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Copper-nickel piping reduces costs, biofouling/corrosion

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10-second summary

Seawater piping systems for offshore drilling rigs and platforms are typically plagued by biofouling and/or corrosion, with piping failures occurring in only a few years. Discussed here are alternate pipe materials with the emphasis on the testing of a copper-nickel alloy in the Gulf of Mexico. Results show that although initially more expensive, use of this alloy can extend system life to 20 years or more while improving productivity and reducing overall costs when compared to a comparable steel system.

CRITICAL TO DRILLING contractors and operating companies alike are increased productivity and decreased maintenance costs for offshore drilling rigs and production platforms. One method that may help lower overall operating costs involves the use of a 90/10 copper-nickel alloy (C706) for seawater piping. Use of this alternative piping material was shown recently to be both cost-effective and operationally superior in a joint test conducted by Dolphin-Titan International Inc. and Marathon Oil Co. in cooperation with the Copper Development Association, Inc.

The test was conducted on a Marathon platform in the Gulf of Mexico, West Delta Block 86. Results indicate Alloy C706 will significantly reduce or eliminate most problems now associated with other materials used in seawater piping systems. The alloy is not only resistant to corrosion, pitting and marine growth, but can be shown to be cost-effective over the life of a platform or drilling rig.

The use of seawater piping systems made from this alloy brings certain advantages enjoyed for years by North Sea operators and drilling contractors. Some of these advantages include:

- ▶ Increased production revenue due to decreased platform downtime
- ▶ Reduced downtime due to unscheduled maintenance
- ▶ Extended life of piping systems
- ▶ Payback of initial system costs in as little as 2 years
- ▶ Lower system maintenance costs and no inhibition treatment costs
- ▶ Reduced piping system weight
- ▶ Increased system operating efficiency due to the mitigation of corrosion, pitting and marine biofouling
- ▶ Possible downsizing of piping diameter as compared to steel.

SEAWATER PIPING SYSTEMS

Seawater piping is one of the most important systems in use on offshore drilling rigs or oil and gas production platforms. For offshore activities, the seawater system provides water for a variety of operations including: engine cooling, firefighting, washdown, sanitary system operation, drilling, cooling water for the drawworks brake cooling unit and bilge/ballast.

The majority of offshore drilling rigs must have a continuous 24-hour per day, seven day per week supply of seawater to service various needs. Often, if the seawater system is shut down, drilling operations may have to be slowed or suspended until the supply is restored. Seawater normally is obtained directly from the ocean and distributed through various-diameter steel piping by a centrifugal, submersible or other type pump capable of meeting head and volume requirements.

Piping system materials. Historically, the offshore drilling industry has used ASTM A-53 Grade B carbon steel pipe as the primary material to convey seawater. Although carbon steel pipe is the low-cost, first-choice material, *it is susceptible to both external and internal corrosion as well as internal biofouling.* Alternative piping materials, such as 90/10 copper-nickel, PVC and fiber reinforced plastic (FRP), are now available for seawater service and can mitigate some or all of the problems associated with steel corrosion and biofouling.

Many platform installations however continue to use steel pipe for critical systems because in some areas, such as firefighting, the seawater distribution system supplies seawater to the fire pumps. If a synthetic material is used, it could melt during a fire and thus compromise the rig's ability to fight an onboard fire. In other less critical areas, internal pipe protection such as epoxy coatings, rubber or plastic are beginning to be used. And more recently, FRP pipes have been specified. While FRP pipes can provide excellent corrosion resistance on both the inside and outside diameter, there can be disadvantages such as susceptibility to marine biofouling and also to impact loading during both construction and operation. In short, FRP is lower in initial cost than special alloy pipe but may be questionable when considered for cost effectiveness over the life of a rig.

Galvanizing remains the standby form of protection even though the long-term reliability of galvanized steel for seawater service has been shown to be less than adequate. The coating adds little to the life of the steel, as it commonly dissolves in 12 months or less after being placed in service. Pitting in carbon steel lines has been known to occur at a rate of 40 mpy, and the first failures can occur after as short a service time as two years, with major replacement required after five years of service.

Copper-nickel piping on the other hand, although initially more expensive, may in fact be more cost-effective on a life-cycle basis because it has significantly better corrosion and biofouling resistance and if properly designed and installed, should last the full life of the platform. The chemistry and mechanical properties of Alloy C706 are shown in Table 1.

TABLE 1—Composition and properties of 90/10 copper-nickel Alloy C706

Composition, %	
Copper	85.7–88.4
Nickel	9.0–11.0
Iron	1.0–1.8
Manganese, maximum	1.0
Zinc, maximum	0.5
Carbon, maximum	0.05
Lead, phosphorous, sulfur, maximum each	0.02
Mechanical properties (typical, annealed temper)	
Ultimate tensile strength, psi	42,000
Yield strength, psi	18,000 (@ 0.5% extension)
Elongation in 2 in., %	35
Physical properties	
Melting point, °F	2,010
Density, lb per cu in. @ 68°F	0.323
Specific gravity,	8.94
Coefficient of thermal expansion, (68–572°F)	9.5×10^{-6}
Thermal conductivity, Btu/sq f/f/h/°F @ 68°F	26
Electrical resistivity, Ohms (circ mil/f) @ 68°F	115
Electrical conductivity, IACS @ 68°F	9.0%
Specific heat, Btu/lb°F @ 68°F	0.09
Modulus of elasticity, psi	18,000,000
Modulus of rigidity, psi	6,800,000

Fig. 1—Hard biofouling on an 8-in. Schedule 80 carbon steel header reduced the ID by 1 1/8-in., and the cross-sectional area by 52% in just 2 1/2 years of offshore service. Such fouling makes oversizing and frequent replacement of steel seawater piping components a practical necessity.

FIELD APPLICATION AND TESTING

In 1982 after 2 1/2 years of operation in the Gulf of Mexico on an 8-pile production platform, Dolphin-Titan returned one of their self-contained platform rigs for retrofitting. When originally placed on the platform, all steel seawater piping on the rig was new. The rig was being prepared for a long-term drilling program, and the 8-in. (Schedule 80) steel seawater header to the engine package was cut to inspect the interior of the pipe.

Problems discovered. As shown in Fig. 1, both intake and discharge headers had extensive marine growth. Biofouling had reduced the 8-in. Schedule 80 pipe with an ID of 7 5/8-in. to approximately 5 1/2-in., thereby reducing the internal cross-sectional area by 52%.

The depth of biofouling was fairly uniform throughout the straight sections of the seawater line, although it was noted that biofouling appeared to be thicker and richer in the discharge piping. This was attributed to the higher water temperature in the line, which enabled biofouling to grow at a faster rate.

Another major problem was discovered on a sister self-contained rig operating in the Gulf of Mexico for the past 3 1/2 years. Corrosion had eaten away the extra-thick pipe wall in a saddle weld where a 3-in. pipe intersected the 8-in. main header and leaks had resulted. In this case, failure was caused by accelerated corrosion due to residual weld stress and possibly poor weld penetration. This observation verified that welded areas of the piping system were the most vulnerable. It was also concluded that in this instance, Schedule 80 pipe was not necessary. Initial rig design could have been improved by selecting better fittings to improve welding and by reducing wall thickness to a Schedule 40 carbon steel pipe.

Testing. This, and other related platform experiences with steel piping systems, prompted Dolphin-Titan, in conjunction with Copper Development Association, to install a new 160-ft section of seawater line for engine cooling aboard its fixed platform drilling Rig 128 operating on a Marathon Oil Co. platform. The (8-in.-diameter) copper-nickel pipe was installed adjacent to the steel line that was routed from the deepwell pumps on the platform cellar deck to the rig's engine room. However, the new pipe was Schedule 10, with a wall thickness of 0.148 in. rather than the Schedule 80 (0.5-in. wall thickness) steel pipe. Pipe lengths were joined by welding, but to facilitate inspection and material comparison, three flanged and bolted spool sections were included in the line. One spool was made of Alloy C706, the second of steel (electrically insulated for galvanic reasons) and the third, of aluminum bronze.

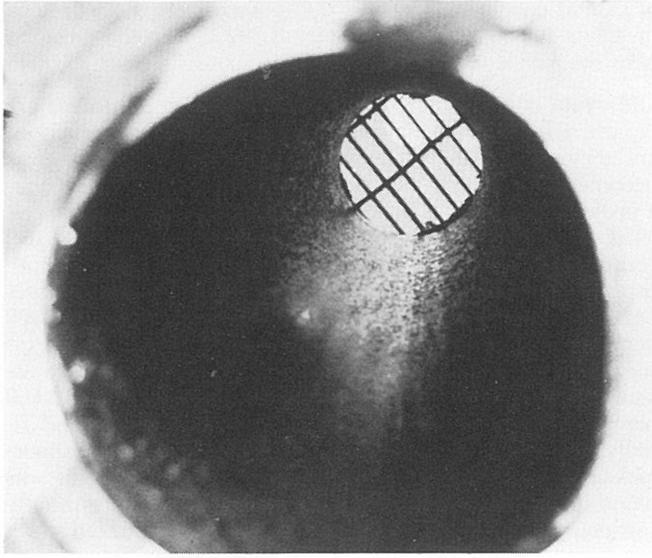

Fig. 2—Copper-nickel seawater piping spool removed for inspection after 22 months of continuous service. Neither biofouling nor measureable metal loss could be detected.

Biofouling. Other alternative piping systems could have been selected, the most likely choices including epoxy; zinc, or galvanized, coated steel; steel protected by sacrificial anode and impressed current; or fiber-reinforced polymers. While all these resist corrosion to some extent, none are immune to biofouling. This meant that piping made from any one of them would have to be oversized (to allow for eventual flow constriction) or a separate fouling inhibition system would have had to be installed.

With carbon steel, inhibition methods are somewhat limited. Most commonly they include chemical, mechanical and electrical inhibiting. Chemical methods include hyperchlorination or routine injection of acid into the line. Mechanically, pipe can be jarred or impacted (during retrofit) to loosen accumulated internal growth. Electrical inhibitors include a sacrificial annode or an impressed current system.

Copper-nickel eliminates the need for these techniques. Also, since the study was undertaken to evaluate which material was best suited for long-term operation, no exotic alternative piping materials or inhibition systems were used.

Pipesizing. After installation, velocity measurements showed a seawater flowrate through the line of only 5.2 fps, well below the supply capabilities of both a steel and copper-nickel piping system. Normally, when using a steel piping system, it is necessary to oversize the pipe to compensate for increased frictional drag due to corrosion and biofouling that will constrict the pipe bore. Such oversizing is not required with a copper-nickel piping system, which corrodes at less than 0.5 mpy. Installation of Alloy C706 piping of a smaller diameter than a comparable steel line may be possible. Flow through a 6-in., Schedule 10 copper-nickel piping system (for this application) was calculated at 8.9 fps, still below the alloy's velocity limit. With this knowledge of flow requirements, a 6-in. copper-nickel pipe system could have been specified for original installation rather than an 8-in. system.

RESULTS

After 22 months of location service, the copper alloy spool sections were removed for inspection. Internal surfaces of both the copper-nickel and aluminum bronze pipes were covered by a characteristically thin and tightly adhering oxide film. Neither were pitted nor had suffered a measurable loss of metal. And both were completely free from biofouling (Figs. 2 and 3). By contrast, the inside of the carbon steel spool piece was already both corroded and heavily biofouled (Fig. 4). Ultrasonic inspection revealed that pitting was also occurring under the corrosion products and marine growth. Although no more detailed tests could be performed at the time, it was clearly evident that the alloy spools were in far better condition than the steel.

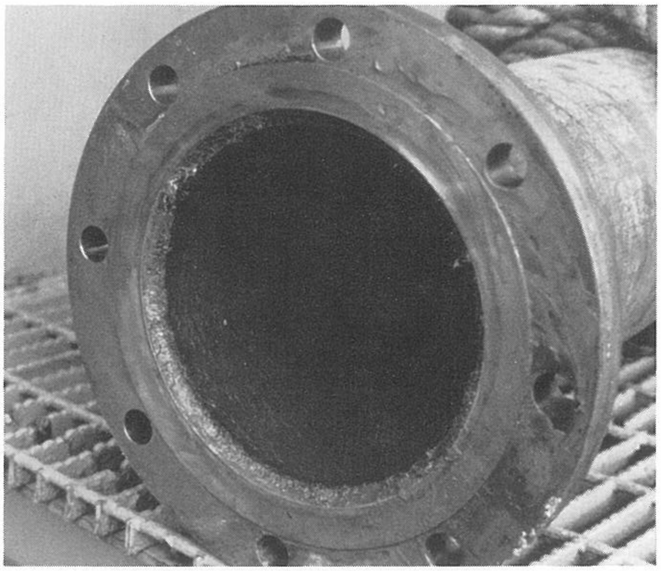

Fig. 3—Shown is an aluminum-bronze piping spool section after two year's service aboard Dolphin-Titan Rig 128. ID surfaces remain free from corrosion and biofouling.

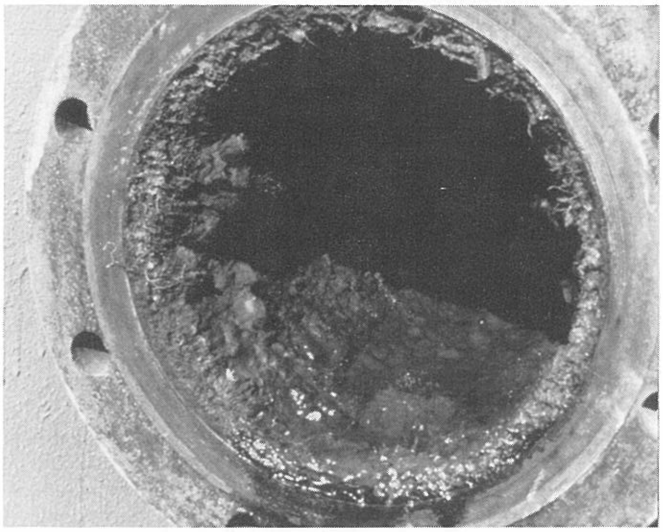

Fig. 4—Illustrated here is the 8-in. Schedule 80 carbon steel spool from same seawater line shown in Figs. 2 and 3. Extensive corrosion and biofouling have developed in less than 2 years. Pitting has also been detected by ultrasonic examination.

ECONOMIC CONSIDERATIONS

System economics are dictated by both *initial capital expenditure* and *maintenance cost* over the life of the platform or drilling rig. A system designed around copper-nickel pipe and components may have a higher cost initially, but over a 20-year rig life it offers greater performance reliability, lower operational maintenance and is the most cost-effective. One

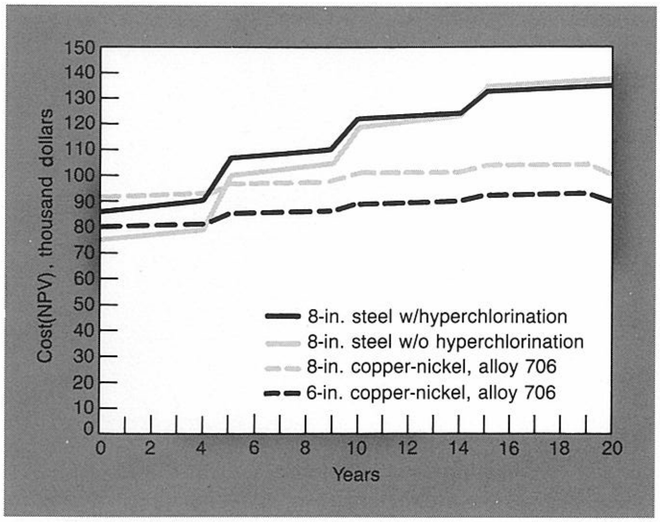

Fig. 5—Total Cost (NPV) of seawater piping systems for steel and Alloy C706 are compared. Copper-nickel systems have been determined to be more (life-cycle) cost-effective than equivalent steel piping.

important, but generally not included factor in the economic analysis, is the increased revenue associated with higher productivity, due to lower production downtime as a result of pipe maintenance. To demonstrate these points, a hypothetical rig similar to Rig 128 was designed and cost-estimated for three piping systems including:

- 90/10 copper-nickel
- Steel
- Steel with provision for chlorination.

Original design was predicated on copper-nickel pipe of the same size as the steel, i.e., an 8-in. system with a pressure rating commensurate with the commonly used 150-psi working pressure rating of steel. However, velocity data obtained from field testing on Rig 128 show that 6-in. copper-nickel could be used in place of 8-in.-diameter pipe. A decision then was made to include both a downsized copper-nickel system and 8-in. system in the cost estimates.

TABLE 2—20-Year life-cycle cost (NPV) summary

System	Capital cost, $	Maintenance cost, $	Salvage value, $	Total cost, $
8-in. diameter 90/10 copper-nickel	92,250	12,221	3,898	100,573
6-in. diameter 90/10 copper-nickel	80,425	12,221	2,920	89,726
Steel	75,610	62,751	–	138,361
Steel with chlorination	86,060	48,919	–	134,979

Material costs. Two steel systems, with and without hyperchlorination, also were considered. Capital costs of the systems are given in Table 2. At $75,610, the 8-in. Schedule 80 steel system has the lowest initial cost. Slightly higher, at $80,425, is the functionally equivalent 6-in. Alloy C706 system. Alloy C706 has a higher material cost (53% premium), but this is offset somewhat by its ease of fabrication, and thus the total differential, considering materials and installation, but excluding common components, is only 11.2 % ($36,825 for Alloy C706 versus $33,107 for carbon steel). The 8-in. steel system with hyperchlorination is next highest in capital cost ($86,060) and the unnecessarily oversized 8-in. Class 200 Alloy C706 system, at $92,250, is the most expensive, *from a first-cost basis,* of those considered.

Life-cycle costs. Since most Gulf of Mexico platforms are designed for combined functions (drilling and production) and service lives of 20 years, considerations of life-cycle costs become more important. For this reason, the total costs over a projected 20-year span were calculated for the various systems. A 5-year replacement schedule was assumed for steel components (pump interiors, valves, etc.) common to both copper-nickel and steel seawater systems. Routine maintenance for the copper-nickel system was estimated to be $300 per year or 25% of that for steel, based on accumulated in-service experience. (Maintenance figures for steel were assumed to be $1,200 per year for the basic system, and $1,560 per year for the system using hyperchlorination). And finally, credit was given for the salvage value of the copper-nickel at the end of the rig's service life. This credit was based on 25% of the material's initial cost plus 7% annually compounded price increases. All costs were discounted to net present values (NPV).

Results of this analysis are graphically illustrated in Fig. 5, which indicates that under optimum conditions, Alloy C706 provides a definite cost advantage over carbon steel. The life-cycle cost of a 6-in. Class 200 copper-nickel system is $28,635 less than that of a functionally equivalent 8-in. steel system. Even when total cost of a steel piping system is reduced by addition of hyperchlorination, it still exceeds the cost of both Alloy C706 systems by wide margins. Viewed in terms of return on investment, copper alloy provides a payback period as short as two years and, even in the least practical case, of using 8-in. 90/10 copper-nickel, the payback period is 8.8 years, still less than half the potential life of the platform or drilling rig.

CONCLUSION

It appears that the use of Alloy C706 for seawater piping systems on Gulf-based offshore platforms and drilling rigs in the Gulf (as well as other parts of the world) can be justified from both technical and economic standpoints. As U.S. platforms become larger and more complex, and are designed for longer service life, it can be expected that they, like their North Sea counterparts, will consider use of copper-nickel as a reliable and cost-effective alternate piping material.

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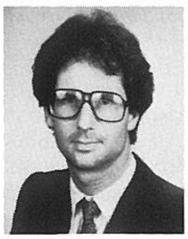

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