

Thermal Spray Manual

A practical reference guide

Located and reviewed by the AWS Product Development Committee as a service for quality-minded welding fabricators.

Acknowledgment

This Thermal Spray Manual was a project of The National Shipbuilding Research Program for the Society of Naval Architects and Marine Engineers Ship Production Committee Welding Panel SP-7. It was prepared in 1996 by Puget Sound Naval Shipyard's Welding Engineering entity. It is the final report of Task 7-92-3 of contract N00167-90H-0057 engaged by the Maritime Administration of the U.S. Department of Transportation with support from the U.S. Navy.

Note

This publication is designed to provide information in regard to the subject matter covered. It is made available with the understanding that the publisher is not engaged in the rendering of professional advice. Reliance upon the information contained in this document should not be undertaken without an independent verification of its application for a particular use. The publisher is not responsible for loss or damage resulting from use of this publication. This document is not a consensus standard. Users should refer to the applicable standards for their particular application.

INTRODUCTION

This thermal spray manual is intended to be a working manual for its user. The user is expected to add and remove information as appropriate based on the users needs. This document provides fundamental information for a variety of intended users, such as:

- * **DESIGN ENGINEERS**
- * **THERMAL SPRAY ENGINEERS**
- * **PRODUCTION SHOP SUPERVISORS**
- * **JOURNEYMAN THERMAL SPRAY OPERATORS**
- * **SHOP PLANNERS**
- * **MACHINIST**

The purpose of this manual is to provide fundamentals and to assist in the use of the thermal spray processes in the refurbishment of shipboard machinery components by aiding individuals in:

- * **THE SELECTION OF APPROPRIATE APPLICATIONS**
- * **TRAINING METHODS**
- * **APPROPRIATE COATING SELECTIONS**
- * **METHODS OF PROCEDURE QUALIFICATION**
- * **SELECTION OF THERMAL SPRAY PROCESSES**
- * **MASKING TECHNIQUES**
- * **SURFACE PREPARATION TECHNIQUES**
- * **SPRAYING TECHNIQUES**
- * **ASSOCIATED MACHINING TECHNIQUES**

To aid individuals in making sound thermal spray decisions, applicable basic information is contained within various section of this manual.

It is the intent of this manual to provide some fundamental structure to be able to find basic information easily and to build upon it. Fundamental information about thermal spraying, coatings, procedure and operator qualification, coating selection, and applications is contained in this manual.

From a thermal spray engineering stand point, this manual is intended to aid designers in making the best decisions as to repair applications, and coating system selections.

INTRODUCTION

This manual is designed to be a guide in performing daily tasks, as a training aid, and as a foundation for building a sound thermal spray program and developing a dedicated staff with knowledgeable personnel.

CONTENTS

TITLE PAGES & CONTENTS

GLOSSARY

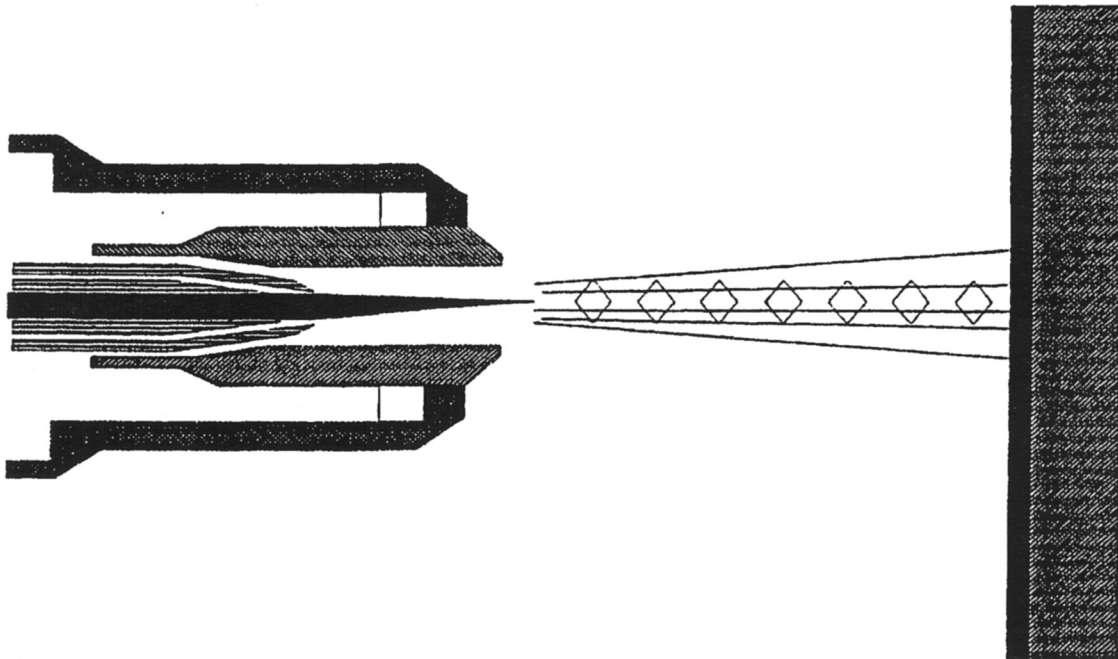
INTRODUCTION

RECOMMENDED READING AND PERSONAL REFERENCE LIBRARY

- 1. FUNDAMENTALS OF THERMAL SPRAYING**
- 2. SEQUENCE OF A THERMAL SPRAY JOB**
- 3. THERMAL SPRAY APPLICATIONS**
- 4. THERMAL SPRAYING PROCESSES**
- 5. COATING SELECTION**
- 6. PREPARING A MACHINERY COMPONENT FOR THERMAL SPRAYING**
- 7. THERMAL SPRAY OPERATIONS**
- 8. FINISHING OF THERMAL SPRAYED COATINGS**
- 9. QUALITY ASSURANCE**
- 10. TRAINING AND CERTIFICATION**
- 11. PROCEDURE/OPERATOR QUALIFICATIONS**
- 12. SAFETY & ENVIRONMENT**

SECTION 1

FUNDAMENTALS OF THERMAL SPRAYING



PREPARED BY: PUGET SOUND NAVAL SHIPYARD

THERMAL SPRAY PROCESS

Thermal spraying is a group of processes in which finely divided metallic or nonmetallic surfacing materials are deposited in a molten or semimolten condition on to a prepared substrate to form a deposited coating. The thermal spray process normally is a cost-effective method for achieving equipment repair or improving new or used equipment performance. The process is an excellent repair method and should be considered, when appropriate, in lieu of other processes. Some of the potential problems of competing processes include the following:

1. Welding existing components may cause unacceptable distortion, cracking, or heat treatment problems. Precise identification of the base metal is required for welding. Some alloys are difficult or impossible to weld. Welding frequently lowers the fatigue life of the component.
2. Electroplating may be too slow or too limited in buildup capability, and it is environmentally hazardous.

BENEFITS

Advantages of using the thermal spray process for machinery components include the following:

1. **BETTER THAN NEW** - Thermal sprayed coating properties can be tailored to suit the application. Coatings (metallic and ceramic) can restore or attain desired dimensions, provide electrical or thermal shielding or conduction, or improve the resistance to abrasion, corrosion, or high temperatures. Thermal sprayed coatings can provide superior service to the extent that some coatings can extend the service life of mating components. For some of these applications, facilities are thermal spraying new components before being placed into service, to further extend equipment service life. In short, thermal sprayed coatings are capable of making many components significantly better than new.
2. **NO DISTORTION OR HEAT AFFECTED ZONE** - Although the substrate is normally preheated, the thermal spray process is still considered a metallurgically cold process. This means that, in most applications, no distortion or heat affected zone is created. This is due to the fact that components generally are kept cooler than 400°F during the entire spraying process.
3. **VARIED SERVICE APPLICATIONS** - Current thermal spray applications in the shipbuilding and ship repair industry include thermal spraying of metallic materials on pump shaft bearing journals, turbine rotor shaft labyrinth seal areas, impeller fit areas, oil fit areas and various other types of applications. Ceramic coatings have been applied to the packing areas of valve stems and other types of packing and seal areas, giving those areas a smoother longer lasting surface than the substrate material thus enhancing the service life of that component. Thermal sprayed coatings can also serve for clearance control by applying abradable coatings at contact points.

1.2/FUNDAMENTALS OF THERMAL SPRAYING

4. **PART AVAILABILITY** - Parts availability plays a significant role in determining whether or not to use thermal spray repair methods. For some older machinery components, parts may simply be unavailable for a variety of reasons. For other items, ordering lead times may be unacceptable due to ship availability requirements. For still other high-cost items, new prices may be several times the cost of thermal spray repairs. In all of these cases, cost savings quickly add up, especially when factoring in the cost of ships unavailable for service commitments.

THERMAL SPRAY SYSTEMS

Shipbuilding and ship repair facilities use five primary thermal spray processes. These processes are the plasma powder process, the arc wire process, the flame powder process, the flame wire process, and the high velocity oxygen fuel process.

All thermal spray processes utilize five basic components. These components vary widely from one manufacturer or process to another, yet these components perform the same basic function (See Figure 1.1).

1. The Thermal Spray Gun is the heart of the system. This is where the heating zone forms and where the spray media enters the spray stream.
2. The Control System provides monitoring and control capabilities for the spray system. Operators use it to set and monitor gas flows and energy levels.
3. The Thermal Energy Supply may be electricity, or combustion from fuel gasses.
4. Compressed gasses include compressed air for cooling and/or atomizing, fuel gasses, and inert gasses used for various functions, such as for plasma and powder carrier gas for powder feeders.
5. The final basic component is the Spray Media Feed System. This system delivers the spray media, usually in either wire or powder form, into the heating zone at a finely controlled rate. The controls for the feed system may be stand-alone or integrated with the spray gun control system.

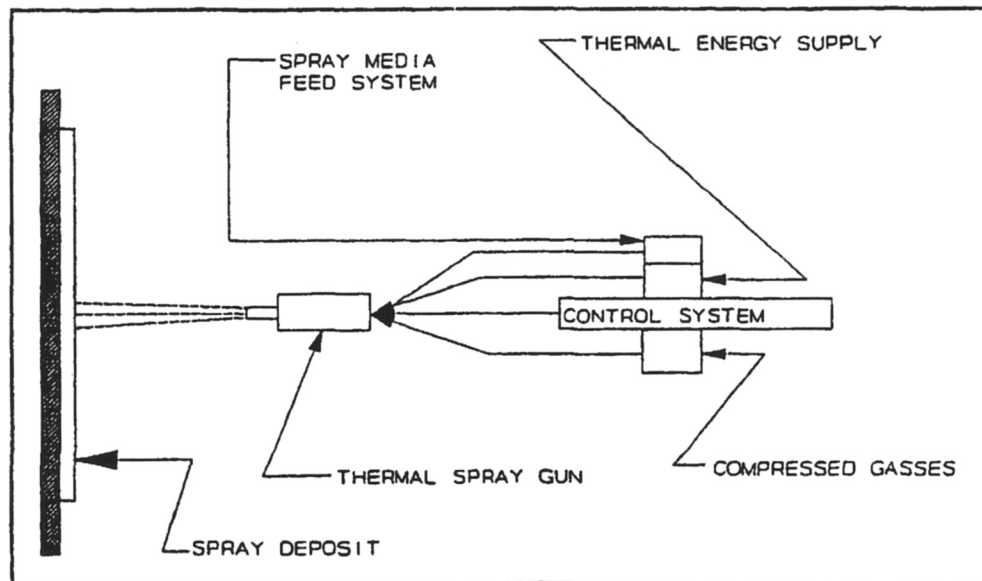


Figure 1.1 THERMAL SPRAY SYSTEM

PLASMA POWDER PROCESS

With the plasma powder process, an arc that is created between a tungsten electrode and a copper nozzle produces the heating zone. The tungsten electrode and nozzle are located in a conducting channel inside the plasma powder gun. A gas or gas mixture passes through this channel. The arc in the gas channel excites the gas into a plasma state, creating temperatures higher than can be obtained with any type of oxygen/fuel mixture. The gas or gas mixture then exits the gun forcing the plasma arc outside the gun. A powder is fed into the arc where it is melted and propelled at sonic or higher velocities to the substrate (See Figure 1.2).

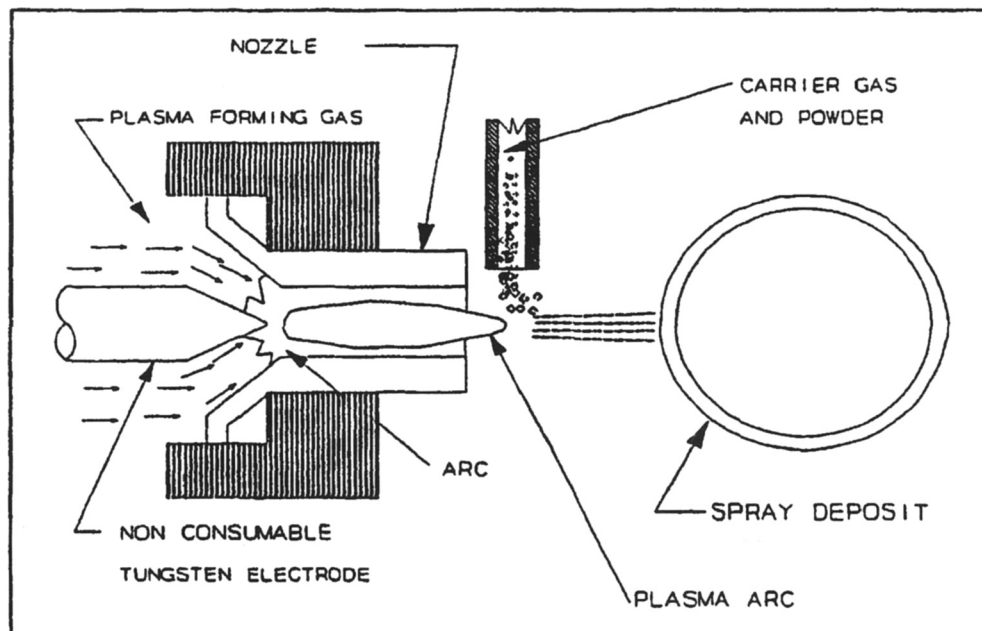


Figure 1.2 PLASMA POWDER PROCESS SCHEMATIC

ARC WIRE PROCESS

The heating zone with the arc wire process forms when an electric arc passes between two continuously fed metallic wires. Compressed air or an inert gas then atomizes and propels the molten material to the substrate (See Figure 1.3).

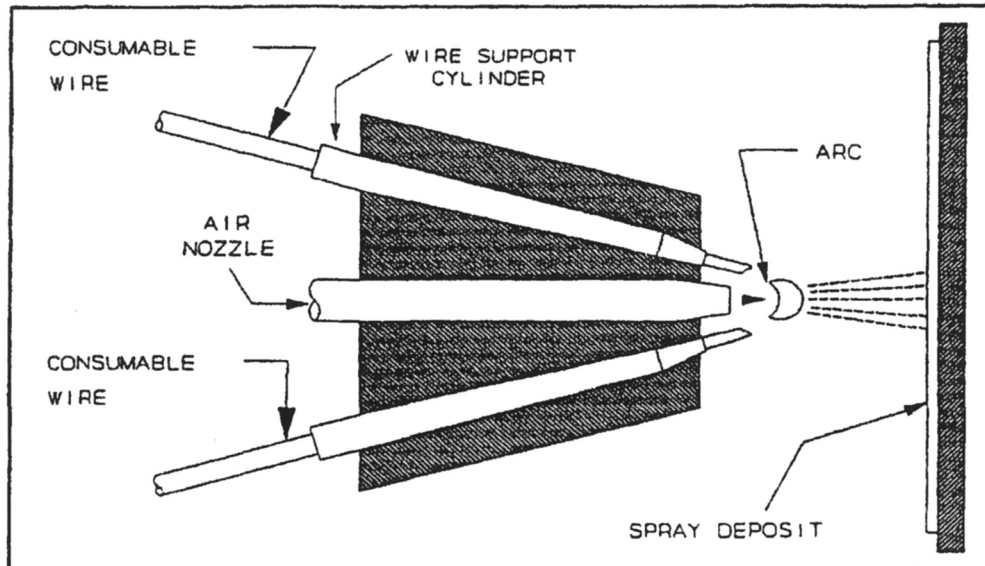


Figure 1.3 ARC WIRE PROCESS SCHEMATIC

FLAME WIRE PROCESS

The flame wire process uses an oxygen/fuel flame to create the heating zone. A wire continuously fed into the heating zone is melted, atomized, and then propelled onto the substrate by the force of the burning gasses and compressed air (See Figure 1.4).

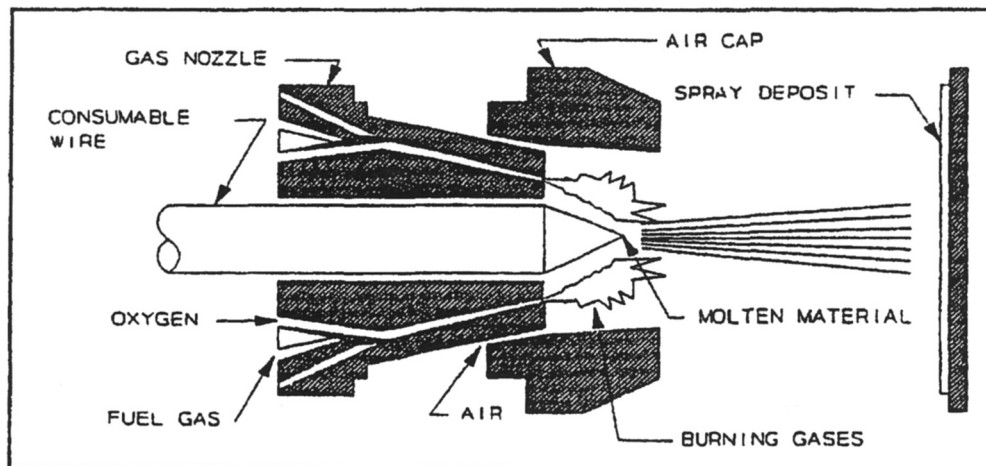


Figure 1.4 FLAME WIRE PROCESS SCHEMATIC

FLAME POWDER PROCESS

The flame powder process uses an oxygen/fuel flame to create the heating zone. Powder enters the heating zone and melts. The molten material is then propelled to the substrate by the force of the burning gasses and compressed air (See Figure 1.5).

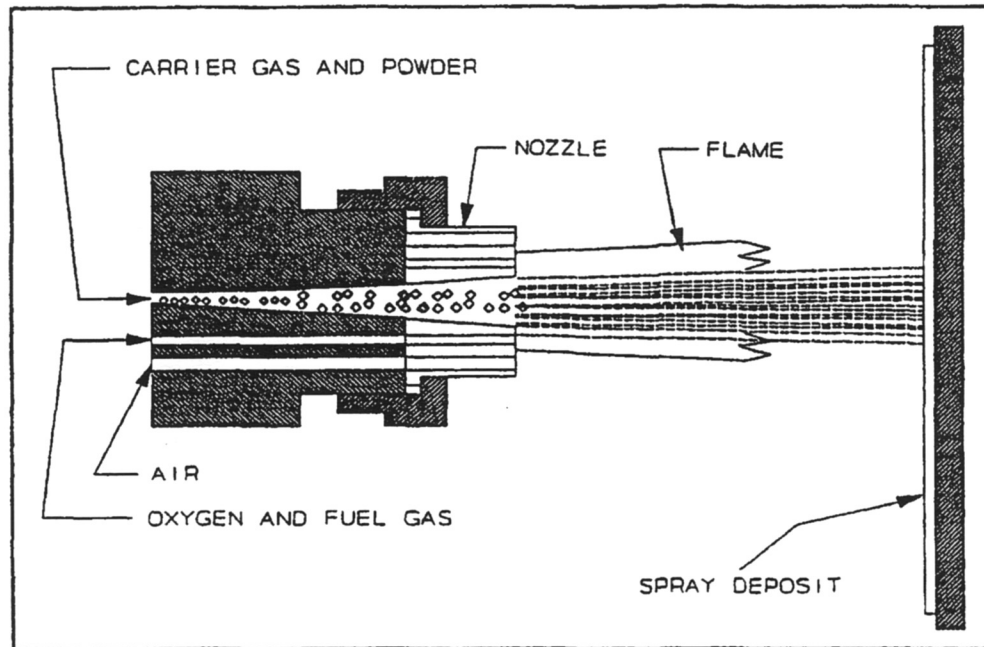


Figure 1.5 FLAME POWDER PROCESS SCHEMATIC

HIGH VELOCITY OXYGEN FUEL (HVOF) PROCESS

The HVOF process is one of the most recently developed of the thermal spray processes. This process uses the combustion of oxygen and fuel (typically propane, propylene, or hydrogen) mixtures at high pressures. This mixture of oxygen and fuel gas burns and is accelerated to supersonic speeds through special shaped nozzles. Thermal spray powder is injected into this constricted flame. The powder then accelerates in the high velocity flame (4500 - 7000 feet per second) (See Figure 1.6). When the thermal spray material collides with the substrate it plasticizes, flattens and adheres to form a coating. Some of the advantages of this process are due to the fact that it uses relatively low thermal energy coupled with high kinetic energy. This process produces coatings with low porosity, low oxide content, low residual stress, and exceptionally high bond strengths. The HVOF process typically produces coatings with reduced changes in the metallurgical phase composition of the thermal spray material when compared to the other common shipyard thermal spray processes.

1.6/FUNDAMENTALS OF THERMAL SPRAYING

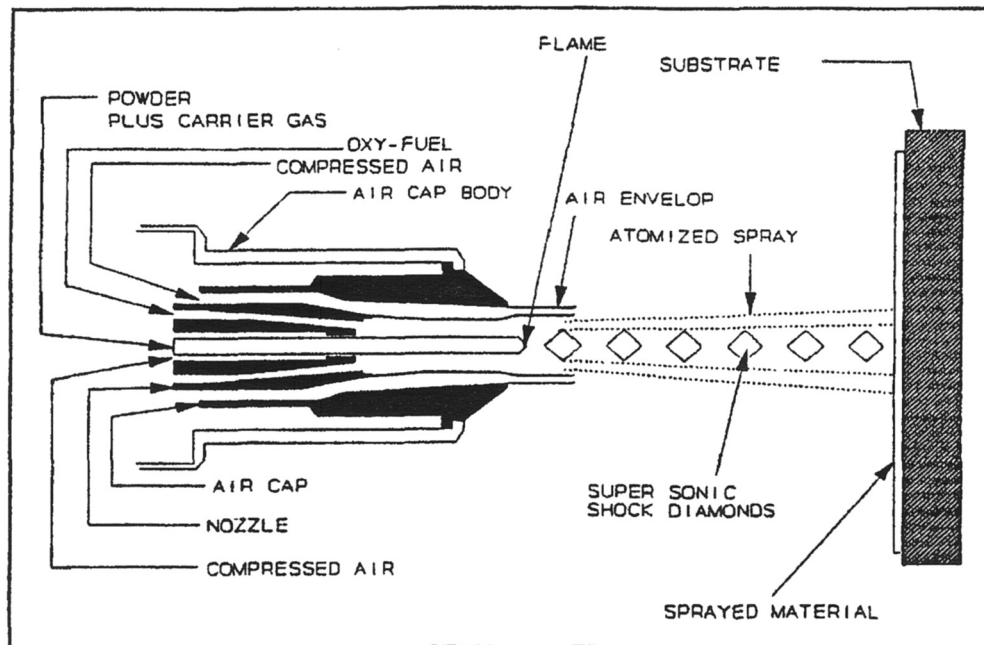


Figure 1.6 HVOF PROCESS SCHEMATIC

FUTURE APPLICATIONS

Around the world, various industries apply the thermal spray process to numerous applications that are not now being fully utilized by shipyards and marine repair facilities. These applications include electromagnetic shielding, thermal barrier coatings, and the thermal spraying of babbitt bearings. New processes and equipment that will provide superior coatings for many future applications are constantly being developed by manufacturers of thermal spray equipment and material.

LIMITATIONS

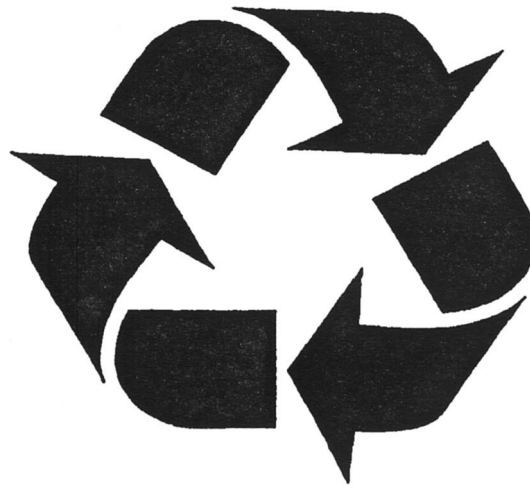
As with any other repair method, Thermal Sprayed Coatings do have some limitations. Thermal Sprayed Coatings have a significantly lower tensile strength than typical structural materials. Therefore, if undercutting for surface preparation reduces component strength to unacceptable levels, alternative repair or preparation methods must be used. Thermal Sprayed Coatings do not typically stand up to point or line loading, such as would be produced in a ball or roller bearing race. Peening is another example of this type of loading. Any application which seems to fall into this category should either be reconsidered or subjected to laboratory or in-service testing.

CONCLUSION

The Thermal Spray Process provides many benefits for new and used components. These benefits are capable of producing significant cost savings for ship repair facilities, especially over the long term. Any facilities desiring information or assistance with thermal spray technology can contact the authors of this manual at Puget Sound Naval Shipyard.

SECTION 2

SEQUENCE OF A THERMAL SPRAY JOB



PREPARED BY: PUGET SOUND NAVAL SHIPYARD

INTRODUCTION

This section provides fundamental information for the sequence of events for using the thermal spray process to repair machinery components. This system is presently used by Naval Shipyards that are authorized by the United States Navy to repair or refurbish machinery components. The following thermal spray system allows Naval Facilities to meet MILITARY STANDARD 1687 (MIL-STD-1687) requirements. This military standard is for thermal spray coating applications for naval machinery and ordnance. This standard is managed and issued by the Naval Sea Systems Command (NAVSEA 03M). The intent of this manual is to help personnel at maritime facilities make sound thermal spray decisions. Note that the sequence phases of the process are described in a brief form for general information only. For complete details please turn to the Manual Section for the process segment of interest.

REASON FOR THERMAL SPRAYING

Thermal sprayed coatings are typically applied to marine machinery components for dimensional restoration or to improve the components performance. Dimensional restoration applications include surface damaged caused by wear, erosion, corrosion, mis-use, or machining errors during the manufacture or repair of a component. The need for dimensional restoration is usually recognized initially by the mechanic reconditioning a system (pump, valve, turbine, etc.) or the system's components (valve stem, pump shaft, turbine rotor shaft, etc.). The mechanic usually contacts the design engineering group to help determine the repair alternatives. The machinist and design engineer meet at the component location and discuss methods of repair or replacement. (To demonstrate the repair sequence system, a damaged 400 Series Stainless Steel pump shaft has been selected. The section to be sprayed is an impeller fit area (See Figure 2.1).



Figure 2.1 400 SERIES STAINLESS STEEL PUMP SHAFT

2.2/SEQUENCE OF A THERMAL SPRAY JOB

Since thermal spraying appears to be a good repair method for this component, the design engineer or machinist mechanic contacts the Thermal Spray Shop or the Thermal Spray Engineering group. The Thermal Spray Shop and the Thermal Spray Engineer inspect the damaged component to determine whether the component is repairable using the thermal spray process (See Figure 2.2). For more information see the "Application" Section of this Manual (Section 3).



Figure 2.2 THERMAL SPRAY ENGINEER & THERMAL SPRAY MECHANIC

COATING SELECTION

Once the Thermal Spray Shop and the Cognizant Engineering Group decide that the damaged component is a good candidate for thermal spray repair, a coating selection is made. Selection of the coating system is based on the following elements;

- a. Base Material Type
- b. Function of Area to be Repaired
- c. Service Environment
- d. Thermal Spray Coating Material Available
- e. Thermal Spray Processes and Equipment Available

To select a thermal spray coating for this 400 Series Stainless Steel Demonstration Shaft, facility personnel used the STAINLESS STEEL ALLOYS Table from the "Coating Selection" Section of this Manual (Section 5). The environment of the packing area is fresh water and the type of section is an impeller fit area. There are four coatings listed in the water fit column of the STAINLESS STEEL ALLOYS Table that could be used to repair the impeller fit area. A ranking is given to each coating system (1 to 4, with 1 as the best selection). If the thermal spray facility has the number one selection material in stock and a plasma powder or flame powder system to apply that material, then the coating system of 21031 is selected.

The other coating systems listed as acceptable could be used if the Eutectic 21031 material is not available. For the purposes of this demonstration pump shaft we shall assume that the thermal spray facility does have the recommended Eutectic material. The ship repair facility that is refurbishing the demonstration pump shaft has plasma powder equipment and a qualified plasma powder procedure for the Eutectic material, so that process is selected to apply the coating. More detailed coating selection information can be located in the "Coating Selection" Section of this manual (Section 5). After the coating selection is made, the Thermal Spray Shop contacts the Design Engineering Group and informs them the component can be repaired with the thermal spray process. The Design Engineer issues a written instruction (Enclosure (2.1)) to the Thermal Spray Shop authorizing the Thermal Spray Shop and the Machine Shop to repair the damaged component.

THERMAL SPRAY JOB CONTROL RECORD (TSJCR)

At this time, the Thermal Spray Shop completes Section I and portions of Section II and III of a Thermal Spray Job Control Record (TSJCR) (Enclosure (2.2)). Record keeping information can be found in the "Quality Assurance Section" of this Manual (Section 9).

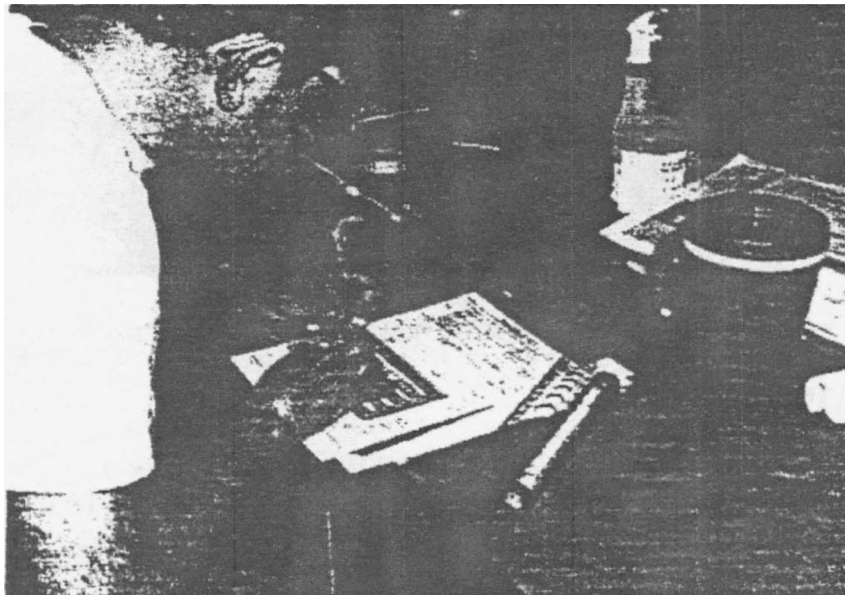


Figure 2.3 OPERATOR FILLING OUT TSJCR

CLEANING

The component is then shipped to the Thermal Spray Shop. For tracking purposes, the TSJCR number is vibratooled onto the component in an area where damage will not be caused to machined surfaces or the service of the component. The component is then cleaned to remove all grease, oil, paint, corrosion products, moisture or any other substance which may contaminate the area that is to be coated. For more detailed information on cleaning see the "Preparing A Machinery Component For Thermal Spraying" Section of this Manual (Section 6).

2.4/SEQUENCE OF A THERMAL SPRAY JOB

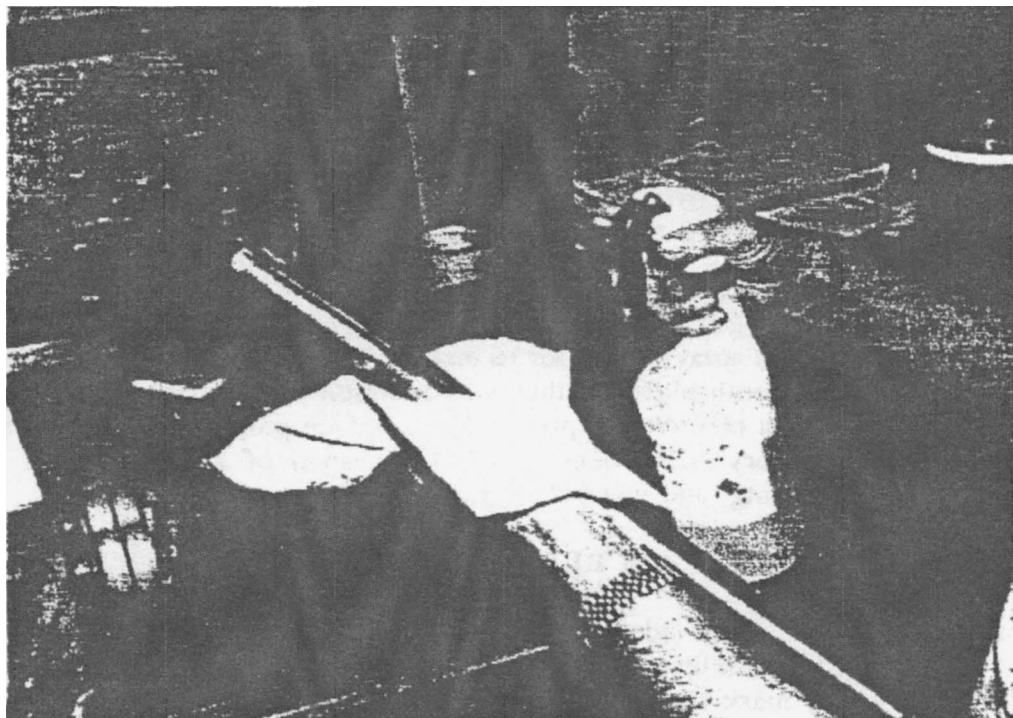


Figure 2.4 CLEANING OF COMPONENT

The bond strength of the coating is extremely dependent on the preparation and cleanliness of the surface to be coated. The application of a coating over a corroded surface must never be attempted. The corrosion products destroy the bond between the coating and the base metal surface. In addition, any moisture that is present in the corrosion product, no matter how minute, will cause further corrosion of the metal and blistering of the coating will occur during service. The metal surface must also be free from contaminants such as oil or grease in order to assure adequate bonding.

UNDERCUTTING

Undercutting allows for a uniform finish coating thickness, removes existing sprayed or plated coatings, and removes damaged or contaminated base metal. In most cases, this step also provides dimensional allowance to permit adequate thermal spray buildup for the application. The TSJCR and the part to be sprayed are sent to the machine shop where the machinist undercuts the component according to the sketch on the TSJCR.

NOTE:

A tapered shoulder should be left at the end of the component whenever possible. A weld bead may be deposited at the end of the component to provide a shoulder, if it causes no mechanical or metallurgical damage to the component. The Welding Engineering Division should be contacted before welding on the machinery component.

After undercutting is completed, component and TSJCR are shipped to the Thermal Spray Shop. The thermal spray operator checks the undercut dimension, list that information on the TSJCR, and cleans the component again. Detailed information on undercutting for thermal spraying can be found in the "Preparing A Machinery Component For Thermal Spraying" Section of this Manual (Section 6).

MASKING

The Thermal Spray Shop masks off areas of the component that may be damaged by surface preparation and/or by thermal spraying. Prior to masking, all oil, grease, rust, scale, paint, or any substance (i.e. anchor tooth blasting) that would inhibit the thermal spray coating from adhering to the substrate must be removed prior to final surface preparation. In order to assure a proper bond, the machinery component should be cleaned of all grease and oil before undercutting, after undercutting, and just before final surface preparation.

FOR ABRASIVE ANCHOR TOOTH BLASTING

Any masking material that gives adequate protection to the substrate and does not cause corrosion or contamination of the sprayed coating or substrate may be used. Following abrasive anchor tooth blasting, any masking material that is unsuitable for production thermal spraying shall be removed and replaced with a suitable masking.

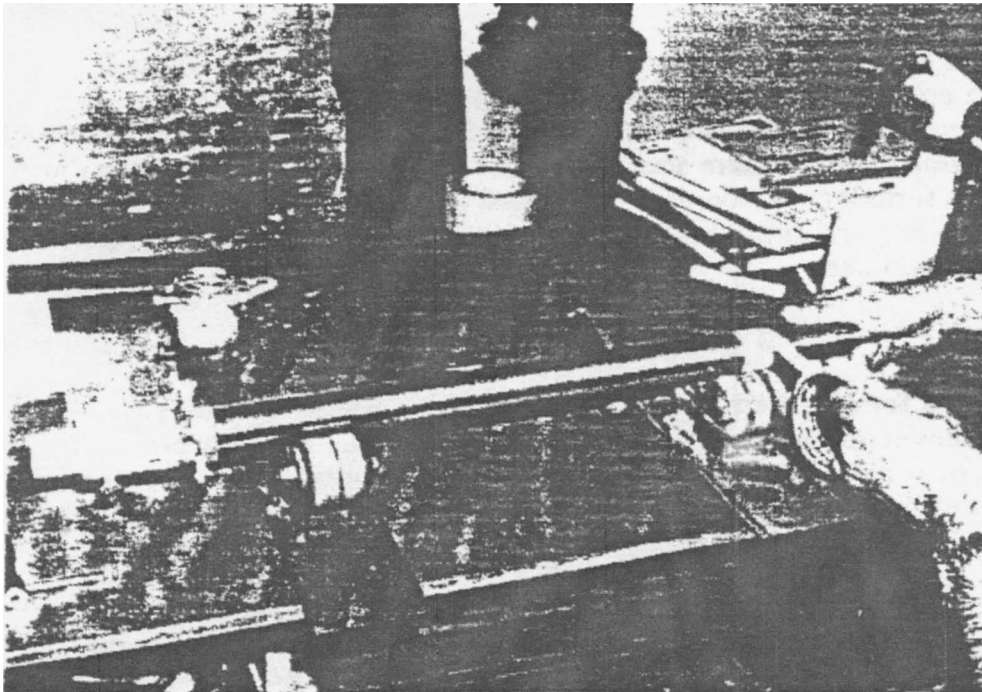
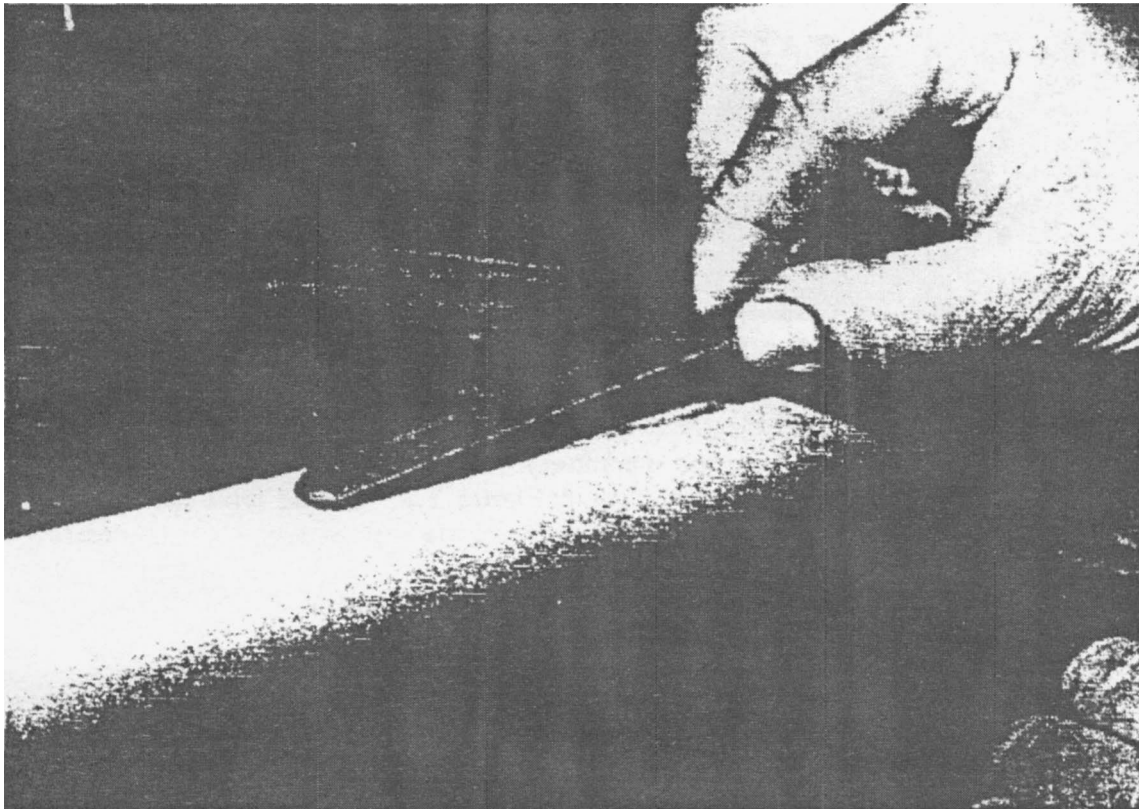


Figure 2.5 MASKING FOR ANCHOR TOOTH BLASTING

2.6/SEQUENCE OF A THERMAL SPRAY JOB

FOR THERMAL SPRAYING

Tapes, liquid masking compounds, silicone rubber or metal shielding may be used as thermal spraying masking materials. Tapes shall be designed for high temperature use. For holes, slots, keyways, or other types of recesses, inserts of carbon or metal may be used. Some types of metal inserts can be left in place during abrasive blasting and spraying, and may be removed after surface finishing. Carbon inserts cannot be used during abrasive blasting, but often serve well for spraying (See Figure 2.6). For more detailed information on masking machinery components for thermal spraying, see the "Preparing A Machinery Component For Thermal Spraying" Section of this Manual (Section 6).



STAGING FOR SPRAYING

To conserve the time between the surface preparation and the thermal spraying of the component, the operator should set up the thermal spray equipment, measuring equipment (micrometer, contact pyrometer, etc.), and the turning fixture before surface preparation is started (See Figure 2.7). Coating bond quality deteriorates with time delays between anchor tooth blasting and applying the thermal sprayed coating. All tools that will touch the area to be sprayed after final surface preparation must be cleaned of all oil and grease. When thermal spraying a machinery component for the United States Navy, an approved procedure is required. The parameters used to thermal spray the demonstration component can be found in the "Procedure Qualification" Section of this Manual (Section 11).

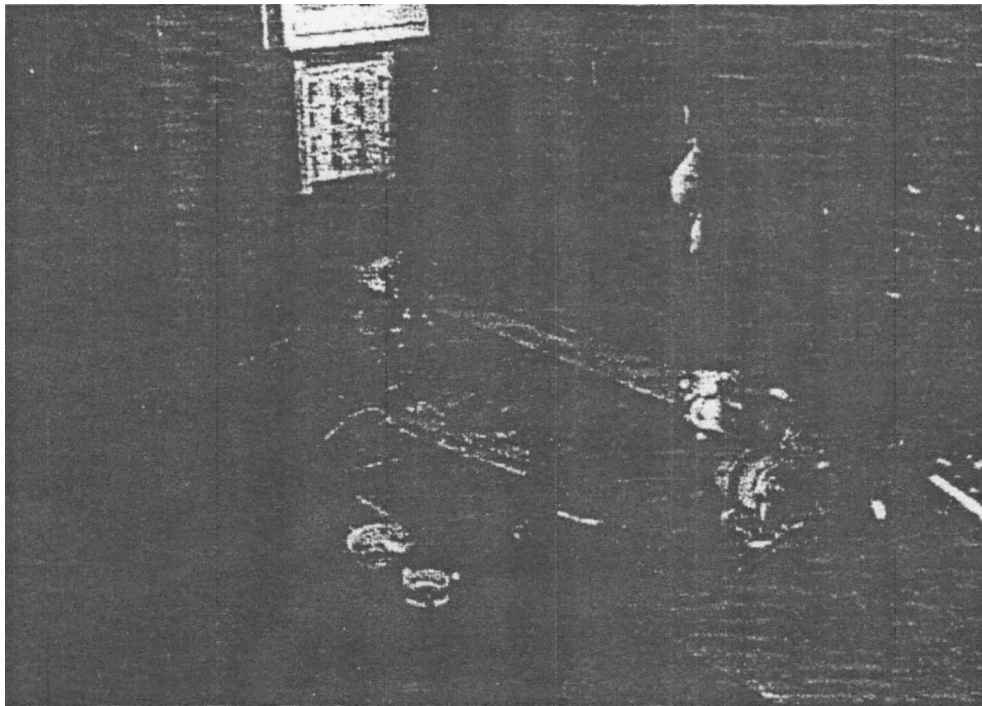


Figure 2.7 STAGING AREA FOR Spraying

SURFACE PREPARATION - ANCHOR TOOTH BLASTING

The thermal spray operator now places the machinery component in a grit blast booth for final surface preparation. The blast booth, as shown in Figure 2.8, should have the capability of creating an anchor-tooth profile of .002" to .004" on the surface to be sprayed. To measure the anchor-tooth profile, use profile tape and a specially designed micrometer. The thermal spray operator lists the results of anchor-tooth measurement in the appropriate area on the thermal spray job control record. Aluminum oxide grit is the most commonly used material used by U. S. Naval thermal spray facilities for final surface preparation blasting. Because of the importance of using clean aluminum oxide grit and the criticality of refurbishing machinery components, many facilities use the aluminum oxide grit only once for anchor tooth blasting during final surface preparation. The used grit is then recycled into other blast machines for less critical applications such as corrosion removal. Final surface preparation for thermal spraying machinery components is one of the two most critical steps prior to coating application. Cleanliness and surface roughness of the area to be thermal sprayed have a direct influence on how well the coating adheres to the substrate material.

THERMAL SPRAYING

When final surface preparation is completed, the operator should inspect the component and insure that all areas to be sprayed are 100% grit blasted. This is also the time to repair damaged masking and replace any masks which are unsuitable for thermal spraying (See Figure 2.9). Next, the operator mounts the component in the turning fixture and begins preheating with the plasma gun (if required by the approved procedure) using the parameters set for the bond coat (See Figure 2.10). During the process the anchor tooth area is never handled with bare hands as this can result in deterioration of the coating bond strength. As soon as preheat is complete, the coating is applied, stopping only under certain conditions.

2.8/SEQUENCE OF A THERMAL SPRAY JOB

These include measurement of coating thickness or temperature, cool down to prevent overheating, switching to the final coating materials that require a change in parameters, and service of equipment. For more detailed information on thermal spraying, see the "Thermal Spraying Operation" Section of this Manual (Section 7).

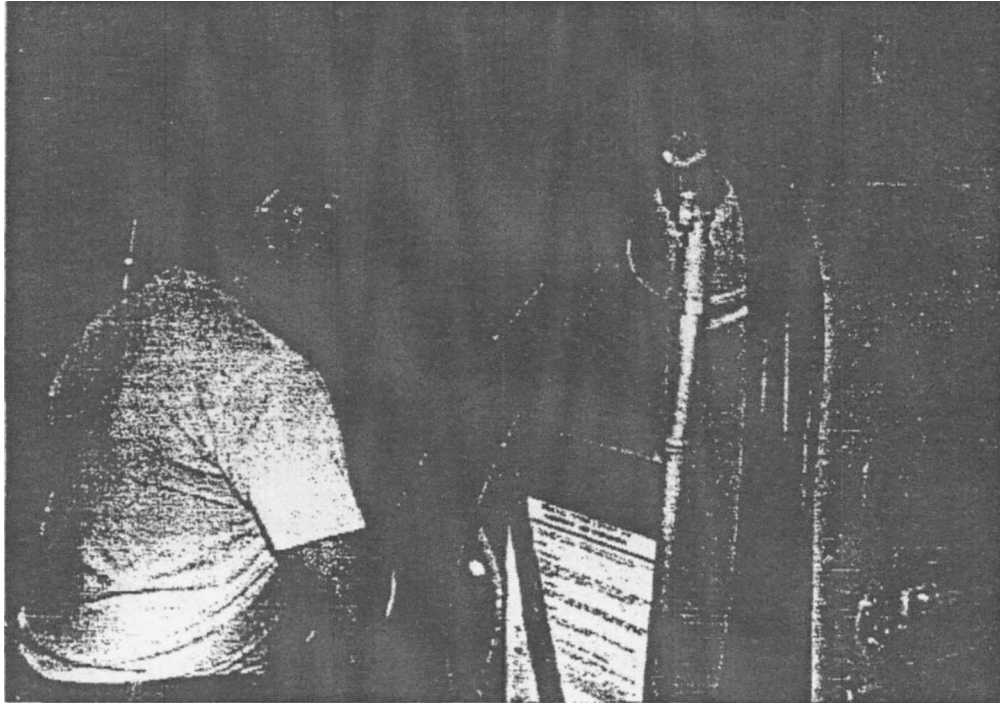


Figure 2.8 GRIT BLASTING OF SHAFT

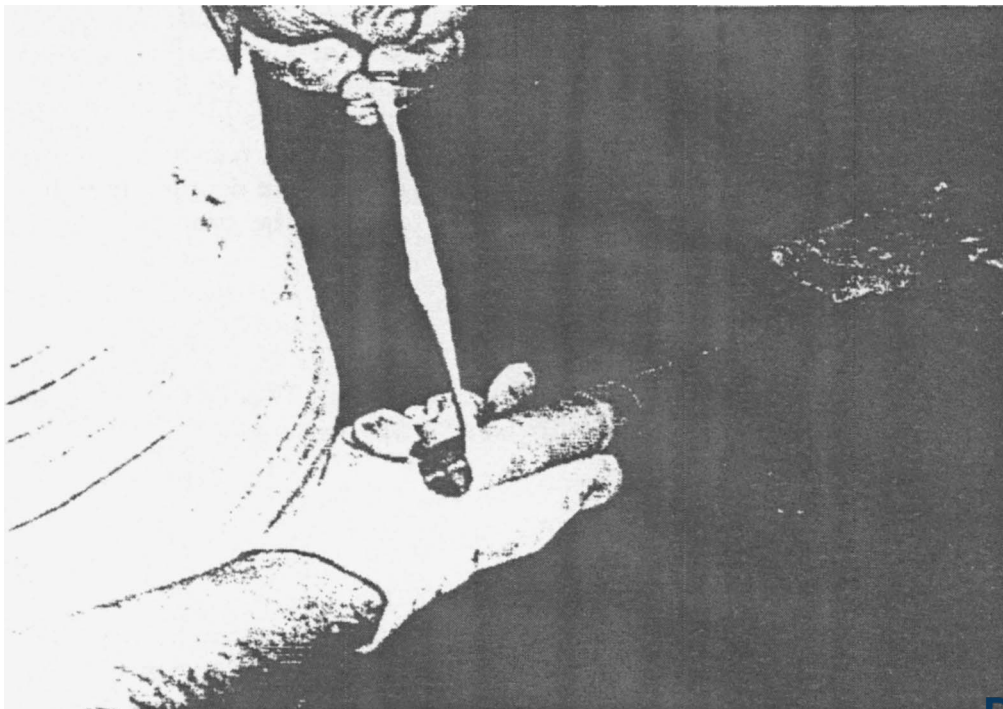


Figure 2.9 MASKING FOR THERMAL SPRAYING

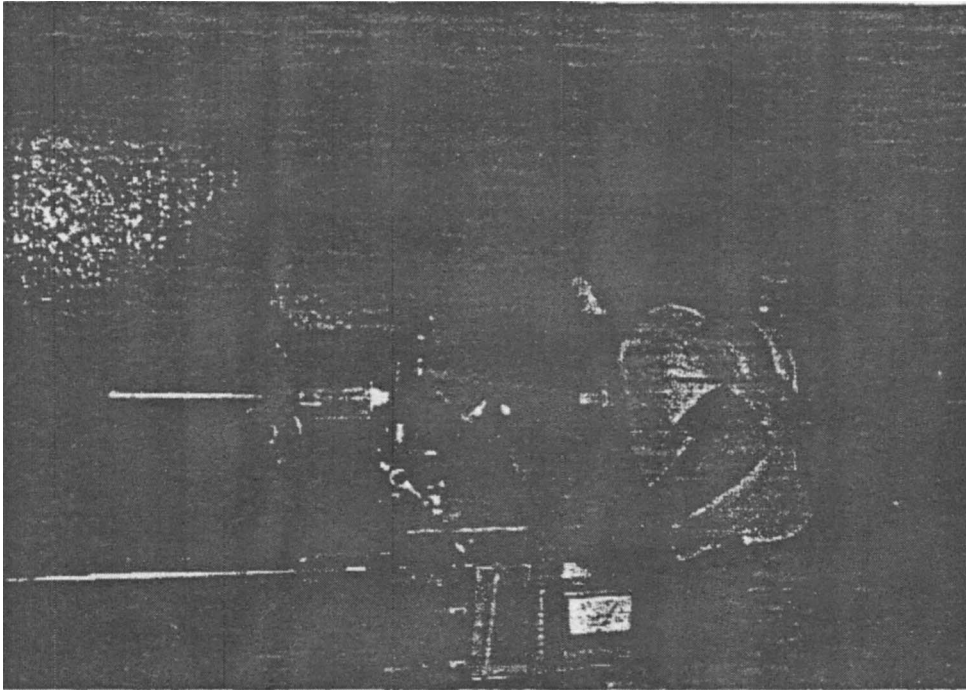


Figure 2.10 PRE HEATING

COOLING & SEALING

When thermal spraying is completed, the operator permits the machinery component to cool. During the cooling cycle, the machinery component should, if practical, be left rotating in the turning fixture to help prevent warpage. While the component is being cooled, the operator may complete Section VII and signs and dates the appropriate area of Section III of the Thermal Spray Job Control Record. When the coating temperature cools to 125° F, a sealer is applied. Phenolic resins in solution are generally used by most ship repair and ship manufacturing facilities. Sealers can be applied by spraying or brushing. More detailed information on cooling and sealing of thermal sprayed machinery components can be found in the "Thermal Spray Operation" Section of this Manual (Section 7)).

DEMASKING

Usually the thermal spray operator removes the masking. This can be done before, after, or during the cooling cycle. Operators must take precautions not to damage the coating while removing the masking.

FINISHING

The machinery component and the Thermal Spray Job Control Record are then sent to the machine shop for finishing. In the case of the demonstration pump shaft, wet grinding was selected as the method of finishing. This is due to the fact that the coating used for the pump shaft required a finish that was unattainable by tooling. Thermal sprayed coatings are routinely machined by wet grinding in lieu of single point tooling.

2.10/SEQUENCE OF A THERMAL SPRAY JOB

FINAL INSPECTION

After the machine shop has completed finishing the thermal sprayed coating, the machinery component and Thermal Spray Job Control Record are sent back to the thermal spray operator. A qualified inspector visually inspects and measures the coating. If the coating passes inspection, the foreman or a designated inspector signs and completes the appropriate portion of Section VI of the TSJCR.



Figure 2.11 FINAL INSPECTION

NOTE:	If the coating fails inspection because of a defect, the coating is removed and the component is resprayed.
--------------	---

At this time, the inspector applies the final coat of phenolic sealer. Because the component has low temperature service, a phenolic sealer works well. The component and Thermal Spray Job Control Record are shipped to the installation shop's inspector where it is examined to assure the finish product meets the plan requirements. If the component meets all of the requirements, the inspector signs the appropriate portion of Section VI of the Thermal Spray Job Control Record and ships the Record back to the thermal spray shop. Thermal spray shop personnel check the Thermal Spray Job Control Record for accuracy and completeness and file copies for future reference. The thermal sprayed surface is protected from damage and the component is then sent to the installation mechanic who completes the final task by installing the component.

NOTE: In some cases, the movement of components and handling of records, as they are sequenced in this chapter, prove to be impractical. When this occurs, the thermal spray shop controls the original Thermal Spray Job Control Record, leaves a copy with the component, and goes to the component whenever practical. This process helps to avoid excessive shipping delays and prevent losses of records and inadvertent damage to thermal sprayed coatings such as ceramics.

IN CONCLUSION

The preceding over site sequence system was developed to enable Naval Shipyards to meet the requirements of MIL-STD-1687 "Thermal Spray Processes for Naval Machinery Applications". Facilities that are thermal spraying machinery components that are used on other than United States Naval Ships should be able to adapt this sequence system to their own circumstances without any loss of product quality.

THERMAL SPRAY MANUAL

ENGINEERING PLANNING INSTRUCTION *		JOB ORDER 81464-90001	KEY-OP 001	REV -																
HULL	COMPONENT AND TITLE THERMAL SPRAY PUMP SHAFT		ABBREVIATED TITLE																	
APL NUMBER		ZONE	LOCATION	CUI																
WORK SCOPE																				
THIS EPI ISSUED TO THERMAL SPRAY REPAIR PUMP SHAFT. PUMP SHAFT IN THE IMPELLER FIT AREA IS SCORED.																				
SPECIAL WORK CONSIDERATIONS																				
OBJECTIVE QUALITY EVIDENCE REQD REPORTS REQUIRED																				
SUMMARY																				
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">TASK ID</th> <th style="width: 10%;">SHOP</th> <th style="width: 10%;">MHR</th> <th style="width: 10%;">STD</th> </tr> </thead> <tbody> <tr> <td>01</td> <td>31</td> <td>M1</td> <td>4</td> </tr> <tr> <td>02</td> <td>26</td> <td>W4</td> <td>6</td> </tr> <tr> <td>03</td> <td>31</td> <td>M1</td> <td>6</td> </tr> </tbody> </table>				TASK ID	SHOP	MHR	STD	01	31	M1	4	02	26	W4	6	03	31	M1	6	
TASK ID	SHOP	MHR	STD																	
01	31	M1	4																	
02	26	W4	6																	
03	31	M1	6																	
MATERIAL 100		EPID FUNDS AUTHORIZATION 1213.8-8146446-0140																		
REVIEW																				
PLANNING (SIGNATURE/CODE)		TECHNICAL (SIGNATURE/CODE)		BRANCH MANAGER (SIGNATURE/CODE)																
DISTRIBUTION																				
COPIES TO: 1213, 246, 362, 133, 136, 224, 260.27, 260.24																				
ROUTING																				
CODE	260.27	260.24	260.2																	
INITIALS																				
DATE																				

* This instruction is initiated by engineering or planning personnel. For repeat/routine work this instruction may be eliminated.

SEQUENCE OF A THERMAL SPRAY JOB

EPI TASK WORK PERMIT/AUTHORIZATION	JOB ORDER 81464-90001	KEY -OP 001	TASK ID 01	TASK REV -
HULL	TASK DESCRIPTION MACHINE PUMP SHAFT		ABBREVIATED TITLE TSR SHAFT	
SYSTEM	ZONE NA	LOCATION S/31	PHASE	CUI
SHOP 31	TSD M1	MAN HORS 4	MAN-HRS REV	STANDARD
PLANNER SHANNON	6-3288	CODE 260.27	BORTVEDT	6-2995
WORK AUTHORIZATION				
SSO/SSS			DATE	
SF CONCURRENCE			DATE	
WTC APPROVAL TO PROCEED WITH WORK			DATE	
TASK/CLOSURE CERTIFICATION				
MECHANIC (SIGNATURE)		SUPERVISOR (SIGNATURE)/DATE		SHOP/CODE BADGE
1. Mechanics signature certifies understands and completion of technical direction.		2. Supervisor's signature certifies completion of task.		3. Send certified copy to Code 246.3.
WORK CONTROL COMPLETION				
SHIPS FORCE			DATE	
WTC			DATE	
SPECIAL CONSIDERATIONS				
OBJECTIVE QUALITY EVIDENCE REQD				
TECHNICAL DIRECTION				
REF: A. MNP 13577 REV B PUMP SHAFT B. PROCESS INSTRUCTION "THERMAL SPRAY MACHINE REPAIR" <1> MACHINE PUMP SHAFT, TO TSJCR No 110-95, AT 1.345" ± 0.005" DIAMETERS TO REMOVE DAMAGED AND SCORED SURFACES. MACHINE TO BE PER REF (B) PARA 6.2.2.1. <2> ENTRY ANGLES TO REDUCED SHAFT DIAMETERS TO BE AT 45 DEGREES, PROVIDE .015/.020" RADIUS AT CORNERS OF UNDERCUT. SHAFT SHOULDERS TO BE PER REF (B) PARA. 6.2.2.3. DO NOT REDUCE SHAFT DIAMETERS WITHIN 1/8" OF THE END OF THE SHAFT. <3> AT COMPLETION OF MACHINING FORWARD PREPARED PUMP SHAFT TO SHOP 26 THERMAL SPRAY FACILITY, BUILDING 460.				

THERMAL SPRAY MANUAL

EPI TASK WORK PERMIT/AUTHORIZATION	JOB ORDER 81464-90001	KEY -OP 001	TASK ID 01	TASK REV -
HULL	TASK DESCRIPTION THERMAL SPRAY PUMP SHAFT		ABBREVIATED TITLE TSR SHAFT	
SYSTEM	ZONE NA	LOCATION S/31	PHASE	CUI
SHOP 26	TSD W4	MAN HORS 6	MAN-HRS REV	STANDARD
PLANNER SHANNON	6-3288	CODE 260.27	BORTVEDT	6-2995
WORK AUTHORIZATION				
SSO/SSS			DATE	
SF CONCURRENCE			DATE	
WTC APPROVAL TO PROCEED WITH WORK			DATE	
TASK/CLOSURE CERTIFICATION				
MECHANIC (SIGNATURE)		SUPERVISOR (SIGNATURE)/DATE		BADGE
1. Mechanics signature certifies understands and completion of technical direction.		2. Supervisor's signature certifies completion of task.		3. Send certified copy to Code 246.3.
WORK CONTROL COMPLETION				
SHIPS FORCE			DATE	
WTC			DATE	
SPECIAL CONSIDERATIONS				
OBJECTIVE QUALITY EVIDENCE REQD				
TECHNICAL DIRECTION				
REF: A. MNP 13577 REV B PUMP SHAFT B. PROCESS INSTRUCTION "THERMAL SPRAY MACHINE REPAIR" <1> RECEIVE PUMP SHAFT, REF (A) FROM SHOP 31 (MACHINE SHOP) AT COMPLETION OF PRELIMINARY MACHINING. <2> ACCOMPLISH REF (B) PARA. 6.2.3 AND 6.2.5 SPECIFIED MASKING AND ANCHOR TOOTH BLASTING. <3> THERMAL SPRAY PUMP SHAFT TO PROVIDE SUFFICIENT BUILDUP FOR FINISH MACHINING. PUMP SHAFT MATERIAL IS 400 CRES. PER CODE 138 RECOMMENDATION THERMAL SPRAY COATING TO BE EUTECTIC 21031. <4> AT COMPLETION OF THERMAL SPRAYING FORWARD PREPARED PUMP SHAFT TO SHOP 31 FOR FINISH MACHINING.				

SEQUENCE OF A THERMAL SPRAY JOB

EPI TASK WORK PERMIT/AUTHORIZATION	JOB ORDER 81464-90001	KEY -OP 001	TASK ID 01	TASK REV -
HULL	TASK DESCRIPTION FINISH MACHINE PUMP SHAFT		ABBREVIATED TITLE TSR SHAFT	
SYSTEM	ZONE NA	LOCATION S/31	PHASE	CUI
SHOP 31	TSD M1	MAN HORS 6	MAN-HRS REV	STANDARD
PLANNER SHANNON	6-3288	CODE 260.27	BORTVEDT	6-2995
WORK AUTHORIZATION				
SSO/SSS			DATE	
SF CONCURRENCE			DATE	
WTC APPROVAL TO PROCEED WITH WORK			DATE	
TASK/CLOSURE CERTIFICATION				
MECHANIC (SIGNATURE)	SUPERVISOR (SIGNATURE)/DATE		SHOP/CODE	BADGE
1. Mechanics signature certifies understands and completion of technical direction.	2. Supervisor's signature certifies completion of task.		3. Send certified copy to Code 246.3.	
WORK CONTROL COMPLETION				
SHIPS FORCE			DATE	
WTC			DATE	
SPECIAL CONSIDERATIONS				
OBJECTIVE QUALITY EVIDENCE REQD				
TECHNICAL DIRECTION				
REF: A. MNP 13577 REV B PUMP SHAFT <1> FINISH MACHINE/GRIND THERMAL SPRAY BUILDUP AREAS TO FINISH SIZE OF 1.372" $\pm$.001". MACHINING/GRINDING TO BE CONCENTRIC TO BEARING DIAMETERS WITHIN .001". SURFACE FINISH TO BE 64 RHR MINIMUM. <2> UPON COMPLETION OF FINISH MACHINING/GRINDING CONTACT SHOP 26 FOR FINAL COATING INSPECTION AND APPLICATION OF SURFACE SEALER. SEALER TO BE METCO AP.				

THERMAL SPRAY JOB CONTROL RECORD (TSJCR)				SERIAL No. 110-95		REF MIL-STD-1687										
SECTION I JOB DATA	JOB ORDER NUMBER 81464-90001-000		SHIP/PROJECT USS THERMAL SPRAY MANUAL		OPERATING MEDIUM WATER											
	FOREMAN/SHOP TRAVIS/138		PHONE 360-476-2469		MECHANIC/SHOP GUNTHER/SHOP 26		PHONE 8812									
	PART DESCRIPTION PUMP SHAFT				DRAWING NO. 88878C-29341349-52		PC. NO. 8									
	FUNCTION OF COATING IMPELLER FIT AREA		BASE MATERIAL/ALLOY/MIL SPEC/ETC 400 SERIES CRES				SCHED COMPL DATE									
	REASON FOR SPRAYING SCORING			SHIP SYSTEM FRESH WATER												
SECTION II PREPARATION	1. PROVIDE CENTERS BOTH ENDS 2. UNDERCUT AND FINISH ON SAME CENTERS CONCENTRIC TO AREAS C AND D WITHIN .001" 3. REMOVE MINIMUM AMOUNT OF MATERIAL NECESSARY TO REMOVE SURFACE DAMAGE 4. MAX TAPER OF UNDERCUT .002" <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="font-size: small;">UNDERCUT DIAMETER "A"</td> <td style="text-align: right;">1.345</td> <td style="text-align: right;">±0.005</td> </tr> <tr> <td style="font-size: small;">ACTUAL DIA "A"</td> <td style="text-align: right;">1.344</td> <td></td> </tr> <tr> <td style="font-size: small;">(FINISH) DIA "B"</td> <td style="text-align: right;">1.372</td> <td style="text-align: right;">±0.001</td> </tr> </table>							UNDERCUT DIAMETER "A"	1.345	±0.005	ACTUAL DIA "A"	1.344		(FINISH) DIA "B"	1.372	±0.001
	UNDERCUT DIAMETER "A"	1.345	±0.005													
ACTUAL DIA "A"	1.344															
(FINISH) DIA "B"	1.372	±0.001														
SECTION III SPRAYING SHOP	PROCEDURE I.D. (APP OR MWP#) APP#9			SEALER TYPE AP		SECTION IV APPROVALS										
	BOND COAT MATERIAL/PROCESS N/A			AUTHORIZING DOCUMENT IDENTIFICATION MIL-STD-1687A												
	FINISH COAT MATERIAL/PROCESS EUTECTIC 31031/PLASMA POWDER															
	S/26 OPERATOR (SIGNATURE)			DATE		SECTION V FINAL MACHINING										
S/26 FOREMAN (SIGNATURE)			DATE													
SECTION VI VERIFICATION SIGNATURES	1. TSJCR UNDERCUT INSTRUCTIONS MEET EPI REQUIREMENTS			(Signature)(S/31)			DATE									
	2. MACHINED PREPARATION IS IN ACCORDANCE WITH SKETCH			(Signature)(S/26)			DATE									
	3. INSPECTION OF FINISHED SURFACE (RESULTS FOUND IN SECTION VIII)			(Signature)(S/26)			DATE									
	4. FINISHED SURFACE CONDITION MEETS PLAN REQ. FOR SIZE, SURFACE COND.			(Signature)(Lead Shop)			DATE									
SECTION VII SPRAY DATA	METHOD OF SURFACE PREPARATION ☐ ALUMINUM OXIDE BLASTING ☐ THREADING ☐ OTHER (SPECIFY):			SECTION VIII INSPECTION INSPECTION METHODS USED: ☐ VISUAL ☒ DIMENSION ☐ THERMAL WAVE NDE ☐ OTHER (SPECIFY): ACCEPTANCE STANDARD: ☐ PROCESS INSTRUCTION ☐ OTHER (SPECIFY): ☐ SAT ☐ UNSAT ☐ SAT ☐ UNSAT ☐ SAT ☐ UNSAT ☐ SAT ☐ UNSAT												
	ANCHOR TOOTH HEIGHT (MILS) <u>1.3</u>															
	BOND COATING THICKNESS APPLIED <u>N/A</u>															
	FINISH COATING THICKNESS APPLIED <u>.028</u>															
	TOTAL COATING THICKNESS APPLIED <u>.028</u>															
REMARKS:																

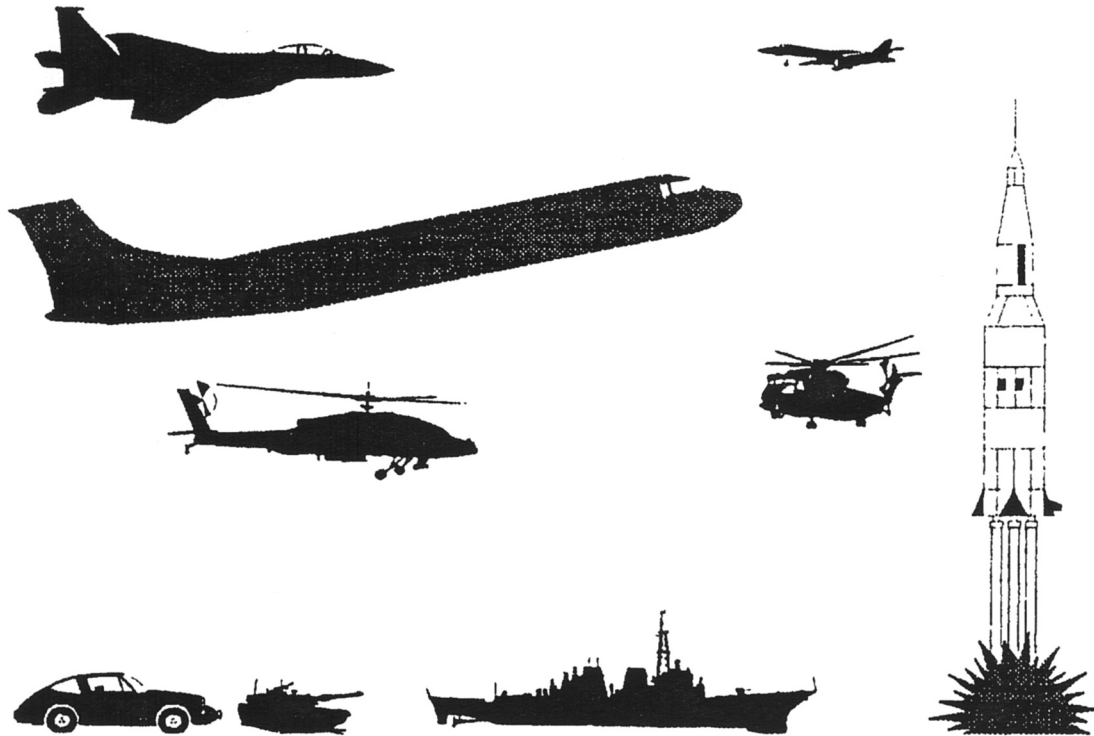


Documents

Document Sharing Hub

SECTION 3

THERMAL SPRAY APPLICATIONS



PREPARED BY: PUGET SOUND NAVAL SHIPYARD

THERMAL SPRAY APPLICATIONS

INTRODUCTION

Thermal spraying is typically performed to restore the dimensions of a machinery component and to a lesser degree to improve surface performance. Some reasons for dimensional restoration include wear, erosion, corrosion or mismachining. Most of the machinery components repaired by this process are shafts. Some ship building and ship repair facilities have used the thermal spray process to repair inside bores. Other thermal spray facilities have repaired mating surfaces of pump casings and babbitt bearings.

HISTORY

Before the Naval Sea Systems Command would permit the use of the thermal spray process on shipboard components, testing was completed to determine the reliability and effectiveness of the process as a repair method for critical machinery components. The Naval Sea System Command; the Naval Surface Warfare Center Annapolis, Maryland (formerly David Taylor Naval Ship Research and Development Center); and Puget Sound Naval Shipyard developed a program to assess the performance of new thermal spray coatings and techniques and to review past industrial applications. To determine the reliability of ships machinery thermal spray applications, the following four-pronged approach was developed:

1. Compile and evaluate case histories of thermal sprayed components.
2. Perform thermal spray coating laboratory and procedure qualification testing.
3. Perform land based service testing of thermal sprayed components.
4. Perform fatigue, wear, corrosion, and shock testing of thermal spray machinery components.

CURRENT APPLICATIONS

Because the above four-pronged program was highly successful, the Naval Sea System Command approved thermal spray applications on many critical machinery components. The Naval Sea System Command's Military Standard 1687 covers the thermal spray processes for repair and overhaul of naval ship machinery and ordnance components. Permitted applications on surface ships presently include main feed pumps, forced draft blowers, and other equipment of equal or lesser criticality. One good example of a Naval Sea Systems Command approved application is the thermal spraying of 410 stainless steel steam valve stems. Steam valve stems have been approved for thermal spraying, because of the cost savings obtained (approximately \$1,000.00 per stem) by repairing the stems instead of purchasing or manufacturing new ones. The coating system used to repair these components is a plasma sprayed bond coating of Eutectic 21031 (Nickel, Chromium, Molybdenum & Aluminum) and a plasma sprayed ceramic final coat of Metco 143 (Zirconia, Titania & Yttria). Frequently these thermal sprayed coatings perform better than new components. Thermal sprayed ceramic stems have superior stagnant fresh water and sea-water corrosion resistance.

3.2/APPLICATIONS

Other approved repairs on machinery components include:

1. Repair of static fit areas to restore original dimensions, finish, and alignment.
2. Repair of seal (including packing) areas to restore original dimensions and finish.
3. Repair of fit areas on shafts to restore original dimensions and finish (except for motor generator sets).
4. Buildup on pump shaft sleeves and wear rings to restore original dimensions.
5. Repair of bearing shaft journals to restore original dimensions.
6. Babbitt bearings for auxiliary equipment.
7. Turbine pump casing flanges to restore original dimensions.
8. Ceramic for corrosion/erosion protection.
9. Exposed areas on shafts to restore surface finish requirements.
10. Ceramic to overcome galling tendencies of current designs.

On United States Navy Ships, applications not specified in Military Standard 1687 require Naval Sea Systems Command approval for each item to be sprayed. That approval should be based on the results of laboratory or service tests to determine the adequacy of using the thermal spray process in the proposed application.

TABLE 3.1 has been created to list some of the types of components which have been repaired by using the thermal spray process. This list of components was obtained from the data base that is kept by the Naval Surface Warfare Center in Annapolis, Maryland. All of the machinery components listed are known successful thermal spray applications performed by Puget Sound Naval Shipyard, Naval Intermediate Maintenance Activities (IMAs), the Naval Shore Repair Facility (SRF) Guam, and private ship repair facilities.

CONCLUSION

In addition to the various types of components currently in service, the potential exists for many new thermal spray applications on military and commercial vessels. Manufacturers produce a wide variety of thermal spray materials to meet the needs of many applications. TABLE 3.2 list a broad range of current and potential applications for which coating materials exist. It is important to note that many of the applications suggested by this table go far beyond the current limits of MIL-STD-1687 approval.

3.3/THERMAL SPRAY APPLICATIONS

TABLE 3.1

CURRENT APPLICATIONS

COMPONENT	SHIPS SYSTEM	AREA REPAIRED	BASE MATERIAL	ENVIRONMENT	* PROCESS	THERMAL SPRAY MATERIAL
FORCE DRAFT BLOWER SHAFT	FORCE DRAFT BLOWER	LABYRINTH SEAL	CARBON STEEL	STEAM	FINAL PP	EUTECTIC 21031
PUMP SHAFT	CONTAMINATED HOLDING TANK	PACKING	NiCu	SALT WATER	BOND PP	DRESSER PP-25
					FINAL PP	METCO 130
WORM SHAFT	LUBE OIL	SEAL	CARBON STEEL	FUEL OIL	FINAL PP	METCO 444
ROTOR SHAFT	PUMP MOTOR	JOURNAL	NiCu	FRESH WATER	FINAL PP	DRESSER P-25
VALVE STEM	MAIN STOP VALVE	PACKING	410 STAINLESS STEEL	STEAM	BOND PP	EUTECTIC 21031
					FINAL PP	METCO 130
SHAFT SLEEVE	CIRCULATING PUMP	PACKING	K-MONEL	SALT WATER	BOND PP	DRESSER PP-25
					FINAL PP	METCO 130
VALVE STEM	MS-9 VALVE	PACKING	410 STAINLESS	STEAM	BOND PP	EUTECTIC 21031
					FINAL PP	METCO 143
PUMP SHAFT	SALT WATER COOLING	FIT	NiCu	SALT WATER	FINAL PP	DRESSER PP-25
VALVE FLANGE	RELIEF VALVE	FLANGE	BRONZE	SALT WATER	FINAL FW	METCO SPRAYBRONZE AA
PUMP SHAFT	DISTILLATION	JOURNAL	NiCu	FRESH WATER	FINAL FP	DRESSER PP-25

*
 AW = ARC WIRE PROCESS
 FW = FLAME WIRE PROCESS
 PP = PLASMA POWDER PROCESS
 FP = FLAME POWDER PROCESS

3.4/THERMAL SPRAY APPLICATIONS

TABLE 3.1

CURRENT APPLICATIONS

COMPONENT	SHIPS SYSTEM	AREA REPAIRED	BASE MATERIAL	ENVIRONMENT	* PROCESS	THERMAL SPRAY MATERIAL
END BELL	PUMP MOTOR	EDGE	CAST IRON	SALT WATER	FINAL PP	EUTECTIC 21031
MOTOR SHAFT	AC MOTOR	FIT	CARBON STEEL	AIR	FINAL PP	METCO 444
PUMP SHAFT	LUBE OIL	SEAL	CARBON STEEL	LUBE OIL	FINAL PP	METCO 443
SHAFT	MAIN FEED BOOSTER	SEAL	CARBON STEEL	SALT WATER	BOND PP	EUTECTIC 21031
					FINAL PP	METCO 130
STRAINER PLUG	SALT WATER CIRCULATION	OUTSIDE DIAMETER	BRONZE	SALT WATER	FINAL AW	METCO SPRAYBRONZE AA
STRAINER PLUG	SALT WATER CIRCULATION	OUTSIDE DIAMETER	BRONZE	SALT WATER	FINAL FW	METCO SPRAYBRONZE AA
STRAINER PLUG	LUBE OIL	OUTSIDE DIAMETER	BRONZE	LUBE OIL	FINAL FW	METCO SPRAYBRONZE AA
TURBINE ROTOR SHAFT	AUXILIARY STEAM	PACKING	CARBON STEEL	STEAM	BOND PP	METCO 443
					FINAL PP	METCO 130
TURBINE ROTOR SHAFT	AUXILIARY STEAM	BEARING JOURNAL	CARBON STEEL	OIL	BOND PP	METCO 443
					FINAL PP	METCO 130

- AW = ARC WIRE PROCESS
FW = FLAME WIRE PROCESS
PP = PLASMA POWDER PROCESS
FP = FLAME POWDER PROCESS

3.5/THERMAL SPRAY APPLICATIONS

TABLE 3.1

CURRENT APPLICATIONS

COMPONENT	SHIPS SYSTEM	AREA REPAIRED	BASE MATERIAL	ENVIRONMENT	PROCESS	THERMAL SPRAY MATERIAL
END BELL	VENTILATION SYSTEM	BEARING JOURNAL	CARBON STEEL	AIR	FINAL FP	METCO 444
PLUG	DUPLEX STRAINER	OUTSIDE DIAMETER	BRASS	SALT WATER	BOND FW	METCO 405
					FINAL FW	METCO SPRAYBRONZE AA
STUB SHAFT	MAIN PROPULSION	SEAL	BRONZE	SALT WATER	BOND PP	METCO 445
					FINAL PP	METCO 130
DONKEY BOILER	RECIRCULATING PUMP	PACKING	CARBON STEEL	CONDENSATE STEAM	FINAL PP	EUTECTIC 21031
VALVE STEM	MAIN FEED PUMP GOVERNOR	PACKING	STAINLESS STEEL	STEAM	BOND PP	EUTECTIC 21031
					FINAL PP	METCO 143
ROTOR SHAFT	CONTAMINATED HOLDING TANK	IMPELLER FIT	NiCu	SEWAGE/ WASTE	FINAL PP	DRESSER PP-25
PUMP PLUNGER	BRINE PUMP	PACKING	STAINLESS STEEL	BRINE	BOND PP	METCO 444
					FINAL PP	METCO 136F
BEARING HOUSING	BALLAST PUMP	INSIDE DIAMETER	BRONZE	GREASE	FINAL PP	METCO 445

*
 AW = ARC WIRE PROCESS
 FW = FLAME WIRE PROCESS
 PP = PLASMA POWDER PROCESS
 FP = FLAME POWDER PROCESS

3.6/THERMAL SPRAY APPLICATIONS

TABLE 3.1

CURRENT APPLICATIONS

COMPONENT	SHIPS SYSTEM	AREA REPAIRED	BASE MATERIAL	ENVIRONMENT	* PROCESS	THERMAL SPRAY MATERIAL
BABBITT BEARING SHELL	LUBE OIL PUMP	OUTSIDE DIAMETER	CARBON STEEL	AIR	FINAL PP	METCO 447
EXPANSION JOINT	CATAPULT STEAM	PACKING	CuNi	STEAM	BOND PP	EUTECTIC 21021
					FINAL PP	METCO 130
BABBITT BEARING	TURBINE GENERATOR	INSIDE DIAMETER	BABBITT	OIL	FINAL AW	BABBITT
PLUNGER	AIRCRAFT ELEVATOR	OUTSIDE DIAMETER	CARBON STEEL	GREASE	FINAL AW	METCO METCOLOY #2
FLOW SERVICE PUMP	FUEL OIL	PACKING	CARBON STEEL	FUEL OIL	BOND PP	METCO 447
					FINAL PP	METCO 130
POTABLE WATER MOTOR SHAFT	POTABLE WATER	JOURNAL	NiCu	POTABLE WATER	FINAL PP	DRESSER PP-25
ROTOR SHAFT	WATER PUMP	PACKING	CARBON STEEL	FRESH WATER	BOND PP	METCO 447
					FINAL PP	METCO 130
MOTOR SHAFT	MOGAS PUMP	FIT	CARBON STEEL	AIR	FINAL PP	METCO 444
ROTOR SHAFT	SALT WATER COOLING PUMP	PACKING	NiCu	SALT WATER	BOND PP	DRESSER PP-25
					FINAL PP	METCO 130

*
 AW = ARC WIRE PROCESS
 FW = FLAME WIRE PROCESS
 PP = PLASMA POWDER PROCESS
 FP = FLAME POWDER PROCESS

3.7/THERMAL SPRAY APPLICATIONS

TABLE 3.1

CURRENT APPLICATIONS

COMPONENT	SHIPS SYSTEM	AREA REPAIRED	BASE MATERIAL	ENVIRONMENT	* PROCESS	THERMAL SPRAY MATERIAL
ROTOR SHAFT	VENTILATION	FIT	CARBON STEEL	AIR	FINAL PP	METCO 447
PUMP SHAFT	SSTG PUMP	FIT	CARBON STEEL	AIR	FINAL PP	METCO 444
HD-977 SP PUMP SHAFT	SP-5-49 COOLING	SEAL	NiCu	SALT WATER	BOND PP	DRESSER PP-25
					FINAL PP	METCO 130
PUMP SHAFT	ELECTRONIC COOLING	SEAL	NiCu	FRESH WATER	BOND PP	DRESSER PP-25
					FINAL PP	METCO 130
PUMP CASING	FIRE PUMP	INSIDE DIAMETER (BEARING JOURNAL FIT)	CARBON STEEL	OIL	FINAL AW	TAFB 75B
PUMP SHAFT	CHILL WATER PUMP	FIT	NiCu	AIR	FINAL AW	EN-60
THRUST ROLLER PLUNGER	AIRCRAFT ELEVATOR		CARBON STEEL	GREASE	FINAL AW	METCO METCOLOY #2
PLUNGER	AIRCRAFT ELEVATOR	SEAL	CARBON STEEL	GREASE	BOND PP	METCO 444
					FINAL PP	METCO 130

- AW = ARC WIRE PROCESS
FW = FLAME WIRE PROCESS
PP = PLASMA POWDER PROCESS
FP = FLAME POWDER PROCESS

3.8/THERMAL SPRAY APPLICATIONS

TABLE 3.1

CURRENT APPLICATIONS

COMPONENT	SHIPS SYSTEM	AREA REPAIRED	BASE MATERIAL	ENVIRONMENT	* PROCESS	THERMAL SPRAY MATERIAL
PISTON ROD	AIRCRAFT ELEVATOR	SEAL	CARBON STEEL	AIR	BOND PP	METCO 447
					FINAL PP	METCO 130
STEAM VALVE STEM	CATAPULT	PACKING	410 STAINLESS STEEL	STEAM	BOND PP	METCO 444
					FINAL PP	METCO 143
IMPELLER	CATAPULT	FIT	GUN METAL BRONZE		FINAL AW	AMPCO 10
PUMP SHAFT	EMERGENCY DIESEL	PACKING	STAINLESS STEEL		BOND PP	METCO 447
					FINAL PP	METCO 130
ROTOR SHAFT	DEFUELING PUMP	FIT	NiCu	OIL	FINAL AW	EN-60
RETRACT SHEAVE SHAFT	ARRESTING GEAR	FIT	CARBON STEEL	STEAM	FINAL PP	METCO 447

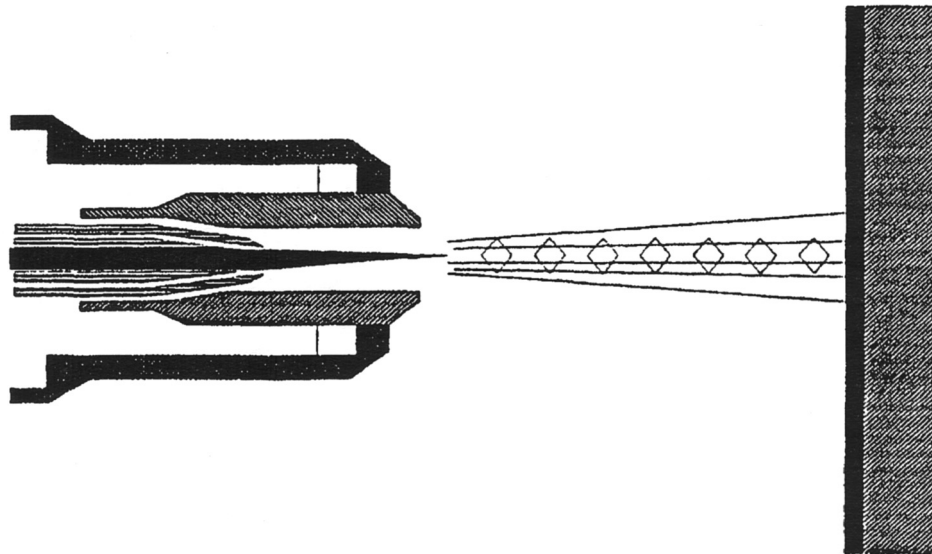
- AW = ARC WIRE PROCESS
FW = FLAME WIRE PROCESS
PP = PLASMA POWDER PROCESS
FP = FLAME POWDER PROCESS

TABLE 3.2	
POTENTIAL THERMAL SPRAY APPLICATIONS	
GENERAL APPLICATIONS	SPECIFIC CONDITIONS
WEAR RESISTANCE	SOFT BEARINGS HARD BEARINGS ABRASIVE RESISTANT FIBER/THREAD CAVITATION PARTICLE EROSION
HEAT & OXIDATION RESISTANCE	OXIDIZING ATMOSPHERES CORROSIVE GASES THERMAL BARRIERS MOLTEN METAL HANDLING
CORROSION RESISTANCE	INDUSTRIAL & SALT ATMOSPHERE FRESH WATER SALT WATER CHEMICAL & FOOD PROCESSING
ELECTRICAL	CONDUCTIVE RESISTORS INSULATORS RADIO FREQUENCY SHIELDING
RESTORATION OF DIMENSIONS	MACHINABLE MATERIALS GRINDABLE MATERIALS VARIOUS ALLOYS
MACHINE ELEMENT CLEARANCE CONTROL	ABRADABLE COATINGS ABRASIVE COATINGS
CHEMICAL CORROSION RESISTANCE	METAL COATINGS CERAMIC COATINGS CERMETS PLASTICS

The thermal spray materials tabulated in this manual have been so listed because of the experience Naval facilities have had using these manufacturers in the past. It is to be noted that other companies also produce excellent quality and equivalent thermal spray materials.

SECTION 4

THERMAL SPRAYING PROCESSES



PREPARED BY: PUGET SOUND NAVAL SHIPYARD

INTRODUCTION

The primary thermal spray processes being used by the marine repair industry are the plasma powder, arc wire, flame wire, high velocity oxygen fuel, and flame powder processes.

PROCESS SELECTION

When choosing a thermal spray process for a specific application, numerous factors which affect quality and productivity must be compared. This can become a complex decision due to the number of conflicting advantages and limitations which each process may possess for a given situation. Each process can be ranked in terms of its deposition rate in pounds of thermal spray material deposited per hour. However, there are other factors which must be considered. For instance, a new process may have a high deposition rate, but may require extensive training and research and development for procedure qualifications. With some processes, the cost to set up in a field situation may be prohibitive. Process selection should be based on personnel skill and their knowledge of available processes. Many factors must be taken into account for the best process selection.

EQUIPMENT AVAILABLE

Most large thermal spray shops have access to the spraying equipment required for the processes discussed. There are times although, when new equipment must be evaluated. TABLE 4.1 is a comparison guide for the most routinely used processes in the marine repair industry.

TABLE 4.1

THERMAL SPRAY PROCESS	PLASMA POWDER	ARC WIRE	FLAME POWDER	FLAME WIRE	HVOF
QUALITY	EXCELLENT	EXCELLENT	GOOD	GOOD	EXCELLENT
SPRAY RATE	GOOD	EXCELLENT	MEDIUM	MEDIUM	GOOD
PORTABILITY	POOR	EXCELLENT	EXCELLENT	GOOD	EXCELLENT
EQUIPMENT MAINTENANCE	MEDIUM	LOW	LOW	MEDIUM	HIGH
OPERATOR SKILL REQUIRED	HIGH	LOW	LOW	MEDIUM	MEDIUM
COST	HIGH	LOW	LOW	LOW	HIGH

This table demonstrates that many variables must be taken into account when selecting the best thermal spray process for a given application. In practice it takes experience to identify and accurately weigh all of the variables involved. The following is a description of these common thermal spraying processes and a summary of their advantages and limitations.

PLASMA POWDER

With the plasma powder process, an arc that is created between a tungsten electrode and a copper nozzle produces the heating zone. The tungsten electrode and nozzle are located in a conducting channel inside the plasma powder gun. A gas or gas mixture passes through this channel. The arc in the gas channel excites the gas into a plasma state, creating temperatures higher than can be obtained with any type of oxygen fuel mixture. The gas or gas mixture then exits the gun forcing the plasma flame outside the gun. A powder is fed into the flame where it is melted and propelled at sonic or higher velocities to the substrate.

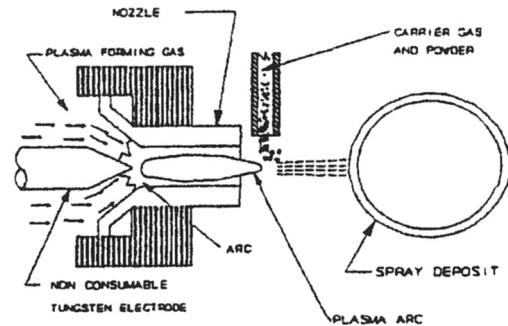


Figure 4.1

ADVANTAGES

- Reliable
- Capable of spraying all thermal spray powders, including ceramics
- Produces coatings with high bond strengths, low porosity, and low oxides
- Easily adapted to robotics
- Low substrate heat input
- Good deposition rates

LIMITATIONS

- Not as portable as some of the other thermal spray processes
- High operating cost
- High start-up cost
- Requires highly skilled thermal spray operators
- High intensity ultra-violet light can quickly cause flash burns to inadequately protected skin or eyes
- May require water cooling
- High noise levels generally require double hearing protection for operators and any other personnel who must work nearby

ARC WIRE

The heating zone with the arc wire process forms when an electric arc passes between two continuously fed metallic wires. Compressed air or an inert gas then atomizes and propels the molten material to the substrate.

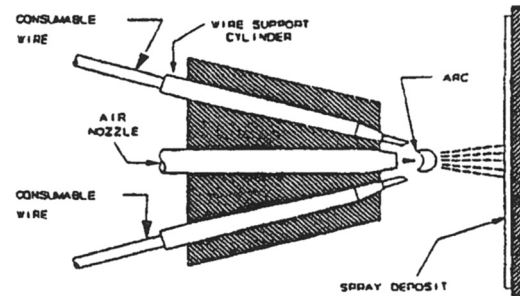


Figure 4.2

ADVANTAGES

- Very portable
- Easy to operate
- High deposition rates
- Relatively inexpensive to purchase and operate
- Produces coatings with high bond strengths
- Has the ability to use low cost materials such as welding wires
- Very low heat input

LIMITATIONS

- Can not thermal spray ceramics (except for a few specialty cermet wires designed for producing non-skid coatings)
- Higher porosity and oxides than plasma powder and high velocity oxygen fuel coatings
- High intensity ultra-violet light can quickly cause flash burns to inadequately protected skin or eyes

FLAME WIRE

The flame wire process uses an oxygen fuel flame to create the heating zone. A wire continuously fed into the heating zone is melted, atomized, and then propelled onto the substrate by the force of the burning gasses and compressed air.

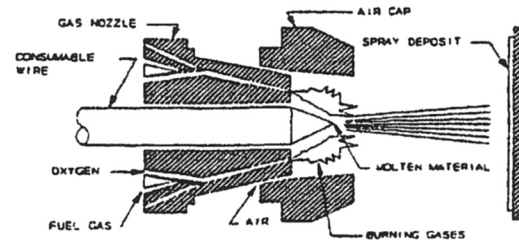


Figure 4.3

ADVANTAGES

- Medium deposition rates
- Capable of spraying most thermal spray wires
- Relatively inexpensive to purchase and operate
- Very portable
- Easy to operate

LIMITATIONS

- Medium ratio of heat conveyed into the substrate
- Unable to spray ceramic materials without some special equipment
- Low velocity spray stream
- Lower bond strengths than arc wire, plasma powder, and high velocity oxygen fuel

FLAME POWDER

The flame powder process uses an oxygen fuel flame to create the heating zone. Powder enters the heating zone and melts. The molten material is then propelled to the substrate by the force of the burning gasses and compressed air

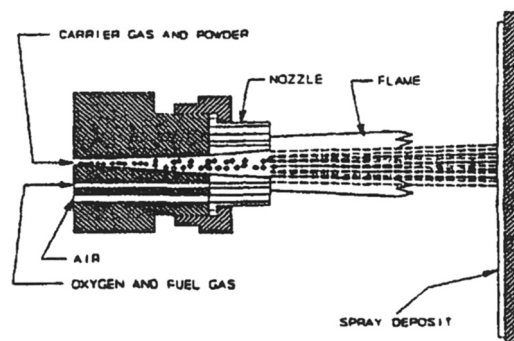


Figure 4.4

ADVANTAGES

- Relatively high deposition rates
- Capable of spraying most thermal spray powders
- Low noise levels
- Relatively inexpensive
- Very portable
- Easy to operate

LIMITATIONS

- High ratio of heat conveyed into the substrate
- Unable to spray some ceramic materials
- Low velocity spray stream

HIGH VELOCITY OXYGEN FUEL

The HVOF process is one of the most recently developed of the thermal spray processes. This process uses the combustion of oxygen and fuel (typically propane, propylene, or hydrogen) mixtures at high pressures. This mixture of oxygen and fuel gas burns and is accelerated to supersonic speeds. Thermal spray powder is injected into this constricted flame. The powder then accelerates in the high velocity flame (4500 - 7000 feet per second) When the thermal spray material collides with the substrate it plasticizes, flattens and adheres to form a coating.

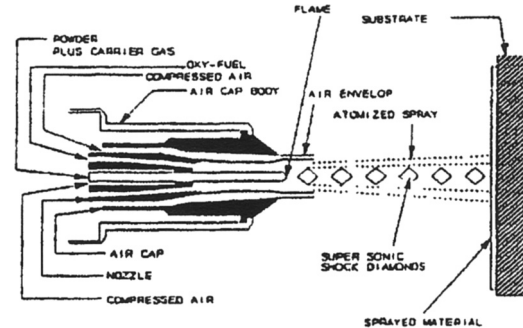


Figure 4.5

ADVANTAGES

Low thermal energy

High kinetic energy

Coatings with low porosity, low oxide content, low residual stress, and exceptionally high bond strengths

Reduced changes in the phase composition of the thermal spray material

LIMITATIONS

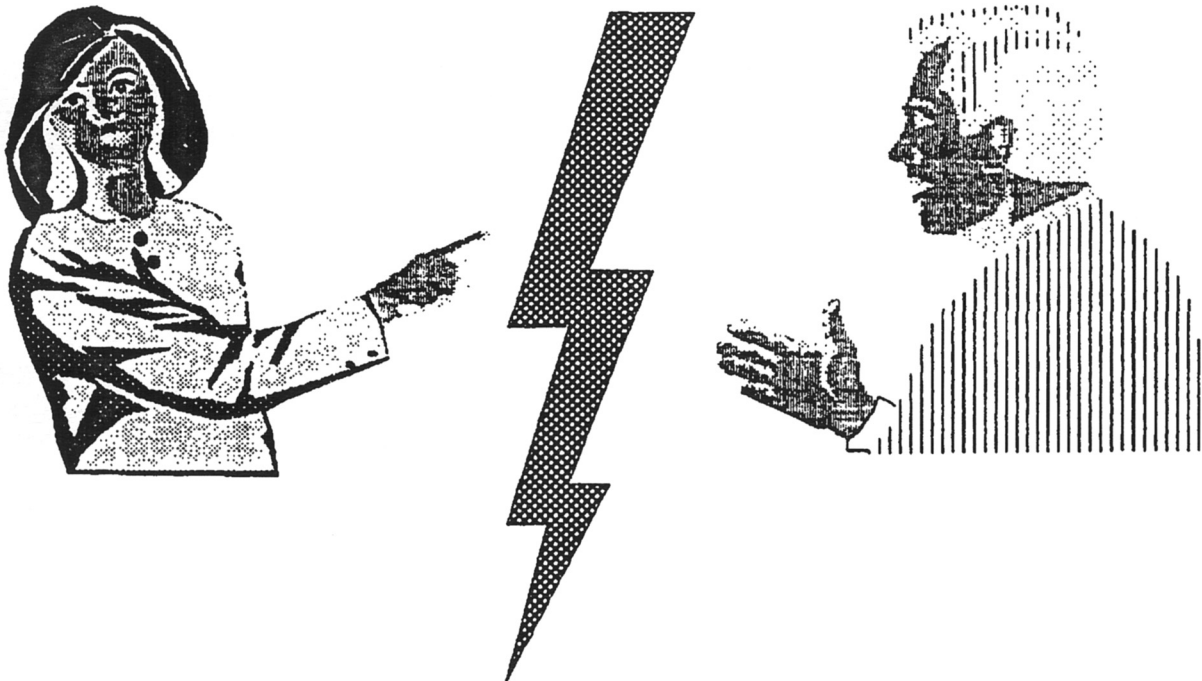
High noise levels generally require double hearing protection for operators and any other personnel who must work nearby

Relative expensive

Requires highly skilled operators

SECTION 5

COATING SELECTION



PREPARED BY: PUGET SOUND NAVAL SHIPYARD

COATING SYSTEMS

Many factors must be considered when selecting a coating system that will be used on ship machinery components. Factors that are considered when making coating selections for maritime machinery components include, but not limited to are, base material, type of area to be repaired, operational environment, thermal spray material available, finishing capabilities, and thermal spray process to be used.

COATING SYSTEM SELECTION

Each organization assigns the responsibility of thermal spray coating system and process selection to different groups or different levels of management. If the application is one that has been accomplished by the thermal spray facility many times, such as steam valve stems, the selection may be left to the operator performing the work. If the application is a new one, but still similar to other applications accomplished by the thermal spray facility, then the coating system selection may be made by a review group consisting of production shop, thermal spray engineering, and design engineering personnel.

Making a coating selection for a new thermal spray application that is not similar to anything before, is a difficult task. Because of the criticality of some ship's machinery components, it is advised that laboratory and land based equipment in-service testing be conducted for new thermal spray applications.

COATING SELECTION CHARTS

The following charts were created by the Naval Surface Warfare Center (Annapolis) and Puget Sound Naval Shipyard. A broad review by these facilities of available thermal spray materials, technical literature, and those Naval Facilities experience in the thermal spray field has led to the development of the subsequent coating selections charts that can be used for most maritime machinery component applications.

- TABLE 5.1 POWDER COATINGS FOR CARBON, LOW ALLOY, STAINLESS STEEL, AND CAST IRON
- TABLE 5.2 POWDER COATINGS FOR NICKEL BASE ALLOYS
- TABLE 5.3 POWDER COATINGS FOR COPPER BASE ALLOYS
- TABLE 5.4 WIRE COATINGS FOR CARBON, LOW ALLOY, STAINLESS STEEL, NICKEL BASE ALLOYS, AND COPPER BASE ALLOYS
- TABLE 5.5 THERMAL SPRAY POWDER MANUFACTURERS

Any facilities desiring information or assistance making coating selections, can contact the authors of this manual at Puget Sound Naval Shipyard.

5.2 / COATING SELECTION

TABLE 5.1 CARBON, LOW ALLOY, STAINLESS STEEL, AND CAST IRON						
COATING SYSTEM	STEAM		FRESH/SALT WATER		AIR/OIL	
	FIT	* SEAL	FIT	* SEAL	FIT	* SEAL
PP-25	N	N	N	N	N	N
444	3	N	3	N	1	N
445	N	N	N	N	N	N
447	4	N	4	N	2	N
21021	2	N	2	N	4	N
21031	1	N	1	N	3	N
PP-25/130	N	N	N	N	N	N
444/130	N	N	N	3	N	1
445/130	N	N	N	N	N	N
447/130	N	N	N	4	N	3
21021/130	N	N	N	2	N	4
21031/130	N	N	N	1	N	2
PP-25/143	N	N	N	N	N	N
444/143	N	3	N	7	N	5
445/143	N	N	N	N	N	N
447/143	N	4	N	8	N	7
21021/143	N	2	N	6	N	8
21031/143	N	1	N	5	N	6

1-8 = NUMBER LISTED IN COLUMN - RANKING BASED ON MIL-STD-1687 OR PSNS QUALIFIED PROCEDURE AND EXPERIENCE - THE NUMBER 1 INDICATES THE BEST COATING SYSTEM SELECTION FOR THE LISTED APPLICATION. THE COATING SYSTEM WITH THE LARGEST NUMBER IN THE COLUMNS COULD BE USED, BUT WOULD BE THE LAST RECOMMENDED SYSTEM FOR THE APPLICATION.

N = POOR SELECTION BASED ON EXPERIENCE OR NOT PERMITTED

(*) = DOES NOT INCLUDE LABYRINTH SEALS

NOTE: WHEN EVER POSSIBLE GRINDING IS THE PREFERRED FINISHING METHOD FOR ALL THERMAL SPRAYED COATINGS.

TABLE 5.2 NICKEL BASE ALLOYS						
COATING SYSTEM	STEAM		FRESH/SALT WATER		AIR/OIL	
	FIT	* SEAL	FIT	* SEAL	FIT	* SEAL
PP-25	N	N	1	N	1	N
444	N	N	N	N	N	N
445	N	N	N	N	N	N
447	N	N	3	N	2	N
21021	N	N	2	N	3	N
21031	N	N	N	N	N	N
PP-25/130	N	N	N	1	N	1
444/130	N	N	N	N	N	N
445/130	N	N	N	N	N	N
447/130	N	N	N	3	N	2
21021/130	N	N	N	2	N	3
21031/130	N	N	N	N	N	N
PP-25/143	N	N	N	4	N	4
444/143	N	N	N	N	N	N
445/143	N	N	N	N	N	N
447/143	N	N	N	6	N	5
21021/143	N	N	N	5	N	6
21031/143	N	N	N	N	N	N

- 1-8 = NUMBER LISTED IN COLUMN - RANKING BASED ON MIL-STD-1687 OR PSNS QUALIFIED PROCEDURE AND EXPERIENCE - THE NUMBER 1 INDICATES THE BEST COATING SYSTEM SELECTION FOR THE LISTED APPLICATION. THE COATING SYSTEM WITH THE LARGEST NUMBER IN THE COLUMNS COULD BE USED, BUT WOULD BE THE LAST RECOMMENDED SYSTEM FOR THE APPLICATION
- N = POOR SELECTION BASED ON EXPERIENCE OR NOT PERMITTED
- (*) = DOES NOT INCLUDE LABYRINTH SEALS

NOTE: WHEN EVER POSSIBLE GRINDING IS THE PREFERRED FINISHING METHOD FOR ALL THERMAL SPRAYED COATINGS.

5.4 / COATING SELECTION

TABLE 5.3 COPPER BASE ALLOYS						
COATING SYSTEM	STEAM		FRESH/SALT WATER		AIR/OIL	
	FIT	* SEAL	FIT	* SEAL	FIT	* SEAL
PP-25	N	N	N	N	N	N
444	N	N	N	N	N	N
445	N	N	1	N	1	N
447	N	N	N	N	N	N
21021	N	N	N	N	N	N
21031	N	N	N	N	N	N
PP-25/130	N	N	N	N	N	N
444/130	N	N	N	N	N	N
445/130	N	N	N	1	N	1
47/130	N	N	N	N	N	N
21021/130	N	N	N	N	N	N
21031/130	N	N	N	N	N	N
PP-25/143	N	N	N	N	N	N
444/143	N	N	N	N	N	N
445/143	N	N	N	2	N	2
447/143	N	N	N	N	N	N
21021/143	N	N	N	N	N	N
21031/143	N	N	N	N	N	N

- 1-8 = NUMBER LISTED IN COLUMN - RANKING BASED ON MIL-STD-1687 OR PSNS QUALIFIED PROCEDURE AND EXPERIENCE - THE NUMBER 1 INDICATES THE BEST COATING SYSTEM SELECTION FOR THE LISTED APPLICATION. THE COATING SYSTEM WITH THE LARGEST NUMBER IN THE COLUMNS COULD BE USED, BUT WOULD BE THE LAST RECOMMENDED SYSTEM FOR THE APPLICATION
- N = POOR SELECTION BASED ON EXPERIENCE OR NOT PERMITTED
- (*) = DOES NOT INCLUDE LABYRINTH SEALS

NOTE: WHEN EVER POSSIBLE GRINDING IS THE PREFERRED FINISHING METHOD FOR ALL THERMAL SPRAYED COATINGS.