Recycling MIL-H-46170 Hydraulic Fluid to Extend Fluid Service Life

March 1995

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This report documents the laboratory efforts in proving that used hydraulic fluid could be recycled by removing contaminants and mixing with new fluid. Once the used fluid has been filtered to remove solid particulate contamination and de-humidified to bring the moisture content below 500 ppm water, it can be mixed with new fluid in a 75:25 ratio to bring the fluid mixture up to specification performance. The recycled used fluid by itself could not pass the foaming characteristic requirement thus requiring re-inhibition. Instead of adding more anti-foaming agent to the fluid, the decision was made to mix recycled fluid with new fluid to provide the re-inhibition effect. Mixing in new fluid results in an enhancement of all additive performance and eliminated any possible problems with adding too much or too little anti-foaming agent. These efforts set the standards for evaluating commercial recycling units that can recycle hydraulic fluid on a large scale and also establish doctrine for successfully extending the service life of used hydraulic fluid.
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Section 1  Introduction and Background

At the request of the Defense General Supply Center (DGSC), the Fuels and Lubricants Division of the Mobility Technology Center - Belvoir has investigated the possibility of recycling hydraulic fluid. In an effort to reduce the waste stream of POL products generated by military units, the DGSC Hazardous Materials Minimization Office provided funding from the Defense Environmental Restoration Account (DERA) to not only demonstrate that hydraulic fluid could be recycled, but to also evaluate commercial recycling technology. Most often, even though hydraulic fluid can contain significant water and particulate contamination, the additive package which provides the fluid's desired performance remains in tact. If hydraulic fluid can be recycled by removing contamination, and the clean fluid determined to retain sufficient performance capabilities, a reduction in the POL waste stream would result because the recycled fluid could be returned to service. Recycling the fluid will not only reduce disposal costs, but also significantly reduce new fluid procurement costs.

In demonstrating the recyclability of hydraulic fluid, this investigation was limited to MIL-H-46170 hydraulic fluid (FRH). The objective of the investigation was to characterize any loss of performance of the used fluid, identify effective means of recycling the fluid, and demonstrating satisfactory performance of the recycled fluid. Two issues were addressed in this effort. First, the fluid was evaluated in the laboratory to determine the viability of recycling hydraulic fluid. The data gained from this investigation provides the baseline for evaluating commercially available recycling technology. Not only must it be proven on a laboratory scale that the fluid can be recycled but also that large quantities generated by maintenance units and depots can be recycled using commercial technology. The effort in the laboratory sets the stage for evaluating the viability of recycling on a large scale.
Section 2  Technical Approach

In demonstrating that hydraulic fluid can be recycled and returned to service, three tasks were performed. First, used fluid was evaluated against specification requirements to identify any loss of fluid performance. Second, techniques were developed for removing the water and particulate contamination present in the used fluid. Finally, techniques were developed for returning the recycled fluid to specification performance. Table 1 provides a summary of the performance requirements as specified in MIL-H-46170. These requirements must be met by the recycled fluid before it can be successfully returned to service.

Table 1. MIL-H-46170 Fluid Performance Requirements

<table>
<thead>
<tr>
<th>PERFORMANCE TEST</th>
<th>MIL-L-46170</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidation/Corrosion</td>
<td>168 hrs @ 135°C</td>
</tr>
<tr>
<td>ASTM D4636, #3</td>
<td>vis. chng &lt; 10%</td>
</tr>
<tr>
<td></td>
<td>acid # chng &lt; + 0.30</td>
</tr>
<tr>
<td>Corrosion Inhibition</td>
<td>100 hrs min</td>
</tr>
<tr>
<td>ASTM D1748</td>
<td></td>
</tr>
<tr>
<td>Galvanic Corrosion</td>
<td>10 days</td>
</tr>
<tr>
<td>FTM 5322</td>
<td></td>
</tr>
<tr>
<td>Low Temp Stability</td>
<td>72 hrs @ -54°C</td>
</tr>
<tr>
<td>FTM 3458</td>
<td></td>
</tr>
<tr>
<td>Pour Point</td>
<td>-60°C min</td>
</tr>
<tr>
<td>ASTM D97</td>
<td></td>
</tr>
<tr>
<td>Viscosity @ 40°C</td>
<td>19.5 cSt max</td>
</tr>
<tr>
<td>ASTM D445</td>
<td></td>
</tr>
<tr>
<td>Viscosity @ 100°C</td>
<td>3.4 cSt min</td>
</tr>
<tr>
<td>ASTM D445</td>
<td></td>
</tr>
<tr>
<td>Viscosity @ -40°C</td>
<td>2600 cSt max</td>
</tr>
<tr>
<td>ASTM D445</td>
<td></td>
</tr>
<tr>
<td>Viscosity @ -54°C</td>
<td>report</td>
</tr>
<tr>
<td>ASTM D445</td>
<td></td>
</tr>
<tr>
<td>Solid particle Count</td>
<td>10,000 max @ 5-25 micrometers</td>
</tr>
<tr>
<td>MIL-H-46170</td>
<td></td>
</tr>
<tr>
<td>Solid Particle Count</td>
<td>250 max @ 26-50 micrometers</td>
</tr>
<tr>
<td>MIL-H-46170</td>
<td></td>
</tr>
<tr>
<td>Solid Particle Count</td>
<td>50 max @ 51-100 micrometers</td>
</tr>
<tr>
<td>MIL-H-46170</td>
<td></td>
</tr>
</tbody>
</table>
Table 1. MIL-H-46170 Fluid Performance Requirements (continued)

<table>
<thead>
<tr>
<th>PERFORMANCE TEST</th>
<th>MIL-L-46170</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Particle Count</td>
<td>10 max @ over 100 micrometers</td>
</tr>
<tr>
<td>MIL-H-46170</td>
<td></td>
</tr>
<tr>
<td>Acid Number</td>
<td>0.2 gm KOH/gm max</td>
</tr>
<tr>
<td>ASTM D664</td>
<td></td>
</tr>
<tr>
<td>Elastomer Swell</td>
<td></td>
</tr>
<tr>
<td>FTM 3603</td>
<td></td>
</tr>
<tr>
<td>Nitrile</td>
<td>0% - 3%</td>
</tr>
<tr>
<td>Fluorocarbon</td>
<td>0% - 1%</td>
</tr>
<tr>
<td>Fluorosilicone</td>
<td>0% - 2%</td>
</tr>
<tr>
<td>Polyacrylate</td>
<td>0% - 2%</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>0% - 1%</td>
</tr>
<tr>
<td>Evaporation Loss</td>
<td>5% max</td>
</tr>
<tr>
<td>ASTM D972</td>
<td></td>
</tr>
<tr>
<td>Steel on Steel Wear</td>
<td>0.3 mm max @ 10 kg load</td>
</tr>
<tr>
<td>ASTM D4172</td>
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<tr>
<td>Steel on Steel Wear</td>
<td>0.65 mm max @ 40 kg load</td>
</tr>
<tr>
<td>ASTM D4172</td>
<td></td>
</tr>
<tr>
<td>Foam Characteristics</td>
<td>65 ml max</td>
</tr>
<tr>
<td>ASTM D892</td>
<td></td>
</tr>
<tr>
<td>Water Content</td>
<td>500 ppm max</td>
</tr>
<tr>
<td>ASTM D1744</td>
<td></td>
</tr>
<tr>
<td>Flash Point</td>
<td>204°C min</td>
</tr>
<tr>
<td>ASTM D92</td>
<td></td>
</tr>
<tr>
<td>Fire Point</td>
<td>246°C min</td>
</tr>
<tr>
<td>ASTM D92</td>
<td></td>
</tr>
<tr>
<td>Storage Stability</td>
<td>12 months</td>
</tr>
<tr>
<td>FTM 3465</td>
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The task of recycling the hydraulic fluid is one of removing unwanted contaminants and treating the fluid to bring performance back to specification requirements. The effects of contamination in a hydraulic system can be disastrous. Solid particle contamination in the fluid can cause wear and jamming. Additionally, a domino effect can take place because wear of the surfaces exposes clean metal which is then subjected to corrosive attack if moisture is present in the system. It is vital in recycling hydraulic fluid that particulate and moisture contamination be removed otherwise the additives in the fluid will be hampered in their ability to provide protection.³
Removing the particulate contamination in the laboratory was relatively straightforward but time consuming. The fluid was first centrifuged to remove any large sediment contamination. The centrifuged fluid was then subjected to a series of successively smaller filters (5.0 microns, 0.8 microns, 0.45 microns) until the particle count fell below the maximum allowed by the specification.

One technique for removing water contamination involves dilution of the hydraulic fluid with a water-immiscible solvent that will separate the water into an immiscible layer then co-distilling the off the water and solvent. This technique is recommended if large amounts of water are present. Used fluid that was obtained from Aberdeen Proving Ground was found to contain only 728 ppm water thus a different technique was employed, which although simpler, could prove to be time consuming.

The used fluid was simply heated to 109°C for a period of time. The amount of time required depended on the volume of fluid being de-humidified and degree of water contamination. One liter of fluid containing less than 0.1% water required only 2 hours of exposure at 109°C. Fluid containing greater than 0.5% water required 24 hours to de-humidify 1 liter. Heating the fluid to 109°C was sufficient enough to drive of any water yet not stress the fluid thermally. In most cases the water content was reduced to half of the maximum (500 ppm) allowed. While the techniques used in the laboratory proved effective, they are not the techniques of choice for recycling hydraulic fluid on the premises of maintenance units and depots. The technology required must allow for high volumes in a short amount of time. In most cases, this can only be accomplished through filtering technology that removes all types of contamination.
Section 3  Results

Table 2 below summarizes the results of all testing performed on the used and recycled fluids. Comparison of the results summarized in this table with the requirements identified in Table 1 indicate that the used fluid does not provide adequate performance in Low Temperature Stability, Water Content, Foaming Characteristics, Fire Point, Particle Count, and Evaporation Loss. The recycled fluid, however, demonstrated an immediate improvement in Low Temperature Stability, Water Content, Particle Count, and Evaporation Loss on simply removing the particulate and water contamination. The recycled fluid still did not exhibit satisfactory performance in Foaming Characteristics or Fire Point.

Table 2. Fluid Performance — Used and Recycled

<table>
<thead>
<tr>
<th>TEST</th>
<th>USED FRH</th>
<th>RECYCLED FRH</th>
</tr>
</thead>
<tbody>
<tr>
<td>5308 ACID NO.</td>
<td>0.22</td>
<td>0.36</td>
</tr>
<tr>
<td>5308 COUPON WT CHNG</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>5308 Δ VISCOSITY</td>
<td>9.6%</td>
<td>3.9%</td>
</tr>
<tr>
<td>HUMIDITY CABINET</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>GALVANIC CORROSION</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>LOW TEMP STABILITY</td>
<td>FAIL</td>
<td>PASS</td>
</tr>
<tr>
<td>VISCOSITY -40 °C</td>
<td>2506 cSt</td>
<td>2494 cSt</td>
</tr>
<tr>
<td>VISCOSITY 40 °C</td>
<td>15.7 cSt</td>
<td>16.4 cSt</td>
</tr>
<tr>
<td>VISCOSITY 100 °C</td>
<td>3.8 cSt</td>
<td>4.2 cSt</td>
</tr>
<tr>
<td>POUR PT</td>
<td>Below -60°C</td>
<td>Below -60°C</td>
</tr>
<tr>
<td>FLASH PT</td>
<td>211°C</td>
<td>208°C</td>
</tr>
<tr>
<td>FIRE PT</td>
<td>233°C</td>
<td>224°C</td>
</tr>
<tr>
<td>WATER CONTENT (PPM)</td>
<td>728</td>
<td>278</td>
</tr>
<tr>
<td>FOAMING</td>
<td>80/0, 30/0, 60/0</td>
<td>90/0, 30/0, 60/0</td>
</tr>
<tr>
<td>4-BALL WEAR</td>
<td>0.382 mm</td>
<td>0.355 mm</td>
</tr>
<tr>
<td>ACID NUMBER</td>
<td>0.25 mg KOH/mg</td>
<td>0.15 mg KOH/mg</td>
</tr>
<tr>
<td>PARTICLE COUNT (MICROMETERS)</td>
<td>127,347 (5-25)</td>
<td>1,257 (5-25)</td>
</tr>
<tr>
<td></td>
<td>32 (26-50)</td>
<td>19 (26-50)</td>
</tr>
<tr>
<td></td>
<td>2 (51-100)</td>
<td>1 (51-100)</td>
</tr>
<tr>
<td></td>
<td>0 (OVER 100)</td>
<td>0 (OVER 100)</td>
</tr>
<tr>
<td>EVAPORATION LOSS</td>
<td>5.95%</td>
<td>4.36%</td>
</tr>
<tr>
<td>ELASTOMER SWELL</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>NITRILE</td>
<td>1.78%</td>
<td>1.45%</td>
</tr>
<tr>
<td>FLUOROCARBON</td>
<td>0.46%</td>
<td>0.39%</td>
</tr>
<tr>
<td>FLUOROSILICONE</td>
<td>2.04%</td>
<td>2.4%</td>
</tr>
<tr>
<td>POLYACRYLATE</td>
<td>1.06%</td>
<td>1.44%</td>
</tr>
<tr>
<td>POLYURETHANE</td>
<td>0.37%</td>
<td>-0.26%</td>
</tr>
</tbody>
</table>
Given that the recycled fluid failed only the foaming characteristics, only minor treatment of the fluid would be required to bring the fluid within specifications. Instead of adding additional anti-foaming agent to solve the problem, new FRH from an unopened can was added to the recycled fluid. Two mixtures were created to identify the maximum and minimum fluid ratios. New FRH was mixed with recycled FRH in 25:75 and 50:50 ratios. These fluid mixtures were evaluated against the same performance criteria with results summarized in Table 3 below.

Table 3. Performance of Recycled FRH Mixed with New FRH

<table>
<thead>
<tr>
<th>TEST</th>
<th>25:75 FRH MIX</th>
<th>50:50 FRH MIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>5308 ACID NO.</td>
<td>0.13 mg KOH/mg</td>
<td>0.21 mg KOH/mg</td>
</tr>
<tr>
<td>308 COUPON WT CHNG</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>5308 Δ VISCOSITY</td>
<td>-1.34%</td>
<td>-4.42%</td>
</tr>
<tr>
<td>HUMIDITY CABINET</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>GALVANIC CORROSION</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>LOW TEMP STABILITY</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>VISCOSITY -40 °C</td>
<td>2473 cSt</td>
<td>2183 cSt</td>
</tr>
<tr>
<td>VISCOSITY 40 °C</td>
<td>16.4 cSt</td>
<td>17.0 cSt</td>
</tr>
<tr>
<td>VISCOSITY 100 °C</td>
<td>3.9 cSt</td>
<td>3.8 cSt</td>
</tr>
<tr>
<td>POUR PT</td>
<td>Below -60°C</td>
<td>Below -60°C</td>
</tr>
<tr>
<td>FLASH PT</td>
<td>212°C</td>
<td>210°C</td>
</tr>
<tr>
<td>FIRE PT</td>
<td>230°C</td>
<td>236°C</td>
</tr>
<tr>
<td>WATER CONTENT (PPM)</td>
<td>324.5</td>
<td>342.1</td>
</tr>
<tr>
<td>FOAMING</td>
<td>55/0,30/0,50/0</td>
<td>55/0,30/0,50/0</td>
</tr>
<tr>
<td>4-BALL WEAR</td>
<td>0.34 mm</td>
<td>0.37 mm</td>
</tr>
<tr>
<td>ACID NUMBER</td>
<td>0.21 gm KOH/gm</td>
<td>0.15 gm KOH/gm</td>
</tr>
<tr>
<td>PARTICLE COUNT (MICROMETERS)</td>
<td>Not Necessary</td>
<td>Not Necessary</td>
</tr>
<tr>
<td>EVAPORATION LOSS</td>
<td>3.84%</td>
<td>3.30%</td>
</tr>
<tr>
<td>ELASTOMER SWELL</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>NITRILE</td>
<td>1.67%</td>
<td>2.24%</td>
</tr>
<tr>
<td>FLUOROCARBON</td>
<td>0.19%</td>
<td>0.81%</td>
</tr>
<tr>
<td>FLUOROSILICONE</td>
<td>1.62%</td>
<td>1.91%</td>
</tr>
<tr>
<td>POLYACRYLATE</td>
<td>0.71%</td>
<td>2.53%</td>
</tr>
<tr>
<td>POLYURETHANE</td>
<td>-0.50%</td>
<td>-0.11%</td>
</tr>
</tbody>
</table>

As can be seen, both fluid mixtures passed all performance requirements except the Fire Point. The foaming characteristics tested below the maximum allowed in the specification. Evaporation Loss, Flash Point, Fire Point, and corrosion/oxidation stability (5308 test) all improved with the addition of the new fluid. Neither fluid mixture, however, passed the Fire Point requirement. The 25% mixture exhibited a Fire
Point of 16°C below the minimum while the 50% mixture exhibited a Fire Point 10°C below the minimum. Although some improvement in Fire Point occurred, there seems to be no significant performance improvement of the 50% mixture over the 25% mixture.
Section 4  Conclusions

While recycled FRH does not meet all specification performance requirements, it can be treated with new FRH to improve fluid performance to specification standards. Although adding new fluid to the recycled fluid did not bring the fire point completely up to the specification requirement, the fluid mixture did meet the flash point and all other requirements. A loss in Fire Point of 10-16°C does not imply a significant loss in fire resistance. Keeping the flash point up to specification standard indicates the fire resistance of the fluid remains predominantly in tact. In evaluating the merits of recycling hydraulic fluid, the negative aspects are simply the slight loss in fire point whereas the positive aspects are the reduction in waste stream and associated costs.

Costs of recycling will be limited to the recycling process itself, with no expenses going toward procurement of additives to extend the service life of the fluid. Treating the recycled fluid with new FRH precludes the difficulties that are inherent in trying to add new additives to a formulated fluid. There will be no danger of adding too much additive and causing instability or too little additive and not meeting performance requirements. Since hydraulic fluid cannot be recycled indefinitely, some procurement of new fluid will always take place, thus a ready source of new fluid to mix with the recycled fluid will always be available. Even though the recycled fluid must be mixed with new FRH, significant savings will result because the waste stream will be reduced thus lowering disposal costs and procurement volumes of new fluid will lessen.

The efforts discussed in this report were limited to proving on a laboratory scale that FRH could be recycled and returned to service. This is just the first step prior to implementing a hydraulic fluid recycling program throughout the military. The next phase of this investigation is to evaluate commercial recycling technology to verify that the fluid can be recycled to meet specification performance on a large scale. Once successful commercial units have been identified, a field test of the units themselves and the recycled fluid in actual vehicles will be conducted. In addition, efforts will also be aimed at performing oil analysis on the used and recycled fluids to better identify the types of solid particulate contamination found in the used fluid and removed in the recycling process.
References


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REDSTONE ARSENAL
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ATTN SARWY RDD
WATERLIEUT NY 12189

DIR AMC LOG SP ACT
ATTN AMXLS LA
REDSTONE ARSENAL
IL 35890-7466

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ATTN SATPC Q
ATTN SATPC QE (BLDG 85 3)
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PA 17070-5005

CDR ARMY LEA
ATTN LOEA PL
NEW CUMBERLAND
PA 17070-5007

CDR ARMY TECOM
ATTN AMSTE TA R
ATTN AMSTE TC D
ATTN AMSTE EQ
APG MD 21005-5006

PROJ MGR PETROL WATER LOG
ATTN AMCPM PWL
4300 GOODFELLOW BLVD
ST LOUIS MO 63120-1798

PROJ MGM MOBILE ELEC PWR
ATTN AMCPM MEP
7798 CISSNA RD STE 200
SPRINGFIELD VA 22150-3199

CDR
ARMY COLD REGION TEST CTR
ATTN STECR TM
ATTN STECR LG
APO AP 96508-7830

CDR
ARMY BIOMED RSCH DEV LAB
ATTN SGRD UBZ A
FT DETRICK MD 21702-5010

CDR FORSCOM
ATTN AFLG TRS
FT MCPHERSON GA 30330-6000

CDR TRADOC
ATTN ATCD SL 5
INGALLS RD BLDG 163
FT MONROE VA 23651-5194

CDR ARMY ARMOR CTR
ATTN ATSB CD ML
ATTN ATSB TSM T
FT KNOX KY 40121-5000

CDR ARMY QM SCHOOL
ATTN ATSM CD
ATTN ATSM PWD
FT LEE VA 23001-5000

CDR
ARMY COMBINED ARMS SPT CMD
ATTN ATCL CD
ATTN ATCL MS
FT LEE VA 23801-6000

Distribution 2
CDR ARMY FIELD ARTY SCH
  1 ATTN ATSF CD
  FT SILL OK 73503

CDR ARMY TRANS SCHOOL
  1 ATTN ATSP CD MS
  FT EUSTIS VA 23604-5000

CDR ARMY INF SCHOOL
  1 ATTN ATSH CD
  1 ATTN ATSH AT
  FT BENNING GA 31905-5000

CDR ARMY AVIA CTR
  1 ATTN ATZQ DOL M
  1 ATTN ATZQ DI
  FT RUCKER AL 36362-5115

CDR ARMY CACDA
  1 ATTN ATZL CD
  FT LEAVENWORTH KA 66027-5300

CDR ARMY ENGR SCHOOL
  1 ATTN ATSE CD
  FT LEONARD WOOD
  MO 65473-5000

CDR ARMY ORDN CTR
  1 ATTN ATSL CD CS
  APG MD 21005

CDR ARMY SAFETY CTR
  1 ATTN CSSC PMG
  1 ATTN CSSD SPS
  FT RUCKER AL 36362-5363

CDR ARMY CSTA
  1 ATTN STECS EN
  1 ATTN STECS LI
  1 ATTN STECS AE
  1 ATTN STECS AA
  APG MD 21005-5059

CDR ARMY YPG
  1 ATTN STEYPMTL M
  YUMA AZ 85365-9130

CDR ARMY CERL
  1 ATTN CECER EN
  P O BOX 9005
  CHAMPAIGN IL 61826-9005

1 DIR
  AMC FAST PROGRAM
  10101 GRIDLEY RD ST 104
  FT BELVOIR VA 22060-5818

CDR I CORPS AND FT LEWIS
  1 ATTN AFZH CSS
  FT LEWIS WA 98433-5000

CDR
RED RIVER ARMY DEPOT
  1 ATTN SDSRR M
  1 ATTN SDSRR Q
  TEXARKANA TX 75501-5000

PS MAGAZINE DIV
  1 ATTN AMXLPS DI
  DIR LOGSA
  REDSTONE ARSENAL
  AL 35898-7466

CDR 6TH ID (L)
  1 ATTN APUR LG M
  1060 GAFFNEY RD
  FT WAINWRIGHT
  AK 99703

DEPARTMENT OF THE NAVY

OFC OF NAVAL RSCH
  1 ATTN ONR 464
  800 N QUINCY ST
  ARLINGTON VA 22217-5660

CDR
NAVAL SEA SYSTEMS CMD
  1 ATTN SEA 03M3
  2531 JEFFERSON DAVIS HWY
  ARLINGTON VA 22242-5160

CDR
NAVAL SURFACE WARFARE CTR
  1 ATTN CODE 632
  1 ATTN CODE 859
  3A LEGGETT CIRCLE
  ANNAPOLIS MD 21401-5067

CDR
NAVAL RSCH LABORATORY
  1 ATTN CODE 6181
  WASHINGTON DC 20375-5342

CDR
NAVAL AIR WARFARE CTR
  1 ATTN CODE PE33 AJD
  1 P O BOX 7176
  TRENTON NJ 08628-0176

1 CDR
NAVAL PETROLEUM OFFICE
CAMERON STA T 40
5010 DUKE STREET
ALEXANDRIA VA 22304-6180

1 OFC ASST SEC NAVY (I 7 E)
CRYSTAL PLAZA 5
2211 JEFFERSON DAVIS HWY
ARLINGTON VA 22244-5110

Distribution-3
DEPARTMENT OF DEFENSE

ODUSD
1 ATTN (L) MRM
PETROLEUM STAFF ANALYST
PENTAGON
WASHINGTON DC 20301-8000

ODUSD
1 ATTN (ES) CI
400 ARMY NAVY DR
STE 206
ARLINGTON VA 22202

HQ USEUCOM
1 ATTN ECJU L1J
UNIT 30400 BOX 1000
APO AE 09128-4209

US CINCPAC
1 ATTN J422 BOX 64020
CAMP H M SMITH
HI 96861-4020

JOAP TSC
BLDG 780
NAVAL AIR STA
PENSACOLA FL 32408-5300

DIR DLA
1 ATTN DLA MMDI
ATTN DLA MMSB
CAMERON STA
ALEXANDRIA VA 22304-6100

CDR
DEFENSE FUEL SUPPLY CTR
1 ATTN DFSC Q BLDG 8
1 ATTN DFSC S BLDG 8
CAMERON STA
ALEXANDRIA VA 22304-6160

CDR
DEFENSE GEN SUPPLY CTR
1 ATTN DGSC SSA
1 ATTN DGSC STA
8000 JEFFERSON DAVIS HWY
RICHMOND VA 23297-5678

DIR ADV RSCH PROJ AGENCY
1 ATTN ARPA/ASTO
3701 N FAIRFAX DR
ARLINGTON VA 22203-1714

DEFENSE TECH INFO CTR
CAMERON STATION
ALEXANDRIA VA 22314

DEPARTMENT OF AIR FORCE

HQ USAF/LGSSF
1 ATTN FUELS POLICY
1030 AIR FORCE PENTAGON
WASHINGTON DC 20330-1030