European market for anticorrosion coatings. The Verband der Deutschen Lackindustrie (VdL) estimates that high solids have a market share of only 1.6% in Germany (total of 30 thousand metric tons in 2003), but that 50% of the high solids are used in industrial maintenance coatings, and another 10% or so in marine coatings. Even before VOC regulations became prevalent, the anticorrosion coatings industry moved to higher solids for several reasons:

- Generally, higher build-coating thicknesses are specified than is typical for most coatings operations, to help ensure lasting protection from corrosion. By using higher solids, film thicknesses can be built more quickly. The industry has found it difficult to apply more than 100-120 microns of wet film in a single coat, so there are limits to the film build in a single pass. In contrast, most other industrial applications of coatings require much lower film thicknesses (typically 30-50 microns).

- The industry prefers to minimize worker exposure to potentially harmful solvent vapors, especially in areas that might be confined (e.g., the insides of storage tanks).

In particular, high-solids epoxies, coal tar epoxies and urethanes have excellent track records. High-solids epoxy coatings contain reactive diluents, which generally have glycidyl ether functionality. However, as the level of reactive diluents is increased, the surface tolerance of the coatings is decreased. Coal tar epoxies present potential toxicity concerns so use has been waning in recent years.

Globally, higher-solid coatings are more prevalent in offshore coatings, accounting for about 75% of the total market. Conventional solvent-based paints predominate in marine coatings, accounting for about 75% of the total. In the onshore market, conventional solventborne paint accounts for roughly 65% of the total market, with higher solids at 25%.

Many coatings manufacturers believe that there is not a large difference in applied costs between conventional low-solids coatings and high-solids. High-solids cost more but display greater coverage on a volume basis. Surface preparation costs may be higher with high-solids because there is less solvent present to clean contamination from the surface of the substrate. Drying time with high-solids is greater, but waste disposal costs are less. On the other hand, it is believed that the overall applied costs for waterbornes will be greater than those for conventional low-solids because of their lower solids content; as a result, labor costs increase because of the additional number of applications required. Some waterbornes, especially zinc-rich primers, are being used in painting shops where the application conditions can be controlled to facilitate drying.

VOC compliance can also be attained through the use of powder coatings; these materials provide excellent corrosion protection and contain no solvent, but must be subjected to heat after application, for proper surface wetting and cure. Currently, a relatively small amount of powder (about 15 thousand metric tons in North America per year) is being shop-applied to oil and gas transmission pipes and steel reinforcing bars. Some manufacturers are marketing powders that are applied in the field by flame spraying; the powder is entrained in one of the gas components feeding an oxygen-propane flame and delivered in molten form to the substrate. Two disadvantages of this process will tend to limit its use: application requires the use of an open flame and must be performed by experienced personnel to ensure quality results.

In addition to air pollution standards, R&D efforts are being directed toward the development of coatings that will meet other government regulations. These include the following.

- **Coatings for Equipment That Holds and Carries Potable Water Supplies.** New U.S. regulations will require that coatings contain only low levels of leachable toxic compounds. All coatings currently used in this market are under close scrutiny by federal agencies. There is a strong possibility that coal tar epoxies will not be recertified because of leachable aromatic compounds in the coal tar. In addition, proposed air pollution regulations complicate this situation since they will prohibit the use of vinyls or chlorinated rubber formulations as water tank coatings because of high solvent emissions during application. To date, the National Sanitation Foundation has approved only coatings based on two-component epoxies and polyurethanes as finishes on the inside of steel tanks that are used to transport and hold potable water.

  In Western Europe, the use of coal tar epoxies for coatings on water and wastewater structures is no longer allowed. Coal tar epoxies are relatively inexpensive and have a long proven record of successful use.

- **Coatings for Wastewater Treatment Equipment**. A continuing problem is the greater demands that are being placed on coatings for wastewater treatment plants because of the increased presence of hydrogen sulfide, a highly corrosive product for both steel and concrete. In some cases, higher-performance coatings of the fluoropolymer type or even thick elastomeric linings must be employed.

- **New Antifouling Coatings for Oceangoing Vessels.** These coatings are currently applied to about 75% of the world's commercial ship hulls to limit the buildup of organisms on immersed portions of the hull. There are some 90,000 registered merchant ships in the world today with a total gross tonnage of 605 million metric tons and an average age of 21 years, all of which require antifoulant coatings. In addition to this, smaller ships, pleasure craft and naval vessels may account for as much as 20% of the market for antifouling coatings.

  When marine organisms (such as algae, barnacles, etc.) adhere to ship bottom surfaces, the surface of the ship bottom loses smoothness, resulting in lower fuel economies. The total global market size for antifouling coatings is 125 million liters worth $1-1.2 billion per year, which includes the use of roughly $300 million of biocides (mainly cuprous oxide). Historically, cuprous oxide was used as the biocide; however, starting in the 1970s, the industry started using tributyltin (TBT) compounds (TBT is chemically attached to methyl methacrylate in the copolymer backbone), which are more effective than cuprous oxide. TBT treatment is very effective, costing $20 thousand for an application lasting five years, which could save an oceangoing vessel $250 thousand in fuel penalties without the treatment. TBTs are also effective for controlling fouling in water intake structures. Unfortunately, in the early 1980s, TBT was found to cause harm to nontarget organisms when released into the environment, especially sediment in harbors. In early 2005, some Yale University researchers found that exposure to TBT may cause hearing difficulties in whales and other aquatic mammals.

  In October 2001, the International Maritime Organization (IMO) agreed to ban the application of TBT on ships starting in January 2003, and to ban its presence on ships starting January 2008.

  Before 2003, ship owners had the option of using TBT-containing paint, but would eventually have to comply with the 2008 legislation at considerable expense of removing all existing paint and treating the washwater, or by applying a seal coat that retards any leaching. In addition, vessels with TBT paint applied after 2002 will experience problems with control at some port states and may be forced to dry-dock prematurely. In 2003, virtually all production and sales of TBT coatings ceased except in China, where all production will cease in 2008. China has vowed to follow IMO guidelines as part of the 11th Five Year Plan.

  Japanese marine paint producers started developing tin-free systems in the late 1980s. By 1992, Japanese marine coatings producers practically stopped using TBT, as well as other tin compounds such as triphenyltin (TPT) and tributyltin oxide (TBTO). All producers introduced TBT alternatives shortly thereafter.

  Most commercial alternative coatings contain biocides that are gradually released in seawater. Coatings can be rosin-based "controlled-depletion polymer" (CDP) (e.g., "Interswift 655" from Akzo Nobel and "Sea Queen" from Jotun) or an acrylic "self-polishing coating" (SPC) (e.g., "Ecloflex" from Nippon and "Exion" from NKM). CDP coatings utilize rosin or synthetic resins, which dissolve very slowly in the slightly alkaline conditions of seawater, slowly releasing biocide. SPCs were developed in the 1970s and rapidly became the most important type of antifouling coatings. Most SPC binders are based on silyl acrylates. Seawater slowly hydrolyses a portion of the coating, making it hydrophilic so that it is washed away and releases biocide. The biocide release rate can easily be controlled by changing the mix of polymers in the mixture. In either case, the leaching of biocide into seawater is carefully controlled in efforts to maximize longevity of the antifouling coating. Hybrid CDP/SPC systems are available that combine the cost advantages of the CDP system with the greater effectiveness of the SPC system.

Cuprous oxide is generally preferred as the biocide, although other forms of copper are used, including copper thiocyanate and copper powder (for nonsteel hulls only). Copper compounds are considered to be less effective (especially against vegetation) and more costly than those based on tin compounds, but do not bioaccumulate to the degree that the tin compounds are alleged to. However, in some bays and inlets, the use of copper compounds is limited as well. Canada has set limits on copper emission rates and the Netherlands has banned its use on small vessels. It is possible that cuprous oxide will be banned globally, but this is unlikely. The table below shows the biocides that are currently used in marine coatings in Japan.

Table 34

Japanese Biocides Used in Marine Coatings—2008[a]

Major Biocides

Cuprous Oxide
Zinc Pyrithione
Copper Pyrithione
Pyridine Triphenylborane

Other Biocides

4,5-Dichloro-2-Octyl-3(2H)-Isothiazolone or Seanine-211
3-(3,4-Dichlorophenyl)-1,1-Dimethyl Urea, Diuron or Preventol A6
2,4,5,6,-Tetrachloroisophthalonitrile
2-Methylthio-4-tert-Butylamino-6-Cyclopropylamino-triazine, Irganol 1051 or 1071
Cuprous Thiocyanate
N,N-Dimethyl-N′-Phenyl-N′-(dichlorofluoromethylthio) Sulfamide
Dichlofluanid or Preventol A4
Naphthenic Acids, Copper Salts
Zinc Dimethyl Dithiocarbamate or Ziram
2,4,6-Trichlorophenyl Maleimide or IT-354
Zinc Ethylenebis (dithiocarbamate) or Zineb
2,3,5,6-Tetrachloro-4-(Methylsulfonyl) Pyridine or Densil S-100
Tetramethylthiuram Disulfide or Thiram

a. Products are listed from high to low by volume.

SOURCE: SRI Consulting based on data from the Japan Paint Manufacturers Association.

Besides copper oxide, other biocides currently approved in the United States are zinc pyrithione, 4,5-dichloro-2-n-octyl-4-isothiazoline-3-one, and 2-methylthio-4-tert-butylamino-6-cyclopropyl-amino-s-triazine. In Western Europe and Australia, only the first two of these materials are approved. Other biocides are now being tested. However, except for TBT, these countries do not prohibit the ship (containing other biocides in coatings) from entering the port. Since January 2008, countries that ratified the IMO prohibition on TBT ban ships with TBT-containing paints/sealers from entering their harbors. Tin acrylate is also used in some developing countries, instead of TBT.

The U.S. marine coatings industry is subject to the VOC regulation that limits any new antifoulant paint to 400 grams of VOC per liter. In the European Union, the Biocidal Products Directive 98/8/EC that entered into force on May 14, 2000, is expected to reduce the number of biocides on the EU market. However, these regulations often motivate the marine industry to move operations away from the industrialized world if possible to other less-VOC-regulated countries.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal may require shipbuilders to take responsibility for proper shipbreaking when the vessel is dismantled at the end of its useful life. Shipbreaking is currently handled by less-developed countries with low labor costs, such as in India, Bangladesh, Pakistan, the Philippines and others. However, ships that were produced 25-30 years ago generally contain TBT in coatings and possibly other toxic chemicals (PCB [polychlorobiphenyl], dichloro-diphenyl-trichloroethane [DDT], chromium compounds and asbestos), which cause serious environmental problems in shipbreaking countries. Currently, it is unclear if the transboundary movements of old ships for the purpose of shipbreaking are against the Basel Treaty. In 2004, delegates representing countries that are parties to the Basel Convention issued a joint declaration calling for stronger global efforts to reduce hazardous waste generation. The delegates also formally approved voluntary guidelines for managing wastes containing certain substances, such as persistent organic pollutants, and agreed to consider tightening restrictions on the transportation of ships destined for scrapping by subjecting them to the same rules as hazardous waste shipments.

Developmental work continues to find replacements for TBT. There is considerable interest in coatings that contain no biocides, but instead permit only a weak bond between the fouling and the coating, which can be broken by the weight of the fouling or the motion of the ship through the water. In practice, use is limited to high-speed watercraft like patrol boats or racing yachts which have a threshold speed of at least 15 knots. Silicone-based “foul release” coatings have been commercialized (e.g., “SeaQuantum” from Jotun, “NuTrim” from Kansai and “Sea Grand Prix 1000” from Chugoku), and have the advantage of not needing extensive premarket toxicity testing. Fluoropolymer-based coatings have also shown some promise. Some of the drawbacks of these coatings are the threshold speed factor, the high initial cost, difficulties in repair, and vulnerability to damage due to their softness.

Testing takes a considerable amount of time to be complete, typically eight to ten years, and must take into account factors like the differences in fouling types present, ocean temperatures and operational patterns. An estimated $4 million is required to conduct the necessary human and environmental toxicity testing for each biocide. Researchers of the Nara Institute of Science and Technology in Japan have shown promising results with an encapsulated silicone containing a special type of antibacterial, which is often used as a glass defogger, into the microscopic mesh-structured polymer by means of strong chemical bonds. If further testing is successful, the groups intend to commercialize the product. The European Council of the Paint, Printing Ink and Artists’ Colours Industry (CEPE) has developed a computer model to generate predicted environmental concentrations (PECs) for antifouling products in the marine environment. The model is available at the CEPE website.

The IMO regulations apply to ships with a gross tonnage of 400 metric tons and above engaged in international voyages, excluding fixed or floating platforms; floating storage units; and floating production, storage and offloading vessels. The offshore oil and gas industry uses antifouling coatings on its riser piping, which is the flexible set of steel pipe conduits, frequently hundreds of feet long, filled with produced crude oil or natural gas under pressure. The riser piping system is an inherently weak link, as the weight of the riser pipe string and the product in it puts tremendous stress on the pipe. The stress is compounded by wave and current action and the potential for storm damage. Every riser column is a delicate balancing act—the thinnest, lightest possible pipe weight against the required strength. Smoothness (fairness) of the exterior of a riser pipe partly determines the amount of vibration induced from external sources. The fairer the exterior of a riser pipe string, the less vibration it picks up from wave, tidal, and current motion in the surrounding water. Engineers seek to design a riser string that will start fair and stay fair for the twenty-year planned life cycle of a production structure. Failure of the riser string can have catastrophic results—loss of production, pollution, fire, explosion and injury or loss of life to structure workers. Vibration is one of the greatest threats to riser piping because continuous vibration can weaken and eventually break weld joints in the riser string. In addition, excess barnacle growth can add a huge amount of weight to the string, making it more prone to failure, and also it masks the surface of the string, making it difficult to inspect underwater. Low-energy surface silicone elastomers are being investigated as likely topcoatings.

The industry is also starting to commercialize coatings containing nanoparticles to reduce barnacle adhesion and water drag resistance, and also to provide an extreme scratch-resistant and self-cleaning boat surface.

- **Longer-Lasting Ballast Tank Coatings.** Effective in July 2008, all new steel ships above 500 tons (and all ships after July 2012) must comply with the new IMO Performance Standard for Protective Coatings (PSPC) for dedicated seawater ballast tank coatings. After the Exxon Valdez accident of 1989 and other incidents, inspections of ballast tanks were intensified to prevent future spillages due to coating failures. Previously, most ballast tanks were coated with coal tar epoxies, which were effective but usually black in color, making inspection difficult. As replacements, light colored coatings began to be accepted in the 1990s. The PSPC requires a nominal total dry film thickness of 320 microns (12.8 millimeters) for epoxy-based coatings. Any defective areas (pin-holes, bubbles, etc.) shall be marked and repaired, followed by reinspection. Due to this PSPC, the coating volume per ship will be increased to secure film thickness, and this will be a positive factor increasing marine paint demand over the next five years. The PSPC requires the use of light-colored, pure epoxy or modified epoxy coating systems on ballast tanks as replacements for the conventional coal tar epoxy coatings. In 2007, more than 95% of epoxy coatings for ballast tanks in the Republic of Korea were non–tar based, and in Japan, 70-80% were non-tar in 2007, up from 35-40% in 2003. Chugoku Marine Paint replaced epoxy coal tar coatings in 2006, as it has developed a tar-free epoxy coating with equivalent anticorrosion properties. Nippon Paint plans to move away from coal tars by 2009.

- **Coatings That Do Not Contain Toxic Heavy Metal (Lead- or Chromate-Based) Pigments.** In cases where these pigments are valued primarily for their aesthetic quality, nontoxic organic-based pigments are being used. The heavy-metal pigments are also noted for their corrosion-inhibition properties. To increase the corrosion barrier performance of their coatings, manufacturers are using coatings that are applied in thicker films and/or contain stronger film-forming binders (e.g., urethanes instead of vinyls, or fluorinated coatings instead of urethanes). As a replacement for conventional lead and chromate-based anticorrosion pigments, pigment producers are offering alternatives such as phosphates (complexes with zinc, calcium oxide and aluminum oxide), molybdates (complexes with zinc oxide and calcium oxide) and phosphate-molybdates (complexes with zinc oxide, calcium oxide and aluminum oxide).

- **Coatings Free of Potentially Hazardous Raw Materials.** Organic solvents like ethylene glycol–based ethers and esters, chlorinated solvents, curing agents that are based on free isocyanates and certain amines (e.g., methylene dianiline [MDA], which is commonly used to cure epoxy tank linings) are free of hazardous raw materials. Sika offers a polyacryl anhydride enamel coating that is claimed to display performance characteristics comparable with urethane; unlike urethane, however, it does not contain any isocyanate curing agent. Regarding isocyanates, certain European countries, such as the United Kingdom, have already restricted the use of urethane coatings in applications where ventilation is perhaps not optimum, such as in automotive refinishing booths and in tunnels. This worry about isocyanates is being slowly felt in the high-performance coatings area with the result that alternatives to urethanes are being used (such as polysiloxanes) and further developed.

- **Secondary Containment Coatings for Concrete.** New regulations in some U.S. states will require companies that produce or use potentially hazardous materials to construct diked concrete areas capable of containing any spill or leak. Chemically resistant elastomeric coatings must be applied to the surface to prevent any migration of the liquid into the concrete.

- **Material Recycling.** In Japan, some paint producers have evaluated the use of recycled materials in coatings. In high-performance anticorrosion coating applications, Nippon Paint and Kansai Paint have commercialized an anticorrosive alkyd product with recycled PET and recycled vegetable oils. Total recycled material usage is about 35% of the total weight. These coatings also do not contain lead, and Nippon Paint intends to market the coatings as environmentally friendly coatings.

- **Coatings That Can Be Applied Under a Broad Range of Conditions.** The pace of construction in many industries has accelerated in recent years. For example, in the biopharmaceutical industry, the typical project is completed much faster than was the case in the 1990s. As a result, finishes are being installed in less controlled environments, often before buildings are completely enclosed or heating, ventilation or air conditioning (HVAC) systems are operational. Sometimes floor coatings must be applied over concrete substrates that have not fully cured and still are wet, with high rates of moisture transmission. In addition, there may be other tradesmen working at the site, which may further complicate the application.

TRENDS AND OPPORTUNITIES

Some of the trends and opportunities in the anticorrosion coatings market are as follows.

- **Increasing Need to Educate Users.** Many facilities have reduced staff, including full-time painting crews, corrosion engineers and other knowledgeable coatings personnel. New managers often do not understand the value of painting and are prone to reduce maintenance coating budgets. Work is often turned over to employees who are not coating specialists or to consultants. The importance of coatings is often lost. In larger facilities, painting schedules are established on reliability and risk assessments; that is, unless there is a chance that a structure will fail and cause delays in production, it will not be earmarked for painting. In some cases, painting is often regarded as a cosmetic activity that can be delayed more readily than many other activities. Management often does not want to have maintenance work slow operations when operating rates are high, yet does not want to spend money when operating rates are low.

In addition, companies continue to shorten their planning horizons. With the waves of mergers, operating companies are more reluctant to consider investments in activities that might only be justified on a long-term planning horizon. Suppliers and applicators of coatings are often chosen solely on the lowest turnkey cost proposal rather than on a life-performance basis.

- **The Rising Costs of the Painting Operations.** Rising costs, particularly as a result of rising labor costs and environmental concerns over paints, are forcing owners to consider alternatives like concrete, plastics and metal alloys. Newer coatings based on one or two coatings (e.g., glass-flake reinforced epoxies and polysiloxanes) are replacing older coatings based on three or four coats. Also, an increasing number of coatings at 70-80% solids are being used, not only to meet VOC regulations, but to give higher film builds with a comparable number of coating passes and to minimize worker exposure to solvents. The cost of labor for applying the coatings is rising as well, due to the need to train workers to use more sophisticated coatings and application equipment, to meet tighter governmental regulations and to meet the increased awareness of safety.

- **Increasing Use of More Automated and Worker Friendly Methods of Cleaning Surfaces Prior to Repainting.** In recent years, there has been an increase in the use of high-pressure water jetting to remove paint, oils, dirt and other contaminants. Water jetting is claimed to reduce costs compared with conventional grit blasting, because the containment, collection and disposal of the abrasive is not required, masking and tarping of surrounding equipment is not necessary, workers are not intimately exposed to the blasting operation and the surface is often cleaner and ready for painting faster. Other products are being marketed, such as water-based biodegradable rust removers and paint disbonders, which are especially favored for use over conventional abrasive blasting when safety, operational or environmental concerns are of paramount importance. However, the performance of the nonconventional strippers does not equal that of abrasive blasting.

- **Increasing Development and Use of Surface-Tolerant Coatings.** End users are attempting to cut costs in the very time-consuming and expensive surface preparation operation by the use of surface-tolerant coatings (i.e., coatings on surfaces that are not perfectly cleaned or that may have a surface layer of oxide). This development is particularly interesting for offshore work but the coatings are not yet of the required high quality.

- **Use of More Durable and Weatherable Coatings That Prove Cost-Effective Over the Long Term.** End users will increasingly focus on the life-cycle cost rather than the initial coating cost. At present, many end users, particularly smaller companies, are still more concerned about the initial cost. Even in large companies, the life-cycle cost concept has lost some momentum because of corporate downsizing, which leads to decisions that focus on short-range implications. Another trend/opportunity will be improvements in application properties so that anticorrosion coatings can be applied in cold weather. The industry is hoping that public sector agencies (such as commissions in charge of maintaining bridges in the Untied States) will move away from selecting coatings on a low-cost basis, and instead focus on the life-cycle costs. In the oil and gas offshore drilling sector, higher-quality, longer-lasting coatings are being used since drilling platforms are now located in deeper waters and are more difficult to access for inspection and maintenance. In the electrical transmission industry, OSHA and corporate rules regarding the climbing and painting of utility poles are becoming more restrictive for safety reasons, so utilities are more willing to use longer-lasting paints (such as high-build inorganic zinc coatings) to delay repair work as long as possible.

Another consideration for the marine coatings industry is that routing through the Arctic Ocean has been increasing as a result of the conclusion of the Cold War. Vessels can complete the voyage between East Asia and Europe using the North Sea route through the Arctic Ocean, which is 50-60% shorter than the distance using the Suez Canal. Because of ice in the water, the marine ship-bottom coating requires special properties to avoid damage by ice. Some suppliers are developing coatings with greater ice resistance.

The U.S. Navy has a goal of increasing the amount of time between coatings of its ships from about five years currently to twelve years. Both industry and the government have research efforts under way to develop new coatings technologies, improve existing coatings and reduce the amount of active antifouling agent that leaches into the environment.

- **Greater Emphasis on Improving Fire Safety for High-Rise Buildings.** The September 11, 2001 terrorist attacks at the World Trade Center in New York City led to a major reevaluation of the fire safety of building materials used in high-rise applications. Even more significantly, there is increasing interest in thin-film intumescent coatings as passive fireproofing materials for commercial buildings because of the growing use of exposed structural steel in building frames for aesthetic and economic purposes. Specifiers are increasingly calling for the use of thin-film intumescents, and coating manufacturers are adding these materials to their product mix. Intumescent coatings do not "fireproof," but swell when exposed to high heat to insulate the metal from the heat of the fire and assist in delaying structure failure for long enough to save human life. Coatings can delay structure failure by creating a thermal barrier between the fire and the structural members that support a building or other edifice. Concerns over safety in offshore platforms intensified after the 1988 disastrous fire at the North Sea installation Piper Alpha when 167 men were killed and the entire installation was lost.

Cementitious coats are also available for fireproofing, but specifiers prefer intumescents, which can be applied in coats that are smoother, thinner and quicker to apply. The industry applies both epoxy and acrylic intumescent coatings.

Also, the industry is developing coatings that can minimize the destructive aftereffects of explosions or terrorist attacks. For example, Line-X of Santa Ana, California, offers an energy-resistant coating (ERC) that has been applied to the walls of the rebuilt Pentagon, the Washington, D.C. naval base and the Federal Building in New York. It is claimed that the coating could save lives in an Oklahoma City–type bombing because it reduces the sharp concrete shrapnel that causes fatalities. Painted walls can withstand explosions up to twenty times greater than uncoated walls and reduce the shrapnel caused by explosions.

Other coatings are available that are considered "fire retardant," in that they do not contribute to a fire by either keeping fire from the substrate or by creating a soft char that will keep plastics from melting and reduce smoke generation. These coatings are generally based on vinyl or vinyl-acrylic latex resins.

The total estimated market for fire retardant and resistant coatings is 5-10 million liters per year in both North America and Europe. The coatings sell for around $8-10 per liter. Growth is estimated at 5-6% per year. Use of intumescent coatings is growing in China, and that country now represents 20-30% of total global demand for these coatings. European intumescent coatings are imported into China, but find competition from lower-cost domestically produced materials that usually provide lesser protection.

- **Continued Development of Waterborne and High-Solids Coatings to Meet Increasingly Stringent Government Regulations.** The coatings industry will be challenged to develop nontoxic and environmentally acceptable products that can be applied over a wide range of environmental conditions and produce highly durable films. Applicators must alter their working practices, educate the workers, and use suitable roller and spray equipment in order to use the high-solids products. Also, applicators are under increasing pressure to reduce the generation of hazardous wastes. Waterborne coatings have been improved considerably in recent years such that their performance is reported to be equivalent to that of solventbornes; however, waterbornes still have some limitations in application and are higher cost than solventbornes.

- **Increased Use of "Green" Materials.** Some of the new raw materials for anticorrosion coatings that are derived from natural, renewable sources include vegetable oils (used in alkyds), natural seed oils (which are converted into polyols by methanolysis, hydrogenation and transesterification for use in spray urethane elastomers), and phenalkamine curing agents for epoxies (derived from cashew nuts).

- **Increasing Acquisition and Merger Activities.** Many small producers are finding it difficult to allot adequate research expenditures to develop more environmentally acceptable coatings and/or cannot afford to compete because of rising liability insurance costs; they will be acquired by or form joint ventures with large companies that can provide financial resources. The European REACH program is putting added pressure on coatings manufacturers. Another motivation for consolidation is to improve economies of scale, mainly to increase purchasing power and also to help ensure sources of raw materials when supplies are short and/or allocated. In some cases, large companies purchase the marketing rights from competitors and proceed to consolidate operations, thus improving efficiency.

  However, there will always be smaller, national or local companies that provide good service to the more localized owner/customer base.

  Companies wishing to enter a high-performance coating market will prefer to acquire an existing producer as opposed to starting a totally new business venture. The cost of entry is relatively high because of both the lengthy interval between product development and market acceptance and the difficulty in establishing a reputation as a reliable supplier in this well-established, mature industry.

- **Consolidation Among the Larger High-Performance Coatings Producers.** For the same reasons as above, and in addition to the acquisition of smaller players, it is foreseen that there will be some consolidation among the larger players. In fact, some of the larger players have a strategic focus (with the accompanying strength) either on coating sectors other than high performance or on other technological areas related to corrosion resistance or on other business sectors altogether.

- **Globalization.** With the general economic slowdown in most industrialized areas of the world, cost reduction has become paramount. Many companies have been undergoing reductions in staff, including technical experts and consolidating research and development in central locations.

- **Increased Demand for Coatings and Application Systems That Reduce Downtime of Plants and Equipment.** For example, offshore platforms are being coated by glass flake–reinforced polyesters instead of conventional five-coat systems. The coatings can be applied on the inside and outside of storage tanks, which are then returned to service much faster compared with painting with the conventional system. Also, there is greater demand for surface-tolerant coatings, which can be applied to surfaces that have been cleaned using pressurized water without complete removal of the existing coating system when it is in fairly good condition. Also, a faster job benefits the contractor since there is less need to pay out overtime or off-shift differential.

- **Faster Access to Information.** All suppliers have websites where customers can now place and track their orders. All businesses now are demanding better management of logistics and just-in-time delivery. Of notable importance to the anticorrosion coatings industry is the availability of precise information on painting contracts. Paint BidTracker (http://www.paintsquare.com/bidtracker/bids_welcome.cfm)) is a bid and award information service designed specifically for the protective coatings industry. The service reports on

  – Bid notices

  – Engineering and design jobs

  – Low bidders and award results

  The auctioning system allows painting contractors to submit and revise bids on jobs based on competitive bids. Paint BidTracker also features a project management tool to help track the status of painting projects with exclusive editor notes, daily e-mails and custom search capabilities. Most customers will limit bids to qualified vendors to keep the process manageable. The system reports on over 700 bids and awards daily. Subscribers can browse and search all of the bids online.

- **Universal Primer System.** Traditionally, applicators have specified many grades of primers for applications on substrates, such as ship flat bottoms, vertical bottoms, boot tops, exposed decks, superstructure, ballast tanks and others. However, it is not economical to prepare different grades of coating product items for each application, and the industry has tended to promote a universal primer system, which means one primer (generally modified epoxy) is used for all primer applications. By doing so, inventory costs are reduced as well as the need for training for multiple products. The big impetus for this trend came in 2000 when the Korean shipbuilding industry identified the economical use of universal primers as the most promising method to help offset rising costs due to regulations (e.g., the ban of TBT antifoulants). These systems have become popular with many applicators of anticorrosion coatings.

- **Increased In-Shop Painting of Structures.** Since painting can usually be done indoors, weather conditions are less of a factor, and the coatings application and inspection process can be more easily controlled. Well-designed steel fabrication shops have used these advantages to become sources of high-quality protective coatings work. With the advent of high-production, centrifugal shot or grit blasting equipment, some shops have combined the process of fabricating, blast cleaning and painting all under one roof. The resulting cost savings and continuity have led to millions of tons of structural steel arriving at end-use destinations fully painted and ready for erection with minimal field touch-up required. Coating manufacturers are responding to fabricators' needs by developing new products that dry and cure in much less time and at lower temperatures than standard coatings. They are also developing products to meet another trend affecting not only the steel but all industries—increasing government regulation of pollution caused by solvent emissions.

CRITICAL FACTORS FOR SUCCESS

The following factors are important or critical in becoming a successful manufacturer of anticorrosion coatings.

- A staff with the knowledge to identify the essential properties of raw materials and the skills to formulate coatings that consistently satisfy long-term corrosion protection requirements. The ability to provide a variety of high-performance anticorrosion coatings, including epoxies, polyurethanes, vinyls, chlorinated rubber, silicates and modified alkyds, is also important.

- A consistent and reliable supply of raw materials with essential properties, via either captive manufacture or merchant market purchases or both. The efficient scheduling and processing of production batches and the use of statistical process control to maximize product uniformity are needed as well.

- Efficient supply-chain management involving raw materials supply, manufacturing and warehousing, all the way through to sales; this is a crucial success factor. As of 2008, the shipping industry is operating at full capacity. Modern cargo shipping is characterized by extreme flexibility on the one hand, and a global shortage of docking areas on the other. Just-in-time delivery of the coatings is absolutely essential. The quality has to be perfect, because in the shipping industry, there's no time for touch-ups or repairs that may otherwise be provided as part of a guarantee.

- The financial resources required to manufacture and deliver products and the associated services from strategic locations, and to support ongoing product development and applications research.

- Marketing and training efforts directed at specifiers, applicators and end users to increase their understanding of the value of using life-cycle costing when evaluating coatings.

- A sophisticated sales force with knowledge of the technical and economic implications of the application of high-performance coatings to the clients' structure or plant.

- The ability to be a global supplier to increasingly global clients.

- A company-wide, cross-functional customer relationship management system involving an efficient customer database (using information technology) that is used to create customer profiles in order to establish the optimum approach to each customer. Such an approach allows coatings companies to supply not only the coatings but also the associated service, which is more often than not a higher-value-added activity. The ultimate objectives of such a system are to develop key customers and eventually to take over the maintenance programs for companies and industrial complexes.

- Use of the Internet as a purchasing and/or selling tool. This has become very important to success.

- A strong presence either in specific country-wide or continent-wide submarkets (e.g., marine structures, food processing plants), or as a regional producer that can provide reliable service; development of business in sectors with high entry barriers using unique products or technologies.

- Strong business relationships with specifiers, applicators and end users, and a successful track record as a reliable supplier over a long period of time. A successful company also needs minimal sales/service personnel turnover to strengthen customer loyalty. Suppliers must also be acutely aware of their customers' needs; for example, some shipbuilders may want a coating system that lasts only three to four years while others may want six to seven years based on the class of the ship and insurance requirements. In the yacht coatings market, about 50% of the coatings are applied by do-it-yourselfers, so the coatings must be as consumer friendly as possible with fast dry times, minimum surface preparation and low odor. Generally, these coatings are applied annually, so the antifoulant paint needs to be effective only for twelve months.

- The ability to support marketing efforts through potentially prolonged negotiations. For example, in 2008, Jotun COSCO Marine Coatings (JCMC) signed a contract to paint eighty vessels to be built at Dayang Shipyard in China. The total contract value is approximately $50 million, and includes a total volume of 10 million liters of paint to be supplied for 75 bulk carriers and 5 LPG tankers. The process toward winning the contract started almost one year earlier through several meetings with representatives from both the yard and the involved owners, both in China and abroad.

- A technical understanding of market trends and the competition's strengths and weaknesses, and a well-trained sales force that responds to customer problems effectively and provides early identification of new business opportunities. It is advisable to have specialists that can develop good business contacts with government agencies, shipyards, waterworks, paper mills, and others.

- Efficient sourcing of raw materials. Some coatings companies have consolidated in recent years in order to purchase raw materials on a large scale.

CONSUMPTION AND MARKETS

CONSUMPTION BY COATING TYPE

A breakdown of coating consumption by resin type in the three major regions is shown in Table 35.

Table 35

Consumption of High-Performance Anticorrosion Coatings by Resin Type and Major Region—2007[a] (percent)

	United States	Western Europe	Japan
Epoxy	38	45	45
Urethane (aliphatic)	18	20	4 (aliphatic and aromatic combined)
Urethane (aromatic)	9	7	
Alkyd	13	10	21
Inorganic Zinc	8	6	9
Acrylic	9	5	2
Chlorinated Rubber	neg	2	5
Vinyl	1	2	1
Other[b]	4	3	13[c]
Total	100%	100%	100%

a. Table includes only coatings used for heavy-duty applications. Data are based on sales value.

b. Includes vinyl esters, unsaturated polyesters, polysiloxanes and fluoropolymers.

c. Includes shipbottom paints.

SOURCE: SRI Consulting.

The breakdown of use in the shipbuilding industry in the United States was estimated in 1994 as follows:

Table 36

U.S. Consumption of High-Performance Anticorrosion Coatings for Shipbuilding and Ship Repair—1994 (percent)

Epoxy	58.8
Antifoulant	11.3
Alkyd	10.1
Inorganic Zinc	9.5
Other[a]	10.3
Total	100%

a. Includes fire retardant, repair and maintenance thermoplastics, high gloss, special marking, nuclear, organic zinc, high-temperature and pretreatment wash primer.

SOURCE: *Surface Coating Operations at Shipbuilding and Ship Repair Facilities—Background Information for Proposed Standards*, U.S. Environmental Protection Agency, EPA 453-D-94-011a, June 21, 1994, p. 63.

The amount of alkyd coatings used in Japan is relatively higher than that used in the United States and Western Europe for several reasons:

- There are fewer offshore platforms in Japan that require heavy-duty corrosion protection.
- The environment in Japan tends to be less severe than in certain heavily industrialized sections of the United States and Europe.
- Local Japanese governments have been experiencing financial problems in recent years and have opted for purchasing the least-expensive paints available.

Chlorinated rubber paints tend to be used relatively more frequently in Japan owing to the greater reliance on the shipbuilding industry and less VOC regulation. This leads to a relatively high tonnage consumption of coatings in Japan compared with other regions of the world. The value on the other hand is on the low side.

Major applications for each type of anticorrosion coating are shown in Table 37.

Table 37

Major Applications for Anticorrosion Coatings

Acrylics (solventborne and waterborne)	Bridges and bulk cargo containers Outdoor applications
Alkyds	General usage in nonimmersion service
Chlorinated Rubbers	Marine and bulk cargo containers Tank exteriors
Epoxies	General industrial plant applications, especially as an intermediate coat Pipe coatings Water storage tanks Marine coatings: deck, freeboard, machinery areas, bilges, ballast tanks and exterior underwater areas
Ethyl Silicates	Primer
Polyesters/Vinyl Esters	Flue gas desulfurization scrubber linings Marine structures (reinforced vinyl esters)
Silicones	Smokestacks
Urethanes	Water tanks Bridges Structural steel Architectural structures General industrial plant applications
Vinyls	Bridges

SOURCE: SRI Consulting.

Acrylic Coatings

Solventborne acrylic lacquers continue to be used to a limited extent in the anticorrosion market, mainly as topcoats for bridges and other structures. These coatings will continue to decline in importance because of their high solvent content. High-solids acrylics are not expected to be used much because of package stability problems. However, in China, acrylic lacquers are used increasingly in bulk cargo container coatings in replacing chlorinated rubber.

Latex coatings (waterbornes using acrylic or vinyl acetate/acrylate copolymers as binders) have been used as architectural coatings for many years; however, the properties of these coatings are generally not suitable for use in high-performance anticorrosion applications, especially when the coating is exposed to or immersed in highly corrosive elements. However, improvements have been made in waterborne acrylic technology in recent years; new “core-shell” polymers are composed of a core that provides good hardness and durability with a soft shell that exhibits good elasticity and coalescing properties. To increase corrosion resistance, several manufacturers are promoting water-based acrylics that are cross-linked with emulsified epoxies upon application. Manufacturers now claim that the long-term-immersion service performance of these newly developed acrylics is comparable to those of solventborne epoxy systems.

The use of waterborne acrylics for industrial maintenance applications has grown considerably since the 1970s, when they were virtually nonexistent. Waterborne acrylics currently find use in a variety of light- and medium-duty applications for both new construction and maintenance of structures. These systems are mainly used in schools, hospitals and other areas that want to eliminate any use of organic solvents and need resistance to institutional cleaners. The growth of this technology has been due to a variety of factors, including compliance with VOC regulations, ease of cleanup, less hazardous and thus less costly waste disposal, lower risk of health hazards caused by exposure to solvents, less concern over flammability and the impact on insurance costs, its one-component ease of use, and its proven performance capabilities in real world settings.

There are some one-component, self-cross-linking waterborne acrylic systems available, but one-component thermoplastic coatings that provide corrosion resistance through their barrier properties (rather than through cross-linking) are more common. Most of the uses of waterborne acrylics as topcoats for bridges and water tanks are in the southern United States, where climates are less harsh.

The use of elastomeric acrylic coatings to coat concrete has been increasing in recent years. These coatings, based on soft (i.e., low-glass-transition-temperature [Tg]) polymers are applied in thick films (12-20 mils) to bridge cracks in concrete caused by vibration, settling, soil movement, local climate changes, exposure to deicing salts and pollutants. By bridging the crack, the coating helps to prevent further deterioration of the concrete. Because of their soft nature, they have good impact resistance to foot traffic or precipitation, and generally have excellent adhesion properties. Traditional waterborne acrylic polymers used in industrial maintenance coatings are unsuitable for this application since they are harder and less flexible, and cannot adjust to surface expansion and contraction caused by temperature fluctuations. Acrylic polymers are also added to cement mixes to improve their patching and resurfacing properties. A typical patching mortar contains 5% acrylic polymer, along with much higher quantities of sand and Portland cement. Elastomeric acrylic coatings are also applied to commercial roofs to reflect heat and protect the roof membrane from the elements. In recent years, there has also been some interest in using elastomeric acrylics as surface-tolerant coatings.

In addition, advances have been made in recent years in reducing particle sizes and molecular weight distributions, and surfactant requirements, so that waterborne acrylics now exhibit improved water resistance, abrasion resistance and coalescence. Newer polymers have been developed that bond efficiently with titanium dioxide pigment particles that improve the gloss, hiding, color and corrosion resistance of the coating. Generally, copolymers of styrene and acrylic are preferred as anticorrosion coatings since they exhibit better water and alkali resistance than straight acrylic resins. Acrylics display excellent adhesion to bare steel, and are often sold as direct-to-metal (DTM) coatings. They can be used as VOC-compliant substitutes for vinyls and chlorinated rubbers, especially for touch-up and recoating work. Newer self-cross-linking acrylic polymers can be used to formulate industrial maintenance coatings that meet the Southern California VOC standard of 100 grams per liter of coating.

Waterbornes are also preferred in coating areas where solvent odors are objectionable, such as food and pharmaceutical processing areas. Still, the use of waterborne systems as heavy-duty anticorrosion coatings was only 5% of the total global market in 1999, but it has been rising in recent years.

Alkyd Coatings

Alkyd resins are polyester compounds that are formed by reactions between polyhydric alcohols (e.g., ethylene glycol or glycerol) and a polybasic acid (e.g., phthalic anhydride) in the presence of a drying oil (e.g., linseed or soybean oil). The specific oil used determines the curing properties of the resin and its ultimate chemical and physical properties. Alkyds are frequently modified chemically to improve their physical properties or their chemical resistance. Modified alkyds are formed by reacting other chemical compounds (such as vinyl, silicone and urethane compounds) with the alkyd. Alkyd coatings require chemical catalysts (driers) to cure. Typical catalysts are mixtures of zirconium, cobalt and manganese salts. Depending on the catalysts and the ambient temperature and humidity, it takes several days to several weeks before the coating is fully cured.

Alkyd coatings are frequently used as anticorrosion primers and topcoats in interior areas and as cosmetic topcoats over high-performance primers in exterior areas. Alkyd coatings are used primarily for habitability spaces, storerooms and equipment finishes. Fire-retardant alkyd paints are some of the most common interior coatings used on ships. Modified alkyds, particularly silicone alkyds, have excellent weathering properties and are good decorative and marking coatings. However, alkyds are not recommended for saltwater immersion service or for use in areas that are subject to accidental immersion. The alkali generated by the corrosion reactions rapidly attacks the coating and leads to early coating failure. Also, alkyds should not be applied over zinc-rich primers because they are attacked by the alkaline zinc corrosion products.

Epoxy Coatings

Epoxies are considered the workhorse of the protective coatings industry with a long, well-established track record. Many users of coatings feel "safe" by specifying epoxy coatings.

Epoxy coatings for anticorrosion coatings applications are typically formed by the chemical reaction of a bisphenol A–type epoxy resin with a "curing agent" (e.g., amines, amine adducts, or polyamide resins). The coatings are packaged with the epoxy portion in one container and the curing agent in a second container. The coatings must be used within their pot life, which ranges from two to eight hours at 25°C (77°F). Epoxy coatings typically dry to touch within three hours and are fully cured after seven days at 25°C (77°F). The time to cure depends on the ambient, coating and surface temperature during the curing period. The curing reaction slows markedly at temperatures below 10°C (50°F). For this reason, other coatings, often two-component urethanes, are preferred under these conditions.

Epoxy coating films are strongly resistant to most chemicals and make excellent anticorrosion coatings. They are one of the principal materials used to control corrosion and are used in many primers and topcoats. However, epoxy coatings chalk when exposed to intense sunlight, and are often used with cosmetic topcoats (e.g., urethanes or silicone alkyds) that are more resistant to sunlight.

Coal tar epoxy paints are packaged with the epoxy portion in one container and the curing agent (either amine or polyamide type) in a second container. The coatings must be thoroughly mixed prior to use and must be used before the mixture solidifies. The liquid coating forms a film by solvent evaporation and continued chemical reaction between the epoxy resin and the curing agent. The "pot life" is different for each unique formulation, and can be adjusted with different ratios of curing agents and accelerators. Coal tar epoxy (CTE) films have high chemical resistance, easily form thick films, and have a high dielectric strength. The high dielectric strength makes them particularly suitable for use near anodes in cathodic protection systems, where the high current densities can damage other types of coatings. Coal tar epoxy coatings are known to exude low-molecular-weight fractions (ooze solvent), which cause recoating and worker toxicity problems. The U.S. Navy limits the use of coal tar and coal tar epoxy coatings to protect workers from the possibility of low levels of carcinogens in the refined coal tar. Republic of Korea shipbuilders are moving toward non-tar epoxy coatings, with currently 80% of epoxy coatings for ballast tanks being nontar based. In the wintertime, Republic of Korea shipyards switched to coal tar urethane coatings, which cure more quickly, but these have been replaced by epoxies cured with phenalkamines.

Epoxy mastics, popular for about the last twenty years, are made by adding some hydrocarbon resin to the epoxy, which enhances moisture resistance, flexibility and the wetting properties of the coating. They also make the paint more user-friendly and economical in use. Epoxy mastics are in many respects similar to CTE, but are much more versatile and reduce or eliminate nearly all drawbacks associated with CTE. Mastics are among the most versatile coatings for industrial use in chemical plants, refineries, tank farms, bridges and others. Because of their very good resistance to water they are used on ships and other marine structures both above and below the waterline. Epoxy mastics are applied at high solids content so they form high film builds rapidly. They are popular for recoating existing painted surfaces since they contain relatively little solvent that can lift existing paint films.

Growth in demand for epoxies was strong during the 1980s, mainly as a result of the increased use of epoxy mastics; these coatings provide good protection over steel that is not totally free of corrosion, and they require less surface preparation. The mastics are two-component systems that are applied in coats of 5-10 mils thickness.

Improvements have been made in the last ten years in 100%-solids, or solventless, epoxies so they display good properties, are relatively low-cost and exhibit zero levels of VOCs. These materials require good surface preparation and plural-component application equipment. Use has increased significantly in recent years, especially in Europe in power generation facilities. In order to make high-solids or nonsolvent epoxy coatings, liquid epoxy resins, reactive diluents and liquid polyamines are used instead of solid resins, solvents, and polyamides or polyamide adducts, respectively.

Resin manufacturers have also promoted systems with internal flexibilizers that enhance their durability when applied to concrete.

Curing agent producers continue to develop newer systems that can cure at lower temperatures, because conventional epoxy coatings have significantly longer curing times in winter. Improved cross-linkers include cycloaliphatic amines and phenalkamines; however, these curing agents are generally more expensive than conventional polyamide/polyamine cross-linkers.

Epoxies can also be formulated to cure underwater for application inside of tanks, manholes, cooling towers, piers and pilings, tanks, pits and sumps. Unlike coatings for dry surfaces, which displace air from the surface, underwater epoxies work by displacing the water between itself and the surface to be coated. The chemical reactions that cause polymerization will proceed in an underwater environment.

More widespread use of hydroblasting and wet abrasive blasting in recent years has resulted in wider use of surface-tolerant epoxies, which can be applied over the flash rusting that normally occurs when using water as a surface preparation tool. The use of modified epoxies will probably grow at the expense of pure epoxies, which have poor gloss and color retention.

Waterborne epoxies are also available; these are multiple-component systems using polyamide-type curing agents. They are used mainly as coatings for concrete. Recent improvements in technology have enabled waterborne epoxies to exhibit properties that are more comparable to solventborne systems. However, the waterborne systems are around 30% more expensive than their solventborne counterparts, such that replacement is rather slow. The curing of the waterborne epoxies is also very sensitive to ambient conditions and the low initial resistance does not allow them to be installed quickly outdoors even after coating in a protected environment. Most of these systems are based on two-component systems that feature an epoxy cross-linked with an acrylic. Thick, “trowelable” epoxy coatings mixed with mortar are commonly used on industrial floors that are subject to heavy industrial traffic, impact and long-term wear. One of the desirable features of waterborne epoxy floor coatings is their ability to “breathe”; that is, they allow moisture to pass from the substrate through the film so it is not trapped, thus eliminating blistering and peeling. Also, a highly durable floor coating is required in food and beverage processing plants since it must withstand various chemicals and cleaning agents.

Some of the trends in the epoxy coatings market include increasing use of the following:

- Very-high-solids or 100%-solids coatings with little or no solvent. Solventless epoxies have certain advantages over conventional epoxies: lower flammability and odor in a potentially hazardous enclosed area, faster film build so fewer coats are needed, longer service life and lower overall cost on a service life comparison. Solvent-free epoxies are very abrasion and chemical resistant, and are now used to coat the exteriors and interiors of pipes, the interiors of tanks, cargo holds and the linings of rail hopper cars. A solvent-free epoxy floor will give a smooth seamless appearance, which limits the ability of contaminants to collect, so they are used in pharmaceutical, food and beverage, and nuclear power plants.

  One major drawback to both high-solids epoxies and solvent-free epoxies is that they use low-molecular-weight liquid epoxy resin (which presents toxicity concerns), are also more difficult to apply and are less tolerant of ambient conditions.

- High (>100°F) and low (<40°F) temperature curing coatings. Epoxies can now be cured with modified phenalkamines that cure at temperatures as low as 0°F and display good edge retention. Phenalkamines are epoxy curing agents obtained through the amination of polymerized cardanol, a chemical derived from the cashew nutshell liquid, which is a renewable resource. They are expensive materials, but can be used at lower loadings than conventional curing agents and can reduce overall coating costs since they cure quickly even at low temperatures so multiple coats are possible even at 0°F. Epoxy coatings cured with phenalkamines are mainly used to coat marine ballast tanks, where they excel due to their excellent corrosion resistance. Sales of phenalkamines were approximately $60 million in 2006, up from about $25 million in 2002. Phenalkamines are manufactured by Palmer International in the United States and by Cardolite in Newark, New Jersey, and Zhuhai, China.

- Edge-retentive coatings.
- New hybrid resin systems.
- Waterborne epoxy coatings that cure at ambient temperatures. To date, use has been mainly in concrete coatings used in hospitals or schools, where solvent odors are quite objectionable.
- Flexible epoxy systems, which have rubber particles built into the polymer backbone.
- Urethane-epoxy hybrid coatings (DTM polyureas).
- Solvent-free penetrating sealers used in the marine coatings industry as replacements for traditional acidic coatings that treat rusty surfaces.

Silicone Coatings

Silicones are expensive binders that are used mainly for high-temperature service such as on smokestacks. In the United States, the leading suppliers of these coatings are Briner Paint (part of RPM-Carboline) located in Corpus Christi, Texas, and Dampney Coatings in Everett, Massachusetts. The sales of both companies are about $5 million per year and each employs 25-30 people.

The consumption of silicones for high-temperature-resistant applications is approximately 1,500 metric tons per year in Western Europe and growing rapidly.

A relatively new high-solids, high-gloss inorganic topcoat based on polysiloxanes (see U.S. patent 5,618,860) has been commercialized for about ten years and is offered by Ameron, Akzo Nobel and others. These coatings display better weatherability than urethanes and reduce the number of topcoats required for excellent chemical and corrosion protection; in fact, one coat of polysiloxane replaces the conventional two-layer epoxy and urethane topcoats. It is claimed that these high-solids coatings cure rapidly in freezing temperatures and high-humidity environments and, in addition, exhibit excellent toughness. The silicone-oxygen bond is characterized by high stability, making it superior to carbon-carbon bonds in terms of weatherability, temperature resistance, chemical resistance and water resistance. Siloxanes are characterized by low viscosities, making them ideal for high-solids formulations. Generally, the siloxanes are mixed with organic oligomers (epoxy, polyether, acrylic, or phenolic entities) and cured at ambient temperatures. Acrylic siloxane hybrids have superior weatherability and offer a cost-effective, isocyanate-free alternative to aliphatic polyurethane topcoats. Epoxy siloxanes have very high solids and low VOCs. They have outstanding resistance to corrosion and better weatherability than aliphatic urethane (it is believed that nonaromatic epoxies are used to achieve high weatherability). These properties allow a single coat of epoxy siloxane to replace the standard two-coat, epoxy/urethane system currently used over zinc-rich primer systems. The improved durability of the epoxy siloxane hybrid and elimination of epoxy primer and epoxy midcoat in two-coat and three-coat high-performance coating systems provides lower application and projected life-cycle costs for the protection of large structures. The combination of cost and performance advantages of epoxy siloxane hybrids has resulted in widespread commercial acceptance, with the coating of over 200 million square feet of steel since the mid-1990s. The coatings industry seems somewhat surprised with the positive reaction to the technology, as siloxane-based coatings are roughly twice as expensive as those they have been replacing.

It has been found that organic-inorganic siloxane hybrid binders containing 20-50% organic resin give optimum performance in terms of film formation, adhesion, mechanical properties and chemical, corrosion and weathering resistance. Lower levels of organic resin result in coating films that exhibit undesirable properties such as low impact resistance and flexibility and loss of adhesion on aging. Higher levels of organic modification detract from important polysiloxane characteristics like resistance to ultraviolet light and oxidation.

Polysiloxanes are being evaluated by the U.S. Navy as replacements for silicon-alkyds, which are considered high-VOC coatings.

New developments in siloxane technology include

- Increasing the flexibility of epoxy siloxanes to improve the tolerance to variations in film thicknesses.

- Use of fluorinated siloxanes to give coatings with even greater weatherability.

- One-pack systems to eliminate mixing, increase application time and reduce waste.

- Elastomeric epoxy siloxanes with increased chemical resistance. These are made by incorporating carboxyl-terminated butadiene-acrylonitrile groups into the epoxy resin.

Urethane Coatings

Urethane coatings were first used in the anticorrosion coatings market in the 1970s, but use was limited until the late 1980s and 1990s. Now they are considered the top-selling topcoat in the industry, with superior weatherability and durability performance compared with the coatings they replaced, namely alkyd, epoxies, vinyls and chlorinated rubbers.

Polyurethane marine coatings are made from resins that contain complex monomers that incorporate isocyanate chemistry, which is highly reactive with hydroxyl groups (e.g., water and alcohols). Coating films are formed in two overlapping steps by solvent evaporation followed by a chemical reaction between the polyol and the isocyanate. The most commonly used polyurethane coatings are packaged as two- or three-component systems. One component contains the polyol, the second contains an isocyanate, and they are mixed just prior to use. Some systems require the use of a third component containing catalysts (e.g., metallic soaps or amine compounds) to accelerate curing.

Polyurethane coatings form tough, chemical-resistant coatings and make particularly good high-gloss cosmetic finishes. They have good abrasion and impact resistance and are particularly useful in high-wear areas. They have good weather resistance. Weathered polyurethane coatings are often difficult to recoat, and subsequent topcoats will not adhere unless special care is taken to prepare the surface before repainting aged or damaged areas. Polyurethane coatings are most commonly used as topcoats (e.g., in a coating system consisting of one coat inorganic zinc, one coat high-build epoxy, and one coat aliphatic polyurethane).

In marine applications, these coatings are used in the areas above the waterline such as the topside, weather deck and superstructure areas.

In comparison with epoxies, urethanes exhibit better abrasion resistance, somewhat better impact resistance and improved resistance to chalking; however, they are generally less resistant to chemicals. Urethane coatings have grown in importance in the last decade, primarily in the industrial maintenance market and to a much lesser extent in the marine market, where their high cost and complexity of operation are disadvantages. Most urethanes for topcoats are formulated with light-stable aliphatic isocyanates (mainly based on hexamethylene diisocyanate [HDI]), which do not yellow upon exposure to sunlight. Urethanes made with aromatic isocyanates (e.g., polymeric MDI) tend to yellow upon exposure to sunlight, but are often acceptable for use as primers. The second component is either a polyester, acrylic or polyether polyol. Generally, polyester polyols are favored when chemical resistance is required, acrylic polyols when long-term weatherability is needed, and polyether polyols in applications where low cost is paramount. Acrylic polyols are made of a combination of acrylic acid and ester monomers, methacrylic acid and esters, and styrene. Styrene adds chemical and water resistance, but lowers weatherability. In recent years, there has been a tendency to use more styrene in formulas, mainly as coating formulators have had to use lesser performing coating resins as a response to market pressures forcing cost reductions. As a result, there have been reports of polyurethane topcoats experiencing a downward performance drift, primarily in regards to weathering. While still called polyurethanes, some products can be inferior in performance to the original standards established in the 1970s. Newer polyols can be modified on aliphatic polyesters and/or silicone to provide excellent gloss and color retention, high gloss finish, good chemical resistance and long-term performance.

Urethanes are available in high-solids formulations that meet the VOC emission guidelines (less than 340 grams of volatile organics per liter). When excellent appearance and corrosion control are important, aliphatic urethanes are used as topcoats over epoxy primers or intermediates. Urethanes have been replacing vinyl and chlorinated rubber formulations because of their better overall durability.

Improvements have been made recently in solventless two-component urethanes, allowing their use on storage tanks, oil and gas piping, water and wastewater tank terminals, bridges, ships and other marine facilities. These coatings require complex application equipment and rigorous application techniques to ensure quality performance. Generally, the performance of these systems is not comparable with solventless epoxies. Certain flexible (elastomeric) urethane coatings are being used to overcoat previously applied chlorinated rubber and vinyl coatings in areas where VOC regulations have been implemented. Probably the fastest growing market sector for polyurethanes is in use as topcoats for medium-size bridges, where they are replacing chlorinated rubbers and vinyls for environmental reasons. Large bridges often are coated with fluorinated coatings in Japan. Also, urethanes are not used much in marine coatings because of lower corrosion resistance.

Currently, in Western Europe, the share held by urethane coatings is continuously increasing because of their excellent abrasion and impact characteristics and because the higher solids meet the VOC guidelines coming into force. Urethanes formulated with aliphatic isocyanates are favored since they have higher yellowing resistance when exposed to sunlight. Two-component systems dominate but one-component types are also used to some extent.

Waterborne urethane coatings are potentially attractive coatings for use in anticorrosion applications because of their low VOC content and good properties. To date, however, use has been small because of their relatively high cost, short working time and uneven film formation. Some newer versions demonstrate very good hardness and chemical resistance. However, use will probably be limited to more specialized applications, like antigraffiti coatings, where they can be used on virtually any painted or unpainted surface, such as brick, concrete, stucco, wood, plastic and metals such as copper and brass. There could be some consumption of two-package, zero-VOC products in fabrication shops that face tough VOC regulations. The industry is trying to develop suitable two-component waterborne urethanes that can be applied in ambient conditions, including concrete floors. To date, however, use has been limited to applications where the environmental conditions can be tightly controlled. Cementitious urethane coatings, based on waterborne urethane resins mixed with Portland cement, have been used to coat floors in food processing plants in Europe, and are beginning to be used more in North America. These coatings can withstand wide temperature swings, exposure to cleaning solutions and various foods and drinks, and abrasion from foot and motor traffic. Urethane cement toppings are very low in odor, and they cure to service very quickly, and are thus ideal for projects with very short installation and cure windows.

Both epoxy and urethane overcoating sealers are being marketed. These products tolerate compromised surfaces (tight old paint and rust) and permit application of a suitable topcoat to extend protection without abrasive blasting. These sealers offer a “band-aid” approach between full repaintings. Recently, plasticizer-free sealers have been developed, which exhibit no bleeding of plasticizer and thus display better resistance to dirt buildup.

Moisture-curing urethanes (MCUs) have grown quickly in recent years in the United States, particularly in the bridge painting market. The chief advantage of these systems is that they cure independently of the weather, so the painting season in the northern United States can be extended during the winter. They can be applied to damp surfaces and make good penetrating sealers, so surface preparation costs can be reduced. MCUs can be used to coat over existing paint, even leaded paint, so public agencies can make structures more environmentally safe, at least for the near term. In another application, they can be applied to the exteriors of water tanks without requiring that the tank be drained. With other coatings, surface moisture will inhibit the curing or drying of the coating. The industry has improved moisture scavengers (e.g., oxazolines), which improve package stability; also, newer micaceous iron oxide pigments are favored, which help promote corrosion resistance. Some of the producers of MCU paints are Wasser, Xymax and Sherwin-Williams. Dai Nippon Toryo is the major producer of MCU coatings in Japan. MC Technology acquired Xymax in 2003, and in 2005, announced that it was opening a plant in Belgium to produce moisture-curing urethane-polyurea-based products with good flexibility and adhesion. This includes MC Miozinc, a surface-tolerant zinc-rich coating, and MC Prepbond, a penetrating primer enabling high film builds. The products are suitable for use in marine and dry-dock applications where there is high humidity.

Most currently used systems are based on either MDI-based prepolymers or higher-molecular-weight TDI-based prepolymers.

The presence of free isocyanate linkages in moisture-curing urethanes and two-component urethanes still poses a problem to some applicators. In Western Europe, the use of two-component urethanes is already excluded in some offshore projects and in the English Channel tunnel.

In the last decade, the industry has been successfully marketing polyurea coatings, applied as thick films which display better durability, impact resistance and abrasion resistance than conventional coatings. Polyureas are similar to polyurethanes except that the isocyanate reacts with an amine group instead of a polyol. Polyurea coatings combine rapid cure (even at temperatures well below 0°C) and insensitivity to humidity with exceptional hardness, flexibility, tear and tensile strength, and chemical and water resistance, as well as good weathering and abrasion resistance. The systems are 100% solids, making them compliant with the strictest VOC regulations. They can be formulated to dry in as little as thirty seconds. Polyureas are elastomeric in nature, so they can be used to bridge cracks in concrete. Often, blends of polyurethanes and polyureas are used, which combine the lower cost and improved wetting and adhesion of the urethane with the thick-film build of the polyurea.

Initially, polyurea was used as a protective layer over polyurethane insulation foam for roofing applications. They became well accepted in the mid-1980s when they started being applied in spray-in truck bed liners. In the 1990s, polyureas started being used as anticorrosion coatings, especially in applications subject to temperature extremes or high ambient moisture. The market developed first in the United States, followed by Asia, with very strong growth during the second half of the 1990s. In Europe, acceptance of polyureas has been slow due to difficulties with application equipment, but in recent years, consumption has increased by 25-30% per year. The largest applications are in flooring and car park decking, waterproofing, containment in storage tanks, anticorrosion in pipes, and abrasion resistance in mining equipment. Rapid growth is predicted in the food sector and in other industrial sectors where downtime must be minimized. Global sales of polyureas were about $200 million in 2007.

Today, polyureas are used for coating concrete in applications such as roof repair, containment liners, membranes, car park decks, tunnels, bridges and offshore applications. They can be used to coat water tanks even in cold weather. Their high abrasion resistance allows application in bulk transport wagons, freight ships and conveyor belts.

Bayer has been promoting the use of polyaspartic esters (i.e., secondary aliphatic diamines), which react with aliphatic or aromatic isocyanates to form polyureas. By using polyaspartic esters, the rate of reaction can be controlled to give a broader application window compared with that of other polyureas. Thus, for many applications, traditional spray equipment can be used, making application less complicated and less prone to error.

Vinyl and Chlorinated Rubber Coatings

The most common vinyl resins used for anticorrosion coatings are based on vinyl chloride/vinyl acetate copolymers. These resins form coatings by solvent evaporation. Freshly applied coatings are dry to the touch within one hour and are fully dried within seven days. Vinyl coatings are particularly useful where fast drying, particularly at low temperatures (0-10°C [32-50°F]), is required. Coatings based on vinyl polymers perform well in immersion situations and are frequently used to protect submerged structures such as the underwater hull of a ship and bridges. These coatings have excellent resistance to many chemicals and are good weather-resistant materials. Vinyl coatings are softened by heat and are not suitable for sustained use above 66°C (150°F). Vinyl paint systems require the use of a thin coat of wash primer (containing acids to etch the surface) as the first coat to ensure good adhesion to steel.

Chlorinated rubbers are formed by reacting natural rubber with chlorine. Chlorinated rubbers by themselves are not suitable for use as coatings and must be blended with other compounds to produce tough, chemically resistant coatings. These coatings cure by solvent evaporation. They are normally partially dry within one hour and fully dry within seven days. For this reason, chlorinated rubber coatings are especially useful where fast drying, particularly at low temperatures (0-10°C [32-50°F]), is required. Chlorinated rubber coatings are tough, resistant to water and chemical resistant. However, they are softened by heat and are not suitable for sustained use at temperatures above 66°C (150°F). Chlorinated rubber coatings are suitable for most exterior ship areas that are not continually exposed to excessively high temperatures.

Vinyl and chlorinated rubber use will continue to decline because of environmental pressures on use of these low-solids coatings; it is doubtful that high-solids or waterborne versions of these coatings can be developed that display satisfactory performance.

Use of chlorinated rubber coatings represents only a small percentage of the European high-performance anticorrosion market, and is nonexistent in North America. Chlorinated rubber coatings present toxicity concerns since they contain 3-8% carbon tetrachloride (used as a solvent in the manufacturing process). Some large producers of anticorrosion coatings no longer offer products based on chlorinated rubber.

Chlorinated rubber is used as a topcoat for bulk cargo container coatings in China, but is being gradually replaced by acrylic lacquers.

High-solids vinyls with hydroxyl-functional groups have been developed to modify urethanes, epoxies or alkyds in reactive coating systems; however, many of the desirable properties of the vinyl resin are compromised.

Zinc-Rich Primers

Inorganic zinc coatings consist of powdered zinc metal held together by a binder of inorganic silicate. The binder is formed by the polymerization of sodium silicate, potassium silicate, lithium silicate, or hydrolyzed organic silicates. The liquid coating forms a film by the evaporation of the solvent (water and/or VOCs), followed by the chemical reactions among the silicate materials, zinc dust, and curing agents. Inorganic zinc coatings use water or organic solvents.

A variety of curing mechanisms are used to form the final inorganic zinc coating film. The coatings are frequently packaged as multicomponent paints. All parts must be mixed thoroughly before being applied. After mixing, inorganic zinc coatings have a pot life of four to twelve hours. The solvent must evaporate from these coatings before they can form a film. For solvent-based, self-cure inorganic zincs, some water is needed to allow the binder to cure. Low humidity will retard cure rate.

Because the coatings consist primarily of zinc, they offer extraordinary galvanic corrosion protection. At the same time and for a variety of reasons, they can be corroded by the same environments that damage zinc. Inorganic zinc coatings are often used on weather (exterior) decks and as primers for the ship superstructure.

Organic zinc coatings use zinc as a pigment in a variety of organic binders. The primary feature of organic zinc coatings is that the coating film is electrochemically active and reacts to provide cathodic protection to the steel substrate. These coatings are not as mechanically durable, do not provide as much corrosion protection to the substrate, and are not as resistant to high temperatures as the inorganic zinc coatings. However, they are frequently more compatible with organic topcoats. Generally, these coatings are more tolerant of application variables than are inorganic zinc coatings. The drying and curing properties of this type of coating are determined by the properties of the binder. These coatings are not recommended for immersion service in saltwater for the same reason given for inorganic zinc coatings, namely, that they can be corroded by the same environments that damage zinc.

Zinc-rich primers offer the ultimate in corrosion protection to steel surfaces exposed to aggressive environments. New systems are being used that are either water-based or based on high solids (VOC content is less than 2.8 pounds per gallon or 340 grams per liter). The binder can be organic (e.g., epoxy resin/polyamide curing agent) or inorganic (e.g., ethyl silicate). Ethyl silicate zinc-rich coatings provide long-term protection to structures exposed to severe weathering conditions and marine environments (as long as they are properly topcoated). Fairly good growth (2-3% per year) is expected for zinc-rich primers. Generally, applicators of maintenance coatings in North America prefer inorganic zinc-rich primers, while those in Europe tend to use epoxy zinc-rich primers. In Western Europe, for example, the breakdown between inorganic zinc and epoxy zinc has gone from 80:20 some years ago to 50:50 at present. One of the main reasons epoxy-zincs are favored in Europe has to do with differences in weather—generally, relative humidities are lower in Europe, so there are fewer restrictions on application conditions.

One of the main advantages of waterborne inorganic zinc-rich primers is that they can be recoated fairly quickly. Some of these systems are based on technology patented by the U.S. National Aeronautics and Space Administration (NASA).

One of the disadvantages to inorganic zinc coatings is that they have very high densities, making them difficult to spray, and they generally cannot be applied in field conditions. Most users apply zinc-rich primers to substrates that have been shot blasted and are thoroughly clean in controlled shop environments.

Recently, zinc (or its alloy with aluminum) hot-melt spray coating has been tried where these metals are melted in a gas-flame coating gun at a temperature of 3,200°C, and shot against the substrate. These "sacrificed" metal coatings are expected to protect steel substrates for a long-term period (allegedly fifty years).

Other

Polyvinylidene fluoride (PVDF) types cannot be used since they require baking. However, for more than twenty years, coating manufacturers around the world have been marketing alternative fluoropolymer products based on Asahi Glass's Lumiflon®, which is an amorphous fluoro-olefin copolymer in which the fluoroethylene and vinyl ether groups alternate regularly along the polymer chain (commonly called a "FEVE" copolymer). The copolymer contains polyol functionality, so it can be cross-linked with an isocyanate at ambient temperature. A number of coating manufacturers are currently producing Lumiflon-based fluorinated coatings as a topcoat of high-performance anticorrosion coatings, especially in large-size public construction and bridge applications. The Japanese Society of Steel Construction has determined that the longevity of a polyurethane coating in a severe environment is about twenty years, while that of a fluoropolymer coating is thirty years or more. The Japanese Society of Steel Construction has developed the following comparison showing long-term (100 years) life-cycle costs of different coatings.

Table 38

Long-Term Coating Cost Comparison[a]

	Conventional Coatings	Conventional Anticorrosion Coatings	Low-Life-Cycle-Cost Coatings
New Coating (in coating plant)			
Primer (first)	Anticorrosive alkyd	Zinc-rich paint	Zinc-rich paint
Primer (second)	Anticorrosive alkyd	Epoxy	Thickness epoxy
Primer Surfacer	Alkyd	Polyurethane	Fluoropolymer
Topcoat	Alkyd	Polyurethane	Fluoropolymer
Durability			
Mildly Corrosive Conditions (years)	10	30	50
Highly Corrosive Conditions (years)	Not applicable	20	30
Refinish System (on-site)			
Primer	Anticorrosive alkyd	Epoxy	Thick epoxy
Primer Surfacer	Alkyd	Polyurethane	Fluoropolymer
Topcoat	Alkyd	Polyurethane	Fluoropolymer
Durability			
Mildly Corrosive Conditions (years)	10	30	50
Highly Corrosive Conditions (years)	Not applicable	20	30
Number of Times that Refinish Painting Is Required in 100 Years			
Mildly Corrosive Conditions	9 times	3 times	1 time
Highly Corrosive Conditions	Not applicable	4 times	3 times
Hundred-Year Life-Cycle Cost			
Mildly Corrosive Conditions (yen)	50,200	23,200	13,700
Highly Corrosive Conditions (yen)	Not applicable	28,200	24,300

a. Long-term = 100 years.

SOURCE: Japanese Society of Steel Construction.

Asahi Glass has been marketing Lumiflon in the United States for about fifteen years. Use has been growing at high rates but from a small base. Most marketing efforts have been directed at selling Lumiflon for coating water towers, which are ideally suited for Lumiflon coatings, since they are difficult to paint, and long-term appearance is important. Increasingly, these coatings are used in architectural markets, for recoating buildings made of galvanized metal panels, or previously coated with PVDF. Lumiflon coatings are used extensively on bridges in Japan, but to date are not widely used for this application in North America or Europe. Asahi Glass has been developing water-based Lumiflon resins, which can be formulated to meet the California standard of 50 grams of VOC per liter of industrial maintenance coating.

Vinyl ester resin reinforced with glass flake is also used in coatings for marine structure or tank applications, where tough impact, corrosion and chemical resistance are required. Glass flake is oriented inside the coating layer to protect water vapor emission to the substrate; thus, the coating has excellent corrosion resistance.

CONSUMPTION BY MARKET

During the late 1970s, global consumption of high-performance anticorrosion coatings increased significantly as costs for new plant construction soared. Owners demanded better protection of their structures to prolong the life of capital goods. The concept of life-cycle costs became important; as labor and capital goods costs increased significantly, the benefits of using longer-lasting coatings became more pronounced.

Demand for anticorrosion coatings increased in the late 1980s, but was generally flat in the United States, Western Europe and Japan during the 1990s and early 2000s because of the slowdown in capital spending for petrochemical plants, paper mills and other processing plants. Consumption of coatings for maintenance and repair of existing structures was flat as well. Many facilities, both private and public, have reduced general and maintenance expenditures, and consequently lowered expenditures for painting, which is often regarded as an activity that can be delayed more readily than others. Starting in 2006, there was some upturn in consumption, as industrial construction activity increased.

Historical demand for high-performance anticorrosion coatings by the United States, Western Europe, Japan and China in recent years and projections for 2012 are shown in Table 39.

Table 39

Consumption of High-Performance Anticorrosion Coatings by Major Region (millions of liters)

	United States	Western Europe	Japan	China
1985	200	215	176	na
1988	210	220	151	na
1992	220	215	183	na
1995	230	225	178	na
1998	235	225	180	na
2001	220	207	181	na
2004	225	200	178	248
2007	235	230	188	300
2012	255	255	200	400

SOURCE: SRI Consulting.

The data presented in the table are expressed on a liquid volume basis; if a dry volume basis were used, the increase in consumption would be somewhat greater, since the use of high-solids formulations is increasing.

The global industrial maintenance coating market is estimated at nearly 660 million liters, or 800 thousand metric tons.

This figure does not include coatings used on bulk cargo containers, for which the global market is estimated at about 210 million liters in 2007, valued at $775 million. This market is currently dominated by China, accounting for about 95% of the total, with the rest accounted for mainly by Eastern Europe, Turkey and Malaysia.

A breakdown of high-performance anticorrosion coating consumption by major market is shown in Table 40 and Table 41.

Table 40

Consumption of High-Performance Anticorrosion Coatings by Market and Major Region—2007 (percent)

	United States	Western Europe	Japan	China
Marine Uses[a]	20	30	59	24
Industrial Maintenance				
Oil and Gas Exploration, Production and Transmission[b]	18	13	11	18
Petrochemical Plants (including oil refineries and chemical plants)	13	12	5	14
Bridges and Other Infrastructure	12	13	16	5
Water and Sewage Treatment Plants	10	9	2	1
Public Utilities	8	11	5	1
National Defense and Space	7	2	0	2
Food and Beverage Processing Plants	4	6	< 1	1
Pulp and Paper Mills	2	2	< 1	1
Primary Metals and Mining Operations	2	2	0	1
Containers	<1	<1	0	31
Other Processing Uses (including textiles)	4	<1	2	1
Total	100%	100%	100%	100%

a. Includes coatings used in the construction, repair and maintenance of ships.

b. Includes onshore and offshore operation, and storage tanks.

SOURCE: SRI Consulting.

Most of the markets for high-performance anticorrosion coatings are expected to grow at moderate rates in the United States, Western Europe and Japan over the next five years, but at higher rates in most other areas of the world.

World Industrial Maintenance Coatings Market

Estimated consumption of high-performance anticorrosion coatings for onshore and offshore structures is as follows:

Table 41

World Consumption of Industrial Maintenance Coatings—2007[a]

	Millions of Liters	Percent
China	196	23
United States	185	22
Western Europe	160	19
Japan	76	9
India	55	6
Korea, Republic of	34	4
Middle East	30	3
Thailand	24	3
Taiwan	18	2
Eastern Europe, Africa, Latin America	15	2
Malaysia	14	2
Singapore	10	1
Pakistan	10	1
Australia	7	1
Vietnam	7	1
Indonesia	7	1
Other	10	1
Total	858	100%

a. Includes coatings applied to onshore and offshore structures and excludes marine vessels. Excludes coatings used on cargo containers and architectural and lower-performance coatings used on structures.

SOURCE: SRI Consulting.

The total value of all industrial maintenance coatings was about $2.75 billion in 2007.

Most of these markets should grow at moderate rates (2-3% per year) in the next five years. Some of the faster growing segments should include:

- Water and wastewater treatment pipes and equipment, which has been identified as a area that is in need of considerable rehabilitation because of aging and neglect, and also because of the U.S. Clean Water Act amendments that have led to the generation of more corrosive wastewater

- Oil and gas exploration and production, a sector that is on the upswing because of the recent increase in oil and gas prices

- Intumescent coatings, which are thin-film decorative finishes that provide a degree of fire protection when exposed to high temperatures

With regard to the types of substrates coated, steel predominates, but in certain markets, concrete is important.

Table 42

German Industrial Protective Coatings Market

	Steel (percent)	Concrete (percent)
Bridges and Highway	30	70
Chemical and Petrochemical	85-90	10-15
Food, Beverage and Pharmaceutical	40	60
Offshore	100	0
Pipelines	95	5
Power	60-70	30-40
Pulp and Paper	10-20	80-90
Rail	80-90	10-20
Water and Waste Treatment	40	60

SOURCE: *Protective Coatings Europe*, November 1998, pp. 24-40.

More discussion of the markets is included in the individual regional sections; the global marine market is discussed separately below.

World Marine Coatings Market

Proper selection of coatings is of paramount importance for large ships. There are a number of sources of corrosion: the marine environment in which ships operate; cargoes, both liquid and solid; and normal operational practices such as ballasting. Coatings are designed for specific applications (e.g., abrasion-resistant coatings for outside shell and cargo holds, antifoulant coatings for the underwater hull, chemically resistant coatings for cargo holds and ballast tanks). In addition, coatings provide aesthetic beauty to the ship. Well-maintained vessels are easier to charter, and will also command a better price in the market for second-hand vessels. Coatings above sea level generally consist of a zinc-rich primer, epoxy intercoat, and topcoat (either epoxy or polyurethane), while coatings below sea level consist of a zinc-rich primer topcoated with an antifouling coating.

It is estimated that for most ships, the cost of applying the coatings to a ship is 7% of the total cost of the ship. While the cost of applying a proper coating seems expensive, one expert found that it was 4-14 times more expensive to replace corroded steel than to apply a coating during construction and maintain that coating. The cost of the coatings for oil carriers and cruise ships is slightly higher, at 10% of a ship's construction cost. Oil tankers require better coatings than most of the industry because of the corrosive nature of chemicals, such as the hydrogen sulfide present in crude oils. Cruise ships require better coatings for tanks that hold the wastewater from their passengers. Cathodic protection systems and corrosion-resistant materials add an additional 3% to the new-build cost of ships.

Usually, ballast tanks account for about 40% of the total area coated on a vessel. Since large portions of the tanks are inaccessible during operation, it is essential that high-quality anticorrosion coatings be applied during building and repair. In the past, coal tar epoxies were used because of their outstanding chemical resistance and low cost. The ship's crew can maintain a vessel at sea to keep it looking shipshape and tidy; major repairs can be undertaken by riding squads placed specifically on-board or alongside; and repairs, especially to the underwater area, are carried out in dry dock to protect the underwater areas of the ship. Dry-dockings are undertaken at regular intervals to allow the vessel to be inspected and repaired. When freight rates are high, ship owners wish to keep their vessels operating at high rates and postpone dry-docking. For projects such as ballast tank refurbishing, dry-dockings are postponed as long as possible.

The ship coatings market consists of paints for shipbuilding and for repair during dry-docking. About 50% of the total is for shipbuilding with the rest for ship repair. The scale of operations and manpower is huge, and demand is tied almost entirely to forces beyond the industry's control. In 1975, for example, the industry's overall order backlog fell quickly from four years to two as the energy crisis hit. It took more than a decade for the industry to recover. In the late 1990s, demand for new shipbuilding surged because of the growing need for replacement of old tankers, most of which were built around 1970. Throughout 2000, shipbuilders were operating at full capacity and continued to expand their fleets; however, in 2001, the shipping industry experienced a drop of about 10% in traffic. Global shipbuilding orders were down about 20% from 2000 levels because of the economy and the abolition of operating aid to shipyards in the European Union starting in 2001, which had the effect of forwarding orders to 2000. Orders for new ships decreased significantly. However, by the middle of 2002, the situation had changed, and the shipping industry was again enjoying prosperous times with high freight rates. In 2003, Republic of Korea shipbuilders doubled their order books to the highest volume level since 1973. The boom has continued ever since. By 2007, oceangoing ship prices were 50% of those in 2003. Shipyard order backlog was valued at $300 billion, or nearly four years' worth of work. Korean and Japanese shipyards have revamped repair yards into shipbuilding sites and started building new yards in lower-cost nations like China and the Philippines.

In Ulsan, the Republic of Korea, all nine dry docks of Hyundai Heavy Industries are occupied with partially built ships. There are 180 on the company's order book, enough to keep the yard busy for three years. Even though Hyundai completes a new ship every four days, this is not fast enough to keep pace with current demand. The driving force behind this demand is China, both as a consumer of raw materials and a producer of finished goods. China's $164 billion trade surplus with the United States in 2007 was 14% higher than the previous year. Most of this trade is seaborne—amounting to 43 billion metric tons a year from China to the United States and 37 billion metric tons from the United States to China—and most is shipped in container ships. The number of containers handled by mainland Chinese ports rose by 35% in 2003, leading to a shortage of shipping capacity and a dramatic rise in freight rates. Demand for shipping continues to increase significantly due to the growth in manufacturing in China and other Asian countries. In 2007, rates for shipping increased to all-time highs as there was a shortage of bulk shipping capacity, which has been exacerbated by inadequate port facilities in many regions. Rates are expected to stay at high levels until 2009 when more bulk freighters will be launched, easing some of the strain on the system. It is expected that shipbuilding will start to level out in 2010, but that ship repair will significantly increase, so no dramatic downturn is expected for the foreseeable future.

The industry is notoriously cyclical, with some of the shortage of capacity attributable to underinvestment in the late 1990s. Over 90% of new merchant ships are now built in Asia, with Japan and the Republic of Korea as the major shipbuilders, with 37% and 34% of global activity, respectively. The Republic of Korea became a major factor in the market starting in the early 1980s. Most of its growth during the last fifteen years has been at the expense of Western European shipyards. Activity in the two countries' shipyards can be influenced by the strength of the Japanese yen compared with the Republic of Korea won. The Republic of Korea has particularly strong positions in oil tankers (with around an 80% market share) and LNG tankers. Republic of Korea shipyards are known for high productivity, with some large shipyards building large ships in less than one week. As a result, coatings must be easy to apply and cure quickly, especially under the temperature and humidity extremes that occur in the Republic of Korea.

Japanese companies are at a distinct labor cost disadvantage compared with competitors in the Republic of Korea and China, but are still the leaders in bulk container ships and LNG tankers. China is growing in importance and in 2007 built 15% of the world's new ships, and is expecting to grow rapidly over the next five years (possibly by 15-18% per year). The largest shipyard in the world is now in Shanghai. Other leading Asian shipyards are operated by Daewoo, Hyundai, Samsung, Mitsubushi and Kawasaki.

Shipbuilding in Western Europe was stagnant from 1995 to 2004, but started to increase again in 2005 as Asian shipyards started operating at near full capacities. The European Union is the leading global producer of passenger boats and cruise ships. The United Kingdom is particularly active in naval construction. Conversion of ships is a viable alternative to new building, especially in specialist markets in which Europe excels. Europe is the world leader with around 40% of this market.

The United States builds only about 0.75% of the new deep sea ships in the world. Demand for marine coatings by shipyards in the United States declined significantly starting in the mid-1980s.

European companies remain as the largest group of owners of large vessels, accounting for about 45% of total ownership. Other regional groups with large ship ownership include Asia (35%) and the United States (10%). Some of the leading ship owners include AP Moller-Maersk, Yang Ming Marine Transport, Hanjin Shipping, and Carnival Cruises.

The table below shows the production of new large oceangoing ships in the world.

Table 43

World New Shipbuilding Statistics[a]
(thousands of gross weight tons)

	Korea, Republic of	Japan	China	Western Europe	Other	Total
1990	3,460	6,824	367	2,849	2,386	15,886
1995	6,218	9,311	953	3,803	2,367	22,652
2000	12,228	12,020	1,647	3,402	2,400	31,697
2001	11,608	12,024	1,827	3,435	2,398	31,292
2002	12,967	11,957	2,207	4,050	2,203	33,383
2004	14,768	14,515	4,679	4,085	2,126	40,173
2007[b]	20,210	17,330	10,430	4,655	3,163	55,788
2012	29,000	22,000	21,000	5,000	5,000	82,000

a. Includes only seagoing vessels that meet certain quality and reliability standards.

b. Estimated from January to September data.

SOURCES: *World Fleet Statistics*, Lloyd’s Register; SRI Consulting (2012 estimate).

These statistics don’t include the construction of coastal and naval vessels. There is a considerable amount of building of coastal ships in some countries, such as the United States. Also, Japan is a nation composed of many islands, so it requires the services of many ships to transport goods within its borders, while the Republic of Korea is mainly one land mass, so it concentrates on oceangoing vessels.

Ship repair is a much more important activity in Japan, China, the United States, Western Europe, Singapore and the Middle East. In Japan, ship repair accounts for about 40% of the marine coatings business, while in the Republic of Korea it is only 5%. Both countries have reduced their repair businesses in the last few years because shipyards are quite busy with shipbuilding.

Asia accounts for about 60% of the world's dry docks for ship repair, with Singapore, China and Japan the most important locations (in order of importance), followed by Taiwan, the Philippines, Vietnam and the Middle East. From 1998 to 2004, China opened ten new large dry docks. Already, the country is benefiting from the tightness in the market, as Japanese and Republic of Korea dry docks currently have large backlogs. Other large locations of dry docks are in the Middle East (10% of the global total) and Europe (10%). Activity in the Middle East is growing due to increased repair of large tankers. For reference, the table below shows major repair docks of more than 300 meters' length in the world.

Table 44

Major World Ship Repair Facilities
(more than 300 meter-long repair dock)

Country (Location)	Company Name
Europe	
Belgium (Antwerp)	Antwerp Shiprepair NV
France (Brest)	Sobrena
France (Dunkerque)	Arno Dunkerque
France (Le Havre)	Port Autonome Du Havre
France (Marseille)	Port Autonome De Marseille
France (Saint-Nazaire)	Chantiers De L'Atlantique
Germany (Hamburg)	Blohm Und Voss Repair A.G.
Germany (Kiel)	Howaldtswerke Deutsche Werft AG (HDW)
Greece (Athens)	Hellenic Shipyard
Italy (Livorno)	Cantiere Navale Flli Orlando
Italy (Trieste)	Fincantieri Cantieri Navali Italiani
Netherlands (Rotterdam)	Verolme Botlek NV
Portugal (Lisbon, Setubal)	Lisnave Shipyard
Romania (Constanza)	S.C. Santierul Naval S.A. Constanta
Romania (Mangalia)	Daewoo Mangalia Heavy Industries
Spain (Madrid)	IZAR Cadiz Ship Repair
United Kingdom (Belfast)	Harland & Wolff Heavy Industries
Asia	
China (Changxing)	China Shipping Industry
China (Dalian, Nantong, Guangzhou, Shanghai, Zhoushan)	COSCO Group
China (Jiangyin)	Chengxi Shipyard
China (Shanghai)	Huarun Dadong Dockyard
Japan (Aichi)	IHI
Japan (Hiroshima)	Koyo Dockyard
Japan (Hiroshima)	Tsuneishi Shipbuilding
Japan (Hyogo)	IHI Amtec
Japan (Kagawa)	Kawasaki Heavy Industries
Japan (Kumamoto)	Universal Shipbuilding
Japan (Mie)	Universal Shipbuilding
Japan (Nagasaki)	Sasebo Heavy Industries
Japan (Nagasaki, Kanagawa)	Mitsubishi Heavy Industries
Japan (Saijo, Ehime)	Imabari Shipbuilding
Japan (Wakayama)	MES Yura (Mitsui Zosen)
Malaysia (Johore)	Malaysia Marine and Heavy Engineering
Philippines (Cebu)	Keppel Philippines
Philippines (Subic Bay)	Subic Shipyard & Engineering
Singapore	Jurong Shipyard
Singapore	Keppel Shipyard
Singapore	Sembawang Shipyard
Taiwan (Kaohsiung)	CSB
Vietnam (Nirh Phuoc)	Hyundai-Viashin Shipyard

Table 44 (concluded)

Major World Ship Repair Facilities
(more than 300 meter-long repair dock)

Country (Location)	Company Name
Other Regions	
Bahrain	Arab Shipbuilding & Repair Yard
Brazil (Rio de Janeiro)	Sermetal Brazil
Malta (Valletta)	Malta Drydocks
Panama	Astilleros Braswell International
Russia (Novorossiysk)	Novorossiysk Shiprepair Yard
South Africa (Cape Town, Durban)	Portnet
Turkey (Istanbul)	Pendik Shipyard & Heavy Industries
Turkey (Istanbul)	Tuzla Shipyard and Tourism
United Arab Emirates	Dubai Drydocks
United States (Newport News, Virginia)	Newport News Shipbuilding & Drydock Co.
United States (Sparrows Point, Maryland)	Baltimore Marine Industries

SOURCE: SRI Consulting.

In previous years, Hanjin Heavy Industries and Hyundai Mipo Shipyards in the Republic of Korea were important dry dock facilities, but little repair work is currently being done at these shipyards since they are busy with shipbuilding.

Suppliers of marine coatings include Akzo Nobel with 32-33% of the global market, followed by other alliances as noted in the table below. Ships can go to any repair dock in the world for repair coating; thus, it is important to establish marine paint supplies in all major locations, so most marine coating companies have established alliances to increase their geographical presence. The following table summarizes marine coating alliances:

Table 45

Marine Coating Company Alliances and Global Market Share—2008

	China	Japan	Korea, Republic of	Other Asia	Rest of World	Major Product Trade Name	Market Share (percent)
Akzo Nobel Group	International Paint of Shanghai	International Paint Japan[a]	International Paint Korea	International Paint	International Paint	Intersmooth	32-33
Chugoku Marine Paint Group	CMP Shanghai (Shanghai Guangdong)	Chugoku Marine Paint[b]	Chugoku Samhwa Paints	Chugoku Marine Paint (Indonesia, Malaysia, Singapore), TOA-Chugoku Paints	Chugoku Marine Paint (sold in the Netherlands and the United States)	Sea Grandprix	17
Hempel Group	Hempel's-Hai Hong Coatings	Dainippon Toryo	Hempel	Hempel	Hempel	Globic SP-ECO	16
KCC Group	KCC (Kunshan)		KCC Corporation	KCC Singapore		Sea-care	4
Nippon Paint Group	Nippon Paint Marine China	Nippon Paint Marine	Nippon Paint Marine Korea[c]	Nippon Paint Marine[c]	Nippon Paint Marine	Ecoloflex, Hisol, LF-Sea	5
PPG: SigmaKalon/ Ameron Group	Sigma Coatings Kunshan	Shinto Sigma Paint	Sigma Samsung	Sigma/Kalon	Sigma/Kalon	Alphagen, Kaisen	5-6
Sea Star Alliance	Jotun COSCO Marine (Guangzhou)/ Jotun Coatings (Zhangiagang)/ Tianjin COSCOP Kansai	NKM Coatings	Chokwang	NKM/Jotun	Jotun Paints/NKM	Sea Quantum	19
Other (no extraregional alliances)		Kanae Paint		Berger International	Tikkurila		1

a. Ended alliance with Nippon Paint in 2003.

b. Includes Kobe Paint, a 100% subsidiary of Chugoku Marine Paint.

c. Company has an alliance with Asian Paints in Taiwan. Production is outsourced in the Republic of Korea.

SOURCE: SRI Consulting.

Total global demand for marine paints is believed to be on the order of 650 million liters, worth about $3.5 billion in 2007. This figure includes roughly 200-250 million liters for new building of oceangoing ships, including tankers (21% of the total), bulk carriers (26%), bulk cargo containers (29%), LNG/LPG carriers (6-7%), chemical carriers (7%), other carriers (8-9%) and passenger vessels (1-2%); another 100 million liters used on new, smaller coastal commercial ships (e.g., yachts, ferry boats, fishing boats and smaller commercial ships); and 300-350 million liters of coatings used for maintenance and repair of existing ships. The coatings market has been increasing by about 7% per year in recent years, and is expected to continue to grow at 5-7% annually for the next five years. The industry is anticipating more orders for container vessels, tankers, bulk carriers and LNG carriers.

The estimated 2007 consumption of marine coatings by country is as follows:

Table 46

World Consumption of Marine Coatings—2007[a]

	Millions of Liters	Percent
Korea, Republic of	123	19
Japan	108	17
China[b]	104	16
Western Europe	70	11
Singapore	60	9
United States	50	8
Middle East	25	4
Taiwan	18	3
Philippines	18	3
India	15	2
Vietnam	12	2
Malaysia	8	1
Indonesia	7	1
Thailand	6	1
Australia	5	1
Pakistan	3	<1
Sri Lanka	2	<1
Other[c]	10	2
Total	644	100%

a. Includes coatings applied to marine vessels. Excludes coatings applied to offshore structures and to yachts and recreational boats.

b. Excludes consumption of architectural and lower-performance coatings used on houseboats, fishing vessels and others, as well as coatings used to repair some large vessels. Estimated 2007 consumption of all marine coatings was about 180 million liters.

c. Including Eastern Europe, Africa and Latin America.

SOURCE: SRI Consulting.

Western European shipyards tend to be the leaders in embracing new marine coatings technology, while applicators in Asia and the Pacific Rim are more advanced in process and equipment development. The Asian shipyards are under more commercial pressure to produce less-expensive ships, resulting in shorter vessel lives. Development of new higher-performance marine coatings in the United States lags because of the preponderance of government (i.e., U.S. Navy) work, which requires adherence to rigid military specifications that were established years ago. These specifications are slowly being relaxed, partly in response to new environmental legislation.

In general, coating consumption tends to grow at a lower rate than shipbuilding because of factors like technological improvements and an ongoing reduction in the average age of the fleet. However, several mandates favor the use of more marine coatings:

- The IMO mandated a phaseout schedule for single hull tankers effective in 2010, when current single hull tankers will be scrapped or converted to bulk carriers, and new double hull tankers will be built to replace all old single hull tankers. All global dry bulk carriers of at least 150 meters long must be outfitted with double hulls, which means more paint on the two additional inner layers should shipbuilders decide to coat the double skins. There are currently 572 ships of the largest carriers, 1,239 of the midsized vessels and 3,312 units of the smallest ships, so the maximum additional area to be painted will amount to 19 million square meters. All tankers entering U.S. ports must be equipped with double hulls by 2015. Also, large ships carrying potentially hazardous materials (including petroleum tankers above 20,000 dead weight tonnage [DWT]) that were constructed before 1995 must install double hulls or install hydrostatic balance loading systems when the ship reaches 25 years of age.

- Following the Exxon Valdez incident of 1989 and other accidents of the 1990s and early 2000s, all ballast tanks must be coated and existing ballast tank coatings must be rigorously inspected. This is a positive factor for marine coating demand over the next few years. Effective July 2008, all new steel ships above 500 tons (and all ships after July 2012) must comply with the new IMO Performance Standard for Protective Coatings (PSPC) for dedicated seawater ballast tank coatings. The coating volume per ship will be increased to secure film thickness, and this will be a positive factor to increase marine paint demand over the next five years.

United States

In the United States, total consumption of anticorrosion coatings in 2007 was approximately 62 million gallons (235 million liters), including about 46 million gallons for onshore protection, 13 million gallons for shipbuilding and repair and 3 million gallons for offshore protection. Another 52 million gallons are used in the light maintenance/commercial market, which includes application to offices, warehouses and other areas that are not exposed to corrosive environments. Generally, the coatings used in the latter markets are latexes and solventborne alkyds, similar to those used in general architectural coatings.

Coatings used in some niche anticorrosion markets, such as water and wastewater treatment, bridges, highways, flue gas desulfurization (FGD) stacks in power plants, cogeneration plants, trash-to-steam plants, food processing plants, breweries and pharmaceutical operations, are expected to exhibit good growth. On the other hand, construction activity in industries such as heavy chemicals and petrochemicals, and pulp and paper will remain slow. Demand for coatings on bridge concrete is expected to grow to reduce corrosion of metal reinforcing bars (rebars) caused by chloride-ion permutation.

The leading suppliers to the U.S. onshore and offshore markets are Carboline, Sherwin-Williams, Akzo Nobel, PPG, Tnemec and Sika. Leading suppliers of marine paint include Akzo Nobel, PPG, Hempel and Jotun.

At present, demand for anticorrosion coatings for maintenance and repair of existing facilities is greater than that for new construction, at a ratio of approximately 80:20. Little change is expected for the next five years. Fifteen years ago these ratios were the reverse. However, with the trend toward globalization in recent years, many companies elect to build plants overseas where labor is cheaper and regulations often less stringent.

Some specific applications have been growing in recent years in the United States.

- **Floor Coatings.** Various industries have been required to coat concrete storage areas in recent years because of the need for secondary containment. The leading suppliers of floor coatings are Stonhard (owned by RPM), Garland, Crossfield, General Polymers (owned by Sherwin-Williams) and Degussa Admixtures (formerly Master Builders).

- **Tank Linings.** Interior tank surfaces are often painted to protect the structure from corrosion and keep leaks to a minimum, as is now mandated by some regulatory bodies. In the past, linings were applied only if there was concern that the contents might be contaminated.

- **Secondary Containment.** As a result of the enactment of the Spill Prevention, Control, and Countermeasure (SPCC) portion of the Oil Pollution Prevention legislation, regulations are requiring the construction of concrete barriers around storage tanks of potentially hazardous materials. The concrete is protected with an impervious coating or lining that must resist attack by any spilled liquid for at least 72 hours. This market has been growing because of strict legislation regarding underground petroleum storage tanks, in efforts to minimize leaks or spills contaminating water supplies. In response, demand for aboveground storage tanks increased significantly in the 1990s.

- **Intumescent Coatings**. The tragic events of September 11, 2001, leading to the collapse of the World Trade Center towers, increased awareness of fire safety in public buildings. Intumescent coatings are coatings that react under the influence of fire and swell to many times their original thickness, producing an insulating char that protects the substrate from the effects of the fire. Steel does not burn, but does have a serious weakness as a construction material because it loses its structural strength at temperatures above approximately 550°C. The intumescent coating protects the steel from structural collapse during a fire, generally for periods of up to two hours, enabling fire fighters to safely evacuate people from the building. Its secondary role is to provide a smooth, aesthetically pleasing finish, which is durable and easy to maintain. The latter function is one of the main reasons why intumescent coatings are increasingly preferred over other types of passive fire protection. Thin-film intumescents enable architects and designers to use the full creative design possibilities of the steel itself, which is not possible with traditional bulky, passive fire protection systems, such as mineral sprays and boards.

At the moment, solventborne intumescent products are still the preferred choice, mainly for reasons of superior durability, but the industry is developing suitable waterborne replacements. Intumescent coatings are generally based on styrene-acrylic copolymer binders. Intumescence generally requires a minimum of three components: a mineral acid catalyst (typically ammonium polyphosphate), a source of carbon (typically pentaerythritol or dipentaerythritol), and a blowing agent (typically melamine). When an intumescent coating is subjected to heat, a series of chemical reactions occurs: the ammonium polyphosphate decomposes to produce phosphoric acid; the phosphoric acid causes dehydration of the pentaerythritol or dipentaerythritol to produce a carbon char; the blowing agent decomposes releasing nonflammable gases which cause the char to foam, thus producing a meringuelike structure that is a highly effective insulator against heat.

Currently, the intumescent market in the United States is concentrated in the industrial, commercial and military sectors, with small coatings companies dominating the niche. It is likely that larger coatings companies will move into the market as it grows, possibly by acquiring smaller manufacturers. The future of intumescent coatings will depend on the development of standardized fire tests, by the desire for increased intervals of fire protection, and the potential for intumescent use in the do-it-yourself (DIY) market.

Specific U.S. markets are discussed below.

Marine

Consumption of ship coatings in North America is about 49 million liters (13 million gallons) per year; market growth has been around 3% per year. Major suppliers include PPG, Chugoku, Akzo Nobel, Hempel, and Jotun/Valspar, which collectively account for about 80% of the market. Consumption of yacht paints (applied only to the bottoms of pleasure boats) in North America is around 7.5 million liters (2 million gallons) per year (not included in the consumption of ship coatings). Major suppliers include Akzo Nobel, Kop-Coat (owned by RPM) and Nautical Paint, with lesser players (E-Paint, Flexidel, Nautical, New Nautical Coatings, Pro-Line and Sherwin-Williams) accounting for the remaining 20% of the market. This market has experienced some growth in the United States in recent years. Alkyds, uralkyds and silicone alkyds are used for smaller (30-35 foot) pleasure craft, but most large pleasure craft now use two-component urethanes.

The marine vessel coatings business in the United States consists of four sectors:

- Military, mainly the Navy fleet of about 300 ships of all different sizes
- Deep-sea marine, with approximately 7,000 vessels
- Coastal, which includes navigational aids, lighthouses and Coast Guard vessels
- Inland waterways, such as the fleet operating in the Great Lakes region (about 740 vessels) and other areas (34,000 vessels)

There are currently over 100 first-tier shipyards operating in the United States, but only few of substantial size that have the capability to produce very large naval ships, including carriers, battleships, submarines and barges, as well as commercial ships such as large cruise liners and liquefied natural gas carriers. Even though the building and repair of the smaller ships is concentrated in the second tier, many first-tier shipyards build and repair ships less than 400 feet in length. Output consists of military and commercial vessels, but is almost entirely military because of overwhelming foreign competition in the commercial sector. Builders of merchant ships were heavily subsidized by the federal government until the early 1980s; when the subsidies ended, the shipyards lost their competitiveness to more modern, efficient European and Asian shipyards with lower labor cost. The decline would have been steeper except for a U.S. Maritime Administration program to construct and modernize more ships. Budgets were slashed significantly in the 1990s with the thawing of the Cold War, but still, business from the U.S. Navy is keeping some shipyards in the United States operating. In 1980, there were 22 major shipyards employing about 120,000 workers, and now there are only eight shipyards employing 45,000 workers.

Between 2000 and 2005, the Navy spent an average of $11.7 billion per year on shipbuilding, with about 10% of that used for ship repair. Approximately $1 billion per year was spent for corrosion-related maintenance between dry-dock cycles. With relatively low activity and high fixed costs, shipyard costs remain relatively high.

In early 2006, the Navy announced a plan for increasing the size of its fleet from about 280 ships to 313 ships by 2019, which would require expenditures of $15 billion annually beginning in 2008 and rising to $20.5 billion in 2012. It is unlikely that the expenditures will be approved, and the Navy is reconsidering its plans.

The total annual corrosion-related costs of the U.S. marine shipping industry are estimated at $2.7 billion annually. One major problem with the industry is that most ships are not built with the best materials and coatings since ships are bought and sold often during their service life, and most original owners know they will not be keeping the vessels long enough for corrosion to become a problem. Thus, life-cycle maintenance costs are usually higher than necessary.

While shipbuilding has been slow, the ship repair business remains fairly healthy. Labor rates are less of a factor in repairing ships, as the downtime factor becomes crucial to many operations and, thus, ship owners are reluctant to send (or tow) vessels from the United States to Asia for repair. Business should stay strong because of the Oil Pollution Act of 1990, which requires oil tankers to be fitted with double hulls by 2015, and the 1990 Clean Air Act Amendments, which require the installation of vapor recovery systems in existing ships.

Another healthy niche in the shipbuilding and repair business is the so-called second-tier shipyards that handle tugboats, supply boats, ferries, fishing vessels and other small- and medium-sized vessels. Some of these yards are competitive in the international marketplace and have successfully built craft for export. There are approximately 300 second-tier shipyards operating in the United States. These shipyards build and repair three general classes of ships: (1) power-driven vessels, including tugboats, towboats, offshore supply boats and crew boats, fishing vessels, ferries and passenger vessels, and military vessels; (2) river barges, including hoppers, tank barges, deck barges and machinery barges; and (3) offshore barges, including dry-cargo hoppers and deck barges, tank barges and machinery barges. The lion’s share of second-tier production is protected from foreign competition by the Jones Act. Thus, unlike in the first tier, production of commercial vessels is an assured market. One area of increased demand is likely to come from construction of riverboat casinos since gambling on riverboats has been legalized in Missouri, Iowa and Louisiana. Growth in demand for second-tier commercial vessels is likely to be around 5% per year.

The tugboat industry, for one, is currently thriving mainly as container ship traffic continues to increase. Newer tugboats are being built with larger engines to enable them to push larger container ships into cramped harbors. In addition, larger tugboats are needed to propel oil barges, which have steadily grown in size due to greater payload capacity and the need to be double hulled by 2015. Shipyards that were nearly abandoned five years ago now have enough work to last at least through 2010. Through the 1990s, the nation’s shipyards built about ten tugboats a year; in 2007, they built about sixty. Many shipyard leaders say they regularly turn away work because they do not have the factory space or the manpower to build any faster. Like other markets for maritime vessels, the tugboat market tends to be highly cyclical with booms and busts.

In the yacht sector, about 50% of the coatings are DIY-applied and 50% are professionally applied in the local boat yard. The products are made as consumer friendly as possible with fast dry times, minimum surface preparation and low odor. The average boater paints each spring, so the antifouling paint needs to be effective for twelve months.

Chemical manufacture

Expenditures for plants and equipment in the chemical, petroleum and paper industries increased in the mid-1990s after the flat levels of the early 1990s. Most chemical and petrochemical industries operated at high rates in 1994-1995 and recorded very high profits. When these large industries make large sums of money, investments in new plant construction usually follow, which eventually leads to lower operating rates and lower profits. Indeed by 1998, most of the petrochemical industry was experiencing breakeven financial conditions. In 2000, conditions were not significantly better, and 2001 was a disaster, especially in the polyolefins sector, where feedstock costs increased dramatically in the beginning of the year, new capacity was coming on stream, and demand was falling. The olefins and polyolefins industries were operating at 80-85% of capacity, which is far below their healthy operating rate of about 90%. The industry stayed depressed until 2003, when demand began to rise. By late 2004, producers were raising prices in response to higher demand and increased feedstocks. Operating rates were over 90% in 2004, and polyethylene prices rose by about 40% in 2004. Polypropylene prices increased by about 75%. Since 2004, operating rates have been slightly higher than 90%. The industry is optimistic that it will continue to make significant profits since there are few significant expansion plans for the foreseeable future. However, with the rise in feedstock costs, the United States loses some of its competitive advantage to most other areas of the world, and it is unlikely that there will be large-scale investment in new petrochemical facilities to support export-driven products.

Most petrochemical manufacturers decreased their domestic capital spending during 1998-2007, along with investments in upstream petroleum operations. On the other hand, spending by the pharmaceutical industry increased significantly over the same time period. The table below estimates domestic capital spending by the U.S. chemical industry since 1989. There was some increase in 2004-2007, but at levels that are still less than that of 2000. The estimates are made by using American Chemistry Council (ACC) estimates (given in current dollars) that have been adjusted using SRI Consulting’s *PEP Cost Index* (a measure of the change in annual plant and equipment costs).

Table 47

Domestic Capital Spending by the U.S. Chemical Industry[a]

	Normalized Deflated Capital Spending Levels in the United States by the Business of Chemistry (1989=100)	Normalized Deflated Repair and Maintenance Levels in the United States by the Business of Chemistry (1989=100)
1989	100	100
1990	116	96
1991	120	94
1992	112	93
1993	105	96
1994	100	97
1995	111	99
1996	132	100
1997	127	100
1998	132	99
1999	126	97
2000	110	99
2001	97	93
2002	88	92
2003	85	90
2004	85	98
2005	91	100
2006	97	100
2007	101	na

a. Includes only spending in the United States by both U.S.-based and overseas-based companies.

SOURCES: American Chemistry Council (nominal capital spending and maintenance and repair spending); *PEP Cost Index*, SRI Consulting (deflation factor).

Of special interest is the ongoing geographical shift in spending by U.S. chemical companies. With a largely mature market and the movement of customer industries overseas, companies are shifting investments toward regions offering lower feedstock costs (and cost of production) as well as in markets experiencing a higher degree of dynamism. The absence of a comprehensive U.S. energy policy ensuring adequate and diverse supplies will retard investment (and subsequent job creation). This is equivalent to "capital flight." The geographic allocation of the capital budgets of producers is evidence of this shift. U.S. chemical companies expect to reduce the U.S. share of their total capital spending budgets from 62% in 2006 to 48% in 2011. They anticipate significantly boosting their share to Africa and the Middle East, from 2% in 2006 to nearly 15% in 2011.

One bright spot for the chemical industry has been ethanol, which has experienced tremendous growth during the 2000s, due to the U.S. requirements for oxygenated gasoline, followed by mandatory use as a renewable fuel. Capacity in the United States increased by about 60% from 2005 to 2007, and is scheduled to almost double again by 2009.

However, construction of new production facilities of most chemicals will tend to gravitate offshore. As an example, Asia accounted for about 25% of the global capacity for ethylene in 2001, 30% in 2006 and is expected to account for an estimated 33% by 2011. The Middle East continues to increase ethylene capacity, accounting for 8% of global capacity in 2001, 10% in 2006 and an estimated 19% in 2011.

Exports of petrochemicals like styrene, acrylonitrile, ethylene dichloride and polyethylene (the United States at one time exported 10-50% of its production of these petrochemicals) are expected to remain flat as a result of greater competition from Asian, Latin American and Middle Eastern producers (or U.S. producers that build capacity in these regions). A number of these are derived from natural gas; at one time, the United States had a clear-cut economic advantage over most other global producers due to low natural gas prices, but this advantage deteriorated in the 2000s. It is unlikely that an export-oriented petrochemical facility will be built in the United States in the next five to ten years. The outlook for construction of new facilities for production of inorganic chemicals like chlor-alkali, salt, sulfuric acid and fertilizers for the near future in North America is not favorable.

The following table shows how capital spending patterns are projected to change over the next five years:

Table 48

U.S. Basic and Specialty Chemical Company Capital Budgets by Geographic Focus (percent)

	2004	2009
North America		
United States	71.2	58.9
Canada	2.4	2.8
Mexico	1.4	1.6
Total	75.0%	63.3%
Latin America	1.9	2.2
Western Europe	16.6	16.8
Central and Eastern Europe	0.5	1.5
Africa and Middle East	0.5	1.0
Asia Pacific		
Japan	0.5	0.6
China	2.9	8.8
Other Asia	2.1	5.8
Total	5.5%	15.2%
Total	100.0%	100.0%

SOURCE: American Chemistry Council.

Design and construction vary from plant to plant depending on size, production and product type, location of site and other factors. In the petrochemical industry, for example, plants often have to withstand high temperatures and operate under high pressure. Pipes, together with their supports and valves, often represent problem areas where corrosion can develop. Large storage tanks are highly visible; therefore, the best exterior corrosion protection together with a long-lasting topcoat is vital for plant appearance. Access (staging) is costly, so maintenance intervals should be as long as possible. Topcoat color should be white or near white as this will prevent heat absorption. Aesthetically pleasing tanks impart favorable publicity for the owner. The decision on the type of coating will depend on complete specifications of the products to be stored, such as pH levels, toxicity, aggressiveness, volatility and expected storage temperature.

The physical environment of major petrochemical plants is often demanding. Installations are often situated in coastal areas and the mixture of marine and industrial atmospheres produces a highly corrosive condition. After the plant is built and production has started, maintenance may often be difficult. In many areas, blast cleaning is forbidden without production shutdown, which will lead to loss of income and increased cost. One of the top priorities of all chemical plants is to minimize downtime on expensive assets, so fast curing coatings are a necessity.

Corrosion conditions in most organic chemical operations are usually rather mild. An exception is acetic acid and derivative operations since acetic acid is a strong organic acid and a good solvent for many organic materials. In the inorganic chemicals sector, large volumes of anticorrosion coatings are used in corrosive atmospheres found in chlor-alkali, salt, bleach, sulfur and fertilizer facilities.

Oil and gas

Activity in the oil and gas industry has fluctuated widely in recent years in response to crude oil and natural gas prices. Natural gas rigs account for 85-90% of the total and account for most of the variability. Operators will install new rigs or reactivate idle production depending on pricing. The average operating oil and gas rig count in the United States was as follows:

Table 49

Average Number of Operating Oil and Gas Rigs in the United States

1997	940
1998	750
1999	600
2000	700
2001	1,250
2002	750
2003	1,000
2004	1,250
2005	1,400
2006	1,700
2007	1,800

SOURCE: U.S. Energy Information Administration.

In the United States, offshore drilling is quite important, with about 30% of domestic oil and 20% of domestic gas generated from the outer continental shelf. The United States accounts for about 50% of total global offshore drilling. The installations are built either for exploration or production (including the preparation of water or gas for injection, processing oil or gas, cleaning produced water for disposal and other functions). Maintenance and repair are very costly on offshore structures, floating platform storage and offloading (FPSO) vessels, supply vessels, and deep-sea installations—and in certain cases, impossible. Design lifetime often exceeds thirty years. The requirements for reliable materials and protection against corrosion are, therefore, most stringent, requiring coatings that are resistant to corrosion and fouling, chemical attack and severe abrasion. Tough, nonskid coatings with extremely high film thicknesses meet the need for durable surfaces on helicopter decks, gangways and escapeways. With the high cost of maintenance painting offshore, it is vital to consider long-term corrosion protection from the earliest planning stage. Most coatings are based on organic zinc-rich primers (predominantly epoxies, but also some moisture-cure urethanes), higher-build epoxy midcoats and polysiloxane topcoats. There is also some use of thermal spray aluminum coatings. The leading suppliers of offshore coatings are PPG (formerly Ameron), RPM-Carboline and Akzo Nobel.

Coatings are applied to natural gas, crude oil and petroleum pipelines to prolong service. In North America, around $80 million worth of coatings are used annually on gas pipelines. Usually, the coatings must be applied in the field instead of in a factory since the coatings will burn off when the pipe sections are welded together in the field.

A good opportunity for the coatings market lies in rehabilitating existing pipelines. There are about 2.4 million miles of pipe in North America, with an estimated 25% in need of rehabilitation or replacement. Most pipelines were built between 1940 and 1960 and are subject to varying degrees of corrosion. Some pipes were subjected to accelerated wear and tear when supply companies began to transmit higher quanties of gas through the lines, thus raising operating temperatures. Most rehabilitation projects are accomplished in the field, so coatings such as coal tar enamel, tape or specialty coatings must be used. Coal tar enamels are being used less because of environmental and safety considerations. Polyethylene tape can be easily applied in the field, but does not display high-corrosion protection. Specialty coatings include high-solids urethanes, epoxies or combinations thereof. Liquid epoxies are usually favored, since they give coatings with excellent corrosion resistance and adhesion, and eliminate concerns over possible worker exposure to isocyanate curing agents.

Powder coatings (fusion-bonded epoxy, or FBE) are applied mainly to oil and gas pipes. Production of pipe coatings is about 10-15 thousand metric tons per year, but can fluctuate, depending on the levels of new installations. Steel piping has been losing ground to plastic piping, especially high-density polyethylene, over the last twenty years. Steel pipe now accounts for about 53% of the distribution mains (pipe usually 1.5-6 inches in diameter for transmission from processing plant to storage) and 43% of the distribution service (pipe usually 0.25-0.75 inch in diameter for transmission from storage to users).

Construction of pipelines spiked in 2000, when about $7 billion was used to build new gas pipelines in the United States, but dropped in 2001-2003, due to lower prices, but also because of resistance by communities to allow new construction. However, with the spike in oil and gas prices in 2004-2008, there has been renewed interest in building. Several new proposals include transporting natural gas from the North Slope, Alaska into the United States in a $2.6 billion, 1.2 million meter pipeline running into the Chicago area. Another proposed pipeline would bring gas from Canada’s Mackenzie Delta into Alberta, where it could be used to recover crude oil from oil shale. The crude then might be moved through another $3 billion, 3.4 million meter pipeline, which is scheduled to begin service into Illinois in 2009 and into Oklahoma in 2010. Altogether, *Pipeline & Gas Journal* estimated in 2008 that about 46,000 miles of new pipelines are either in the construction or planning phase in North America. Most of the pipelines will be built to support additional distribution of natural gas. As of early 2008, about 32% of the new pipelines being built or planned around the world are located in North America.

In recent years, the crude oil industry has been recovering and transporting crude oil with higher viscosity, which must be heated for pumping. The higher temperatures lead to greater corrosion rates, so pipeline companies are demanding higher-quality coatings.

On the downstream side, it is unlikely that the oil industry will build any new facilities, but will likely add capacity to existing units. The number of U.S. refineries shrank from 324 in 1981 to around 145 in 2007. Historically, the refining industry has experienced very poor returns on capital (even though there was profitability in recent years). In addition, environmental and political pressures are difficult obstacles to new construction.

One growing area of the industry is imports of liquefied natural gas. The increase of natural gas prices to unprecedented high levels in recent years has led suppliers to build LNG terminals in the United States. LNG imports are expected to increase from less than one trillion cubic feet to 5 trillion cubic feet by 2020. Current capacity is about one trillion cubic feet, with another 0.5 trillion cubic feet in the construction stage. The increased demand for natural gas has outstripped the ability of domestic natural gas production to meet that demand and the disparity will only increase with time. As a result, there will be a major increase in growth in LNG both internationally and in North America. As of 2007, there were five existing LNG import and regasification terminals, located in Everett, Massachusetts; Cove Point, Maryland; Elba Island, Georgia; Lake Charles, Louisiana; and Altamira, Mexico. There are six more under construction, with start-up expected in 2010. The average capital value is $500 million per project. A number of other grassroots LNG terminals are being planned, but it is likely that many of the facilities will never be built because of environmental and political pressures.

Pharmaceuticals

The floor coatings used in pharmaceutical plants must withstand thermal shock from exposure to hot water, chemicals and cleaning agents, and forklift traffic. Either urethane mortar or troweled epoxy coatings are typically used. In solvent extraction areas, high-performance novolac epoxy coatings are typically used for their excellent chemical resistance to a variety of agents including the extremely corrosive tetrahydrofuran. Packaging areas require supersmooth, cleanable and reflective coatings; typically, terrazzo and decorative epoxy mortars are used. Aesthetics are important as well, as pharmaceutical plants are frequently inspected by Food and Drug Administration (FDA) representatives.

Pulp and paper

A pulp and paper mill probably presents the most diverse challenges for a supplier of corrosion-resistant metals and coatings in the general chemical process industry. Coatings must be specially formulated to withstand an extremely aggressive mix of water, acids and caustics. In addition, bleaching, high-temperature cooking and recovery processes generate corrosive gases that must be contained and scrubbed. Corrosion as a result of chemical buildup in recycled wastewater streams is becoming a serious problem not only in the bleach plant and the pulp mill, but on paper-making machines as well. New bleaching processes that use sodium chlorate and chlorine dioxide pose particular problems with corrosion-resistant metals.

As with the chemical industry, the North American pulp and paper industry is expected to encounter more competition from developing nations. Some U.S.-based producers are rapidly installing capacity in Brazil and Asia, where labor rates are lower, timber growing rates are much faster and there is less environmental and political interference. New facilities in Brazil can produce pulp and paper at about 50% the cost of an average facility in the United States. Paper demand in the United States is expected to decline at about 1.5% per year, while growth in Latin America is expected to be about 2% per year, that in Eastern Europe about 6.5% per year, and that in Asia Pacific about 4-5% per year. From 2000 to 2006, paper and paperboard capacity in the United States shrank by 0.6% annually. Little, if any, growth is expected in the near future. Some capital is being spent on deinking facilities as new laws are aimed at extending the life of landfills by promoting recycling of paper and paper products. By 2010, it is expected that 47% of all fiber will be recycled. Many states now require 40% recycled content in newspapers.

Utilities

Power plants often present corrosion concerns since many are located near oceans in order to use seawater as cooling water. Specific areas that are subject to strong corrosion forces are oil storage tanks in oil-fired power plants, conveyor systems and stacks in coal-fired plants, and dams and powerhouses in hydroelectric plants.

Demand for electricity is expected to rise approximately 2% per year on average. Most of the new capacity is based on natural gas–fired (80% of the total in 2003) or petroleum/natural gas dual-fired units (16%). Additionally, repowering of large coal-fired plants into more efficient natural gas combined-cycle plants, as well as the retirement of older coal-fired units, has slightly reduced overall coal-fired capacity. Natural gas and dual-fired capacity together account for 40% of the total generating capacity. Coal is still the largest single energy source at 33% of total capacity. Hydroelectric and nuclear each have a 10% share of the total, while petroleum and others, including renewables, account for 4% and 3% of the total, respectively.

Most new electrical generation capacity in the United States is expected to be based on natural gas, with no new coal-based facilities in the works, but there will be additions to capacity at existing plants. Gas-fired generation is expected to grow from 17% of total U.S. generation to 31% by 2015. Coal-fired plants will account for about 50% of total capacity in 2015, down from 60% in 2007. The coal-fired utility industry has been required to spend capital on flue gas desulfurization (FGD) stacks to minimize sulfur dioxide emissions to meet the 1990 Clean Air Act Amendments, which have been strengthened by the Clean Air Interstate Regulations (CAIR). As a result, the utility industry is scheduled to add about 300 FGD units between 2005 and 2010, mostly in the eastern half of the United States. Some of the FGDs are constructed of steel and lined with an unsaturated polyester finish, but other solutions included using exotic metal alloys or solid fiberglass-reinforced plastic (FRP) as materials of construction, or lining with acid-resistant ceramic tiles.

In addition to construction of new facilities, modification and maintenance of existing plants will be required. The electric power industry in the United States was deregulated in 1992, resulting in utilities' selling many plants off to reduce costs or concentrate on electricity transmission and distribution. In turn, power plants have become their own profit centers, requiring more attention to plant life and efficiencies. The downside to these events is the refocusing on the short-term results. Capital expenditures have fallen significantly, with much of the transmission and distribution equipment well over thirty years old. Still, projected capital spending in the power generation industry is expected to remain only at GDP growth levels for the near future.

Of all the types of power plants, coal-fired plants probably pose the toughest environment for coatings because of the highly corrosive nature of the products of combustion. Also, the nature of raw materials runs from alkaline (limestone) to acidic (coal and ash).

Special coatings are used in nuclear power plants, mainly as standby protection to prevent any radioactive material from penetrating into concrete or any bare steel areas. If any radioactive material is allowed to penetrate these areas, the whole structure must be destroyed. Inorganic zinc primers and epoxy topcoats are used to ensure protection for the life of the unit, usually forty years or more. The nuclear power industry, which has suffered from the disaster at Chernobyl in 1986, has been in decline in the United States in the last few decades. However, with the rising cost of fossil fuels and concern over greenhouse gas emissions, as well as safer new plant designs, nuclear power is becoming a more attractive energy option. New plants are being proposed that might be approved and commissioned.

Another growing source of power is windmills. New wind projects accounted for about 30% of new power-producing capacity installed in 2007 in the United States. Capacity is now at 6,300 megawatts, having expanded at an average annual rate of 28% in the past five years. Certain states have embraced wind energy as one of the favored renewable and alternative sources of green, nonpolluting energy generation. Texas has the most installed capacity, followed by California. The section of the United States with the highest wind potential is a corridor stretching north from Texas through the middle of the country, including sparsely populated states like Montana and the Dakotas. The United States is currently the leader in installed windpower capacity, with roughly 20% of the global total. Some forecast that $65 billion will be spent on new capacity over the next ten years, but this will be partially dependent on decisions on the extension of tax credits, which are currently under debate in the U.S. Congress. At least fourteen new manufacturing facilities were opened, or announced, in 2007 across the nation to make wind turbines and wind turbine components. Consumption of coatings has been increasing by about 30% per year.

Consumption of coatings in Canada has been increasing as well. Installation of wind power generation is expected to grow by 25% per year over the next ten years.

Bridges

Bridges are often subject to corrosive conditions since they are often located in marine areas, along coastal sections or over saltwater waterways. Bridges present difficulties in worker access because of elevation and traffic, and are usually difficult structures to protect because of the many angles, corners, braces, rivets, bolts and cables used. The bearings are also exposed to a high degree of friction and stress that can lead to premature coating deterioration and corrosion of the underlying steel substrate. Expansion joints are another problem area, because improper design or insufficient maintenance can lead to expansion joints that leak, thus spilling deicing salts and sand directly onto the coated steel structures below. Generally, the best types of coatings are used to reduce maintenance costs as much as possible.

The 90,000 bridges built in the United States during the 1930s are nearing the end of their useful lives, while another 223,000 interstate bridges built between 1965 and 1975 need major repairs, including painting. Public awareness of the problem was elevated with the collapse of the Interstate-35W bridge in Minneapolis in August 2007. A U.S. Federal Highway Administration (FHWA) report categorized over half of the nation’s 197,000 steel bridges as structurally or functionally deficient because of past neglect and inadequate protection from deicing chemicals and other corrosive elements. The FHWA is currently spending $217 billion to repair and rebuild the nation’s transportation infrastructure over a multiyear period, with an estimated $500 million spent per year for repainting existing steel bridges. In addition, a large number of bridges must be recoated since they are currently protected by oil or alkyd paints containing lead compounds. The replacement of lead coatings is very expensive; for example, in New York City, a recent lead removal project initially received a bid of $3.50 per square foot, but when OSHA requirements were factored in, the cost rose to $35 per square foot. One contractor estimates his average costs at $7-8 per square foot for lead removal after being $2-3 per square foot before regulations started in the early 1990s. Overcoating is gaining recognition as an alternative to complete removal of deteriorated lead-based coatings.

For many years, highway agencies from a majority of U.S. states have specified in-shop application techniques, mostly of a primer coat to new structural steel, with additional coats of paint applied after the steel was shipped to a job site and erected. Increasingly, it is becoming common practice for a bridge builder to have not only the primer, but often a system's second and third coats applied in the fabricating shop. In fact, many officials report that they expect to convert to total in-shop painting. In-shop painting of structural steel used in bridge construction has several advantages over field painting:

- The coatings are not subject to weather conditions during application.
- The entire coatings application and inspection process can be more easily controlled.
- There are cost savings when the processes of fabrication, blast cleaning and painting are all done under one roof.
- The difficulties of field painting, such as working around other trades, are eliminated, so in-shop painting helps to meet demands of accelerated construction schedules.

Because of the trend toward in-shop painting of structural steel, coatings manufacturers have been responding to fabricators' needs by developing new products that dry and cure in much less time and at lower temperatures than standard coatings, to help fabrication shops improve production. They are also developing products to meet increasingly strict government regulations through water-based and higher-solids coatings that eliminate or reduce the emissions of VOCs. As a result, a number of coatings systems are available that meet all forthcoming environmental regulations, provide excellent long-term corrosion control, and can be easily applied in-shop with the proper equipment and know-how.

Most shops/states are now using systems comprising an inorganic zinc primer, a polyamide epoxy intermediate coat and an acrylic polyurethane topcoat. Recent tests and studies sponsored by the FHWA have found that in marine atmospheric exposure testing these systems showed excellent long-term performance and corrosion control. While applying these coatings is slightly more difficult than the very forgiving alkyd paints of the past, they provide significant performance advantages in harsh exposures. High-solids solventborne zinc-rich primers and waterborne zinc-rich primers have been developed to enable fabricators to reduce VOCs. The concentration of zinc powder in the mixed coating is about 80% by weight for the best performing inorganic zinc paints. Historically, inorganic zinc coatings have been specified for in-shop painting of bridge structural steel. However, more states are now allowing organic zinc coatings as the primer.

Urethanes and waterborne acrylics will be used increasingly as topcoats, replacing vinyls, which contain high VOC levels. In recent years, there has been a strong push toward the use of moisture-cured one-component urethane coatings for outdoor topcoating, which offer the benefits of curing even in cold temperatures, being single-component systems (no mixing is required), and being well suited to penetration of corrosion areas so that extensive surface preparation is not required.

Concrete bridges, parking garages and highways are usually reinforced with steel rebar. Deterioration of these structures has become a major problem in the last thirty years because the rebar is being attacked by chlorides from deicing chemicals. Rebars have been coated since the mid-1970s with fusion-bonded epoxy (FBE) powder coatings in controlled plant conditions. They are applied electrostatically to pipe heated to about 250°C (500°F); the coating fully cures in seconds. In recent years, some producers have been topcoating the FBE-coated pipe with extruded polyolefins. The first layer is an FBE coating that is subsequently topcoated with a primer and polyethylene or polypropylene. The FBE contributes excellent corrosion protection and good adhesion, while the polyolefin provides mechanical toughness. The three-layer coating costs two to three times the cost of the FBE, but is already used extensively outside the United States. Generally, U.S. consumers are more price-sensitive than those elsewhere. In the 1990s, the FBE business was negatively impacted by reports of large bridge failures in the Florida Keys and failures of applications in Ontario, Canada, but authorities later concluded that most of the failures occurred because of improper concrete preparation. In North America, production of epoxy-based rebar coatings is about 3-4 thousand metric tons per year. FBE rebars are used in most new bridge construction, but stainless steel and solid rebars are used in more severe environments. About 20,000 bridges now contain FBE-coated rebar, representing about 95% of all new bridge construction since 1975. The Concrete Reinforcing Steel Institute (CRSI) estimates that the increase in the cost of coating the upper and lower mats of rebar is typically between 1% and 3% of the total cost of the structure and increases the installed cost of the rebar by 25%, but increases the lifespan of the bridge to forty years. If the rebar is not coated, the lifespan is often less than ten years in coastal areas or where road deicing salts are heavily used.

Consumption of coatings in the bridge industry will largely depend on government spending. In California, for example, expenditures for bridge coatings have remained largely stagnant for the last ten years. The amount of steel painted has actually decreased, as more money, time and manpower must be expended for containment when removing existing coatings. There is a trend toward building all future bridges with concrete which is cheaper to maintain in the long run. The new section of the San Francisco Bay Area Oakland bridge is being made of concrete instead of steel. Generally, the California Transportation Department does not coat concrete, except to cover up graffiti. An exception to this policy was made during the construction of the San Mateo Bridge in the Bay Area in the late 1990s, where a 1.5 mm polyurea coating was applied to the concrete to help provide a 125-year lifetime to the structure.

Water and waste treatment

Consumption of protective coatings by the water and waste treatment business is expected to increase significantly, and should be one of the highest growing sectors in the anticorrosion coatings industry. Many manufacturers of coatings have experienced a significant increase in sales to this market in recent years.

As mentioned in the **INTRODUCTION**, it has been estimated that the cost of corrosion to the water and wastewater industry is $36 billion annually, making it the sector most affected by corrosion. This includes the cost of replacing the aging infrastructure, lost water from unaccounted leaks, treating water that seeps into the collection system, the addition of corrosion inhibitors, and the installation of internal mortar lining, external coatings and cathodic protection.

The wastewater sector represents about 60% of the total. Currently, utilities are rushing to respond to pent-up demand to replace aging facilities, many of which are 75-100 years old. Nearly all are compromised to some degree by corrosion, overburdening and structural fatigue. Even as these existing systems are deteriorating, population demands are pressing upon cities to expand their wastewater collection capabilities. Expansion of water and sewage systems continues in the south and southwestern portions of the United States where populations continue to grow. Replacement and expansion projects have slowed in some municipal and industrial areas.

Private and public water and wastewater facilities are at the crossroads between increasing capacity and budgetary constraints. Deteriorating infrastructure, demanding time restrictions and mandated capital improvement projects require a focused analysis of existing problems and solutions. A major problem that utilities face is that the effects of wastewater collection system corrosion are often unseen and undetected until there is a major disruption of service or contamination of the environment. An estimated $670 billion is required to upgrade drinking water facilities and another $330 billion is needed to upgrade the United States' 16,000 existing wastewater treatment systems over the next twenty years.

Despite the obvious need to upgrade the infrastructure, it is not certain that governmental funding will be adequate. There are some legislators that are proposing sizable reductions in the Clean Water State Revolving Fund (SRF), a federal loan program that finances local water infrastructure projects. If enacted, it is likely that crucial maintenance work will be further delayed.

In the wastewater treatment sector, some manufacturers are developing alternatives to standard epoxies and urethanes that may not be able to withstand the new demands placed on wastewater facilities resulting from the processing of streams with higher levels of hydrogen sulfide. Up until the late 1970s, hydrogen sulfide (H_2S) levels stayed generally below 10 parts per million (ppm), but levels have risen significantly in recent years for several reasons.

- The passage of the Clean Water Act in 1980 required industrial pretreatment to reduce or eliminate the presence of heavy metals from wastewater discharges. These metals had been killing anaerobic bacteria found on concrete pipe and tank surfaces, and therefore dissolved sulfide concentrations were maintained at relatively low levels, thereby also reducing gaseous H_2S levels. Because gaseous H_2S is equally as responsible for odors as it is for corrosion of concrete in wastewater treatment systems, both odor and corrosion problems have increased as a result of industrial pretreatment of heavy metals.

- The construction of larger regional treatment plants over the last two decades has resulted in longer travel distances and detention time for wastewater. The pumping of wastewater through force mains means that pipes run full and slime layers cover the entire circumference of the pipes. Both factors have increased the sulfide production, subsequently increasing H_2S concentrations in aerated headspaces within wastewater systems. In collection systems for large domestic plants today, it is not uncommon to measure H_2S concentrations in headspaces as high as several hundred ppm.

- New methods of odor control, such as covered headspaces over clarifiers combined with higher concentrations of H_2S, have led to an increase in the volume of gases to which the coatings are exposed on a routine basis.

- Increased presence of hydrogen sulfide has led to higher concentrations of corrosive sulfuric acid, from 1-3% to concentrations greater than 7% in some municipalities.

This general trend toward higher H_2S concentrations has promoted much higher concrete corrosion rates in domestic treatment plants (especially larger regional plants) than seen in the past. During periods of low rain or high temperatures, levels can rise to 30-50 ppm, accelerating corrosion of concrete and causing depth losses of up to three-quarters of an inch of concrete a year. Prior to the late 1980s, relatively thin film coatings based on coal tar epoxy and amine-cured epoxy formulations provided effective corrosion protection of concrete for up to ten to twelve years, but in recent years, these same coating materials have failed prematurely. Some thicker film coatings and linings (up to one-eighth of an inch thick) based on polyester, epoxy and polyurethane resins have also failed under these relatively new and more adverse exposure conditions related to higher sulfide generation. Newly developed coatings show good resistance to H_2S vapors as well as to sulfuric acid.

There are many types of material used for piping in sewage collection systems, including vitrified clay, steel, cast iron, ductile iron, asbestos cement, concrete and plastic. Coatings are applied to steel and concrete piping, both for new construction and rehabilitation of deteriorated sewer lines. Other materials can be used to coat the insides of pipes, including PVC sheet lining (which are imbedded in newly poured concrete and can provide a dense impervious lining) and flexible rubber liners. Coatings are often preferred because of their low cost and favorable application properties.

Solventborne epoxies and urethanes are the workhorse coatings in the industry, as they have been for the last ten to twenty years, but improvements are being made in coatings technologies to better accommodate construction schedules, reduce VOC emissions and paint more plastic (PVC- and fiberglass-reinforced plastic) parts. Polyureas are being used since they have a fast cure, build thick films quickly and can set up on damp surfaces. Coatings are often applied over concrete. Usually, thick coatings, often at thicknesses of 80 mils (2 millimeters), are applied to concrete that is only minimally prepared and often contains high levels of moisture that can interfere with curing or drying. Epoxy-modified cementitious coatings are often used.

In the future, it is likely that there will be increased use of 100% solids coatings to further reduce the potential for the leaching of solvents and other chemicals into drinking water systems. A majority of these high-solids coatings whether epoxy, polyurethane, or polyurea, can or should be and in some instances must be, applied using plural-component spray equipment.

Offshore

The offshore market for anticorrosion coatings in the United States is estimated to be about 3 million gallons (11 million liters) per year. These coatings are mainly used on oil and gas rigs (previously discussed in the ***Oil and gas*** section), and to a much lesser extent, desalination units and ammonia/ methanol plants. Painting these structures is very difficult because of the extremely corrosive environment and the difficulty in reaching many of the platforms, production equipment and superstructures. Because of the very high cost of painting, long-lasting high-build systems based on zinc primers, epoxy intermediates and urethane topcoats are preferred. About two-thirds of the coatings are used to maintain the 4,000 existing offshore production platforms and rigs. The leading suppliers to this market are PPG, Akzo Nobel and Carboline. Lesser participants include CeramKote, Hempel, Jotun and Wasser, which collectively account for about 30% of the market. The industry has been shifting from lower-solids vinyls and chlorinated rubber coatings to higher-solids and waterborne coatings in recent years. Lower-solids coatings accounted for about 70% of the market in 1990, and now account for less than 60%. Two-component systems predominate, with about 75% of the total market. The present use of waterbornes is less than 5%. Epoxies account for about 50% of use, aliphatic isocyanate-based polyurethanes for 20% and alkyds for about 8%. Activity in the oil and gas drilling rig business is quite cyclical, depending heavily on natural gas and crude oil prices.

Other

The food and beverage industry is one of the most regulated businesses today, requiring stringent quality, safety and sanitary controls for virtually every facet of plant operations, from wet storage and processing to wet packaging and refrigeration. Coatings must protect against solvent sprays, oil and fat spillage, heat resistance and many other food processing chemicals and by-products. Most process and warehouse floors are concrete which must be coated to eliminate dust, seal the surface to prevent bacterial growth and resist degradation because of frequent cleaning to assure purity of the operation. Epoxies are preferred for most applications because of their high chemical resistance, ability to be applied at high solids contents and high durability.

In the metal and mining industries, highly chemical-resistant coatings for steel structures and equipment must withstand both aggressive chemicals and physical abuse. The price of metals significantly affects the economics of new plants and creates constant pressure to increase productivity and efficiency while lowering product costs. More and more facilities are moving to solvent extraction/electrowinning processes, creating a high potential rate of corrosion resulting from this severe acid and acid vapor environment.

The microelectronics industry is the most dynamic and rapidly expanding industry in the world. Microelectronics companies are faced with constant changes in technology and manufacturing practices, including more stringent clean-room specifications, greater use of high-purity chemicals in daily operations, increased sensitivity of electronic components to static electricity and faster fabrication of billion-dollar production facilities. The latest coatings technology for the microelectronics market includes low-particulate-generating intumescent fireproofing designed specifically for clean-room environments.

Western Europe

In Western Europe, 2007 consumption of anticorrosion coatings for protection of onshore structures was about 145 million liters and for offshore protection approximately 15 million liters. Major suppliers of onshore coatings are Akzo Nobel, PPG, Sika, Hempel, Jotun and Tikkurila, with Leigh being active in the United Kingdom. Major suppliers of offshore coatings are Akzo Nobel, PPG, Hempel and Jotun. From 1998 to 2005, there was little growth, but there was some increase in 2006-2007 as the construction industry started to bounce back and shipbuilding recovered somewhat. All major suppliers are refocusing their operations on the growing areas of the world, including Asia and the Middle East (as discussed in the **STRUCTURE OF THE INDUSTRY** section of the report).

Consumption of marine coatings, excluding yacht coatings, is estimated to have been 70 million liters in 2007. The market in Western Europe encountered considerable difficulties in the early 2000s. The major players in the Western European marine coatings sector are Akzo Nobel, Hempel, Jotun, PPG and Chugoku.

German statistics indicate that demand for protective and marine coatings was largely stagnant from 1998 to 2004, but started growing again in 2005:

Table 50

German Consumption of Anticorrosion Coatings
(thousands of metric tons)

	Protective Coatings	Marine Coatings	Total
1998	50	na	na
1999	49	na	na
2000	48	na	na
2001	47	na	na
2002	46	16	62
2003	44	17	61
2004	42	17	59
2005	43	18	61
2006	45	19	64
2007	47	21	68

SOURCE: Verband der Deutschen Lackindustrie e.v. (Vdl).

In France, demand for anticorrosion coatings fell significantly from 1996 to 2005, but started growing again in 2006:

Table 51

French Sales of Anticorrosion Coatings
(1995 = 100)

1995	100.0
1996	95.1
1997	87.6
1998	86.3
1999	89.3
2000	93.8
2001	91.0
2002	88.1
2003	87.6
2004	85.3
2005	87.6
2006	92.3

SOURCE: Service des Statistiques du Ministère de l'Industrie (SESSI).

The Netherlands reports sales data as follows:

Table 52

Dutch Sales of Anticorrosion Coatings (thousands of metric tons)

	Protective Coatings	Shipbuilding and Repair
1998	15.5	10.0
1999	12.8	10.6
2000	12.4	9.8
2001	12.4	9.5
2002	13.9	9.8
2003	10.5	9.0
2004	9.8	9.9

SOURCE: VVVF Statistieken.

Spain reports the following sales figures:

Table 53

Spanish Sales of Anticorrosion Coatings (thousands of metric tons)

	Protective Coatings	Maritime
2004	16.5	7.2
2005	15.0	7.6
2006	16.0	8.0

SOURCE: Paint Research Association.

In Western Europe, most of the growth in anticorrosion coatings through 2012 will be in coatings for oil and gas exploration and production, bridges, highways, pollution abatement equipment in power plants, pharmaceutical plants, and water and wastewater treatment facilities. Consumption trends in Western Europe have been similar to those in the United States. In Western Europe, an estimated 70-75% of expenditures for anticorrosion coatings are for the maintenance of existing constructions, whereas 25-30% was spent on new facilities. In 1982, these percentages were the reverse. No significant change is anticipated in the near future.

Marine

In Western Europe, consumption of coatings by the marine industry continues to decline. After a decrease in the late 1980s, there was an upturn during 1989-1992 in Italy, France and Greece, which partly offset the drop in activity in the Scandinavian countries, Germany, Spain and the United Kingdom. From 1996 to 1998, activity in the Netherlands and Norway increased while that in Germany remained flat, and France increased before decreasing. Overall Western European consumption decreased in 1999, but increased by an estimated 2-3% in 2000 before falling dramatically in 2001. Over the 1998-2001 period it is estimated that the consumption of marine coatings fell by around 15%. Companies that focused more on maintenance saw their performance suffer in 2000 as ship owners reacted to the high freight rates by delaying dry-docking.

The focus of the shipbuilding industry, and new construction in particular, continues to shift to Southeast Asia. One major marine coatings manufacturer (Hempel) shut capacity in Western Europe in 2003 because of falling demand. However, in 2005, Western European consumption started to increase again as some work migrated back from Asia due to capacity constraints.

In 2004, the EU ban on single-hull ships carrying heavy fuel took effect despite shipping industry concerns that the approach was ill-advised. The new regulation required

- The prohibition of transportation of heavy-grade oil in single-hull tankers to and from ports of EU member states
- All single-hull tankers more than fifteen years old must undergo a Condition Assessment Scheme to determine the ship's structural integrity
- All single-hull tankers 23 years or older must be phased out by 2005 instead of 2007

The commission is also calling for the complete phaseout of single-hull vessels worldwide by 2010. Coating use for replacement and maintenance is expected to increase because the average age of crude oil vessels is thirty years.

Intertanko, the leading trade group representing the independent tanker owners, said the costs of the new EU rules on single-hull tankers far outweigh the benefits. It estimates that the new measures will cost $4 billion because of the loss of the use of the single-hull ships.

Europe is the major builder of cruise ships. One cruise operator, Royal Caribbean Cruises, decided in late 2001 to scale back expansion plans, including plans to have $3 billion of work performed in European shipyards, following the September 11, 2001, terrorist attacks. However, business has since recovered nicely. From 2001 to 2005, global passenger traffic grew by about 10% per year, and grew by another 6% in both 2006 and 2007. In 2004, the industry added twelve new ships to the global fleet, which is a record. In 2005, three new ships were added to the existing fleet of 142, and in 2006, eight new ships were launched. Currently, the cost of a new cruise vessel is $400-500 million. With lost revenue running at $4-5 million per week, it is essential that the vessel be kept in service for as long as possible. Therefore, getting the paint specification correct and having the paint applied properly is an important aspect of the ship design and construction.

Cruise ships are complex structures. Appearance is still all-important, as is the ability to keep the finishes clean. Surface preparation also needs to be carried out thoroughly to ensure good adhesion because topcoat detachment cannot be allowed. However, both commercial and environmental pressures on operators mean that the ships need to reduce maintenance costs and time. The challenge, therefore, is to build and protect new ships that can be maintained and operated in a cost-effective and truly environmentally friendly way. The future service life targets are ten years using toxic-free underwater coatings, ten years for finishes on topsides structures, and more than fifteen years for tanks.

For all maritime vessels, the toughest challenge is with underwater antifouling coatings. Because of their high marine and public profile, cruise companies were among the first to recognize the negative publicity possible because of the continuing use of TBT-containing self-polishing coating (SPC) antifoulants. Therefore, from the mid- to late 1990s, cruise companies were specifying tin-free types in anticipation of the forthcoming ban that the IMO finally imposed in 2001. As an added complication, cruise vessels very often may have to dry-dock in the United States, where the paint makers in many cases have had, or still have, different types or formulations of antifoulant coatings available than those applied at the ship's building in Europe. Current tin-free antifoulants meet the minimum specification of 36 months' protection, but cruise companies may consider longer-lasting coatings. Ideally, this new bottom coating should be nontoxic, extremely hard and abrasion resistant, and easily cleaned, and it should have a service life of more than ten years (possibly to last the life of the ship).

Major suppliers of ship coatings include Akzo Nobel (International), Chugoku, Hempel, Jotun and PPG. These suppliers control about 80% of the market. European shipbuilding is still fragmented, with the European Shipyards' Association listing 375 yards. According to the French industry minister, Europe has 21 naval industrial groups and 23 large shipyards. This compares with just eight shipyards in the United States. A new impetus toward cross-border consolidation, typified by Germany and France, is now emerging. In Germany, the Thyssen Krupp conglomerate agreed in 2004 to merge its shipyards with those of submarine producer Howaldtswerke Deutsche Werft, which is being welcomed as a necessary step toward further European consolidation. In France, the naval activities of the Thales defense group were merged with DCN, the state-owned military shipyard. Beyond this, French government officials would welcome a Franco-German shipyard combination, similar to the pan-European aerospace group Airbus. German officials, however, would support such a French-German merger only if the headquarters of the two countries' shipyards remained in Germany. A further obstacle is the French desire to see the civil shipyards of Alstom, with its 12,000 employees, included in the Thales/DCN tie-up.

Production of marine coatings in Western Europe has traditionally been higher than consumption, since a sizable amount (around 30% of production) was exported to the Republic of Korea, Japan, China and Taiwan. This export market, however, has been eroded as the leading producers install production capacity in these countries.

Public sector

In Europe, as in the United States, bridges and other infrastructure are aging and in need of repair. It is estimated that the cost of poor roads, bridges and other public structures to the general economy is about $30 billion per year in France and $15 billion in the United Kingdom, where, in addition, it has been estimated that $1.1-1.3 billion is needed to bring the general standard of all UK bridges to acceptable levels. Europe's power distributors face billions of dollars in backlogged underinvestment.

New orders for construction were generally in decline throughout Western Europe from 1998 to 2005, but have started to increase in recent years. There has been a trend to privatize public works, which has prompted some investment. European countries are scheduled to invest $330 billion over the next ten years on rail, waterway and highway development.

In 2005-2007, civil engineering construction output in Great Britain increased by an estimated 4% per year after years of decline. Much of the development in recent years is due to increased activity in the utilities sector which has been brought on by key investment programs in the sewage, electricity, gas pipelines, air transport, railways and harbors sectors. In the United Kingdom, the Water Framework Directive will likely cost £15-20 billion to upgrade the sewage system, include a £2 billion tunnel under the Thames to prevent river pollution when sewers overflow in storms, and bigger sewers or pipes to separate surface water from sewage. The investments are being made between 2005 and 2010. Furthermore, the 2012 Olympic Games will increase demand for civil engineering projects to build the supporting infrastructure on a fixed timescale.

As in the United States, spending on infrastructure is always subject to delays. In general, however, infrastructure rebuilding will grow faster in southern Europe than in northern Europe.

Oil and gas

In the oil and gas sector, the North Sea remains a major area of activity in exploration, development and production. Capital expenditures are cyclical, depending on the price of gas and oil. Following the oil price crash in the late 1990s, capital investment reached a low of $4.5 billion in the United Kingdom in 2000 compared with $5.5 billion in 1998. Some platform fabrication yards in the United Kingdom operated at only 25-50% of capacity. Investment started to pick up in the latter part of 2000 and there was an increase to $5.6 billion in 2001.

By 2003, the situation had changed significantly. With the price of crude oil around $40-50 per barrel, the oil industry was making huge profits and planning to significantly increase investment in exploration and production. In 2000, the top thirty publicly quoted oil companies invested around $62 billion in capital expenditures globally. By 2003, that had risen to $98 billion and was even higher in 2004-2007. Shell ramped up its capital expenditures for European oil and gas exploration and production from about $2 billion in 2005 to $2.8 billion in 2007. BP has invested $1.5-2 billion annually in projects in the North Sea in recent years. The North Sea remains an important region for BP on both a volume and a value basis—around 10% of the company’s global value is generated by the region’s business.

In the current high-price environment, oil companies generally see higher margins in Organisation for Economic Co-operation and Development (OECD) countries than in non-OECD areas. In the latter, governments tend to use revenue systems based on production-sharing contracts, which offer hedged security when oil prices are low, precluding companies from reaping the full benefit of high prices.

In the Norwegian sector, Statoil has significantly increased capital expenditures for exploration and production and refining in recent years. Its 2006 capital expenditures for exploration and production in Norway were about 25% higher than those in 2004. ExxonMobil’s total capital expenditures in Europe were about 30% higher in 2006 than they were in 2004. Eni increased its exploration and production capital expenditures in Europe and Africa from 3.7 billion euros in 2005 to almost 5 billion euros in 2007. Total is expecting production of oil and natural gas in the North Sea to decline through 2010, and will instead increase exploratory efforts in Africa and Asia.

Drilling for European offshore oil and gas started in Norway in the early 1970s. The standard coating is now an organic zinc primer (usually with epoxy), an epoxy middle coat and a polyurethane topcoat. However, in recent years, there has been increased use of polysiloxanes. In some cases, the rigs are fabricated from sections made in the Republic of Korea and elsewhere for assembly in the North Sea area. In the early stages of drilling, some gas fields had extremely long lives, but more projects now feature shorter life cycles. As a result, some operators have switched from thermal aluminum coatings, which are expensive and time consuming to apply, to shorter-life-cycle coatings.

It is expected that there will be more demand for high-performance coatings based on epoxies and urethanes as operators use longer-lasting coatings as a means of extending the lives of their platforms, sometimes beyond the initial expected lifetime since, in many cases, field lifetimes are being extended by new oil extraction technologies. Spending on maintenance coatings for existing structures will therefore increase as production facilities age. Both the size and number of new platforms are expected to decline since the oil fields being discovered and developed are relatively small and often in deep water such that large platforms are unusable. Thus, the industry is installing more subsea production facilities (where newly producing satellite wells are connected underwater to an existing large central platform to decrease production equipment requirements); this should negatively affect the use of anticorrosion coatings. Also, the use of so-called floating production, storage and offloading vessels (FPSO) is increasing. These vessels are ships that stay on station throughout the lifetime of the field. A typical vessel built for a field with 150 thousand barrels per day of capacity and 2 million barrels of storage costs $2.5 billion consuming about one thousand metric tons of paint worth $5 million. It is forecast that 40% of new production in the North Sea will use subsea connections and 20% FPSOs. U.S. and Western European companies have been forming joint ventures for the construction of FPSOs and FPUs (floating production units) in China. Sometimes the hulls of FPSOs are built in Southeast Asia while the topsides are fitted in Western Europe.

Pipeline coatings (mainly fusion-bonded epoxies and polyurethanes) are applied in shops as opposed to in the field. These coatings compete with polyethylene that is extruded; however, there has been increasing use of systems consisting of an epoxy innerlayer and a polyethylene outerlayer. The construction of pipelines, particularly for natural gas transmission, has remained at a fairly high level in recent years. Use of FBE epoxies in Europe for pipeline protection is about 7 thousand metric tons per year. Growth to 2012 is forecast to be about 2% per year. Major suppliers, which together have a 50% market share, include 3M, Akzo Nobel, BASF, BS Coatings (formerly Bitumes Speciaux), Sika and Jotun. Globally, it is estimated that over 100 thousand kilometers of pipeline are coated with fusion-bonded epoxies.

Pipeline construction in Western Europe is not expected to grow as rapidly as in North America and Asia. In 2007, the Langeled pipeline was completed; it links a natural gas field in Norway to England through the longest subsea pipeline in the world. In Eastern Europe, there are plans to move oil and gas into China, Japan and the Republic of Korea. Most are still at the planning stage, but one project to move crude oil from Eastern Siberia to China and Japan is proceeding. The pipeline will be built in stages, with a 2.7 million meter line running from Taishnet in Siberia to Skovorodino (near the Chinese border) expected to be operational by the end of 2008. Plans are for the $11.5 billion pipeline to be finally finished in 2015. Like the United States, demand for liquefied natural gas (LNG) is increasing, at a rate of 10-15% per year.

In the refining sector, poor margins in Europe for the last twenty years have led producers to reduce capacity. There has been some investment in recent years mainly to meet stricter legislation on the sulfur content of gasoline and diesel. In the 1990s, refiners also installed expensive catalytic crackers to increase production of gasoline, but gasoline consumption in Europe has dropped as motorists have tended to buy diesel cars instead of gasoline-powered automobiles. Sales of diesel-powered cars grew from about 25% of total sales in 1995 to nearly 50% by 2006. As a result, Europe is a large net exporter of gasoline, mainly to the United States, but a net importer of middle distillate for diesel production. The cost of exporting product is high for inland refiners, which depresses margins. Over the long term, European diesel demand is expected to increase by about 2% per year while demand for gasoline will decrease by 1% per year, but growth of both refinery products will be less due to greater mandated use of ethanol in gasoline and of biodiesel. Gasoline exports to the United States are expected to moderate or decrease due to stagnant demand and greater mandated use of ethanol. Due to these factors, the European refining industry will not undertake large-scale investments, although there will be some expenditures for projects to upgrade heavier crudes, to process high-sulfur crudes and to modernize refining sites, improving safety and energy efficiency and reducing environmental impacts.

Chemical manufacture

Capital investment expenditures in the European chemical and petrochemical industry peaked in 1998 and then dropped through 2005, due to depressed operating rates and low margins. Instead, European producers tended to expand in the growing Asian market. However, by 2006, the European chemical industry had rebounded, in part due to strong demand from abroad, leading to greater internal investment. In 2007, business remained strong in nearly every sector of the chemical industry. Capacity utilization rates increased, and chemical producers expanded production and turnover figures, which had already reached a high level in the second quarter. In Germany, capacity utilization in 2007 was around 87%, prompting capital investment in the industry to rise by an estimated 3% to a total of 5.8 billion euros. Sales were expected to increase by 7-8% in 2008. Exports to the United States have slowed some, but demand in other regions remains robust.

Still, in the longer term, the most large-scale investments in Western Europe will be focused on revamping and debottlenecking processes, and building projects to facilitate the recycling of production wastes and recovery of by-products. No new petrochemical cracker is foreseen for Western Europe in the next five to ten years, with most future large petrochemical plants being planned for China and the Middle East (eight planned in 2008-2012 with ethylene capacity of at least one million metric tons per year each). Most Western European petrochemical facilities are relatively small scale (average of 400 thousand metric tons per year), and hence less economical than the large, modern complexes that are being built in the Middle East and Asia. Some of the loss of business in the petrochemical and chemical sector will be offset by coatings production in the Middle East and Asia by affiliates and joint ventures of the major European producers (which are also, of course, major global players).

Other

Investment in other industries, such as food and beverage, pulp and paper, and metals and mining has been flat over the last few years, and is expected to remain so. Consumption of anticorrosion coatings in these markets will not increase.

In the United Kingdom, intumescent coatings account for 35% of the fireproof coating market, more than double the percentage of cementitious coatings. The development of off-site application procedures for these materials is credited with the increased use of intumescents in the United Kingdom.

As in the United States, consumption of coatings for wind turbines has been growing at a rapid pace. In Europe, some wind farms operate offshore, and turbines must be coated with long-lasting durable finishes to withstand the harsh marine environment. Once set in place, the structure is quite difficult to service without major expenditures, so long-lasting, high-performance coatings are specified. The nations with the largest installed base of wind turbines are Germany and Spain; with time, other nations will install more capacity, as well as Eastern European nations like Poland and Turkey. The offshore market is expected to grow rapidly in the United Kingdom, Germany and Spain, and should account for roughly 10% of Europe’s total capacity by 2015. Altogether, the installed base of European windpower capacity is expected to grow by about 12% per year over the next ten years.

Central and Eastern Europe

In Central and Eastern European countries, the overall paint and coatings markets are growing at rates of around 4-5% per year; the 2007 consumption of protective and marine coatings was estimated at 10 million liters and 5 million liters, respectively. These values may not include all high-performance coatings as defined for this report. However, it is clear that the markets are growing, particularly in the marine sector, as work is moving from Western Europe to countries like Poland, in particular. In the protective coatings sector, much maintenance work remains to be done in Central and Eastern Europe, but this requires investment that is often difficult to obtain. Currently, much of the work in the protective coatings area is conducted on heavy construction that is subsequently exported.

Western European coatings companies have accelerated investment in this region, with Tikkurila and Akzo Nobel being particularly active in the high-performance area.

Japan

Shipments of marine and structure coatings as compiled by the Japan Paint Manufacturers Association (JPMA) are summarized in the table below. Data are compiled from sales data reported to the JPMA, and exclude export figures.

Table 54

Japanese Consumption of Anticorrosion Coatings[a]
(thousands of metric tons)

	Marine Coatings	Structural Coatings[b]	Total	Total (millions of equivalent liters)
1989	88	122	210	171
1990	96	128	224	182
1991	97	138	235	191
1992	101	124	225	183
1993	100	124	224	182
1994	97	114	211	172
1995	94	124	218	178
1996	103	127	230	187
1997	110	131	241	196
1998	108	113	221	180
1999	110	110	220	183
2000	115	106	221	184
2001	114	103	217	181
2002	118	98	216	180
2003	117	95	212	177
2004	120	99	219	178
2005	120	89	209	167
2006	125	99	224	179
2007	132	99	231	188

a. Fiscal year basis, from April 1 through March 31.

b. Excludes some applications that are categorized in construction material.

SOURCES: *The State of Paint Manufacturing Industry Survey*, Japan Paint Manufacturers Association; SRI Consulting (data for 2006-2007).

According to the Japan Paint Manufacturers Association, domestic shipments of shipbottom coatings have been about 20 thousand metric tons in recent years.

The main market for high-performance anticorrosion coatings in Japan is shipbuilding and repair. Other large markets include bridges and other infrastructure such as airports, electric power utilities, petroleum and gas manufacture and transportation, petrochemical and chemical plants, and potable water and wastewater treatment systems. Compared with the United States and Western Europe, the proportion of the marine and bridges sectors is relatively large, which reflects the fact that Japan has been the leading country in shipbuilding. For example, the oil and gas exploration industry is negligible in Japan, and almost all oil and most gas is imported through tanker or LPG/LNG ships.

The marine sector consumes the largest volume of protective coatings in Japan. During the 1990s, consumption for marine paints gradually increased, except in 1994-1995. Consumption was estimated to be about 114 thousand metric tons in 2001, increasing to about 120 thousand metric tons in 2004 and to 132 thousand metric tons in 2007. The ratio of paint consumption for repair versus new building was estimated to have been around 60:40 in 2004; however, this ratio was the reverse, 40:60, in 2007.

When Japan stopped using TBT-based antifouling coatings in 1992, prior to the IMO decision, some foreign ship owners decided to apply TBT-based coatings outside Japan, because of lower costs and the long-term reliability of their effectiveness. However, TBT-based antifouling paints were also largely banned in other countries starting in 2003, so Japanese exports of coatings have once again started to increase. Japanese coatings producers are some of the worldwide leaders in developing TBT alternatives.

Major marine paint suppliers are trying to expand sales of their TBT-free antifouling paint products in overseas countries. Nippon Paint continues to license its tin-free antifouling paints to International Paint (part of Akzo Nobel), even after the dissolution of the alliance in October 2004. Also, NKM (formerly NOF/Kansai Paint) has a licensing agreement with Jotun and distributes products globally. Chugoku started to manufacture its products at overseas affiliated companies or subsidiaries in 1999 for worldwide distribution.

Other Japanese high-performance anticorrosion coatings markets include protection for public sector structures such as bridges, highways and airports; potable water and sewage systems; and electric utilities. Private sector markets include petrochemical and chemical plants, pipelines and other industrial structures. As there is almost no oil and gas exploration or production in Japan, the consumption of coatings in this category is mainly for petroleum storage tanks, which contain about 70 million liters of petroleum. Fiber-reinforced resins (vinyl ester, unsaturated polyester or epoxy) are used to construct tanks filled with petroleum products. MODEC (formerly Mitsui Kaiyo Kaihatsu) is one of the leading producers of offshore oil and gas production/storage facilities, such as FPSO (floating production storage and offloading system) and FSO (floating storage and offloading system). Facilities are located in other Asian countries, such as Singapore, China and the Republic of Korea, and protective coatings are consumed in these locations.

Demand for coating steel and concrete structures has been decreasing in recent years. Demand for coatings by the public sector fluctuates with the government's economic policy, whereas use by the private sector varies with the overall economic situation. Most public works are complete, and the government's budget for new public constructions is expected to decrease over the next five years. The government's budget for public works peaked at about ¥13.7 trillion ($112 billion) in 1993, then dropped to ¥11.9 trillion ($110 billion) in 2000 and even further to ¥7.8 trillion ($72 billion) in 2004 and ¥6.9 trillion ($59 billion) in 2007. New construction decreased, but coatings demand for refinishing steel works remains stable. Maintenance of existing structures accounted for 80-90% of large-structure coatings in 2007.

Under these economic conditions, many consumers of coatings in both the private and public sectors have reduced expenditures on anticorrosion coatings, often by reducing the frequency of refinishing. As a result, coatings manufacturers now often propose coating systems with higher performance that will lead to reduced maintenance costs even though the initial cost is generally higher. For example, using fluorinated coatings instead of urethane topcoats can reduce repainting times leading to long-term costs. Melted zinc coating is also expected to impart fifty years of anticorrosion protection.

In the public sector, the largest volume of industrial maintenance coatings is consumed for bridges. About 8.7% of the government budget for public works is for bridges. There are 137,000 bridges in Japan. Coatings are consumed not only for large cross-bay bridges like those between Honshu Island and Shikoku Island, but also for a number of smaller bridges nationwide. Use of coatings has been fairly constant, but the outlook for the near future is less optimistic. Most large bridge construction is finished, especially between Shikoku and Honshu islands. In 2007, the materials used for construction of bridges were 40% steel, 37% prestressed concrete (PC), 19% reinforced concrete (RC) and 4% other. However, when comparing spans, steel bridges account for 49% of the total bridge lengths, which means longer bridges are often made of steel. RC and PC bridges use relatively smaller amounts of coatings than metal bridges. The table below lists major bridges (more than 350 meters in span length). Future coatings consumption will mainly be for refinishing existing bridges rather than for new bridges.

Table 55

Major Japanese Bridges

	Center Span Length (meters)	**Year of Completion**	**Steel Used (thousands of metric tons)**
Akashi Kaikyo Ohashi Bridge (Hyogo)	1,991	1997	178
Minami-Bisan Seto Ohashi Bridge (Kagawa)	1,100	1986	80
Kurushima Kaikyo No. 3 Ohashi (Ehime)	1,030	1998	28
Kurushima Kaikyo No. 2 Ohashi (Ehime)	1,020	1998	30
Kita-Bisan Seto Ohashi Bridge (Kagawa)	990	1986	67
Shimotsui Seto Ohashi Bridge (Okayama-Kagawa)	940	1986	60
Tatara Ohashi Bridge (Hiroshima)	890	1998	32
Ohnaruto Bridge (Tokushima-Hyogo)	876	1984	54
Innoshima Bridge (Hiroshima)	770	1982	13
Akinada Ohashi Bridge (Hiroshima)	750	1999	14
Shiratori Ohashi Bridge (Hokkaido)	720	1996	20
Kanmon Bridge (Yamaguchi)	712	1973	20
Kurushima Kaikyo No. 1 Ohashi (Ehime)	600	1998	16
Meiko Chuo Ohashi Bridge (Aichi)	590	1996	37
Rainbow Bridge (Tokyo)	570	1992	45
Toyoshima Bridge (Hiroshima)	540	2008	na
Minato Ohashi Bridge (Osaka)	510	1974	33
Tsurumi Tsubasa Bridge (Kanagawa)	510	1993	36
Yokohama Bay Bridge (Kanagawa)	460	1989	47
Hitsuishi-jima Bridge (Kagawa)	420	1986	34
Iwaguro-jima Bridge (Kagawa)	420	1986	33

SOURCE: *Kyoryo Nenkan*, Japan Association of Steel Bridge Construction.

There has been increasing demand for coatings on concrete structures in water and sewage treatment plants, mostly where high levels of corrosive elements like hydrogen sulfide are present. Construction of the sewage system has been conducted steadily by the Ministry of Land, Infrastructure and Transportation.

Small amounts of coatings are applied to concrete highways, mostly in areas that are exposed to salt damage. There is also some demand for paints on airport facilities, especially those constructed on the seacoast.

Consumption of coatings for power plants is not large in Japan because they are constructed mostly with concrete and the usage of steel is small. Demand for coatings will remain rather sluggish because some construction plans have been postponed as a result of stagnant demand, especially for industrial use.

Consumption of protective coatings by the petrochemical sector dropped significantly in recent years because of cost containment measures. Many plants postponed scheduled refinishes of steel structures such as tanks. Demand is not expected to recover in the near future.

The table below shows the consumption of steel for civil engineering work and shipbuilding during 2004-2007. The surface area of steel to be coated depends on the shape of the steel and type of application; generally a large volume of anticorrosion coatings is applied to plate steel, especially thick-gauged steel plate, and a fairly large amount of thick-gauged steel plating is used in bridges and shipbuilding. The estimated surface area of these types of steel is close to 100 million square meters.

Table 56

Japanese Steel Shipments for Civil Engineering and Shipbuilding (thousands of metric tons)

	Civil Engineering	Shipbuilding	Total
2004	3,133	4,289	7,422
2005	3,118	4,864	7,982
2006	2,980	4,998	7,978
2007	3,120	5,330	8,450

SOURCE: Steel Supply Demand Statistics, Steel Club.

China

Marine coating plants are located in the coastal areas, such as Dalian, Qingdao, Shanghai and Guangzhou. Most coatings applied to large oceangoing ships are supplied by large multinationals, such as International Paint (Akzo), Chugoku, Hempel, Kansai Paint, Jotun, PPG (formerly SigmaKalon) and Korea Chemical (KCC), with local presence in China. The price of these functional coatings is fairly similar to the international price. On the other hand, coatings for fishing boats are generally supplied at low prices by domestic Chinese coating manufacturers, such as Shanghai Kailin, Guangzhou Pearl River, Guangzhou Supe Chemical and others.

Chinese demand for high-performance anticorrosion coatings in 2007 is estimated in the table below.

Table 57

Chinese High-Performance Anticorrosive Coatings Market—2007

	Volume (millions of liters)	Value (millions of dollars)
Industrial Anticorrosion Coatings	196	565
Marine Coatings	104	340
Total	300	905

SOURCE: SRI Consulting.

China also uses a large amount of lower-performance paint, including that used by small businesses and homeowners on structures and private boats, as well as some oceangoing vessels. It is likely however, that some of these coatings will be replaced by higher performing coatings as Chinese owners will tend to upgrade their standards.

Protective coatings

Industrial anticorrosive coatings are applied to petrochemical and electric power plants, oil tanks and bridges.

Since the 1980s, China has focused on the development of the petrochemical industry. Some new petrochemicals plants were built, such as Huizhou Petrochemical Plant of China National Offshore Oil Corporation and Hainan Petrochemical Plant of Sinopec, and the Qingdao Petrochemical Plant of Sinopec is currently being built. Petrochina just finished the engineering of a cross-country gas transmission pipeline, with yet another pipeline being planned. Many chemical participants are establishing or enlarging chemical capacities in 2007-2012.

As a result of the development of the chemical and oil industries, consumption of protective anticorrosion coatings has increased significantly. However, not all of these coatings are considered high-performance as defined in this report. A significant amount of decorative and other lower-performance paint is used by small businesses and homeowners on structures and facilities.

Some large bridges have been constructed in China in recent years, including Xihoumen Bridge (1,650 meters, completed in 1998), Runyang South Bridge (1,490 meters, in 2005), Tsing Lung Bridge (1,418 meters, in 2007), Jiangyin Changjiang Bridge (1,385 meters, in 1999) and the Yangluo Bridge (1,280 meters, in 2005). China is continuing to build many bridges, including the following under construction: Hangzhou Bay Sea-Crossing Bridge, Zhoushan Bridge, Qingdao Trans-Ocean Bridge and the Xia-Zhang Bridge. Other bridges that will be constructed include the Dalian Trans-Ocean Bridge, Changdao-Penglai Bridge and the Zhu-Gang-Au Bridge.

Additional coatings will be used on offshore oil and gas drilling platforms being erected off the Chinese coast.

Another growing market is wind turbines. China has a large land mass and long coastline, with relatively abundant wind resources. Currently, China is ranked sixth in terms of world windpower capacity, but capacity is expected to grow quickly due to the country's rising demand for power and the government's desire to install renewable energy sources. Capacity is now about 4 gigawatts (gW), and is projected to rise to 10 gW in the next few years. There are about twenty local manufacturers of wind turbines, mostly of medium generating capacity, but with intentions of building megawatt-scale turbines. The local manufacturers compete with the larger international suppliers like GE, Vestas, Gamesa and others. The large local manufacturers now account for about 50% of the Chinese market, while in 2005, their market share was only 15% or so.

Container coatings

Coatings used on large cargo containers are sometimes considered anticorrosion coatings as the same types of coatings are used as in protective and marine coatings and are supplied by the same producers. However, for this report, use of these coatings is not included in the consumption tables.

The container transportation market has grown in China, with the economic globalization. Because of lower labor costs and the large volume of trading activity, China has become the hub of the container manufacturing industry across the world. Chinese container production has been the largest in the world since the end of the 1990s. Container production was 1.1 million TEU (container capacity is often expressed in twenty-foot equivalent units [TEUs]) in 2001, and increased to 3.18 million TEU in 2004 in China. But production of containers started to decrease in 2005. Container production was 2.74 million TEU in 2005, increasing to more than 3.3 million TEU in 2007. Containers can be classified as dry-cargo containers (80-90% of total), refrigerated containers and special containers.

Demand for large ship containers has risen significantly in recent years. China is an ideal location to produce containers (hence, applying container coatings) because it handles the largest volume of containers for trading in the world, labor costs are relatively low, and environmental regulations are less severe than in developed countries. Unlike marine coatings, container coatings are applied one time only at container production (no refinish coatings generally); after ten years of use, the container is usually scrapped. Global container coating consumption was around 210 million liters in 2007, valued at $775 million; about 95% (around 200 million liters) was consumed in China. However, some of the coatings are considered low performance; consumption of high-performance coatings was 135 million liters worth about $500 million. There is also some consumption in Europe, with the major producers being Chugoku, Emil Frei, Hempel and Jotun.

The typical coating consists of zinc-rich epoxy primer, an epoxy intercoat, and mainly acrylic emulsion as a topcoat. In the past, alkyd or chlorinated rubber was used as a topcoat, but these have been recently replaced by acrylic emulsions. Bulk cargo containers generally are used for about ten years before they are scrapped, and coatings are formulated to last for the duration of service.

Major market participants are Kansai Paint joint ventures (such as Tianjin COSCO Kansai Paint & Chemicals), Hempel joint ventures (Hempel Hai Hong [Kunshan]), Chugoku Marine Paints (Shanghai and Guangzhou) and KCC (Kunshan). In 2007, Chugoku had the largest market share (29%), followed by Kansai (26%), Hempel (26%), KCC (8%) and others.

Major container producers in China are listed below.

Table 58

Major Chinese Producers of Containers—2008

Company and Plant Location
Jiangsu CXIC Group Co., Ltd. Changzhou, Jiangsu
Nantong CIMC Smooth Sail Container Co., Ltd. Nantong, Jiangsu
Qingdao CIMC Container Manufacture Co., Ltd. Qingdao, Shangdong
Shanghai CIMC Far East Container Co., Ltd. Shanghai
Shanghai CIMC Refrigerator Co., Ltd. Shanghai
Shanghai Pacific International Container Co., Ltd. Shanghai
Shenzhen Southern CIMC Containers Manufacture Co., Ltd. Shenzhen, Guangdong
Shunde Shun An Da Pacific Co., Ltd. Foshan, Guangdong
Tianjin CIMC Northern Ocean Container Co., Ltd. Tianjin
Yangzhou Tong Yun Container Co., Ltd. Yangzhou, Jiangsu

SOURCE: SRI Consulting.

According to the *Containerisation International Yearbook*, the six largest "container handling" ports are all in Asia—Singapore, Hong Kong, Shanghai, Shenzhen (China), Pusan (the Republic of Korea) and Kaoshiung (Taiwan). Other large ports in Asia include Qingdao, Tianjin, Ningbo and Guangzhou, all in China, Tokyo and Yokohama in Japan, and Tanjung Pelepas in Malaysia. In the Middle East, the largest port is at Dubai in the UAE. The container transportation market has grown in China, along with the economic globalization. Because of lower labor costs and the large volume of trading activity, China has become the hub of the container manufacturing industry across the world. The domestically made standard containers are mainly for trading, but inland transportation is also increasing as the domestic economy increases. Containers can be classified as dry-cargo containers (80-90% of total), refrigerated containers and special containers.

Marine coatings

In recent years, China has been building shipbuilding facilities, and many coatings companies have built plants in China to serve the market. China accounted for about 10% of oceangoing shipbuilding in 2004, and this figure increased to 20% in 2007. Many observers feel that the Chinese ship industry will continue to compete strongly with other Asian companies, such as those in the Republic of Korea (new oceangoing shipbuilding), Japan (bulk cargo container ships) and Singapore (in-ship repairs). About 10% of ships in the world are now repaired in China because of its low labor rates and fewer environmental regulations. Increasing numbers of shipowners have more confidence in the Chinese repair yards, motivating them to award larger and more complicated projects, including sandblasting, tank repair and application of antifoulant coatings. Chinese shipbuilding annual capacity is expected to reach 23 million gross tons in 2010.

The following table lists major shipbuilders in China:

Table 59

Major Chinese Shipbuilders—2008

China Changjiang National Shipping (Group) Corporation (CSC)
China Shipbuilding Industry Corporation (CSIC)
Bohai Shipbuilding Heavy Industry Co., Ltd.
Chongqing Shipyard
Dalian New Shipbuilding Heavy Industry Co., Ltd.
Qingdao Beihai Shipbuilding Heavy Industry Co,. Ltd.
Shanhaiguan Shipbuilding Industry Co., Ltd.
Wuchang Shipyard
China State Shipbuilding Corporation (CSSC)
Donghai Shipyard
Guangxi Guijiang Shipyard
Guangzhou Huangpu Shipyard
Guangzhou Shipyard International Co., Ltd. (GSI)
Guangzhou Wenchong Shipyard
Hodong Zhonghua Shipbuilding (Group) Co., Ltd.
Hudong-Zhonghua Shipbuilding (Group) Co., Ltd.
Jiangnan Shipyard (Group) Co., Ltd.
Jiangzhou Shipyard
Shanghai-Chengxi Shipbuilding Co., Ltd.
Shanghai Waigaoqiao Shipbuilding Co., Ltd. (SWS)
Wuhu Xinlian Shipbuilding Co., Ltd.
Nantong COSCO KHI Shipping Engineering Ltd., Co. (NACKS)
New Century Shipbuilding Co., Ltd. (NCS)
Yangzijiang Shipbuilding Co., Ltd.

SOURCE: SRI Consulting.

China's shipbuilding industry can be categorized into three groups:

- China Shipbuilding Industry Corporation (CSIC), which includes Dalian New Shipbuilding Heavy Industry and Qingdao Beihai Shipbuilding Heavy Industry

- China State Shipbuilding Corporation (CSSC), including Shanghai Waigaoqiao Shipbuilding, Hudong-Zhonghua Shipbuilding and Guangzhou Wenchong Shipyard

- Local manufacturers, which include China Ocean Shipping (Group) Company (COSCO), Shanhaiguan Shipyard, Ministry of Navy Equipment of China and China Ocean Petrochemical Industry Corporation.

All of these companies consume marine coatings of international standards. There are many smaller-scale shipbuilding companies that consume lower-priced, low-quality coatings. China marine coatings also include coatings used on large offshore steel structures.

At present, competition in the marine coatings market is high. The present quality of marine anticorrosion coatings produced by local manufacturers is not high enough to compete with foreign producers. It is believed that about 180 million liters of coatings were applied to marine vessels in China in 2007, but only about 80 million liters were high-performance coatings. The leading multinational suppliers of high-performance coatings are Akzo Nobel (25-30%), Chugoku (15-20%), Hempel (15-20%) and Jotun/NKM (15-20%), followed by Nippon Paint and KCC. These suppliers have established sole or joint ventures in China, and represent most of the marine coating market in China.

Marine anticorrosion coating consumption will increase at a very high growth rate in the next five years in China. The annual growth rate has been estimated at more than 20%. Chinese consumption of high-performance marine coatings was estimated at 125 thousand metric tons (104 million liters) in 2007. The annual growth rate will be 10% from 2007 to 2012 due to greater demand and to consumers' switching from low performance to higher performance coatings.

Republic of Korea

The Republic of Korea is the largest market for marine coatings in the world. The development laboratory facility of International Paint Research was opened on Koje Island, where it is close to the largest shipyards in the world, including operations by Hyundai, Daewoo and Samsung. Major multinational marine coating producers have established joint ventures to produce paints in the Republic of Korea. The Republic of Korea is also the largest producer of FSPO units, which are produced in its shipyards and often shipped to Southeast Asian locations.

In the Republic of Korea, production of marine coatings has been reported as shown in the following table. The market value of marine coatings was $605 million, and that of structural steel coatings was $135 million in 2007.

Table 60

Republic of Korea Production of Anticorrosion Coatings (millions of liters)

	Marine Coatings[a]	Structural Steel Coatings
1995	65.9	40.9
1996	70.0	45.9
1997	64.6	41.7
1998	51.9	38.0
1999	60.6	38.6
2000	71.1	38.8
2001	96.2	36.0
2002	63.6	37.5
2003	93.4	39.6
2004	108	37
2005	101	34
2006	112	34
2007	123	34

a. These figures include exports, which were about 20-30 million liters in 2007.

SOURCES: Korean Paint and Ink Association (data for 1995-2006); SRI Consulting (2007 estimates).

Major Korean shipbuilders are listed below.

Table 61

Major Republic of Korea New Shipbuilders—2008

Company Name and Location
Daewoo Shipbuilding & Marine Koje-Do
Hyundai Mipo Dockyard Ulsan
Hyundai Heavy Industries Ulsan
Hyundai Samho Heavy Industries Sambo
Samsung Heavy Industries Koje-Do
STX Shipbuilding Chinhae

SOURCE: SRI Consulting.

In the Republic of Korea, the repair marine paint market is very small, as Hyundai Mipo Dockyard has moved its repair dockyard to Vietnam, and there is no more large repair dockyard in the Republic of Korea since shipbuilding has become so important. Consumption of marine paints for shipbuilding accounted for 95% of the total in 2007.

Singapore

In Singapore, the marine coatings market is the third largest in Asia, and is all for repair coatings. Singapore is strategically located in the ship route between East Asia and the Middle East. The location is suitable for repair of petroleum tankers; for example, after carrying petroleum to Japan, the flammable gas is evaporated on the way back to the Middle East, and then the empty tanker is cleaned and sealed at the port of Singapore. A number of ships are converted to FPSO (floating production, storage and offloading system) and FSO (floating storage and offloading system) in Singapore, and a large volume of paints is consumed. Keppel Shipyard has several large repair dockyards in Singapore.

Singapore has reported its production of marine/protective coatings as shown in the following table. In 1996-2001, the statistics include the production of 0.8 million liters of undercoats and 7.3 million liters of primers, most of which are consumed for industrial maintenance coatings.

Table 62

Singaporean Production of Marine/ Protective Coatings (millions of liters)

1996	46.3
1997	44.4
1998	43.5
1999	41.8
2000	41.5
2001	39.5
2004	35
2007	50

SOURCES: Singapore Paint Manufacturers Association (data for 1996-2001); SRI Consulting (data for 2004 and 2007).

In recent years, Singapore has been importing 20 thousand metric tons of marine coatings per year, mainly from Malaysia; thus, consumption of marine coatings was about 60 million liters and consumption of protective coatings was about 10 million liters in 2007.

Rest of Asia

There is also some consumption of marine coatings in the Philippines, Taiwan and, recently, Vietnam, mainly because the Singapore dockyards are operating at full capacity; thus some ships enter dockyards in other Southeast Asian locations.

The current anticorrosion coating markets of other countries in Asia Pacific are estimated as follows:

- In Australia, coating production for mining, road marking and marine coating is 12 million liters. Marine paints are mainly used for yachts.
- Total high-performance anticorrosion coatings in India are estimated at about 55 million liters per year, while marine coatings are estimated at about 15 million liters. The market for anticorrosion coatings has been growing because of investment in the oil and gas sector and in infrastructure including power plants, roads and ports. In general, there is increased use of high-value finishes as replacements for low-value, limited-performance coatings.
- In Indonesia, many general coatings are used for boats. International standard-grade marine paint consumption is about 7 million liters.
- In Malaysia, the structural steel coatings market is estimated at about 14 million liters per year, marine coatings at about 8 million liters, and container coatings at less than 5 million liters. In addition, 20 million liters of marine coatings are exported, mainly to Singapore.
- In Pakistan, the steel structure coating market is estimated at about 10 million liters, while marine coatings are less than 5 million liters.
- In the Philippines, marine coatings are about 18 million liters, while steel structure coatings are less than 5 million liters. Marine paint is mainly for repair, but some is also used for new ships. Tsuneishi Shipbuilding has a new shipbuilding facility in Cebu.
- In Taiwan, production of heavy-duty maintenance coatings is about 18 million liters annually, and that of marine coatings is about 18 million liters. Marine paint is mainly for repair, but some is also used for shipbuilding.
- In Thailand, the structural steel coatings market is estimated at about 24 million liters, while that of marine coatings is about 6 million liters.
- In Vietnam, marine repair paint is a major application, about 12 million liters. Hyundai Mipo has a repair dockyard. Protective coatings are about 7 million liters.

PRICES

The average global price for a high-performance anticorrosion coating tends to vary among regions. In 2007, the average price of a marine coating in North America was $5-6 per liter, about 4-5 euros per liter in Western Europe, and about $4 per liter in Asia. Protective coatings tend to be priced somewhat less.

The average sales value of marine coatings reported by the U.S. government is presented in the following table:

Table 63

U.S. Unit Shipment Values for High-Performance Anticorrosion Coatings (dollars per gallon)

	Industrial New Construction and Maintenance Paints—Interior	Industrial New Construction and Maintenance Paints—Exterior	Marine Paints, Ship and Offshore Facilities for New Construction and Refinish and Maintenance	Marine Paints for Yachts and Pleasure Craft
1997	14.96	12.67	19.00	14.74
1998	10.38	14.87	na	na
1999	10.55	22.62	24.52	14.56
2000	11.33	19.15	21.54	na
2001	14.39	19.08	21.77	na
2002	9.82	16.43	18.65	na
2003	15.07	20.45	20.99	24.32
2004	15.39	20.83	20.06	22.38
2005	9.53	21.80	20.31	25.02
2006	10.79	23.01	na	na

SOURCE: *Current Industrial Reports*, series MQ325F, U.S. Department of Commerce, Bureau of the Census.

The exact price depends on the film former, solids content, quantity ordered, gloss, pigmentation and other factors. Estimated average market prices for anticorrosion coatings sold in the United States in 1996 are shown in Table 64.

Table 64

Average U.S. Market Prices for Anticorrosion Coatings—1996[a]

Binder	Dollars per Gallon	Dollars per Liter
Acrylic (waterborne)	16-18	4.23-4.76
Alkyd	16-18	4.23-4.76
Chlorinated Rubber	25	6.60
Coal Tar Epoxy	15-20	3.96-5.28
Epoxy (two-component)	17-21	4.49-5.55
Epoxy (waterborne)	45	11.90
Epoxy Ester	22-24	5.81-6.34
Epoxy Mastic	27-30	7.13-7.93
Urethane (aliphatic isocyanate–based)	33-36	8.72-9.51
Urethane (aromatic isocyanate–based)	33-35	8.72-9.25
Vinyls	27-29	7.13-7.66
Zinc-Rich, Inorganic	33-38	8.72-10.04
Zinc-Rich, Organic	38-43	10.04-11.36

a. Figures are considered to be representative market prices for coatings used in relatively large commercial jobs.

SOURCE: SRI Consulting.

In general, prices rose about 5% in both 1995 and 1996. However, from 1995 to 1999, prices stayed nearly constant. The Steel Structures Painting Council (SSPC) estimated that the average price of industrial maintenance coatings in the United States was $23 per gallon in 1998 and $24 per gallon in 1999, and that prices rose an average of 3% in 1998 and 4% in 1999.

Table 65

Average U.S. Market Prices for Anticorrosion Coatings—1999[a]

Binder	Dollars per Gallon	Dollars per Liter
Acrylic (waterborne)	16-18	4.23-4.76
Alkyd	16-18	4.23-4.76
Alkyd-Silicone	18	4.76
Chlorinated Rubber	25	6.60
Coal Tar Epoxy	15-20	3.96-5.28
Epoxy (two-component)	17-21	4.49-5.55
Epoxy (waterborne)	45	11.90
Epoxy Ester	22-24	5.81-6.34
Epoxy Mastic	27-30	7.13-7.93
Urethane (aliphatic isocyanate–based)	40	10.58
Urethane (aromatic isocyanate–based)	28-30	7.41-7.94
Urethane (moisture-cure aliphatic isocyanate–based)	45-50	11.90-13.23
Urethane (moisture-cure aromatic isocyanate–based)	28-35	7.41-9.26
Vinyls	27-29	7.13-7.66
Zinc-Rich, Inorganic	33-38	8.72-10.04
Zinc-Rich, Organic	38-43	10.04-11.36

a. Figures are considered to be representative market prices for coatings used in relatively large commercial jobs.

SOURCE: SRI Consulting.

Prices remained about the same in 2000, but dropped about 10% on average in 2001 because of the decreasing cost of raw materials and lower industry demand for coatings. Prices finally started to rise in 2004 and early 2005. Epoxy prices were considerably higher due to greater global demand and restricted supply. Acrylics rose in price some in 2006 due to shortages in acrylic monomers. By 2007, prices had stabilized.

Table 66

Average U.S. Market Prices for Anticorrosion Coatings—2004[a]

Binder	Dollars per Gallon	Dollars per Liter
Acrylic (waterborne)	16-18	4.23-4.76
Alkyd	15-17	3.96-4.49
Alkyd-Silicone	18	4.76
Chlorinated Rubber	25	6.60
Coal Tar Epoxy	15-20	3.96-5.28
Epoxy (two-component)	17-21	4.49-5.55
Epoxy (waterborne)	45	11.90
Epoxy Ester	22-24	5.81-6.34
Epoxy Mastic	27-30	7.13-7.93
Urethane (aliphatic isocyanate–based)	38	10.04
Urethane (aromatic isocyanate–based)	25-28	6.61-7.41
Urethane (moisture-cure aliphatic isocyanate–based)	45-50	11.90-13.23
Urethane (moisture-cure aromatic isocyanate–based)	26-33	6.87-8.72
Vinyls	26-28	6.87-7.41
Zinc-Rich, Inorganic	33-38	8.72-10.04
Zinc-Rich, Organic	38-43	10.04-11.36

a. Figures are considered to be representative market prices for coatings used in relatively large commercial jobs.

SOURCE: SRI Consulting.

Table 67

Average U.S. Market Prices for Anticorrosion Coatings—2007[a]

Binder	Dollars per Gallon	Dollars per Liter
Acrylic (waterborne)	17	4.49
Acrylic Elastomeric	60	15.85
Alkyd	17	4.49
Alkyd-Silicone	18	4.76
Epoxy (two-component)	20	5.28
Epoxy (waterborne)	45	11.89
Epoxy Ester	25	6.61
Epoxy Mastic	30	7.93
Urethane (aliphatic isocyanate–based)	35	9.25
Urethane (aromatic isocyanate–based)	25	6.61
Zinc-Rich, Inorganic	45	11.89

a. Figures are considered to be representative market prices for coatings used in relatively large commercial jobs.

SOURCE: SRI Consulting.

Prices for epoxy powder coatings used for pipe and reinforcing bars were approximately $2-3 per pound ($4.40-6.60 per kilogram) in 2001. Prices have decreased some in recent years, but started rising in 2004 when epoxy resin prices rose by about 20%.

Prices for specialized coatings can be very high. Siloxane-epoxy (PSX) coatings are priced at around $100 per gallon. A typical floor coating costs about $100 per gallon. Advanced Polymer System's Siloxirane® heavy-duty coating runs about $250 per gallon. This coating is used for tank coatings where they are exposed to heavy-duty chemicals like sulfuric acid. New generation antifouling ship paints generally sell for about $100-200 per gallon, while other ship paints are generally $70-100 per gallon. Fluoropolymer coatings based on Lumiflon resins sell in the range of $200-450 per gallon.

After remaining flat during most of 1995-2004, European prices for anticorrosion coatings started to rise in 2005 in response to higher raw material prices. Germany reports the average sales values of anticorrosion coatings as follows:

Table 68

Average German Sales Values of Anticorrosion Coatings (euros per kilogram)

	Anticorrosion Coatings	Marine Coatings
1998	3.20	na
1999	2.92	na
2000	2.88	na
2001	2.94	na
2002	2.98	3.75
2003	2.98	3.53
2004	3.07	3.65
2005	3.21	3.77
2006	3.38	3.80
2007	3.51	3.86

SOURCE: Verband der Deutschen Lackindustrie e.v. (Vdl).

The Spanish report recent sales value data as follows:

Table 69

Spanish Sales Values for Anticorrosion Coatings (euros per liter)

	Protective Coatings	Marine
2004	3.12	3.54
2005	3.16	3.62
2006	3.32	3.72

SOURCE: Paint Research Association.

In Japan, the Ministry of Economy, Trade and Industry publishes sales values by producer for several types of anticorrosion coatings, as shown in Table 70.

Table 70

Japanese Unit Sales Values for High-Performance Anticorrosion Coatings

	Yen per Kilogram					
	Marine Shipbottom Paints	Two-Component Polyurethanes[a]	Epoxy Enamels[b]	Vinyls[c] (solvent-based)	Coal Tar Epoxies	Chlorinated Rubber
1986	801	697	592	477	366	415
1990	747	753	588	473	334	400
1995	676	714	542	476	283	369
1996	648	701	526	467	275	356
1997	642	690	515	465	267	340
1998	611	695	498	465	262	328
1999	598	681	481	462	257	316
2000	628	688	479	470	249	313
2001	655	683	461	461	240	301
2002	656	660-680	467	460-470	230-240	280-300
2003	625	660-680	427	460-470	230-240	280-300
2004	613	660-680	404	460-470	230-240	280-300
2005	636	660-680	401	460-470	230-240	280-300
2006	675	660-680	400	460-470	230-240	280-300
2007	704	660-680	411	460-470	230-240	280-300

	Dollars per Liter[d]					
	Marine Shipbottom Paints	Two-Component Polyurethanes[a]	Epoxy Enamels[b]	Vinyls[c] (solvent-based)	Coal Tar Epoxies	Chlorinated Rubber
1986	5.70	4.96	4.22	3.40	2.61	2.96
1990	6.18	6.23	4.87	3.91	2.76	3.31
1995	8.62	9.10	6.91	6.07	3.60	4.71
1996	7.15	7.73	5.80	5.15	3.03	3.93
1997	6.37	6.84	5.11	4.61	2.65	3.37
1998	5.60	6.37	4.56	4.28	2.40	3.01
1999	6.34	7.22	5.10	4.90	2.72	3.35
2000	6.99	7.66	5.33	5.23	2.77	3.48
2001	6.47	6.75	4.55	4.55	2.37	2.97
2002	6.30	6.34-6.53	4.48	4.42-4.51	2.21-2.30	2.69-2.88
2003	6.46	5.69-5.86	4.42	3.97-4.05	1.98-2.07	2.41-2.59
2004	6.81	6.11-6.30	4.49	4.26-4.35	2.13-2.22	2.59-2.78
2005	6.94	6.00-6.18	4.37	4.18-4.27	2.09-2.18	2.55-2.73
2006	6.98	5.69-5.86	4.14	3.97-4.05	1.98-2.07	2.41-2.59
2007	7.28	5.69-5.86	4.25	3.97-4.05	1.98-2.07	2.41-2.59

a. Includes all two-component polyurethane coatings, not just those used for anticorrosion purposes.

b. Includes all epoxy enamels, not just those used for anticorrosion purposes.

c. Includes all solvent-based vinyl coatings, not just those used for anticorrosion purposes.

d. Calculated by assuming that the average density of the coating is 1.2 kilograms per liter (10 pounds per gallon), and using the following currency conversions (yen per dollar):

1986	168.52
1990	144.83
1995	94.10
1996	108.78
1997	120.99
1998	130.31
1999	113.23
2000	107.8
2001	121.5
2002	125
2003	116
2004	108
2005	110
2006	116
2007	116

SOURCE: *Chemical Industry Statistics*, Ministry of Economy, Trade and Industry.

Japanese list prices by primary dealer (mainly subsidiaries of the producers) are shown in the following tables.

Table 71

Japanese List Prices for Anticorrosion Coatings—2002

Binder	Yen per Liter	Dollars per Liter[a]
Alkyd (primer)	450-770	3.60-6.16
Alkyd (topcoat)	490-1,240	3.92-9.92
Alkyd-Silicone (topcoat)	1,080-1,140	8.64-9.14
Chlorinated Rubber (primer)	570-920	4.56-7.36
Coal Tar Epoxy	650-730	5.20-5.84
Coal Tar Epoxy (nonsolvent)	1,420	11.36
Epoxy (two-component)	980-1,260	7.84-10.08
Epoxy MIO[b]	1,160	9.28
Epoxy (modified)	980-1,050	7.84-8.40
Fluorinated	1,110-6,470	8.88-51.76
Phenol	450-540	3.60-4.32
Phenol MIO[b]	620	5
Urethane (primer)	1,440-2,330	11.52-18.64
Urethane (topcoat)	1,010-1,720	8.08-13.76
Zinc-Rich, Inorganic	810-890	6.48-7.12
Zinc-Rich, Organic	840-950	6.72-7.60

a. The exchange rate was ¥125 per dollar in 2002.

b. With micaceous iron oxide pigment.

SOURCE: Kensetsu Bukka.

Table 72

Japanese List Prices for Anticorrosion Coatings—2005

Binder	Yen per Liter	Dollars per Liter[a]
Alkyd (primer)	425-730	3.86-6.64
Alkyd (topcoat)	470-1,185	4.27-10.77
Alkyd-Silicone (topcoat)	1,050	9.55
Chlorinated Rubber (primer)	550-570	5.00-5.18
Coal Tar Epoxy	645-990	5.86-9.00
Coal Tar Epoxy (nonsolvent)	600-720	5.45-6.55
Epoxy (two-component)	850-1,370	7.73-12.45
Epoxy MIO	1,000	9.09
Epoxy (modified)	980	8.91
Epoxy (nonsolvent)	850	7.73
Fluorinated	1,050-6,030	9.55-54.82
Phenol	450-465	4.09-4.23
Phenol MIO	600-610	5.45-5.55
Urethane (primer)	950-970	8.64-8.82
Urethane (topcoat)	1,040-2,120	9.45-19.27
Zinc-Rich, Inorganic	1,310-2,120	11.91-19.27
Zinc-Rich, Organic	950	8.64

a. The exchange rate was ¥110 per dollar in 2005.

SOURCE: SRI Consulting.

Table 73

Japanese List Prices for Anticorrosion Coatings—2007

Binder	Yen per Liter	Dollars per Liter[a]
Alkyd (primer)	175-200	1.50-1.72
Alkyd (topcoat)	400-450	3.45-3.90
Alkyd-Silicone (topcoat)	1,000-1,100	8.62
Chlorinated Rubber (primer)	500-700	4.31-6.03
Coal Tar Epoxy	600-720	5.17-6.21
Coal Tar Epoxy (nonsolvent)	1,300-1,400	11.20-12.10
Epoxy (two-component)	850-1,000	7.33-8.62
Epoxy MIO[b]	600-980	5.17
Epoxy (modified)	850-900	7.33
Fluorinated	1,900-2,000	16.40
Phenol	3,000-6,000	25.86-51.72
Phenol MIO[b]	400-500	3.45-4.31
Urethane (primer)	550-650	4.74-5.60
Urethane (topcoat)	900-1,000	7.76-8.62
Zinc-Rich, Inorganic	1,200-1,300	10.34-11.21
Zinc-Rich, Organic	850-950	7.33-8.20

a. The exchange rate was ¥116 per dollar in 2007.

b. With micaceous iron oxide.

SOURCE: Kensetsu Bukka.

Chinese list prices are shown in the following table:

Table 74

Chinese List Prices for Anticorrosion Coatings—2007

Binder	RMB per Kilogram	Dollars per Kilogram[a]
Acrylic	22-28	2.90-3.70
Acrylic-Urethane (topcoat)	34-40	4.46-5.26
Chlorinated Rubber (primer)	19-25	2.50-3.28
Coal Tar Epoxy	20-35	2.62-4.60
Epoxy (two-component)	28-35	3.70-4.60
Epoxy (modified)	38	5.00
Epoxy (nonsolvent)	35	4.60
Fluorinated	120-140	15.80-18.40
Phenol	15-20	2.00-2.63
Urethane (primer)	18-20	2.36-2.63
Urethane (topcoat)	19.5-22	2.56-2.90
Zinc-Rich, Inorganic	35-38	4.60-5.00
Zinc-Rich, Organic	24-30	3.15-3.94

a. The exchange rate was RMB7.6079 per dollar in 2007.

SOURCE: SRI Consulting.