NESDI Program Evaluates Technologies to Address Puget Opacity Limits

Cutting Technologies & Enclosures Offer the Most Viable Options for Shipbreaking

PUGET SOUND NAVAL Shipyard and Intermediate Maintenance Facility (PSNS&IMF), Bremerton, Washington—the Navy's shipbreaking and recycling activity for nuclear powered submarines and ships—needs new metal cutting technologies to meet its mission. The standard and most efficient technology for metal cutting on submarines and ships is oxy-fuel cutting. This technology, however, generates visible particulate matter (PM) that has the potential to exceed local air quality limits on opacity (the visual density of smoke or particulate emissions). To meet its shipbreaking mission within the opacity limits, PSNS&IMF needs a new approach.

The Navy Environmental Sustainability Development to Integration (NESDI) Program sponsored a study of existing and developing technologies for future on-site demonstrations. The resultant Initiation Decision Report (IDR) developed by the Naval Facilities Engineering Service Center (NAVFAC ESC) Port Hueneme, California, in a joint effort with Naval Surface Warfare Center Carderock Division (NSWCCD), Bethesda, Maryland, and PSNS&IMF, presents technology recommendations to help alleviate opacity concerns. As emissions regulations across the country become more stringent, other shipyards could benefit from these efforts.

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Background

As nuclear powered submarines and ships leave active service, they must be dismantled. Reactor compartments are removed intact and disposed of at the Department of Energy's Hanford site in Washington State. PSNS&IMF's proximity to the Hanford site contributes to its designation as the Navy's shipbreaking and recycling activity for preparing Reactor Compartment Disposal Packages.

Since the beginning of the vessel recycling program in 1986, PSNS&IMF has processed and packaged reactor compartments from 106 submarines and eight cruisers. The majority of this work involved hand-held oxy-fuel torches, a form of hot metal cutting. In 2008, the facility was recycling a 1950's vintage nuclear submarine that posed unique problems compared to the newer submarines that the facility typically dismantles. The coatings and heavy rust on the older submarines caused the cutting operation to be particularly smoky. During that operation, the facility briefly exceeded the Puget Sound Clean Air Agency's (PSCAA) daily opacity limit. PSNS&IMF submitted a deviation report to PSCAA and received a written warning to address the issue. PSNS&IMF initiated mitigation measures (ventilated enclosures) to ensure that there would not be any additional failures that might result in Notices of Violation or fines.

Interim Measures

To prevent exceeding opacity limits without sacrificing the work schedule, PSNS&IMF is using a combination of both hot cutting within smoke capturing enclosures and cold cutting methods. Steps being followed include:

1. Cutting smaller vessels (i.e., submarines) in enclosures to contain the visible PM emissions.
2. Using oxy-fuel cutting on high-tensile strength steel, referred to as High-yield 80 (HY80), and plasma arc cutting on stainless steel.
3. Cutting larger vessels like carriers and cruisers using cold cutting processes until work pieces are small enough to be sold to scrappers or transported to indoor facilities for special demolition tasks.

Unfortunately, this strategy is not sustainable over the long-term—it is expensive, inefficient, and can pose risks to worker safety.

Puget Sound area.

While the current enclosures at PSNS&IMF are estimated to capture 98 percent of non-smoke particulates during regular cutting practice, the remedy does not prevent emissions at the source; further, the workers are hampered by spatial limits and other activity constraints.

Initially installed in 2009, the tension fabric tents (enclosures) are just large enough to sufficiently envelop the sections of submarines. Their exhaust systems actively capture PM emissions (or smoke). However, the enclosures preclude the use of cranes, and are vulnerable to wind damage. It takes up to six minutes for the PMs generated by working torches to be captured before enclosures can be open again for transport of workers and substrates. PSNS&IMF has spent up to $2.5M in one year on the outdoor tensile fabric enclosures and its associated infrastructure equipment, including smoke collectors, vent ducting, and crane rails. These enclosures cannot be used for much larger surface ships, and the site personnel do not anticipate the availability of financial resources in the near future to fund customized orders for nuclear cruisers or carriers.

Cold cutting technologies are generally slower and pose increased risks for workers. Despite provisions for some user convenience, heavy, hand-held cold cutting tools have been linked to increased risks for repeated movement injuries including carpel-tunnel syndrome and Raynaud's phenomenon (blood vessel spasms that block blood flow to the extremities (i.e., fingers, toes, ears, and nose)).

In sum, these interim measures are insufficient to accommodate the projected workload increase at PSNS&IMF.

Urgent Need for New Technologies

At least eight submarines are to be dismantled at PSNS&IMF by 2016. Larger ships also are scheduled to be dismantled in the near future—the ex-USS Long Beach (CGN 9), an 800-foot cruiser beginning in 2013, and the aircraft carrier USS Enterprise (CVN 65) to begin in 2018.

Puget Sound Naval Shipyard.
MC2 Jesus Uranga

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> *–Kurt Doehnert*

Several Navy organizations associated with ship disposal have voiced their support for demonstrating new technologies because they recognize the urgency involved. As Kurt Doehnert, Naval Sea System Command, stated, "This NESDI project is critical for maintaining environmental compliance and addressing the opacity abatement problem for the Ship Inactivation and Recycling program at PSNSY&IMF. This project is especially vital, timely and relevant given the upcoming significant ship recycling workload at PSNSY&IMF, particularly for application to the extraordinary opacity abatement challenges that will be presented by the ex-Long Beach and ex-Enterprise. In addition to environmental compliance, these NESDI projects offer substantial cost and schedule improvement benefits to PSNSY&IMF and our primary Ship Inactivation and Recycling program customers (PMS 392 and PMS 312). These opacity abatement NESDI demonstration projects are the highest priority in our corporate Naval Shipyard technology program project portfolio."

This position was reinforced by Christopher Knoble, PMS 392 Program Manager. He said, "PMS 392 also strongly endorses continued NESDI efforts in advancing cutting technologies that address the opacity abatement issues facing hull recycling projects. The compliance requirements associated with the traditional cutting techniques currently employed have significantly increased the cost to recycle hulls, which ultimately diverts funding that could be used in the maintenance accounts that sustain the active fleet. The development of less costly technologies is crucial to regaining cost control in these areas."

In addition to the above endorsements, Lee Bowersox, Director of Process Excellence for Program Executive Office (Carriers) expressed his ongoing support for this effort.

Researching the Possibilities

While the oxy-fuel torch technology is difficult to replace, the experience of PSNS&IMF highlights that its use must be modified, reduced or eliminated. The goal of the NESDI-sponsored investigation was to identify the best available alternatives to oxy-fuel cutting to bring daily opacity levels at PSNS&IMF below the PSCAA limit and recommend technologies for on-site demonstrations. While PSNS&IMF is the only organization currently affected by the opacity limit, the emerging trend of increasing stringency on regulatory enforcements for environmental compliance is expected to involve more organizations in

Metal Cutting Technologies–Hot Versus Cold

A METAL CUTTING technology can usually be distinguished as either cold or hot. Oxy-fuel, plasma arc, and laser are examples of hot cutting technologies. These generally have high lineal cutting speed, but tend to have high levels of visible PM emissions and can cause heat affected zones that lead to re-fusion, hampering demolition work. Mechanical cutting instruments are usually synonymous with cold cutting, and are generally slower than hot cutting; however, they benefit from little or no PM emissions.

similar predicaments. The results from this IDR and its follow-on projects are expected to be useful for mitigation at other locations down the road.

The investigation team applied a series of refining criteria first to identify possible technologies then to sort possible technologies before recommending a subset for demonstration.

Three primary criteria guided the investigation:

1. Limit visible PM emissions to the environment
2. Maintain or increase cutting efficiency
3. Ensure worker safety

Options to address the first criterion can include containing the emissions (e.g., working within enclosures) and preventing emissions via other fuels or cutting technologies.

Characteristics required of alternative technologies to meet the first two criteria include:

- Capacity to cut either HY80 high-tensile steel or stainless steel
- Kerf width (cutting width) of at least 3/4-inch
- Opacity below the limit set by PSCAA and also lower than the norm of oxy-propane torch cutting

The Basics About the NESDI Program

THE NESDI PROGRAM seeks to provide solutions by demonstrating, validating and integrating innovative technologies, processes, materials, and filling knowledge gaps to minimize operational environmental risks, constraints and costs while ensuring Fleet readiness. The program accomplishes this mission through the evaluation of cost-effective technologies, processes, materials and knowledge that enhance environmental readiness of naval shore activities and ensure they can be integrated into weapons system acquisition programs.

The NESDI program is the Navy's environmental shoreside 6.4 Research, Development, Test and Evaluation program. The NESDI technology demonstration and validation program is sponsored by the Chief of Naval Operations Energy and Environmental Readiness Division and managed by the Naval Facilities Engineering Command. The program is the Navy's complement to the Department of Defense's Environmental Security Technology Certification Program which conducts demonstration and validation of technologies important to the tri-Services, U.S. Environmental Protection Agency and Department of Energy.

For more information, visit the NESDI program web site at www.nesdi.navy.mil or contact Leslie Karr, the NESDI Program Manager at 805-982-1618, DSN: 551-1618 or leslie.karr@navy.mil.

TYPES OF MITIGATION TECHNOLOGIES

Mitigation Type (Impact on Visible PM Emissions)	REDUCTION Thermal "Hot" Cutting	ELIMINATION Non-Thermal "Cold" Cutting	CONTROL Enclosures
Emissions	Metals and visible particulates (opacity)	Barely any emissions	Some emissions may escape → variance in total release
Special Requirement	Required; restricted space – some work pieces may be too big (e.g., early stages of a carrier or a cruiser)	Many require clean-up of solid debris. Cutting can be conducted outdoors.	This mitigation must accompany a cutting technology.
Speed	Good, 10–12 inches per minute on two-inch HY80 at PSNS&IMF	Wide range of speed	N/A (This is not a cutting technology.)
Substrate Compatibility	Carbon steel No stainless steel	Can be applied to any substrate as long as the mechanical strength exceeds material resilience	N/A (This is not a cutting technology.)
User Flexibility	Barely any restrictions- torches are the most convenient tool for the workers	Often cannot handle long, horizontal cuts (i.e., along the length of the submarines)	May cause some special restrictions for workers

- Lineal cutting speed of 10 inches per minute or better on two inches thick, HY80 sheet (same speed or much higher on thinner work pieces)
- Acceptable preparation and set-up time, take down/ clean-up time, and cutting speed in terms of true productivity (e.g., feet/workday)

The table on the previous page describes relevant technologies by their categorization (in relation to their impact on opacity)—Reduction, Elimination, and Control. Reduction refers to cutting technologies of comparable performance but less visual PM emissions.

Cold cutting technologies have little or no opacity and would therefore result in the elimination of opacity once those technologies have been substituted for oxy-fuel cutting. (Note: Cold cutting technologies that are priced below $1M are generally slower than oxy-fuel cutting technology.) Their consumable components (e.g., cutting blades, bits, etc.) add to the monthly maintenance cost that is often orders of magnitude greater than the propane gas acquisition required for oxy-fuel torches. Complete replacements of the current technology will likely affect both the shop economics and workflow.

Control technologies, such as enclosures, are not cutting technologies themselves, but are important in their ability to prolong the use of high performance cutting technologies by capturing their visible emissions.

Ultimately, the NESDI team identified nearly twenty relevant metal cutting technologies to review. Most were introduced to the team through a Federal Business Opportunities Solicitation issued by NAVFAC ESC, while others were introduced internally by the organizations involved in this study (NAVFAC ESC, PSNS&IMF, National Center for Manufacturing Sciences, and NSWCCD).

Each competing alternative was ranked as either Potential or Deprioritized based on the following criteria:

- Visible particulate emissions (lower is ranked higher)
- Speed of cutting (faster is ranked higher)
- Capital cost (lower is ranked higher)
- Cost for operation and maintenance (lower is ranked higher)

Additional considerations during the review included:

- Availability of technology for use by Navy employees. (All of the respondents offering full service scrapping were considered irrelevant.)
- Current involvement in laboratory testing of various torch gases for opacity readings.
- Applicability to metal cutting or to control of emissions. This was a preference in the design focus.
- Continued interest in pursuing partnership with the Navy for metal cutting at PSNS&IMF.
- Capital equipment costs.
- Technology maturity, i.e., need for further development, to harness advantages in a metal cutting

RECOMMENDED TECHNOLOGIES FOR DEMONSTRATION

Technology	Type	Comments
MagneGas™	Hot Cutting Technology	• Alternative fuel for the torch cutting infrastructure (smaller tips) • Equivalent speed to oxy-propane cutting • Disadvantage to investigate: Equivalent actual opacity in comparison with that from propane or gasoline, cost
Submarine Hull Cutting System	Cold Cutting Technology	• Capital Equipment: Latest order was sold at $345,000 for submarines. PSNS&IMF may get a unit at a lower price if cutting will be restricted to work pieces of only 1/2-inch thickness. • Hydraulic reciprocating saw module • Up to eight inch stroke • Straight and circumferential rail mounting • Final product is open to customization
Travel-L-Cutter Model E	Cold Cutting Technology	• Capital Equipment: 200 pounds, approximately $120,000 per unit • Accessories: Track with clamping system for the capital unit, $1,000 per foot. This is a portable infrastructure system. • Cutting speed around 1.5 to two inches per minute on 2-inch thick steel. Demonstration will need to test for speed on 1/2-inch thickness hulls of cruisers.


Puget Sound Naval Shipyard.
Rick Chaffee

application. (Successfully adapted technologies will be re-evaluated for their potential at PSNS&IMF.)

Recommendations

At the time the IDR was completed in January 2012, the team recommended three technologies listed on the previous page for immediate demonstration. (Note: These companies and their technologies were selected only for further consideration, are not funded or scheduled for demonstration, and are not endorsed by the Navy.) To ensure effective reduction of visible PM emissions at PSNS&IMF by the start of the breaking of USS Long Beach in 2013, NAVFAC ESC recommended an immediate NESDI demonstration on at least one cold cutting application.

As a result, the NESDI program is sponsoring two new projects—*Controlling Opacity During Ship Hull Cutting & Demolition* (project #481) to demonstrate the Submarine Hull Cutting System cold cutting technology and *Alternative Metal Hot Cutting Operations for Opacity* (project #480) to demonstrate the MagneGas hot cutting technology.

Additional technologies are not currently appropriate for demonstration but may warrant consideration in the future depending upon technology refinements. These are presented as secondary recommendations:

1. Motion Assisted Environmental Enclosure (MAEE)

   The MAEE is a modular enclosure with semi-autonomous motion. It uses electrical signals to detect proximity on aerial work. It is designed to capture overspray during ship hull painting and would need adapted to accommodate metal plumes.

2. MobiWeld™

   This device manufactured by the Robotic Institute of Tennessee is a trackless, automated welding application. With design adaptations it has the potential to complement metal cutting operations. It may help to address worker safety concerns, particular if used with the Beam of Life (see following entry).

3. Beam of Life Device

   This battery-powered laser gun is suitable for short and quick break-in through steel in emergency situations (similar use as the Jaws of Life). Prototypes are not fitted to the workload capacity of ship-breaking and recycling. This was developed through the Military to Market (M2M) program.

Conclusion

NAVFAC ESC recognizes that the current use of enclosures to contain visible particulate emissions from oxy-fuel and plasma arc cutting technologies is the best, immediate response to avoid any future opacity limit violations. This solution will temporarily allow for the continued regularity of work on submarines. However, PSNS&IMF will ultimately need a new cutting protocol comprising alternative cutting technologies for the long-term. The last cruiser will soon arrive for recycling, followed by carriers. An aircraft carrier is about 15 times larger than a submarine—it would be extremely expensive and laborious to customize and fit an enclosure for it. Therefore a cold cutting technology or a hot cutting technology with opacity that is significantly lower than for currently used oxy-fuel technologies will need to be identified to justify outdoor cutting activity. In short, the final cutting protocol will need to comprise both hot and cold technologies to both maintain regularity of work flow and prevent ongoing violation of the PSCAA opacity limit.

Note: Edwin Chiang and Christine Ahn, NAVFAC ESC and Jim Howell, NSWCCD made significant contributions to this IDR.

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