Defense Standardization Program

Case Study

Mechanically Attached Pipe Fittings

More Cost-Effective Pipe Fabrication Through Standardization

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Background

Following the end of the Cold War, the Navy sought to lower the cost of maintenance while maintaining fleet material readiness. Repair of shipboard piping systems offered potential cost savings. A typical ship contains miles of pipe and thousands of joints carrying everything from fuel to steam. Shipboard pipe is joined by various methods such as welding and brazing.

When pipe and fittings are installed in Navy ships, they must be tested for quality and integrity to ensure performance and to protect the health and safety of the ship and her personnel. As new pipe-joining technologies emerge, they must be thoroughly tested and approved before being used in U.S. Navy ships. Sometimes, this testing process can delay the introduction of promising technologies for years and preclude the realization of substantial savings.

In the1980s, a new pipe-fitting technology, the mechanically attached fitting (MAF), was developed, promising substantial improvements over other existing pipe-joining technologies such as welding and brazing. Several different types of MAFs were available from several different manufacturers. These included axially swaged, shape memory alloy (SMA), swage marine, bite-type, flared, and elastic strain preload (ESP) fittings. Many MAFs offered easy fabrication, high reliability, and lower installed cost. Within the Naval Sea Systems Command's (NAVSEA) Auxiliary Equipment Division, the life-cycle manager for pipe-fitting components recognized an opportunity to save money and improve performance.

The Problem

The Navy needed proof that MAFs could provide the same or better integrity than brazing or welding before authorizing their use in the fleet. Testing standards were needed to provide that proof. The Navy initially began testing, approving, and procuring various MAFs for the Navy using the test procedures provided by the individual manufacturers. Different fitting types were subjected to different tests and test requirements. The test procedures were informal, sometimes inconsistent, and not standardized.

Some MAF manufacturers were not happy when their fittings were tested under different tests than those used for their competitors; they wanted a level playing field. In addition, procurement decisions potentially were subject to protests because of the differing test methods and acceptance criteria. Also, because the Navy tested different fittings using different tests, it had no way to ensure it would get the best fitting at the best price for a given application. The Navy needed a universal test standard.

The Solution

The Navy encouraged industry innovation by developing an NGS standard, which increased competition and drove down unit costs.

The Navy had a choice; it could write a military product specification(s) for one or more of the already approved MAF types or it could write a universal performance standard for testing that would apply to all current and future MAF products. By selecting and specifying a preferred MAF technology, the Navy could end the testing controversy and be assured of an acceptable MAF solution to its pipe fitting requirements. Developing a universal test standard would be a more difficult task because it would need to address all of the differing MAF technologies and would require reaching consensus on acceptable test procedures among all the MAF manufacturers.

Developing new military specifications for MAFs, while offering an easier solution, had the potential of limiting competition, proliferating military documents, and possibly discouraging innovation. The Navy's MAF life-cycle manager chose to work with industry to develop an NGS performance standard for MAF testing, an approach advocated by the industry. This approach prevailed because increasing competition, stimulating innovation, and helping drive down unit costs outweighed the added effort to reach consensus on an NGS.

The life-cycle manager led the effort to develop a single non-government MAF test standard. He worked with industry to accelerate NGS development and to speed adoption of this important new technology.

The Approach

An NGS committee with jurisdiction over MAFs already existed within the American Society for Testing and Materials (ASTM), but it had been relatively inactive. The Navy, working with its industry partners, revitalized the committee to reach consensus on a common standard. Committee members included the key MAF manufacturers with the U.S. Coast Guard and the Navy representing the user community.

The Navy conducted aggressive market research to evaluate the range and capabilities of available products and worked diligently to evaluate, approve, and track MAF designs for Navy applications. The goal was to produce a standard acceptable to the Navy and build industry consensus on testing. The result was a flexible but stringent commercial performance standard, ASTM Standard F1387, *Standard Specification for Performance of Mechanically Attached Fittings,* which addressed all potential MAF designs. These efforts enabled the Navy to adopt and use many MAF designs early and successfully with substantial savings. By 1993, the Navy had used many approved MAFs with excellent results and saved millions of dollars in the first few years.

Mechanically Attached Fittings

MAFs evolved from aerospace technology as an economic alternative to welding and brazing for joining pipe used in fluid transfer. MAFs function as welded joints, but they can be installed in a fraction of the time required for a welded pipe connection. The connection is leak tight, even when subjected to extreme pressure, bending, heat, and external flame. Welded repairs to piping systems are costly and involve many man-hours. The use of MAFs for pipe repair and replacement is faster, less costly, and eliminates the requirement for numerous related tasks.

The most popular MAF, the ESP fitting, accounts for 90 percent of Navy MAF procurements. The fittings are available in various forms including unions, couplings, elbows, flange adapters, tees, and other shapes illustrated in Figure 1 (on the right).

Figure 1 ***Typical ESP Fittings***

A hydraulic tool is used to install ESP MAFs, illustrated in Figures 2a and 2b. MAF performance is comparable to a welded joint, and MAF joints are more uniform and consistent than welded joints. ESP fitting installation is simple and fast. It requires only basic training in pipefitting. The installer attends formal training presented by a qualified instructor. The training consists of classroom work, a written exam, and a practical test. No additional training is required.

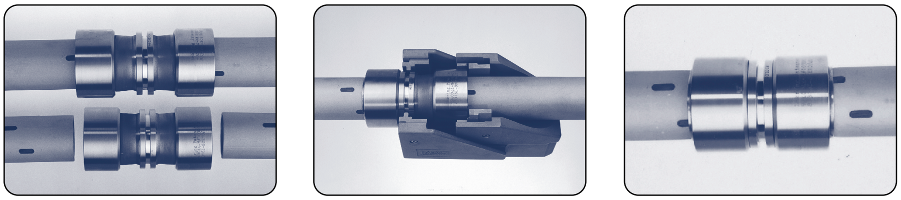

Figure 2a *ESP Fitting Assembly*

Figure 2b *ESP Fitting Assembly*

Advantages and Disadvantages of MAF Technology

The advantages of using MAFs for piping system repair and replacement include safety, quality, increased productivity, and cost savings.

Improved Safety

MAF technology offers the following safety improvements:

- Risk of fire or explosion is eliminated because the coupling requires no hot work for installation.
- Fumes and smoke are not produced, eliminating the need for special ventilation and creating a safer environment, particularly in confined spaces.
- Hazardous materials are neither used in the process nor created by the process; therefore, there is no requirement for disposal of hazardous materials after the process is complete.
- Welding and grinding are not required, significantly reducing the potential of eye injuries.

Improved Quality

MAF technology offers the following quality improvements:

- Joint reliability is machined-in and does not rely on the skill or touch of the welder.
- The quality of the joint is unaffected by pipe position or by the presence of liquids.
- A metal-to-metal seal produces a gas-tight connection that is safe for service in fire hazardous areas and systems. The fitting will not melt or degrade during a fire.
- Installation is a cold-work process, which eliminates the heat-affected zone associated with welding and brazing and the deteriorated metallurgical properties of pipe that has been welded or brazed.
- Rework is significantly reduced or eliminated. Based on data collected from the customer base, failure (fitting leaks) is less than 0.1 percent. In a shipyard environment, the hydrostatic test failure rate for silver-brazed joints averages 6–10 percent.

MAF technology has freed man-hours while at the same time provided a real-world skill for sailors as well as decreased overall maintenance time.

Increased Productivity

MAF increases productivity:

- Installation times are a fraction of that required for welded or brazed connections.
- Work delays caused by removing volatile gas from tanks and spaces prior to welding are eliminated.
- Hydrostatic testing is not required for newly installed fittings. Operational test at system pressure meets the testing requirements.
- No hot work is required, which eliminates fire watches and disruptions caused by events that stop hot work (e.g., ammo loading,

fuel loading, painting, hot oil flushes, fuel spills).

- Fittings can be installed in a system that is not or cannot be completely isolated or thoroughly drained and dried.
- Joint inspection is visual only. Non-destructive testing of the joint is not required.
- The skill level and training required to install ESP fittings is significantly less than that required to weld or braze.
- Time off the job for training and qualification requirements is minimal, and training costs are reduced.
- Damage from welding splatter to surrounding wiring, tile, terrazzo, equipment, and painted surfaces is eliminated.
- Reduced installation time allows for greater schedule flexibility.
- Space cleanliness is not affected because there is no installation by-product such as grinding debris and spent welding rods.

A complete standard was developed by the Navy with guidance and standards established by industry.

Following are some disadvantages to using MAFs:

- The initial cost of special hydraulic tooling used to install the MAFs is a significant investment.
- Pipe sizes currently are restricted to 2½ inches and less.
- ESP fittings weigh more than brazed or welded fittings.
- Space limitations exist because of the size and configuration of the hydraulic tooling.
- If the fitting leaks, it cannot be repaired, and it must be cut out and replaced, which requires installation of additional fittings to make the repair.
- The physical size of the fitting sometimes requires piping configuration to be modified to affect repairs.

MAFs are a proven economic alternative to welding small-bore pipe without losing reliability. The use of the fitting lowers installed costs and increases productivity. A fitter/helper team routinely can install 50–60 fittings in a single shift, more than double the rate at which welded piping systems typically are shop fabricated. By eliminating welding, many overhead costs relating to safety, personnel, equipment and supplies, inspections, rework, and monitoring are eliminated or substantially reduced. Using MAFs reduces the time required to repair piping systems on ships. MAFs can be used by all engineering-rated labor classes. Sailors learn and maintain a marketable skill. Valuable maintenance dollars are freed up for use on critical repairs.

Costs

One-Time Investment Cost

The ASTM Standard F1387 development took 3 years and resulted in a single ASTM standard plus a supplement for certain unique Navy requirements. The Navy representative devoted about half his time during this period to conducting market research, evaluating tests, coordinating with interested parties, and expediting the consensus process. Other government employees were involved to a lesser degree, including the U.S. Coast Guard committee member and various Navy engineers who coordinated on technical issues such as pipe structural strength and fire-related requirements. Table 1 shows the one-time investments costs.

The participating MAF manufacturers each brought their own test procedures and requirements to the committee for consideration. The Navy had a consultant perform a study of commercial pipe-joint testing practices, procedures, and requirements used in the United States and overseas. This study established a baseline and helped the committee develop a complete and robust standard. The Navy also funded a study by the Massachusetts Institute of Technology (MIT) to determine the minimum number of MAF design types, quantities, and sizes that must be tested to approve or qualify a manufacturer's family of MAFs for Navy use.

Resource	Investment	Cost
Navy representative	Half time for 3 years	$225,000
USCG and other Navy	Participated in meetings and provided support	75,000
Independent consultant	Study	100,000
MIT	Study	50,000
Total		$450,000

Table 1 ***One-Time Investment***

Recurring Costs

Developing an NGS performance standard rather than a military product specification increased competition in MAFs, which resulted in more stock numbers in the Navy system. A military specification might have resulted in about 100 different stock numbers. The ASTM performance-based standard motivated manufacturers to produce additional new products to meet the requirements, resulting in about four times more stock numbers in the system. Maintaining a stock number takes an estimated $100 per year. Developing a military specification would have cost $10,000 per year to maintain 100 stock numbers, while the NGS approach costs about $40,000 per year to maintain 400 stock numbers; a $30,000 difference in annual recurring cost, or $300,000 during a 10-year period.

It also costs the Navy 2–3 person-weeks per year to maintain a document, whether it is military or NGS. A military specification must be kept current and periodically validated. An adopted NGS also must be maintained, and the Navy's cost is incurred through its participation in the NGS consensus process. For MAFs, the costs of maintenance for a military specification or NGS are considered equal. Table 2 shows a comparison of recurring costs between an NGS and a military specification.

Category	Baseline Period	Cost
Stock number maintenance	10-year recurring cost	$300,000
Standard maintenance	No difference between approaches	0

Table 2 ***Recurring Costs***

Cost Savings/Avoidance

One-Time Cost Savings

During the development of ASTM Standard F1387, the manufacturers funded and conducted about $1 million worth of MAF testing to prove concepts and validate tests. The Navy would have needed to fund similar tests if it had chosen to develop a military specification. The NGS route resulted in considerable savings for the Navy.

The Navy achieved more stock numbers at lower cost in man-hours and dollars by adopting an NGS standard.

Each MAF requires 6–12 months to complete qualification testing. By expediting the development of the ASTM standard and engaging industry in validation, the Navy brought the new technology to the fleet faster, better, cheaper, and with greater choice of products. Savings were available to the Navy an estimated 3 years earlier through development of an NGS rather than a military standard. The Navy was able to leverage the industry resources rather than conducting the research, testing, and validating using its own resources. Table 3 shows the Navy's one-time cost savings of an NGS.

Category	Rationale	Cost Savings
Concept validation tests	Conducted at industry expense rather than Navy expense	$1,000,000

Table 3 ***One-Time Savings***

Recurring Cost Savings

Several different cost studies show that the use of MAFs saves up to 50 percent of the installed cost compared with the use of welded or brazed fittings. Table 4 shows that the actual savings per installed unit vary significantly, depending on the type of system, the fitting, labor rates, and other factors. Although the material cost of a MAF is higher than the same configuration welded fitting, the labor cost savings more than offset the increased material cost, resulting in a lower total installed cost.

Study	Reported Savings	MAFs Installed	Savings per Installed MAF
FFG Halon P1 piping	$30,309	1,558	$20
USS *America*	445	20	22.25
Shell X-Pan	295,525	4,000	64
AD AFFF sprinkler P2 piping	26,193	400	65
Valve hydraulic P3 piping	71,895	676	106
American Cyanimid	123,967	1,063	116
IP Corporation	6,966	52	134
BASF	400,186	2,240	178
USS *Enterprise*	1,332,720	6,840	194
DuPont	11,857	50	237
Totals	$2,300,062	16,910	$136 (average)

Table 4 ***Cost Comparison Between MAF and Welded Fittings***

About a third of the Navy's approximately 300 ships spend time in repair or overhaul each year. The Navy installs an estimated 2,500 MAFs per year on these ships using Ship Intermediate Maintenance Activity (SIMA) or ships crew. In addition, shipyards install an estimated 40,000 MAFs each year in ship overhauls and new ship construction. Table 5 shows an average recurring cost savings with NGS rather than military standard.

Category	Installations per Year	Installations in 10 Years	Average Savings per Unit	Total Savings
SIMA/crew	2,500	25,000	$136	$3,400,000
Shipyard installations	40,000	400,000	136	54,400,000
Total 10-year saving	42,500	425,000	$136	$57,800,000

Table 5 ***Recurring Savings (Average Savings per Unit)***

Table 6 shows one-time and recurring costs and savings using NGSs rather than military standards.

Category	Type	Value
One-time cost	Labor investment	$450,000
Recurring 10-year cost	Stock number maintenance	300,000
Net 10-year cost		750,000
One-time savings	Testing cost avoidance (Navy)	1,000,000
Recurring 10-year savings	Total installed unit cost savings	57,800,000
Net 10-year savings		58,800,000
Total 10-year benefit		58,050,000
Navy return on investment		77 to 1

Table 6 ***The Bottom Line***

Lessons Learned

New, emerging, and changing technologies are important opportunities for performance-based standardization. Using performance-based NGS may provide better results than developing and using military specifications. Simple standardization can yield dramatic results. Simple items, such as pipe fittings, can provide opportunities for huge savings. Individual initiatives in standardization can make major differences. As the Navy continues to qualify new MAFs and adds new applications for MAFs, the recurring savings and cost avoidance continues to grow.

Making Systems Work Together

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