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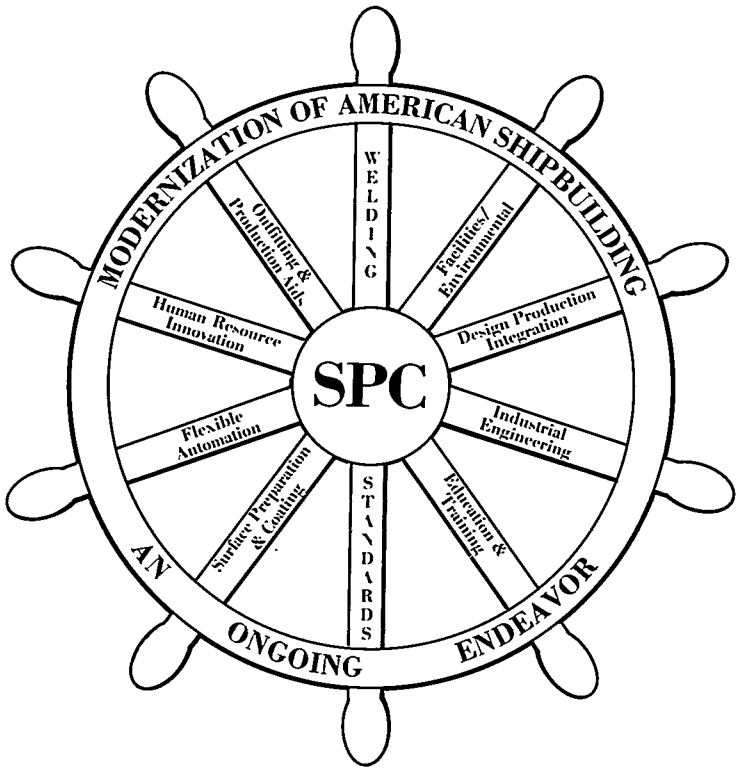

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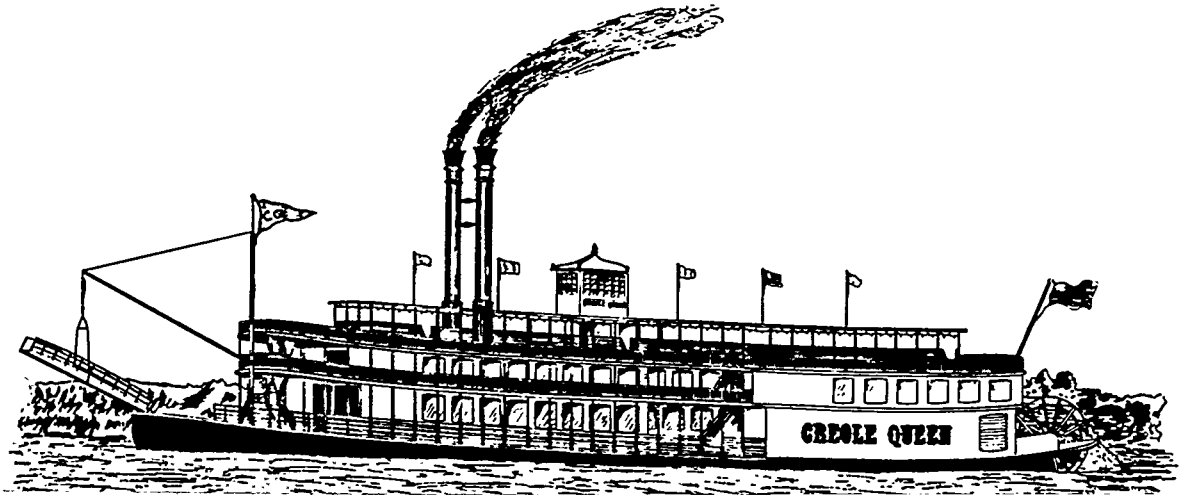

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A Planning Guide-New Technologies in Pipe NO.16 Joint Fabrication

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ABSTRACT

In the past few years. methods of joining pipe together have been introduced to supplement and. in some cases replace, both the traditional welded and the brazed pipe fitting. It is necessary to examine what is available. and to justify its place and application in the marine market.

This paper intends to examine the Swage Marine Fitting (SMF) and the Heat Recoverable Coupling (HRC) and, briefly. the Compression and the bite type fittings. We will look at them from economic, performance, and environment al standpoints. In the case of the SMF and HRC fittings, technical papers on the usage of each fitting and its constraints have been presented. The purpose of this paper is to evaluate them together and incorporate them into an overall piping system.

In addition. the two primary guides for piping on military ships will be examined. These will be used to place the SMF and HRC into correct perspective, and to make recommendations for further applications. Comments will also be offered on the testing method and the results gained. Graphs are provided to illustrate the economic advantage of the SMF application.

INTRODUCTION

A plaque seen at a major shipbuilder best expresses *the two* main concerns within the shipbuilding community: cost and quality. The plaque reads as follows:

> "we shall build good ships.
> *At* a profit if we can,
> At a loss if we must,
> But always good ships."

Another point of view is that of the owner, who must balance the money available against the function of the vessel. From this, he must generate specifications and a contract package. An ancient teXt best states his dilemma:

> "Suppose one of you wants to build a tower. Will he not first sit down and estimate the cost and see if he has enough money to complete it? For if he lays the foundation and is not able to finish it, everyone who sees it will ridicule him, saying, This fellow began to build and was not able to finish."
> LUKE 14:28 (NIV)

The primary cost factor in the ship is not the material, but the manpower involved. Labor costs have driven shipbuilding into automation, modular construction, and zone outfitting. Labor costs have driven shipbuilding, first to Japan, then to Korea, and in the future, possibly to the People's Republic of China. Furthermore, the volume of ship construction has decreased markedly, to some degree caused by the downswing in the Petro-Chem industry. It is apparent that in order for yards to be more cost competitive, gains in productivity will have to be achieved.

It appears that one of two approaches are currently taken with regard to new technologies. Some technologies are moving so fast that to test them prior to specifying them would have them obsolete prior to implementation. Additionally, they greatly affect the ability of the ship to perform the job for which it was built. Failure to implement these technologies would possibly place the owner behind the competition. The owner's response, and logically so, is to order the technologies off the drawing board. Other technologies are not advancing as fast, and do not affect the mission or purpose of the ship, other than the cost. These are thoroughly tested prior to implementation.

It is in this second area that we are going to develop comments and conclusions, specifically in the area of pipe joining technology. Two technologies have been introduced in the past several years that offer advantages that

hould be considered by yards and owners. The Swage Marine Fitting (SMF) offered by the Deutsch Company under the trade name Pyplok(R), and the Heat Recoverable Coupling (HRC) offered by the Raychem Corporation under the name *of* Cryofit(R) or Cryoweld(R), are both available to the marine industry, both have aerospace fitting counterparts. and both are approved by NAVSEA for use on nuclear and non-nuclear surface ships in non-nuclear applications. Neither has been approved, however. for use within the reactor compartment or on a nuclear submarine. *A* one-time SMF application has been made with NAVSEA approval on a U.S. nuclear submarine: it is interesting to note, in contrast, that both SMF and HRC have been applied on the British Trafalgar Class and on French nuclear submarines.

Two questions must be answered to the satisfaction of the owners or Navy for yard application: these are: Do SMF and HRC perform the job for which they are designed? Do they offer significant economic advantages?

To answer these questions. Navy standards and SAE guidelines will be used. These include. but are not limited to:

Mil-Std 777 Schedule *of* Piping, Fittings, and Associated Piping Components for Naval Surface Ships

Mil-Std 438 Schedule of Piping. Valves, Fittings and ASSociated Piping Components for Submarine Service

Mil-Std 278 Fabrication Welding and Inspection: and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels in Ships of the United States Navy

Mil-Std 1629 Procedures for Performing Failure Mode, Effects and Criticality Analysis

SAE-HIR 1694 Materials for Fluid Systems for Marine Vehicles

SAE-HIR 1063 General Environmental Considerations for Marine Vehicles

The traditional methods of assembling shipboard piping have been either welding or brazing. Both methods have associated problems. including system contamination, hot work restrictions. non-destructive testing requirements, and a high degree of labor skill required. The public sector yards have documented the amount of time required to accomplish each of these two methods of pipe joining (see Table 2). The labor intensity. particularly for the walding process. is high. Note that the decrease in time for subsequent joints is not significant. These, however, are the estimating standards. It is to these standards that we will make performance and economic comparisons.

-TABLE 2-

OPERATION .1.6 SHOP 56 W/C 5612
FITUP AND INSTALL PI PIPING
SURFACE CRAFT

	1/4	1/2	3/4	1	1.1/4	1.1/2	2	2-1/2
Butt Weld	2.6	2.9	3.0	3.5	4.0	4.3	*5.0*	*5.8*
Each Additional joint in area	2.2	2.5	2.6	3.0	3.4	3.7	4.3	4.8
Socket Weld	2.0	2.2	2.3	2.6	2.7	2.9	3.2	3.4
Each Additional joint in area	1.2	1.4	1.5	1.7	1.8	1.9	2.2	2.5
Flanged Joint	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8

OPERATION .1.6 SHOP 66 W/C 5612
FITUP AND INSTALL P3A PIPE*
SURFACE CRAFT

	1/4	1/2	3/4	1	1-1/4	1.1/2	2	2-1/2
Braled	1.2	1.6	2.0	2.3	2.6	2.9	3.4	3.7
Each Additional joint in area	0.6	0.8	1.0	1.4	1.8	2.0	2.4	2.8
Flanged joint**	1.3	1.5	2.0	2.1	2.2	2.4	2.7	2.9
Threaded	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5

☛ NOTE An additional 25% man-hour allowance should be added for coverage of special P-3A submarine field joints that require documentation and hub cleaning for ultrasonic inspection.

**NOTE Tbe time values to make up a flanged joint include time to clean flange faces, install gaskets, and bolt-up only. Attachment of flange to pipe or fitting in included in the time for the fit-up and brazing of the connecting joint.

Rather than do elaborate re-introductions of the SMF and HRC fittings, technical considerations can be reviewed by referring to papers presented by LCDR Baskerville to ASNE in September 1981 (on the HRC) and by LCDR Mahoney, also to ASNE in September 1981 (on the SMF). The differences between the two fittings center on the method of attachment to the pipe, residual stresses. configurations available. and on current approval status.

The choice for method *of* attachment is between a "passive" crimp and an "active" crimp. The "passive" crimp Of the SMF is characterized by a plastic deformation of both the PiPe and the fitting in which little residual force exists (less than 20,000 psi). The "active" crimp of the HRC is characterized by plastic deformation of the pipe only. This results in a balance of forces between the swaging force of the fitting and the "spring back" of the pipe (70,000 to 100.000 psi in residual stress).

The SMF is currently manufactured in 6,000 pound pressure class in 70-30 Copper-Nickel for use on 70-30 and 90-10 Copper-Nickel, and on all grades of Copper pipe to 3/4" NPS (I" O.D.). Additionally, a Stainless Steel fitting is approved for 3,750 psi service on ferrous pipe to 1-1/2" NPS. Both pressure classes are approved for use from -60 - 400 degrees F. The SMF is installed by the USE of a hydraulic tool which mechanically reduces (swages the fitting around the pipe. The SMF is a one piece fitting, available in numerous configurations and end standards, with low residual stress at the joint.

The HRC is available in two versions *for 6,000* psi service: a monolithic (Nitnol) and a composite (Nitnol with a Cuprous liner). Due to the "active" crimp, a limitation on pipe wall thickness exists. Additionally, for seawater service, ths composite coupling is required. The temperature limits are generally from -65 to 575 degrees F, except when environmental protection is used. This requires a protective heat shrink sleeve that drops the upper temperature limit to 194 degrees F. *A* low pressure HRC fitting (400 psi) has been NAVSEA approved for use on Cuprous piping with wall thicknesses, dependent on pipe size, to 2-1/2" NPS. HRCS have been approved For use on non-nuclear submarines, in addition to surface ships.

The HRC is available as a coupling only, requiring machine shapes to make up configurations and adapters. Moderate to high residual stress is associated with the HRC.

APPLICATION

A review of Mil-std 438 provides the best indication where the SMF and HRC might find application. Both documents name systems, define the system parameters,and define materials for assembly of *that* system. The documents suggest that for some systems. alternate material selection is acceptable. In Mil-Std 777, more than 110 system/material combinations are available. Of these, twenty fall outside of the temperature range of the SMF. and fifteen outside of the temperature range of the HRC. Another ten system/material combinations must be discounted due to material compatibility (brass, aluminum, GRP, and PVC).

The largest number of systems are found under 400 psi, and are usually assembled with Mil-F-1183 (brazed) fittings.

In Mil-Std 438. we find fewer of the high temperature systems. However, we find systems that were not critical on a surface ship. that are critical in nature due to exposure to seawater pressure. The quality control standard imposed on the submarine is a great deal more stringent.

The use *of* both the SMF and the HRC has been evaluated by General Dynamics, Electric Boat Division. initially to determine suitability for gage and instrumentation piping. A recommendation has' been made that, SNF and HRC be considered for service tkroughout the submarine. Currently, both the "Bite Type", Mil-F-10866, and the "compression style", find usage in the gage instrumentation systems. as wall as other systems within the submarine. NAVSEA has been working to provide alternate fittings for the "compression" type. Since many manufacturers exist, the control/interchangeability of components associated with this type of fitting is a Problem.

We also find three levels of application under consideration. In new construction, pipe and fittings are new. and cleanliness can be enforced more easily. There is more shop fabrication of subassemblies. and modular outfitting is commonplace. In an overhaul mode. there are modifications and/or additions to existing piping, some subassembly work, and routing around existing installations. Hot work and gas freeing are added job complications. The third possibility is a repair situation where only a handful of fittings will be involved. In this option, cleanliness. gas freeing, and proximity of weapons or other combustibles become major Considerations. In all three cases, nondestructive testing and final system hydrostatic test are required. It is apparent that as you escalate from one situation to the next. the installed cost on a per fitting basis is increased.

PERFORMANCE

Performance tasting of both SMF and HRC was done in line with test criteria developed by David Taylor Naval Ship Research and Development Center. These tests address some of the criteria required by SAE-HIR 1694: Table 1 reflacts the test data. It is interacting to note that two the tests (burst and tensile) are test-to-fail in nature. while the balance are test-to-pass. It is not unusual, therefore, that we pay the most attention to the burst and tensile data. We find that we know little about the extreme limits *of SMF* or HRC performance. other than that they exceed the requirements as set down by the Navy. With the comparison to traditional methods. we know more about the outer limits of performance. Traditional fittings failed in the critical tests

-TABLE 1-

PERFORMANCE TEST BANKING
CONVENTIONAL vs. NON-CONVENTIONAL PIPE JOINTS

Measure of performance	Butt Weld	Socket Weld	SMF	*HRC*	rase	Bite	Compression
Fatigue	Pass	Fail(1)	Pass	Pass	Fail(2)	Pass	Untested
Burst	Pass	Pass	Pass	Pass	Pass	Pass	
Tensile	Pass	Pass	Pass	Pass	Pass	Pass	
Impulse	Pass	Fail(3)	Pass	Pass	Fail(4)	Pass	
Torsion	Pass	Pass	Pass	Unk.	Pass	Pass	
shock	Pass	Pass	Pass	Pass	Pass	Untested	
Vibration	Pass	Pass	Pass	Pass	Pass	Untested	
Fire	Pass	Pass	Pass(5)	Pass(5)	Fail(6)	Untested	
Environment	Pass	Pass	Pass	Pass(7)			

Note(1) Catastrophic joint failure occurred between 20% and 40% of test cycle.

(2) Catastrophic joint failure occurred between 20% and 40% of teat cycle.

(3) Catastrophic failure occurred below 5O% of test cycle.

(4) Catastrophic failure occurred below 60% of test cycle.

(6) During 20 min. ffre test at 2000 with GN^2 at 100 psi..

(6) Catastropbic joint separation occurrcd within three minutes of start fire test.

(7) Potential stress cracking during salt spray tests requires that environmental protection measures be taken in area - where exposurres may occur.

Fatigue - 80,000 cycles hydraulic impulse at operating pressure Plus bending stress dependent on pipe material (60 KSI for steel, 44 KSI for 70/30 CUNI, 30 KSI for copper).

Burst - four times operating pressure

Tensile - greater than minimum pipe yield

Impulse - one, and one half times operatiig pressure

Torsion - varied

Shock - Per Mil-901C

Vibration - Per Mil-167

Fire- Thirty minutes at 2000 degrees F. at l00 psi dry nitrogen with proof and burst to follow.

Environmental -168 hours of salt spray test.

(fatigue and impulse). SMF and HRC have been tested to extremes without failure.

Several comments can be made With regard to the information presented in Table 1. These are tests in a 1aboratory environment, and do not fully duplicate "real world" conditions. Factors that are currently unknown may be significant considerations in future applications. This does not mean that the testing was incomplete, but that factors may exist that were not taken into account. As new areas are considered, such as nuclear power. new problems and considerations may develop.

Within the temperature band (-60 to 400 degrees F for the SMF and -65 to 575 degrees F for the HRC). both fittings offer significant benefits over the socket weld and the braze fitting. The important aspects of the SMF. HRC, or any fitting are performance limits and boundaries. If the engineer or planner recognizes that limits exist, and respects them, problems will be few, if any. NAVSEA technical approval letters explicitly define the operating limits for both technologies.

Some testing presents a problem because of incomplete data. The engineer will make an effort to determine the value of the data generated from the fire testing. In this case, a pipe with a low (100 psi) pressure in it, without a heat-sink, is characteristic of few systems. The addition of fluid to the pipe changes the whole nature of the test. Additionally. consideration of the test results by the engineer or

planner is essential. The engineer must be concerned with "Maximum Economic Safety". *A* perfect system can be built, if one is willing to pay for it: the engineer must determine what is necessary for the job. If the fire test is reviewed from these standpoints, we come to the following conclusion: The most unacceptable joint is the braze joint, which catastrophically fails in a short time.

Within service limits, the following conclusion can be reached from the summary of tests: The SMF and HRC can provide comparable performance to the butt weld and better performance than the socket weld. If fire is a major consideration, braze joints should not be used in any system. Careful examination of the specification for the Mil-F-18866 fitting, in particular the 3,000 psi limit to 1" O.D. and *2,000* psi above that, quickly disqualify it from applications covered by NAVSEA Std. Dwg. 810-1385850. The use of compression fittings is severely limited by NAVSEA.

The testing is demanding. The "standard" joints fare the worst, failing catastrophically in fatigue and impulse tests. If a system failure occurs, obviously strains greater than those of testing were seen. When does the average pipe joint see temperatures like those in the fire tests? The answer is, rarely. In this case, the question of heat sinks has not been addressed. If considered, the fire around a fluid filled pipe would have to be out of control for more than 30 minutes to reach the internal temperatures required to validate the 2,000 degree F test requirement.

The environmental tests, however, do bring up some concerns about the HRC. Although seawater was used as the attacking media, it is not alone. Consider the chlorides that are present in insulating materials, or the generation of gaseous acids in a closed environment. These are valid concerns to the engineer and the planner.

Both the SMF and the HRC have each put thousands of fittings to sea in service on various vessels in varied applications. Both have enviable records from the standpoint of reliability and rework. The question about which *offers* the economic advantage remains. Let us examine the standard fittings and draw a comparison.

ECONOMICS

The economic considerations are developed around the time required to apply a conventional fitting and associated materials costs. We will use the data provided by a public yard, the way they use it (labor hours, times 1-1/3 to cover labor and material). We will take standard work day and divide it in half, because of the disruptions for a midday break (break-down and set-up of equipment, cool-down periods, etc.), to determine the maximum number *of* joints completed. This will give us an average joint cost. Average joint cost times 2 is the installed cost *of* a coupling or elbow: a multiple of 3 is the cost of a tee joint.

We will develop our method around a P-1 welded joint (shipboard). Graphs will cover alternative situations (shop, submarine, P-3A, F-3B, P-2, etc.). For the sake of simplicity. three data points are used; 1/4", 3/4". and 1-1/2" NPS.

From the table for P-1 welded joints. the following information is given (figures are in manhours):

	1/4 "	3/4"	1-1/2"
Socket weld	2.0	2.3	2.9
Each additional joint in area	1.2	1.5	1.9

With material cost:

	1/4 "	3/4 "	1- 1/2"
Socket weld	2.6	3.0	3.8
Each additional joint in area	1.6	2.0	2.5

Average joint requirement with material:

	1/4 "	3/4 "	1-1/2 "
Socket weld	1.2	2.5	3.1

To make this data useful. everything must be converted to either manhours or dollars. We will use dollars. Manhour rates vary from $25 to as high as $50. depending on the area (manhour rates may include labor, overhead. support labor. consumable materials. and other costs, including profits). We will use a value *of* $30, realizing that it is close to some labor rates but lower than others. It offers the advantage of a simple multiplication to make it useful to the reader.

The cost per joint becomes:

	1/4 "	3/4 "	1-1/2"
Socket weld	$66	$75	$93

A coupling or elbow would cost $132 at 1/4 ". $150 at 3/4"'. and $186 at 1-1/2" NPS.

We have plotted *the* joint costs, the coupling/elbow costs, and the tee costs on graphs (see Figures 1 through 7) which represent the possibilities.

To compare the alternate fittings, the acquisition cost must be altered by a factor to cover labor, storage, receipt-inspection, and/or tooling depreciation. Using 25% for the sake of discussion, if an SMF coupling cost:

	1/4"	3/4"	1-1/2"
SMF	$23.20	$35.00	$67.50
SMF (corrected)	$29.15	$43.75	$84.38

Navy contracts should reflect the current pricing. Additionally, quantity purchasing may or may not be a consideration in the prices reflected. For the P-1 welding comparison, above, a 3,750 psi CRES SMF was used. Keep in mind that at this point, many applications will be a fitting "overkill", in that the fitting far exceeds the system requirement. Additionally, remember that this will probably be true in other categories. These charts, even without cost data on the SMF or HRC, will give the user a point of evaluation for other new fitting concepts or procedures as they become available.

In each chart, the traditional method of assembly is the baseline. The installed cost for the SMF developed above has been included in Figures 1 and 2 for comparison. Below the baseline will be referred to as "Economically Acceptable", and above the baseline is "Conditionally Unacceptable"; conditional, because of the possibility of mitigating circumstances.

No one fitting method accomplishes all aspects of the piping problem without imposing some drawbacks. What is required is a method of evaluation that will allow the planner or the designer to establish that method or group of methods that will give him the desired system, having made acceptable trade-offs between performance, economics, schedules, environment, and conditions imposed by the work location.

In evaluating the joining methods, the following considerations are necessary, in the order given:

Temperature
Pressure/ Material Compatibility
Shapes and Adapters required
Protection Requirements
Working Space
Economic Considerations

The easiest assessments to make are the categorizations by temperature. They are:

Temperature	Weld	Braze	SMF	HRC(P)	HRC
575&above	Y	N	N	N	N
400 to 575	Y	N	N	N	Y
194 t0 400	Y	Y	Y	N	Y
-65 to 194	Y	Y			Y
-65 & below	Y	Y	N	N	N

Legend Y=Yes N=No

Note-The limits on the Mil-F-ll83 Fitting has a upper temp limit of 425 degrees.

Note-HRC(P)with environmental protection.

Note-For the ease of charting the lower temperature limits of tbe HRC and the SMF were assumed to be the same

PRESSURE/MATERIAL CONSIDERATIONS

The SMF is currently approved for 6.000 psi for any of the Cuprous pipes. and 3,750 psi for any of the Ferrous pipes. The HRC is approved for 6,000 psi for either the Cuprous or Ferrous pipes (thin wall copper requires the composite version. as do seawater applications). Additionally, the HRC has a 400 psi version, provided pipe wall thickness boundaries are observed. Weld or braze fittings can be procured by pressure class and material compatibility.

OTHER CONSIDERATIONS

There are certain intangible items that must be evaluated by the planner or engineer. These include such items as fittings requirements (shapes, adapters, etc.). space restrictions. and weight, fire hazard, and environmental considerations.

In review, the weld or braze joints offer a variety of configurations and material/pressure compatibility. They also bring with them the problems associated with hot work, labor skill and intensity, and cleanliness. If these problems can be overcome at reasonable cost, then both are viable options. In some cases, this will be true: in many others, the SMF or HRC would be better choices.

The bite type fitting has to be examined carefully due to the limitations imposed by the Mil-Spec. The fitting has been available for so long that its limits have been forgotten or overrated. This fitting q must be re viewed to ensure that its application remains in line with its design limits.

The compression fitting offers its own set of problems. A variety of vendors exist. and though the parts needed to assemble a fitting look similar, theY are not. The fitting offers 1imited inspectability. and is confined to O.D. sizes.

The SMF is offered in both pipe and tube sizes, and is available in numerous configurations and adapters. Considerations for the planner include sufficient access to the pipe to get the tooling over the fitting. Normally, to get one's hand around the fitting is sufficient. It is possible to complete a system with no hot work involvement with the variety of fittings available, thereby minimizing or eliminating systems flush.

The HRC offers an advantage in the area of tooling requirements and working envelope. Its drawbacks are the storage requirement (liquid nitrogen bath required until installed). the hazard of handling liquid nitrogen. the need to position the fitting right the first time, and the lack of one piece fitting configurate other other than couplings. The time limit to install the fitting is dependent on the ambient temperature, and configurations are achieved through the use of machine shapes and multiple couplings.

It would not be unreasonable to use more than one fitting concept to accomplish assembly of a system. A system would consist of all aspects of the piping requirement. It would be Possible that sections would be best accomplished in a shop environment. then joined to other sections onboard ship. Depending on the capabilities available, two or even three joining methods could be used,

By using this information, the planner or engineer may have two or more methods of assembly. His decision should be to select the best choice, yet giving the trades the option of other methods if conditions or considerations differ from those originally planned.

It seems apparent that neither the system classification (P-1, P-2. P-3a. etc.) or the system being discussed gives valid grounds for joining method selection. System classification is a method of assigning "Maximum Economic Safety" through testing and inspection. The cost differential between P-1 and P-2 can be determined, as can the differential between P-3a and P-3b. The installed cost of either the SMF or HRC does not change, regardless of system designation (P-1 versus P-2 or P-3a versus P-3b). The ship system is also a variable, due to its changing requirements (pressure, temperature. environment, and location). The engineer must be aware of all aspects affecting the system being developed, and all factors that affect it.

Having settled on those fitting types that will accomplish the assembly of the system, consult the graphs {Figures 1 through 7) to determine how the greatest economic advantage is obtained. Depending on the application, both the SMF and HRC should provide cost advantages required by the current economic climate. Proper consideration and application of new technologies is essential to protect the future *of* the U.S. shipbuilder.

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"The Introduction of Heat Recoverable Couplings to Ship Repair and Maintenance" by LCDR Donald J. Liberatore and LCDR James E. Baskerville, presented to ASNE 17-18 September 1981.

"Enhanced Piping System Reliability with HRCS" by William Honeywell, Raychem Corporation, presented to SNAME Hampton Roads Section 9 October 1986.

"HRC - Shipboard Application Considerations" by T. M. Williams, Jr.. prepared for SNAME Hampton Roads Section 9 October 1986.

Engineering Method and Standard No. 0056-505A CH-1, Charleston Naval Shipyard.

FIGURE 1

P– 1 PIPING COST COMPARISON

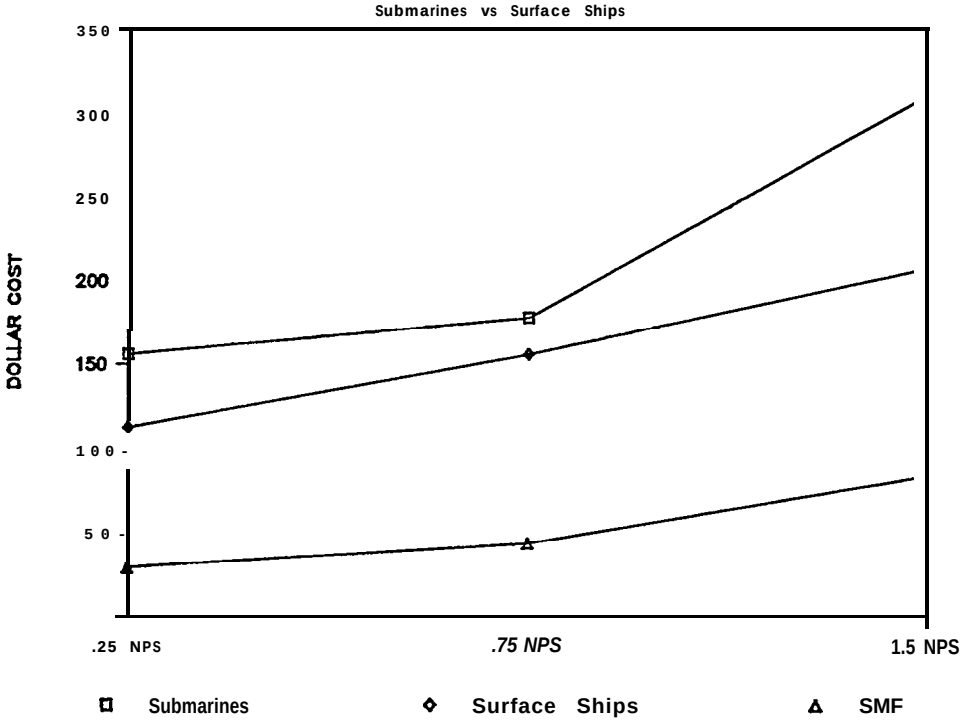

FIGURE 2

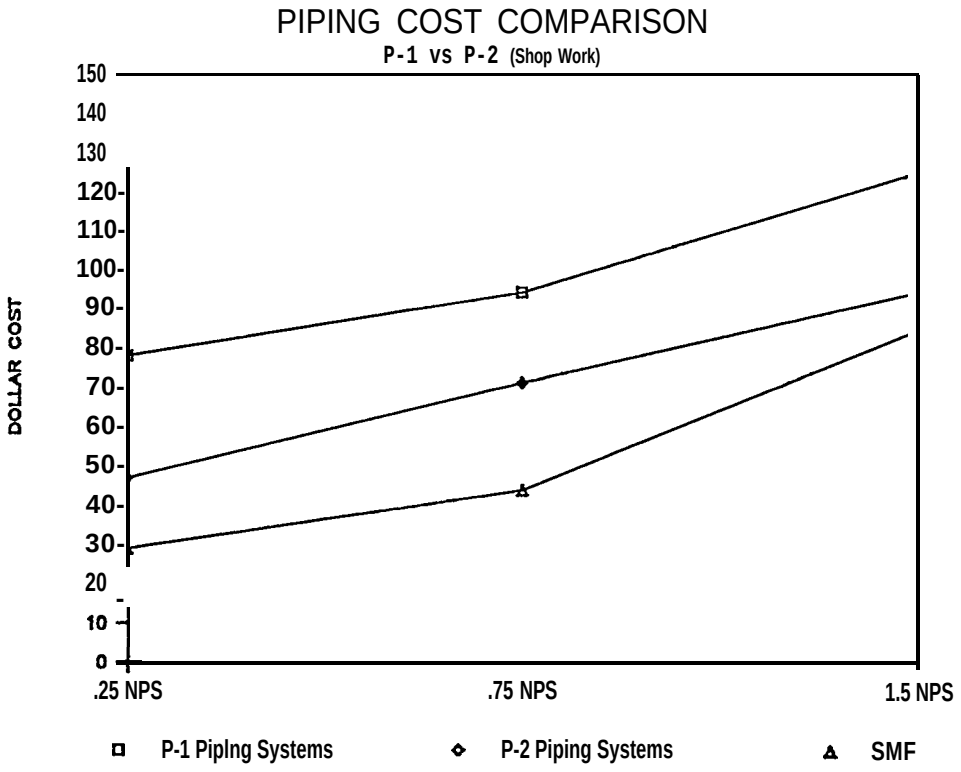

FIGURE 3

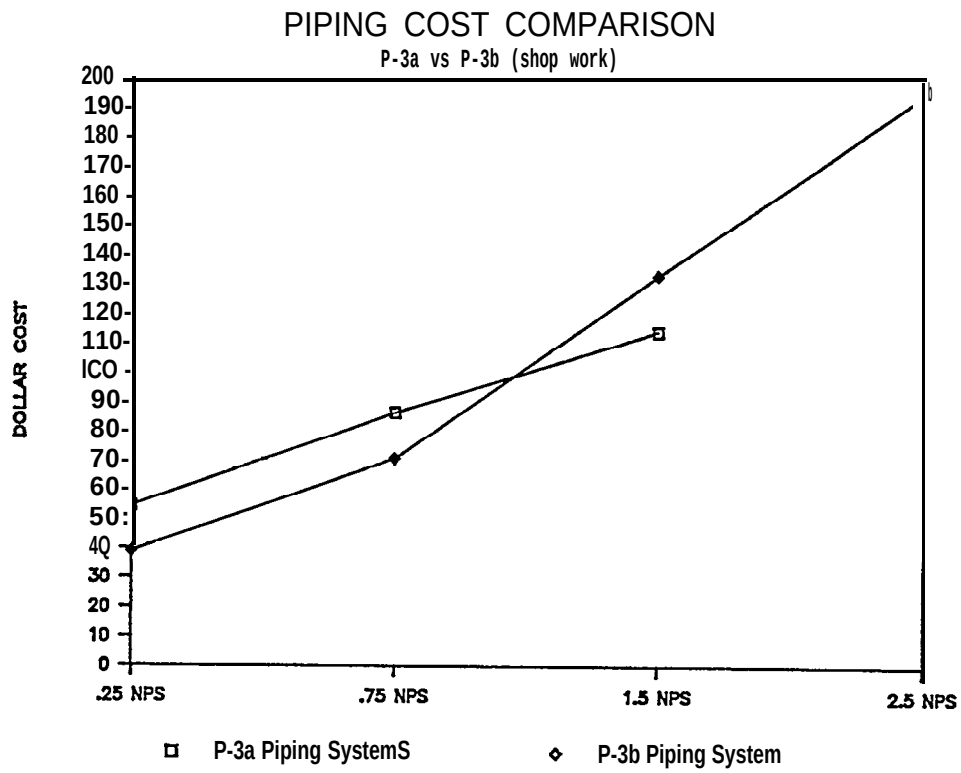

FIGURE 4

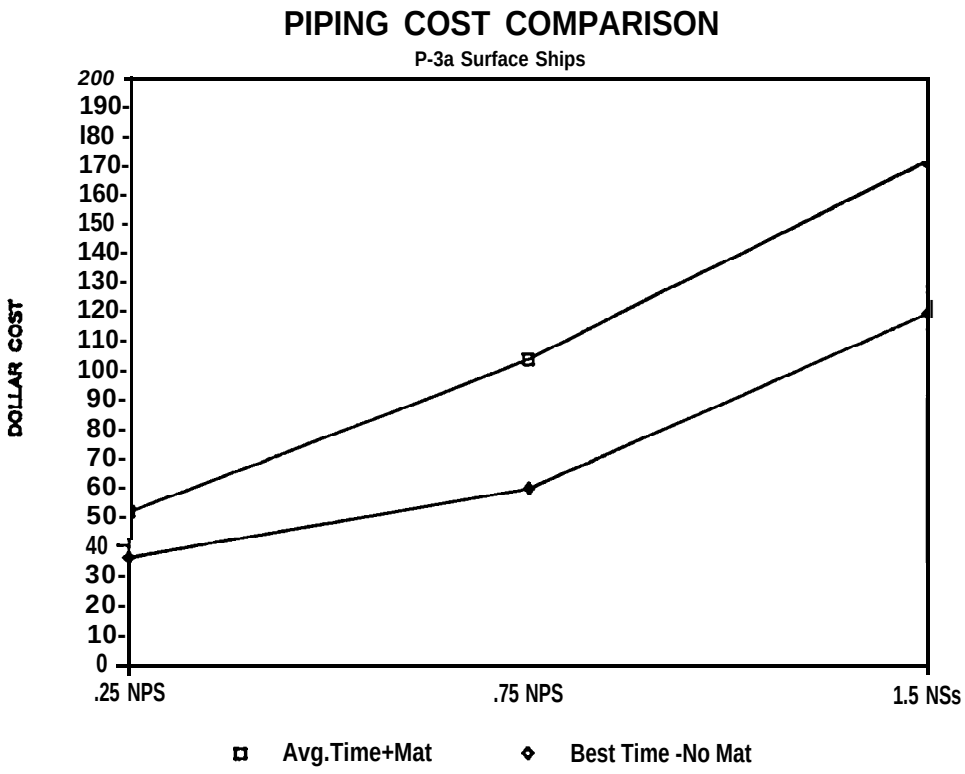

FIGURE 5

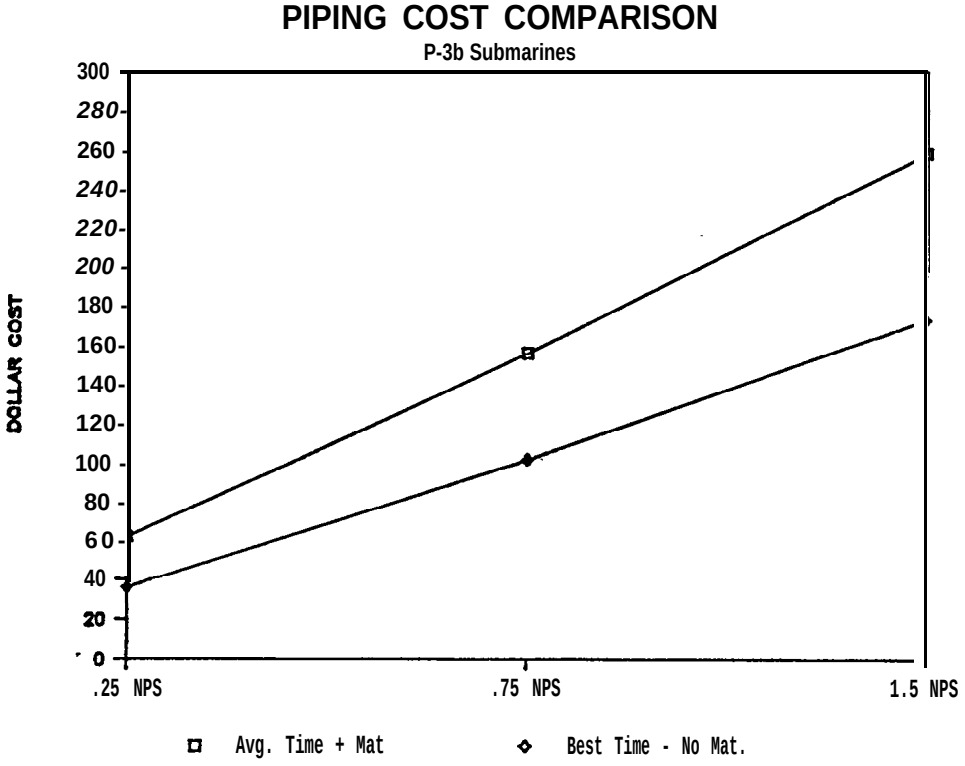

FIGURE 6

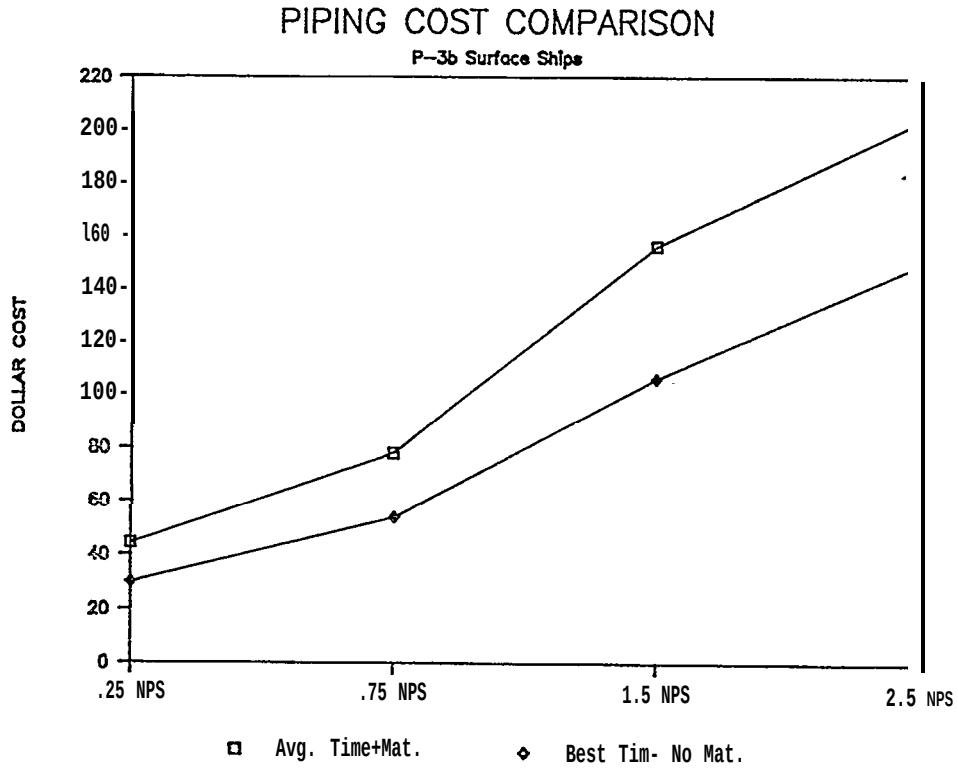

FIGURE 7

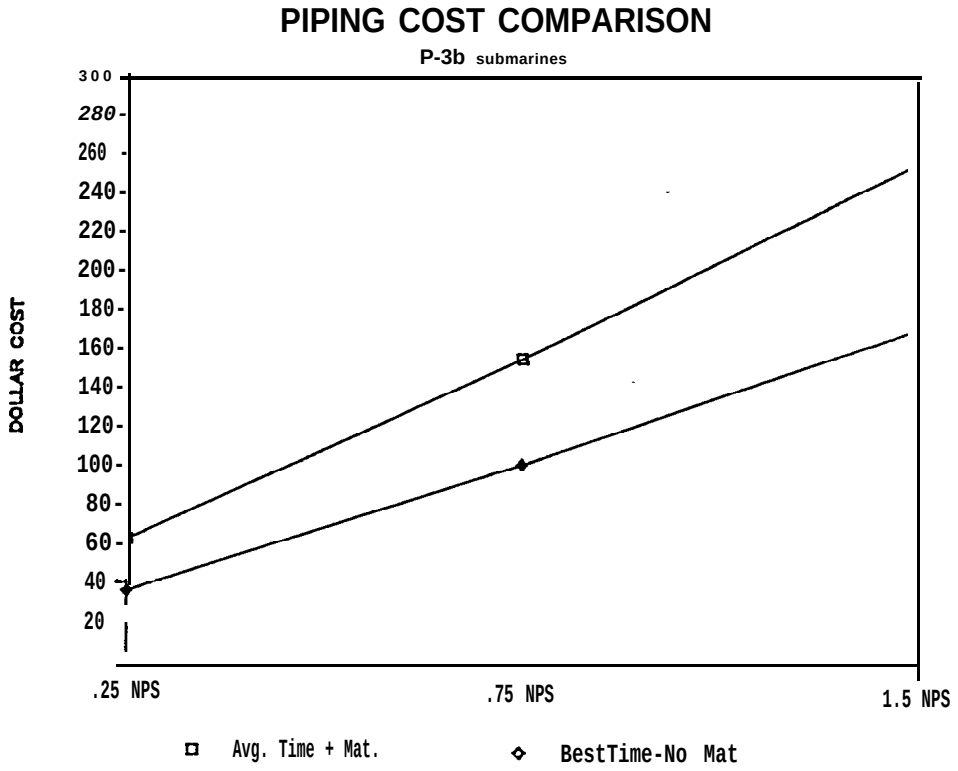

FIGURE 6

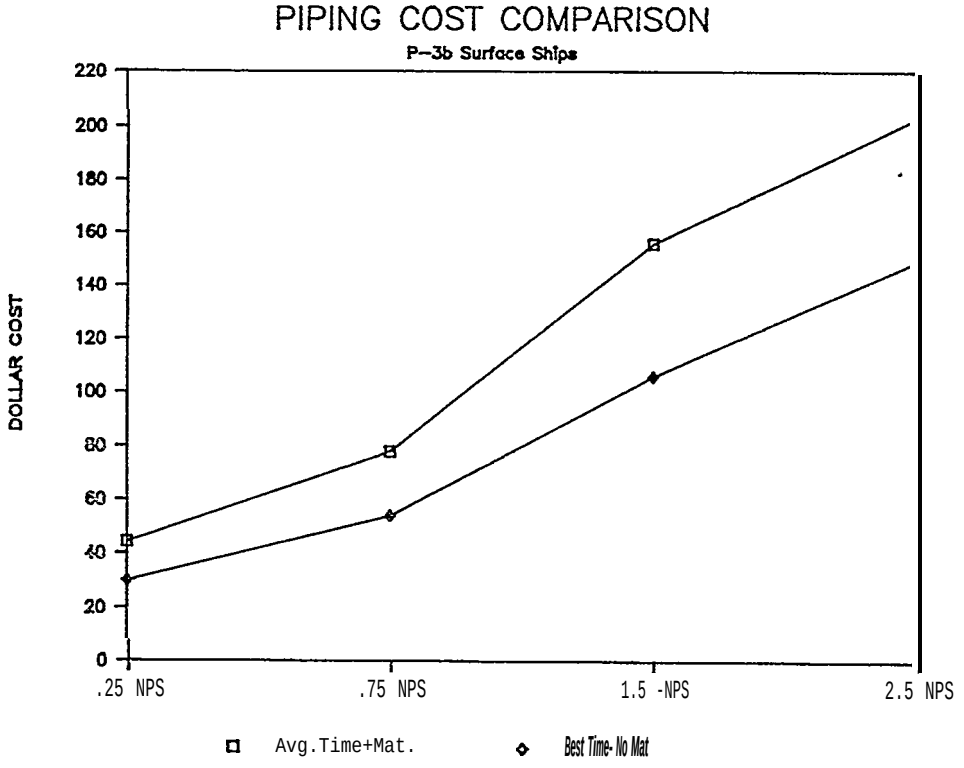

FIGURE 7