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PORTSMOUTH NAVAL SHIPYARD USED OIL SEGREGATION STUDY

KITTERY, MAINE

SELECTION OF PREFERRED RECYCLING OPTIONS

Presented To:

U.S. Department of the Navy
Naval Facilities Engineering Command
and
Portsmouth Naval Shipyard

Presented By:

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June 7, 1983

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Commanding Officer
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Attention: Mr. Robert Kowalczyk, Code 114

Dear Bob:

Enclosed is our analysis of the recycling options for the "Portsmouth Used Oil Segregation Study". As requested, we have documented the engineering assumptions and judgments, and cost estimates used to select a preferred recycling scheme.

The recommended scheme consists of the following components:

- Recycle hydraulic oils individually (closed loop) (Waste Group 1A-H), subject to field testing;
- Blend all other potential fuels for burning at PNSY (Waste Groups 5A and 1A);
- Blend Wheelerizer waste oil for burning at PNSY if suitable; otherwise, sell or dispose of via DLA (Waste Group 11);
- Sell low flash fuels/solvents via DLA (Waste Groups 5B and 6);
- Recover freon 113 by distillation and dispose of residue via DLA (Waste Group 8);
- Centrifuge coolants and dispose of residues via DLA (Waste Group 4); and
- Dispose of all other used oils via DLA (Waste Groups 10 and 12).

If field testing of hydraulic oil recycling indicates that it will not be effective, then we recommend that the hydraulic oils also be blended for use as fuel at PNSY.

This is the basis upon which we propose to develop the Used Oil Management Plan. Should you wish us to make any modifications to the recommended scheme, please let us known as soon as possible. Your feedback would also be appreciated on the assumptions used in developing administrative costs which are presented in Appendix B.

Very truly yours,

MPScott

Michael P. Scott
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Enclosure

cc: Mr. H. Olson
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SELECTION OF PREFERRED RECYCLING OPTIONS

INTRODUCTION

The purpose of this submittal is to present to the PNSY Oily Waste/Waste Oil Committee the rationale for the selection of preferred recycling options for each waste group. The preferred combination of options will then form the basis for the used oil management plan at PNSY. We have accordingly documented here our engineering assumptions and judgments, and preliminary cost estimates used to arrive at a preferred scheme.

We have used essentially a two-stage process in evaluating, first a broad range of options at a coarse level of detail, and subsequently, the reduced range of options at a finer level of detail. In our earlier Used Oil Segregation Study report (May 27, 1983), we categorized the used oils at PNSY into separate waste groups within recycling categories. These same groups are used here in considering the suitability of different recycling options.

Throughout the evaluation process, we have taken a conservative approach to the quantities and levels of contamination that may arise in particular waste groups. Where a high level of variability or uncertainty is anticipated, e.g., for the Wheelerizer wastes, we have suggested an approach which is not fundamentally dependent on the availability or characteristics of these items. Basic premises of this kind and the assumptions used in our analysis are explictly documented in the following sections.

SCREENING OF AVAILABLE OPTIONS

Our analysis of recycling options is based on the decision-making process developed by RECON[1], which consists of the following hierarchy:

- Recycling of a specific product with or without contaminant removal by:
  - The Navy for the original or a similar purpose;
  - The transfer to an outside contractor through a closed loop arrangement; or
  - Sale through Defense Logistics Agency (DLA).
- Segregate each recovered product with other compatible used oil products and solvents (based on MILSPECS) for:
  - Recycling by the Navy or outside contractor;
  - Burning as a fuel supplement in the PNSY Power Plant; or

- Sale through DLA.

- Disposal of used oil products by the Navy, DLA, or an outside contractor when quantities are small or alternative recycling options are not available.

The application of these options to each recycling category identified at PNSY is shown in Table 1. In screening the list of available options to develop feasible options for more detailed analysis, account was taken of the following principal factors:

- Volume of Used Oil - In some cases, volumes may be too small to merit the cost of any systematic recovery system, e.g., for certain solvents;

- Probable Contamination - Contamination may limit the feasibility of options such as fuel blending unless processing is undertaken, e.g., to reduce bottom sediment and water (BS&W);

- Environmental Acceptability - Contamination may limit the acceptability of options such as burning as boiler fuel. The most significant environmental problem in burning waste oil is generally lead, although other components such as halogenated hydrocarbons could also be a problem; and

- Regulatory Constraints - Regulatory initiatives at both the Federal and state levels may impose certain limitations and administrative burdens, particularly for oils/solvents classified as hazardous wastes.

These factors are discussed further in the evaluation of the available recycling options for each waste group.

Waste Group 4 - Coolants

The centrifuge currently planned for Shop 31 will be able to reclaim coolants for re-use. It will be a batch operation capable of separately recycling different products, and will reduce both the amount of product used and the volume of waste for disposal. No further consideration of alternative recycling is necessary or appropriate.

Waste Group 10 - Natural Source Products

The natural source products are all low volume items, mostly cutting oils. The relatively large number of separate products and the low volumes preclude any recycling options.

Waste Group 12 - Anti-Freeze

The volume of anti-freeze is very low (360 gallons/year) and is in a water solution, so that any cost-effective reclamation

TABLE 1. FEASIBLE RECYCLING/RECOVERY OPTIONS BY WASTE GROUP

Recycling Category	Waste Group	Options Considered	Feasible Options	Comments
A. Synthetic and Other Chemically Complex High Boiling Products	4: Cutting oils including water-soluble (synthetic) coolants	Recycling each product individually Disposal	Recycle each product individually Disposal	Centrifuge to be installed will maximize product recycle
	10: Natural source products		Disposal	Volumes too small for recovery
	12: Anti-freeze		Disposal	Volumes too small for recovery and no suitable available technology
B. Fuels	5A: Fuels and inhibitors with flash point $\geq$140°F	Direct use as fuel Blending for fuel without reprocessing Blending for fuel with reprocessing Sale via DLA Disposal	Blending for fuel without reprocessing Sale via DLA Disposal	Volumes too small to justify fuel blending facilities, but would likely be suitable for fuel blending without processing
	11: Recovered oil from Wheelerizers		Blending for fuel with reprocessing Blending for fuel without reprocessing Sale via DLA Disposal	High degree of uncertainty as to characteristics of oil from Wheelerizer waste treatment systems may make reprocessing necessary for fuel blending
C: Low Flash Fuel and Non-Halogenated Solvents	5B: Fuels and inhibitors with flash point <140°F	On-site recycling for original or secondary use Recycling by contractors Recycling/blending for fuel without reprocessing Recycling/blending for fuel with reprocessing Sale via DLA Disposal	Sale via DLA Disposal	Technically suitable for fuel blending, but small volume and regulatory constraints make this unattractive
	6: Low boiling hydrocarbons		Sale via DLA Disposal	Small volume (largest single product is Stoddard solvent - 889 gallons/year) would preclude on-site recycling, although sale of Stoddard solvent is feasible. Blending for fuel unattractive due to regulatory constraints
D. Halogenated Hydrocarbons	8: Halogenated hydrocarbons (freon)	On-site recycling Recycling by contractors (closed loop) Sale via DLA Disposal	On-site recycling Recycling by contractors (closed loop) Site via DLA Disposal	Existing on-site distillation unit recovers freon with <5 percent contamination
E. Re-Refinable/Fuel-Blending	1A: Petroleum-based lubricating oils	On-site recycling Recycle by contractors/outside re-refiners Blending for fuel without reprocessing Blending for fuel with reprocessing Sale via DLA Disposal	Blending for fuel without reprocessing Sale via DLA Disposal	No local re-refiners available. Likely suitable for direct blending without reprocessing with volumes sufficient to merit blending facilities
	1A-H: Petroleum-based hydraulic oils		Recycle by contractors Blending for fuel without reprocessing Site via DLA Disposal	No local re-refiners available. Relatively low levels of contamination may make reclaiming of individual products a feasible option. Also suitable for direct blending for fuel

activities are precluded and disposal is the only feasible option.

Waste Group 5A - Fuels and Inhibitors with Flash Points >140°F

The volume of contaminated high flash point fuels is relatively low, and on its own would not merit consideration for fuel blending. However, should such facilities exist, this oil would likely be suitable for blending without processing. Otherwise, the only other alternative to disposal would be sale through DLA.

Waste Group 11 - Recovered Oil from the Wheelerizers

There is a high degree of uncertainty as to both the quantity and quality of the oil that will be recovered from the Wheelerizer waste treatment system. Freon contamination could pose a problem for fuel blending (although the levels in the four samples analyzed are not unaaceptable) and the levels of BS&W can only be fully determined once the treatment plant is operating. It is considered undesirable therefore to rely on recovered oil from the Wheelerizer to play a major role in establishing the feasibility of recycling options. In practice, the feasible options for the Wheelerizer oil will depend on the contamination levels, so that the oil may have a positive value for fuel blending without processing; it may need processing to reduce the water content; it may be saleable through DLA; or it may be contaminated to the point where it must be disposed of at a cost to PNSY.

Waste Group 5B - Fuels and Inhibitors with Flash Points <140°F

The low flash point fuels are essentially diesel fuel and like Waste Group 5A, are low in volume. From a technical point of view, they are likely suitable for direct fuel blending, if such facilities can be justified by other high volume waste groups. However, because of their low flash point, these materials would be considered hazardous wastes under EPA's RCRA regulations and by the State of Maine. While EPA's regulations currently exempt "re-used, recycled or reclaimed" wastes, this is undergoing review[2]; and in the State of Maine, no such exemption exists. Under the Maine regulations, blending of hazardous wastes with non-hazardous used oil would render the mixture a hazardous waste. Burning in an industrial boiler would then be subject to the following requirements:

- Boiler capacity of $\not<$ 25 million BTU's/hour;
- Analysis of waste to be submitted to the State DEP;
- Amount of waste $\not>$ 10 percent of total fuel feedstock;
- Detailed design of combustion system to be submitted to State DEP;

- Purpose of combustion is energy recovery.

While these requirements would not absolutely preclude the burning of low flash fuels, they would impose an additional administrative burden. Given the low volume of this waste group and the uncertainty as to the direction of Federal regulations in this area, it is recommended that low flash materials not be burnt as fuel. The alternative would be sale through DLA, or in the last resort disposal.

Waste Group 6 - Low Boiling Hydrocarbons

The low boiling hydrocarbons are low volume products, of which the largest single commodity is Stoddard solvent (889 gallons/year).

Consideration was given to the application of small-scale solvent recovery units. Units are available that are designed for volumes as low as 15 gallons per shift[3] and are being used at DoD installations. The low volumes of Stoddard solvent generated at PNSY however would not be sufficient to justify this type of equipment.

Blending for fuel used at PNSY is also not recommended for the same reasons identified in discussion of Waste Group 5B. Sale through DLA would be the most cost-effective option depending on the local solvent market and the level of contamination in the solvent.

Waste Group 8 - Halogenated Hydrocarbons

The only halogenated hydrocarbon generated in significant quantities is freon 113, which is currently recycled in a still in Shop 99. The still is used only for freon containing <5 percent contamination. Freon containing higher levels and the residues from the still will continue to require disposal as a hazardous waste.

Waste Group 1A - Petroleum-Based Lubricating Oils

Petroleum-based lubricating oils will be the largest single group of used oils at PNSY. In evaluating the suitability of these oils for use as a fuel supplement, consideration was given to the potential problems that might arise both in terms of environmental pollution and in operational aspects. Concerns with burning waste oils generally focus on lead contamination, and perhaps to a lesser extent on halogenated hydrocarbons[4,5]. The concern with lead is primarily a result of the high levels found in used automotive crankcase oils. Lead emissions are not considered to be a problem with Waste Group 1A for two reasons:

- The oils are from various sources, including machine and gear lubricants and not primarily crankcase oil, which is generally the primary source of lead contamination; and

- The total of No. 6 fuel oil burned in the PNSY power plant was 9.4 million gallons/year in 1982, compared to the total waste oil volume of 37,150 gallons/year. Blending the used oil with the current volume of No. 6 fuel oil would result in a dilution of approximately 0.3 percent.

For chlorinated hydrocarbons, the segregation of oils and solvents will prevent contamination of this type. Other pollutants such as sulfur oxides, polynuclear aromatic hydrocarbons (PAHs) and particulates are expected to be essentially similar to those from the burning of No. 6 fuel oil. The impact of the waste oil burning on emissions is therefore not likely to be significant. The air emission license for the power plant would need modifying however - a letter request to the Maine DEP is likely all that would be required.

With regard to operational aspects such as flame stability and maintenance requirements, the oils in Waste Group 1A are expected to contain relatively low levels of BS&W, and are considered suitable for fuel blending without processing. Maintenance problems can arise in pumps, feed lines, burners, heat exchange surfaces and firewalls, depending upon the characteristics of the oil and the ratio of used oil to conventional feedstock. Review of the literature[5,6] however suggests that a conservative conclusion is that successful burning can be achieved without any increased maintenance if used oil addition is limited to 10 percent. That this is a conservative conclusion is supported by a recent Navy-sponsored study[7] that documents the experience of Naval activities in using used oil at shore-based facilities in blends up to 100 percent used oil. A section from this study entitled "Experience of Naval Activities in Burning Used Oil" is included here as Appendix A.

In the event that burning lubricating oils at PNSY is not pursued, the alternative to burning would be sale through DLA for use off-site as a fuel supplement. No local re-refiners exist, so re-refining is precluded as an option.

Waste Group 1A-H - Petroleum-Based Hydraulic Oils

The hydraulic oils were separated from the other petroleum-based lubricating oils on the basis of their lower levels of contamination, and the relatively high cost of some of these products. Three products in particular have been identified that are used in hydraulic systems:

- 2190 TEP - 6,430 gallons/year;
- 2110 - 2,360 gallons/year; and
- 2075 - 500 gallons/year.

While to some extent these are already being recycled by vacuum purification at PNSY, it would seem that this practice is

not been consistently implemented throughout PNSY. Recent inquiries of PNSY indicated that the existing vacuum purification units are fully utilized in high priority boat-servicing activities, so that on-site processing is not available at this time. A closed loop recycling arrangement with a contractor would be an alternative, and it appears that this service would be available locally.

Other alternatives would be blending without processing for burning in the power plant boilers, or sale via DLA. For burning, similar considerations apply as were described for Waste Group 1A, with the only difference being that the hydraulic oils are less contaminated. For sale via DLA, lightly-contaminated "clear" oils of this type are in demand locally for processing as chain oil for chain-saws.

FEASIBLE RECYCLING SCHEMES

From consideration of the recycling options for each waste group, it is apparent that in some cases, the options are relatively limited and clear, e.g., coolants will be centrifuged and the non-reusable fraction disposed of. In other instances, there are several feasible options, e.g., hydraulic oils can be reclaimed individually, burnt as fuel, or sold as a group for reprocessing as chain oil. In such cases, the choice of recycling option impacts on the recycling option for other waste groups, particularly when considering the feasibility of establishing fuel blending facilities for use of used oil in the PNSY power plant. The choice of the most beneficial recycling option for each waste group should therefore not be considered in isolation from other waste groups. We have accordingly constructed a number of alternate schemes which address the recycling strategy for the waste groups in an integrated fashion. The principal factors in comparing the alternate schemes were:

- Net Cost Saving - Preliminary life-cycle costs were developed focusing on the major cost items and the differences between recycling schemes. Detailed life-cycle costs will be developed for the selected scheme as part of the Management Plan;

- Ease of Implementation - Consideration was given to the administrative burden and time-frame required to implement a scheme, either partially or fully. Similarly, preference was given to schemes which would not be complex to operate; and

- Flexibility - It was considered desirable for the selected scheme to be easily modified to reflect possible changes in preferred recycling options as more information becomes available, e.g., for the Wheelerizer wastes.

Five feasible schemes were developed. For purposes of comparison, the existing scheme of used oil management has also been

included. These schemes deal only with Recycling Categories B, C and E, since A and D have clearly defined preferred options, which are already in effect or about to be implemented. The recovered oil from the Wheelerizer wastes was excluded from the analysis in view of the uncertainty in its characteristics.

The five feasible schemes are summarized in Table 2, along with the additional equipment required. This additional equipment is based on the following assumptions:

- Fuel blending facilities would consist of two 4,000 gallon tanks and associated liner and appurtenances. The first of these would act as a holding tank and be set up to allow water stripping. Waste oil from this tank would be metered to a second tank where it would be mixed with No. 6 fuel oil in a fixed ratio, and pumped to the burners. The two tank system would allow a high degree of control over the quality of fuel supplied to the burners. An in-line injection system fed from one tank would be an alternative arrangement, but for the purposes of this preliminary cost estimate, the two tank configuration will be used;

- Recycling facilities for the three hydraulic oils would consist of three separate tanks of 2,000, 1,000 and 275 gallons, respectively. This would allow for an approximately quarterly servicing of the oil by a contractor, which would provide all other services. The processed oil would be pumped into existing product drums available on-site at no additional cost; and

- Scheme 4 calls for all used oils in Recycling Categories B, C and E to be sold via DLA. The two existing Jamaica Island tanks would be used to segregate the hydraulic oils from the lubricating oils, so that additional tankage would not be required. Stoddard solvent would be held in drums.

COMPARISON OF RECYCLING SCHEMES

Based on the foregoing assumptions, preliminary cost estimates were prepared to compare the net benefits from each scheme and are presented in Table 3. The net benefit was defined as:

Benefit from Oil Utilization/Sale - Additional Equipment and Maintenance Costs - Operating Labor and Administration Costs.

Table 3 also shows the incremental benefit for each scheme, defined as the sum of the net benefit and the cost currently incurred for disposal of these waste groups. To provide the necessary cost components for these cost estimates, a brief market survey of the local used oil market was carried out by contacting

TABLE 2. RECYCLING SCHEMES FOR RECYCLING CATEGORIES B, C AND E

Scheme	Recycling Components	Waste Groups	Additional Equipment
0	Dispose of all oils/solvents	5A, 5B, 6, 1A, 1A-H	None
1	Recycle hydraulic oils individually	1A-H	2,000, 1,000 and 275 gallon tanks
	Sell all other potential fuels via DLA	5A, 5B, 6, 1A	
2	Recycle hydraulic oils individually	1A-H	2,000, 1,000 and 275 gallon tanks
	Blend all other potential fuels for burning at PNSY	5A, 1A	2 x 4,000 gallon tanks with metering pumps, mixer, delivery pump and appurtenances
	Sell low flash fuels/solvents	5B, 6	
3	Blend all potential fuels for burning at PNSY	5A, 1A, 1A-H	2 x 4,000 gallon tanks with metering pumps, mixer, delivery pump and appurtenances
	Sell low flash fuels/oils via DLA	5B, 6	
4	Sell hydraulic oils as a group via DLA	1A-H	None
	Sell all other potential fuels via DLA	5A, 5B, 1A, 6	
5	Sell hydraulic oils as a group via DLA	1A-H	2 x 4,000 gallon tanks with metering pumps, mixer, delivery pump and appurtenances
	Blend all other potential fuels for burning at PNSY	5A, 5B, 6, 1A	
	Sell low flash fuels/solvents via DLA	5B, 6	

TABLE 3. COST COMPARISON FOR FEASIBLE OPTIONS

Scheme	Benefit from Oil Utilization/Sale ($/year)	Annualized Additional Equipment and Maintenance Costs ($/year)	Operating Labor and Administration ($/year)	Disposal Cost ($/year)	Net Benefit/ (Cost) ($/year)	Incremental Benefit* ($/year)
0	--	--	3,000	10,718	(13,718)	--
1	19,424	500	6,000	0	12,924	27,000
2	29,656	3,500	7,600	0	18,556	32,000
3	24,203	3,500	4,600	0	16,103	30,000
4	12,470	0	3,500	0	8,970	23,000
5	22,702	3,000	4,300	0	15,402	29,000

* Incremental benefit values are rounded to the nearest $1,000

a number of contractors and the DPDO. Similarly, a set of assumptions were developed for the calculation of life-cycle costs. The basis for the cost estimates was as follows:

- Prices and Disposal Costs:

  - Processing cost for recycling of hydraulic oil, $1.50/gallon (contractor's estimate - Maine Lubrication Services);

  - Purchase price for 2190 TEP, $2.71/gallon;

  - Purchase price for 2110 TH, $3.34/gallon;

  - Purchase price for 2075 TH, $5.25/gallon;

  - Purchase price for No. 6 fuel oil, $0.91/gallon;

  - Market price for mixed hydraulic oil, $0.75/gallon;

  - Current PNSY disposal cost for waste oil, $0.39/gallon;

  - Market price for mixed lubricating oils, $0.30/gallon; and

  - Market price/disposal cost for Stoddard solvent, $0.30/gallon (solvent market is highly sensitive to levels of contamination).

- Life-Cycle Cost Analysis (25 Years):

  - All tanks and pumps are replaced after 15 years;
  - Interest rate is 10 percent; and
  - O&M costs are 10 percent of capital costs.

Operating labor and administration costs have been included in the cost estimates, as they are a significant part of the implementation cost for each of the recycling schemes, and are generally greater than the annualized capital costs involved. It is recognized that these costs may be not inclusive of all administrative costs, but rather are presented here to determine where significant differences may arise between the recycling schemes. In calculating this component of the costs, it was necessary to make many assumptions about the personnel costs for both current operations and the projected schemes. These assumptions are documented in Appendix B in order to provide the Waste Oil/Oily Waste Committee the opportunity to comment on their validity. This will ultimately assist in the precision of the detailed life-cycle costs calculation for the preferred recycling scheme.

In general, the benefits from the five schemes are similar within the precision of the estimates, and represent an incremental benefit over current practices in the range of $23,000/year to $30,000/year. (Note that this does not include the cost saving that will be realized by installation of the planned coolant centrifuge.) In comparing the five schemes, it would appear that those involving fuel blending options are the most cost-effective. It is emphasized however that the cost differences are marginal, so that considerations other than cost may be the dominating factors in selecting a preferred scheme. Notwithstanding this caution, fuel blending options do offer PNSY other advantages: they provide direct control over its used oil, whereas sale via DLA will be subject to fluctuations in demand. They also provide the flexibility to extend the fuel blending to include both the hydraulic oil (should its recycling as an individual product not prove effective) and the recovered oil from the Wheelerizers, should its quality be appropriate.

Of the three schemes involving fuel blending, the most cost-effective would be Scheme 2 - the recycling of the individual hydraulic oils by outside contractor and the blending of all other potential fuels for burning at PNSY. This is the preferred scheme which can be summarized in total as:

- Recycle hydraulic oils individually (closed loop) (Waste Group 1A-H);
- Blend all other potential fuels for burning at PNSY (Waste Groups 5A and 1A);
- Blend Wheelerizer waste oil for burning if suitable, otherwise sell or dispose of via DLA (Waste Group 11);
- Sell low flash fuels/solvents via DLA (Waste Groups 5B and 6);
- Recover freon 113 by distillation and dispose of residue via DLA (Waste Group 8);
- Centrifuge coolants and dispose of residues via DLA (Waste Group 4); and
- Dispose of all other used oils via DLA (Waste Groups 10 and 12).

In the interim, we recommend that the practicality of hydraulic oil reclamation be verified by on-site testing at PNSY before any investment is made in new tankage. Should hydraulic oil reclamation not prove practical, we recommend that Scheme 3 be adopted and the hydraulic oils also be blended for fuel.

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APPENDIX A

REPORTED EXPERIENCE USING WASTE OIL AS A BOILER FUEL

APPENDIX A

REPORTED EXPERIENCE USING WASTE OIL AS A BOILER FUEL

Source: VSE Corporation. "Use of Waste Oil as a Supplemental Boiler Fuel". September 1981

Waste oil has been burned as a matter of course and used as a supplemental boiler fuel in tests at a number of military activities. The experience from these activities can be of interest to other activities investigating its use. A total of 24 Naval shore activities were surveyed by telephone. Information beneficial to this Handbook was obtained from 12 activities and is included in this part of the Handbook. Certain activities surveyed reported no utilization of waste oil. These were:

- NSD Subic Bay, Philippines;
- NAVFAC Antiqua;
- NOS Indian Head, Maryland;
- NAS Patuxent River, Maryland; and
- NSY Philadelphia, Pennsylvania.

Certain activities that did burn waste oil in the past or on a one-time basis, no longer do so. These include:

- NAF Atisugi, Japan;
- NAS Brunswick, Maine;
- NAS Memphis, Tennessee; and
- PWC San Diego, California.

Two activities reported utilization of contaminated fuel, but not in boilers. These were:

- NAPC Trenton, New Jersey; and
- PWC Subic Bay, Philippines.

Narrative summaries of information gathered is presented in the paragraphs that follow. Table A-1 provides an overview of pertinent experience by activity.

U.S. ARMY, ABERDEEN PROVING GROUND

During 1968-1972, the U.S. Army burned approximately 40,000 gallons of used lube oils each year in a boiler plant (60 MB/hour, water tube boiler with steam atomization burner) at Aberdeen Proving Ground. This oil was simply dumped into the No. 6 fuel oil tank at a proportion of 1:3 (or 25 percent used lube oil in the mixture). Since no deliberate blending or mixing was attempted, the exact concentration of the blend may have varied considerably. No difficulty was encountered. In 1972, when low sulfur oil had to be used to limit the SO_2 emissions, two series of short-term tests were conducted burning No. 2 and used lube oil blends using a rotary cup burner in a 5.4 MB/hour fire

TABLE A-1. SUMMARY OF ACTIVITIES BURNING WASTE OIL AS A SUPPLEMENTAL BOILER FUEL

Activity	Quantity Burned (FY 80)	Type of Waste Oil	Blending Method	Comments
Aberdeen Proving Ground, Maryland	40,000 gallons	Used lube oil	Direct	No stack emission problems encountered with up to 27 percent used lube oil in the blend
NAVSTA Adak, Alaska	34,000 gallons	Many types of high flash point products	Direct	Blending occurs at fuel farm with specification fuel and issued to the base steam plant
NWC China Lake, California	30,000 gallons	JP-4, JP-5, Diesel fuel Used lube oil	In-Line	
NAS Fallon, Nevada	2,400 gallons	Used lube oil and some hydraulic fluid	Direct	Boiler is operated only during winter for 7 to 8 months
PWC Guam	8,000 gallons 600,000 gallons	Used lube oil Contaminated fuel	Direct	Waste oil is blended into regular fuel oil tank when half full
NAVSTA Guantanamo Bay, Cuba	180,000 gallons	Used lube oil Hydraulic fluid Contaminated fuel	Direct	Blended with NSFO in existing tankage at a concentration of about 5 percent waste oil
NAC Indianapolis, Indiana	5,000 gallons	Machine shop cutting oil Used lube oil	Direct	Metal filings are removed by a centrifuge prior to burning
NAVSTA Mayport, Florida	650,000 gallons	Ship bilge waste oil	In-Line	Removal of water and sediment from this type of waste oil is important in reducing repair and maintenance
PWC Norfolk, Virginia	4,000,000 gallons 10,000 gallons	FOR Used lube oil	Direct	
NSY Norfolk, Virginia	182,000 gallons*	Contaminated fuel Used lube oil Hydraulic oils	Burned straight (at 100 percent)	Prior to burning, waste oil and reclaimed fuel is analyzed for specification requirements and burned as regular fuel
NAS Oceana, Virginia	**	FOR	Direct	An increased burn rate of regular fuel is required to offset lower BTU value of FOR
NAVSTA Rota, Spain	115,000 gallons	Contaminated fuel	In-Line	Fuel loading pier is equipped with drains and holding tank for collection of spillage
NAS Whidbey Island, Washington	60,000 gallons	Contaminated fuel Used lube oil Solvents	Burned straight (at 100 percent)	One burner in the boiler is designated for burning waste oil
PWC Yokosuka, Japan	2,000 gallons	Used lube oil Transformer oil	Burned straight (at 100 percent)	Waste oil is burned in a boiler specifically for the purpose

* Quantity for last 6 months of FY 81
** No previous quantities available - just now beginning to burn

tube boiler. The results showed that with up to 27 percent used lube oil in the blend, no stack emission problem was encountered.

NAVSTA ADAK, ALASKA

Generates 34,000 gallons of all types of high flash products collected throughout the island. This waste oil is stored in holding tanks and allowed to settle out and then direct blended with specification fuel and issued to the base steam plant for consumption.

AIR FORCE TESTS

A systematic test series was conducted by the U.S. Air Force. Used lube oils containing aviation piston engine oils, synthetic turbine lubricant, hydraulic fluid, Stoddard solvent, etc. were mixed with No. 2 and No. 6 fuel oils at concentrations of 0.1, and 1, and 10 percent. These blends were then fired for 30 minutes each to determine the firing characteristics. No difficulty was encountered and no ill effects (e.g., emissions, corrosions, degradation of boiler systems) were observed. A series of 2-3 hour tests were than conducted at 5 percent concentration. Satisfactory firing was achieved and no increase in particulate emissions were measured. As a result, long-term in-service boiler tests were recommended. Tests of this nature were conducted at three Air Force bases. Up to 26 percent used lube oil in No. 2 oil, 6 percent JP-4 in No. 5 oil, 16 percent JP-4 in No. 2 oil, 4 percent and 11 percent of 50/50 JP-4/used lube oil respectively in No. 2 and No. 5 oils were tested. Results showed that relatively clean burning fuel (e.g., JP-4) mixed in relatively dirty fuel (e.g., No. 5) would not adversely affect emissions. But relatively dirty fuel (e.g., used lube oil) mixed in clean fuels will significantly increase the particulate emissions although the emissions are still below standards. Overall, the combustion performance either remained the same or improved.

NWC CHINA LAKE, CALIFORNIA

In 1978 and 1979, CEL and NWC China Lake conducted a series of controlled tests burning waste oil in one boiler. The boiler utilized was a single-burner, water tube boiler producing 125 psi saturated steam at 20,700 pound/hour rated capacity. These tests were run blending the waste oil in concentrations of 8 percent to 90 percent with No. 6 fuel oil. Control tests were also conducted with No. 6 fuel alone and burning 100 percent waste oil.

NWC China Lake generates approximately 2,500 gallons of waste oils per month that are comprised primarily of contaminated JP-4, JP-5, diesel fuels, and used lubricating oils. The mixture of these oils is a dark colored liquid resembling light fuel oil and is somewhat heavier and higher in viscosity than diesel fuel. This material had been used in the past for firefighter training and dust control. Only high flash point waste oils (e.g., used lubricating oils, contaminated JP-5 and diesel fuels, etc.) were

used for the tests. Low flash point and other materials (e.g., contaminated JP-4, gasoline, solvent, etc.) were collected separately for firefighters' training and were not mixed with the high flash materials.

The NWC waste oil resembled a light grade fuel oil. After removal of water and solid contaminants, this waste oil was satisfactorily fired in boilers, either straight or in blends of any concentration with the regular No. 6 fuel oil. To minimize the requirement for burner adjustments, the firing temperature of a blend was controlled so that its viscosity was nearly the same as that of the regular fuel oil at its normal firing temperature. No operational or environmental emission difficulties were encountered due to the presence of waste oil during either batch or in-line blending tests. In-line blending was successfully achieved by combining two oil streams using a "T" arrangement.

NAS FALLON, NEVADA

Generates and burns approximately 200 gallons of waste oil each month. Collected in drums at motor pool service areas, it is transported to the boiler plant and strained through a fire wire screen prior to introduction into primary fuel oil storage. The waste oil consists primarily of used lube oil with some hydraulic fluid and rarely small amounts of greases. The 200 hp boiler is operated for only 7 to 8 months out of the year at 40 to 55 gallons of fuel per hour. The fuel normally used is No. 6 fuel oil with No. 2 oil backup capability. The normal fuel is stored in a 12,000 gallon tank and pumped through a filter into the burners. No special modifications to boiler equipment or operational changes have been required to burn this waste oil and no adverse effects of use have been noted.

PWC GUAM

Generates two types of waste oil. Approximately 8,000 gallons a year of used lube oil results from oil changes of diesel engine generators. As much as 600,000 gallons of contaminated fuel each year is received from the tank farm. This fuel is contaminated DFM which has been purged from pipelines and no longer meets specification. No quality assurance measures are taken since the fuel is not really dirty, but contains water and maybe small amounts of No. 6 oil. This waste oil is not burned on a regular basis, but rather only when a supply accumulates or becomes available from the tank farm. As a result, it is direct blended into existing No. 6 fuel oil tankage by placing the waste oil in the tank when half full and then filling the tank with No. 6 fuel oil. This oil is utilized by three 200,000 pounds/hour and three 150,000 pounds/hour boilers using approximately 4,500 barrels of fuel oil a day. This waste oil is being burned without modification to existing equipment and within normal boiler operation guidelines.

NAVSTA GUANTANAMO BAY, CUBA

Burns about 180,000 gallons of waste oil a year in a combination desalination/steam power plant. The waste oil consists of used lube oil, hydraulic fluid, and contaminated fuel from transportation and maintenance service areas. Currently, the oil is collected and stored in a Ship Waste Off-Load Barge (SWOB). Future plans include the use of a Waste Oil Raft (DONUT) to aid in separation of water and solids from the oil. Transported to the plant, the waste oil is direct blended into existing tankage with NSFO at a concentration of about 5 percent (typically 2,000 gallons in 40,000 gallons regular fuel) and burned at the normal rate. Analysis of the waste showed an average heating value of 135,000 BTU's/gallon. No problems with burning were encountered for the past year. However, early problems included flameouts due to high water concentrations in the oil and "globs" and sediment clogging burners and equipment. Increased settling time prior to burning has greatly reduced operational problems. Unknown quantities of abandoned fuel found in oil underground storage tanks are also being salvaged and utilized as a supplemental fuel.

NAC INDIANAPOLIS, INDIANA

Burns approximately 5,000 gallons of waste oil per year in one of three 17,000 pounds/hour boilers used for steam production. The major source is machine shop cutting oil. Metal filings present in the fluid are the major problem and are removed by a centrifuge prior to storing/burning. Used lube oil is the secondary source and is collected from 60 vehicles in the transportation department and from a collection center provided for the individual to recycle waste oil. The boilers are designed to burn natural gas as primary fuel and have the capacity of No. 5 fuel oil backup. Storage of No. 5 fuel oil is maintained in six 1,500 gallon tanks, one of which is set aside to receive waste oil. Clean No. 5 fuel oil and waste oil are mixed at about 50:50 ratio in this tank prior to burning. Problems of increased smoke emission and clogged filters due to dirt and sediment suspended in the waste oil are sometimes experienced.

NAVSTA MAYPORT, FLORIDA

Burned 650,000 gallons of waste oil during FY 80, 750,000 gallons during FY 79, and 500,000 gallons during FY 78. The major source is ship discharge which consists of very dirty DFM (greater than 90 percent), water, and sediment. To treat the waste oil, the ship discharge is placed in a 157,500 gallon tank and allowed to settle and water is drained off the bottom. The oil fraction is then transferred to a second 157,500 gallon tank to settle. The oil is again transferred to a third tank (157,500 gallon capacity) and allowed to settle for 24 hours before trucking. The top 4 to 5 feet of oil is skimmed off the tank and trucked to the boiler plant. Future plans include the installation of a 100 gallon per hour 25 hp centrifuge to remove water

and sediment prior to burning. When this facility is completed, waste oil can be hauled or pumped directly to the boiler plant without lengthy settlement periods. At the boiler plant, waste oil is stored in a 10,000 gallon waste oil tank. The three 33,500 pounds/hour water tube boilers are designed to normally burn No. 5 fuel oil. The waste oil, which is basically No. 2 fuel oil, blends in well with the regular fuel. Estimated heating value of the waste oil is 140,000 BTU's/gallon, which closely approximates that of DFM. Samples of the waste oil burned are periodically taken and analyzed by the local government.

Maintenance and operational problems include:

- Pump - Rotary vane pumps used for fuel transport were especially intolerant to solids. Damage included scored liners and pitted vanes.

- Strainers - Strainers required cleaning up to four times as often when using waste oil.

- Burner Tips - Deformation of burner tip orifices was increased. The orifices became enlarged, elongated, and pitted.

Removal of water and especially solids from the water prior to burning is important in reducing maintenance and repair of boiler equipment.

PWC NORFOLK, VIRGINIA

Utilizes two different sources of supplemental fuel. The major source (4 million gallons per year) is reclaimed fuel oil (FOR) obtained from Craney Island at a cost of $0.35 per gallon. FOR is burned independently in a separate burner with little or no operational changes required. Although existing No. 6 fuel oil pumps will handle the lighter weight FOR, they are being replaced with pumps designed specifically to handle fuel of No. 2 oil consistency when ordinary wear and service life dictates. This activity has been burning FOR since 1979 with no problems or deviations from normal boiler operation. The secondary source is used lube oil and hydraulic fluid that never amounts to more than 10,000 gallons per year. This waste oil is collected from the motor pool and service areas and transported to the boiler plant where it is direct blended into existing No. 6 fuel oil tankage, and burned along with the regular fuel.

NSY NORFOLK, VIRGINIA

Utilizes oils originating from ship bilges and shipboard facilities that consist of reclaimed fuel, new and used lube oil, and hydraulic oils. Wastes such as cutting oil and solvents generated in the shipyard are sold to a contractor. The main source of hydraulic oil is aircraft carriers. Waste oil not sold to the contractor is treated by gravity separation and tested for the

specification requirements of VV-F-815C. If acceptable, the oil is directly burned in the boiler plant. If the oil fails to meet specification requirements, it is sent to Craney Island for treatment and reissue. Quantities for 6 months of FY 81 are:

- Turned into DLA for sale - 11,000+ gallons;
- Burned directly in boiler - 182,000 gallons; and
- Sent to Craney Island - 760,000 gallons.

A current project is the construction of a facility specifically for collection, storage, and use of hydraulic oils in the boiler plant. The project includes tanks, pumps, piping, etc., and will be on-line in about 6 months.

NAS OCEANA, VIRGINIA

Operates four boilers totaling 210,000 pounds/hour, all of which periodically burn reclaimed fuel oil (FOR) obtained from Craney Island. FOR is placed in the main tanks in the same manner as regular fuel and burned at a 50 percent concentration with No. 6 fuel oil. No handling differences from that of regular fuel are experienced. However, the BTU rating of the FOR (135,000 to 140,000 BTU/gallon) is lower than that of No. 6 fuel oil, and as a result, an increase in the firing rate is required to offset the deficit. Since FOR is purchased at $0.35 per gallon, a significant savings in fuel costs is achieved.

NAVSTA ROTA, SPAIN

Burns approximately 115,000 gallons of contaminated fuel each year in its two 85,000 pounds/hour boilers that normally burn No. 6 fuel oil. The two sources of this oil are fuel pier spillage and fuel/water pumped from fuel tankers during tank cleaning. The fuel pier is equipped with spillage drains and holding tanks. Fuel spilled during unloading operations is automatically collected and stored. Contaminated fuel unloaded from ships during tank cleaning operations is placed in the same holding tanks. The fuel mixture is then transferred to an API separator for gravity separation and then into either low or high flash point tanks (the flash point is checked by a chemist). When the power plant calls for it, the fuel is transferred first to a direct blending tank and then pumped into a plant tank where it is held for 72 hours before burning at a concentration of 5 to 10 percent. Little or no adverse effects of use have been identified. However, deposits of ash may be accumulating on internal boiler surfaces.

NAS WHIDBEY ISLAND, WASHINGTON

Collects and burns approximately 60,000 gallons a year of waste oil and contaminated fuel from two different type areas on the base. The waste oil burned consists of a wide range of solvents, phenols, JP fuel, hydraulic fluids, and used lube oils. Enlisted personnel collect fuel, solvents, and used lube oil from

the flight line in mobile bowsers (700 to 1,000 gallon capacity) and transport it to the boiler plant, where it is stored in a 25,000 gallon underground tank. There is no treatment of this oil. Secondly, Public Works collects used lube oil from garages, service areas, and other locations throughout the base and place it in a 5,000 gallon tank to settle. The oil that rises is skimmed off the top and placed in a second tank (3,000 gallon capacity) to settle, and water is drained off the bottom periodically. After settling, this oil is transported to the underground tank at the boiler plant. The waste oil is burned in one of the three 44 M BTU/hour boilers which use natural gas as the primary fuel, and No. 2 fuel oil as backup. One of the three burners is set aside to burn waste oil. No modifications to the burner itself were required. The waste oil is pumped from the underground holding tank (25,000 gallon capacity) through a fine strainer and into the burner. While the waste is being burned, adjustments of the natural gas burners are made to compensate for fluctuations of the waste oil burner. Increased boiler cleaning requirements have been observed. The boiler utilizing waste oil experiences increased ash accumulation and requires cleaning twice a year. Boilers burning regular oil may be cleaned only every year or two.

PWC YOKOSUKA, JAPAN

Utilizes approximately 2,000 gallons a year of used lube oil from the transportation shop and transformer oil NOT containing PCB. The waste oil burned is that generated and collected by PWC only. This waste oil is collected in 55 gallon drums and poured through a fine screen filter into a 1,000 gallon tank where it settles until the tank is full. Once accumulated, the oil is burned at a 100 percent concentration in a boiler specified for the purpose. This burning occurs once every 6 to 9 months, and the quantity collected during that time (1,000 gallons) is about one day's fuel supply requirement for the boiler. Ship bilge waste oil generated at dockside is collected in DONUT's and SWOB barges and transported to the Naval Supply island 1/2 mile offshore. The waste oil goes through gravity separation and is blended into No. 6 fuel oil and sold.

APPENDIX B

ASSUMPTIONS USED FOR ADMINISTRATIVE/PERSONNEL COSTS

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ASSUMPTIONS USED FOR ADMINISTRATIVE/PERSONNEL COSTS

ADMINISTRATION OF SALE OR DISPOSAL CONTRACTS

Administrative costs were approximated to 1 percent of the contract value, and in the case of the existing disposal contract, an additional 1 percent was included for manifest preparation.

PERSONNEL COSTS

All personnel costs were calculated on a salary rate of $26,000/year plus 100 percent overhead.

SAMPLING AND ANALYSIS

Sampling and analysis requirements were included as "administrative" costs on the basis that every batch of used oil/solvents will require sampling (by waste group) and analysis prior to sale, disposal, or burning. For the recycling of hydraulic oils (closed loop) analysis will be required to determine if the recycled oil meets the specifications. Laboratory analysis was costed at $250/sample.

CONTROL OF FUEL BLENDING

A batch operation was the basis for costing personnel requirements for fuel blending. Waste oil would be burnt 4 to 6 times per year depending on the volume generated. Supervision of the process was based on one operator being assigned full-time for the duration of the burn plus 1 day.

RECORDKEEPING

Recordkeeping costs were not included in the cost estimate on the basis that they would likely be similar for all schemes.