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ALTERNATE SPECTROMETRIC OIL ANALYSIS TECHNIQUES

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Oil analysis results from currently used AE and AA techniques are compared with those from various other techniques such as ICP, DCP, graphite furnace AA, ferrography and particle size distribution using the acid dissolution method (ADM). The effect of fine filtration on the analysis capability of the various methods was investigated using a test rig equipped with a 3-micron operational "in-depth" type oil filter. This investigation also includes studies related to ICP sample introduction systems, overloading of ICP sources, and the use of different diluents for improving ICP analyses.

Considering the data from all sample groups all analysis techniques investigated (except ferrography and the acid dissolution method) were iron particle size sensitive. None of the techniques offered any improvement over the currently used AE with respect to analyzing large particles, monitoring capability with or without microfiltration, analysis time or analysis cost or person-power. The study also indicated that microfiltration could have a small effect on spectrometric oil analysis results.

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FOREWORD

This report describes the research conducted by personnel of the University of Dayton Research Institute on Contract No. F33615-87-C-2714 Task #4. The work was sponsored by SA-ALC/LDEN, Kelly AFB TX with Mr. Griffin L. Jones as the Project Engineer. This work was conducted at the Air Propulsion and Power Directorate, Wright Laboratory, Air Force Systems Command, Wright-Patterson AFB, Ohio.

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   Sheppard AFB
   Myrtle Beach AFB

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SECTION I

INTRODUCTION

Spectrometric oil analysis programs for determining wear metals in used aircraft turbine engine lubricants have been used for over 25 years for detecting those engines experiencing abnormal wear and the removal of those engines from service prior to catastrophic failure. Many different methods and techniques have been developed and used for monitoring the wear metals in used lubricants depending on such factors as the type equipment being monitored, monitoring organization, equipment usage, etc. Also during the past 25 years many reports and papers have been published on the success (or failure) of the various monitoring techniques and programs and as such a detailed discussion of lubricant monitoring will not be given in this report unless a specific technique is related to the objective of the test program.

Current Army, Navy and Air Force procedures employ the analysis of the wear metals in used aircraft and other engine oils to detect abnormal operating engines. These procedures are known as the Spectrometric Oil Analysis Program (SOAP). The joint oil analysis program for the Army, Navy and Air Force is known as JOAP. The program requires lubricant samples to be periodically taken from engines and analyzed in a laboratory for various wear metal concentrations. Abnormal operating engines are identified by the level and/or rate of change in specific wear metal concentrations.

The two instruments currently used for conducting oil analyses are the rotating disk electrode atomic emission spectrometer (AE) and the flame atomic absorption spectrometer (AA). Studies have shown that the wear metal analyses of these techniques are particle size dependent and the analyses of the AE are affected by the type of lubricant. However, through establishing different wear metal trending guidelines and threshold values for each instrument, both monitoring techniques have been used reasonably successfully by SOAP to detect abnormal operating engines prior to component failure.

Due to different types and degrees of wear and metal failure, the generated wear particles associated with failure may range from submicron to millimeters in size. For many years oil filters were used having nominal filtration capabilities of 35 to 50 microns and in some cases much greater than 50 microns. In recent years "finer" filtration has been investigated for the purpose of inhibiting secondary wear caused by the primary or initial wear particles and external contamination. Currently, finer filters are often used and ones having ratings of $\beta_3>200$ are being considered for use or are actually used in aircraft turbine engine lubrication systems. A $\beta_3>200$ rating means that no more than 1 particle in 200 having sizes greater than 3 microns will pass through the filter. These "fine" filtration filters have the potential of greatly reducing the metal content of SOAP samples and current techniques for oil analyses may prove unsatisfactory for use in monitoring turbine engines equipped with these filters.

The objective of this investigation was an evaluation and comparative analysis of the currently used AE and AA techniques with various wear metal analysis techniques such as inductively coupled plasma (ICP) spectrometry, direct coupled plasma (DCP) spectrometry, graphite furnace atomic absorption (PWMA), ferrography and particle size distribution using the acid dissolution method (ADM). The effect of 3 micron filtration on the analysis capability of the various methods was investigated using a test rig equipped with a 3 micron operational "in-depth" type oil filter and using parameters of pressures, temperatures and flow rates typical of operating turbine engines.

This investigation also included studies relating to ICP sample introduction systems, overloading of ICP sources, and the use of different diluents for improving ICP analyses.

SECTION II

TEST EQUIPMENT AND PROCEDURES

1. MICROFILTRATION TEST RIG

A detailed description of the microfiltration test rig (MFR) has been previously reported (Ref. 1) and only a brief description of the test rig and filter will be given in this report. The test rig consists mainly of a 5 gallon capacity conical bottom oil reservoir, a constant speed gear pump for oil circulation and a 3/4 inch stainless steel oil circulation system incorporating a turbine flow meter, in-line thermocouples and pressure transducers and a pressure relief valve. A 7 gallon seamless stainless steel container is used for collecting the fluid after passing through the filter. A small scavenger gear pump is used for transferring the filtered fluid back into the oil reservoir for subsequent passes through the filter. The test fluid can be circulated in a by-pass mode prior to filtering for obtaining an uniform (mixed) sample. An "upstream" filter sample can be taken either from the oil reservoir or sampling port while the filtered sample is obtained immediately after filtering from the 7 gallon collection container using a precleaned vacuum flask.

The nomenclature for identifying samples obtained during the filtration study of a test fluid incorporates the test fluid number, the filter pass number (A thru D) and whether it is a pre-filter (1) or post-filter (2) sample. For example the following samples were obtained during filtration testing of test fluid No. 6.

Sample Identification	Description of Sample
MFR-6-A-1	Test Fluid No. 6, First pass, Pre-filter
-6-A-2	Test Fluid No. 6, First pass, Post-filter
-6-B-1	Test Fluid No. 6, Second pass, Pre-filter
-6-B-2	Test Fluid No. 6, Second pass, Post-filter
-6-C-1	Test Fluid No. 6, Third Pass, Pre-filter
-6-C-2	Test Fluid No. 6, Third Pass, Post-filter
-6-D-1	Test Fluid No. 6, Fourth Pass, Pre-filter
-6-D-2	Test Fluid No. 6, Fourth Pass, Post-filter

Some filtration tests involved only 3 passes through the test rig due to the high efficiency of the 3 micron filter in removing debris. The test rig is cleaned by using new MIL-L-7808 or MIL-L-23699 lubricant and a "clean-up" 3 micron filter. A new filter is used for each test.

The filter elements (3 micron absolute, $\beta_3 > 200$) were operational type "in-depth" elements made of Ultipor resin impregnated organic and inorganic fibers capable of withstanding temperatures in the range of $-65^{\circ}F$ to $350^{\circ}F$. The pressure drop across the filter at a rated flow of 4 GPM is 4 psi at $100^{\circ}F$ and has an element collapse differential pressure of 100 psi.

Prior to the filtration studies the amount of wear generated by the two gear pumps was investigated using iron analyses (AE and ADM) and ferrography (Ref. 1). This investigation showed that a very small amount of wear debris was generated by the pumps and was of such a small quantity that the debris would not interfere with the filtration studies.

2. WEAR METAL ANALYSIS TECHNIQUES

a. Atomic Emission Spectroscopy (AE)

Two different atomic emission spectrometers were used for determining the trace metal concentrations of the various samples. Analyses were conducted on all the samples by an Air Force SOAP Laboratory using the Baird A/E35U-3 spectrometer and by UDRI personnel using the Jarrell Ash Model 44181

(Atom-Comp) atomic emission spectrometer. Both instruments employ a rotating disk lower electrode, no sample dilution, AC spark excitation, multi-element simultaneous analysis, data reporting and each using SOAP oil standards R-19 for instrument calibration. The wavelengths used by the RDE spectrometers are listed in Table 1. Normal SOAP procedures were used during the operation of both spectrometers.

b. Atomic Absorption Spectrophotometry (AA)

Trace element concentrations of the samples were made using a Perkin-Elmer Model 3030 and an Analyte Model 16 atomic absorption spectrophotometer. The Perkin-Elmer Model 3030 is a single element mode instrument and only iron determinations were conducted on this instrument since iron was the most prevelant metal present in most of the samples. These analyses were made using a 1 part sample to 4 parts methylisobutyl ketone dilution (by weight), nitrous oxide-acetylene flame, and 1:4 diluted SOAP oil standards for instrument calibration.

The Analyte Model 16 atomic absorption spectrophotometer is a multi-element sequential instrument. Analyses were conducted by Analyte Corp. using a dilution of 1 part sample and 4 parts (by weight) kerosene, nitrous oxide-acetylene flame and 1 to 4 diluted SOAP standards.

c. Inductively Coupled Plasma Spectrometry (ICP)

Two different inductively coupled plasma spectrometers were used in this study. Analyses were conducted by UDRI personnel using a Jarrell-Ash Model ICAP-60 ICP instrument. These analyses were made using 1 part sample and 9 parts kerosene dilution, spray nebulizer using argon gas, multi-element simultaneous analysis and 1 to 9 diluted SOAP standards for calibration. ICP analyses were also conducted by Baird Atomic Corp. using their Model PST/ICP spectrometer incorporating an automatic sampling attachment. These analyses

TABLE 1

WAVELENGTHS (A) USED BY ATOMIC EMISSION SPECTROMETERS

	Jarrell Ash ICP	Baird Atomic ICP	Baird Atomic A/E35U-3	Jarrell Ash RDE	Applied Research Lab DCP
Ag	3281	3218	3281	3281	3281
Al	3082	3944	3081	3961	3082
Cr	2677	2677	4254	2677	2677
Cu	3247	3247	3247	3247	3247
Fe	2599	2599	2599	2599	2599
Mg	2795	2803	2803	2795	2803
Ni	2316	3415	3415	3415	2316
Pb	2203	2833	2833	2833	2833
Si	2881	2516	2516	2881	2516
Sn	2839	3034	3175	3175	3034
Ti	3349	3349	3349	3349	3234

RDE - Rotating Disk Electrode

were made using 1 part sample and 5 parts kerosene dilution, spray nebulizer using argon gas, multi-element simultaneous analysis and using 1 to 5 diluted SOAP standards for calibration. The wavelengths used by the ICP spectrometers are listed in Table 1.

d. Direct Current Plasma Spectrometry (DCP)

The direct current plasma spectrometric analyses were conducted by Applied Research Laboratories (ARL) using their Spectraspan VB Spectrometer. These analyses were made using 1 part sample and 4 parts kerosene dilution, spray nebulizer using argon gas, multi-element simultaneous analysis and diluted SOAP standards for calibration. Wavelengths used for DCP analyses are listed in Table 1.

e. Portable Wear Metal Analyzer (PWMA)

The portable wear metal analyzer is a graphite furnace atomic absorption spectrophotometer. The PWMA is a microprocessor controlled automatic sequential multielement instrument that will analyze for nine elements (Fe, Cu, Al, Cr, Ag, Mg, Ni, Si and Ti) using electrothermal element excitation. Analyses made with the PWMA required no dilution. Conostan Standards in MIL-L-7808 lubricant were used for calibration.

f. Acid Dissolution Method (ADM)

The Acid Dissolution Method has been previously reported in detail (Ref. 2) and only a brief summary of the method will be given in this report. The appropriate amount of sample is combined with a HNO_3/HCL (1:3 by volume) acid mixture and hand shaken for 10 seconds. The mixture is then agitated in an ultrasonic bath for 5 minutes at 40^{o}C (65^{o}C if Mo analysis is required). The mixture is then diluted with Neodol-MIBK solvent for selected wear metal analysis using the Perkin-Elmer Instrument 3030 AA or with Neodol-Kerosene for multielemental analysis using the Jarrell Ash 44181 ICP instrument.

g. Particle Size Distribution Measurements (PSD)

Particle size distribution of iron wear debris was determined using a microfiltration technique. Aliquots of the sample were filtered through 12-, 8-, 5-, 3-, 2-, 1- and 0.4-micrometer Nuclepore membrane filters. The filtrate was then analyzed for iron by the ADM using the Perkin-Elmer Model 3030 AA Spectrophotometer.

h. Ferrography

Ferrography is a technique that uses magnetic separation and collection of wear debris (primarily iron) from lubricating fluids for the subsequent evaluation of the debris with respect to the amount and morphology (particle size, shape, source or type wear, etc) of the debris (Ref. 1). Two types of ferrographs can be used for the evaluation of wear debris in lubricant samples. One is the analytical ferrograph which involves depositing the debris onto a glass slide and subsequent microscopic evaluation as to particle morphology and densitometer measurements. The densitometer measurements provide a relative concentration of the various size particles deposited down the slide from which the ratio of large (L) to small (S) particles can be calculated. The other type ferrograph was the direct reading ferrograph where "large" and "small" particle measurements are made by the ferrograph itself. However, with the direct reading ferrograph, microscopic examination of the particles is not possible. All ferrograph analyses referenced in this report were conducted on the Analytical Ferrograph.

SECTION III

TEST LUBRICANTS

1. INTRODUCTION

The various type lubricant samples used in this investigation were obtained from operational engines, laboratory prepared samples using new lubricant blended with commercially purchased metallic powders and with new lubricant blended with wear debris generated by a pin-on-disk wear test rig. Some of the operational engine samples were obtained specifically for this program while other samples were obtained from normal (Routine) and abnormal (Failure and Hit) operating engines saved from a previous test program (Ref. 3). In all cases, the samples were newly shaken and sonicated prior to analysis. Many of the samples consisted of such small volumes that only limited analyses could be conducted before and after 3 micron membrane filtration. In other cases, two or three samples were combined for providing sufficient sample for microfiltration rig studies.

2. MICROFILTRATION RIG SAMPLES

A description of the samples obtained for microfiltration testing is given in Table 2. Only 12 of the listed 23 samples were filtered using the microfiltration rig due to the small quantity of some samples and low metal content of other samples. Two microfiltration samples (MFR-18 and MFR-22) were blends of three samples each to produce sufficient quantity for test rig filtering.

TABLE 2

DESCRIPTION OF MICROFILTRATION TEST RIG FLUIDS

Test No.	Description of Test Fluid
MFR-1	Six and one half gallons of MIL-L-7808 lubricant (Qualification No. 11E) blended with 519 grams of O-86-2 lubricant containing 1200 ppm iron wear debris generated by pin-on-disk wear testing of O-86-2.
MFR-2	Oil from microfiltration Test No. 1 with the addition of 1.2 grams of pin-on-disk wear debris.
MFR-3	Three and one half gallons of used MIL-L-7808 lubricant from a "test stand" J57 engine.
MFR-4	Four gallons of new MIL-L-23699 lubricant blended with 1.1 grams of debris obtained from "Engine Simulator" test rig.
MFR-5	Five gallons of used 10W30 weight automotive lubricant.
MFR-6	Used MIL-L-23699 lubricant from T56 engine gearboxes received from Pope AFB.
MFR-7	Five gallons of used MIL-L-7808 lubricant from TF33 engines received from Wright-Patterson AFB.
MFR-8	Five gallons of used lubricant from J85 and T56 engines received from Randolph AFB.
MFR-9	Five gallons of used MIL-L-23699 lubricant from T56 engine gearboxes received from Pope AFB.
MFR-10	Five Gallons of used MIL-L-23699 lubricant from T56 engine gearboxes received from Pope AFB.

MFR-11	Used lubricant from OH-58D (SN 83-24141) Helicopter after 88.1 hours and received from Fort Rucker Aviation Center.
MFR-12	Five gallons of lubricant from UH-1, T53-L-13 engine received from Fort Rucker Aviation Center.
MFR-13	Five gallons of used MIL-L-7808 lubricant from Kelly AFB test cells.
MFR-14	Approximately 2 gallons of lubricant from H-53 Helicopter (T64-GE-6B engine SN 154571) received from Pensacola Naval Air Depot.
MFR-15	Five gallons of used oil from J69 and J85 engines received from Sheppard AFB
MFR-16	Approximately 75 mL used lubricant from T-34E aircraft (PT-6A-25 engine). Sample container broken in shipment. Received from Pensacola Naval Air Depot.
MFR-17	Approximately 300 mL sample from intermediate gearbox, H-3 Helicopter.
MFR-18	Blend of samples MFR-15, MFR-16 and MFR-17.
MFR-19	One gallon sample from intermediate gearbox of H-53 Helicopter SN 154884.
MFR-20	One gallon sample from J85-GE-4 engine SN 301350 from test cell, Pensacola Naval Air Depot.
MFR-21	Five gallons of mixed used oil from Randolph AFB.
MFR-22	Blend of samples MFR-19, MFR-20 and MFR-21.
MFR-23	Two gallon sample from TF34-GE-100 engine having 4 ppm Cu reading and copper appearing particles on oil filter. Received from Myrtle Beach AFB.

3. USED OIL SAMPLES

In addition to the five gallon used oil samples passed through the microfiltration rig, MIL-L-7808 and MIL-L-23699 used oil samples (10-40 mL in size) obtained during a previous program were also studied. The used oil samples were obtained from abnormal operating engines (H-Hits), high SOAP readings (P-High) or from failed (F-Failure) T56, J85, J79, J69 and J57 aircraft gas turbine engines not detected by SOAP. Four MIL-L-23699 type used oil samples were also obtained from the gas turbine engines of normal operating Army and commercial helicopters and of normal operating Navy jet aircraft. The used oil samples used for this study are described in Table 3.

To simulate microfiltration, 10-20 ml portions of the used oil samples were passed through a 3 μm Nucleopore membrane filter.

TABLE 3

DESCRIPTION OF SAMPLES USED FOR 3 MICRON PORE SIZE MEMBRANE FILTRATION

Sample No.	Type Engine	HSOC	Sample History
H-54	J57	456	Soap Hit - High Fe
P-43	"	Unknown	High Fe Sample
H-13	"	989	Soap Hit - High Fe
H-66	J69	175	Soap Hit - High Fe, Cr, Pb
P-71	"	345	High Fe, Si
H-84	"	134	SOAP Hit - High Fe, Si
H-12	J79	305	SOAP Hit - High Fe, Cu
H-30	"	271	SOAP Hit - High Fe, Cu
H-67	"	393	SOAP Hit - High Fe, Cu
H-55	"	4	SOAP Hit - High Fe, Cu, Pb
P-81	"	9	High Fe
H-47	"	454	SOAP Hit - High Fe, Cu
P-110	J85	339	High Fe, Mg
P-111	"	Unknown	High Fe, Cr
H-24	"	Unknown	SOAP Hit - High Fe
H-26	"	357	SOAP Hit - High Fe
H-5	"	1	SOAP Hit - High Fe
H-20	"	25	SOAP Hit - High Fe, Ag, Cu
H-89	T56	517	SOAP Hit - High Fe, Mg
P-108	"	583	High Mg
H-6	"	393	SOAP Hit, High Fe, Cu, Mg
H-61	"	442	SOAP Hit, High Fe, Cu, Mg
F-41	"	1081	Engine Failure, SOAP miss, High Fe & Mg
F-5	"	755	Engine Failure, SOAP miss, High Fe
Gearbox 1	Commercial Helicopter	1124	Normal Sample
Gearbox 2	"	1146	Normal Sample
Combined Gearboxes	Army Helicopter	Unknown	Normal Sample
J52 & J60 (Combined)	J52 & J60 (Navy Acft)	Unknown	Normal Sample

Residual SOAP samples were received during this program from various type aircraft for providing trending data using both AE and ICP analyses. A description of these aircraft, type engines and locations are given in Table 4.

TABLE 4

AIRCRAFT MONITORED BY
AE and ICP USING RESIDUAL SOAP SAMPLES

Type Aircraft	Type Engine	Location
C-9B	JT8D	MCAS, Cherry Point, NC
OV-10A & D	T76-G-420	" " " "
A-6E	J52-P-8B	" " " "
AV-8A	F402-RR-406	" " " "
EA-6B	J52-P-408	" " " "
CH-46E	T58-GE-16 (and XMSN)	" " " "
CH-53E	T64-GE-416 (and Gearboxes)	" " " "
HH-46	T58-GE-10 (and XMSN)	" " " "
F-18	F404-GE-400	..ADEP, Pensacola, FL
H-60	Gearboxes	" " " "
SH-60B	Main XMSN	" " " "

SECTION IV

RESULTS AND DISCUSSION

1. INTRODUCTION

In addition to the comparative studies among the various wear metal analysis techniques, the effects of various experimental parameters and sample characteristics on the ICP results were studied in order to improve its detection. Sample introduction system, nebulizing inlet gas pressure, diluting solvent type and spectral line interferences were among the parameters investigated. Conditions required for overloading the ICP source with wear debris particles, effects of the sample matrix (ester-based versus hydrocarbon-based oils) and effects of concomitant element were also investigated.

2. SAMPLE INTRODUCTION SYSTEM (ICP)

a. Manual and Peristaltic Pump Sample Aspiration

The effects of different sample introduction system designs on the ICP results were studied since the Air Force SOAP is interested in performing automated wear metal analyses. Manual analyses were performed with a cross-flow nebulizer in which the sample is drawn through the sample tube into the nebulizer by the venturi effect. Thus, the rate of sample uptake is dependent on the nebulizing gas flow rate. Manual and automated analyses were performed using a Babbington type nebulizer and the sample uptake was controlled by a peristaltic pump. Thus, the rate of sample uptake was independent of the nebulizing gas flow rate. The sample uptake rates of the cross-flow and Babbington nebulizer systems were 1.0 and 0.8-2.0 ml/min., respectively. The manual and peristaltic pump results listed in Table 5 were obtained by UDRI personnel while the automated (using a peristaltic pump and automatic sampling system) results shown in Figure 1 were performed by a commercial source.

TABLE 5

EFFECTS OF SAMPLE INTRODUCTION SYSTEM ON
THE ICP WEAR METAL ANALYSES

Sample No.	Analysis on ICP	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
MFR-13	Manual	1.39	0.0	0.49	0.12	1.53	0.23	0.10	5.59	3.22	0.11	0.00
	Peristaltic	0.70	0.0	0.18	0.02	1.07	0.08	0.00	4.42	2.21	0.00	0.00
MFR-14	Manual	2.91	0.08	8.96	0.99	1.18	0.70	1.44	0.00	0.39	0.00	0.00
	Peristaltic	1.94	0.10	6.33	0.62	0.84	0.43	0.90	0.00	0.37	0.00	0.00

The initial results in Table 5 indicate that the peristaltic pump decreases the capability of the ICP to analyze wear metal debris in used oil samples. Varying the sample uptake rate between 0.8-2.0 ml/min. did not improve the wear debris analysis capability of the ICP spectrometer.

To further evaluate the effect of the peristaltic pump on the ICP wear debris analyses, several used oil samples (unfiltered and after filtering through 3 micron filters) were analyzed by an automated ICP. The results shown in Figure 1 demonstrate that the automated ICP produces wear debris analyses which are significantly lower than the results produced by the manual ICP.

In addition to the effect on the ICP wear metal analyses, the effect of the sample introduction system on the pre-analysis flush time was also investigated. To determine the flush time required to eliminate the previous sample from the nebulizing system, the R19-100 standard was analyzed followed by the immediate analysis of the blank. The intensities of the Cu and Fe channels were then plotted versus the analysis time to determine the flush

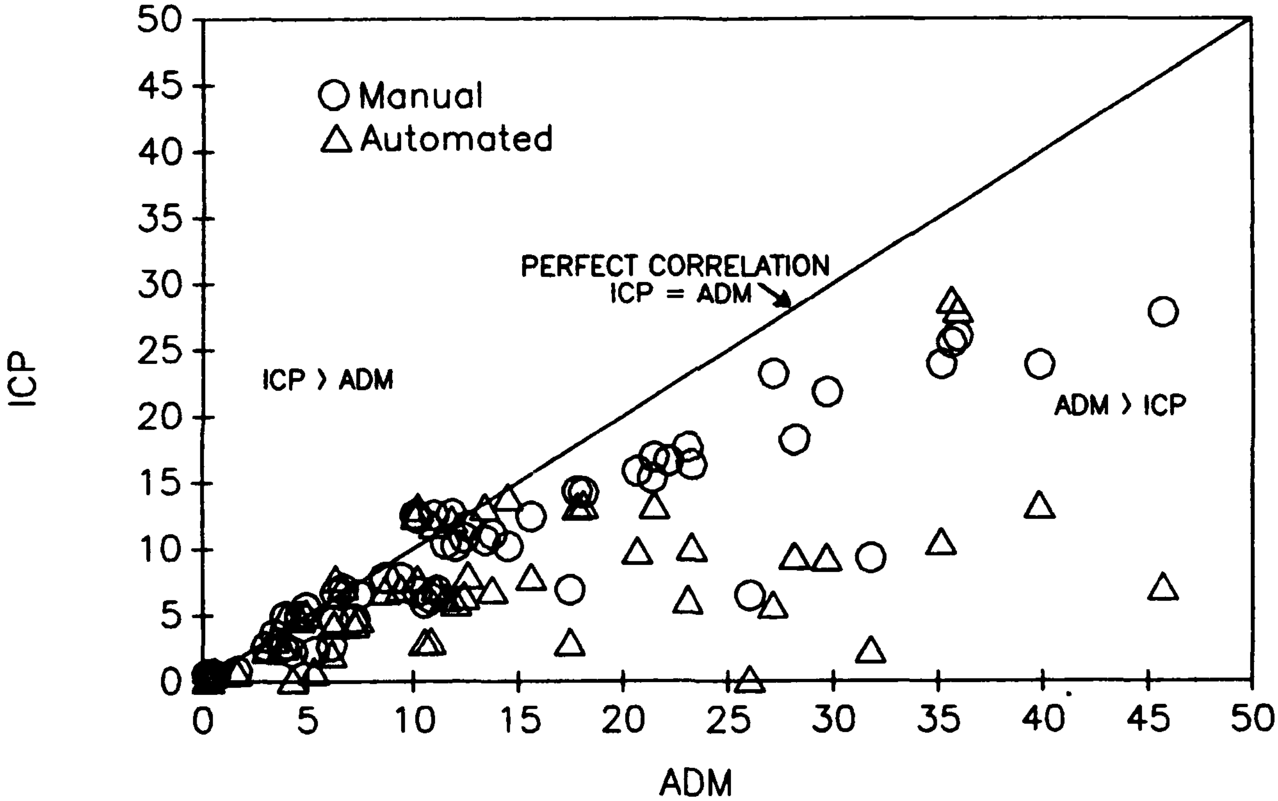

Figure 1. Direct Aspiration Versus Peristaltic Pump ICP Analyses for Unfiltered and 3-Micron Filtered Used Oil Samples

time required to reach a minimum intensity. As shown in Figure 2 the intensity versus time plots do not reach a minimum until after 50 seconds of flushing with the blank. The flush time required by the cross flow nebulizing system (manual) was 50 seconds.

Therefore, the initial results indicate that the nebulizing system would need to be optimized to improve the accuracy and shorten the analysis time of automated ICP techniques.

b. Argon Inlet Pressure

An instrumental parameter that must be held constant during ICP analyses is the inlet pressure of the argon line. The flow rate meter readings for the coolant and nebulizing gases do not change as the argon inlet pressure decreases from 60 psig (optimum) to 50 psig (plasma automatically turns off). However, the decrease in the inlet pressure has a strong effect on the readouts of the different elements as illustrated by the readouts for the R19-100 standard listed in Table 6.

Therefore, for ICP analyses to be performed with complete confidence a pressure sensing device must be added to the argon line prior to the flow meters to ensure the inlet pressure is always 60 psig. This device will be especially important as the argon tank becomes empty.

c. Solvent Type for Sample Dilution

Although very few types of solvent can be used to dilute oil samples for ICP analysis, the use of kerosene is limited by the 1:9 dilution ratio required by kerosene to negate viscosity differences and the inability of kerosene to dissolve certain lubricating oils (e.g. polyphenyl ether). Therefore, a short study was performed to determine the types of solvent that can be used for ICP analyses of used lubricating oils. Since toluene has been used by commercial labs for ICP analyses of lubricating oils, aromatic

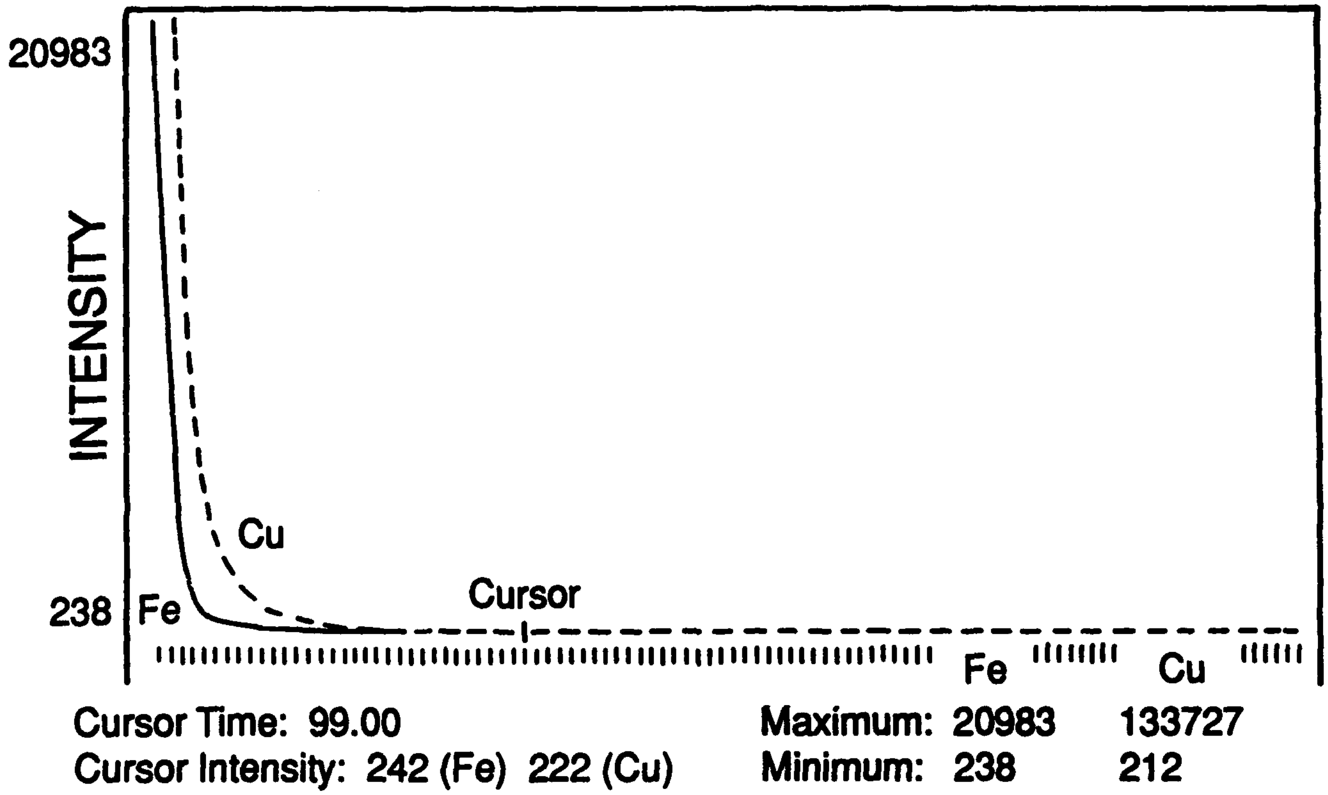

Figure 2. Plots of Cu and Fe Channel Intensities Versus Flush Time After R19-100 Analysis (X-Axis Divisions = 3 Sec)

TABLE 6

EFFECT OF ARGON INLET PRESSURE ON R19-100 STANDARD READOUTS

Pressure (psig)	Element: Fe	Ag	Al	Cr	Cu	Mg
60	100.31	100.01	99.89	100.15	100.01	100.05
57	97.63	96.52	95.31	98.37	95.63	95.82
52	87.23	85.94	83.37	88.27	83.89	84.63

Pressure (psig)	Ni	Pb	Si	Sn	Ti
60	99.85	99.65	100.35	100.31	100.01
57	93.65	91.53	96.50	93.12	96.71
52	83.57	80.31	87.98	80.56	84.39

solvents were studied as an alternative to kerosene. The aromatic solvents studied during this project were toluene, xylene and Aromatic 150 [industrial aromatic solvent from Exxon with a boiling range of 135 (xylene) to 185°C (diethylbenzene)].

The uptake rates for 1:9 dilution ratios of kerosene, toluene, xylene and Aromatic 150 were 1.0, 1.8, 1.6 and 1.2 ml/min, respectively. Therefore, the dilution factor of 1:9 would not be necessary for toluene or xylene to negate viscosity differences. The smaller dilution factor for the aromatic solvents would be beneficial by lowering the amount of waste produced by the ICP analyses.

To determine the effect of solvent type on the ICP analyses of used oil samples, the used oil samples MFR-4-A-1 (large particles) and MFR-6-A-1 (small particles) were diluted 1:9 with kerosene, xylene and Aromatic 150 and analyzed with the cross flow nebulizing system. The nebulizing gas rate was decreased from 0.6 to 0.4 ml/min. for the aromatic solvents to optimize the ICP sensitivity. Even with the slower nebulizing gas flow rates, the toluene destabilized the plasma resulting in erratic results, and consequently, the toluene results were not included in this report.

The results listed in Table 7 for kerosene, xylene and Aromatic 150 indicate that the different solvents produce similar wear metal analyses. Therefore, the solvent chosen for use by the Air Force would depend on cost, flammability, toxicity, dilution factors, and other handling factors. Due to the volatility of xylene a reclamation system could be used to reduce cost and disposal considerations.

In addition to the organic solvents, a water solution containing an additive to emulsify the oil sample was also investigated. Satisfactory results were obtained if the emulsified oil sample was shaken during analysis. However, a deposit (additive nonvolatile) formed quickly on the sample introduction tip of the ICP torch requiring cleaning after only three samples. Therefore, a volatile emulsifying additive would have to be used if a water based solution is to be used as the diluting solvent.

TABLE 7

EFFECT OF SOLVENT TYPE ON THE ICP WEAR METAL ANALYSES

Sample No.	Solvent	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
MFR-4-A-1	Kerosene	6.43	0.00	0.34	0.11	0.00	0.00	0.00	0.31	0.32	0.00	0.00
	Xylene	6.45	0.00	0.37	0.19	0.00	0.03	0.00	0.00	0.00	0.39	0.00
	Aromatic 150	6.31	0.04	0.43	0.27	0.18	0.06	0.38	0.56	1.21	0.00	0.00
MFR-6-A-1	Kerosene	6.57	0.39	1.03	0.76	2.05	2.24	0.45	0.82	5.34	0.00	0.00
	Xylene	6.59	0.36	0.92	0.83	1.82	2.38	0.00	0.00	4.66	0.53	0.00
	Aromatic 150	6.71	0.43	0.94	0.82	1.78	1.88	0.78	0.00	4.51	0.00	0.05

d. Spectral Line Interferences

Spectral line interferences occur when one element emits light at the same wavelength chosen to detect a second element so that the concentrations determined for the second element are artificially high when the first element is present. To determine if spectral line interferences occur for the wavelengths chosen for the ICP spectrometer (Table 1) 100 ppm single element standards were analyzed by the ICP spectrometer and the readouts of all the channels were recorded. A readout of more than 1 ppm in a second channel was considered evidence of spectral line interference. The elements checked for spectral line interference were Ag, Al, B, Cr, Cu, Fe, Mg, Mo, Ni, Pb, Si, Sn, Ti, V and Zn. Since tricresyl phosphate (antiwear additive) is present in the used oil samples but not the standards, spectral interferences from P (1000 ppm) were also studied.

Of the elements studied only Cr and Mo produced spectral line interferences: Cr produced 46 ppm on the Sn channel and Mo produced 2 ppm on the Al channel. Although the Cr spectral line interference is strong, mathematical compensation to eliminate the interference can be programmed into the computer used to control the ICP spectrometer. All of the ICP results presented in this report were obtained using computer programs which eliminated spectral line interferences.

3. SAMPLE CHARACTERISTICS

a. Particle Overloading of ICP Source

As previously described in paragraph 2.a, the system flush time of the ICP spectrometer was determined using R-19-100 standards. In the case of used samples, the high concentration of metal is present as undissolved metal particles. To determine the effect of particles on the flush time of the plasma source, M12-10, M12-50 and M12-100 metal powder suspensions were analyzed followed immediately by the blank. The produced emission intensity versus time plots for the Ag and Fe channels from M12-50 are shown in Figure 3. The increases in the emission intensity plots in Figure 3 are indicative of particles being analyzed.

The plots in Figure 3 show that particles are being detected up to 100 seconds after the metal powder suspension analyses were ended. In fact, particles were detected on the Ag channel during the following 100 second flush period (Figure 3). Therefore, very long flush times (~ 3 minutes) will be needed if used oil samples containing high concentrations of wear debris are analyzed prior to analyzing used oil samples containing low concentrations of wear debris (routine gas turbine engine samples).

In addition to the effect on flush time, a high percentage of large

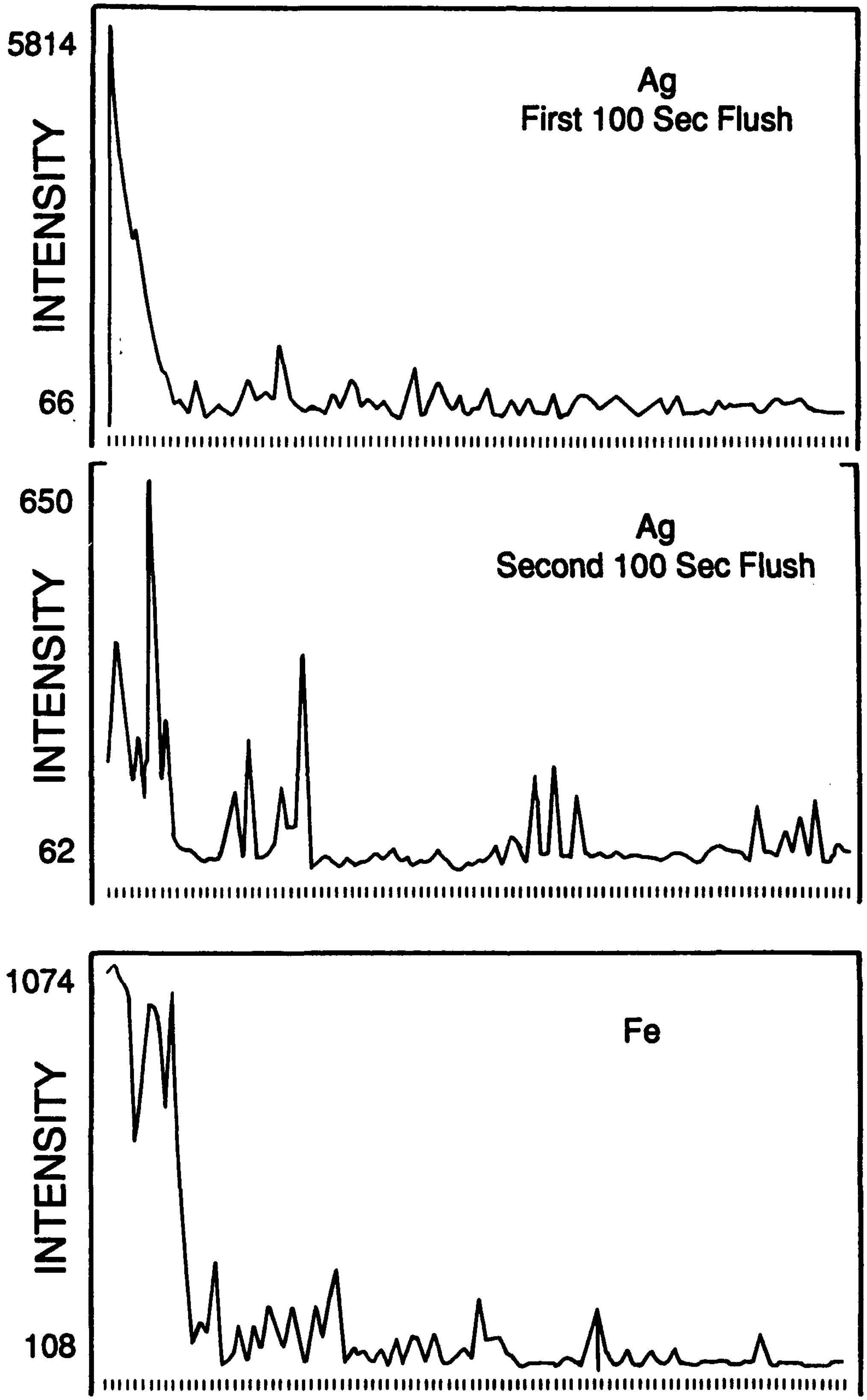

Figure 3. Plots of Ag and Fe Channel Intensities Versus Flush Time After M12-50 Analysis (X-Axis Division = 1 Sec)

particles can overload the ICP source reducing the source's capability to quantitatively analyze the particles. To test the particle analysis capability of the ICP spectrometer, 50 ppm Fe powder suspensions containing -3, +6-9 and +12 μm metal powders were analyzed. The emission intensity versus time plots for the Fe channel are shown in Figure 4 for the -3, +6-9 and +12 μm metal powders.

The intensity plots indicate that the ICP source is unable to quantitatively analyze the +12 μm particles since the emission increases (particle analyzed) for the +12 μm particles range up to 180 units per particle while the emission increases for the +6-9 μm particle range up to 440 units per particle. If the + 12 m particles were analyzed quantitatively the particles would be expected to produce emission intensities 2-4 times greater than those produced by the +6-9 μm particles. It has been shown (Ref. 4) that the emission of the particles can be increased by viewing a higher portion of the ICP plasma. As expected the emission intensity is fairly constant for the -3 μm particles since the particle transport to the source is quantitative (Ref. 5) and the -3 μm, 50 ppm suspension contains many more particles than the +6-9 and +12 μm, 50 ppm suspensions. For comparison the emission intensity versus time plots for R-19-100 standard and the blank (0 ppm Fe) are shown in Figure 5 and have emission intensities that remain fairly constant with maximum increases of 30 and 3 units, respectively.

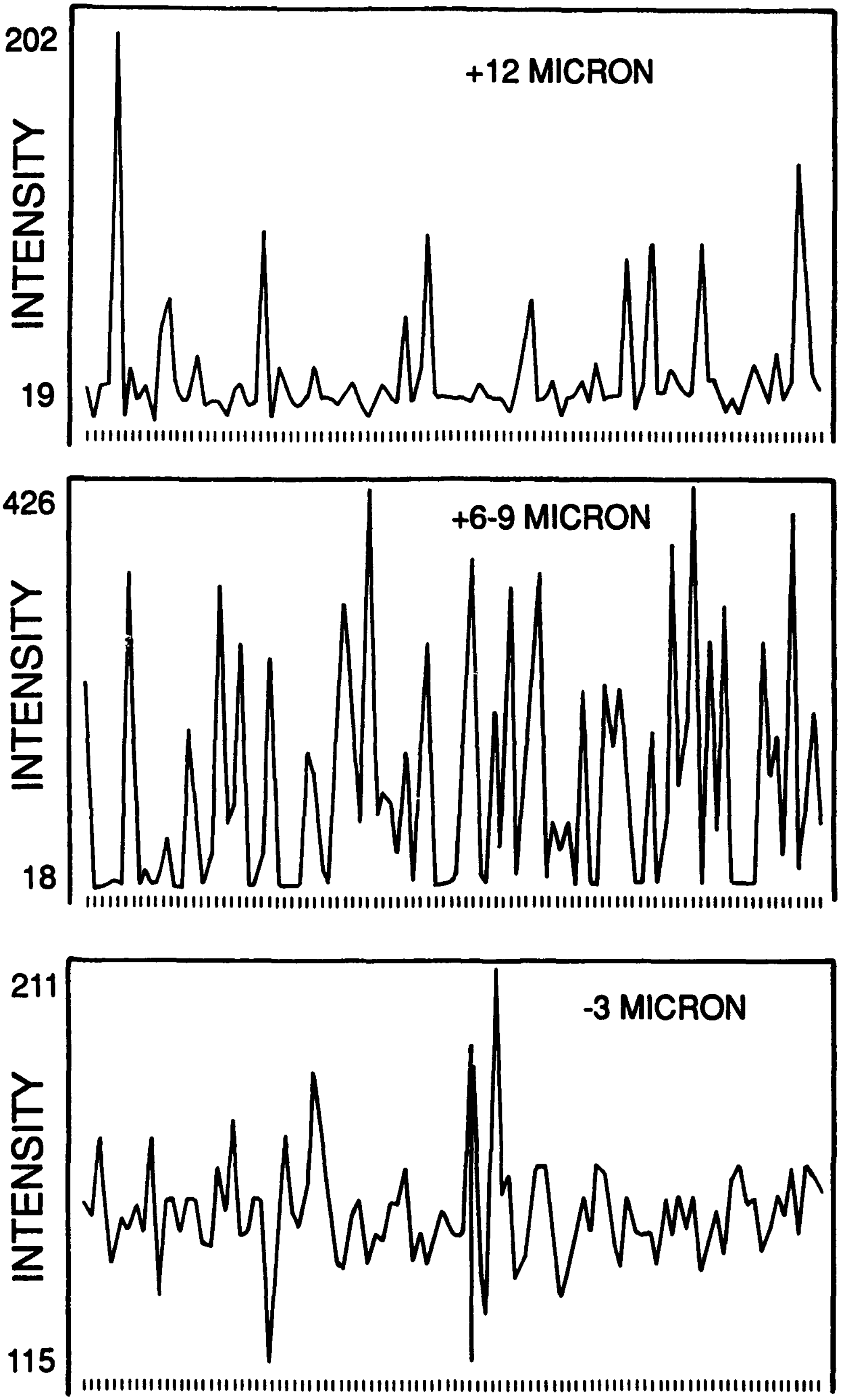

Figure 4. Plots of Fe Channel Intensities Versus Time for +12, +6-9 and -3 Micron Fe Metal Powder Suspensions (X-Axis Division = 0.1 Sec)

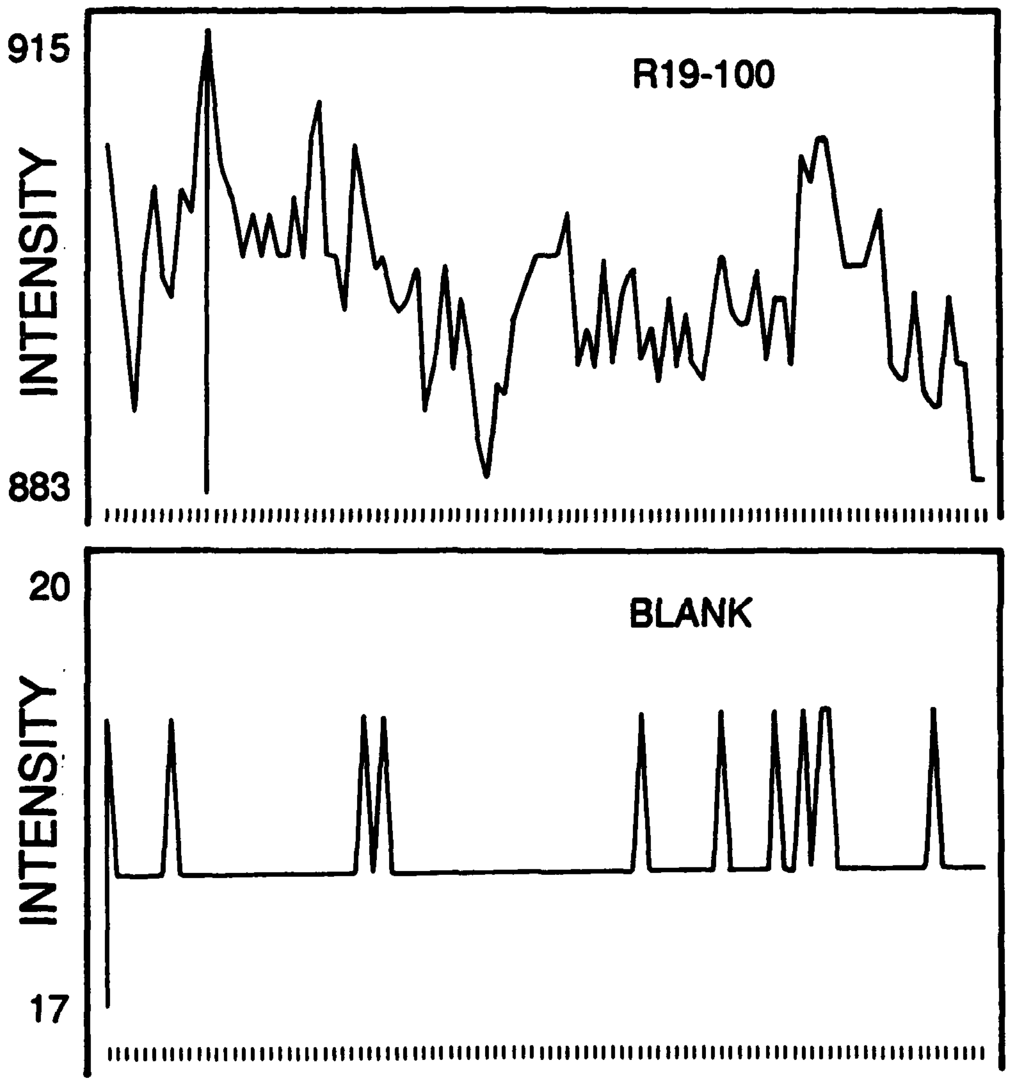

Figure 5. Plots of Fe Channel Intensities Versus Time for R19-100 Standard and the Blank (X-Axis Division = 0.1 Sec)

b. Matrix Effect

Since the standards for the ICP are prepared in heavy hydrocarbon oils and the used oil samples are hydrocarbon and ester-based with varying viscosities, the oil matrix may effect the ICP wear metal analyses. To determine the effects of matrix viscosity, R19-100 standards were prepared from heavy and light hydrocarbon oils. To determine the effects of matrix composition, R19-100 standards were also prepared from MIL-L-7808 ester-based lubricating oils. The ICP spectrometer was standardized with the R19-100 standard prepared in the heavy hydrocarbon oil diluted 1:4 with kerosene. The R19-100 standards prepared in light hydrocarbon and MIL-L-7808 oils were then analyzed and the results are listed in Table 8.

The results in Table 8 show that a dilution ratio of 1:9 is necessary to negate the viscosity differences between the heavy and light hydrocarbon oils. The dilution ratio of 1:9 was used throughout the comparative study of this report.

The results in Table 8 also show that regardless of the dilution ratio, the MIL-L-7808 oil produces analyses 101-119% higher than the heavy hydrocarbon oil. It seems that a dilution ratio of 1:6 is sufficient to negate the viscosity differences between the heavy hydrocarbon and MIL-L-7808 oils. These results indicate that the standards will have to be prepared in ester-based oils if accurate ICP wear metal analyses are to be performed.

c. Concomitant Elements

Another factor that affects the accuracy of the ICP spectrometer is the presence of concomitant elements. Concomitant elements are elements which affect the emission intensities of the other elements present in standards and used oil samples. The effect of concomitant elements was evaluated by analyzing R19-100 and R12-100 standard prepared in heavy mineral

TABLE 8

MATRIX EFFECT ON R19-100 STANDARD READOUTS

Oil	Dilution Ratio	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
Light Hydrocarbon	1:4	124.7	123.8	124.1	125.1	124.0	123.8	124.2	124.7	125.1	124.2	124.6
	1:6	106.7	105.9	106.9	106.8	106.1	107.1	105.9	106.3	106.4	105.5	105.8
	1:9	101.8	100.9	99.8	101.3	101.5	101.4	99.9	100.1	100.9	101.5	101.9
Mil-L-7808	1:4	127.6	136.8	139.3	138.3	126.8	128.6	128.5	133.0	130.3	127.5	118.7
	1:6	106.8	115.2	119.0	115.6	106.5	108.0	106.5	105.2	108.4	106.4	102.3
	1:9	107.8	115.2	119.6	116.8	107.2	108.7	107.8	108.1	109.7	106.5	101.5

oil. The ICP spectrometer was standardized with the R19-100 standard. The R12-100 standard was then analyzed and the results are listed in Table 9.

The results in Table 9 show that the concomitant element effect between the R19 and R12 standards (B, Ba, Be, Cd, Mn, V and Zn not included in R12 standard) causes a large enhancement of the Cr and Si channels and a suppression of the Ti channel. All of the other channels listed in Table 9 show small enhancements for the R12-100 standard. Thus, not only does the oil matrix affect the readouts of the ICP spectrometer but also the number of elements to be included in the standard.

4. SPECTROMETRIC CHARACTERISTICS

a. Linearity Range of ICP Spectrometer

Due to the wide range of wear debris and additive concentrations in the used oil samples obtained from different equipment monitored by the Military Services, the calibration curves of the ICP spectrometer should be linear over a wide range of concentrations. The spectrometer was standardized with the R19-100 standard and then standards up to 4000 ppm were analyzed for the various metals. The results listed in Table 10 indicate that the calibration curves of the ICP spectrometer are linear up to approximately 1000 ppm.

b. Stability of ICP Spectrometers' Standardization

One of the reported advantages of the ICP spectrometer is the stability of its standardization allowing large numbers of samples to be analyzed without need of restandardization. The standardization stability of the ICP spectrometer was evaluated by three methods. In the first two methods, the R19-100 standard was analyzed by the JA ICP after every thirty minutes for two hours and after every 15 used oil samples for 45 used oil samples. In the third method, the R19-50 standard was analyzed by the

TABLE 9

EFFECT OF CONCOMITANT ELEMENTS ON THE R12100 STANDARD READOUTS

Standard	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
R12-100	106.5	106.6	103.6	118.5	104.1	106.9	104.6	106.4	112.4	100.9	93.5

TABLE 10

LINEARITY RANGE OF ICP SPECTROMETER

Standard	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
R19-1	1.061	1.014	1.051	1.049	1.071	1.032	1.091	1.121	1.048	1.081	1.014
R19-10	10.90	10.57	10.55	10.72	10.46	10.78	10.82	10.90	10.35	10.39	10.26
R19-50	53.06	51.88	52.10	52.29	51.74	52.51	52.57	52.61	51.58	51.88	51.22
R19-900	888	937	893	1009	882	892	888	890	938	940	879
R8-2000	1381	1418	1204	-	1521	-	1348	1410	1538	-	1752
R8-4000	2699	2876	2545	-	2965	-	2730	2810	3098	-	3503

automated ICP at intermediate periods during the analysis of 75 used oil samples.

The results in Table 11 show that the standardization of the ICP spectrometer was stable for over two hours when samples are not analyzed but the spectrometer needs to be restandardized every 15 to 30 samples to produce reliable results. Changes in the sample introduction system (gas flow variation, debris collecting in sampling tube, etc.) are most likely responsible for the frequent restandardization since the standardization was stable when samples were not analyzed.

Another reported advantage of the ICP spectrometer is the precision of its analyses. Table 11 shows that Fe analytical results were within 1 and 3% for the JA ICP using the 100-ppm standard for the first two methods above and within 5% using the 50-ppm standard for the third method.

5. WEAR METAL ANALYSIS

a. General Discussion Relative to Analyses Conducted and Data Evaluation

The microfiltration tests (MFR) utilized larger size samples than the SOAP samples permitting a greater in-depth evaluation of the MFR samples. The effects of microfiltration on the wear metal concentrations of the various oil samples were insignificant after the first pass. Thus the correlation of data obtained on MFR samples were made only on the first pass sample of each MFR test although three or four passes through the filter were made during the MFR test. Complete data for all samples obtained during each pass for the MFR samples and for the complete analyses of the SOAP samples have been included in Appendix A.

The SOAP samples utilized in this study have been divided into three groups as follows:

TABLE 11

STANDARDIZATION STABILITY OF ICP SPECTROMETER USING
R19-50 OR R19-100 STANDARDS

Std	Time Min.	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
R19-100	0	100.2	99.95	100.1	99.87	100.1	100.1	101.0	100.8	100.0	101.2	101.1
	30	100.8	100.1	100.2	100.1	100.1	100.7	100.7	101.1	101.1	101.8	100.8
	60	100.9	100.2	101.3	100.5	101.2	100.2	102.1	101.2	100.8	100.1	100.1
	90	100.7	99.91	99.91	101.4	99.85	100.1	102.2	103.4	99.72	99.85	99.75
	120	101.1	99.82	102.2	102.1	100.1	99.85	101.8	102.5	101.8	99.75	100.1
R19-100	0	100.8	100.7	99.91	100.1	100.2	100.0	101.9	100.9	100.2	100.5	99.99
	15	102.3	98.12	96.45	103.5	95.86	102.7	105.3	101.1	101.1	100.6	99.08
	30	101.1	96.59	93.47	102.9	93.59	101.9	105.9	101.8	100.3	97.60	97.74
	45	103.4	95.69	91.41	101.3	91.42	100.8	106.8	102.1	100.0	91.40	96.89
R19-50	10	48.95	50.52	50.50	50.13	50.23	49.26	49.07	48.64	49.98	50.28	50.43
	34	49.06	49.03	49.37	49.10	49.22	49.15	49.03	49.68	49.16	48.96	49.12
	52	47.52	47.49	47.10	46.06	48.62	46.02	47.03	46.21	47.31	46.16	46.85
	78	48.95	50.33	50.70	50.28	50.28	49.96	49.69	49.36	50.09	50.19	50.48

Group 1. Samples from a previous test program which were "Hit" samples. Hit - SOAP detected abnormal wear prior to component failure. Abnormal wear confirmed by maintenance personnel.

Group 2. Samples from a previous test program which were not "Hit" samples.

Group 3. Residual SOAP samples obtained from two locations during this program. Base analyses were compared with UDRI ICP for trending purposes.

Samples used by UDRI to evaluate the analytical capabilities of the ICP, AE/JA, PWMA, AA, ADM, and ferrography and to perform particle size distribution analyses were heated and sonicated prior to analysis. A/E35U-3 emission analyses were conducted by SOAP laboratories using normal procedures. PST/ICP analyses employed automatic sampling and were not sonicated or shaken just prior to analysis.

In general the data obtained by the various analysis techniques have been tabulated and arranged in order from high to low for initial iron content and percent iron loss. Since eight different analysis techniques were used (ADM is reference technique) for some of the samples, ranking of the various techniques from high (value of 8) to low (value of 1) was done for each sample. This approach provided for determining the relative rankings of the various analysis techniques to ADM values with respect to total iron content and iron loss due to three micron filtration. For sample groups where less than eight analysis techniques were used (6 for example), the ranking ranged from 8 to 3. This approach permits comparing the rankings of those analysis techniques which were conducted on various sample groups.

Correlation between all analysis techniques including ferrography were made only for MFR samples since no ferrography measurements were conducted on the SOAP samples.

Since all analysis techniques do not have the same sensitivity or value readability the following guidelines were used in reporting of data.

Atomic Emission Analysis (J.A. 44181). All metals reported to 0.1 ppm up to 10 ppm and 1 ppm above 10 ppm level.

Atomic Emission Analysis (A/E35U-3). All metals reported to 0.1 ppm up to 10 ppm (if reported by base) and one ppm above 10 ppm level.

Atomic Absorption (AA). Iron on all samples along with other significant wear metals. Reported to 0.1 ppm up to 10 ppm level. One ppm above 10 ppm level.

Inductively Coupled Plasma (ICP). All metals reported to 0.01 ppm up to 10 ppm level, 0.1 ppm from 10 to 100 ppm level and 1 ppm above 100 ppm level.

Direct Current Plasma (DCP). All metals reported to 0.01 ppm up to 10 ppm level, 0.1 ppm from 10 to 100 ppm level and 1 ppm above 100 ppm level.

Portable Wear Metal Analyzer (PWMA). All metals reported to 0.1 ppm up to 10 ppm and 1 ppm above 10 ppm level.

Particle Size Distribution ADM/AA. Iron only reported to 0.1 ppm up to 10 ppm level and 1 ppm above 10 ppm level.

Acid Dissolution Method-ICP. Iron and other significant metals reported to 0.01 ppm up to 10 ppm level, 0.1 ppm from 10 to 100 ppm level and 1 ppm above 100 ppm level.

Since iron is the primary wear metal, a more in-depth evaluation and correlation of the various analysis techniques with respect to initial content, particle size distribution and the effects of three micron filtration were made for the "iron" data. A discussion of the other wear metals present in a few of the samples as determined by the various analysis techniques and the effects of filtration on these analyses will be given in a separate section of the report.

b. Matrix Effects and Particle Size Sensitivities

Previous research (Ref. 3) has shown that determined iron concentrations of ester base oils can be up to 2.5 times the actual iron concentration when determined using the A/E 35U-3 spectrometer calibrated with mineral oil base standards. This same research also showed decreasing emission sensitivities for particles above approximately eight microns.

The data obtained during this study have shown similar matrix effects and changing of particle size sensitivity when using atomic emission analysis techniques. As shown in Table 12 samples having small iron particle sizes (less than 3 microns such as sample MFR-8) have much higher atomic emission values than corresponding ADM values. For samples having very large iron particles such as sample MFR-4 the ADM values are much higher than the corresponding emission values.

This study has also shown matrix effects and particle size sensitivity effects to be present when using other analysis techniques. Table 13 shows the matrix effects on atomic absorption analyses when using different solvents and standards and that AA analyses are affected by particle size to the same degree as atomic emission techniques. Data obtained from the MFR samples (Table 12) show that other techniques such as ICP and DCP are particle size sensitive.

However, the investigation and determination of matrix effects and particle size effects for all the analysis techniques investigated was beyond the scope of this program and were not conducted.

c. Microfiltration Test Rig (MFR) Data

The original iron content and iron loss due to three micron test rig filtering are given in Table 12 and show a wide variation between the various analysis techniques for both the original iron content and percent loss. The

TABLE 12

ORIGINAL IRON CONTENT AND IRON LOSS DUE TO THREE MICRON TEST RIG FILTERING

Sample	Orig. Fe & Loss due to Filt.	ICP	PST/ICP	A/E 35	A/E JA	PWMA	DCP	AA	ADM
		Method of Analysis, ppm							
MFR-1-A-1	Orig. Fe	9.28	2.35	25	25	60	8.72	7.5	31.8
	Filt. Loss	3.01	(0.67)[1]	16	11	51	2.76	2.3	21.0
	% Loss	32	(28)	64	44	85	32	31	66
MFR-2-A-1	Orig. Fe	32.7	9.46	62	93	61	34.2	15.0	60.4
	Filt. Loss	10.9	0.14	22	39	27	12.6	3.0	30.7
	% Loss	33	2	37	42	44	37	20	51
MFR-3-A-1	Orig. Fe	11.1	6.93	22	32	15	7.36	9.0	13.8
	Filt. Loss	0.7	0.63	2	5	2	0.35	0.6	2.3
	% Loss	6	9	9	16	13	5	7	17
MFR-4-A-1	Orig. Fe	6.43	0.16	2.0	17	40	5.03	4.0	26.0
	Filt. Loss	5.90	(0.01)	1.0	17	38	4.50	2.4	25.8
	% Loss	92	(6)	50	100	95	89	60	99
MFR-5-A-1	Orig. Fe	96.1	69.1	94	110	54	99.0	89	110
	Filt. Loss	14.8	0.3	5	2	5	13.3	(3)	11.3
	% Loss	15	0	5	2	9	13	(3)	10
MFR-6-A-1	Orig. Fe	6.57	4.74	11	13	10	6.67	5.1	7.41
	Filt. Loss	1.67	(.03)	1	2	5	2.27	1.0	2.79
	% Loss	25	(1)	9	15	50	0.34	20	38
MFR-7-A-1	Orig. Fe	0.49	0.75	2.0	0.80	0.8	0.34	0.6	0.61
	Filt. Loss	0.02	0.04	0.5	0.50	0.1	0.03	0	0.20
	% Loss	4	5	25	62	12	10.3	0	33
MFR-8-A-1	Orig. Fe	12.50	12.50	27	28	11	10.3	11	10.1
	Filt. Loss	(0.01)	0.30	6	6	0	0.1	0	(1.7)
	% Loss	0	2	22	21	0	1	0	(17)
MFR-9-A-1	Orig. Fe	3.61	3.26	5.6	6.2	2.7	-	2.2	3.41
	Filt. Loss	0.32	0.06	(0.1)	1.4	0.3	-	0.3	(0.2)
	% Loss	9	2	(2)	23	11	-	14	(6)
MFR-10-A-1	Orig. Fe	2.69	2.11	4.0	6.1	2.6	-	1.6	6.14
	Filt. Loss	0.78	0.46	2.0	2.8	0.8	-	0.4	2.81
	% Loss	29	22	50	46	31	-	25	46
MFR-18-A-1	Orig. Fe	2.30	0.81	3.2	8.6	2.4	-	1.9	5.31
	Filt. Loss	1.50	0.11	1.4	5.2	1.4	-	1.2	3.68
	% Loss	65	14	44	60	58	-	63	69
MFR-22-A-1	Orig. Fe	8.56	-	17	23	8.6	-	6.2	8.57
	Filt. Loss	1.20	-	2	4	1.6	-	1.1	1.39
	% Loss	14	-	12	17	19	-	18	16

[1]Values in ( ) show ppm and % increase in value after filtering

TABLE 13

COMPARISON OF IRON CONTENT AS DETERMINED BY
VARIOUS ATOMIC ABSORPTION TECHNIQUES WITH ADM VALUES
Values in ppm)

Sample	Analyte Corp. Data Conostan Std.[1]	D-19 Std.[2]	UDRI AA Data[3]	ADM Data
MFR-4-A-1	0.89	1.24	5.03	26.0
MFR-4-A-2	0.00	0.36	0.53	0.2
MFR-5-D-1	39.34	90.09	90	110
MFR-5-D-2	38.18	86.20	89	98.7
MFR-8-A-1	7.46	12.52	11	10.1
MFR-8-A-2	7.60	12.64	11	11.8
H-1	6.88	11.32	-	-
H-20	12.26	21.29	12.0	39.8
H-48A	9.35	16.30	-	-
H-55	7.77	13.81	13	
H-84	11.66	21.40	19.0	45.7
P-43	26.38	51.31	36.1	58.2
P-71	12.02	19.55	19	60.7
P-71A	10.54	13.67	15	27.1
P-108	4.98	7.33	11.5	7.0
Comb. Army	0.64	1.55	2.0	3.83

[1] Sample Dilution of 1 part Sample and 4 parts Kerosene. Consostan Standard Diluted with 1 part blank Conostan oil and 8 parts Kerosene.
[2] D-19-100 Standard Diluted 1 part Standard and 1 part Conostan Base Oil. New Standard diluted 1 part Standard to 4 parts Kerosene.
[3] R-19 Standards and Samples diluted 1 part to 4 parts MIBK.

variation in original iron content is better observed in Table 14 where iron values are arranged from high to low for each sample. As expected the range between values generally increase with increased iron concentration. Table 14 also includes data for MFR samples not filtered using the test rig.

The initial ADM iron value and percent loss due to test rig filtering using the various analysis techniques are arranged in order of high to low iron loss as shown in Table 15. Since the iron loss is given in percent the wide variation between analyses is not as directly related to concentration as the analyses for initial iron content. Samples having low initial iron concentrations can have as large of variations between percent loss analyses as high iron content samples. Iron particle size can also have a greater effect on percent iron loss due to filtering than on initial iron concentration.

Table 16 gives a summary of rankings based on iron content determined in the MFR samples by the analysis techniques. For example ADM analyses ranked in the highest position (8) four of twelve analyses, in seventh position six of the twelve analyses, etc. These data show that ADM, PWMA, A/E35 and A/EJA rank 5 and above 83% of the time while ICP, AA, DCP and PST/ICP ranks 4 and below 81% of the time. Table 17 gives similar type data for percent iron loss due to filtering. Again ADM, PWMA, A/E35 and A/EJA ranked 5 and above 73% of the time and ICP, AA, DCP and PST/ICP ranked 4 and below 70% of the time. Table 18 gives the rankings for each analysis technique for MFR samples not filtered. Since only six analysis techniques were used rankings ranged from 8 to 3. In this case ADM, A/EJA, A/E35 and PWMA ranked 6 and above 72% of the time while ICP and AA ranked 5 and below 94% of the time.

A summary of all the test data presented in Tables 14 thru 18 is

TABLE 14

IRON CONTENT AS DETERMINED BY VARIOUS ANALYSIS TECHNIQUES
WITH VALUES ARRANGED FROM HIGH TO LOW (VALUES IN PPM)

(MFR Samples Filtered)

MFR-1-A-1	PWMA	ADM	A/E35	A/EJA	ICP	DCP	AA	PST/ICP
	60	31.8	25	25	9.28	8.72	7.5	2.35
MFR-2-A-1	A/EJA	A/E35	PWMA	ADM	DCP	ICP	AA	PST/ICP
	93	62	61	60.4	34.2	32.7	15.0	9.46
MFR-3-A-1	A/EJA	A/E35	PWMA	ADM	ICP	AA	DCP	PST/ICP
	32	22	15	13.8	11.1	9.0	7.36	6.93
MFR-4-A-1	PWMA	ADM	A/EJA	ICP	DCP	AA	A/E35	PST/ICP
	40	26.0	17	6.43	5.03	4.0	2.0	0.16
MFR-5-A-1	ADM	A/EJA	DCP	ICP	A/E35	AA	PST/ICP	PWMA
	110	110	99	96.1	94	89	69.1	54
MFR-6-A-1	A/EJA	A/E35	PWMA	ADM	DCP	ICP	AA	PST/ICP
	13	11	10	7.41	6.67	6.57	5.1	4.74
MFR-7-A-1	A/E35	PWMA	A/EJA	PST/ICP	ADM	AA	ICP	DCP
	2	0.8	0.8	0.75	0.61	0.6	0.49	0.34
MFR-8-A-1	A/EJA	A/E35	ICP	PST/ICP	PWMA	AA	DCP	ADM
	28	27	12.50	12.50	11	11	10.3	10.1
MFR-9-A-1	A/EJA	A/E35	ICP	ADM	PST/ICP	PWMA	AA	DCP
	6.2	5.6	3.61	3.41	3.26	2.7	2.2	-
MFR-10-A-1	ADM	A/EJA	A/E35	ICP	PWMA	PST/ICP	AA	DCP
	6.14	6.1	4.0	2.69	2.6	2.11	1.6	-
MFR-18-A-1	A/EJA	ADM	A/E35	PWMA	ICP	AA	PST/ICP	DCP
	8.6	5.31	3.2	2.4	2.30	1.9	0.81	-
MFR-22-A-2	A/EJA	A/E35	PWMA	ADM	ICP	AA	PST/ICP	DCP
	23	17	8.6	8.57	8.56	6.2	-	-

(MFR Samples Not Filtered)

MFR-11	ADM	A/E35	PWMA	ICP	A/EJA	AA	PST/ICP	DCP
	0.67	0.3	0.2	0.13	0.0	0.0	-	-
MFR-12	A/EJA	A/E35	ADM	PWMA	AA	ICP	PST/ICP	DCP
	3.7	3.0	2.64	1.9	1.9	1.39	-	-

TABLE 14 (CONCLUDED)

MFR-13	ADM	A/EJA	A/E35	AA	PWMA	ICP	PST/ICP	DCP
	2.81	2.40	2.00	2.0	1.7	1.39	-	-
MFR-14	A/EJA	A/E35	ADM	PWMA	ICP	AA	PST/ICP	DCP
	6.2	5.0	3.70	3.0	2.91	0.8	-	-
MFR-15	A/EJA	ADM	ICP	PWMA	A/E35	AA	PST/ICP	DCP
	7.7	5.12	3.91	3.3	3.0	1.2	-	-
MFR-19	A/E35	A/EJA	PWMA	ADM	ICP	AA	PST/ICP	DCP
	20	17	7.9	7.50	6.66	4.6	-	-
MFR-20	A/E35	A/EJA	ADM	PWMA	ICP	AA	PST/ICP	DCP
	48	33	15.2	13.8	12.8	7.2	-	-
MFR-21	A/EJA	A/E35	PWMA	ICP	ADM	AA	PST/ICP	DCP
	20	16	9.60	9.24	8.50	4.0	-	-

TABLE 15

ADM IRON VALUE AND PERCENT LOSS DUE TO 3 MICRON TEST RIG FILTERING FOR VARIOUS MEASURING TECHNIQUES ARRANGED FROM HIGH TO LOW IRON LOSS

Percent Loss Due to 3 Micron Filtration

	ADM PPM								
MFR-1-A-1	31.8	PWMA	ADM	A/E35	A/EJA	ICP	DCP	AA	PST/ICP
		85	66	64	44	32	32	31	(28)[a]
MFR-2-A-1	60.4	ADM	PWMA	A/EJA	A/E35	DCP	ICP	AA	PST/ICP
		51	44	42	37	37	33	20	2
MFR-3-A-1	13.8	ADM	A/EJA	PWMA	A/E35	PST/ICP	AA	ICP	DCP
		17	16	13	9	9	7	6	5
MFR-4-A-1	26.0	ADM	A/EJA	PWMA	ICP	DCP	AA	A/E35	PST/ICP
		100	100	95	92	89	60	50	(6)
MFR-5-A-1	110	ICP	DCP	ADM	PWMA	A/E35	A/EJA	PST/ICP	AA
		15	13	10	9	5	2	0	(3)
MFR-6-A-1	7.41	PWMA	ADM	DCP	ICP	AA	A/EJA	A/E35	PST/ICP
		50	38	34	25	20	15	9	(1)
MFR-7-A-1	0.61	A/EJA	ADM	A/E35	DCP	PWMA	PST/ICP	ICP	AA
		62	33	25	24	12	5	4	0
MFR-8-A-1	10.1	A/E35	A/EJA	PST/ICP	DCP	ICP	PWMA	AA	ADM
		22	21	2	1	0	0	0	(17)
MFR-9-A-1	3.41	A/EJA	AA	PWMA	ICP	PST/ICP	A/E35	ADM	DCP
		23	14	11	9	2	(2)	(6)	-
MFR-10-A-1	6.14	A/E35	ADM	A/EJA	PWMA	ICP	AA	PST/ICP	DCP
		50	46	46	31	29	25	22	-
MFR-18-A-1	5.13	ADM	ICP	AA	A/EJA	PWMA	A/E35	PST/ICP	DCP
		69	65	63	60	58	44	14	-
MFR-22-A-1	8.57	PWMA	AA	A/EJA	ADM	A/E35	ICP	-	-
		19	18	17	16	12	4	-	-

[a]Values in ( ) show an increase in Fe value after filtering

TABLE 16

SUMMARY OF RANKINGS FOR EACH ANALYSIS TECHNIQUE AND MFR FILTERED SAMPLES BASED ON IRON CONTENT (12 SAMPLES EXCEPT AS NOTED)

Measuring Technique	Number of Times Ranked in Position High to Low Readings							
	8	7	6	5	4	3	2	1
ADM	2	3	0	5	1	0	0	1
PWMA	2	1	4	1	2	1	0	1
A/E35	1	6	3	0	1	0	1[a]	0
A/EJA	7	2	2	1	0	0	0	0
ICP	0	0	2	3	4	2	1	0
AA	0	0	0	0	0	7	5	0
DCP (8 Values)	0	0	1	0	3	1	2	1
PST/ICP (11 Values)	0	0	0	2	1	1	2	5

[a]Suspect Value Sample MFR-4-A-1

TABLE 17

SUMMARY OF RANKINGS FOR EACH ANALYSIS TECHNIQUE BASED ON PERCENT LOSS DUE TO 3 MICRON FILTERING OF TEST RIG SAMPLES (12 SAMPLES EXCEPT AS SHOWN)

	Number of Times Ranked in Position (High to Low Readings)							
Measuring Technique	8	7	6	5	4	3	2	1
ADM	4	4	1	1	1	1	0	0
PWMA	3	1	3	2	3	0	0	0
A/E35	2	0	2	2	2	2	2	0
A/EJA	2	3	3	2	0	2	0	0
ICP	1	1	0	3	3	2	2	0
AA	0	2	1	0	2	3	3	1
DCP (8 values)	0	1	1	2	2	1	0	1
PST/ICP (11 values)	0	0	1	0	2	1	3	4

TABLE 18

SUMMARY OF RANKINGS OF EACH ANALYSIS TECHNIQUE
FOR MFR SAMPLES NOT FILTERED AND BASED ON IRON CONTENT

	Number of Times Ranked in Position (High to Low Readings)					
Measuring Technique	8	7	6	5	4	3
ADM	2	1	3	1	1	0
A/EJA	4	3	0	0	1	0
A/E35	2	4	1	0	1	0
PWMA	0	0	3	4	1	0
ICP	0	0	1	2	3	2
AA	0	0	0	1	1	6

given in Table 19 for eight samples having 8 different type analyses. Since the ADM analyses are particle size independent various values obtained using the other analysis techniques are shown as ratios to appropriate ADM value. The data in Table 19 show three interesting points. First, the data for ADM, A/EJA, A/E35 and PWMA are fairly close with the ICP and DCP data being close but slightly lower than for the ADM, A/EJA, A/E35 and PWMA values. The data obtained by AA and PST/ICP are much lower than that for the other techniques. Secondly, the percent iron loss values based on initial minus final total iron content are fairly close to the average percent decrease (total of percent decrease for each sample divided by the number of samples) considering all factors. Third, the total iron content and percent loss as determined by PST/ICP shows the extreme importance of sample agitation immediately before analyzing for suspended particles.

A summary of test data for twelve microfiltration tests using seven different analysis techniques is given in Table 20. These data show the same ranking of analysis techniques and observations as were discussed for Table 19. The ratio values and percent loss values are very close to the values in Table 19.

The summary of test data for eight MFR samples not filtered and using six analysis techniques is given in Table 21. The data are similar to that of Tables 19 and 20 except that the total iron ratios of A/E35 and A/EJA to the ADM value are much higher (1.95 versus 1.28 for A/EJA and 2.11 versus 0.96 for A/E35).

These two much higher ratio values are due to three of the eight samples (MFR-19, MFR-20 and MFR-21) which were blended to provide sample MFR-22 which was filtered. The A/EJA and A/E35 ratio values to the ADM value for this sample were 2.68 and 1.98 respectively. These high ratio values

TABLE 19

SUMMARY OF TEST DATA FOR EIGHT MICROFILTRATION TESTS USING EIGHT DIFFERENT ANALYSIS TECHNIQUES

	Method of Analysis							
	ADM	A/EJA	PWMA	A/E35	ICP	AA	PST/ICP	DCP
Total Iron Content, ppm	260	319	252	245	175	141	106	172
Ratio to ADM	1.00	1.23	0.97	0.94	0.67	0.54	0.41	0.66
Sum of Ranking, Iron Content[a]	42	56	46	48	31	21	17	26
Average Ranking, Iron Content	5.3	7	5.7	6	3.9	2.6	2.1	3.3
Total % Decrease in Iron after MFR Filt.	314	322	308	221	207	138	18	235
Ratio to ADM	1.00	1.02	0.98	0.70	0.66	0.44	0.06	0.75
Sum of Ranking, % Loss[a]	55	46	48	38	33	21	19	35
Average Ranking, % Loss	6.9	5.8	6.0	4.8	4.1	2.6	2.4	4.4
Total Iron Loss, ppm	94.1	83	128	54	37	9.3	1.41	36.0
Ratio to ADM	1.00	0.88	1.36	0.57	0.39	0.10	0.01	0.38
% Iron Loss Based on Initial Minus Final Total Iron Content	36	26	51	22	21	7	1	21
Average % Decrease (Total % Decrease Divided by No. of Samples)	39	40	39	28	26	17	2	29

[a] 8 for highest value, 1 for lowest value

TABLE 20

SUMMARY OF TEST DATA FOR TWELVE MICROFILTRATION TESTS USING SEVEN DIFFERENT ANALYSIS TECHNIQUES

	Method of Analysis						
	ADM	A/E JA	PWMA	A/E35	ICP	AA	PST/ICP
Total Iron Content, ppm	283.6	362.7	268.1	274.8	192.3	153.1	112.2
Ratio to ADM	1.00	1.28	0.95	0.97	0.68	0.54	0.40
Sum of Ranking, Iron Content[a]	68	87	65	76	54	36	34[b]
Average Ranking, Iron Content	5.7	7.3	5.4	6.3	4.5	3.0	3.1
Total % Decrease in Iron after MFR Filtering	445	448	427	327	324	258	56
Ratio to ADM	1.00	1.01	0.96	0.74	0.73	0.58	0.13
Sum of Ranking, % Loss[a]	80	73	74	58	55	50	33
Average Ranking, % Loss	6.7	6.2	6.2	4.8	4.6	4.2	3.0
Total Iron Loss, ppm	102	95.9	132.2	58.9	40.8	12.3	2.04
Ratio to ADM	1.00	0.94	1.30	0.58	0.40	0.12	0.02
% Iron Loss Based on Initial Minus Final Total Iron Content	36	26	49	21	21	8	2
Average % Increase (Total % Decrease Divided by No. of Samples)	37	37	36	27	27	22	5

[a] 8 for highest value, 2 for lowest value
[b] 11 values for PST/ICP

TABLE 21

SUMMARY OF TEST DATA FOR EIGHT MFR
SAMPLES NOT FILTERED USING SIX ANALYSIS TECHNIQUES

	Method of Analysis					
	ADM	A/EJA	PWMA	A/E35	ICP	AA
Total Iron Content, ppm	46.1	90	41.4	97.3	38.4	21.7
Ratio to ADM	1.00	1.95	0.90	2.11	0.83	0.47
Sum of Ranking, Iron Content[a]	50	57	42	54	34	27
Average Ranking, Iron Content	6.3	7.1	5.3	6.8	4.3	3.4

[a] 8 for highest value, 3 for lowest value

were greatly attenuated when averaged with the values from the other eleven microfiltration samples.

A summary of the ferrographic analysis of the MFR filtered samples is given in Table 22. Samples are arranged in order of decreasing ADM iron content. Ferrographic data provide a comparative rating of the quantity of iron present and a comparative rating of large (entry position reading) to small (50 mm position reading). These data show several interesting points. First the level of iron content is ranked the same when using the percent covered for the entry position, percent area covered for the entry plus 50 mm positions or the total of the percent area covered for the entry, 50, 40, 30, 20 and 10 mm positions. Secondly, these rankings are very close to the ADM iron content rankings considering the small differences in the iron content of some of the samples. Sample MFR-5-A appears to be the only sample out of order in ferrographs ranking. This could be due to this sample being the only automotive mineral oil having a very high iron content consisting of small (less than 3 micron) particles. The initial L/S rankings do not correlate to the percent area covered rankings which would be expected but do correlate to particle size which will be discussed in detail when evaluating and determining correlation of all data obtained on all samples. It should be noted that the L/S (Initial) ranking correlate very well with the L/S loss due to filtration ranking. This shows that L/S values as obtained by the analytical ferrograph are particle size dependent.

d. SOAP "Hit" Sample Data

The original iron content and iron loss due to three micron membrane filtration of SOAP samples from a previous test program are given in Table 23 and includes test data for both "hit" and other membrane filtered SOAP samples and for the purpose of this report are labeled "routine" SOAP

TABLE 22

SUMMARY OF ANALYTICAL FERROGRAPH DATA AND EFFECTS OF MFR FILTRATION ON THE RATIO OF LARGE TO SMALL PARTICLES

		Ferrograph Data									
	ADM Iron	Entry Pos. % A.C.[4]		E[1]+50 mm Pos. % A.C.		Total[2] % A.C.		L/S[3] (Init)		L/S (Filt. Loss)	
Sample	ppm	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
MFR-5-A	110	444[5]	4	856[5]	3	1289[5]	4	1.08	8	0.05	10
MFR-2-A	60.4	1407	1	2217	1	3453	1	1.74	5	0.57	5
MFR-1-A	31.8	771	2	1086	2	1398	2	2.45	3	1.29	3
MFR-4-A	26.0	717	3	834	4	1323	3	6.13	1	4.79	1
MFR-3-A	13.8	25.9	8	62.7	6	267	5	0.77	12	(+0.11)	12
MFR-8-A	10.1	26.5	7	39.8	9	82.2	9	1.99	4	0.84	4
MFR-22-A	8.57	21.6	9	47.6	8	177	7	0.83	11	0.27	9
MFR-6-A	7.41	40.2	5	76.6	5	190	6	1.10	7	0.30	8
MFR-10-A	6.14	13.3	10	24.9	10	75	10	1.15	6	0.36	7
MFR-18-A	5.13	27.3	6	54.8	7	109	8	0.99	10	0.46	6
MFR-9-A	3.41	9.8	11	19.3	11	37.3	11	1.03	9	(+0.01)	11
MFR-7-A	0.61	5.4	12	7.3	12	11.5	12	2.84	2	1.84	2

[1] E= Ferrogram entry position
[2] Total of % area covered readings at the entry, 50, 40, 30, 20 and 10 mm ferrogram positions
[3] L/S Ratio of large (Entry) particles to small (50 mm)
[4] A.C. = Area Covered
[5] Values adjusted to normal 3 mL sample size

TABLE 23

ORIGINAL IRON CONTENT AND IRON LOSS DUE TO THREE MICRON MEMBRANE FILTRATION

Sample	Orig. Fe & Loss due to Filtration	Method of Analysis, ppm[a] ICP	PST/ICP	A/E35	DCP	AA	ADM
H-84	Orig. Fe	27.8	7.09	14	29.0	19.0	45.7
	Filt. Loss	10.2	0.97	2	11.7	6.0	22.6
	% Loss	37	14	14	40	32	49
H-13	Orig. Fe	11.1		19	10.1	10.0	15.1
	Filt. Loss	0.4		1	0.5	1.0	0.4
	% Loss	4		1	5	10	3
H-61	Orig. Fe	12.3		27	12.2		17.0
	Filt. Loss	(0.4)		0	0.6		0.5
	% Loss	(3)		0	5		3
H-6	Orig. Fe	12.4	7.89	23	10.9	9.0	15.6
	Filt. Loss	0.7	(0.10)	1	0.4	0.0	3.0
	% Loss	6	(1)	4	4	0	19
H-54	Orig. Fe	10.2	13.9	22		9.0	14.5
	Filt. Loss	(0.4)	0.8	1		2.0	1.1
	% Loss	(4)	6	5		11	8
H-89	Orig. Fe	25.5	28.7	46	24.3	22	35.6
	Filt. Loss	(0.5)	0.7	0	(0.1)	(1)	(0.3)
	% Loss	(2)	2	0	(0)	(5)	(1)
H-47	Orig. Fe	12.2		13	10.6	8.0	17.8
	Filt. Loss	(1.1)		2	0.79	0	(0.4)
	% Loss	(9)		15	7	0	(2)
H-20	Orig. Fe	23.8	13.2	29	23.9	12.0	39.8
	Filt. Loss	7.1	0	9	7.3	5.0	18.3
	% Loss	30	0	31	31	42	46
H-66	Orig. Fe	10.8		20	8.69	7.0	13.6
	Filt. Loss	(0.1)		0	(0.09)	0	0.3
	% Loss	(1)		0	(1)	0	2
H-5	Orig. Fe	16.6		36	14.5	13	22.2
	Filt. Loss	1.3		0	0.7	1	0.8
	% Loss	8		0	5	8	4

TABLE 23 (CONT'D)

H-26	Orig. Fe	18.7		39	18.1	13	23.2
	Filt. Loss	(0.1)		1	0.5	1	2.1
	% Loss	(1)		3	3	8	9
H-24	Orig. Fe	21.0		44	19.5	13	23.8
	Filt. Loss	0.3		0	(0.1)	(1)	0.4
	% Loss	1		0	(1)	(8)	2
H-55	Orig. Fe	16.3	10.1	20	16.2	13	23.3
	Filt. Loss	0.5	0.3	1	0.5	3	2.6
	% Loss	3	3	1	3	23	11
H-67	Orig. Fe	11.8		21	9.88	8.0	13.4
	Filt. Loss	0.3		5	0.44	0	0.2
	% Loss	3		24	4	0	1
H-12	Orig. Fe	7.80	7.04	14	5.61	6.0	9.41
	Filt. Loss	(0.02)	0.20	0	0.25	0.0	0.74
	% Loss	0	3	0	4	0	8
H-30	Orig. Fe	14.2	13.3	27	11.5	13	18.1
	Filt. Loss	(0.1)	0.1	0	(0.7)	(2)	0.3
	% Loss	(1)	1	0	(6)	(15)	2
P-71	Orig. Fe	34.4	3.78	6.1	34.4	19	60.7
	Filt. Loss	11.2	(1.99)	(1.4)	13.2	4.0	33.6
	% Loss	33	(53)	(23)	38	21	55
P-43	Orig. Fe	45.1	51.3	79	36.7	36.1	58.2
	Filt. Loss	(0.20)	0.6	1	(0.6)	1.1	1.4
	% Loss	0	1	1	(1)	3	2
P-108	Orig. Fe	8.03		19	6.80	11.5	7.0
	Filt. Loss	(0.05)		0	(0.61)	(0.1)	0.0
	% Loss	(1)		0	(9)	(1)	0
P-81	Orig. Fe	7.83		10.0	6.90	13.0	23.2
	Filt. Loss	0.73		0.4	2.62	1.0	2.1
	% Loss	9		4	38	8	9
P-111	Orig. Fe	21.7		31	17.4	13.0	21.4
	Filt. Loss	0.7		9	7.5	5.0	8.0
	% Loss	3		29	43	38	37
P-110	Orig. Fe	7.41		16	6.26	8.83	5.0
	Filt. Loss	0.41		0	0.05	0.20	0.0
	% Loss	6		0	1	2	0

TABLE 23 (CONCLUDED)

F-5	Orig. Fe	14.0		30		13	15.4
	Filt. Loss	(0.4)		1		0	0.3
	% Loss	(3)		3		0	2
F-41	Orig. Fe	4.53		12	4.07	4.0	6.36
	Filt. Loss	0.10		0	(.02)	0.0	0.56
	% Loss	2		0	0	0	9
Navy Com.	Orig. Fe	4.73	4.34	9.7	5.06	4.0	7.22
	Filt. Loss	0.10	0.01	0.6	(0.51)	0.0	0.99
	% Loss	2	0	6	(10)	0	14
Gear-Box 2	Orig. Fe	6.73	7.74	13	5.08	4.0	10.20
	Filt. Loss	0.09	(0.03)	1	(1.11)	0	3.86
	% Loss	1	0	8	(22)	0	38
Army Heli-copter	Orig. Fe	2.63	2.70	5.2	2.38	2.0	3.83
	Filt. Loss	0.01	0.28	0.1	0.12	0.0	0.79
	% Loss	0	10	2	5	0	21
Gear-Box 1	Orig. Fe	6.83	7.01	11		4.0	11.1
	Filt. Loss	(0.15)	(0.20)	(1)		0.0	4.42
	% Loss	(2)	(3)	(9)		0	40

[a]Values in ( ) show ppm and % increase in value after filtering

samples. As shown by these data six analysis techniques were utilized although insufficient sample existed for the analysis of all samples using all techniques. Table 24 shows the initial iron content of all the membrane filter SOAP samples with the iron values arranged from high to low. The range of iron values is large and similar to that of the MFR samples. Table 25 gives the ADM iron value and percent loss due to 3 micron membrane filtering using various measuring techniques with percent loss values arranged from high to low. Overall the percent loss due to membrane filtration for these samples is lower than that for the MFR samples (Table 15) indicating smaller particle size distribution or better filtering efficiency using in-depth filters.

The summary of rankings of the various analysis techniques for the SOAP "Hit" samples based on iron content is given in Table 26 and shows that ADM and A/E35 analyses rank seventh and eighth 97% of the time while DCP, AA and PST/ICP analyses ranked fifth and below 89% of the time. ICP analyses ranked sixth 81% of the time. The summary of rankings of these samples based on iron loss due to filtering is given in Table 27 and except for the ADM analyses, the rankings of each analysis technique are more evenly ranked from high to low. The ADM values rank seventh and eighth 75% of the time.

A complete summary of all the test data for the fourteen membrane filtered SOAP "Hit" samples using five different analysis techniques is given in Table 28. PST/ICP analyses of these samples were not included since only seven samples were analyzed by this method. The data shown in Table 28 are very similar to the same data for the MFR samples except that the percent loss due to filtering is much lower for the "Hit" samples than for the MFR samples. A close comparison of these data is made in a later section of this report after presenting the routine SOAP sample data.

TABLE 24

IRON CONTENT AS DETERMINED BY VARIOUS ANALYSIS TECHNIQUES
WITH VALUES ARRANGED FROM HIGH TO LOW
(VALUES IN PPM)

H-84	ADM	DCP	ICP	AA	A/E35	PST/ICP
	45.7	29.0	27.8	19.0	14	7.09
H-13	A/E35	ADM	ICP	DCP	AA	
	19	15.1	11.1	10.1	10.0	
H-61	A/E35	ADM	ICP	DCP		
	27	17	12.3	12.2		
H-6	A/E35	ADM	ICP	DCP	AA	PST/ICP
	23	15.6	12.4	10.9	9.0	7.89
H-54	A/E35	ADM	PST/ICP	ICP	AA	
	22	14.5	13.9	10.2	9.0	
H-89	A/E35	ADM	PST/ICP	ICP	DCP	AA
	46	35.6	28.7	25.5	24.3	22
H-47	ADM	A/E35	ICP	DCP	AA	
	17.8	13	12.2	10.6	8.0	
H-20	ADM	A/E35	DCP	ICP	PST/ICP	AA
	39.8	29	23.9	23.8	13.2	12.0
H-66	A/E35	ADM	ICP	DCP	AA	
	20	13.6	10.8	8.69	7.0	
H-5	A/E35	ADM	ICP	DCP	AA	
	36	22.2	16.6	14.5	13	
H-26	A/E35	ADM	ICP	DCP	AA	
	39	23.2	18.7	18.1	13	
H-24	A/E35	ADM	ICP	DCP	AA	
	44	23.8	21.0	19.5	13	
H-55	ADM	A/E35	ICP	DCP	AA	PST/ICP
	23.8	20	16.3	16.2	13	10.1
H-67	A/E35	ADM	ICP	DCP	AA	
	21	13.4	11.8	9.88	8.0	
H-12	A/E35	ADM	ICP	PST/ICP	AA	DCP
	14	9.41	7.80	7.04	6.0	5.61
H-30	A/E35	ADM	ICP	PST/ICP	AA	DCP
	27	18.1	14.2	13.3	13	11.5

TABLE 24 (CONCLUDED)

P-71	ADM	ICP	DCP	AA	A/E35	PST/ICP
	60.7	34.4	34.4	19	6.1	3.78
P-43	A/E35	ADM	PST-ICP	ICP	DCP	AA
	79	58.2	51.3	45.1	38.7	36.1
P-108	A/E35	AA	ICP	ADM	DCP	
	19	11.5	8.03	7.0	6.80	
P-81	ADM	AA	A/E35	ICP	DCP	
	23.2	13.0	10.0	7.83	6.90	
P-111	A/E35	ICP	ADM	DCP	AA	
	31	21.7	21.4	17.4	13.0	
P-110	A/E35	AA	ICP	DCP	ADM	
	16	8.83	7.41	6.26	5.0	
F-5	A/E35	ADM	ICP	AA		
	30	15.4	14.0	13		
F-41	A/E35	ADM	ICP	DCP	AA	
	12	6.36	4.53	4.07	4.0	
Navy Com.	A/E35	ADM	DCP	ICP	PST/ICP	AA
	9.7	7.22	5.06	4.73	4.34	4.0
Gearbox-2	A/E35	ADM	PST/ICP	ICP	DCP	AA
	13	10.2	7.74	6.73	5.08	4.0
Army	A/E35	ADM	PST/ICP	ICP	DCP	AA
Helicopter	5.2	3.83	2.70	2.63	2.38	2.0
Gearbox-1	ADM	A/E35	PST/ICP	ICP	AA	
	11.1	11	7.01	6.83	4.0	

TABLE 25

ADM IRON VALUE AND PERCENT LOSS DUE TO 3 MICRON MEMBRANE FILTERING FOR VARIOUS MEASURING TECHNIQUES ARRANGED FROM HIGH TO LOW PERCENT LOSS

Sample	ADM PPM	Percent Loss due to 3 Micron Filtration[a]					
H-66	13.6	ADM 2	A/E35 0	AA 0	DCP (1)	ICP (1)	
H-5	22.2	ICP 8	AA 8	DCP 5	ADM 4	A/E35 0	
H-26	23.2	ADM 9	AA 8	A/E35 3	DCP 3	ICP 0	
H-24	23.8	ADM 2	ICP 1	A/E35 0	DCP (1)	AA (8)	
H-55	23.3	AA 23	ADM 11	ICP 3	PST/ICP 3	DCP 3	A/E35 1
H-67	13.4	A/E35 24	DCP 4	ICP 3	ADM 1	AA 0	
H-12	9.41	ADM 8	DCP 4	PST/ICP 3	ICP 0	A/E35 0	AA 0
H-30	18.1	ADM 2	PST/ICP 1	A/E35 0	ICP (1)	DCP (6)	AA (15)
H-84	45.7	ADM 49	DCP 40	ICP 37	AA 32	A/E35 14	PST/ICP 14
H-13	15.1	AA 10	DCP 5	ICP 4	ADM 3	A/E35 1	
H-61	17.0	DCP 5	ADM 3	ICP (3)	A/E35 0		
H-6	15.6	ADM 19	ICP 6	A/E35 4	DCP 4	AA 0	PST/ICP (1)
H-54	14.5	AA 11	ADM 8	PST/ICP 6	A/E35 5	ICP (4)	
H-89	35.6	PST/ICP 2.0	A/E35 0	ADM (1)	DCP (1)	ICP (2)	AA (5)
H-47	17.8	A/E35 15	DCP 7	AA 0	ADM (2)	ICP (9)	

TABLE 25 (CONCLUDED)

H-20	39.8	ADM	AA	A/E35	DCP	ICP	PST/ICP
		46	42	31	31	30	0
P-71	60.7	ADM	DCP	ICP	AA	A/E35	PST/ICP
		55	38	33	21	(23)	(53)
P-43	58.2	AA	ADM	A/E35	PST/ICP	ICP	DCP
		3	2	1	1	0	(1)
P-108	7.0	ADM	A/E35	AA	ICP	DCP	
		0	0	(1)	(1)	(9)	
P-81	23.2	DCP	ADM	ICP	AA	A/E35	
		38	9	9	8	4	
P-111	21.4	DCP	AA	ADM	A/E35	ICP	
		43	38	37	29	3	
P-110	5.0	ICP	AA	DCP	ADM	A/E35	
		6	2	1	0	0	
F-5	15.4	A/E35	ADM	AA	ICP		
		3	2	0	(3)		
F-41	6.36	ADM	ICP	A/E35	AA	DCP	
		9	2	0	0	0	
Navy Com.	7.22	ADM	A/E35	ICP	AA	PST/ICP	DCP
		14	6	2	0	0	0
Gearbox-2	10.2	ADM	A/E35	ICP	AA	PST/ICP	DCP
		38	8	1	0	0	(22)
Army	3.83	ADM	PST/ICP	DCP	A/E35	ICP	AA
Helicopter		21	10	5	2	0	0
Gearbox-1	11.1	ADM	AA	ICP	PST/ICP	A/E35	
		40	0	(2)	(3)	(9)	

[a]Values in ( ) gives a % increase in value after filtering

TABLE 26

SUMMARY OF RANKINGS OF EACH ANALYSIS TECHNIQUE FOR MEMBRANE FILTERED SOAP "HIT" SAMPLES BASED ON IRON CONTENT (16 SAMPLES UNLESS SHOWN)

Measuring Technique	Number of Times Ranked in Position (High to Low Readings)					
	8	7	6	5	4	3
ADM	4	12	0	0	0	0
A/E35	12	3	0	0	1	0
ICP	0	0	13	3	0	0
DCP[a]	0	1	1	10	1	2
AA[a]	0	0	0	1	12	2
PST/ICP[b]	0	0	2	2	1	3

[a] DCP and AA Analyses conducted on 15 samples
[b] PST/ICP Analysis conducted on 8 samples

TABLE 27

SUMMARY OF RANKINGS OF EACH ANALYSIS TECHNIQUE BASED ON PERCENT LOSS DUE TO 3 MICRON MEMBRANE FILTERING OF "HIT" SOAP SAMPLES (16 SAMPLES UNLESS SHOWN)

	Number of Times Ranked in Position					
Measuring Technique	8	7	6	5	4	3
ADM	8	4	1	3	0	0
A/E35	2	2	6	2	3	1
ICP	1	4	7	1	2	1
DCP[a]	1	7	5	2	0	0
AA[a]	4	4	4	1	2	0
PST/ICP[b]	1	1	2	1	2	1

[a] DCP and AA Analyses conducted on 15 samples
[b] PST/ICP Analyses were conducted on 8 samples

TABLE 28

SUMMARY OF TEST DATA FOR FOURTEEN MEMBRANE FILTERED SOAP "HIT" SAMPLES USING FIVE DIFFERENT ANALYSIS TECHNIQUES

	Method of Analysis				
	ADM	A/E35	ICP	DCP	AA
Total Iron Content, ppm	317	365	230	213	166
Ratio to ADM	1.00	1.15	0.73	0.67	0.52
Sum of Ranking, Iron Content[a]	116	121	93	73	59
Average Ranking Iron Content	7.3	7.6	5.8	4.9	3.9
Total % Decrease in Iron After Membrane Filtration	156	93	92	106	123
Ratio to ADM	1.00	0.60	0.59	0.68	0.79
Sum of Ranking, % Loss[a]	113	91	91	97	97
Average Ranking, % Loss	7.1	5.7	5.7	6.5	6.5
Total Iron Loss, ppm	51.7	22	21.3	23.1	17
Ratio to ADM	1.00	0.43	0.41	0.45	0.33
% Iron Loss Based on Initial Minus Final Iron Content	16	6	9	11	12
Average % Decrease (Total of % Decrease Divided by No. of Samples	11	7	7	8	9

[a] 8 for highest value, 4 for lowest value

e. SOAP "Routine" Sample Data

The original iron content and iron loss due to 3 micron filtering and the ranking of these data from high to low with respect to each analysis technique are included in Tables 23 thru 25 and are very similar to the data for the "Hit" samples. The rankings for each analysis technique for the membrane filtered SOAP "Routine" samples based on iron content is given in Table 29. The ADM and A/E35 analyses rank seventh and eighth 75% of the time while ICP analyses ranked sixth 60% of the time and DCP and AA ranked below sixth 65% of the time. These rankings are similar for the "Hit" and MFR sample rankings. The rankings of these analyses based on percent iron loss due to filtering are given in Table 30 with the data being very similar to that of the "Hit" sample data in that rankings of all techniques with the exception of ADM analyses are more evenly ranked. ADM analyses ranked seventh or eighth 80% of the time.

A complete summary of all the test data for the membrane filtered "Routine" SOAP samples is given in Table 31. These data are similar to that obtained for the membrane filtered "Hit" samples which show close ADM and A/E35 values for initial iron content while ICP, DCP and AA values are slightly lower. However, the values for iron loss due to filtering are less than half of the ADM loss for all other analyses techniques except DCP. This was not true for all the data for the MFR filtered samples.

f. Correlation of MFR Test Rig Data and SOAP Data

A summary of average rankings of the different analyses techniques for various sample groups is given in Table 32. The data for initial iron content show that the rankings are about the same for all sample groups considering that only five analysis techniques were conducted on the membrane filtered samples. The data for percent iron loss show a much more equal

TABLE 29

SUMMARY OF RANKINGS FOR EACH ANALYSIS TECHNIQUE FOR 10 MEMBRANE FILTERED "ROUTINE" SOAP SAMPLES BASED ON IRON CONTENT

	Number of Times Ranked in Position (High to Low Readings)				
Measuring Technique	8	7	6	5	4
ADM	2	5	1	1	1
A/E35	8	0	1	0	1
ICP	0	2	6	2	0
DCP	0	0	4	4	2
AA	0	3	0	1	6

TABLE 30

SUMMARY OF RANKINGS FOR EACH ANALYSIS TECHNIQUE BASED ON PERCENT LOSS DUE TO 3 MICRON FILTERING OF TEN "ROUTINE" SOAP SAMPLES

	Number of Times Ranked in Position (High to Low Readings)				
Measuring Techniques	8	7	6	5	4
ADM	6	2	1	1	0
A/E35	1	2	2	3	2
ICP	2	1	4	2	1
DCP	3	2	2	3	0
AA	2	2	1	5	0

TABLE 31

SUMMARY OF TEST DATA FOR TEN MEMBRANE FILTERED ROUTINE SOAP SAMPLES USING FIVE DIFFERENT ANALYSIS TECHNIQUES

	Method of Analysis				
	ADM	A/E35	ICP	DCP	AA
Total Iron, ppm	203	201	143	127	115
Ratio to ADM	1.00	0.99	0.70	0.63	0.57
Sum of Ranking, Iron Content	66	74	60	52	50
Average Ranking, Iron Content	6.6	7.4	6.0	5.2	5.0
Total % Decrease in Iron After Membrane Filtration	185	50	56	125	72
Ratio to ADM	1.00	0.27	0.30	0.68	0.39
Sum of Ranking, % Loss[1]	73	52	61	65	61
Average Ranking, % Loss	7.3	5.2	6.1	6.5	6.1
Total Iron Loss, ppm	51.3	12.1	13.3	23.5	11.3
Ratio to ADM	1.00	0.24	0.26	0.46	0.22
% Iron loss Based on Initial Minus Final Iron Content	25	6	9	18	10
Average % Dec. (Total of % Dec. Divided by No. of Samples	19	5	6	13	7

[1] 8 For highest value, 4 for lowest value

TABLE 32

SUMMARY OF AVERAGE RANKINGS OF DIFFERENT ANALYSIS TECHNIQUES FOR VARIOUS SAMPLE GROUPS

	Method of Analysis							
Sample Group	ADM	A/EJA	PWMA	A/E35	ICP	AA	PST/ICP	DCP
			Iron Content Data					
12 MFR Tests, 7 Analysis	5.7	7.3	5.4	6.3	4.5	3.0	3.1	-
8 MFR Tests, 8 Analysis	5.3	7.0	5.7	6.0	3.9	2.6	2.1	3.3
8 MFR Samples Net Filt.	6.3	7.1	5.3	6.8	4.3	3.4	-	-
14 Membrane Filt. "H" Samp.	7.3	-	-	7.6	5.8	3.9	-	4.9
10 Membrane Filt. "R" Samp.	6.6	-	-	7.4	6.0	5.0	-	5.2
			% Iron Loss Due to Filtering Data					
12 MFR Tests, 7 analyses	6.7	6.2	6.2	4.8	4.6	4.2	3.0	-
8 MFR Tests, 8 Analyses	6.9	5.8	6.0	4.8	4.1	2.6	2.4	4.4
14 Membrane Filt. "H" Samp.	7.1	-	-	5.7	5.7	6.5	-	6.5
10 Membrane Filt. "R" Samp.	7.3	-	-	5.2	6.1	6.1	-	6.5

distribution of rankings for the membrane filtered samples than the rankings for the MFR samples. The data presented in Table 33 show that this is most probably due to less sensitivity to larger particles of the lower ranked techniques.

The data in Table 33 give a summary of ratios of total iron content and percent iron loss for various sample groups to ADM values. These data also show that ICP, AA and PST/ICP analysis techniques have lower sensitivity (analysis capability) to large particles than ADM, PWMA or the emission spectrographic techniques when considering total iron content data. The difference between the percent loss ratio values for the membrane filtered "Hit" and "Routine" samples using A/E35, ICP and AA analysis techniques is not clear. This difference was not observed with the DCP data. If the "Hit" samples had a larger particle size distribution, then the percent loss ratios values should be higher for the "Hit" samples than for the "Routine" samples. However, the percent iron loss between the two SOAP sample groups was slightly higher (19%) for the "Routine" samples than for the "Hit" samples (11%) as determined by ADM analyses (Reference Tables 28 and 31). These data suggest that higher iron values and high rates of iron increases responsible for "Hit Samples" were not due to a large increase in the generation of larger wear particles and that three micron filtration should not prevent the use of SOAP.

The correlation of membrane filtration loss of iron from particle size distribution data and iron loss due to microfiltration rig testing using the various analysis techniques are given in Table 34. These data show that the efficiency of the three micron operational filter in removing wear debris is equal to and in most cases is better than the laboratory 3 micron membrane filter. This is to be expected since the operational filter is a depth

TABLE 33

SUMMARY OF RATIOS OF TOTAL IRON CONTENT AND PERCENT IRON LOSS DUE TO FILTERING TO ADM VALUES USING DIFFERENT ANALYSIS TECHNIQUES AND VARIOUS SAMPLE GROUPS

Sample Group	Method of Analysis							
	ADM	A/EJA	PWMA	A/E35	ICP	AA	PST/ICP	DCP
Total Iron Content								
12 MFR Tests, 7 Anal.	1.00	1.28	0.95	0.97	0.68	0.54	0.40	-
8 MFR Tests, 8 Anal.	"	1.23	0.97	0.94	0.67	0.54	0.41	0.66
8 MFR Samp. Not Filt.	"	1.95	0.90	2.11	0.83	0.47	-	-
14 Mem.[3] Filt. "H" Samp.	"	-	-	1.15	0.73	0.52	-	0.67
10 Mem. Filt. "R" Samp.	"	-	-	0.99	0.70	0.57	-	0.63
% Iron Loss Due to Filtering[1]								
12 MFR Tests, 7 Anal.	1.00	1.01	0.96	0.74	0.73	0.58	0.13	-
8 MFR Tests, 8 Anal.	"	1.02	0.98	0.70	0.66	0.44	0.06	0.75
14 Mem. Filt. "H" Samp.	"	-	-	0.60	0.59	0.79	-	0.68
10 Mem. Filt. "R" Samp.	"	-	-	0.27	0.30	0.39	-	0.68
% Iron Loss Due to Filtering[2]								
12 MFR Tests, 7 Anal.	1.00	0.94	1.30	0.58	0.40	0.12	0.02	
8 MFR Tests, 8 Anal.	"	0.88	1.36	0.57	0.39	0.10	0.01	0.38
14 Mem. Filt. "H" Samp.	"	-	-	0.43	0.41	0.33	-	0.45
10 Mem. Filt. "R" Samp.	"	-	-	0.24	0.26	0.22	-	0.46

[1] Based on Total of % decrease of each sample
[2] Based on % loss calculated from total initial and final iron content
[3] Mem. - Membrane

TABLE 34

CORRELATION OF MEMBRANE FILTRATION LOSS OF IRON FROM PARTICLE SIZE DISTRIBUTION DATA AND IRON LOSS DUE TO MICROFILTRATION RIG TESTING USING VARIOUS ANALYSIS TECHNIQUES
(Samples Arranged from High to Low 3 Micron Filtration Loss)

	ADM Fe PPM	3 Micron Loss, %	Microfiltration Test Rig Loss, %							
			ADM	A/EJA	PWMA	A/E35	ICP	AA	PST/ICP	DCP
MFR-4-A	26.0	85.9	99	100	95	50	92	60	0	89
MFR-10-A	6.14	64.5	46	46	31	50	29	25	22	-
MFR-18-A	5.13	52.6	69	60	58	44	65	63	14	-
MFR-1-A	3[illegible]9	52.2	66	44	85	64	32	31	0	32
MFR-7-A	0.61	40.0	33	62	12	25	5	0	5	24
MFR-2-A	60.4	34.4	51	42	44	37	33	20	2	37
MFR-6-A	7.41	22.4	38	15	50	9	25	20	0	34
MFR-22-A	8.57	19.9	16	17	19	12	4	18	-	-
MFR-3-A	13.8	15.4	17	16	13	9	6	7	9	5
MFR-5-A	110	0.0	10	2	9	5	15	0	0	13
MFR-8-A	10.1	0.0	0	21	0	22	0	0	2	1
MFR-9-A	3.41	0.0	0	23	11	0	9	14	2	-

filter. Also the data show that the PST/ICP analysis technique is not detecting large particles.

The data in Table 35 give a correlation between rankings of ADM iron content, ADM iron loss due to three micron membrane and MFR filtering and decreases in L/S Ferrograph values due to MFR filtering. These data show good correlation between decreases in L/S Ferrograph values and percent loss due to filtration either by membrane or test rig filtering for eleven of the twelve samples. These data show no correlation between initial ADM iron content and percent loss due to filtration or in the L/S ferrograph values.

g. Analysis of Wear Metals Other Than Iron

Very few MFR samples contained any significant concentrations of wear metals other than iron as shown by the data in Appendix A. Silicon metal was present in several of the samples with the concentrations not being reduced by filtration. However, other studies have shown most silicon values are due to silicone contamination which is not filterable. Sample MFR-5-A (automotive oil) had very large quantities of Al, Cu, Mg and Pb with the concentrations of these metals not being affected by filtration. Samples MFR-6-A thru MFR-9-A contained 3 to 30 ppm Mg and with samples MFR-6-A, MFR-8-A and MFR-9-A containing 1 to 3 ppm Cu. Again, filtration did not reduce the concentrations of these metals. This could be due not only to small particle size but part of the metals being in solution after reaction with oil breakdown products.

Some of the SOAP samples (Appendix A) contained 1 to 3 ppm Ag, 1 to 30 ppm Mg, 1 to 10 ppm Cu and 1 to 20 ppm Pb. These metals may have been dissolved since the three micron membrane filtration had only a very slight effect on reducing the concentration of the values for any samples.

The above data indicate that the use of 3 micron absolute filters

TABLE 35

RANKING OF MFR SAMPLES FROM HIGH (1) TO LOW (12) BASED ON ADM IRON CONTENT, PERCENT IRON LOSS BASED ON MFR AND MEMBRANE FILTERING AND FERROGRAPH L/S VALUES

Sample	ADM Iron Content ppm	(Ranking)	ADM Iron Loss 3 Micron Memb. Filtering		ADM Iron Loss MFR Filtering		Percent L/S Ferrograph Rating Decrease MFR Filt.
MFR-5-A	110	(1)	10	(0)[1]	10	(10)[1]	10
MFR-2-A	60.4	(2)	6	(34)	4	(1)	9
MFR-1-A	31.8	(3)	4	(59)	3	(66)	4
MFR-4-A	26.0	(4)	1	(86)	1	(99)	1
MFR-3-A	13.8	(5)	9	(15)	8	(17)	12
MFR-8-A	10.1	(6)	11	(0)	11	(0)	3
MFR-22-A	8.59	(7)	8	(22)	9	(16)	6
MFR-6-A	7.41	(8)	7	(22)	6	(38)	9
MFR-10-A	6.14	(9)	2	(82)	5	(46)	8
MFR-18-A	5.13	(10)	3	(49)	2	(69)	5
MFR-9-A	3.41	(11)	12	(0)	12	(0)	11
MFR-7-A	0.61	(12)	5	(40)	7	(33)	2

[1] Percent Iron Loss

would primarily affect only the iron concentrations of lubricant systems.

h. Wear Metal Trending of SOAP Samples
Using AE and ICP Spectrometric Analysis

Four hundred eighty four residual SOAP samples were submitted by the base level operating activities described in Section III including their AE spectrometric analyses of the samples for additional studies. ICP spectrometric analyses were conducted on these residual SOAP samples for determining if any differences in "trending" could be established by using either of the two analysis techniques and for comparing data obtained on lubricant systems having "fine" filtration when using both AE and ICP spectroscopy. These 484 samples were obtained from 9 type of engines and from 2 transmission systems and two gearbox systems. Table 36 gives a summary and comparison of the AE and ICP analyses along with other pertinent information relative to the various lubricant systems. Complete test data for these samples including system serial numbers, hours since overhaul and hours since oil change are given in Appendix B.

Based upon information provided by the operating activities all engine lubricant systems utilized 10 micron oil filters except for the F404-GE-400 engines which utilized 5 micron filters.

The SH-60B helicopter transmission lubricant systems and the F404-GE-400 engine lubricant systems were the only systems from which a significant total number of samples were obtained or systems from which consecutive samples were obtained. No increasing iron trends occurred for any of the consecutive sample series which should not be surprising since none of the lube systems being monitored were reported as having any problems during the monitoring period. The average ratio of AE iron to ICP iron values of the 484 samples summarized in Table 36 is very close to the average

TABLE 36

SUMMARY OF AE AND ICP SPECTROMETRIC OIL ANALYSIS DATA FOR SOAP MONITORING SAMPLES

Type System	Number of Samples Total	Number of Samples Consec.	Iron Trends	Ratio AE/ICP Fe	Iron Range AE	Iron Range ICP		Average Trace Metal Conc., ppm Fe	Ag	Al	Cr	Cu	Mg	Ni	Si	Ti
C-9B Acft JT8D Eng	2	0	None	0.3	0.2 to 0.3	0.02 to 0.12	AE	0.2	0.0	1.1	0.0	0.1	0.0	0.0	0.2	0.0
							ICP	0.7	0.00	0.06	0.04	0.00	0.00	0.00	0.00	0.00
OV-10A Acft T76-G-420 Eng	6	0	None	1.7	0.9 to 6.8	0.73 to 3.84	AE	3.3	0.0	0.0	0.0	0.5	0.5	0.4	2.9	0.7
							ICP	1.91	0.04	0.97	0.31	0.67	0.26	0.36	2.97	0.04
A-6E Acft J52-P-8B Eng	10	0	None	2.4	0.8 to 5.0	0.27 to 2.19	AE	2.1	0.0	0.8	0.6	0.0	0.6	0.1	1.1	0.4
							ICP	0.87	0.04	0.29	0.59	0.11	0.39	0.13	0.64	0.03
AV-8 Acft F402-RR-406 Eng	12	1 Eng 2 Samp.	None	2.7	0.6 to 3.0	0.12 to 1.2	AE	1.5	0.0	0.6	0.0	1.3	0.9	0.0	1.7	0.6
							ICP	0.55	0.00	0.12	0.05	0.54	0.38	0.03	0.80	0.00
EA-6B Acft J52-P-408 Eng	22	4 Eng 2 Each	None	2.0	0.4 to 4.8	0.11 to 2.38	AE	2.0	0.0	0.7	0.2	0.0	0.1	0.2	1.1	0.6
							ICP	0.98	0.00	0.19	0.43	0.09	0.16	0.04	0.13	0.06
SH-60B Acft Main Transmission	82	15 Units Total of 34 Samp.	1 (Decr. Iron)	3.3	0 to 22	0.00 to 8.01	AE	5.9	0.2	0.2	0.5	2.9	2.3	0.5	5.0	1.1
							ICP	1.77	0.05	0.65	0.20	1.04	0.67	0.07	4.11	0.10
CH-46E Acft T58-GE-16 Eng	28	0	None	1.7	0 to 3.9	0.26 to 2.90	AE	1.7	0.2	0.0	0.0	0.4	0.0	0.6	1.3	1.0
							ICP	1.01	0.26	0.90	0.25	0.62	0.08	0.35	1.18	0.01
CH-46E Acft Gearbox	24	0	None	1.8	1.4 to 36	0.7 to 21.6	AE	15	0.0	1.2	0.5	2.0	4.3	0.6	5.7	0.6
							ICP	3.80	0.12	1.89	0.82	1.24	2.11	0.36	4.67	0.01
CH-53E Acft T64-GE-416 Eng	6	0	None	2.3	2 to 8	0.60 to 5.62	AE	5.2	0	0	0	0	0.2	0	1.2	0.5
							ICP	2.24	0.00	0.22	0.14	0.30	0.04	0.10	1.07	0.00

TABLE 36 (CONCLUDED)

Type System	Number of Samples Total	Number of Samples Consec.	Iron Trends	Ratio AE/ICP Fe	Iron Range AE	Iron Range ICP		Fe	Ag	Al	Cr	Cu	Mg	Ni	Si	Ti
								Average Trace Metal Conc., ppm								
CH-53E Acft Gearbox	12	0	None	1.9	1 to 37	0.63 to 17	AE	12	0.1	0.2	0.0	4.1	5.0	0.3	0.6	0.5
							ICP	6.49	0.09	0.98	0.29	2.17	2.66	0.24	0.73	0.07
HH-46D Acft T58-GE-10 Eng	2	0	None	1.5	5.7 to 8.9	3.58 to 6.43	AE	7.3	0.6	0.8	0.4	0.3	1.2	1.6	4.5	0.7
							ICP	5.00	0.60	2.10	0.99	0.77	0.98	1.16	3.69	0.08
HH-46D Transmission	3	0	None	1.9	3.7 to 43	1.95 to 22.5	AE	19	0.0	1.6	0.3	1.6	4.0	0.4	4.7	0.3
							ICP	9.95	0.03	1.16	0.44	0.95	1.72	0.24	3.39	0.05
F-18 Acft F404-GE-400 Eng	275	37 Eng Total of 150 Samp	None	4.4	0 to 3	0.00 to 0.63	AE	0.7	0.1	0.0	0.4	0.5	0.0	0.7	1.6	0.3
							ICP	0.16	0.02	0.31	0.16	0.30	0.01	0.20	0.40	0.03

of the AE and ICP iron ratio values for the MFR samples and all three micron membrane filtered samples. These AE/ICP ratios were 1.7 ± 0.5 for the MFR and membrane filter samples and 2.0 ± 0.7 for the SOAP monitoring samples with the one exception of the F404-GE-400 engines which had an AE/ICP iron ratio of 4.4. This ratio is probably high since many of the AE analyses were conducted on the high range setting of the AE spectrometer (the ICP iron range was 0.30 to 0.63 for these engines).

The trace metal concentration of elements Ag, Al, Cr, Cu, Mg, Ni and Si for all the 13 lubricant systems monitored and shown on Table 36 is low using either the AE or ICP analysis technique with the AE analysis usually being slightly higher. Although most Ti values are low, Ti analyses conducted by AE spectroscopy are usually much higher than the corresponding ICP values.

Analyses for Pb and Sn are not shown in Table 36 due to a small number of intermittent unexplained very high ICP values of Pb and the Sn enhancement when using AE spectroscopy for specific formulations of ester base lubricants. Overall, monitoring of the 13 lubricant systems shown in Table 36 gave low analysis values for all metals, no iron "trending" data for either analysis technique and with the similarity between the AE data and ICP data being about the same as that shown by the corresponding data obtained on the MFR and membrane filtered samples.

However, other useful information was obtained from this part of the program. First it was demonstrated that the ICP values of the collected samples consistently equaled the modified AE values performed by SOAP personnel. A/E35 results are usually 1.7 to 2.0 higher than the ICP or AA results due to the dissimilarity of the sample and standard matrices. Oxygen containing lubricants enhance the emission signal. Since the oil standards are prepared in hydrocarbon oils, any hydrocarbon oil sample analyzed by A/E35 would give an accurate value. However, an ester oil sample is an oxygen containing lubricant and its analysis by A/E35 would usually give 1.7 to 2.0 higher than a hydrocarbon oil sample. Thus, applying a correction factor to the A/E35 trending limits used by SOAP could produce initial SOAP trending limits similar to ICP and AA trending limits. Second, it was determined that the used gas turbine engine oils contained fibrous material which clogged the sample tube of the ICP nebulizer. Consequently, design changes need to be made in the sample tube-nebulizer connection to limit accumulation of material extending the time between nebulizer cleanings and restandardizations. Third, the plasma source extinguished rapidly when the sample tube was allowed to fill with air. Consequently, solvent (kerosene or water) will need to be nebulized constantly if the source is to be maintained between series of samples resulting in increased argon usage and waste accumulation.

SECTION V

CONCLUSIONS

The initial evaluation of the ICP spectrometer demonstrated that the experimental and instrumental conditions of the ICP emission spectrometer need to be optimized for the Joint Oil Analysis Program (AFOAP, AOAP and NOAP). For oil analysis programs concerned primarily with gas turbine engine oil analyses, the ICP procedure should be optimized for analyses of ester-based oils (standards prepared in ester oils) with low levels of wear debris (longer flush times) present in a wide range of particle sizes (plasma height optimization, particle detection capability). Whereas, oil analysis programs concerned primarily with internal combustion engine lubricant analyses, the ICP procedure should be optimized for analyses of hydrocarbon-based oils (concomitant element effects from additive packages) with high levels of wear debris and additives (less sensitive spectral lines for increased linearity ranges and plasma height optimization) and high levels of contaminants (more frequent standardization checks).

For this study the majority of the samples analyzed by the ICP spectrometer were used gas turbine engine oil samples obtained from normally operating engines with particle sizes below 3 micron. Therefore, the following parameters were used to optimize the ICP spectrometer for evaluation:

Dilution Ratio:	1 : 9 (oil sample : kerosene)
Flush Time:	100 seconds (to ensure removal of particles)
Inlet Argon Pressure:	60 psig
Sample Introduction:	Manual
Standard:	10 ppm Air Force Standard (50 ppm used if 10 ppm samples analyzed)
Restandardization:	Every ten samples*

*ICP had to be restandardized every 10 samples due to fibrous material collecting in, and eventually clogging, the nebulizer sample tube. Every 30-40 samples the nebulizer was cleaned with a thin wire to prevent clogging of the sample tube.

The comparative study of the various analysis techniques has indicated that microfiltration could have a small effect on spectrometric oil analysis results. Although no abnormal operating engines were monitored during this program, the use of previously obtained SOAP samples showed that the abnormal operating engines (Hit samples) had approximately 9% less iron particles, greater than 3 microns, than the routine or normal samples (25.2% greater than 3 micron for the Routine samples versus 16.3% greater than 3 micron for the Hit samples).

Considering the data from all sample groups, all analysis techniques investigated (except ferrography and the acid dissolution method) were iron particle size sensitive with none showing significant improvement over the currently used emission spectrometric technique with respect to analyzing large particles.

None of the analytical analysis techniques investigated offered any improvement over the currently used emission technique with respect to monitoring capability with or without microfiltration, analysis time or analysis cost, or person-power.

The study has shown that the use of "in-laboratory" automatic sampling must be avoided unless sample agitation can be incorporated.

Although the analytical ferrograph showed good correlation with iron particle size as well as total iron concentration it is not recommended that ferrography be used for the routine analysis of all SOAP samples due to analysis time and cost. However, ferrography could be useful in supplementing the current SOA programs where specific lubricant related problem areas exist.

SECTION VI

RECOMMENDATIONS

This study has shown that future research for improving the monitoring capability of lubricant systems through the use of diagnostic methods for wear metal analyses would be best directed towards the following areas.

Abnormal operating engines or lubricant systems which were not detected by SOAP should be drained and all the drained oil submitted to an appropriate laboratory for an in-depth evaluation including wear particle size distribution measurements. Associated lubricant filters should be included for analyses. The data obtained from this type study would identify the reasons for the SOAP misses and identify specific type of measurements or data evaluation techniques which would reduce the number of SOAP misses.

Research effort should be directed towards improving the currently used atomic emission spectrometric technique. These improvements would include such factors as instrument and calibration stability, reduced instrument down time, reducing repair costs and equipment modifications such as incorporating computers for updating data acquisition and data evaluation capability.

APPENDIX A

MICROFILTRATION TEST RIG DATA

Appendix A contains all analyses conducted on all samples obtained from the microfiltration test rig. This test data is tabulated as follows

TABLE A-1. ACID DISSOLUTION (ADM) ANALYSIS USING ADM/ICP

TABLE A-2. ATOMIC EMISSION SPECTROMETRIC ANALYSIS (A/E 35U-3)

TABLE A-3. ATOMIC EMISSION SPECTROMETRIC ANALYSIS (J.A. 44181)

TABLE A-4. INDUCTIVELY COUPLED PLASMA (ICP) SPECTROMETRIC ANALYSIS

TABLE A-5. INDUCTIVELY COUPLED PLASMA (PST/ICP) ANALYSIS

TABLE A-6 ATOMIC ABSORPTION SPECTROMETRIC ANALYSIS

TABLE A-7. PORTABLE WEAR METAL ANALYZER (PWMA) ANALYSIS

TABLE A-8. DIRECT CURRENT PLASMA (DCP) SPECTROMETRIC ANALYSIS

TABLE A-9. PARTICLE SIZE DISTRIBUTION USING ADM/AA

TABLE A-10. ANALYTICAL FERROGRAPH DATA

TABLE A-1

Sample	Acid Dissolution (ADM) Analysis Using ADM/ICP (Values in ppm)										
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
MFR-1-A-1	31.8	0.53			0.00	0.40			5.69		
-1-A-2	10.8				0.00	0.15			2.94		
-1-B-1											
-1-B-2											
-1-C-1											
-1-C-2											
-1-D-1											
-1-D-2											
MFR-2-A-1	60.4	1.22			0.54				8.57		
-2-A-2	29.7	0.89			0.36				6.22		
-2-B-1											
-2-B-2											
-2-C-1											
-2-C-2											
MFR-3-A-1	13.8	0.1			0.09	0.12			10.29		
-3-A-2	11.5				0.14				9.81		
-3-B-1											
-3-B-2											
-3-C-1											
-3-C-2											

TABLE A-1 CONT'D

Sample	Acid Dissolution (ADM) Analysis Using ADM/ICP (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Hg	Ni	Pb	Si	Sn	Ti		
MFR-4-A-1	26.0	0.00	1.33	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-A-2	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-B-1	4.30	0.00	0.23	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-B-2	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-C-1	-	-	-	-	-	-	-	-	-	-	-		
-4-C-2	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-D-1	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-D-2	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
MFR-5-A-1	110	0.00	13.4	4.82	43.2	557	1.82	69.5	37.4	2.83	0.00		
-5-A-2	98.7	0.00	11.4	4.10	40.3	556	1.63	68.4	36.8	1.32	0.00		
-5-B-1	105	0.00	12.8	5.11	41.9	543	1.19	67.4	38.5	1.99	0.00		
-5-B-2	95.4	0.00	11.9	4.32	40.3	542	1.17	66.5	37.9	1.35	0.00		
-5-C-1	101	0.00	11.2	5.00	40.0	550	1.32	67.4	39.1	1.83	0.00		
-5-C-2	97.3	0.00	11.6	4.80	39.8	548	1.19	65.4	37.5	1.49	0.00		
-5-D-1	99.5	0.00	11.3	5.13	40.1	549	1.23	67.1	40.1	1.75	0.00		
-5-D-2	98.5	0.00	11.4	4.91	39.0	545	1.08	66.3	38.1	1.61	0.00		
MFR-6-A-1	7.41	0.31	1.93	0.72	1.91	2.33	0.24	1.00	4.21	0.00	0.00		
-6-A-2	4.62	0.03	1.82	0.41	1.53	1.61	0.03	2.01	3.40	0.00	0.00		
-6-B-1	4.93	0.41	0.92	0.53	1.64	1.65	0.10	0.90	3.51	0.63	0.00		
-6-B-2	3.93	0.40	1.13	0.34	1.45	1.42	0.00	1.04	3.23	0.24	0.00		
-6-C-1	4.31	0.51	0.93	0.42	1.54	1.50	0.00	0.71	3.50	0.00	0.00		
-6-C-2	3.93	0.53	1.03	0.32	1.41	1.54	0.21	0.80	3.23	0.00	0.00		
-6-D-1	4.01	0.49	1.12	0.23	1.52	1.57	0.13	0.92	3.81	0.00	0.00		
-6-D-2	3.75	0.40	0.88	0.31	1.48	1.39	0.00	0.81	3.10	0.00	0.00		

TABLE A-1 CONT'T

Sample	Acid Dissolution (ADM) Analysis Using ADM/ICP (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-7-A-1	0.61	0.00	0.10	0.41	0.00	0.90	0.00	0.00	0.00	0.00	0.00		
-7-A-2	0.41	0.00	0.10	0.31	0.00	0.80	0.00	0.00	0.00	0.00	0.00		
MFR-8-A-1	10.1	0.51	1.63	0.83	1.21	8.82	0.33	1.10	1.81	0.05	0.04		
-8-A-2	11.8	0.10	1.92	1.01	1.40	10.6	0.52	0.30	1.33	0.03	0.01		
-8-B-1	11.0	0.40	1.36	1.15	1.34	10.0	0.34	0.44	1.15	0.43	0.00		
-8-B-2	10.2	0.20	1.13	0.81	1.10	9.34	0.35	0.36	0.80	0.00	0.00		
-8-C-1	11.1	0.13	1.21	1.23	1.08	10.1	0.41	0.28	1.23	0.00	0.00		
-8-C-2	11.0	0.21	1.23	1.01	1.44	9.93	0.42	0.20	1.43	0.01	0.02		
MFR-9-A-1	3.41	0.00	0.51	0.91	1.47	1.58	0.00	1.54	1.01	0.00	0.00		
-9-A-2	3.61	0.00	0.54	0.81	1.56	1.66	0.00	1.39	1.13	0.19	0.00		
-9-B-1	3.22	0.00	0.48	0.78	1.61	1.49	0.00	0.63	1.23	0.00	0.00		
-9-B-2	3.38	0.00	0.41	0.59	1.53	1.34	0.00	0.21	1.09	0.00	0.00		
-9-C-1	3.15	0.00	0.51	0.69	1.58	1.71	0.00	0.93	0.98	0.00	0.00		
-9-C-2	3.09	0.00	0.38	0.71	1.52	1.32	0.00	0.34	0.89	0.00	0.00		
MFR-10-A-1	6.14	0.00	0.00	0.34	0.10	0.10	0.00	0.00	16.3	0.00	0.00		
-10-A-2	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.8	0.00	0.00		
-10-B-1	5.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.1	0.00	0.00		
-10-B-2	3.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.1	0.00	0.00		
-10-C-1	4.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.2	0.00	0.00		
-10-C-2	2.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.28	0.00	0.00		
MFR-11	0.67	0.00	0.00	0.10	0.21	0.21	0.24	0.50	1.70	0.00	0.00		
MFR-12	2.64	0.00	0.00	0.21	0.24	0.24	0.00	0.00	0.81	0.00	0.00		

TABLE A-1 CONCLUDED

Sample	Acid Dissolution (ADM) Analysis Using ADM/ICP (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Hg	Ni	Pb	Si	Sn	Ti		
MFR-13	2.81	0.21	0.89	0.11	0.81	0.32	0.00	0.00	7.31	0.00	0.00		
MFR-14	3.70	0.00	10.2	1.00	1.10	1.40	1.80	0.00	1.20	0.00	0.00		
MFR-15	5.12	0.00	0.00	0.41	0.42	0.00	0.32	0.53	1.12	0.00	0.09		
MFR-18-A-1	5.31	0.30	0.50	0.39	0.94	0.34	0.88	0.37	0.88	0.00	0.00		
-18-A-2	1.63	0.00	0.38	0.31	0.00	0.00	1.01	0.00	0.90	0.00	0.00		
-18-B-1	2.10	0.10	0.59	0.25	0.21	0.00	0.12	0.72	0.83	0.00	0.00		
-18-B-2	1.13	0.00	0.00	0.19	0.00	0.00	0.51	0.31	0.75	0.00	0.00		
-18-C-1	1.33	0.00	0.31	0.21	0.31	0.12	0.31	0.59	0.99	0.00	0.00		
-18-C-2	1.12	0.00	0.12	0.14	0.09	0.09	0.21	0.43	0.74	0.00	0.00		
MFR-19	7.51	0.00	1.23	0.19	0.32	8.45	0.00	0.00	1.54	0.31	0.00		
MFR-20	15.2	0.95	0.81	1.54	0.00	0.51	0.00	0.00	1.13	0.00	0.00		
MFR-21	8.53	0.20	0.42	0.31	0.45	0.21	0.10	0.00	0.10	0.00	0.00		
MFR-22-A-1	8.57	0.00	0.55	0.46	0.57	2.08	0.36	0.00	0.89	0.00	0.00		
-22-A-2	7.18	0.00	0.47	0.29	0.41	1.05	0.16	0.00	0.15	0.00	0.00		
-22-B-1	7.99	0.00	0.49	0.39	0.42	1.53	0.30	0.00	0.53	0.00	0.00		
-22-B-2	6.85	0.00	0.41	0.31	0.31	1.03	0.14	0.00	0.14	0.00	0.00		
-22-C-1	7.00	0.00	0.51	0.50	0.40	0.98	0.28	0.00	0.49	0.00	0.00		
-22-C-2	6.54	0.00	0.39	0.38	0.35	0.85	0.17	0.00	0.17	0.00	0.00		
-22-D-1	6.90	0.00	0.53	0.49	0.31	1.15	0.18	0.00	0.51	0.00	0.00		
-22-D-2	6.81	0.00	0.38	0.29	0.28	0.81	0.19	0.00	0.19	0.00	0.00		

TABLE A-2

Sample	Atomic Emission Spectrometric Analysis (A/E35U-3) (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-1-A-1	25	0.0	0.0	0.0	0.0	1.0	0.0	0.0	7.0	4.5	0.0		
-1-A-2	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	5.0	0.0		
-1-B-1	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	5.0	0.0		
-1-B-2	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	5.5	0.0		
-1-C-1	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	5.0	0.0		
-1-C-2	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	5.0	0.0		
-1-D-1	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	5.0	0.0		
-1-D-2	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	6.0	0.0		
MFR-2-A-1	62	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	6.5	0.0		
-2-A-2	40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	5.5	0.0		
-2-B-1	40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	5.0	0.0		
-2-B-2	41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	6.0	0.0		
-2-C-1	44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	6.0	0.0		
-2-C-2	37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	6.5	0.0		
MFR-3-A-1	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16	6.0	0.0		
-3-A-2	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16	5.5	0.0		
-3-B-1	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16	5.5	0.0		
-3-B-2	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16	5.5	0.0		
-3-C-1	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16	6.0	0.0		
-3-C-2	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16	6.5	0.0		
MFR-4-A-1	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	0.0		
-4-A-2	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	0.0		
-4-B-1	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	0.0		
-4-B-2	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	0.0		

TABLE A-2 CONT'T

Sample	Atomic Emission Spectrometric Analysis (A/E35U-3) (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-4-C-1	-	-	-	-	-	-	-	-	-	-	-		
-4-C-2	1.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0		
-4-D-1	2.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	7.4	0.0		
-4-D-2	0.3	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	7.5	0.0		
MFR-5-A-1	94	0.0	16	4.9	49	483	1.0	89	34	2.7	0.0		
-5-A-2	89	0.0	14	4.9	47	456	1.4	84	33	2.1	0.0		
-5-B-1	93	0.0	15	5.3	49	482	1.3	87	35	3.7	0.0		
-5-B-2	95	0.0	14	4.8	49	500	0.7	88	35	3.9	0.0		
-5-C-1	94	0.0	15	4.9	49	499	1.0	88	35	2.8	0.0		
-5-C-2	97	0.0	15	5.2	51	533	1.2	90	36	4.0	0.0		
-5-D-1	100	0.0	15	5.0	49	475	0.5	90	32	3.5	0.0		
-5-D-2	104	0.0	15	5.0	50	490	0.5	92	34	4.0	0.0		
MFR-6-A-1	11	1.0	0.0	0.0	4.0	4.0	0.5	0.0	7.0	8.0	1.5		
-6-A-2	10	1.0	0.0	0.5	4.0	4.0	1.0	0.0	6.0	7.5	1.0		
-6-B-1	10	1.0	0.0	0.5	4.0	4.0	1.0	0.0	6.0	8.5	1.0		
-6-B-2	10	1.0	0.0	1.0	4.0	4.0	1.0	0.0	6.0	8.0	1.0		
-6-C-1	10	1.0	0.0	0.5	4.5	4.0	0.5	0.0	6.0	7.5	1.0		
-6-C-2	10	1.0	0.0	1.0	4.0	4.0	1.0	0.0	6.0	8.5	1.0		
-6-D-1	10	1.0	0.0	1.0	4.0	4.0	1.0	0.0	7.0	7.5	1.0		
-6-D-2	10	1.0	0.0	0.5	4.0	4.0	1.0	0.0	6.0	8.0	1.0		
MFR-7-A-1	2.0	0.0	0.0	0.5	0.0	2.0	0.0	0.0	0.0	6.0	1.0		
-7-A-2	1.5	0.0	0.0	0.5	0.0	2.0	0.0	0.0	0.0	7.0	1.5		
-7-B-1	2.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	7.0	1.5		
-7-B-2	1.5	0.0	0.0	0.5	0.0	2.0	0.0	0.0	0.0	6.5	1.0		

TABLE A-2 CONT'T

Sample	Atomic Emission Spectrometric Analysis (A/E35U-3) (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-7-C-1	2.0	0.0	0.0	0.5	0.5	2.0	0.5	0.0	0.0	6.5	1.0		
-7-C-2	2.0	0.0	0.0	1.0	0.0	2.0	0.5	0.0	0.0	7.0	1.0		
MFR-8-A-1	27	1.0	0.0	2.0	4.0	27	1.5	1.0	5.5	6.0	1.0		
-8-A-2	21	1.0	0.0	2.0	4.0	28	1.5	0.0	2.5	7.0	1.0		
-8-B-1	27	1.0	0.0	1.5	4.0	28	1.5	0.0	3.0	6.0	1.0		
-8-B-2	25	1.0	0.0	2.0	4.0	25	1.0	0.0	3.0	5.5	1.0		
-8-C-1	26	1.0	0.0	2.0	4.0	26	1.0	0.0	4.0	7.0	1.0		
-8-C-2	26	1.0	0.0	1.5	4.0	28	1.0	0.0	4.0	6.5	1.0		
MFR-9-A-1	5.6	0.0	0.0	0.6	2.1	3.1	0.0	0.0	1.1	7.3	0.8		
-9A-2	5.7	0.0	0.0	0.6	2.1	2.8	0.0	0.0	0.8	7.4	0.8		
-9-B-1	5.3	0.0	0.0	0.5	2.0	2.9	0.0	0.0	0.7	7.1	0.8		
-9-B-2	5.2	0.0	0.0	0.6	2.1	2.8	0.0	0.0	0.6	7.5	0.7		
-9-C-1	5.5	0.0	0.0	0.4	2.1	2.9	0.0	0.0	0.7	7.5	0.8		
-9-C-2	5.0	0.0	0.0	0.4	1.9	2.6	0.0	0.0	0.7	7.1	0.5		
MFR-10-A-1	4	0	0	0	0	0	0	0	22	-	0		
-10-A-2	2	0	0	0	0	0	0	0	20	-	0		
-10-B-1	3	0	0	0	0	0	0	0	21	-	1		
-10-B-2	3	0	0	0	0	0	0	0	23	-	0		
-10-C-1	3	0	0	0	0	0	0	0	21	-	0		
-10-C-2	3	0	0	0	0	0	0	0	22	-	0		
MFR-11	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	5.7	7.6	0.8		
MFR-12	3.0	0.3	0.0	0.0	0.2	0.0	0.0	0.0	11.8	7.7	0.9		

TABLE A-2 CONT'T

Sample	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
	Atomic Emission Spectrometric Analysis (A/E35U-3) (Values in ppm)												
MFR-13	2	0	0	0	3	0	0	9	5	-	0		
MFR-14	5	0	11	0	1	1	2	0	1	-	0		
MFR-15	3	0	0	0	0	0	0	0	1	-	0		
MFR-16	28	0	0	0	10	0	0	24	2	12	0		
MFR-17	7	0	0	0	28	0	0	0	3	10	1		
MFR-18-A-1	3.2	0.0	1.2	0.0	0.2	0.0	0.0	0.1	1.1	5.8	0.0		
-18-A-2	1.8	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.9	5.5	0.0		
-18-B-1	2.4	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0		
-18-B-2	1.4	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.0	5.9	0.0		
-18-C-1	1.8	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	6.2	0.0		
-18-C-2	1.6	0.0	1.2	0.0	0.0	0.0	0.0	0.0	1.2	6.4	0.0		
MFR-19	20	0.0	0.0	0.6	0.2	26	0.4	0.0	26	11	0.7		
MFR-20	48	2	0	3	0	0	0	3	0	11	1		
MFR-21	16.2	0.4	0.0	0.2	0.8	0.0	0.8	0.6	1.0	7.4	0.5		
MFR-22-A-1	17	0.2	0.0	0.0	0.8	3.6	0.0	0.0	1.1	5.1	0.4		
-22-A-2	15	0.0	0.0	0.0	0.6	1.8	0.0	0.0	1.0	5.8	0.5		
-22-B-1	15	0.0	0.0	0.0	0.6	2.3	0.0	1.5	0.0	4.9	0.3		
-22-B-2	15	0.0	0.0	0.0	0.8	1.6	0.2	0.0	0.9	5.5	0.4		

TABLE A-2 CONCLUDED

Sample	Atomic Emission Spectrometric Analysis (A/E35U-3) (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-22-C-1	14	0.0	0.0	0.0	0.6	1.5	0.0	0.0	0.8	5.3	0.3		
-22-C-2	14	0.0	0.0	0.3	0.5	1.2	0.5	0.2	1.2	6.3	0.5		
-22-D-1	14	0.0	0.0	0.0	0.7	1.2	0.3	0.0	1.1	6.5	0.7		
-22-D-2	13	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.8	6.0	0.6		

TABLE A-3

Sample	Atomic Emission Spectrometric Analysis (J.A. 44181) (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-1-A-1	25	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0		
-1-A-2	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	0.0		
-1-B-1	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0		
-1-B-2	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0		
-1-C-1	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0		
-1-C-2	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0		
-1-D-1	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0		
-1-D-2	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0		
MFR-2-A-1	93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.9	0.0		
-2-A-2	54	0.0	0.0	0.0	0.0	0.0	0.0	4.8	3.1	2.8	0.0		
-2-B-1	62	0.0	0.0	0.0	0.0	0.0	0.0	4.6	2.4	2.4	0.0		
-2-B-2	51	0.0	0.0	0.0	0.0	0.0	0.0	3.6	3.5	0.0	0.0		
-2-C-1	62	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	2.5	0.0		
-2-C-2	51	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.9	4.3	0.0		
MFR-3-A-1	32	0.2	0.0	0.0	0.0	0.3	0.0	0.0	12	0.0	0.0		
-3-A-2	27	0.4	0.0	0.0	0.0	0.3	0.0	0.0	10	0.0	0.0		
-3-B-1	28	0.2	0.0	0.0	0.0	0.3	0.0	0.0	12	0.0	0.0		
-3-B-2	26	0.0	0.0	0.1	0.0	0.2	0.0	0.0	12	0.0	0.0		
-3-C-1	28	0.1	0.0	0.1	0.0	0.3	0.0	0.0	13	0.0	0.0		
-3-C-2	26	0.2	0.0	0.1	0.0	0.2	0.0	0.0	12	0.0	0.0		
MFR-4-A-1	17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-4-A-2	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-4-B-1	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-4-B-2	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

TABLE A-3 CONT'D

Sample	Atomic Emission Spectrometric Analysis (J.A. 44181) (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-4-C-1	ND	-	-	-	-	-	-	-	-	-	-		
-4-C-2	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-4-D-1	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-4-D-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
MFR-5-A-1	110	0.0	16	2.3	61	757	0.0	73	40	0.0	0.0		
-5-A-2	108	0.0	15	2.0	57	670	0.0	82	40	0.0	0.0		
-5-B-1	121	0.0	16	1.8	61	853	0.0	84	40	0.0	0.0		
-5-B-2	110	0.0	16	1.6	61	720	0.0	82	40	0.0	0.0		
-5-C-1	119	0.0	16	2.3	63	833	0.0	72	40	0.0	0.0		
-5-C-2	107	0.0	14	1.9	60	832	0.0	72	40	0.0	0.0		
-5-D-1	100	0.0	15	1.7	56	674	0.0	71	40	0.0	0.0		
-5-D-2	95	0.0	13	1.3	56	664	0.0	59	37	0.0	0.0		
MFR-6-A-1	13	0.4	0.0	0.6	2.3	5.6	0.0	0.0	3.6	0.0	0.0		
-6-A-2	11	0.2	0.0	0.6	2.7	5.4	0.0	0.0	3.6	0.0	0.0		
-6-B-1	12	0.3	0.0	0.6	2.8	6.0	0.0	0.0	4.4	0.0	0.0		
-6-B-2	9.9	0.0	0.0	0.6	2.4	4.7	0.0	0.0	4.0	0.0	0.0		
-6-C-1	11	0.2	0.0	0.5	2.6	5.4	0.0	0.0	3.8	0.0	0.0		
-6-C-2	10	0.1	0.0	0.3	2.5	5.2	0.0	0.0	3.1	0.0	0.0		
-6-D-1	10	0.1	0.0	0.4	2.6	5.1	0.0	0.0	3.9	0.0	0.0		
-6-D-2	10	0.0	0.0	0.2	2.0	3.9	0.0	0.0	3.1	0.0	0.0		
MFR-7-A-1	0.8	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0		
-7-A-2	0.3	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0		
-7-B-1	0.5	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0		
-7-B-2	0.4	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0		

TABLE A-3 CONT'D

Sample	Atomic Emission Spectrometric Analysis (J.A. 44181) (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Hg	Ni	Pb	Si	Sn	Ti		
MFR-8-A-1	28	0.4	0.0	1.0	2.7	29	0.0	-	1.6	0.0			
-8-A-2	22	0.3	0.0	0.0	1.5	23	0.0	-	0.0	0.0			
-8-13-1	27	0.5	0.0	0.8	2.4	28	0.0	-	1.1	0.0			
-8-B-2	26	0.5	0.0	0.2	2.1	27	0.0	-	0.8	0.0			
-8-C-1	26	0.4	0.0	0.5	2.1	26	0.0	-	0.7	0.0			
-8-C-2	23	0.3	0.0	0.0	1.8	25	0.0	-	0.7	0.0			
MFR-9-A-1	6.2	0.0	0.0	0.0	1.6	4.5	0.0	-	0.8	-	0.0		
-9-A-2	4.8	0.0	0.0	0.0	1.2	3.9	0.0	-	0.0	-	0.0		
-9-B-1	6.1	0.0	0.0	0.0	1.4	5.2	0.0	-	2.2	-	0.0		
-9-B-2	3.5	0.0	0.0	0.0	0.8	3.1	0.0	-	0.0	-	0.0		
-9-C-1	4.1	0.0	0.0	0.0	1.1	2.8	0.0	-	0.0	-	0.0		
-9-C-2	4.5	0.0	0.0	0.0	1.4	3.2	0.0	-	0.0	-	0.0		
MFR-10-A-1	6.1	0.0	0.0	0.3	0.1	0.1	0.0	0.0	16	0.0	0.0		
-10-A-2	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12	0.0	0.0		
-10-B-1	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11	0.0	0.0		
-10-B-2	4.2	0.0	0.0	0.6	0.1	0.0	0.0	0.0	17	0.0	0.0		
-10-C-1	1.3	-	-	-	-	-	-	-	-	-	-		
-10-C-2	1.2	-	-	-	-	-	-	-	-	-	-		
MFR-11	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
MFR-12	3.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
MFR-13	2.4	0.0	0.0	0.0	1.8	0.0	0.0	15	20	0.0	0.0		

TABLE A-3 CONT'd

Sample	Atomic Emission Spectrometric Analysis (J.A. 44181) (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-14	6.2	0.0	11	1.4	1.2	0.7	0.0	0.0	0.0	0.0	0.0		
MFR-15	7.7	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
MFR-16	23	0.0	0.0	0.3	25	0.0	0.0	24	0.0	3.7	0.0		
MFR-17	4.7	0.0	0.0	0.3	0.0	22	0.0	0.0	0.0	0.0	0.0		
MFR-18-A-1	8.6	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-18-A-2	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-18-B-1	4.7	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-18-B-2	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-18-C-1	3.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
-18-C-2	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
MFR-19	17	0.0	0.0	0.0	0.0	23	0.0	0.0	0.0	0.0	0.0		
MFR-20	33	0.5	0.0	1.8	0.0	0.4	0.0	0.0	0.0	0.0	0.0		
MFR-21	20	0.0	0.0	0.0	0.1	0.9	0.0	0.0	0.0	0.0	0.0		
MFR-22-A-1	23	0.0	0.0	0.1	0.2	5.1	0.0	0.0	0.0	0.0	0.0		
-22-A-2	19	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0		
-22-B-1	19	0.0	0.0	0.2	0.5	3.6	0.0	0.0	0.5	0.0	0.0		
-22-B-2	17	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0		
-22-C-1	16	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0		
-22-C-2	18	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0		

TABLE A-3 CONCLUDED

Sample	Atomic Emission Spectrometric Analysis (J.A. 44181) (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-22-D-1	16	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0		
-22-D-2	16	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0		

TABLE A-4

Sample	Inductively Coupled Plasma (ICP) Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-1-A-1	9.28	0.00	0.15	0.00	0.12	0.00	0.03	0.00	3.13	0.00	0.00		
-1-A-2	6.27	0.00	0.16	0.00	0.11	0.00	0.00	0.00	2.59	0.00	0.00		
-1-B-1	6.91	0.00	0.14	0.00	0.11	0.00	0.00	0.00	2.79	0.00	0.00		
-1-B-2	5.92	0.00	0.18	0.00	0.12	0.00	0.04	0.00	2.34	0.00	0.00		
-1-C-1	6.20	0.00	0.19	0.00	0.12	0.00	0.05	0.00	2.36	0.00	0.00		
-1-C-2	6.07	0.00	0.24	0.00	0.12	0.00	0.07	0.00	2.60	0.00	0.00		
-1-D-1	6.02	0.00	0.22	0.00	0.12	0.00	0.06	0.00	2.96	0.00	0.00		
-1-D-2	5.70	0.00	0.22	0.02	0.13	0.00	0.04	0.00	2.33	0.00	0.00		
MFR-2-A-1	32.7	0.00	0.15	0.02	[illegible]	0.00	0.03	0.00	1.75	0.00	0.00		
-2-A-2	21.8	0.00	0.19	0.01	0.13	0.00	0.06	0.00	2.08	0.00	0.00		
-2-B-1	23.9	0.00	0.23	0.01	0.12	0.00	0.04	0.00	2.40	0.00	0.00		
-2-B-2	18.2	0.00	0.19	0.00	0.16	0.00	0.04	0.00	2.18	0.00	0.00		
-2-C-1	20.1	0.00	0.24	0.01	0.15	0.00	0.04	0.00	2.04	0.00	0.00		
-2-C-2	18.2	0.00	0.23	0.02	0.15	0.00	0.11	0.00	2.19	0.00	0.00		
MFR-3-A-1	11.1	0.00	0.30	0.30	0.26	0.06	0.01	0.00	8.87	0.00	0.00		
-3-A-2	10.4	0.00	0.34	0.31	0.29	0.07	0.03	0.00	8.58	0.00	0.00		
-3-B-1	10.8	0.00	0.38	0.31	0.28	0.08	0.02	0.00	9.41	0.00	0.00		
-3-B-2	10.2	0.00	0.31	0.27	0.27	0.04	0.03	0.00	8.89	0.00	0.00		
-3-C-1	10.6	0.00	0.40	0.29	0.27	0.06	0.01	0.00	9.09	0.00	0.00		
-3-C-2	10.1	0.00	0.26	0.27	0.28	0.07	0.00	0.00	8.70	0.00	0.00		
MFR-4-A-1	6.43	0.00	0.34	0.11	0.00	0.00	0.00	0.31	0.32	0.00	0.00		
-4-A-2	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-B-1	2.25	0.00	0.22	0.28	0.00	0.00	0.00	0.05	0.00	0.00	0.00		
-4-B-2	0.35	0.00	0.00	0.01	0.00	0.00	0.00	0.08	0.00	0.00	0.00		

TABLE A-4 CONT'D

Sample	Inductively Coupled Plasma (ICP) Spectrometric Analysis (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-4-C-1	-	-	-	-	-	-	-	-	-	-	-		
-4-C-2	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00		
-4-D-1	1.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
-4-D-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00		
MFR-5-A-1	96.1	0.00	10.8	3.90	37.5	459	0.98	75.6	34.2	3.16	0.00		
-5-A-2	81.3	0.00	8.65	3.33	32.4	420	0.84	67.8	28.5	2.41	0.00		
-5-B-1	91.2	0.00	9.88	3.73	36.0	452	0.92	73.5	31.3	2.84	0.00		
-5-B-2	88.8	0.00	9.45	3.68	35.5	449	0.88	73.0	31.5	2.82	0.00		
-5-C-1	85.7	0.00	9.03	3.48	34.3	436	0.89	70.9	30.6	2.86	0.00		
-5-C-2	85.4	0.00	9.03	3.53	34.0	434	0.86	70.5	30.5	2.72	0.00		
-5-D-1	86.2	0.00	9.13	3.55	34.5	439	0.87	71.8	30.4	2.79	0.00		
-5-D-2	87.0	0.00	9.23	3.58	35.1	446	0.88	72.7	31.4	2.79	0.00		
MFR-6-A-1	6.57	0.39	1.03	0.76	2.05	2.24	0.45	0.82	5.34	0.00	0.00		
-6-A-2	4.90	0.17	0.58	0.53	1.86	1.84	0.28	0.81	4.86	0.00	0.00		
-6-B-1	5.58	0.26	0.71	0.56	1.99	1.98	0.30	0.80	5.02	0.00	0.00		
-6-B-2	4.89	0.19	0.57	0.51	1.87	1.86	0.21	0.79	4.93	0.00	0.00		
-6-C-1	5.06	0.18	0.59	0.54	1.89	1.91	0.25	0.64	4.89	0.00	0.00		
-6-C-2	4.57	0.16	0.55	0.49	1.85	1.82	0.25	0.61	4.87	0.00	0.00		
-6-D-1	4.72	0.17	0.52	0.47	1.85	1.84	0.22	0.61	4.76	0.00	0.00		
-6-D-2	4.48	0.16	0.63	0.48	1.82	1.79	0.24	0.58	4.84	0.00	0.00		
MFR-7-A-1	0.49	0.00	0.10	0.42	0.13	1.04	0.02	0.00	0.00	0.00	0.00		
-7-A-2	0.47	0.00	0.11	0.44	0.13	0.96	0.04	0.00	0.00	0.00	0.00		
-7-B-1	0.50	0.00	0.09	0.38	0.13	0.96	0.08	0.00	0.00	0.00	0.00		
-7-B-2	0.40	0.00	0.14	0.40	0.12	0.93	0.05	0.00	0.00	0.00	0.00		

TABLE A-4 CONT'D

Sample	Inductively Coupled Plasma (ICP) Spectrometric Analysis (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-8-A-1	12.5	0.18	1.32	1.18	1.68	11.5	0.65	0.58	2.45	0.00	0.00		
-8-A-2	12.6	0.15	1.25	1.18	1.62	11.5	0.68	0.54	2.33	0.00	0.00		
-8-B-1	12.5	0.16	1.32	1.18	1.62	11.3	0.66	0.58	2.26	0.00	0.00		
-8-B-2	12.3	0.13	1.27	1.15	1.59	11.3	0.62	0.59	2.13	0.00	0.00		
-8-C-1	12.3	0.14	1.32	1.17	1.61	11.3	0.63	0.50	2.32	0.00	0.00		
-8-C-2	12.3	0.14	1.35	1.14	1.55	11.2	0.60	0.49	2.14	0.00	0.00		
MFR-9-A-1	3.61	0.00	0.36	0.88	1.58	1.70	0.13	0.16	0.16	0.00	0.00		
-9-A-2	3.29	0.00	0.42	0.93	1.66	1.68	0.50	0.93	0.30	0.27	0.00		
-9-B-1	3.21	0.02	0.64	0.93	1.64	1.64	0.18	0.00	0.52	0.00	0.00		
-9-B-2	3.41	0.05	0.60	1.01	1.59	1.74	0.17	0.00	0.43	0.00	0.00		
-9-C-1	3.39	0.02	0.49	0.98	1.59	1.76	0.21	0.00	0.38	0.00	0.00		
-9-C-2	3.31	0.02	0.41	0.94	1.55	1.70	0.17	0.00	0.58	0.00	0.00		
MFR-10-A-1	2.69	0.35	0.32	0.28	0.70	0.41	0.20	0.00	17.6	0.00	0.00		
-10-A-2	1.91	0.01	0.34	0.23	0.64	0.33	0.16	0.00	16.3	0.00	0.00		
-10-B-1	2.40	0.12	0.30	0.27	0.76	0.38	0.20	0.00	17.4	0.00	0.00		
-10-B-2	1.61	0.09	0.30	0.22	0.74	0.30	0.22	0.00	16.5	0.00	0.00		
-10-C-1	1.97	0.09	0.48	0.26	0.79	0.36	0.22	0.00	17.4	0.00	0.00		
-10-C-2	1.72	0.09	0.41	0.22	0.76	0.32	0.16	0.00	17.5	0.00	0.00		
MFR-11	0.13	0.00	0.14	0.14	0.26	0.06	0.17	0.00	0.17	0.00	0.00		
MFR-12	1.39	0.50	0.30	0.27	0.27	0.08	0.01	0.50	0.17	0.50	0.50		
MFR-13	1.39	0.00	0.49	0.12	1.53	0.23	0.10	5.59	3.22	0.11	0.00		

TABLE A-4 CONT'D

Sample	Inductively Coupled Plasma (ICP) Spectrometric Analysis (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-14	2.91	0.08	8.96	0.99	1.18	0.70	1.44	0.00	0.39	0.00	0.00		
MFR-15	3.91	0.34	0.29	0.67	0.34	0.12	0.17	0.21	0.62	0.00	0.03		
MFR-16	8.80	0.50	0.45	0.47	8.02	0.08	0.38	6.82	0.36	0.36	0.09		
MFR-17	3.19	0.12	0.69	0.49	0.18	10.8	0.16	0.00	1.45	0.00	0.13		
MFR-18-A-1	2.30	0.30	0.09	0.34	0.41	0.40	0.05	0.05	1.33	0.00	0.00		
-18-A-2	0.80	0.09	0.00	0.13	0.16	0.08	0.00	0.00	0.80	0.00	0.00		
-18-B-1	1.38	0.17	0.34	0.28	0.14	0.09	0.00	0.65	0.80	0.00	0.00		
-18-B-2	0.79	0.07	0.01	0.15	0.01	0.06	0.00	0.00	0.62	0.00	0.00		
-18-C-1	0.91	0.10	0.22	0.17	0.00	0.06	0.00	0.00	0.72	0.00	0.00		
-18-C-2	0.70	0.06	0.06	0.14	0.02	0.01	0.00	0.00	0.61	0.00	0.00		
MFR-19	6.66	0.00	0.86	0.14	0.11	7.55	0.00	0.00	0.93	0.34	0.01		
MFR-20	12.84	0.63	0.44	1.15	0.02	0.13	0.00	0.00	0.46	0.14	0.01		
MFR-21	9.24	0.34	0.27	0.38	0.69	0.33	0.24	0.62	0.72	0.00	0.01		
MFR-22-A-1	8.56	0.33	0.25	0.48	0.41	1.78	0.29	0.84	1.08	0.00	0.00		
-22-A-2	7.36	0.21	0.22	0.39	0.41	1.13	0.19	0.51	0.80	0.00	0.00		
-22-B-1	7.73	0.22	0.30	0.43	0.42	0.13	0.16	0.63	0.91	0.21	0.00		
-22-B-2	6.88	0.18	0.10	0.37	0.35	0.97	0.18	0.54	0.73	0.00	0.00		
-22-C-1	6.84	0.17	0.22	0.36	0.41	0.98	0.18	0.97	0.70	0.00	0.00		
-22-C-2	6.54	0.15	0.07	0.32	0.38	0.87	0.11	0.92	0.65	0.00	0.00		

TABLE A-4 CONCLUDED

Sample	Inductively Coupled Plasma (ICP) Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-22-D-1	6.86	0.18	0.31	0.41	0.39	0.97	0.15	1.05	0.89	0.20	0.00		
MFR-22-D-2	6.63	0.16	0.20	0.35	0.40	0.86	0.11	1.06	0.76	0.00	0.00		

TABLE A-5

	Inductively Coupled Plasma (PST/ICP) Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-1-A-1	2.35	0.01	0.10	0.09	0.05	0.00	0.00	1.43	2.94	0.28	0.02		
-1-A-2	3.02	0.00	0.11	0.07	0.01	0.00	0.00	1.10	3.43	0.42	0.01		
-1-B-1	2.97	0.00	0.09	0.06	0.03	0.00	0.00	0.81	3.43	0.42	0.00		
-1-B-2	2.98	0.00	0.09	0.06	0.04	0.00	0.00	1.02	3.18	0.63	0.01		
-1-C-1	3.09	0.00	0.13	0.06	0.02	0.00	0.00	0.99	3.44	0.42	0.00		
-1-C-2	3.11	0.00	0.10	0.05	0.02	0.00	0.00	0.94	3.40	0.49	0.00		
MFR-2-A-1	9.46	0.00	0.10	0.07	0.00	0.00	0.00	1.15	2.28	0.56	0.00		
-2-A-2	9.32	0.00	0.03	0.07	0.00	0.00	0.00	0.69	2.72	0.42	0.00		
-2-B-1	10.5	0.00	0.08	0.07	0.00	0.00	0.00	0.82	2.92	0.28	0.00		
-2-B-2	9.42	0.00	0.05	0.04	0.00	0.00	0.00	0.68	2.80	0.42	0.00		
-2-C-1	9.52	0.00	0.13	0.09	0.10	0.00	0.00	0.83	2.84	0.56	0.01		
-2-C-2	10.3	0.00	0.14	0.08	0.02	0.00	0.00	0.71	2.92	0.42	0.00		
MFR-3-A-1	6.93	0.24	0.24	0.33	0.14	0.04	0.00	1.20	9.29	0.28	0.00		
-3-A-2	6.30	0.01	0.19	0.31	0.10	0.03	0.00	0.91	9.06	0.28	0.00		
-3-B-1	6.45	0.00	0.18	0.30	0.12	0.03	0.00	0.79	9.11	0.35	0.00		
-3-B-2	5.97	0.01	0.13	0.28	0.12	0.02	0.00	1.21	8.74	0.42	0.00		
MFR-4-A-1	0.16	0.00	0.08	0.18	0.00	0.00	0.00	1.10	0.16	0.35	0.00		
-4-A-2	0.17	0.00	0.03	0.18	0.00	0.00	0.00	1.24	0.20	0.42	0.00		
-4-B-1	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.90	0.17	0.28	0.00		
-4-B-2	0.17	0.00	0.02	0.18	0.00	0.00	0.00	1.09	0.17	0.21	0.00		
-4-C-1	-	-	-	-	-	-	-	-	-	-	-		
-4-C-2	-	-	-	-	-	-	-	-	-	-	-		
-4-D-1	0.20	0.00	0.04	0.17	0.03	0.00	0.00	0.94	0.20	0.42	0.00		
-4-D-2	0.03	0.00	0.01	0.14	0.00	0.00	0.00	0.97	0.09	0.28	0.00		

TABLE A-5 CONT'D

	Inductively Coupled Plasma (PST/ICP) Spectrometric Analysis (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-5-A-1	69.1	0.07	7.17	5.70	29.9	448	0.00	60.9	29.9	8.27	0.13		
-5-A-2	68.8	0.07	7.15	5.67	29.0	443	0.00	60.6	29.1	8.13	0.11		
-5-B-1	70.2	0.06	7.39	5.78	29.6	452	0.00	62.1	29.9	8.42	0.11		
-5-B-2	70.5	0.05	7.25	5.80	29.5	453	0.00	61.9	29.4	8.27	0.10		
-5-C-1	71.8	0.06	7.37	5.87	29.4	460	0.00	63.4	30.1	8.91	0.11		
-5-C-2	72.5	0.06	7.58	5.98	30.0	466	0.00	63.8	30.4	8.77	0.11		
MFR-6-A-1	4.74	0.44	0.77	0.66	2.25	2.89	0.00	1.83	5.72	0.84	0.01		
-6-A-2	4.77	0.40	0.72	0.65	2.37	2.58	0.00	1.67	5.93	0.84	0.00		
-6-B-1	5.15	0.44	0.79	0.69	2.43	2.71	0.00	1.98	6.28	0.98	0.00		
-6-B-2	4.95	0.40	0.76	0.68	2.36	2.51	0.00	1.76	6.26	0.98	0.01		
-6-C-1	5.16	0.34	0.86	0.74	2.50	2.67	0.00	1.84	6.46	0.91	0.01		
-6-C-2	4.72	0.38	0.73	0.67	2.34	2.44	0.00	1.83	6.22	0.91	0.01		
MFR-7-A-1	0.75	0.03	0.28	0.68	0.23	1.36	0.00	0.96	0.33	0.79	0.00		
-7-A-2	0.71	0.03	0.29	0.67	0.20	1.31	0.00	1.26	0.35	0.91	0.00		
-7-B-1	0.76	0.12	0.33	0.68	0.30	1.28	0.00	1.16	0.43	0.85	0.10		
-7-B-2	0.63	0.05	0.27	0.57	0.22	1.07	0.00	0.78	0.34	0.73	0.03		
-7-C-1	0.62	0.04	0.24	0.58	0.18	1.07	0.00	0.68	0.30	0.67	0.02		
-7-C-2	0.61	0.04	0.25	0.56	0.20	1.07	0.00	0.86	0.36	0.85	0.01		
MFR-8-A-1	12.5	0.33	1.43	1.36	1.79	11.5	0.00	1.71	2.68	0.97	0.05		
-8-A-2	12.2	0.31	1.36	1.32	1.64	11.5	0.00	1.80	2.57	1.16	0.05		
-8-B-1	11.8	0.29	1.36	1.25	1.61	11.2	0.00	1.51	2.51	0.97	0.04		
-8-B-2	13.1	0.33	1.47	1.38	1.73	12.2	0.00	2.06	2.76	1.34	0.05		

TABLE A-5 CONCLUDED

	Inductively Coupled Plasma (PST/ICP) Spectrometric Analysis (Values in ppm)										
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
MFR-9-A-1	3.26	0.06	0.30	0.84	1.33	1.72	0.00	1.18	0.67	0.61	0.00
-9-B-2	3.20	0.06	0.28	0.84	1.36	1.64	0.00	1.25	0.69	0.79	0.00
MFR-10-A-1	2.11	0.15	0.21	0.29	0.49	0.37	0.00	1.58	16.8	0.61	0.00
-10-B-2	1.65	0.11	0.12	0.24	0.83	0.28	0.00	1.44	15.9	0.55	0.00
MFR-18-A-1	0.81	0.14	0.12	0.26	0.14	0.15	0.00	1.52	0.81	0.43	0.00
-18-A-2	0.70	0.11	0.10	0.24	0.05	0.09	0.00	1.14	0.61	0.37	0.00

TABLE A-6

Sample	Atomic Absorption Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-1-A-1	7.5												
-1-A-2	5.2												
-1-B-1	5.9												
-1-B-2	5.5												
-1-C-1	5.6												
-1-C-2	5.2												
-1-D-1	5.4												
-1-D-2	5.3												
MFR-2-A-1	15												
-2-A-2	12												
-2-B-1	14												
-2-B-2	13												
-2-C-1	13												
-2-C-2	13												
MFR-3-A-1	9.0												
-3-A-2	8.4												
-3-B-1	8.7												
-3-B-2	8.2												
-3-C-1	8.4												
-3-C-2	8.2												
MFR-4-A-1	4.0												
-4-A-2	1.6												
-4-B-1	2.5												
-4-B-2	1.5												

TABLE A-6 CONT'd

Sample	Atomic Absorption Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-4-C-2	1.4												
MFR-5-A-1	89												
-5-A-2	92												
-5-B-1	88												
-5-B-2	89												
-5-C-1	88												
-5-C-2	87												
-5-D-1	90												
-5-D-2	89												
MFR-6-A-1	5.1												
-6-A-2	4.1												
-6-B-1	4.3												
-6-B-2	3.7												
-6-C-1	4.0												
-6-C-2	3.7												
-6-D-1	3.7												
-6-D-2	3.7												
MFR-7-A-1	0.6												
-7-A-2	0.6												
MFR-8-A-1	11												
-A-2	11												
-B-1	10												
-B-2	9.9												

TABLE A-6 CONT'D

Sample	Atomic Absorption Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-8-C-1	11												
-C-2	10												
MFR-9-A-1	2.2												
A-2	1.9												
MFR-10-A-1	1.6												
-10-A-2	1.2												
-10-B-1	1.4												
-10-B-2	1.4												
-10-C-1	1.3												
-10-C-2	1.2												
MFR-11	0.0												
MFR-12	1.9												
MFR-13	2.0												
MFR-14	0.8												
MFR-15	1.2												
MFR-16	-												
MFR-17	-												

TABLE A-6 CONCLUDED

Sample	Atomic Absorption Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-18-A-1	1.9												
-18-A-2	0.7												
-18-B-1	0.9												
-18-B-2	0.7												
-18-C-1	0.6												
-18-C-2	0.5												
MFR-19	4.6												
MFR-20	7.2												
MFR-21	4.0												
MFR-22-A-1	6.2												
-22-A-2	5.1												
-22-B-1	5.0												
-22-B-2	5.0												
-22-C-1	5.0												
-22-C-2	5.0												
-22-D-1	5.2												
-22-D-2	4.9												

TABLE A-7

Sample	Portable Wear Metal Analyzer (PWMA) Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-1-A-1	60	0	1	0	1	0	1	N/A	2	N/A	2		
-1-A-2	9	0	0	0	1	0	1		2		3		
MFR-2-A-1	61	0	0	0	1	0	1		2		1		
-2-A-2	34	0	1	0	0	0	0		1		4		
MFR-3-A-1	15	0	1	0	0	0	0		2		14		
-3-A-2	13	0	1	0	1	0	0		3		5		
MFR-4-A-1	40	0	3	1	1	0	1		3		1		
-4-A-2	2	0	1	0	0	0	0		0		1		
-4-B-1	13	0	1	0	1	0	0		1		1		
-4-B-2	1	0	0	0	0	0	0		1		1		
-4-C-1*	-	-	-	-	-	-	-		-		-		
-4-C-2	1	0	0	0	0	0	0		0		1		
-4-D-1	4	0	1	0	1	0	0		0		0		
-4-D-2	0	0	0	0	1	0	0		0		0		
MFR-5-A-1	54	0	13	2	20	>50	2		2		4		
-5-A-2	49	0	11	2	22	47	2		2		5		
-5-B-1	54	0	12	2	20	49	2		2		5		
-5-B-2	52	0	11	2	20	48	2		2		4		
-5-C-1	54	0	12	2	23	>50	2		3		4		
-5-C-2	52	0	11	2	21	48	2		2		4		
-5-D-1	46	0	10	1	22	49	2		2		4		
-5-D-2	43	0	10	1	21	49	1		2		2		

*Sample not obtained

TABLE A-7 CONT'D

Sample	Portable Wear Metal Analyzer (PWMA) Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-6-A-1	10	1	1	1	2	3	1	N/A	3	N/A	1		
-6-A-2	5	0	1	1	1	2	1		2		2		
-6-B-1	7	0	1	1	1	1	1		2		1		
-6-B-2	5	0	0	0	0	2	0		1		1		
-6-C-1	5	0	0	1	2	2	0		1		1		
-6-C-2	4	0	1	0	2	2	0		1		0		
-6-D-1	5	0	0	0	0	2	0		1		0		
-6-D-2	4	0	1	0	0	2	0		0		0		
MFR-7-A-1	0.8	0.0	0.3	0.[illegible]	0.6	0.9	0.4		2.3		0.0		
-7-A-2	0.7	0.0	0.5	0.4	0.6	1.0	0.2		5.6		0.0		
-7-B-1	0.7	0.0	0.2	0.4	0.4	0.9	0.2		2.1		0.2		
-7-B-2	0.6	0.0	0.2	0.6	0.6	0.8	0.2		2.0		0.2		
-7-C-1	0.7	0.0	0.2	0.4	0.5	0.9	0.2		1.9		0.1		
-7-C-2	0.5	0.0	0.1	0.3	0.4	0.8	0.2		1.9		0.1		
MFR-8-A-1	11	0.5	1.4	0.8	2.2	12	1.0		3.1		0.0		
-8-A-2	11	0.4	1.4	0.8	2.2	15	0.9		3.3		0.0		
-8-B-1	10	0.4	1.5	0.8	2.2	13	0.8		3.5		0.2		
-8-B-2	10	0.5	1.5	0.8	1.9	12	0.8		3.4		0.1		
-8-C-1	11	0.4	1.5	0.8	2.2	16	0.7		3.6		0.0		
-8-C-2	12	0.4	1.8	0.8	2.6	17	0.8		3.7		0.1		
MFR-9-A-1	2.7	0.1	0.7	0.6	2.4	1.4	0.5		1.5		0.0		
-9-A-2	2.4	0.0	0.2	0.5	1.1	1.0	0.1		1.8		0.0		
-9-B-1	2.5	0.0	0.3	0.6	1.1	1.1	0.1		1.9		0.0		
-9-B-2	2.4	0.0	0.3	0.5	1.1	1.2	0.2		2.7		0.0		

TABLE A-7 CONT'D

Sample	Portable Wear Metal Analyzer (PWMA) Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-10-A-1	2.6	0.1	0.5	0.1	0.8	0.3	0.2	N/A	7.5		0.0		
-10-A-2	1.8	0.1	0.1	0.1	0.6	0.2	0.2		6.0		0.0		
-10-B-1	2.3	0.1	0.4	0.1	0.5	0.3	0.1		10.4		0.0		
-10-B-2	1.8	0.1	0.2	0.1	0.5	0.2	0.1		6.5		0.0		
-10-C-1	1.9	0.1	0.3	0.1	0.6	0.2	0.1		5.7		0.0		
-10-C-2	1.8	0.1	0.2	0.1	0.4	0.2	0.1		5.8		0.0		
MFR-11	0.2	0.0	0.2	0.0	0.2	0.1	0.1		1.3		0.4		
MFR-12	1.9	0.0	0.1	0.2	0.1	0.1	0.0		1.9		0.0		
MFR-13	1.7	0.0	0.6	0.1	1.3	0.2	0.1		0.5		0.0		
MFR-14	3.0	0.4	9.4	0.8	1.5	0.4	1.5		1.2		0.0		
MFR-15	3.3	0.4	0.4	0.4	0.2	0.4	0.2		1.6		0.0		
MFR-16													
MFR-17													
MFR-18-A-1	2.4	0.4	0.4	0.3	0.2	0.2	0.1		0.9		0.8		
-18-A-2	1.0	0.1	0.2	0.1	0.2	0.1	0.1		0.0		0.4		
-18-B-1	1.3	0.2	0.1	0.2	0.1	0.1	0.0		5.4		0.1		
-18-B-2	0.9	0.1	0.0	0.1	0.0	0.1	0.1		0.0		0.3		
-18-C-1	1.6	0.2	0.1	0.2	0.0	0.1	0.0		0.9		0.0		
-18-C-2	0.8	0.1	0.1	0.1	0.4	0.1	0.1		0.1		0.1		

TABLE A-7 CONCLUDED

Sample	Portable Wear Metal Analyzer (PWMA) Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-19	7.9	0.0	1.0	0.1	1.1	9.1	0.4	-	1.3	-	0.0		
MFR-20	13.8	1.0	0.6	0.9	0.4	0.1	0.3	-	1.3	-	0.0		
MFR-21	9.6	0.3	0.6	0.3	0.8	0.4	0.4	-	0.6	-	0.0		
MFR-22-A-1	8.6	0.4	0.4	0.2	0.7	1.6	0.2	-	1.4	-	0.0		
-22-A-2	7.0	0.2	0.6	0.2	0.4	1.1	0.1	-	0.6	-	0.0		
-22-B-1	7.5	0.3	0.5	0.2	0.7	1.4	0.3	-	1.1	-	0.0		
-22-B-2	7.4	0.2	0.5	0.2	0.5	1.1	0.1	-	0.9	-	0.1		
-22-C-1	6.8	0.2	0.6	0.2	0.5	1.0	0.1	-	0.6	-	0.0		
-22-C-2	6.8	0.2	0.5	0.2	0.5	0.9	0.2	-	1.8	-	0.1		
-22-D-1	6.3	0.2	0.3	0.2	0.3	1.0	0.1	-	0.3	-	0.0		
-22-D-2	7.1	0.2	0.3	0.2	0.7	1.4	0.1	-	0.0	-	0.0		

TABLE A-8

	Direct Current Plasma (DCP) Spectrometric Analysis (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-1-A-1	8.72	-	<.17	<.05	<.02	0.00	<2	<.05	3.32	<0.7			
-1-A-2	5.96	-	<.16	<.05	<.02	0.00	<2	<.05	3.04	<0.7			
-1-B-1	6.74	-	<.17	0.12	<.01	0.00	<2	<.05	3.29	<0.7			
-1-B-2	5.88	-	<.17	0.06	<.01	0.00	<2	<.05	3.07	<0.7			
-1-C-2	5.47	-	<.16	<.05	<.01	0.00	<2	<.05	3.15	<0.7			
-1-D-1	5.72	-	<.17	<.05	0.02	0.00	<2	<.05	3.42	<0.7			
MFR-2-A-1	34.2	-	<.17	0.12	<.02	0.00	<2	<0.5	2.31	1.1			
-2-A-2	21.6	-	<.17	.06	<.02	0.00	<2	<0.6	2.29	<0.9			
-2-B-1	23.8	-	0.39	0.14	<.02	0.01	<2	0.8	3.06	<0.5			
-2-B-2	20.2	-	<.17	0.05	0.02	0.00	<2	< 0.5	3.20	<0.7			
-2-C-1	21.4	-	<.17	0.12	0.00	0.00	<2	<0.5	3.31	<0.9			
-2-C-2	19.4	-	<.17	0.07	0.02	0.00	2	<0.5	3.19	<0.7			
MFR-3-A-1	7.36	-	<.17	0.29	0.09	.02	<2	<0.5	8.20	<0.7			
-3-A-2	7.01	-	<.17	0.32	0.07	.02	<2	<0.5	8.20	<0.7			
-3-B-2	7.91	-	<.17	0.37	0.07	.03	<2	<0.5	8.46	<0.7			
-3-C-1	6.73	-	<.17	0.34	0.07	.03	<2	<0.5	8.17	0.8			
-3-C-2	7.01	-	<.17	0.26	0.06	.02	<2	<0.5	8.20	<0.7			
MFR-4-A-1	5.03	-	1.04	0.65	0.10	0.01	<2	2.4	1.28	2.7			
-4-4-2	-	-	-	-	-	-	-	-	-	-			
-4-B-1	1.86	-	0.24	0.40	0.00	0.00	<2	<.05	0.77	1.0			
-4-B-2	0.53	-	<.17	0.25	0.00	0.00	<2	<.05	0.36	<0.7			
-4-C-1	-	-	-	-	-	-	-	-	-	-			
-4-C-2	0.32	-	<.17	0.27	0.00	0.00	<2	<0.5	<0.12	1.3			
-4-D-1	0.96	-	<.17	0.33	0.00	0.00	<2	<0.5	0.25	1.7			

TABLE A-8 CONT'd

	Direct Current Plasma (DCP) Spectrometric Analysis (Values in ppm)												
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
-4-D-2	5.10	-	0.25	0.14	0.02	0.00	< 2	1.2	2.76	1.4	-		
MFR-5-A-1	99.0	-	12.0	3.99	> 35	430	3	72.8	31.4	6.8	-		
-5-A-2	85.7	-	10.0	3.59	> 35	> 430	2	67.9	28.9	6.4	-		
-5-B-1	94.3	-	11.4	3.88	> 35	> 430	3	74.0	31.0	6.8	-		
-5-B-2	91.3	-	10.9	3.87	> 35	> 430	4.9	74.1	31.1	6.1	-		
-5-C-1	90.9	-	10.5	3.86	> 35	> 450	5.2	73.1	30.0	6.2	-		
-5-C-2	92.2	-	10.5	3.91	> 35	> 450	4.5	73.0	30.8	6.2	-		
-5-D-1	92.1	-	10.5	3.90	> 35	> 450	5.3	73.1	30.3	6.1	-		
-5-D-2	93.1	-	10.6	3.95	> 35	> 450	5.2	73.7	30.8	6.3	-		
MFR-6-A-1	6.67	-	1.0	1.12	2.44	2.69	< 4	< 0.7	5.72	< 14	-		
-6-A-2	4.40	-	< 0.3	0.78	2.06	2.10	< 3	< 0.9	4.77	< 1.2	-		
-6-B-1	4.89	-	< 0.4	0.86	2.10	2.24	< 4	< 0.9	4.79	< 1.4	-		
-6-B-2	3.81	-	< 0.3	0.71	1.88	1.91	< 4	< 0.9	4.44	< 1.4	-		
-6-C-1	4.26	-	< 0.4	0.79	2.02	2.08	< 4	< 0.9	4.61	< 1.4	-		
-6-C-2	3.60	-	0.33	0.61	1.42	1.33	< 3	< 0.5	3.40	1.7	-		
-6-D-1	3.90	-	0.46	0.63	1.45	1.38	< 2	< 0.5	4.14	1.6	-		
-6-D-2	3.59	-	0.36	0.57	1.41	1.35	< 3	< 0.5	3.49	1.6	-		
MFR-7-A-1	0.34	-	< 0.3	0.51	0.11	1.09	< 3	< 0.7	0.27	< 1.1	-		
-7-A-2	0.26	-	< 0.3	0.57	0.01	1.12	< 3	< 0.8	0.21	< 1.3	-		
-7-B-1	0.23	-	< 0.3	0.56	< .04	1.09	< 3	< 0.8	0.17	< 1.3	-		
-7-B-2	0.22	-	< 0.3	0.56	< .04	1.07	< 3	< 0.8	0.31	< 1.3	-		
-7-C-1	< 0.13	-	< 0.3	0.47	< 0.04	1.02	< 3	< 0.8	0.20	< 1.3	-		
-7-C-2	< 0.13	-	< 0.3	0.55	< 0.04	1.05	< 3	< 0.8	0.26	< 1.3	-		

TABLE A-8 CONCLUDED

	Direct Current Plasma (DCP) Spectrometric Analysis (Values in ppm)											
	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
MFR-8-A-1	10.3	-	0.4	1.05	1.79	12.4	<3	<.7	2.15	<1.2	-		
-8-A-2	10.2	-	0.7	1.05	1.66	12.5	<3	0.9	2.18	<1.2	-		
-8-B-1	10.5	-	1.1	1.38	2.29	12.6	<3	1.1	2.62	<1.3	-		
-8-B-2	8.13	-	<0.3	0.88	1.45	10.2	<3	<.8	1.97	<1.3			
-8-C-1	7.93	-	0.4	0.82	0.8	10.0	<3	<0.8	1.98	<1.3			
-8-C-2	10.01	-	0.3	0.98	0.7	11.8	<3	<0.7	2.15	<1.1			

TABLE A-9

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)											
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-1-A-1	27												
<12 µm	16												
<10 µm	16												
< 8 µm	15												
< 5 µm	13												
< 3 µm	11												
< 2 µm	13												
< 1 µm	7.7												
<0.4 µm	3.1												
MFR-1-A-2	10												
<12 µm	8.1												
<10 µm	8.6												
< 8 µm	8.6												
< 5 µm	8.6												
< 3 µm	8.1												
< 2 µm	9.9												
< 1 µm	7.9												
<0.4 µm	4.2												
MFR-2-A-1	61												
<12 µm	52												
<10 µm	53												
< 8 µm	50												
< 5 µm	46												
< 3 µm	40												
< 2 µm	33												

TABLE A-9 CONT'D

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)											
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-2-A-1													
<1 µm	25												
<0.4 µm	8.2												
MFR-2-A-2	27												
<12 µm	27												
<10 µm	26												
< 8 µm	27												
< 5 µm	26												
< 3 µm	28												
< 2 µm	24												
< 1 µm	18												
<0.4 µm	5.4												
MFR-3-A-1	13												
<12 µm	12												
<10 µm	11												
< 8 µm	12												
< 5 µm	12												
< 3 µm	11												
< 2 µm	13												
< 1 µm	10												
<0.4 µm	1.1												
MFR-3-A-2	11												
<12 µm	12												
<10 µm	12												

TABLE A-9 CONT'D

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)												
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-3-A-2													
<8 μm	12												
<5 μm	11												
<3 μm	9.1												
<2 μm	10												
<1 μm	9.5												
<0.4 μm	2.5												
MFR-4-A-1	32												
<12 μm	17												
<10 μm	14												
< 8 μm	12												
< 5 μm	7.9												
< 3 μm	4.6												
< 2 μm	-												
< 1 μm	-												
< 0.4 μm	-												
MFR-4-A-2	1.1												
<12 μm	1.8												
<10 μm	-												
< 8 μm	-												
< 5 μm	-												
< 3 μm	2.2												
< 2 μm	1.8												
< 1 μm	1.0												
< 0.4 μm	1.6												

TABLE A-9 (CONT'D)

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)												
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-5-A-1	121												
<12 µm	122												
<10 µm	112												
< 8 µm	113												
< 5 µm	112												
< 3 µm	130												
< 2 µm	94												
< 1 µm	-												
<0.4 µm	-												
MFR-5-A-2	116												
<12 µm	99												
<10 µm	102												
< 8 µm	103												
< 5 µm	104												
< 3 µm	109												
< 2 µm	105												
< 1 µm	-												
<0.4 µm	-												
MFR-6-A-1	9.4												
<12 µm	-												
<10 µm	-												
< 8 µm	-												
< 5 µm	7.3												
< 3 µm	7.3												
< 2 µm	6.4												

TABLE A-9 (CONT'D)

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)												
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-6-A-1													
<1 µm	5.1												
<0.4 µm	2.5												
MFR-6-A-2	6.7												
<12 µm	-												
<10 µm	-												
< 8 µm	-												
< 5 µm	6.2												
< 3 µm	6.3												
< 2 µm	6.3												
< 1 µm	5.7												
<0.4 µm	2.6												
MFR-7-A-1	1.0												
<5 µm	0.5												
<3 µm	0.6												
<2 µm	0.8												
<1 µm	0.5												
<0.4 µm	0.6												
MFR-7-A-2	0.7												
<5 µm	0.5												
<3 µm	0.5												
<2 µm	0.5												
<1 µm	0.5												
<0.4 µm	0.4												

TABLE A-9 (CONT'D)

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)												
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-8-A-1	11												
<5 μm	11												
<3 μm	11												
<2 μm	10												
<1 μm	10												
<0.4 μm	5.9												
MFR-8-A-2	11												
<5 μm	11												
<3 μm	10												
<2 μm	10												
<1 μm	10												
<0.4 μm	4.2												
MFR-9-A-1	2.6												
<5 μm	3.1												
<3 μm	2.8												
<2 μm	2.9												
<1 μm	3.3												
<0.4 μm	-												
MFR-9-A-2	2.4												
<5 μm	2.8												
<3 μm	3.0												
<2 μm	3.1												
<1 μm	3.1												
<0.4 μm	2.8												

TABLE A-9 (CONT'D)

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)											
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-10-A-1													
< 12 µm	3.1												
< 10 µm	3.1												
< 8 µm	2.9												
< 5 µm	2.5												
< 3 µm	1.1												
< 2 µm	1.0												
< 1 µm	1.0												
<0.4 µm	0.7												
MFR-10-A-2													
<5 µm	1.1												
<3 µm	1.1												
<2 µm	1.1												
<1 µm	1.1												
<0.4 µm	0.8												
MFR-18-A-1													
<12 µm	5.7												
<10 µm	5.6												
< 8 µm	5.7												
< 5 µm	5.2												
< 3 µm	2.7												
< 2 µm	2.5												
< 1 µm	2.5												
<0.4 µm	2.1												

TABLE A-9 (CONCLUDED)

SAMPLE	Particle Size Distribution Using ADM/AA (Values in ppm)												
	FE	AG	AL	CR	CU	MG	NI	PB	SI	SN	TI		
MFR-18-A-2													
<5 µm	2.5												
<3 µm	2.4												
<2 µm	2.1												
<1 µm	2.3												
<0.4 µm	2.1												
MFR-22-A-1	(ADM/	ICP)											
<12 µm	8.4												
<10 µm	8.14												
< 8 µm	7.30												
< 5 µm	7.31												
< 3 µm	6.74												
< 2 µm	4.98												
< 1 µm	5.11												
<0.4 µm	3.98												
MFR-22-A-2													
<5 µm	6.91												
<3 µm	6.81												
<2 µm	5.39												
<1 µm	5.25												
<0.4 µm	3.57												

TABLE A-10

ANALYTICAL FERROGRAPH DATA

Sample	Percent Area Covered						L/S	Major Type Debris
	Entry	50	40	30	20	10		
MFR-1-A-1[1]	84.3	83.7	75.4	60.2	51.9	43.3	1.01	Rubbing, Severe & Cutting Wear. Non-Wear Debris
-1-A-2	52.4	52.0	49.0	42.9	42.3	42.3	1.01	Rubbing and Non-Wear Debris
-1-B-1	67.8	62.2	47.1	44.2	43.0	44.6	1.09	Rubbing and Non-Wear Debris. Few Severe Wear Particles
-1-B-2	55.2	55.7	52.4	43.8	38.0	39.7	0.99	Rubbing Wear
-1-A-1(0.1)[2]	25.7	10.5	4.3	3.3	2.0	0.8	2.45	Rubbing, Severe & Cutting Wear. Non Wear Debris
-1-A-2(1)	48.6	42.0	39.0	20.1	19.1	20.0	1.16	Rubbing and Non-Wear Debris
-1-B-1(0.1)	17.7	13.5	4.8	3.4	4.2	5.8	1.31	Rubbing and Non-Wear Debris. Few Severe Wear Particles
-1-B-2(1)	45.7	44.7	28.5	17.3	14.2	14.8	1.02	Rubbing Wear
MFR-2-A-1(0.1)	46.9	27.0	14.0	10.3	9.3	7.6	1.74	Rubbing Wear With a Few Severe and Non-Wear Particles
2-A-2(0.1)	17.0	14.5	9.5	7.4	7.0	9 '	1.17	Rubbing Wear
-2-B-1(0.1)	28.2	21.2	17.5	13.6	15.8	15.4	1.37	Rubbing Wear With a Few Severe and Non-Wear Particles
-2-B-2(0.1)	11.6	17.6	11.4	12.0	5.7	7.6	0.66	Rubbing Wear
MFR-3-A-1	25.9	36.8	44.6	48.0	51.7	60.2	0.77	Rubbing Wear
-3-A-2	36.5	41.3	47.0	50.5	55.5	45.6	0.88	Rubbing Wear

[1]Sample size of 3 mL unless different sample size is shown

[2]Sample size, mL

TABLE A-10 (CONT'D)

ANALYTICAL FERROGRAPH DATA

Sample	Percent Area Covered						L/S	Major Type Debris
	Entry	50	40	30	20	10		
MFR-4-A-1[1]	77.8	50.3	-	-	-	31.0	1.55	Severe and Cutting Wear, Oxides and Non-Metallic Debris
-4-A-1(0.1)[2]	23.9	3.9	2.8	3.6	4.2	5.7	6.13	" " " "
-4-A-2	9.0	6.7	7.4	5.4	7.9	4.0	1.34	Rubbing Wear and Non-Wear Debris
MFR-5-A-1(1)	67.3	61.5	46.3	28.7	37.4	34.9	1.09	Rubbing Wear and Carbon Particles
-5-A-1(.5)	52.0	43.5	33.6	23.7	22.7	23.0	1.20	" " " "
-5-A-1(0.25)	37.0	34.3	13.6	9.4	8.4	5.0	1.08	" " " "
-5-A-2(1)	68.4	63.2	46.6	32.7	31.4	25.6	1.08	" " " "
-5-A-2(.5)	37.2	36.2	29.0	22.7	19.3	15.8	1.03	" " " "
MFR-6-A-1	40.2	36.4	29.7	24.1	27.2	32.2	1.10	Severe, Cutting and Rubbing Wear. Non-Wear Debris
-6-A-2	8.1	10.1	11.5	9.4	18.6	16.9	0.80	Rubbing Wear and Non-Wear Debris
MFR-7-A-1	5.4	1.9	1.5	0.8	1.2	0.7	2.84	Severe and Cutting Wear. Non-Wear Debris
-7-A-2	0.4	0.4	0.3	0.4	0.2	0.3	1.00	Mostly Non-Wear Debris

[1] Sample size of 3 mL unless different sample size is shown
[2] Sample size, mL

TABLE A-10 (CONT'D)

ANALYTICAL FERROGRAPH DATA

Sample	Percent Area Covered						L/S	Major Type Debris
	Entry	50	40	30	20	10		
MFR-8-A-1[1]	26.5	13.3	9.1	7.3	14.9	11.1	1.99	Rubbing, Severe and Cutting Wear
MFR-8-A-2	8.5	10.1	10.4	9.1	11.6	13.2	0.84	Rubbing and Non-Wear Debris
MFR-9-A-1	9.8	9.5	3.7	3.6	6.7	4.0	1.03	Rubbing and Non-Wear Debris
MFR-9-A-2	2.4	2.3	2.6	3.3	5.6	2.3	1.04	Rubbing and Non-Wear Debris
MFR-10-A-1	13.3	11.6	9.7	10.0	16.3	14.5	1.15	Rubbing, Severe and Cutting Wear
MFR-10-A-2	5.2	6.6	7.9	7.4	8.1	11.8	0.79	Rubbing Wear
MFR-11	1.8	1.6	1.0	0.6	2.3	0.5	1.13	Rubbing Wear With a Few Severe Wear Particles
MFR-12	3.5	2.4	0.7	0.3	1.0	1.6	1.50	Few Severe Wear Particles. Non-Wear Debris
MFR-13	9.0	14.0	8.2	16.3	4.6	10.2	0.64	Rubbing Wear and Non-Wear Debris
MFR-14	5.0	5.5	5.5	6.9	7.3	10.1	0.91	Rubbing and Severe Wear, Few Bright Non-Magnetic Particles

[1] Sample size of 3 mL unless different sample size is shown

TABLE A-10 (CONT'D)

ANALYTICAL FERROGRAPH DATA

Sample	Percent Area Covered						L/S	Major Type Debris
	Entry	50	40	30	20	10		
MFR-15[1]	69.7	65.1	32.7	18.3	15.6	9.8	1.07	Rubbing Severe and Cutting Wear. Heavy Amount of Fibers
MFR-16	Insufficient Sample							
MFR-17	Insufficient Sample							
MFR-18-A-1	27.3	27.5	20.8	15.4	11.0	7.5	0.99	Rubbing Wear
-18-A-2	8.2	15.4	10.7	8.7	6.8	6.1	0.53	" "
MFR-19	18.2	10.5	16.9	24.6	35.4	24.0	1.73	Rubbing & Severe Wear. Same Non-Wear Debris
MFR-20	47.7	41.7	55.4	61.3	60.0	54.4	1.14	Rubbing, Severe & Cutting Wear
MFR-21	34.8	34.2	27.8	24.1	26.0	39.8	1.02	Rubbing, Severe & Cutting Wear. Oxides and Non-Wear Debris

[1]Sample size of 3 mL unless different sample size is shown.

(TABLE A-10 (CONCLUDED)

ANALYTICAL FERROGRAPH DATA

Sample	Percent Area Covered						L/S	Major Type Debris
	Entry	50	40	30	20	10		
MFR-22-A-1	21.6	26.0	28.5	29.1	41.3	30.5	0.83	Rubbing, Severe and Cutting Wear
-22-A-2	7.2	12.8	15.1	18.0	23.5	34.8	0.56	Rubbing Wear
-22-B-1	13.2	19.1	19.5	19.6	23.3	33.2	0.69	Rubbing Wear
-22-B-1	9.0	10.6	19.0	19.0	20.6	25.9	0.85	Rubbing Wear

APPENDIX B

MEMBRANE FILTRATION SOAP SAMPLE DATA

Appendix B contains all analyses conducted on the membrane filtered SOAP samples obtained from a previous test program.

TABLE B-1

MEMBRANE FILTRATION SOAP SAMPLE DATA

IRON (Fe)

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-71-U	34.40	3.78	6.10			34.40	60.70	19.00
P-71-F	23.20	5.77	7.50			21.20	27.10	15.00
F-5-U	14.00		30.00				15.40	13.00
F-5-F	14.40		31.00				15.10	13.00
H-84-U	27.80	7.09	13.70			29.00	45.70	19.00
H-84-F	17.60	6.12	11.70			17.30	23.10	13.00
F-41-U	4.53		12.00			4.07	6.36	4.00
F-41-F	4.43		12.00			4.09	5.80	4.00
H-13-U	11.10		19.00			10.07	15.11	10.00
H-13-F	10.70		18.00			9.60	14.73	9.00
H-61-U	12.30		27.00			12.20	17.00	
H-61-F	12.70		27.00			11.62	16.50	
P-43-U	45.10	51.34	79.00			38.70	58.20	36.00
P-43-F	45.30	50.70	78.00			39.30	56.80	35.00
H-6-U	12.40	7.89	23.00			10.93	15.60	9.00
H-6-F	11.70	7.99	22.00			10.49	12.60	9.00
H-54-U	10.21	13.91	22.50				14.50	9.00
H-54-F	10.63	13.14	21.00				13.40	9.00
P-108-U	8.03		19.00			6.80	11.50	7.00
P-100-F	8.08		19.00			7.41	11.60	7.00
Navy Com.-U	4.73	4.34	9.70			5.06	7.22	4.00
Navy Com.-F	4.63	4.33	9.10			5.57	6.23	4.00
H-89-U	25.50	28.74	46.00			24.00	35.60	22.00
H-89-F	26.00	28.00	46.00			24.20	35.90	23.00
H-47-U	12.20		13.10			10.56	17.80	8.00
H-47-F	13.30		12.40			9.48	18.20	8.00
H-20-U	23.80	13.24	29.30			23.90	39.80	16.00
H-20-F	16.69	13.25	29.20			16.60	21.50	12.00
H-66-U	10.80		20.20			8.69	13.60	7.00
H-66-F	10.90		19.60			8.60	13.30	7.00
H-5-U	16.60		35.50			14.50	22.20	13.00
H-5-F	15.30		35.50			13.80	21.40	12.00
P-81-U	7.83		10.00			6.90	9.54	6.00
P-81-F	7.10		9.60			4.28	8.82	5.00
H-26-U	18.70		39.40			18.10	23.20	13.00
H-26-F	18.80		37.80			17.60	21.10	12.00
GEARBOX-U	6.73	7.74	13.20			5.08	10.20	4.00
GEARBOX-F	6.64	7.77	11.70			6.19	6.34	4.00
H-24-U	21.00		44.00			19.50	23.80	13.00
H-24-F	20.70		44.20			19.60	23.40	14.00
H-55-U	16.30	10.10	20.00			16.20	23.30	13.00
H-55-F	15.80	9.82	19.00			15.70	20.70	10.00
P-111-U	21.70		30.80			18.10	24.90	14.00
P-111-F	21.00		30.70			17.40	21.40	13.00

TABLE B-1 CONT'D

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
H-67-U	11.80		22.10			9.88	13.40	8.00
H-67-F	11.50		21.40			9.44	13.20	8.00
P-110-U	7.41		16.00			6.26	8.83	5.00
P-110-F	7.00		16.00			6.21	8.63	5.00
ARMY HEL.-U	2.63	2.70	5.20			2.38	3.83	2.00
ARMY HEL.-F	2.62	2.42	5.10			2.26	3.04	2.00
H-12-U	7.00	7.04	13.80			5.61	9.41	6.00
H-12-F	7.82	6.84	13.80			5.36	8.67	6.00
GEARBOX-U	6.83	7.01	11.10				11.10	4.00
GEARBOX-F	6.98	7.21	11.60				6.68	4.00
H-30-U	14.20	13.32	27.30			11.45	18.10	13.00
H-30-F	14.30	13.17	26.90			12.20	17.80	15.00

TABLE B-1 CONT'D

LEAD (Pb)

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-71-U	0.60	1.01	0.10			0.73	0.63	
P-71-F	0.46	0.70	0.50			0.40	1.41	
F-5-U	0.13						0.12	
F-5-F	0.14							
H-84-U	3.44	3.96	5.20			2.80	7.91	
H-84-F	3.03	3.44	4.50			2.20	7.71	
F-41-U	0.18		1.00			0.40	4.01	
F-41-F	0.33					0.60	3.18	
H-13-U	0.93		2.00			1.10	1.83	
H-13-F	1.00		2.00			0.90	1.94	
H-61-U	3.51		8.00			3.80	6.41	
H-61-F	3.58		9.00			4.20	5.53	
P-43-U	6.90	9.08	13.00			5.50	7.96	
P-43-F	6.94	8.70	14.00			5.60	8.97	
H-6-U	0.28	2.22				0.50		
H-6-F	0.42	1.91				0.70		
H-54-U	1.84	4.03	4.00				5.81	
H-54-F	2.21	3.83	4.10			1.80	2.93	
P-108-U	0.94		2.00			1.80	2.50	
P-108-F	1.01		2.00			1.20	2.01	
NAVY COM.-U	3.81	5.67	8.20			3.80	6.87	
NAVY COM.-F	3.54	5.69	8.00			3.70	7.11	
H-89-U	0.81	2.42	1.70			0.70	1.58	
H-89-F	0.78	2.60	1.50			0.70	1.88	
H-47-U	3.28		4.00			2.70	5.23	
H-47-F	3.53		3.70			2.10	4.73	
H-20-U	1.31	2.09	1.58			0.90	5.63	
H-20-F	1.43	2.24	1.90			1.40	5.61	
H-66-U	10.00		23.00			9.30	14.60	
H-66-F	10.00		22.80			9.10	14.70	
H-5-U	2.18		5.00			2.60	6.87	
H-5-F	1.60		5.00			2.60	4.51	
P-81-U	0.21		0.20			0.40	1.83	
P-81-F	0.10		0.40			0.40	2.01	
H-26-U	0.31		0.90			1.10	1.53	
H-26-F	0.40		0.40			1.20	0.32	
GEARBOX-U	0.43	1.85	0.20			0.70	0.52	
GEARBOX-F	0.43	1.81				0.70	0.32	
H-24-U	2.51		5.20			2.60	2.72	
H-24-F	2.48		4.70			2.80	1.98	
H-55-U	10.60	12.70	23.00			9.20	19.10	
H-55-F	10.80	12.66	22.00			9.10	14.50	
P-111-U	0.68		0.40			0.40	1.21	
P-111-F	0.58		0.50			0.40	1.10	
H-67-U	0.21		0.30			0.30	2.23	
H-67-F	0.10		0.30			0.30	1.92	

TABLE B-1 CONT'D

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-110-U			1.00			0.40		
P-110-F			1.00			0.40		
ARMY HEL.-U		1.54	0.10			0.80		
ARMY HEL.-F		1.26	0.20			0.80		
H-12-U	2.23	3.49	4.90			1.70	5.83	
H-12-F	2.28	3.52	4.80			1.70	4.81	
GEARBOX-U	0.21	1.71					0.29	
GEARBOX-F	0.53	1.91	0.20				0.18	
H-30-U	2.56	3.30	4.40			1.60	7.28	
H-30-F	2.83	2.93	4.60			1.70	4.21	

TABLE B-1 CONT'D

COPPER (Cu)

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-71-U	3.90	1.54	2.70			3.14	7.80	
P-71-F	2.92	1.66	2.80			2.33	2.81	
F-5-U	0.54		1.00				0.80	
F-5-F	0.47		1.00				0.20	
H-84-U	1.53	1.46	2.70			1.34	1.60	
H-84-F	1.55	1.39	2.70			1.20	1.64	
F-41-U	1.87		5.00			1.74	2.54	
F-41-F	1.80		5.00			1.79	2.23	
H-13-U	0.54		1.00			0.53	0.20	
H-13-F	0.51		1.00			0.47	0.31	
H-61-U	3.68		9.00			4.06	5.28	
H-61-F	3.83		9.00			4.11	5.08	
P-43-U	2.43	2.94	4.00			2.28	2.83	
P-43-F	2.43	2.74	4.00			2.18	2.64	
H-6-U	4.24	4.51	10.00			4.44	5.84	
H-6-F	4.08	4.39	10.00			4.03	4.41	
H-54-U	1.44	2.06	3.10				1.72	
H-54-F	1.51	1.96	2.90			1.52	1.83	
P-108-U	1.20		3.00			1.10	2.31	
P-108-F	1.17		3.00			1.14	2.44	
NAVY COM.-U	0.44	0.40	0.80			0.42	0.41	
NAVY COM.-F	0.45	0.41	0.70			0.45	0.35	
H-89-U	2.88	3.41	5.70			2.92	3.82	
H-89-F	3.00	3.28	5.60			2.92	3.81	
H-47-U	7.23		8.30			5.83	10.80	
H-47-F	7.87		8.30			5.57	11.50	
H-20-U	6.87	5.97	12.70			5.93	8.83	
H-20-F	6.26	5.88	11.60			5.55	7.08	
H-66-U	1.91		3.60			1.56	2.53	
H-66-F	1.92		3.60			1.55	2.03	
H-5-U	1.23		2.00			0.80	1.00	
H-5-F	1.20		3.00			0.85	1.00	
P-81-U	1.52		3.30			1.25	1.63	
P-81-F	1.43		3.00			0.97	1.61	
H-26-U	0.61		0.80			0.37	0.10	
H-26-F	0.61		0.80			0.37	0.23	
GEARBOX2-U	4.30	5.21	8.90			4.21	4.81	
GEARBOX2-F	4.31	5.22	8.00			4.54	4.00	
H-24-U	0.60		0.80			0.33	0.51	
H-24-F	0.57		0.60			0.31	0.72	
H-55-U	8.83	7.21	14.00			8.58	13.90	
H-55-F	8.83	7.09	14.00			8.41	11.50	
P-111-U	1.08		1.80			0.70	1.00	
P-111-F	1.07		1.80			0.72	0.88	
H-67-U	5.61		11.50			4.83	6.10	
H-67-F	5.53		11.00			4.73	6.07	

TABLE B-1 CONT'D

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-110-U	0.61		1.00			0.60	0.51	
P-110-F	0.62		1.00			0.59	0.42	
ARMY HEL.-U	1.20	1.22	2.30			1.28	1.00	
ARMY HEL.-F	1.31	1.21	2.50			1.21	0.98	
H-12-U	10.60	9.46	18.30			7.80	11.10	
H-12-F	10.50	9.33	19.30			7.51	11.60	
GEARBOX1-U	4.21	4.89	7.90				5.41	
GEARBOX1-F	4.21	5.00	8.10				4.22	
H-30-U	5.83	5.90	11.50			5.14	6.91	
H-30-F	5.87	5.91	11.50			5.21	7.38	

TABLE B-1 CONT'D

SILICON (Si)

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-71-U	0.83	0.66	0.60			1.56	0.40	
P-71-F	0.71	0.62	0.90			0.99	0.12	
F-5-U								
F-5-F								
H-84-U	26.70	20.92	26.90			22.90	29.32	
H-84-F	23.60	20.50	27.10			21.40	25.83	
F-41-U	0.60		1.00			0.81	0.43	
F-41-F	0.64		1.00			0.68	0.32	
H-13-U	1.01		3.00			1.25	0.71	
H-13-F	0.81		3.00			1.20	0.52	
H-61-U	2.87		6.00			3.80	4.10	
H-61-F	3.10		7.00			3.79	3.88	
P-43-U	1.21	1.87	3.00			1.75	2.84	
P-43-F	1.00	1.63	6.00			1.52	0.71	
H-6-U	1.58	1.77	3.00			2.48	1.61	
H-6-F	1.51	1.72	3.00			1.86	1.78	
H-54-U	9.71	12.54	13.60				13.60	
H-54-F	10.00	13.02	14.20			9.57	11.64	
P-108-U						0.52		
P-108-F			1.00			0.39		
NAVY COM.-U	0.12	0.57	0.80			0.59		
NAVY COM.-F	0.28	0.51	0.80			0.62		
H-89-U	5.03	7.11	10.90			5.37	6.06	
H-89-F	4.88	6.46	11.60			4.90	6.41	
H-47-U	0.81		1.20			0.64	0.53	
H-47-F	1.00		1.30			1.07	0.38	
H-20-U	1.68	1.78	4.00			1.61	1.18	
H-20-F	1.51	1.71	7.10			0.16	0.63	
H-66-U	4.81		7.00			4.12	8.21	
H-66-F	4.93		7.00			3.69	6.93	
H-5-U	1.86		4.00			2.21	2.06	
H-5-F	1.72		7.00			1.86	1.78	
P-81-U	1.10		4.20			1.38	0.81	
P-81-F	0.70		3.40			0.97	0.73	
H-26-U	0.20		0.90			0.17		
H-26-F	0.43		2.80			0.17		
GEARBOX2-U	0.31	0.98	1.20			0.67		
GEARBOX2-F	0.32	0.98	2.20			0.69		
H-24-U	0.63		1.70			0.17		
H-24-F	0.58		2.50			0.17		
H-55-U	4.32	5.64	8.00			4.39	5.73	
H-55-F	4.32	5.20	7.00			4.43	5.21	
P-111-U	0.38	0.50				0.66	0.10	
P-111-F	0.37	1.90				0.67	0.18	
H-67-U	1.93	2.40				1.66	2.01	
H-67-F	1.62	2.40				1.59	2.31	

TABLE B-1 CONT'D

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-110-U		2.00				0.56		
P-110-F		2.00				0.51		
ARMY HEL.-U	2.63	2.03	2.90			1.92	1.73	
ARMY HEL.-F	2.01	1.96	2.80			1.84	0.72	
H-12-U	1.52	1.37	2.50			1.38	0.42	
H-12-F	1.21	1.39	2.70			1.10	1.03	
GEARBOX-U	0.42	0.92	1.00					
GEARBOX-F	0.48	0.92	1.20				1.63	
H-30-U	1.41	1.68	1.70			1.94	0.10	
H-3-F	1.61	1.56	4.70			1.50	1.28	

TABLE B-1 CONT'D

SILVER (Ag)

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-71-U	0.14					1.23		
P-71-F						0.69		
F-5-U								
F-5-F								
H-84-U		0.11	0.20					
H-84-F			0.20					
F-41-U								
F-41-F			1.00					
H-13-U								
H-13-F								
H-61-U								
H-61-F								
P-43-U	0.23	0.53	1.00				0.20	
P-43-F	0.28	0.43	1.00				0.20	
H-6-U	1.21	0.75	3.00				1.71	
H-6-F	1.11	0.72	3.00				1.28	
H-54-U		0.28	0.40					
H-54-F		0.26	0.40					
P-108-U			1.00					
P-108-F			1.00					
NAVY COM.-U		0.11	0.30					
NAVY COM.-F		0.11	0.10					
H-89-U	0.81	1.05	1.80				1.42	
H-89-F	0.80	1.07	2.10				1.28	
H-47-U								
H-47-F								
H-20-U	1.12	0.59	1.60				1.47	
H-20-F	0.81	0.56	1.30				0.88	
H-66-U	0.32		0.70				1.03	
H-66-F	0.31		0.70				0.43	
H-5-U	0.52		1.00				0.78	
H-5-F	0.38		2.00				0.68	
P-81-U								
P-81-F			0.10					
H-26-U	0.31		0.90				0.21	
H-26-F	0.28		0.80				0.22	
GEARBOX2-U			0.10					
GEARBOX2-F								
H-24-U	0.44		0.90				0.43	
H-24-F	0.38		0.80				0.31	
H-55-U		0.14						
H-55-F		0.13						
P-111-U	0.58		1.20				1.00	
P-111-F	0.63		1.20				0.87	
H-67-U			0.10					
H-67-F			0.10					

TABLE B-1 CONT'D

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PMMA	DCP	ADM	AA
P-110-U	0.18		1.00				0.21	
P-110-F			1.00					
ARMY HEL.-U	0.10							
ARMY HEL.-F								
H-12-U	0.13	0.20	0.30				0.10	
H-12-F	0.13	0.18	0.20					
GEARBOX-U								
GEARBOX-F								
H-30-U		0.17	0.30					
H-30-F		0.16	0.20					

TABLE B-1 CONT'D

MAGNESIUM (Mg)

Oil #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-71-U	2.33	1.66	3.20			2.25	2.33	
P-71-F	2.14	1.79	3.30			1.82	2.01	
F-5-U	6.30		14.00				6.10	
F-5-F	6.40		14.00				5.87	
H-84-U	0.53	0.50	0.50			0.50	0.53	
H-84-F	0.42	0.39	0.40			3.90	0.42	
F-41-U	5.78		16.00			5.13	7.71	
F-41-F	5.51		16.00			5.18	7.07	
H-13-U	0.73		2.00			0.76	0.91	
H-13-F	0.81		2.00			0.71	0.82	
H-61-U	17.38		40.00			16.73	24.20	
H-61-F	17.81		40.00			16.34	23.30	
P-43-U		0.27						
P-43-F		0.12						
H-6-U	7.80	8.39	21.00			7.29	10.61	
H-6-F	7.67	8.53	21.00			7.12	7.73	
H-54-U	6.51	8.51	17.40				9.61	
H-54-F	6.71	8.40	16.40			6.34	8.60	
P-108-U	20.60		45.00			15.92	27.90	
P-108-F	20.90		42.00			17.64	27.90	
NAVY COM.-U	3.35	3.25	8.10			4.49	4.80	
NAVY COM.-F	3.44	3.40	8.60			5.18	4.51	
H-89-U	8.51	10.56	19.20			8.58	12.00	
H-89-F	8.60	10.20	19.10			8.53	12.36	
H-47-U	6.41		8.90			5.59	9.21	
H-47-F	6.81		9.10			5.21	9.52	
H-20-U	1.73	1.80	4.80			1.38	1.86	
H-20-F	1.68	1.78	4.80			1.43	1.65	
H-66-U	0.92		1.90			0.83	1.63	
H-66-F	0.91		1.90			0.80	1.01	
H-5-U	0.22					0.29	0.21	
H-5-F	0.21					0.23	0.23	
P-81-U	0.54		1.20			0.49	0.83	
P-81-F	0.43		1.20			0.34	0.51	
H-26-U	0.62		1.30			0.59	0.68	
H-26-F	0.65		1.20			0.56	0.73	
GEARBOX2-U	1.04	1.36	2.40			1.20	1.21	
GEARBOX2-F	1.00	1.37	3.00			1.26	1.01	
H-24-U	0.88		2.00			0.76	0.81	
H-24-F	0.87		2.20			0.77	0.87	
H-55-U	0.71	0.93	2.00			0.81	1.00	
H-55-F	0.71	0.89	2.00			0.80	1.10	
P-111-U	0.21					0.19	0.51	
P-111-F	0.20					0.19	0.51	
H-67-U	2.93		6.60			2.41	3.01	
H-67-F	2.82		6.40			2.34	3.03	

TABLE B-1 CONCLUDED

OIL #	ICP	PST/ ICP	AE/35	AE/JA	PWMA	DCP	ADM	AA
P-110-U	4.23		12.00			3.74	4.82	
P-110-F	3.87		12.00			3.72	4.66	
ARMY HEL.-U	1.21	1.31	2.40			1.35	1.42	
ARMY HEL.-F	1.10	1.21	2.40			1.36	1.03	
H-12-U	0.83	1.10	1.80			0.50	1.08	
H-12-F	0.81	0.93	1.80			0.57	0.71	
GEARBOX1-U	1.08	1.29	2.20				1.03	
GEARBOX1-F	1.08	1.34	2.20				0.88	
H-30-U	1.08	1.15	2.70			1.03	0.81	
H-30-F	1.13	1.14	2.80			0.95	1.20	

APPENDIX C

SPECTROMETRIC OIL ANALYSIS DATA FOR SOAP MONITORING SAMPLES

Appendix C contains all A/E35U analyses and ICP analyses conducted on 484 samples taken from 9 type engines, 2 transmission systems and 2 gearbox systems during the course of this program.

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
C-9B 160047	JT8D 667135	15677.0	N/A	AE	0.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0
				ICP	0.12	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
//	JT8D 667130	13046.3	N/A	AE	0.3	0.0	1.2	0.0	0.2	0.0	0.0	0.0	0.4	6.7	0.0
				ICP	0.02	0.00	0.11	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				AE											
				ICP											
OV-10A 155435	T76-6-420 000078	3660	0159	AE	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	10	0.7
				ICP	3.20	0.00	0.79	0.28	0.87	0.30	0.34	0.55	2.22	0.00	0.12
//	T76-6-420 007625	2164	0059	AE	0.9	0.0	0.0	0.0	0.0	0.0	0.4	0.3	1.5	10	0.8
				ICP	0.74	0.00	1.70	0.23	0.49	0.18	0.23	0.75	1.97	0.00	0.03
OV-10A 155481	T76-6-420 000173	1446.3	42.8	AE	6.8	0.0	0.0	0.0	0.4	0.0	0.7	0.0	3.4	9.3	0.7
				ICP	3.84	0.23	0.86	0.50	0.59	0.14	0.43	0.44	3.74	0.20	0.04
//	T76-6-420 000636	438.3	42.8	AE	1.5	0.0	0.0	0.0	0.6	0.2	0.5	0.0	1.1	9.3	0.6
				ICP	0.96	0.01	0.98	0.23	0.73	0.50	0.39	0.25	1.44	0.00	0.02
OV-10A 155487	T76-6-420 000393	1080	0724	AE	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	9.0	0.7
				ICP	0.73	0.00	0.79	0.27	0.40	0.07	0.28	0.00	1.4	0.00	0.01
//	T76-6-420 000512	1870	0440	AE	3.8	0.0	0.0	0.0	1.8	2.8	0.7	0.0	8.7	9.0	0.7
				ICP	2.02	0.01	0.80	0.37	0.93	0.37	0.52	0.00	7.04	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
A-6E 152614	J52-P-8B 660956	4372.9	339.9	AE	1.2	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.1
				ICP	0.42	0.00	0.20	0.17	0.00	0.21	0.00	0.00	0.00	0.00	0.00
A-6E 152614	J52-P-8B 677505	2325.8	633.1	AE	5.0	0.0	1.8	1.2	0.0	0.0	0.0	0.0	1.7	6.7	0.1
				ICP	2.19	0.00	0.32	1.06	0.00	0.00	0.14	0.00	0.50	0.00	0.00
A-6E 152923	J52-P-8B 660944	4319.2	49.2	AE	3.4	0.0	1.2	0.4	0.0	0.6	0.0	0.2	3.5	5.9	0.0
				ICP	1.42	0.00	0.31	0.44	0.00	0.39	0.00	0.12	0.71	0.00	0.00
A-6E 154169	J52-P-8B 660662	6023.0		AE	2.3	0.0	0.0	0.0	0.0	0.9	0.3	0.0	0.7	9.2	1.4
				ICP	0.96	0.04	0.43	0.29	0.21	0.64	0.23	0.00	0.97	0.00	0.24
A-6E 154169	J52-P-8B 701549	1029.0		AE	1.3	0.0	0.0	0.5	0.0	0.0	1.0	0.0	0.8	8.7	0.3
				ICP	0.79	0.14	0.46	0.60	0.27	0.20	0.27	0.00	0.86	0.14	0.03
A-6E 155719	J52-P-8B 650683	3035.9	382.0	AE	1.2	0.0	1.4	0.0	0.2	1.3	0.0	0.1	0.0	6.8	0.0
				ICP	0.31	0.00	0.00	0.40	0.00	0.63	0.00	0.00	0.60	0.00	0.00
A-6E 155719	J52-P-8B 677721	1533.4	38.9	AE	0.9	0.0	1.2	0.4	0.0	1.2	0.0	0.4	0.0	6.9	0.0
				ICP	0.29	0.00	0.00	0.41	0.00	0.63	0.00	0.10	0.59	0.00	0.00
A-6E 160998	J52-P-8B 660676	4648.2		AE	3.1	0.0	0.0	3.2	0.2	2.0	0.6	0.0	1.3	9.3	0.9
				ICP	1.29	0.09	0.78	2.11	0.42	0.99	0.31	0.00	1.12	0.05	0.02
A-6E 161663	J52-P-8B 661244	5702.6		AE	2.0	0.0	0.0	0.3	0.0	0.0	0.6	0.0	0.3	9.3	0.9
				ICP	0.30	0.15	0.31	0.48	0.23	0.22	0.23	0.00	0.83	0.16	0.03

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
A-6E	J52-P-8B	754.4	44.4	AE	0.8	0.0	1.4	0.0	0.0	0.0	0.0	0.0	2.3	6.7	0.1
161687	677712			ICP	0.27	0.00	0.06	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00
				AE											
				ICP											
AV-8B	F402-RR-406	401		AE	1	0	0	0	0	2	0	0	3	7	1
162069	12095			ICP	0.30	0.00	0.00	0.10	0.36	0.80	0.02	0.60	1.62	0.00	0.00
AV-8B	"	883		AE	1	0	0	0	1	0	0	0	2	8	1
162076	12047			ICP	0.26	0.00	0.17	0.09	0.41	0.08	0.10	0.65	0.77	0.00	0.00
AV-8B	"	747		AE	1	0	0	0	1	0	0	0	1	7	—
162731	12072			ICP	0.36	0.00	0.00	0.04	0.45	0.16	0.00	0.44	0.60	0.00	0.00
AV-8B	"			AE	1	0	0	0	0	1	0	0	1	7	0
162736	12043			ICP	0.69	0.00	0.21	0.08	0.25	0.21	0.02	0.42	0.87	0.00	0.00
AV-8B	"	858		AE	3	0	0	0	1	2	0	0	1	7	1
162945	12006			ICP	1.20	0.00	0.46	0.13	0.51	0.52	0.09	0.71	0.83	0.00	0.00
AV-8B	"	368		AE	1	0	0	0	0	1	0	0	2	8	1
162948	12081			ICP	0.42	0.00	0.22	0.13	0.36	0.42	0.07	0.41	1.18	0.23	0.00
"	"	373		AE	1	0	0	0	1	1	0	0	2	7	1
"	"			ICP	0.45	0.00	0.12	0.05	0.47	0.42	0.03	0.74	0.50	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
AV-8B 162962	F402-RR-406 12174	432	432	AE	1.3	0.0	1.2	0.0	1.7	0.0	0.0	0.0	0.9	6.7	0.0
				ICP	0.36	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.16	0.00	0.00
AV-8B 162962	" 12194	287	287	AE	1.0	0.0	1.2	0.0	1.6	2.1	0.0	0.0	0.9	6.9	0.0
				ICP	0.30	0.00	0.00	0.00	0.52	0.88	0.00	0.00	0.15	0.00	0.00
AV-8B 163183	" 12196	328	328	AE	1.2	0.0	1.1	0.0	2.1	0.0	0.0	0.0	0.6	6.6	0.0
				ICP	0.37	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.20	0.00	0.00
AV-8B 163422	" 12202		200.5	AE	0.6	0.0	1.0	0.0	0.8	0.0	0.0	0.0	0.2	6.0	0.0
				ICP	0.12	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00
AV-8B 163665	" 12230	58	58	AE	1.5	0.0	1.1	0.0	2.3	0.0	0.0	0.0	2.6	6.6	0.0
				ICP	0.63	0.00	0.00	0.00	0.85	0.03	0.00	0.00	1.11	0.00	0.00
				AE											
				ICP											
EA-6B 158032	J52-P-408 678462	2694.3	2078.0	AE	2	0	0	1	0	0	1	0	0	–	1
				ICP	0.75	0.00	0.27	0.98	0.12	0.15	0.32	0.00	0.32	0.00	0.21
EA-6B 158032	" 696909	1904.7	271.8	AE	4	0	0	0	0	0	0	0	0	–	1
				ICP	2.11	0.00	0.42	0.64	0.13	0.21	0.08	0.00	0.00	0.00	0.00
EA-6B 158035	" 711707	160.7	160.7	AE	1	0	0	0	0	0	0	0	0	–	1
				ICP	0.79	0.00	0.18	0.35	0.20	0.27	0.10	0.16	0.09	0.00	0.08

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
EA-6B	J52-P-408	179.2	179.2	AE	1.5	0.0	1.4	0.0	0.0	0.0	0.0	0.0	1.7	6.2	0.0
158035	711707			ICP	0.61	0.00	0.15	0.16	0.00	0.00	0.00	0.00	0.03	0.00	0.00
EA-6B	〃	160.7	160.7	AE	1	0	0	0	0	0	0	0	0	—	1
158035	711714			ICP	0.62	0.00	0.11	0.35	0.19	0.32	0.08	0.00	0.00	0.00	0.12
EA-6B	〃	179.2	179.2	AE	1.2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	1.0	6.7	0.1
158035	〃			ICP	0.43	0.00	0.26	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EA-6B	〃	973.1	973.1	AE	1.2	0.0	1.2	0.0	0.0	0.0	0.0	0.0	1.8	6.6	0.6
158540	711664			ICP	0.36	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EA-6B	〃			AE	2.8	0.0	1.1	1.7	0.0	0.0	0.0	0.0	2.2	6.1	0.0
160435	678495			ICP	1.27	0.00	0.06	1.43	0.00	0.10	0.00	0.00	0.32	0.00	0.00
EA-6B	〃	3530.4	329.5	AE	0.8	0.0	1.6	0.0	0.0	0.0	0.0	0.0	3.6	6.3	0.0
160435	678536			ICP	0.40	0.00	0.13	0.30	0.00	0.00	0.00	0.00	0.52	0.00	0.00
EA-6B	〃	358.2	358.2	AE	0.5	0.0	1.2	0.0	0.0	0.0	0.0	0.0	2.5	6.5	0.0
160786	678611			ICP	0.41	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EA-6B	〃	2311.2	381.3	AE	3.2	0.0	1.6	0.9	0.0	0.0	0.0	0.0	2.1	6.6	1.1
160788	678562			ICP	1.24	0.00	0.00	0.37	0.00	0.13	0.00	0.00	0.00	0.00	0.24
EA-6B	〃	1536.6	301.8	AE	1.8	0.0	1.3	0.0	0.0	0.0	0.0	0.0	1.1	6.3	0.0
162939	711627			ICP	0.63	0.00	0.00	0.06	0.00	0.18	0.00	0.00	0.00	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
EA-6B 162939	J52-P-408 711643	550.4	10.0	AE	0.4	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.6	6.4	0.2
				ICP	0.11	0.00	0.00	0.25	0.00	0.11	0.00	0.00	0.00	0.00	0.02
EA-6B 163035	" 711697	458.3		AE	1.4	0.0	1.2	0.4	0.0	0.0	0.0	0.0	2.9	6.1	0.0
				ICP	1.95	0.00	0.10	0.26	0.00	0.22	0.00	0.00	0.00	0.00	0.00
EA-6B 162939	" 711627	1516.6	1516.6	AE	2	0	0	0	0	1	1	0	0	—	1
				ICP	0.78	0.00	0.24	0.18	0.19	0.44	0.08	0.00	0.12	0.00	0.00
EA-6B 162939	" 711684	583.9	583.9	AE	3	0	0	0	0	0	1	0	0	—	1
				ICP	1.24	0.00	0.28	0.59	0.13	0.22	0.06	0.00	0.25	0.00	0.22
EA-6B 163031	" 711682	524.9	524.9	AE	2	0	0	0	0	0	0	0	0	—	1
				ICP	0.98	0.00	1.04	0.45	0.44	0.15	0.05	0.00	0.23	0.00	0.03
EA-6B 163031	" 711692	524.9	524.9	AE	3	0	0	1	0	0	1	0	0	—	2
				ICP	1.30	0.00	0.24	1.01	0.19	0.14	0.08	0.00	0.67	0.00	0.27
EA-6B 163035	" 711696	427.1	4[illegible].1	AE	6	0	0	0	0	1	1	0	0	—	1
				ICP	0.68	0.00	0.17	0.59	0.17	0.27	0.05	0.00	0.09	0.00	0.00
" "	" "	450.3	450.3	AE	4.8	0.0	1.5	0.0	0.0	0.0	0.0	0.2	2.7	6.9	0.3
				ICP	1.95	0.00	0.10	0.26	0.00	0.22	0.00	0.00	0.00	0.00	0.00
EA-6B 163035	" 711697	427.1	427.1	AE	1	0	0	0	0	0	0	0	0	—	1
				ICP	2.38	0.00	0.34	0.41	0.19	0.49	0.08	0.00	0.78	0.00	0.11

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
					Trace Metal Concentration, ppm										
EA-6B	J52-P-408	458.3	458.3	AE	1.4	0.0	1.2	0.4	0.0	0.0	0.0	0.0	2.9	6.0	0.0
163035	711697			ICP	0.56	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				AE											
				ICP											
SH-60B	Main XMSM	0	0	AE	3	0	0	0	2	0	0	1	0	6	1
Test Cell Eng.	A26401539			ICP	1.34	0.24	1.03	0.28	1.05	0.57	0.10	0.00	1.11	0.00	0.01
"	" "	"	"	AE	5	0	0	1	2	0	0	0	0	6	0
"	"			ICP	2.10	0.21	0.75	0.32	1.08	0.58	0.09	0.00	0.93	0.14	0.00
SH-60B	Main XMSM	0	0	AE	3	0	0	0	2	0	0	0	1	6	1
Test Cell Eng.	A26401642			ICP	1.22	0.28	1.20	0.19	1.03	0.60	0.10	0.00	1.22	0.00	0.02
"	" "	"	"	AE	4	0	0	1	2	0	1	0	0	7	2
"	"			ICP	1.49	0.22	1.57	0.24	1.03	0.58	0.14	0.00	1.18	0.00	0.02
SH-60B	Main XMSM	0	0	AE	4	0	0	0	2	1	0	1	0	7	3
Test Cell Eng.	A2640616			ICP	1.18	0.18	1.05	0.16	1.10	0.66	0.04	0.32	0.98	0.00	0.00
"	" "	"	"	AE	3	0	0	0	2	1	0	0	0	7	1
"	"			ICP	1.04	0.19	0.70	0.17	1.09	0.67	0.07	0.56	0.98	0.00	0.00
SH-60B	Main XMSM	0	0	AE	3	0	0	0	2	1	0	0	0	6	1
Test Cell Eng.	A26401977			ICP	1.06	0.20	0.90	0.16	1.02	0.66	0.00	0.00	0.96	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B Test Cell Eng.	Main XMSN A26401977	0	0	AE	3	0	0	0	2	1	0	0	0	7	1
				ICP	1.09	0.20	0.95	0.20	1.05	0.66	0.06	0.18	1.07	0.49	0.00
SH-60B 162095	Main XMSN A34200118	540	104	AE	13	0	2	0	6	7	1	0	4	9	6
				ICP	4.69	0.18	1.18	0.28	2.37	1.80	0.21	0.71	2.24	0.00	0.28
"	"	583	147	AE	10	0	0	0	5	5	1	2	2	11	1
				ICP	3.23	0.00	1.36	0.24	2.00	1.29	0.13	0.93	2.03	0.00	0.20
"	"	670	234	AE	10	0	0	0	5	5	0	0	2	11	2
				ICP	3.98	0.00	1.72	0.27	1.90	1.49	0.07	–	2.53	0.00	0.20
"	"	719	283	AE	9	0	1	1	4	4	0	0	6	4	0
				ICP	4.22	0.00	1.78	0.27	1.91	1.65	0.00	–	–	0.00	0.10
"	"	780	344	AE	8	0	0	1	4	3	1	1	3	6	1
				ICP	2.72	0.00	0.41	0.09	1.58	1.03	0.00	0.49	2.75	0.00	0.08
		903	467	AE	8	0	0	1	4	4	1	1	7	10	1
				ICP	1.64	0.11	0.21	0.29	0.85	0.56	0.14	0.00	1.97	0.08	0.13
SH-60B 162099	Main XMSN A34200099	108	108	AE	12	0	1	0	5	5	1	0	6	10	2
				ICP	4.46	0.06	0.96	0.31	1.89	1.40	0.14	0.95	4.04	0.00	0.19
"	"	228	89	AE	9	1	2	1	4	5	0	0	3	9	2
				ICP	2.16	0.00	0.97	0.10	1.05	0.74	0.00	0.29	7.20	0.00	0.05

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 162100	Main XMSN A34200122	296	196	AE	8	0	0	0	4	2	1	1	5	11	1
				ICP	1.80	0.01	0.05	0.15	1.03	0.43	0.00	0.00	4.39	0.00	0.07
"	"	348	248	AE	17	0	1	0	4	5	0	1	3	7	0
				ICP	5.18	0.00	0.26	0.38	1.30	1.35	0.18	0.00	4.25	0.00	0.24
"	"	406	306	AE	11	0	0	1	4	3	1	0	5	8	0
				ICP	3.72	0.05	0.47	0.34	1.19	0.99	0.09	0.00	4.24	0.21	0.23
SH-60B 162101	Main XMSN A34200135	87	87	AE	10	2	0	0	3	3	1	0	4	11	1
				ICP	2.66	0.88	0.12	0.00	0.95	0.29	0.00	5.62	1.24	0.00	0.00
SH-60B 162124	Main XMSN A34200098	2098	720	AE	2	0	0	0	1	0	1	0	8	10	0
				ICP	0.55	0.00	0.27	0.10	0.04	0.24	0.04	0.00	8.17	0.00	0.07
SH-60B 162127	Main XMSN A342000024	1680	304	AE	7	0	1	0	1	3	0	0	2	9	1
				ICP	2.12	0.00	1.18	0.26	0.41	0.72	0.11	–	2.52	0.00	0.18
"	"	630	547	AE	6	0	0	0	2	2	1	0	6	10	2
				ICP	0.39	0.00	0.00	0.00	0.47	0.00	0.00	–	2.72	0.17	0.00
H-60 162131	Main GBX A34200092		184	AE	22	0	0	1	6	6	1	0	11	10	0
				ICP	8.01	0.12	1.33	0.49	3.61	2.11	0.36	4.41	8.51	0.00	0.06
SH-60B 162132	Main XMSN A34200077	654	654	AE	3	0	0	0	1	2	1	0	3	10	11
				ICP	0.65	0.00	0.22	0.18	0.30	0.36	0.00	0.00	2.21	0.01	0.06

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 162132	Main XMSN A34200077	925	228	AE	4	0	0	1	2	3	1	1	13	9	1
				ICP	1.02	0.01	0.51	0.27	0.89	0.66	0.03	0.29	—	0.14	0.05
SH-60B 162328	Main XMSN A34200006 ?	2453	216	AE	2	0	0	0	3	1	0	0	5	9	0
				ICP	0.00	0.00	0.00	0.00	0.63	0.00	0.00	—	2.04	0.05	0.00
"	"	2512	275	AE	3	0	0	0	3	3	0	0	4	9	0
				ICP	0.23	0.00	0.00	0.00	0.85	0.00	0.00	—	2.12	0.11	0.00
SH-60B 162333	Main XMSN A34200012	1858	75	AE	4	0	0	0	3	3	0	0	3	9	1
				ICP	1.64	0.00	1.14	0.34	1.42	1.48	0.11	0.00	3.92	0.00	0.15
"	"	1917	134	AE	5	0	0	0	4	5	0	1	4	8	1
				ICP	1.72	0.18	1.24	0.36	1.55	1.57	0.04	0.00	4.14	0.24	0.15
"	"	2038	255	AE	3	0	0	1	3	3	1	0	3	7	0
				ICP	0.88	0.00	1.32	0.19	1.13	0.78	0.12	—	4.34	0.00	0.08
"	"	2095	315	AE	3	0	0	1	3	2	0	0	4	6	2
				ICP	0.62	0.00	0.45	0.05	1.06	0.48	0.00	0.00	3.81	0.00	1.02
"	"	2157	374	AE	2	0	0	1	3	1	1	0	4	9	0
				ICP	0.68	0.01	0.16	0.15	1.26	0.52	0.01	0.00	3.80	0.00	0.11
SH-60B 162334	Main XMSN A34200014	2080	243	AE	3	0	0	0	4	2	0	0	3	12	0
				ICP	0.95	0.00	0.98	0.21	1.42	0.55	0.12	—	3.87	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 162334	Main XMSN A34200014	2142	307	AE	3	0	0	0	3	1	0	0	3	11	0
				ICP	0.37	0.00	0.24	0.05	1.10	0.28	0.00	0.42	2.89	0.00	0.00
"	"	2199	362	AE	1	0	0	0	3	0	0	1	4	11	1
				ICP	0.46	0.02	0.06	0.17	1.38	0.18	0.10	0.00	3.58	0.00	0.01
SH-60B 162340	Main XMSN A34200023	2249	477	AE	0	0	0	0	2	0	1	0	6	10	0
				ICP	0.11	0.04	0.20	0.08	0.89	0.03	0.03	2.23	6.88	0.21	0.01
"	"	2307	58	AE	1	0	0	1	2	1	1	1	11	8	0
				ICP	0.41	0.01	0.09	0.08	0.72	0.23	0.12	1.25	–	0.10	0.01
SH-60B 162342	Main XMSN A34200027	1587	197	AE	1	0	0	0	1	0	1	1	2	11	2
				ICP	0.27	0.00	0.49	0.25	0.66	0.31	0.07	0.98	3.35	0.00	0.00
"	"	1705	315	AE	1	0	0	0	2	0	0	0	4	11	0
				ICP	0.39	0.00	0.65	0.42	0.44	0.15	0.07	–	3.70	0.00	0.00
"	"	1771	381	AE	1	0	0	1	1	0	0	0	5	9	0
				ICP	0.22	0.00	0.00	0.19	0.44	0.04	0.00	0.53	3.53	0.00	0.00
"	"	1828	438	AE	0	0	0	0	1	0	0	2	5	11	1
				ICP	0.11	0.00	0.00	0.18	0.56	0.04	0.04	0.00	4.70	0.00	0.01
"	"	2068	240	AE	1	0	0	1	2	1	1	1	2	9	1
				ICP	0.24	0.01	0.10	0.07	0.70	0.09	0.00	0.01	3.48	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 162982	Main XMSN A34200046		38	AE	1	0	0	0.	1	1	0	0	2	8	0
				ICP	0.37	0.00	0.14	0.06	0.35	0.17	0.00	0.39	1.50	0.00	0.00
"	"	1500	165	AE	1	0	0	0	2	0	0	0	3	11	0
				ICP	0.00	0.00	0.17	0.00	0.16	0.00	0.00	-	1.63	0.00	0.00
"	"	1672	337	AE	2	0	0	1	2	1	1	0	3	7	1
				ICP	0.47	0.00	0.27	0.11	0.71	0.19	0.00	0.00	9.93	0.17	0.04
"	"	1733	398	AE	2	1	0	1	3	1	0	0	4	11	0
				ICP	0.50	0.00	0.55	0.21	0.55	0.26	0.06	0.00	3.02	0.00	0.06
H-60 162986	Main GBX A34200053	-	-	AE	3	0	0	0	3	0	0	0	3	9	1
				ICP	1.13	0.00	0.91	0.35	1.45	0.51	0.08	0.00	3.37	0.00	0.06
"	"	1047	60	AE	4	0	0	0	3	2	0	0	3	10	0
				ICP	2.12	0.00	1.16	0.32	0.41	0.72	0.11	-	2.52	0.00	0.18
SH-60B 162989	Main XMSN A34200096	1049	449	AE	3	0	0	1	3	0	0	0	5	11	1
				ICP	0.00	0.00	0.00	0.00	0.45	0.00	0.00	-	4.01	0.00	0.00
SH-60B 163233	Main XMSN A34200068	416	416	AE	8	0	0	1	1	2	1	8	6	9	1
				ICP	2.02	0.00	0.86	0.25	0.48	0.48	0.00	0.10	6.42	0.00	0.05
"	"	449	449	AE	10	1	2	2	2	4	1	1	6	10	2
				ICP	2.22	0.00	0.71	0.29	0.50	0.52	0.05	0.07	6.67	0.00	0.09

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 163233	Main XMSN A34200068	662	209	AE	5	0	0	0	2	2	0	1	8	7	2
				ICP	1.53	0.00	0.30	0.00	1.07	0.10	0.00	—	3.25	0.10	0.00
"	"	720	266	AE	6	0	0	1	3	3	1	1	6	10	1
				ICP	1.67	0.00	0.46	0.42	0.92	0.61	0.05	0.64	6.78	0.00	0.09
H-60 163237	Main GBX A34200078	53	53	AE	6	1	0	0	2	2	0	0	6	9	1
				ICP	1.23	0.27	0.67	0.26	1.40	0.28	0.16	0.00	5.02	0.00	0.02
"	"	245	245	AE	8	0	1	0	1	2	0	0	5	8	1
				ICP	1.64	0.00	1.77	0.26	0.59	0.38	0.27	—	6.06	0.00	0.06
"	"	605	141	AE	7	0	0	0	2	5	1	0	6	8	1
				ICP	1.88	0.00	1.07	0.00	0.53	0.49	0.00	—	2.31	0.00	0.00
"	"	734	270	AE	7	0	0	1	3	4	1	0	7	8	0
				ICP	1.55	0.00	0.76	0.23	0.19	1.22	0.02	0.00	5.43	0.05	0.06
H-60 163238	Main GBX A34200068	—	297	AE	8	0	0	0	2	2	1	0	7	7	1
				ICP	1.72	0.01	1.93	0.22	1.74	0.52	0.20	2.27	6.20	0.00	0.88
"	"	—	297	AE	5	0	0	1	2	0	1	0	8	9	1
				ICP	1.50	0.02	0.55	0.28	1.38	0.43	0.22	0.00	7.10	0.05	0.07
H-60 163239	Main GBX A34200085	—	—	AE	10	0	0	0	2	2	1	0	6	9	1
				ICP	2.20	0.01	1.65	0.33	1.63	0.49	0.25	0.00	5.49	0.00	0.09

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 163243	Main XMSN A 34200100	669	432	AE	7	0	0	1	5	5	1	0	2	10	1
				ICP	1.63	0.03	0.58	0.26	1.63	1.15	0.00	2.01	2.07	0.03	0.07
//	//	//	//	AE	7	0	0	1	5	5	1	0	2	10	1
				ICP	2.24	0.00	0.96	0.46	1.39	1.58	0.00	0.00	1.78	0.00	0.06
SH-60B 163243	Main XMSN A 34200103	138	102	AE	8	0	2	1	1	3	0	0	2	2	0
				ICP	3.64	0.00	0.49	0.19	0.46	1.36	0.05	0.55	4.13	0.00	0.07
//	//	185	161	AE	11	0	0	1	1	6	1	0	3	8	2
				ICP	3.84	0.00	0.51	0.21	0.48	1.57	0.00	0.55	4.47	0.00	0.07
SH-60B 163244	Main XMSN A 34200107	183	183	AE	8	0	0	1	0	3	1	1	10	12	1
				ICP	2.32	0.01	1.37	0.34	0.24	0.93	0.19	0.00	6.72	0.00	0.01
//	//	307	307	AE	5	0	0	0	2	2	1	0	10	9	2
				ICP	0.74	0.00	0.00	0.00	0.38	0.04	0.00	–	5.40	0.00	0.00
//	//	421	421	AE	2	0	0	1	1	0	1	0	3	9	0
				ICP	0.37	0.00	0.60	0.09	0.33	0.18	0.00	0.00	2.58	0.00	0.04
SH-60B 163245	Main XMSN A 34200103	359	336	AE	8	0	0	0	5	3	1	0	12	9	5
				ICP	2.48	0.01	0.39	0.27	1.65	1.95	0.06	1.13	2.85	0.00	0.09
//	//	389	366	AE	4	0	0	0	4	4	0	0	2	10	0
				ICP	2.52	0.03	0.54	0.16	1.91	0.83	0.01	0.77	6.60	0.16	0.21

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 163245	Main XMSN A34200103	425	403	AE	8	0	0	1	6	4	1	2	10	11	2
				ICP	2.39	0.02	0.31	0.16	1.74	0.72	0.06	0.00	7.26	0.00	0.16
//	//	476	453	AE	7	0	0	1	7	5	0	0	4	12	0
				ICP	2.01	0.00	0.59	0.17	1.67	1.21	0.00	0.00	2.05	0.00	0.10
SH-60B 163245	Main XMSN A34200109	48	26	AE	7	1	1	1	3	1	1	0	2	2	0
				ICP	2.70	0.03	0.30	0.11	0.90	0.60	0.08	0.33	3.12	0.00	0.00
//	//	58	35	AE	6	1	0	0	4	2	0	1	3	4	0
				ICP	2.25	0.19	0.40	0.21	1.12	0.59	0.07	0.00	4.30	0.00	0.02
//	//	—	—	AE	8	1	1	1	23	3	1	0	8	10	0
				ICP	2.47	0.23	0.41	0.23	5.13	0.57	0.10	0.65	6.17	0.00	0.05
SH-60B 163248	Main XMSN A34200124	175	139	AE	8	1	0	1	1	2	1	0	6	10	1
				ICP	3.25	0.40	0.78	0.32	0.04	0.76	0.10	0.00	4.84	0.00	0.18
//	//	235	199	AE	9	1	0	1	2	3	1	0	6	10	0
				ICP	3.50	0.11	0.77	0.30	0.10	0.72	0.14	0.00	6.41	0.00	0.17
SH-60B 163249	Main XMSN A34200085	—	118	AE	4	0	0	1	1	1	0	0	5	9	1
				ICP	0.61	0.00	0.45	0.14	0.75	0.14	0.08	0.00	4.86	0.00	0.02
SH-60B 163249	Main XMSN A34200130	34	34	AE	6	1	0	0	2	2	0	1	5	9	1
				ICP	1.24	0.07	0.00	0.00	0.99	0.00	0.00	—	1.98	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
SH-60B 163249	Main XMSN A 34200130	118	118	AE	9	0	0	0	0	2	1	0	8	8	0
				ICP	3.55	0.20	0.52	0.38	0.59	0.86	0.18	0.67	5.36	0.17	0.08
SH-60B 163593	Main XMSN A34200139	58	58	AE	9	1	0	0	1	2	0	0	6	10	1
				ICP	2.32	0.14	0.56	0.17	0.65	0.47	0.15	0.57	3.09	0.00	0.07
//	//	121	121	AE	12	1	0	1	2	3	1	12	5	10	2
				ICP	2.36	0.11	0.92	0.18	0.85	0.53	0.09	0.00	5.64	0.26	0.06
				AE											
				ICP											
CH-46E 152579	FWD. XMSN A 7-528	149.9	149.9	AE	23.5	0.0	6.7	3.1	1.8	0.7	2.3	0.3	4.0	9.6	0.5
				ICP	13.70	0.00	6.08	2.60	1.44	0.76	1.34	2.13	3.55	0.30	0.01
//	AFT XMSN A9-222	777.6	37.9	AE	4.6	0.0	0.0	0.0	0.0	4.9	0.2	0.0	2.2	9.7	0.5
				ICP	2.98	0.11	1.03	0.14	0.55	2.51	0.19	2.67	2.34	0.00	0.00
//	T58-GE-16 216011	2441.8	324.9	AE	1.2	0.0	1.1	0.0	0.3	0.0	0.4	0.0	0.7	10.3	0.8
				ICP	0.68	0.20	2.49	0.22	0.50	0.11	0.30	0.21	0.96	0.00	0.01
//	T58-GE-16 216093	763.7	79.9	AE	1.3	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.4	10.1	1.1
				ICP	0.61	0.00	1.11	0.23	0.40	0.02	0.35	1.06	0.81	0.00	0.01
CH-46E 153330	AFT. XMSN	—	—	AE	30.0	0.0	0.0	0.0	1.9	8.0	0.8	1.1	7.9	8.4	0.6
				ICP	14.38	0.02	0.91	0.31	1.11	4.66	0.38	0.00	4.17	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
CH-46E 153330	FWD XMSN A7-716C	—	—	AE	13.4	0.0	0.0	0.6	4.3	4.6	0.4	3.2	3.2	8.0	0.7
				ICP	8.12	0.02	1.08	0.91	2.70	2.48	0.33	2.07	2.92	0.23	0.01
〃	T58-GE-16 216432	—	395.9	AE	2.3	0.0	0.0	0.0	0.5	0.0	1.1	0.0	1.0	8.5	0.9
				ICP	0.70	0.04	0.79	0.19	0.60	0.08	0.40	0.00	0.60	0.00	0.01
〃	T58-GE-16 216493	—	360.8	AE	0.9	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.7	8.5	0.7
				ICP	0.26	0.01	0.51	0.19	0.59	0.05	0.28	0.00	0.38	0.00	0.00
CH-46E 153382	T58-GE-16 216201	1391.4	1.2	AE	2	0	0	0	0	0	1	0	0	—	0
				ICP	1.32	0.06	0.83	0.20	0.51	0.04	0.24	0.00	0.57	0.00	0.00
〃	T58-GE-16 216228	2111.8	1.2	AE	3	3	0	0	0	0	0	0	1	—	0
				ICP	1.77	2.12	1.04	0.26	1.20	0.08	0.48	0.00	1.41	0.00	0.00
CH-46E 153953	FWD XMSN A7-130C	512.1	420.1	AE	1.4	0.0	0.0	0.0	1.6	1.7	0.4	0.0	4.3	9.3	0.4
				ICP	0.71	0.40	0.25	0.34	1.19	0.74	0.26	0.12	3.51	0.10	0.00
〃	AFT XMSN A9-358	51.1	51.1	AE	14.1	0.2	0.7	0.0	1.8	2.8	0.7	0.0	14.1	10.0	0.8
				ICP	7.01	0.32	1.67	0.38	1.21	1.34	0.51	0.87	16.3	0.00	0.00
〃	T58-GE-16 216379	—	351.1	AE	2.6	0.0	0.0	0.0	1.8	0.0	0.9	0.0	1.5	9.4	0.6
				ICP	1.22	0.07	0.79	0.28	1.14	0.09	0.38	0.00	0.95	0.00	0.01
〃	T58-GE-16 216604	—	138.9	AE	3.9	0.3	0.0	0.0	1.8	0.0	0.7	0.0	1.2	9.4	0.7
				ICP	1.72	0.15	0.64	0.22	1.24	0.10	0.50	0.00	0.95	0.02	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
CH-46E 153974	T58-GE-16 216065	2251.9	1.0	AE	0	0	0	0.	0	0	0	0	1	—	0
				ICP	0.34	0.00	0.31	0.13	0.39	0.00	0.17	0.00	0.41	0.00	0.00
//	T58-GE-16 216582	1483.2	1.0	AE	0	0	0	0	0	0	0	0	1	—	0
				ICP	0.47	0.00	0.46	0.14	0.31	0.01	0.10	0.30	0.43	0.00	0.00
CH-46E 153981	FWD XMSN A7-1100	357.3	332.6	AE	19.9	0.0	1.4	1.5	2.5	1.8	0.5	0.3	2.5	9.1	0.4
				ICP	11.68	0.00	2.25	1.56	1.65	1.19	0.26	0.00	2.32	0.13	0.00
//	AFT XMSN A9-1030	357.3	332.6	AE	20.1	0.0	1.3	0.4	1.5	4.7	0.7	0.3	9.6	11.0	0.9
				ICP	10.43	0.05	1.75	0.51	0.86	2.28	0.42	0.00	7.36	0.11	0.00
//	T58-GE-16 216074	—	335.0	AE	2.2	0.3	0.0	0.0	0.3	0.0	0.4	0.0	1.9	10.4	0.9
				ICP	0.84	0.18	0.83	0.22	0.23	0.05	0.23	0.00	1.20	0.02	0.01
//	T58-GE-16 216675	—	333.5	AE	2.8	0.4	0.0	0.0	1.1	0.0	1.4	0.0	1.9	9.4	0.4
				ICP	1.50	0.42	0.93	0.46	0.78	0.09	0.75	0.00	1.17	0.22	0.01
CH-46E 153990	FWD XMSN A7-555	6706	435.5	AE	8.1	0.0	0.0	0.0	3.3	1.2	0.4	0.0	4.1	9.0	0.9
				ICP	4.14	0.01	0.87	0.22	1.71	0.76	0.21	0.00	3.21	0.14	0.01
//	AFT XMSN A9-1099	726.5	435.5	AE	27.9	0.0	1.4	0.0	1.9	4.7	0.4	0.3	12.1	9.2	1.1
				ICP	13.1	0.05	2.24	0.49	1.05	2.01	0.44	0.51	8.63	0.05	0.01
//	T58-GE-16 216120		203.7	AE	2.4	0.0	0.0	0.0	0.7	0.0	0.8	0.2	0.9	8.7	0.7
				ICP	1.37	0.19	1.36	0.30	0.53	0.06	0.31	0.00	1.15	0.18	0.02

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
CH-46E 153990	T58-GE-16 216378	—	285.5	AE	1.5	0.5	0.0	0.0	1.3	0.0	0.6	0.0	0.8	8.5	0.6
				ICP	0.94	0.39	0.96	0.18	0.87	0.11	0.17	0.00	0.90	0.02	0.01
CH-46E 153992	FWD XMSN A7-143C	371	370.2	AE	28.6	0.0	1.7	0.0	0.2	2.6	0.2	0.0	2.3	9.0	0.8
				ICP	16.85	0.03	2.88	1.06	0.78	2.63	0.73	0.29	4.38	0.37	0.07
"	AFT XMSN A9-55-9	371.0	371.0	AE	2.8	0.2	1.7	0.0	0.2	2.6	0.2	0.0	2.3	9.0	0.8
				ICP	1.94	0.41	2.66	0.29	0.62	1.27	0.13	1.88	2.57	0.13	0.01
"	T58-GE-16 153992	—	370.2	AE	2.7	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.9	8.1	0.7
				ICP	1.24	0.11	0.72	0.30	0.39	0.05	0.58	0.00	0.86	0.09	0.02
"	T58-GE-16 216026	—	370.2	AE	1.3	0.0	0.0	0.0	0.5	0.0	0.8	0.0	1.0	8.3	0.7
				ICP	0.82	0.14	0.34	0.24	0.62	0.10	0.30	0.00	1.28	0.18	0.02
CH-46E 154020	FWD XMSN A7-934C	1064.8	412.5	AE	4.8	0.0	0.0	0.7	1.7	0.6	0.4	0.3	0.7	9.8	0.5
				ICP	2.39	0.20	1.72	0.78	1.06	0.48	0.18	1.07	0.97	0.07	0.02
"	AFT XMSN A9-1046	1071.2	97.9	AE	17.7	0.0	2.7	0.5	3.3	2.9	0.8	0.4	10.1	1.1	—
				ICP	9.88	0.09	3.02	0.66	1.85	1.54	0.43	1.15	7.98	0.00	0.00
"	T58-GE-16 216111	1722.5	564.2	AE	0.8	0.0	0.0	0.0	0.2	0.0	0.3	0.0	1.2	9.2	0.6
				ICP	0.65	0.02	1.28	0.24	0.54	0.02	0.33	0.44	1.09	0.00	0.00
"	T58-GE-16 216630	2099.5	842.6	AE	0.4	0.0	0.0	0.0	0.4	0.0	0.3	0.0	6.8	9.6	0.5
				ICP	0.38	0.01	1.00	0.15	0.65	0.03	0.27	0.58	4.73	0.02	0.03

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
CH-46E 156469	FWD XMSN A7-142	486.0	444.0	AE	29.5	0.0	0.9	0.6	0.5	5.3	1.1	0.7	5.1	9.0	0.8
				ICP	15.5	0.03	1.84	0.66	0.54	2.47	0.46	0.00	4.01	0.34	0.02
"	AFT XMSN A9-211	486.0	123.0	AE	4.3	0.0	0.0	0.0	0.3	7.5	0.0	0.0	3.2	9.9	1.1
				ICP	2.30	0.14	0.75	0.13	0.18	3.19	0.19	0.09	2.94	0.22	0.01
"	T58-GE-16 216088	–	123.0	AE	1.1	0.0	0.0	0.0	0.5	0.0	0.7	0.0	1.2	8.7	0.6
				ICP	0.66	0.09	0.86	0.24	0.43	0.06	0.23	0.00	1.07	0.00	0.01
"	T58-GE-16 216390	–	123.0	AE	2.7	0.0	0.0	0.0	0.0	0.0	1.5	0.0	1.1	8.9	0.6
				ICP	1.49	0.15	0.90	0.44	0.31	0.06	0.59	0.00	0.89	0.00	0.02
CH-46E 157687	FWD XMSN A7-646C	637.6	397.6	AE	6	0	0	0	2	0	0	0	5	–	0
				ICP	3.96	0.00	0.68	0.69	1.26	0.35	0.17	2.66	4.12	0.00	0.00
"	AFT XMSN A7-1107	1015.8	391.1	AE	16	0	0	0	3	7	1	0	3	–	0
				ICP	10.6	0.00	1.62	0.27	2.19	3.70	0.26	0.26	2.00	0.00	0.00
"	T58-GE-16 216075	1214.3	125.2	AE	2	0	0	0	0	0	1	0	1	–	1
				ICP	1.22	0.07	0.50	0.19	0.48	0.00	0.25	0.39	0.32	0.00	0.00
"	T58-GE-16 216490	1439.5	442.6	AE	1	0	0	0	0	0	0	0	1	–	0
				ICP	0.65	0.00	0.37	0.06	0.52	0.00	0.22	0.22	0.59	0.00	0.00
CH-46E 157706	FWD XMSN A7-240	529	273	AE	9	2	0	0	3	5	0	0	3	7	0
				ICP	3.76	0.86	0.52	0.32	0.51	1.34	0.06	0.29	1.79	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
CH-46E 157706	AFT XMSN A9-1021	570	273	AE	26	0	1	0	4	10	0	0	20	7	0
				ICP	11.4	0.00	2.17	0.53	1.55	3.29	0.23	0.00	10.5	0.00	0.00
"	T58-GE-16 216220	1680	1680	AE	1	0	1	0	0	0	0	0	0	0	0
				ICP	2.90	0.38	1.24	0.53	0.84	0.09	0.80	0.28	4.31	0.20	0.00
"	T58-GE-16 216716	1680	1680	AE	1	0	0	0	0	0	0	0	2	10	0
				ICP	0.67	0.08	0.34	0.14	0.56	0.02	0.14	0.00	0.90	0.00	0.00
CH-46E 157713	FWD XMSN A7-418C	664.5	462.5	AE	15.1	0.0	2.7	2.6	2.6	1.5	0.7	0.0	2.9	8.9	0.5
				ICP	8.13	0.05	3.07	2.21	1.51	0.94	0.40	0.31	2.71	0.19	0.08
"	AFT XMSN A9-832	1248.8	462.2	AE	31.2	0.0	4.0	0.7	2.4	8.3	1.0	1.0	4.7	10.5	0.9
				ICP	15.6	0.03	3.31	0.70	1.19	3.62	0.51	0.00	3.92	0.17	0.01
"	T58-GE-16 216253	—	155.2	AE	1.8	0.0	0.0	0.0	1.0	0.0	0.7	0.0	2.3	9.7	0.8
				ICP	0.84	0.11	1.19	0.31	0.75	0.07	0.33	0.00	1.74	0.18	0.02
"	T58-GE-16 216502	—	155.2	AE	1.0	0.0	0.0	0.0	0.3	0.0	0.6	0.0	0.5	9.8	0.8
				ICP	0.70	0.06	0.74	0.23	0.55	0.05	0.29	0.00	0.84	0.23	0.01
CH-46E 157726	AFT XMSN —	—	—	AE	36	0.0	1.4	0.3	3.8	13.0	0.6	1.0	9.0	10.7	0.8
				ICP	21.6	0.15	2.25	0.87	2.29	6.54	0.55	0.32	7.77	0.00	0.00
"	FWD XMSN A7-1116C	1037.3	241.3	AE	1.5	0.0	0.0	0.0	1.0	0.8	0.4	0.0	0.4	9.3	0.4
				ICP	1.42	0.00	0.84	0.22	1.09	0.65	0.16	0.00	1.89	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
CH-46E 157726	T58-GE-16 216189	-	389.4	AE	1.5	0.0	0.9	0.0	0.0	0.0	1.2	0.0	1.3	9.5	0.3
				ICP	1.04	0.08	1.92	0.41	0.60	0.10	0.58	0.20	1.08	0.00	0.02
"	T58-GE-16 216411	—	898.8	AE	2.2	0.0	0.0	0.0	0.5	0.0	0.5	0.2	1.6	12.6	1.1
				ICP	1.02	0.15	1.26	0.28	0.71	0.07	0.40	0.32	1.41	0.02	0.02
				AE											
				ICP											
CH-53E 162523	Nose GBX A1501074	79	79	AE	1	0	1	0	0	0	0	0	0	0	0
				ICP	2.54	0.09	1.19	0.23	1.69	6.40	0.19	0.00	5.56	0.00	0.00
"	Nose GBX A1501075	79	79	AE	12	0	0	0	7	20	0	0	1	8	0
				ICP	4.78	0.02	1.32	0.27	2.83	6.29	0.18	0.00	0.43	0.07	0.00
"	T64-GE-416 269579	79	79	AE	6	0	0	0	0	1	0	0	1	4	1
				ICP	0.60	0.00	0.26	0.12	0.26	0.03	0.13	0.22	0.96	0.16	0.00
"	T64-GE-416 269580	79	79	AE	6	0	0	0	0	0	0	0	1	5	1
				ICP	0.69	0.00	0.34	0.11	0.22	0.00	0.10	0.00	1.03	0.00	0.00
"	T64-GE-416 269582	79	79	AE	2	0	0	0	0	0	0	0	1	7	0
				ICP	0.74	0.00	0.33	0.13	0.30	0.00	0.19	0.00	0.93	0.00	0.00
"	Main GBX A14600170	79	79	AE	37	0	1	0	15	7	1	0	1	7	1
				ICP	17.0	0.00	2.30	0.39	6.27	2.54	0.49	4.55	1.21	0.32	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
					Trace Metal Concentration, ppm										
CH-53E 162523	Access. GBX A14700149	79	79	AE	17	0	0	0	4	6	0	0	1	7	0
				ICP	6.3	0.00	1.22	0.32	1.56	1.57	0.10	0.71	1.12	0.00	0.00
"	Int. GBX A23500187	79	79	AE	2	0	0	0	0	0	0	0	0	8	0
				ICP	0.63	0.00	0.51	0.10	0.34	0.10	0.16	0.05	1.28	0.14	0.00
"	Tail GBX A23600180	79	79	AE	36	0	0	0	14	7	1	1	2	8	1
				ICP	16.4	0.08	1.31	0.41	6.14	2.52	0.61	3.72	2.00	0.12	0.14
CH-53E 162524	Main GBX A14600171	68.4	68.4	AE	23	0	0	0	3	4	1	3	1	–	1
				ICP	15.3	0.23	1.00	0.41	2.18	2.42	0.49	3.50	0.55	0.00	0.10
"	Access. GBX A14700150	68.4	68.4	AE	9	0	0	0	0	3	0	0	0	–	1
				ICP	7.15	0.00	0.78	0.43	0.40	1.94	0.15	0.00	0.05	0.00	0.00
"	Nose GBX A1501077	68.4	68.4	AE	4	0	0	0	3	4	0	0	0	–	1
				ICP	2.51	0.08	0.55	0.42	1.82	2.59	0.17	0.47	0.28	0.00	0.00
CH-53E 162526	T64-GE-416 269589	26.9	26.9	AE	6	0	0	0	0	0	0	0	1	–	1
				ICP	3.63	0.00	0.16	0.18	0.36	0.15	0.08	0.00	0.94	0.00	0.00
"	T64-GE-416 269590	26.9	26.9	AE	8	0	0	0	0	0	0	0	2	–	0
				ICP	5.62	0.00	0.08	0.14	0.31	0.05	0.05	0.00	1.72	0.00	0.00
"	T64-GE-416 269591	26.9	26.9	AE	3	0	0	0	0	0	0	0	1	–	0
				ICP	2.16	0.00	0.13	0.13	0.37	0.01	0.07	0.00	0.82	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
CH-53E 162526	Nose GBX A1501089	26.9	26.9	AE	2	1	0	0	1	4	0	0	1	–	0
				ICP	1.51	0.32	0.78	0.16	1.07	2.48	0.08	0.00	0.75	0.00	0.00
"	Nose GBX A150 18084	26.9	26.9	AE	2	0	0	0	2	5	0	0	0	–	0
				ICP	1.66	0.09	0.53	0.22	1.71	2.77	0.11	0.00	0.21	0.04	0.00
"	Int. GBX A2350019 1	26.9	26.9	AE	4	0	0	0	0	0	1	0	0	–	1
				ICP	2.09	0.21	0.28	0.07	0.65	0.29	0.13	0.00	0.28	0.00	0.00
				AE											
				ICP											
AH-460 151948	FWD XMSN A7-192C	8351	31.6	AE	9.4	0.0	0.0	0.5	1.8	2.4	0.9	0.4	3.7	8.7	0.3
				ICP	5.40	0.00	0.76	0.74	1.32	1.37	0.24	0.12	3.17	0.12	0.01
"	AFT-XMSN A9-1123	3398.3	31.6	AE	3.7	0.0	0.0	0.0	0.0	0.9	0.3	0.0	0.4	9.5	0.5
				ICP	1.95	0.09	0.42	0.16	0.33	0.43	0.25	0.00	0.97	0.00	0.14
"	T58-GE-10 282 003	5294.4	31.6	AE	5.7	0.3	0.0	0.2	0.0	0.0	1.2	0.0	2.7	9.8	0.9
				ICP	3.58	0.25	1.14	0.70	0.42	0.24	0.94	0.23	2.54	0.28	0.06
"	T58-GE-10 282 124	4248.3	31.6	AE	8.9	0.9	1.7	0.6	0.6	2.3	2.0	0.0	6.3	8.7	0.5
				ICP	6.43	0.94	3.05	1.27	1.12	1.71	1.38	0.00	4.94	0.16	0.09
AH460 150964	AFT XMSN A9-964	6449.0	–	AE	43	0.0	4.7	0.3	2.9	8.6	0.0	0.0	10	6.6	0.0
				ICP	22.5	0.00	2.29	0.41	1.19	3.37	0.24	0.00	6.04	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
Test Cell	F404-GE-400 310250	505	-	AE	0	0	0	0	1	0	1	0	1	11	1
				ICP	0.12	0.00	0.08	0.15	0.24	0.01	0.28	0.69	0.13	0.00	0.00
"	F404-GE-400 310890	468	-	AE	0	0	0	0	0	0	1	0	1	10	1
				ICP	0.09	0.00	0.39	0.22	0.17	0.00	0.81	0.80	0.30	0.00	0.00
"	F404-GE-400 311005	442	-	AE	1	0	0	0	1	0	1	0	1	10	1
				ICP	0.18	0.00	0.13	0.14	0.45	0.02	0.26	0.53	0.35	0.00	0.00
"	F404-GE-400 311010	481	-	AE	0	0	0	0	1	0	1	0	1	11	1
				ICP	0.14	0.00	1.30	0.14	0.24	0.01	0.13	0.67	0.36	0.00	0.00
"	F404-GE-400 311029	405	-	AE	0	0	0	0	1	0	1	0	1	9	1
				ICP	0.12	0.00	0.57	0.16	0.32	0.02	0.30	0.06	0.44	0.00	0.01
Test Cell	F404-GE-400 311056	177	-	AE	1	0	0	0	0	0	1	1	2	11	1
				ICP	0.27	0.00	0.18	0.18	0.40	0.02	0.23	0.53	0.35	0.00	0.00
F-18 161354	"	235	12	AE	1	1	0	0	1	1	1	0	2	10	2
				ICP	0.19	0.13	0.34	0.16	0.43	0.00	0.20	0.50	0.25	0.00	0.00
"	"	240	17	AE	1	0	0	0	1	0	1	0	1	7	0
				ICP	0.23	0.01	0.53	0.22	0.45	0.01	0.17	0.00	0.51	0.14	0.00
"	"	243	20	AE	0	0	0	0	1	0	1	0	1	8	1
				ICP	0.22	0.03	0.15	0.18	0.48	0.02	0.28	0.00	0.70	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
Test Cell	F404-GE-400 311057	177	-	AE	1	0	0	[illegible]	2	0	1	0	1	10	1
				ICP	0.33	0.00	0.12	[illegible]	0.68	0.02	0.23	0.45	0.45	0.00	0.00
F-18 161854	"	235	12	AE	1	1	0	0	4	0	1	0	2	10	2
				ICP	0.25	0.00	0.83	0.18	0.58	0.00	0.20	0.00	0.32	0.06	0.00
"	"	240	17	AE	1	0	0	0	1	0	0	0	1	7	0
				ICP	0.31	0.00	0.44	0.19	0.74	0.01	0.19	0.00	0.47	0.00	0.00
"	"	243	20	AE	0	0	0	0	2	0	0	0	1	9	1
				ICP	0.31	0.01	0.05	0.21	0.85	0.01	0.39	0.14	0.59	0.00	0.00
Test Cell	F404-GE-400 311069	200	-	AE	1	0	0	0	0	0	1	0	1	11	1
				ICP	0.17	0.00	0.18	0.16	0.32	0.02	0.12	0.49	0.32	0.00	0.00
F-18 161354	F404-GE-400 310658	1316	-	AE	1	0	0	1	0	0	0	0	0	3	10
				ICP	0.23	0.00	0.39	0.23	0.19	0.02	0.41	0.00	0.47	0.00	0.04
"	"	1320	2	AE	1	0	0	1	0	0	1	0	3	11	0
				ICP	0.20	0.00	0.51	0.21	0.25	0.02	0.46	0.00	0.33	0.00	0.04
"	"	2286	-	AE	0	0	0	1	0	0	1	0	1	7	0
				ICP	0.19	0.03	0.28	0.17	0.30	0.01	0.33	0.61	1.52	0.23	0.04
"	"	2307	-	AE	0	0	0	0	0	0	1	0	1	9	0
				ICP	0.14	0.00	0.02	0.11	0.31	0.01	0.18	0.00	0.30	0.00	0.34

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F18 161354	F404-GE-400 310 658	2334	-	AE	1	0	0	0	0	0	1	0	[illegible]	[illegible]	0
				ICP	0.18	0.03	0.28	0.19	0.33	0.01	0.24	1.96	0.35	0.20	0.04
"	"	-	-	AE	1	0	0	1	1	0	2	0	1	10	0
				ICP	0.15	0.00	0.12	0.16	0.04	0.01	0.29	0.00	0.00	0.00	0.02
"	"	-	-	AE	1	0	0	0	0	0	1	0	1	10	0
				ICP	0.18	0.00	0.81	0.19	2.31	0.01	0.21	0.00	0.29	0.17	0.04
F-18 161354	F404-GE-400 310775	935	-	AE	0	0	0	0	1	0	0	0	0	11	0
				ICP	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	949	-	AE	1	0	0	1	0	0	0	1	3	11	0
				ICP	0.12	0.00	0.24	0.16	0.12	0.02	0.18	0.00	0.43	0.00	0.05
"	"	959	-	AE	0	0	0	1	0	0	0	0	2	11	0
				ICP	0.20	0.00	0.51	0.21	0.25	0.02	0.96	0.00	0.33	0.00	0.04
"	"	-	-	AE	1	0	0	1	1	0	0	0	1	10	1
				ICP	0.00	0.00	0.00	0.00	0.08	0.00	0.00	—	0.00	0.20	0.00
"	"	2276	-	AE	1	0	0	1	1	0	0	0	1	7	0
				ICP	0.00	0.00	0.00	0.00	0.13	0.00	0.00	—	0.00	0.00	0.00
"	"	2307	-	AE	0	0	0	0	0	0	0	0	0	8	0
				ICP	0.10	0.00	0.00	0.09	0.29	0.01	0.17	0.00	0.78	0.00	0.02

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161354	F404-GE-400 310775	2334	-	AE	1	0	0	0	0	0	1	0	0	11	0
				ICP	0.17	0.06	0.05	0.18	0.32	0.01	0.15	2.15	2.11	0.00	0.02
"	"	-	-	AE	1	1	0	1	1	0	1	0	1	10	0
				ICP	0.14	0.00	0.49	0.16	0.00	0.00	0.19	0.00	0.00	0.00	0.02
F-18 161355	F404-GE-400 310380	-	-	AE	1	0	0	0	1	0	2	0	1	7	0
				ICP	0.36	0.00	0.05	0.28	0.55	0.05	0.42	0.00	0.41	0.00	0.10
"	"	1164	22	AE	2	0	0	1	1	0	1	0	4	11	0
				ICP	0.38	0.00	0.26	0.29	0.42	0.04	0.63	0.00	0.46	0.00	0.07
"	"	1174	12	AE	1	0	0	1	1	0	1	0	3	11	0
				ICP	0.42	0.01	0.24	0.33	0.54	0.03	0.52	0.00	0.38	0.00	0.07
"	"	1181	5	AE	1	0	0	1	2	0	2	1	2	10	0
				ICP	0.44	0.03	0.38	0.43	0.66	0.02	0.50	0.00	0.65	0.05	0.11
"	"	1198	17	AE	2	1	0	1	2	0	1	0	0	11	0
				ICP	0.28	0.00	0.00	0.26	0.	0.03	0.40	0.00	0.31	0.00	0.06
"	"	1347	166	AE	1	0	0	0	1	0	1	1	1	11	0
				ICP	0.00	0.00	0.00	0.21	0.00	0.00	0.40	0.00	0.00	0.00	0.14
		2326	-	AE	0	0	0	0	0	0	1	0	1	9	0
				ICP	0.09	0.00	0.00	0.07	0.32	0.01	0.25	0.00	0.09	0.00	0.03

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161354	F404-GE-400 310969	-	-	AE	0	0	0	0	0	0	1	0	1	7	0
				ICP	0.19	0.31	0.04	0.21	0.35	0.08	0.10	0.98	1.03	0.00	0.08
"	"	874	22	AE	1	0	0	1	0	0	0	0	5	10	0
				ICP	0.13	0.02	0.22	0.18	0.08	0.01	0.24	0.00	0.69	0.00	0.02
"	"	883	12	AE	1	0	0	1	0	0	0	0	3	12	0
				ICP	0.16	0.03	0.29	0.19	0.13	0.00	0.24	0.00	0.59	0.00	0.02
"	"	890	5	AE	1	0	0	0	0	0	1	0	3	9	0
				ICP	0.01	0.03	0.00	0.20	0.20	0.00	0.05	0.00	0.78	0.00	0.02
"	"	908	17	AE	0	1	0	1	1	0	1	0	1	12	0
				ICP	0.03	0.02	0.10	0.12	0.00	0.02	0.18	0.00	0.64	0.00	0.03
"	"	986	95	AE	1	0	0	0	1	0	0	0	0	11	0
				ICP	0.00	0.00	0.00	0.16	0.02	0.00	0.12	0.00	0.00	0.00	0.03
Test Cell	F404-GE-400 310138	1024	—	AE	1	0	0	0	1	0	1	0	1	11	1
				ICP	0.25	0.03	0.13	0.18	0.55	0.03	0.20	0.68	0.29	0.00	0.00
F-18 161355	"	1097	—	AE	1	1	0	0	2	1	1	0	1	11	3
				ICP	0.15	0.00	0.78	0.19	0.56	0.00	0.23	0.00	0.23	0.00	0.00
"	"	1121	—	AE	0	0	0	0	2	0	1	0	0	8	0
				ICP	0.56	0.00	0.38	0.33	1.10	0.02	0.40	0.00	0.48	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18	F404-GE-400	1136	25	AE	0	0	0	0	0	0	1	0	1	7	0
161355	310131			ICP	0.23	0.00	0.62	0.19	0.93	0.01	0.25	0.00	0.38	0.06	0.00
"	"	1144	-	AE	0	0	0	0	2	0	1	0	0	9	1
				ICP	0.16	0.03	0.29	0.18	0.88	0.02	0.32	0.04	0.38	0.00	0.00
"	F404-GE-400	2326	-	AE	0	0	0	1	0	0	1	0	1	8	0
	310242			ICP	0.07	0.02	0.12	0.07	0.28	0.01	0.14	0.00	0.03	0.00	0.02
"	"	2355	-	AE	1	0	0	0	0	0	1	0	1	12	0
				ICP	0.13	0.00	0.11	0.11	0.27	0.01	0.13	2.04	0.43	0.00	0.06
"	"	-	-	AE	1	0	0	0	0	0	1	0	1	10	0
				ICP	0.17	0.00	0.61	0.21	0.16	0.00	0.16	0.00	0.00	0.00	0.03
"	"	-	-	AE	1	0	0	1	0	0	1	0	1	10	0
				ICP	0.12	0.00	0.43	0.15	0.23	0.01	0.14	0.00	0.00	0.00	0.02
"	F404-GE-400	2355	-	AE	1	0	0	0	0	0	1	0	0	12	0
	310449			ICP	0.10	0.00	0.00	0.08	0.29	0.01	0.10	2.04	0.27	0.00	0.00
"	"	"	-	AE	1	0	0	0	0	0	1	0	1	11	0
				ICP	0.09	0.00	0.30	0.12	0.22	0.01	0.07	0.00	0.00	0.00	0.01
"	F404-GE-400	1256	-	AE	1	0	0	0	2	0	1	0	0	11	0
	310685			ICP	0.25	0.00	0.00	0.36	0.50	0.00	0.57	0.00	0.00	0.00	0.06

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F13-161355	F404-GE-400 310685	–	–	AE	1	0	0	1	1	0	0	0	1	10	0
				ICP	0.00	0.00	0.00	0.00	[illegible]	0.00	0.00	–	0.00	0.00	0.00
"	"	2276	–	AE	0	0	0	1		0	0	0	1	6	0
				ICP	0.00	0.00	0.00	0.00	0.18	0.00	0.00	–	0.00	0.08	0.00
"	F404-GE-400 310830	–	–	AE	2	0	0	2	2	0	0	0	1	10	1
				ICP	0.00	0.00	0.00	0.00	0.58	0.00	0.00	–	0.00	0.00	0.00
Test Cell	F404-GE-400 311055	231	–	AE	1	0	0	0	1	0	1	0	1	11	1
				ICP	0.20	0.02	0.95	0.18	0.38	0.01	0.21	0.65	0.41	0.02	0.00
F18 - 161355	"	304	–	AE	1	1	0	0	1	0	1	0	2	9	2
				ICP	0.08	0.00	0.72	0.12	0.32	0.00	0.21	0.00	0.22	0.00	0.00
"	"	328	–	AE	0	0	0	0	0	0	1	0	0	10	0
				ICP	0.18	0.00	0.43	0.22	0.64	0.01	0.26	0.00	0.32	0.00	0.00
"	"	343	–	AE	0	0	0	0	0	0	1	0	0	6	0
				ICP	0.16	0.01	0.43	0.19	0.41	0.00	0.15	[illegible]	0.35	0.00	0.00
"	"	351	–	AE	0	0	0	0	1	0	0	0	1	9	1
				ICP	0.14	0.06	0.00	0.19	0.46	0.02	0.28	1.01	0.36	0.00	0.00
Test Cell	F404-GE-400 310123	850	–	AE	1	0	6	0	1	0	1	1	1	12	1
				ICP	0.20	0.00	4.12	0.17	0.50	0.01	0.24	0.31	0.27	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F18 161519	F404-GE-400 310123	942	-	AE	2	1	0	0	1	0	1	0	1	14	2
				ICP	0.03	0.00	0.67	0.18	0.80	0.00	0.22	0.00	0.04	0.14	0.00
"	"	950	-	AE	1	0	0	0	1	0	1	1	1	11	1
				ICP	0.05	0.00	1.17	0.15	0.40	0.00	0.16	0.24	0.20	0.04	0.00
"	"	970	-	AE	0	0	0	0	1	0	1	0	1	9	1
				ICP	0.32	0.01	0.63	0.26	0.59	0.03	0.69	0.00	0.42	0.00	0.01
"	"	984	-	AE	0	0	0	0	0	0	1	0	0	7	0
				ICP	0.18	0.01	0.35	0.19	0.37	0.00	0.00	0.00	0.72	0.00	0.00
"	"	993	-	AE	0	0	0	0	1	0	1	0	0	9	1
				ICP	0.22	0.04	0.32	0.18	0.72	0.02	0.51	0.04	0.29	0.00	0.01
F-18 161519	F404-GE-400 310137	1863	-	AE	2	1	0	0	2	0	1	0	1	14	2
				ICP	0.08	0.00	0.56	0.19	0.96	0.00	0.27	0.00	0.11	0.00	0.00
"	"	1870	-	AE	1	0	0	0	1	0	1	0	1	10	0
				ICP	0.06	0.00	0.65	0.13	0.60	0.00	0.21	0.22	0.21	0.00	0.00
"	"	1235?	-	AE	0	0	0	0	1	0	0	0	0	8	0
				ICP	0.09	0.07	0.36	0.19	0.53	0.05	0.22	0.25	0.35	0.07	0.01
F-18 161519	F404-GE-400 310895	830	-	AE	1	0	0	0	1	0	1	0	0	11	0
				ICP	0.00	0.00	0.00	0.14	0.00	0.00	0.16	0.00	0.00	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr		Mg	Ni	Pb	Si	Sn	Ti
F-18 161519	F404-GE-400 310895	1425	-	AE	0	0	0	1	1	0	0	0	1	7	0
				ICP	0.00	0.00	0.00	0.00	0.13	0.00	0.00	—	0.00	0.00	0.00
"	"	-	-	AE	1	0	0	1	1	0	0	0	1	8	0
				ICP	0.00	0.00	0.00	0.00	0.19	0.00	0.00	—	0.00	0.00	0.00
"	"	1448	-	AE	0	0	0	0	0	0	1	0	1	7	0
				ICP	0.14	0.05	0.14	0.12	0.23	0.01	0.19	0.00	0.17	0.00	0.03
"	"	1473	-	AE	0	0	0	0	0	0	1	0	0	6	0
				ICP	0.13	0.03	0.09	0.11	0.27	0.00	0.22	0.00	0.09	0.00	0.02
"	"	1502	-	AE	1	0	0	0	0	0	1	0	2	10	0
				ICP	0.11	0.04	0.20	0.10	0.33	0.01	0.15	—	0.16	0.00	0.02
"	"	-	-	AE	1	1	0	1	1	0	1	1	1	11	0
				ICP	0.09	0.00	0.36	0.12	0.22	0.01	0.09	0.00	0.00	0.00	0.01
"	"	-	-	AE	1	0	0	0	0	0	1	0	2	11	0
				ICP	0.10	0.00	0.64	0.11	0.25	0.01	0.00	0.00	0.00	0.00	0.01
"	F404-GE-400 311920	-	-	AE	1	0	0	0	0	0	1	0	1	8	0
				ICP	0.14	0.04	0.02	0.17	0.34	0.02	0.16	0.00	0.49	0.00	0.02
"	"	391	-	AE	2	0	0	1	0	0	2	0	4	11	1
				ICP	0.16	0.04	0.26	0.16	0.24	0.01	0.22	0.00	0.65	0.00	0.02

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161519	F404-GE-400 311920	402	-	AE	1	0	0	1	0	0	0	0	3	12	0
				ICP	0.18	0.04	0.22	0.41	0.28	0.00	0.34	0.00	0.39	0.00	0.02
"	"	410	-	AE	1	0	0	0	1	0	1	0	3	10	0
				ICP	0.40	0.03	0.22	0.21	0.40	0.00	0.22	0.00	0.36	0.00	0.03
"	"	432	-	AE	1	1	0	1	1	0	1	0	0	11	0
				ICP	0.05	0.04	0.05	0.15	0.09	0.02	0.30	0.00	0.43	0.00	0.09
"	"	451	-	AE	1	0	0	0	1	0	0	0	1	11	0
				ICP	0.00	0.00	0.00	0.15	0.00	0.00	0.17	0.00	0.00	0.00	0.00
"	"	1425	-	AE	0	0	0	2	1	0	0	0	1	7	0
				ICP	0.00	0.00	0.00	0.00	0.10	0.00	0.00	-	0.00	0.21	0.00
"	"	-	-	AE	1	0	0	2	1	0	0	0	1	8	0
				ICP	0.00	0.00	0.00	0.00	0.13	0.00	0.00	-	0.00	0.02	0.00
"	"	1448	-	AE	0	0	0	0	0	0	0	0	1	8	0
				ICP	0.10	0.02	0.16	0.14	0.09	0.01	0.19	0.00	0.85	0.00	0.01
"	"	1473	-	AE	0	0	0	1	0	0	1	0	0	6	0
				ICP	0.11	0.07	0.24	0.10	0.25	0.01	0.10	0.04	0.70	0.03	0.05
"	"	1502	-	AE	1	0	0	0	0	0	1	0	0	10	0
				ICP	0.15	0.07	0.20	0.15	0.30	0.01	0.17	-	0.64	0.25	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161519	F 404-GE-400 311920	–	–	AE	1	1	0	1	1	0	1	1	1	11	0
				ICP	0.12	0.02	0.45	0.14	0.11	0.00	0.12	0.00	0.00	0.00	0.02
"	"	–	–	AE	1	0	0	1	0	0	1	0	1	9	0
				ICP	0.10	0.00	0.52	0.13	0.23	0.01	0.14	0.00	0.00	0.00	0.01
"	F404-GE-400 310661	1225	–	AE	0	0	0	0	1	0	1	0	1	7	0
				ICP	0.36	0.00	0.54	0.19	0.67	0.04	0.57	0.00	0.36	0.00	0.00
"	"	–	–	AE	0	0	0	0	0	0	1	0	1	7	0
				ICP	0.06	0.04	0.06	0.18	0.19	0.01	0.02	0.00	0.57	0.00	0.01
"	"	1408	–	AE	1	0	0	1	0	0	0	0	5	11	0
				ICP	0.06	0.01	0.16	0.14	0.07	0.02	0.12	0.00	0.70	0.00	0.01
"	"	1419	–	AE	1	0	0	1	0	0	0	0	3	11	0
				ICP	0.09	0.03	0.19	0.16	0.13	0.01	0.18	0.00	0.49	0.00	0.01
"	"	1427	–	AE	1	0	0	0	1	0	1	0	4	10	0
				ICP	0.14	0.05	0.27	0.24	0.25	0.00	0.17	0.00	0.69	0.13	0.03
"	"	1448	–	AE	1	1	0	1	1	0	1	1	1	11	0
				ICP	0.00	0.00	0.00	0.09	0.00	0.01	0.09	0.00	0.38	0.00	0.00
F-18 161520	F404-GE-400 311018	383	–	AE	2	1	0	0	2	1	1	1	3	11	3
				ICP	0.22	0.05	0.60	0.16	0.64	0.00	0.29	0.23	0.38	0.16	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161520	F 404-GE-400 310661	1212	–	AE	1	1	0	0	1	0	1	0	2	10	2
				ICP	0.00	0.00	0.50	0.18	0.25	0.00	0.07	0.00	0.33	0.00	0.00
F-18 161523	F 404-GE-400 310824	783	–	AE	2	1	0	0	1	1	1	1	1	14	2
				ICP	0.28	0.00	0.36	0.24	0.60	0.01	0.34	0.00	0.50	0.13	0.02
"	"	790	–	AE	1	0	0	0	0	0	1	0	1	9	0
				ICP	0.14	0.00	0.59	0.17	0.26	0.00	0.22	0.02	0.20	0.00	0.00
"	"	808	–	AE	0	0	0	0	0	0	1	0	1	10	1
				ICP	0.22	0.03	0.61	0.29	0.58	0.03	0.29	0.00	0.59	0.00	0.02
"	"	820	–	AE	0	0	0	0	1	0	1	0	0	7	1
				ICP	0.21	0.03	0.17	0.20	0.49	0.01	0.33	–	0.24	0.00	0.16
Test Cell	F 404-GE-400 311012	350	–	AE	1	0	0	0	1	1	1	0	1	8	1
				ICP	0.26	0.00	0.33	0.16	0.32	0.01	0.20	0.00	0.45	0.00	0.01
F-18 161523	"	459	–	AE	2	1	0	0	1	0	1	1	1	13	2
				ICP	0.40	0.01	0.06	0.26	0.61	0.00	0.45	0.00	0.82	0.34	0.01
"	"	467	–	AE	1	0	0	0	0	0	1	0	0	10	0
				ICP	0.19	0.00	0.19	0.17	0.28	0.00	0.20	0.31	0.21	0.00	0.00
"	"	484	–	AE	1	0	0	0	0	0	1	0	1	10	1
				ICP	0.33	0.19	0.53	0.29	0.62	0.04	0.39	0.00	0.80	0.00	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161523	F404-GE-400 311012	497	-	AE	0	0	0	0	0	0	0	0	1	9	1
				ICP	0.16	0.00	0.00	0.25	0.40	0.01	0.22	–	0.31	0.00	0.09
F-18 161524	F404-GE-400 310178	–	-	AE	0	0	0	0	0	0	0	0	1	7	0
				ICP	0.06	0.10	0.00	0.16	0.21	0.01	0.00	0.00	0.45	0.01	0.01
"	"	2196	-	AE	1	0	0	1	0	0	0	0	3	11	0
				ICP	0.09	0.08	0.33	0.16	0.12	0.02	0.11	0.00	0.50	0.00	0.02
"	"	2207	-	AE	1	0	0	1	0	0	1	0	3	12	0
				ICP	0.10	0.09	0.18	0.17	0.14	0.03	0.22	0.00	0.50	0.00	0.03
"	"	2215	-	AE	1	0	0	0	1	0	1	0	6	9	0
				ICP	0.10	0.04	0.21	0.20	0.18	0.00	0.16	0.00	0.54	0.00	0.04
"	"	2232	-	AE	0	1	0	1	1	0	1	0	0	10	0
				ICP	0.00	0.05	0.02	0.12	0.09	0.00	0.15	0.00	0.38	0.00	0.02
"	"	2254	-	AE	0	0	0	0	1	0	0	0	0	11	0
				ICP	0.00	0.00	0.00	0.15	0.00	0.00	0.17	0.00	0.00	0.00	0.00
"	"	2330	-	AE	0	0	0	1	0	0	0	0	1	7	0
				ICP	0.00	0.00	0.00	0.00	0.03	0.04	0.00	–	0.00	0.00	0.00
"	F404-GE-400 310652	1196	-	AE	1	0	0	0	1	0	0	0	1	12	2
				ICP	0.07	0.00	0.79	0.25	0.63	0.00	0.18	0.00	0.07	0.54	0.00

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18	F404-GE-400			AE	0	0	0	0	0	0	1	0	0	9	0
161524	310652	1203	914	ICP	0.01	0.00	0.77	0.18	0.23	0.00	0.12	0.15	0.00	0.00	0.00
"	"	1220	6	AE	0	0	0	1	0	0	1	0	1	9	1
				ICP	0.17	0.00	0.67	0.31	0.54	0.02	0.28	0.00	0.44	0.03	0.02
"	"	1230	-	AE	0	0	0	0	0	0	1	0	2	6	0
				ICP	0.15	0.00	0.73	0.27	0.33	0.00	0.19	0.00	0.35	0.05	0.00
"	"	1239	-	AE	0	0	0	0	0	0	1	0	0	7	1
				ICP	0.12	0.01	0.62	0.22	0.50	0.01	0.29	0.54	0.14	0.00	0.16
"	F404-GE-400	-	-	AE	1	0	0	0	0	0	1	0	1	6	0
	310972			ICP	0.13	0.00	0.00	0.17	0.[illegible]2	0.03	0.24	0.00	0.29	0.00	0.02
"	"	1217	-	AE	1	0	0	1	0	0	1	0	3	9	0
				ICP	0.20	0.02	0.49	0.20	0.27	0.03	0.51	0.00	0.50	0.00	0.04
"	"	1228	-	AE	1	0	0	1	0	0	1	0	2	11	0
				ICP	0.23	0.00	0.18	0.18	0.25	0.03	0.43	0.00	0.39	0.00	0.04
"	"	1235	-	AE	1	0	0	0	1	0	1	0	3	9	0
				ICP	0.21	0.00	0.40	0.26	0.32	0.02	0.39	0.25	0.74	0.17	0.05
"	"	1253	-	AE	1	1	0	1	1	0	1	0	0	10	0
				ICP	0.01	0.00	0.00	0.11	0.17	0.16	0.26	0.00	0.20	0.00	0.01

Trace Metal Concentration, ppm (Fe through Ti)

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm												
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti		
F-18 161524	F404-GE-400 310972	1274	-	AE	1	0	0	0	1	0	0	0	1	10	0		
				ICP	0.00	0.00	0.00	0.16	0.28	0.00	0.30	0.00	0.00	0.00	0.02		
"	"	2330	-	AE	1	0	0	1	1	0	0	0	1	9	0		
				ICP	0.00	0.00	0.00	0.00	0.15	0.00	0.00	-	0.00	0.00	0.00		
Test Cell	F404-GE-400 311046	308	-	AE	0	0	0	0	1	0	1	0	1	10	1		
				ICP	0.68	0.00	0.25	0.1	0.30	0.02	0.22	0.67	0.48	0.00	0.00		
F-18 161529	"	411	-	AE	2	1	0	0	1	1	1	0	2	13	2		
				ICP	0.08	0.00	0.36	0.19	0.62	0.00	0.21	0.00	0.29	0.39	0.00		
"	"	419	-	AE	1	0	0	0	0	0	1	0	0	10	0		
				ICP	0.07	0.00	0.74	0.14	0.31	0.00	0.10	0.10	0.37	0.14	0.00		
"	"	436	-	AE	0	0	0	0	0	0	0	0	1	9	0		
				ICP	0.16	0.02	0.41	0.26	0.60	0.02	0.27	0.00	0.59	0.00	0.01		
"	"	446	-	AE	0	0	0	0	0	0	0	0	1	8	0		
				ICP	0.15	0.01	0.38	0.18	0.39	0.00	0.21	0.00	0.49	0.00	0.00		
"	"	454	-	AE	0	0	0	0	1	0	0	0	2	9	1		
				ICP	0.09	0.03	0.00	0.16	0.52	0.01	0.22	0.15	0.26	0.00	0.21		
F-18 161526	F404-GE-400 310949	391	13	AE	0	0	2	0	1	0	0	0	1	7	0		
				ICP	0.17	0.00	2.18	0.19	0.44	0.01	0.06	0.00	0.46	0.00	0.00		

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161526	F404-GE-400 310999	392	19	AE	0	0	0	0	1	0	0	0	0	9	1
				ICP	0.13	0.00	0.91	0.19	0.98	0.02	0.19	0.93	0.40	0.00	0.00
"	F404-GE-400 311903	210	13	AE	0	0	0	0	1	0	0	0	2	8	0
				ICP	0.14	0.00	0.75	0.17	0.44	0.13	0.10	0.00	0.00	0.00	0.00
"	"	211	14	AE	0	0	0	0	1	0	0	0	1	8	1
				ICP	0.16	0.00	0.00	0.16	0.59	0.02	0.21	0.66	0.67	0.00	0.06
Test Cell	F404-GE-400 310206	1038	-	AE	0	0	0	0	0	0	0	0	1	10	1
				ICP	0.13	0.00	0.19	0.18	0.27	0.01	0.16	0.59	0.38	0.00	0.00
F-18 161527	"	1140	24	AE	1	1	0	0	1	0	1	0	1	13	2
				ICP	0.03	0.00	0.43	0.18	0.75	0.00	0.11	0.00	0.15	0.02	0.00
"	"	1148	32	AE	1	0	0	0	0	0	0	0	0	10	0
				ICP	0.04	0.00	0.73	0.14	0.31	0.00	0.11	0.00	0.21	0.04	0.00
"	"	1166	-	AE	0	0	0	0	0	0	0	0	1	9	0
				ICP	0.12	0.04	0.38	0.24	0.57	0.01	0.18	0.00	0.46	0.00	0.00
"	"	1177	-	AE	0	0	0	0	0	0	1	0	0	10	1
				ICP	0.13	0.02	0.39	0.20	0.47	0.01	0.21	0.00	0.24	0.00	0.06
"	F404-GE-400 310242	—	—	AE	0	0	0	0	0	0	1	0	1	7	0
				ICP	0.17	0.01	0.18	0.15	0.24	0.01	0.05	0.00	0.46	0.00	0.02

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161527	F404-GE-400 310242	1656	21	AE	2	0	0	1	0	0	1	0	3	8	0
				ICP	0.31	0.02	0.30	0.18	0.19	0.02	0.20	0.00	0.72	0.00	0.09
	″	1668	10?	AE	1	0	0	0	0	0	0	0	3	10	0
				ICP	0.22	0.00	0.00	0.13	0.18	0.01	0.26	0.00	0.43	0.00	0.30
	″	1678	30?	AE	1	0	0	0	1	0	1	0	5	10	0
				ICP	0.25	0.00	0.18	0.19	0.24	0.00	0.27	0.00	0.56	0.00	0.05
	″	1697	10?	AE	1	1	0	1	1	0	1	0	0	10	0
				ICP	0.19	0.00	0.00	0.14	0.11	0.00	0.35	0.00	0.96	0.00	0.02
	″	-	-	AE	1	0	0	2	1	0	0	0	1	10	1
				ICP	0.00	0.00	0.00	0.00	0.04	0.00	0.00	-	0.00	0.15	0.00
	F404-GE-400 310585	-	-	AE	0	0	0	0	0	0	1	0	1	7	0
				ICP	0.12	0.02	0.00	0.17	0.26	0.01	0.21	0.00	0.35	0.00	0.02
	″	2058	10	AE	0	1	0	1	1	0	1	0	0	11	0
				ICP	0.06	0.01	0.00	0.12	0.09	0.01	0.16	0.00	0.30	0.00	0.01
	″	2065	21?	AE	1	0	0	1	0	0	1	0	3	10	0
				ICP	0.18	0.04	0.24	0.19	0.19	0.01	0.30	0.00	0.47	0.00	0.02
	″	2077	10?	AE	0	0	0	1	0	0	0	0	3	10	0
				ICP	0.13	0.02	0.00	0.17	0.19	0.01	0.28	0.00	0.29	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161527	F404-GE-400 310585	2087	30?	AE	1	0	0	0	1	0	1	1	3	11	0
				ICP	0.16	0.04	0.08	0.22	0.28	0.01	0.72	0.00	0.28	0.06	0.03
F-18 161527	F404-GE-400 311060	301	-	AE	2	1	0	0	1	1	0	0	2	14	2
				ICP	0.09	0.00	0.30	0.19	0.76	0.00	0.24	0.00	0.16	0.00	0.00
"	"	310	32	AE	2	1	0	0	1	1	0	0	2	14	2
				ICP	0.05	0.00	0.63	0.12	0.29	0.00	0.13	0.00	0.23	0.00	0.00
"	"	328	15?	AE	0	0	0	0	0	0	1	0	2	9	1
				ICP	0.16	0.00	0.38	0.25	0.60	0.02	0.19	0.00	0.41	0.00	0.00
"	"	359	30?	AE	0	0	0	0	1	0	1	0	0	9	1
				ICP	0.26	0.00	0.15	0.20	0.56	0.01	0.38	0.00	0.14	0.00	0.02
F-18 161945	F404-GE-400 310975	1870	-	AE	1	0	0	2	0	0	0	0	1	6	0
				ICP	0.00	0.00	0.00	0.00	0.01	0.00	0.00	-	0.00	0.27	0.00
"	"	-	-	AE	1	0	0	1	0	0	0	0	1	9	0
				ICP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	0.00	0.00
"	"	1875	-	AE	0	0	0	0	0	0	0	0	1	9	0
				ICP	0.06	0.00	0.10	0.11	0.20	0.01	0.09	0.34	0.09	0.00	0.01
"	"	1896	-	AE	1	0	0	1	0	0	1	0	0	7	0
				ICP	0.37	0.08	0.22	0.36	0.19	0.01	0.31	0.40	0.09	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161945	F404-GE-400 310975	1925	-	AE	1	0	0	1	0	0	1	0	0	10	0
				ICP	0.21	0.03	0.15	0.25	0.24	0.01	0.11	-	0.88	0.04	0.02
"	"	-	-	AE	1	1	0	1	1	0	1	1	1	10	0
				ICP	0.17	0.00	0.48	0.24	0.05	0.00	0.09	0.00	0.00	0.00	0.01
"	"	-	-	AE	1	0	0	1	0	0	1	0	1	10	0
				ICP	0.14	0.00	0.62	0.20	0.23	0.00	0.08	0.00	0.00	0.00	0.02
"	F404-GE-400 311902	-	-	AE	1	0	0	1	0	0	0	0	1	9	0
				ICP	0.00	0.00	0.06	0.00	0.01	0.00	0.00	-	0.00	0.00	0.00
"	"	1870	-	AE	0	0	0	1	0	0	0	0	1	7	0
				ICP	0.00	0.00	0.00	0.00	0.01	0.00	0.00	-	0.00	0.37	0.00
"	"	1875	-	AE	0	0	0	0	0	0	1	0	1	6	0
				ICP	0.30	0.03	0.34	0.31	0.20	0.01	0.17	-	0.22	0.17	0.04
"	"	1896	-	AE	0	0	0	0	0	0	0	0	1	7	0
				ICP	0.07	0.02	0.29	0.13	0.20	0.01	0.07	0.03	0.40	0.30	0.01
"	"	1925	-	AE	1	0	0	0	0	0	1	0	1	12	0
				ICP	0.11	0.03	0.35	0.17	0.24	0.01	0.11	-	0.83	0.17	0.02
"	"	-	-	AE	1	0	0	1	1	0	1	0	1	11	0
				ICP	0.09	0.00	0.48	0.15	0.12	0.00	0.00	0.00	0.00	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 101945	F400 GE-400 311902	-	-	AE	1	0	0	1	0	0	1	0	1	9	0
				ICP	0.28	0.00	0.51	0.10	0.25	0.00	0.00	0.00	0.00	0.00	0.01
F-18 161955	GTCP 36-200 0072	-	-	AE	1	1	2	0	1	0	1	0	4	11	0
				ICP	0.30	0.01	2.47	0.13	0.04	0.05	0.00	0.00	1.54	0.00	0.00
"	"	-	-	AE	1	0	2	0	1	0	1	0	4	10	0
				ICP	0.20	0.00	2.37	0.17	0.05	0.47	0.02	0.00	1.40	0.00	0.02
"	F404-GE-400 310455	-	-	AE	1	0	0	1	0	0	0	1	1	10	1
				ICP	0.00	0.00	0.00	0.00	0.07	0.00	0.00	—	0.00	0.00	0.00
"	"	1824	-	AE	1	0	0	1	0	0	0	0	1	6	0
				ICP	0.00	0.00	0.00	0.00	0.05	0.00	0.00	—	0.00	0.00	0.00
"	"	1843	-	AE	0	0	0	1	0	0	1	0	9	10	0
				ICP	0.16	0.00	0.64	0.12	0.17	0.05	0.14	0.00	3.78	0.30	0.01
"	"	1875	-	AE	1	0	0	0	0	0	1	0	1	10	0
				ICP	0.16	0.00	0.12	0.15	0.29	0.01	0.12	-	0.84	0.00	0.02
"	"	— -	-	AE	1	0	0	1	0	0	1	0	2	10	0
				ICP	0.07	0.00	0.41	0.31	0.19	0.00	0.06	0.00	0.00	0.00	0.02
"	F404-GE-400 310686	1164	5	AE	1	0	0	0	0	0	0	0	3	11	0
				ICP	0.09	0.00	0.22	0.14	0.13	0.01	0.26	0.00	0.24	0.00	0.02

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161955	F404-GE-400 310686	1176	21?	AE	1	0	0	0	1	0	1	1	2	10	0
				ICP	0.16	0.03	0.30	0.22	0.20	0.00	0.18	0.00	0.42	0.00	0.04
"	"	1197	30	AE	1	1	0	1	1	0	1	0	1	10	0
				ICP	0.00	0.00	0.00	0.13	0.00	0.01	0.21	0.00	0.38	0.00	0.01
"	"	1219	52	AE	1	0	0	0	1	0	0	0	1	11	0
				ICP	0.21	0.00	0.12	0.23	0.00	0.09	0.22	0.00	0.00	0.23	0.02
"	"	1975	–	AE	1	0	0	0	0	0	1	0	8	11	0
				ICP	0.06	0.37	0.24	0.11	0.24	0.00	0.00	–	5.37	0.00	0.02
"	"	–	–	AE	0	0	0	1	0	0	1	0	5	9	0
				ICP	0.06	0.00	0.45	0.18	0.10	0.00	0.01	0.00	1.86	0.09	0.02
"	F404-GE-400 310939	368	3	AE	1	0	0	0	0	0	0	0	3	11	0
				ICP	0.17	0.01	0.37	0.19	0.19	0.01	0.21	0.00	0.41	0.00	0.02
"	"	380	21?	AE	1	0	0	0	1	0	1	1	3	10	0
				ICP	0.19	0.09	0.21	0.21	0.28	0.00	0.07	0.30	0.62	0.03	0.04
"	"	401	30	AE	1	1	0	1	1	0	1	0	0	10	1
				ICP	0.08	0.01	0.00	0.12	0.00	0.04	0.07	0.00	0.47	0.00	0.01
"	"	423	52	AE	0	0	0	0	1	0	0	0	0	11	0
				ICP	0.00	0.00	0.00	0.12	0.00	0.00	0.18	0.00	0.00	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161955	F404-GE-400 311939	–	–	AE	1	0	0	1	1	0	0	0	1	9	0
				ICP	0.00	0.00	0.00	0.00	0.17	0.00	0.00	–	0.00	0.00	0.00
"	"	1824	–	AE	1	0	0	1	1	0	0	4	1	5	0
				ICP	0.00	0.00	0.00	0.00	0.14	0.00	0.00	6.08	0.00	0.00	0.00
"	"	1843	–	AE	1	0	0	0	0	0	1	0	1	10	0
				ICP	0.16	0.01	0.26	0.10	0.22	0.02	0.06	0.00	0.29	0.00	0.01
F-18 161987	F404-GE-400 310541	1646	–	AE	0	0	0	1	0	0	0	0	1	8	0
				ICP	1.00	0.00	0.00	0.00	0.00	0.00	0.00	–	0.00	0.00	0.00
"	"	1666	–	AE	0	0	0	0	0	0	1	0	1	10	0
				ICP	0.11	0.00	0.10	0.12	0.09	0.01	0.10	0.00	0.29	0.00	0.02
"	"	1692	–	AE	0	0	0	1	0	0	1	0	1	6	0
				ICP	0.06	0.00	0.10	0.08	0.19	0.00	0.07	0.00	0.39	0.00	0.01
"	"	1718	–	AE	1	0	0	1	0	0	1	0	0	13	0
				ICP	0.05	0.01	0.16	0.14	0.25	0.01	0.05	–	1.60	0.00	0.01
"	"	–	–	AE	1	0	0	1	0	0	1	0	1	10	0
				ICP	0.08	0.00	0.44	0.18	0.02	0.00	0.06	0.00	0.00	0.00	0.02
"	"	–	–	AE	0	0	0	0	0	0	0	0	1	7	0
				ICP	0.09	0.00	0.54	0.15	0.21	0.00	0.00	0.00	0.00	0.00	0.01

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161957	F404-GE-400 310944	1646	-	AE	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	9.0	0.0
				ICP	0.00	0.00	0.00	0.00	0.04	0.00	0.00	—	0.00	0.00	0.00
"	"	1666	-	AE	0	0	0	0	0	0	0	0	1	9	0
				ICP	0.04	0.01	0.17	0.09	0.12	0.01	0.07	0.00	0.55	0.00	0.02
"	"	1692	-	AE	0	0	0	1	0	0	0	0	1	6	0
				ICP	0.04	0.00	0.00	0.10	0.17	0.00	0.09	0.39	0.20	0.00	0.00
"	"	1718	-	AE	1	0	0	0	0	0	0	0	2	10	0
				ICP	0.08	0.02	0.17	0.14	0.73	0.01	0.01	2.01	0.75	0.15	0.02
"	"	-	-	AE	1	0	0	1	1	0	1	1	1	11	0
				ICP	0.06	0.00	0.45	0.17	0.05	0.00	0.05	0.00	0.00	0.00	0.01
"	"	-	-	AE	1	0	0	0	1	0	1	0	1	10	0
				ICP	0.04	0.00	0.48	0.09	0.21	0.01	0.00	0.00	0.07	0.00	0.01
F-18 161973	F404-GE-400 310499	-	-	AE	1	0	0	0	0	0	1	1	0	7	0
				ICP	0.18	0.02	0.27	0.16	0.36	0.02	0.21	0.00	0.50	0.00	0.01
"	"	1677	13	AE	2	0	0	1	0	0	0	0	4	10	0
				ICP	0.23	0.23	0.37	0.19	0.22	0.04	0.26	0.00	0.77	0.00	0.05
"	"	1711	47?	AE	1	0	0	1	1	0	1	0	3	11	0
				ICP	0.26	0.05	0.53	0.20	0.32	0.09	0.57	0.00	0.50	0.00	0.03

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161973	F404-GE-400 310999	1896	25	AE	1	0	0	0	1	0	1	0	2	7	0
				ICP	0.22	0.02	0.35	0.22	0.29	0.00	0.30	0.67	0.91	0.00	0.04
"	"	1914	7	AE	1	1	0	1	1	0	1	0	0	10	0
				ICP	0.05	0.10	0.01	0.13	0.13	0.02	0.24	0.00	0.43	0.00	0.16
"	"	1943	36	AE	1	0	0	0	1	0	0	0	1	11	0
				ICP	0.00	0.01	0.00	0.12	0.15	0.01	0.16	0.00	0.00	0.00	0.02
"	"	2350	-	AE	1	0	0	1	1	0	0	1	1	8	1
				ICP	0.00	0.00	0.00	0.00	0.11	0.00	0.00	-	0.00	0.08	0.00
"	"	-	-	AE	0	0	0	1	1	0	0	0	1	8	0
				ICP	0.00	0.00	0.00	0.00	0.16	0.00	0.00	-	0.00	0.00	0.00
"	"	2374	-	AE	0	0	0	0	0	0	1	0	4	8	0
				ICP	0.14	0.08	0.52	0.14	0.17	0.01	0.16	0.00	0.22	0.26	0.08
"	F404-GE-400 310666	-	-	AE	0	0	0	0	1	0	0	0	1	11	0
				ICP	0.00	0.00	0.00	0.16	0.21	0.00	0.14	0.00	0.44	0.00	0.01
"	F404-GE-400 310866	-	-	AE	0	0	0	0	0	0	1	0	1	6	0
				ICP	0.09	0.00	0.00	0.19	0.16	0.01	0.11	0.00	1.18	0.00	0.02
"	"	-	-	AE	1	0	0	0	0	0	1	0	2	7	0
				ICP	0.12	0.01	0.21	0.20	0.19	0.02	0.13	0.00	1.62	0.02	0.03

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161973	F404-GE-400 310866	992	13	AE	1	0	0	1	0	0	1	0	4	10	0
				ICP	0.10	0.02	0.22	0.17	[illegible]	0.02	0.21	0.00	1.30	0.00	0.03
"	"	1002	4	AE	1	0	0	1	0	0	0	0	5	11	0
				ICP	0.12	0.00	0.19	0.17	0.09	0.01	0.30	0.00	1.46	0.00	0.04
"	"	1019	25	AE	1	0	0	0	1	0	1	0	3	9	0
				ICP	0.11	0.00	0.31	0.21	0.15	0.00	0.20	0.00	1.35	0.16	0.04
"	"	1029	-	AE	0	1	0	1	1	0	1	0	1	10	0
				ICP	0.00	0.00	0.06	0.14	0.00	0.00	0.10	0.00	0.97	0.00	0.01
"	"	2350	-	AE	0	0	0	1	0	0	0	0	2	9	0
				ICP	0.00	0.20	0.00	0.08	0.07	0.00	0.00	—	0.00	0.00	0.00
"	"	"	-	AE	1	0	0	2	0	0	0	0	2	9	0
				ICP	0.00	0.00	0.00	0.00	0.09	0.00	0.00	—	0.02	0.00	0.00
"	"	2374	-	AE	0	0	0	[illegible]	0	0	1	0	2	9	0
				ICP	0.13	0.00	0.00	0.11	0.11	0.01	0.12	0.00	3.10	0.00	0.02
Test Cell	F404-GE-400 310880	867	-	AE	0	0	0	0	0	0	1	0	1	11	1
				ICP	0.08	0.00	0.84	0.14	0.19	0.01	0.08	0.58	0.36	0.00	0.10
F-18 161973	"	976	-	AE	2	1	0	0	1	0	1	1	2	15	3
				ICP	0.13	0.00	0.56	0.20	0.67	0.00	0.31	0.00	0.14	0.47	0.09

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161973	F404-GE-400 310880	986	9	AE	1	0	0	0	1	0	1	0	1	9	1
				ICP	0.09	0.00	0.68	0.19	0.73	0.00	0.17	0.00	0.12	0.00	0.12
"	"	1002	23	AE	0	0	0	0	1	0	1	0	1	8	1
				ICP	0.22	0.02	0.47	0.26	0.71	0.01	0.29	0.00	0.40	0.00	0.14
"	"	1012	13?	AE	0	0	0	0	0	0	1	0	1	6	1
				ICP	0.26	0.21	0.69	0.23	0.50	0.04	0.26	0.00	0.79	0.00	0.18
"	"	1021	4?	AE	0	0	0	0	1	0	1	0	1	10	1
				ICP	0.25	0.05	0.17	0.22	0.80	0.10	0.33	0.78	0.39	0.04	0.19
"	F404-GE-400 310008	549	-	AE	2	1	0	0	1	0	1	0	1	13	2
				ICP	0.21	0.00	1.35	0.20	0.77	0.00	0.27	0.00	0.14	0.06	0.00
"	"	552	9	AE	1	0	0	0	1	0	1	0	0	10	0
				ICP	0.20	0.00	1.17	0.19	0.49	0.00	0.23	0.74	0.24	0.23	0.00
"	"	569	23	AE	0	0	0	0	1	0	1	0	0	8	1
				ICP	0.27	0.02	0.58	0.27	0.74	0.01	0.29	0.00	0.49	0.02	0.02
"	"	579	13?	AE	0	0	0	0	1	0	1	0	1	6	0
				ICP	0.27	0.08	0.60	0.24	0.51	0.01	0.31	0.00	0.54	0.00	0.02
"	"	588	4?	AE	0	0	0	0	1	0	1	0	0	8	1
				ICP	0.20	0.06	0.26	0.20	0.63	0.01	0.27	0.90	0.28	0.01	0.02

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161978	F400-GE-400 310428	2020	23	AE	0	0	0	0	0	0	0	0	1	6	0
				ICP	0.19	0.00	0.41	0.23	0.28	0.00	0.12	0.00	0.30	0.00	0.08
"	"	-	-	AE	1	0	0	0	0	0	2	0	1	8	0
				ICP	0.12	0.09	0.09	0.19	0.30	0.02	0.24	0.00	0.43	0.00	0.03
"	"	2188	5	AE	0	0	0	1	0	0	1	0	3	10	0
				ICP	0.15	0.09	0.15	0.18	0.21	0.01	0.43	0.00	0.51	0.00	0.04
"	"	2195	28?	AE	1	0	0	0	1	0	1	0	3	11	0
				ICP	0.18	0.06	0.12	0.21	0.36	0.00	0.30	0.00	0.67	0.00	0.04
"	F400-GE-400 310522	1242	-	AE	2	1	0	0	1	0	1	1	1	16	3
				ICP	0.14	0.00	1.10	0.19	0.60	0.00	0.21	0.00	0.20	0.45	0.01
"	"	1251	23	AE	2	0	0	0	.	0	1	0	3	11	1
				ICP	0.08	0.00	0.82	0.14	0.37	0.00	0.19	0.88	0.09	0.00	0.02
"	"	1266	6?	AE	0	0	0	0	0	0	1	0	2	8	1
				ICP	0.21	0.01	0.63	0.24	0.59	0.07	0.19	0.00	0.40	0.00	0.08
"	"	1280	23?	AE	0	0	0	0	0	0	1	0	1	7	0
				ICP	0.18	0.00	0.49	0.19	0.34	0.00	0.24	0.00	0.22	0.00	0.07
"	"	1289	6?	AE	0	0	0	0	1	0	1	0	1	9	0
				ICP	0.21	0.24	0.13	0.22	0.52	0.04	0.38	0.35	0.43	0.00	0.03

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161978	F404-GE-400 310835	1365	5	AE	1	0	0	1	0	0	1	0	4	10	0
				ICP	0.13	0.01	0.20	0.25	0.22	0.02	0.65	0.00	0.92	0.00	0.05
"	"	1372	28	AE	1	0	0	0	1	0	2	0	3	11	0
				ICP	0.28	0.05	0.24	0.28	0.35	0.00	0.53	0.00	1.07	0.00	0.05
"	"	-	-	AE	1	0	0	0	0	0	2	0	1	7	0
				ICP	0.29	0.03	0.17	0.22	0.38	0.04	0.95	0.00	0.79	0.00	0.04
Test Cell	F404-GE-400 311025	376	-	AE	1	0	0	0	1	0	1	0	1	11	0
				ICP	0.19	0.01	0.31	0.15	0.53	0.02	0.41	0.47	0.26	0.00	0.00
F-18 161978	"	486	-	AE	2	1	0	0	1	0	1	1	2	15	2
				ICP	0.13	0.00	0.59	0.17	0.74	0.00	0.41	0.00	0.16	0.38	0.00
"	"	495	23	AE	2	0	0	0	1	0	1	0	1	11	1
				ICP	0.09	0.00	0.72	0.14	0.91	0.00	0.27	0.00	0.12	0.00	0.00
"	"	513	6?	AE	0	0	0	0	1	0	2	0	0	9	0
				ICP	0.22	0.00	0.34	0.27	0.81	0.05	0.56	0.00	0.38	0.00	0.03
F-18 161984	F404-GE-400 311019	-	-	AE	2	0	0	1	0	0	2	0	1	9	0
				ICP	0.56	0.02	0.13	0.38	0.30	0.09	0.38	0.00	0.42	0.00	0.07
"	"	404		AE	3	0	0	1	0	0	1	0	4	12	0
				ICP	0.63	0.02	0.31	0.39	0.21	0.03	0.49	0.00	0.63	0.00	0.07

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161989	F404-GE-400 311019	415	-	AE	2	0	0	1	0	0	0	0	3	10	0
				ICP	0.63	0.01	0.39	0.38	0.24	0.07	0.54	0.00	0.51	0.00	0.06
"	"	424	-	AE	2	0	0	1	1	0	2	1	3	10	1
				ICP	0.61	0.02	0.20	0.38	0.18	0.04	0.38	0.00	0.50	0.00	0.08
"	"	443	-	AE	2	1	0	1	1	0	1	0	1	11	0
				ICP	0.53	0.03	0.02	0.32	0.02	0.06	0.42	0.00	0.63	0.06	0.06
"	"	464	-	AE	1	0	0	0	1	0	0	0	1	11	0
				ICP	0.12	0.00	0.00	0.20	0.00	0.00	0.23	0.00	0.00	0.00	0.03
"	"	1950	-	AE	2	0	0	1	1	0	0	0	1	10	0
				ICP	0.00	0.00	0.00	0.00	0.12	0.00	0.00	—	0.00	0.00	0.00
"	"	-	-	AE	1	0	0	2	1	0	0	0	1	10	1
				ICP	0.00	0.00	0.00	0.00	0.19	0.00	0.00	-	0.00	0.00	0.00
"	"	1968	-	AE	1	0	0	0	0	0	1	0	1	9	0
				ICP	0.24	0.03	0.13	0.10	0.22	0.02	0.23	0.00	0.92	0.00	0.04
"	"	1998	-	AE	1	0	0	1	0	0	1	1	1	8	0
				ICP	0.21	0.01	0.07	0.14	0.33	0.01	0.24	0.00	1.49	0.00	0.02
"	"	2025	-	AE	1	0	0	1	0	0	1	0	1	11	0
				ICP	0.26	0.09	0.33	0.20	0.33	0.01	0.26	—	0.68	0.09	0.04

Type Aircraft	Type Eng. and S/N	HSOH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161984	F404-GE-400 311019	–	–	AE	1	1	0	1	1	0	2	0	1	10	0
				ICP	0.27	0.00	0.37	0.25	0.15	0.01	0.23	0.00	0.00	0.00	0.03
"	"	–	–	AE	1	0	0	1	0	0	1	0	2	10	0
				ICP	0.19	0.00	0.45	0.16	0.31	0.00	0.10	0.00	0.00	0.00	0.02
"	F404-GE-400 311047	–	–	AE	1	0	0	0	0	0	1	0	1	9	0
				ICP	0.04	0.02	0.00	0.15	0.23	0.04	0.14	0.00	0.50	0.00	0.02
"	"	410	–	AE	1	0	0	0	0	0	0	0	4	10	0
				ICP	0.12	0.02	0.09	0.13	0.09	0.01	0.17	0.00	0.63	0.00	0.18
"	"	421		AE	0	0	0	0	0	0	0	0	2	11	0
				ICP	0.14	0.02	0.19	0.16	0.15	0.01	0.19	0.00	0.56	0.00	0.02
"	"	430		AE	1	0	0	0	1	0	1	0	3	10	0
				ICP	0.12	0.06	0.18	0.20	0.18	0.00	0.10	0.00	0.64	0.00	0.03
"	"	449	–	AE	1	1	0	0	1	0	1	0	1	11	0
				ICP	0.02	0.02	0.00	0.10	0.00	0.01	0.30	0.00	0.42	0.00	0.01
"	"	–	–	AE	1	0	0	1	0	0	0	0	1	10	0
				ICP	0.00	0.00	0.00	0.00	0.02	0.00	0.00	–	0.00	0.00	0.00
"	"	1950	–	AE	0	0	0	0	0	0	0	0	1	8	0
				ICP	0.00	0.00	0.00	0.00	0.04	0.00	0.00	–	0.00	0.25	0.00

Type Aircraft	Type Eng. and S/N	HS/OH	HSOC	Type Anal.	Trace Metal Concentration, ppm										
					Fe	Ag	Al	Cr	Cu	Mg	Ni	Pb	Si	Sn	Ti
F-18 161984	F404-GE-400 311047	1968	-	AE	0	0	0	0	0	0	0	0	1	8	0
				ICP	0.07	0.00	0.21	0.10	0.10	0.01	0.05	0.00	0.28	0.00	0.03
"	"	1998	-	AE	0	0	0	0	0	0	0	0	1	8	0
				ICP	0.00	0.00	0.10	0.07	0.22	0.01	0.04	0.00	0.22	0.00	0.03
"	"	2025	-	AE	1	0	0	0	0	0	1	1	0	11	0
				ICP	0.08	0.02	0.16	0.14	0.23	0.01	0.04	2.00	0.34	0.16	0.02
"	"	-	-	AE	1	0	0	1	✓	0	1	0	1	11	0
				ICP	0.08	0.00	0.38	0.16	0.15	0.00	0.08	0.00	0.00	0.00	0.01
"	"	-	-	AE	1	0	0	0	0	0	1	0	2	10	0
				ICP	0.04	0.00	0.27	0.10	0.15	0.00	0.10	0.00	0.00	0.00	0.01
				AE											
				ICP											
				AE											
				ICP											
				AE											
				ICP											
				AE											
				ICP											

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