MTS FSE MODULAR TRAINING

Hydraulic Oil

November 30, 2016 Rev F

be certain.

Hydraulic Oil

- MTS servohydraulic test systems use close tolerance servovalves and components
  - Servovalves operate thousands of cycles per test
  - Each cycle slices base oil and additives apart
  - This degrades oil which then degrades system performance

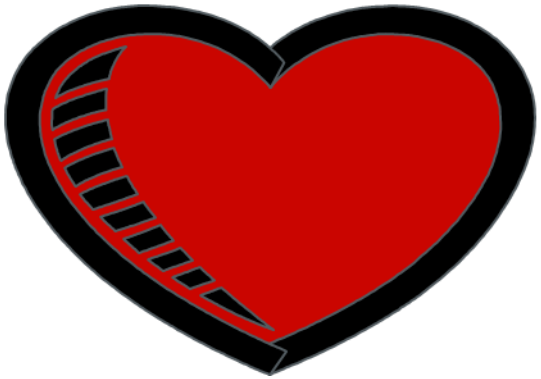
- MTS has established Mobil DTE 25 as the primary approved oil
  - Over 40 years of usage has proven this oil to be superior in our systems

Hydraulic Oil

Consider the hydraulic system as a body...

The heart = the pump

The veins = the hoses



The arms and legs = the actuators

The kidneys = the filters

The brain = complex valves

The "life blood" = the hydraulic oil

Hydraulic Oil

- Hydraulic Power Units shipped from MTS do not contain hydraulic oil.
- This is a change from previous methods. In the past some HPU's were shipped with oil inside the reservoir.
- Hydraulic oil will need to be added during installation using a transfer pump.
- Different brands or types of Hydraulic Oil should NEVER be mixed
- Use of a non-approved oil may invalidate warranty

Hydraulic Oil

- The MTS preferred Oil is Mobil DTE 25.
  - Mobil DTE 25 contains zinc as an anti-wear additive
- An alternative zinc free oil is Mobil DTE 10 Excel
- When Mobil oil is not available use an approved Shell alternative.
- Shell Tellus S3 M is an approved zinc free oil.
  - Shell Tellus S2 which is "DTE 25 equivalent" is NOT an approved oil.
- An alternative synthetic oil that is MTS approved is Mobil SHC525. This oil has a high flash point which is good for fire suppression regulations.
- Shell Tellus S4 ME can be used in place of Mobil SHC525 as a synthetic alternative.

Hydraulic Oil

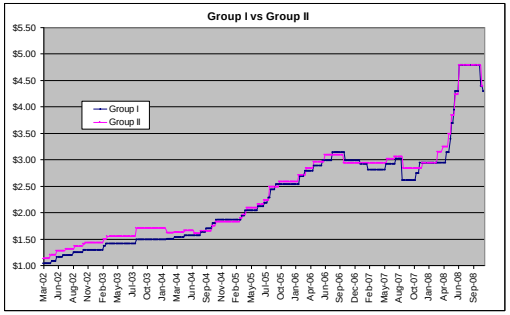
- Below is a reference chart of approved oils.
- Mobil is the preferred supplier. Use Shell when Mobil is not available.

	Mobil	**Shell**
Preferred mineral base oil with zinc anti-wear additive	DTE 25	None Approved
Mineral base zinc free	DTE 10 Excel	Tellus S3 M
Synthetic	SHC525	Tellus S4 ME

Hydraulic Oil

- Specifications for hydraulic oil is wide open
- Using a "DTE Equivalent" oil not manufactured by Mobil is not recommended

1. Common Approach



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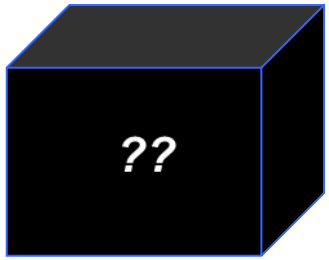

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Cost Competitive Base Stock
Depends on daily $$$ - can change

Off-the-Shelf
Additive Package

General Product with
Reasonable Performance

Oil Cleanliness

- The hydraulic oil in the system is filtered to a level of 3 micron
- On the right is a table of common particle sizes
- Note that red blood cells are larger than the filters used in our systems
- 3 micron hydraulic filters would remove red blood cells from your body if your blood was filtered using these

Relative Sizes of Particles *

Substance	Microns	Inches
Grain of table salt	100	.0039
Human hair	70	.0027
Lower limit of visibility	40	.0016
Milled flour	25	.0010
Red blood cells	8	.0003
Bacteria	2	.0001

* Parker Handbook of Hydraulic Filtration

Cleanliness requirement

- Cleanliness of oil is measured using the ISO cleanliness code
  - This is a count of the number of particles per quantity of oil greater than a specified size
  - For MTS equipment the target oil cleanliness should meet or exceed ISO 16/13/9
  - Oil which is at 17/15/11 is marginal
  - Oil which is at 18/16/13 is unsatisfactory

- The first number represents the quantity of particles larger than 4 micron
- The second number represents the quantity of particles larger than 6 micron
- The third number represents the quantity of particles larger than 14 micron

ISO cleanliness code

» The chart on the right shows the number of particles per ml for ISO 4406 16/13/9

- Number of particles per ml larger than 4 micron is between 320 and 640
- Number of particles per ml larger than 6 micron is between 40 and 80
- Number of particles per ml larger than 14 micron is between 2.5 and 5

ISO 4406 Chart

Range Number	Number of particles per ml	
	More than	Up to and including
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	.64	1.3
6	.32	.64

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* Parker Handbook of Hydraulic Filtration

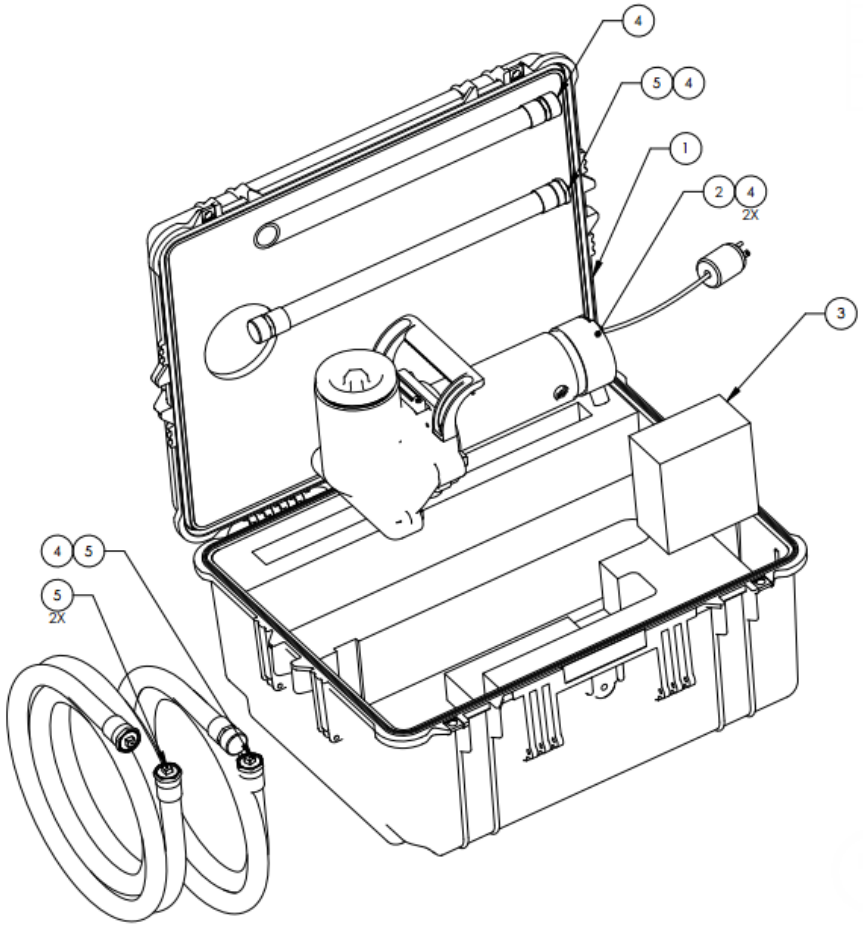
New Oil Cleanliness

- New oil from a barrel, pail or tote does not meet the cleanliness requirement
- Must be filtered prior to being added to the reservoir
  - Use a transfer pump with a 3micron filter. No larger than10 micron filter

Transfer Pump Part Number

» The MTS part numbers for a transfer pump with a 10 Micron filter are listed below.

Part Number	Cord / Plug
100-320-427	US
100-320-428	Europe
100-320-429	UK
100-320-430	Italy
100-320-431	China
100-320-432	Australia
100-320-433	Brazil
100-320-434	Japan
100-320-435	ZA/India



Oil Degradation

- Oil can be degraded from many different sources
  - Contamination such as dirt
  - Running system while exceeding maximum recommended reservoir temperature
  - Water – commonly caused by heat exchanger failure
  - Additive package degradation

- Oil quality can be determined by sampling oil and submitting for analysis using MTS Fluid Care

Indicators of Oil Degradation

- New hydraulic oil has a very light amber color
- DTE series oil which is dark with no other unusual characteristics does not indicate bad oil. DTE 25 will keep smaller than 3 micron particles in suspension.
- Clear "DTE equivalent" oil not manufactured by Mobil can be spreading deposits throughout the system even though it doesn't appear to be bad oil.
- Don't rely on color alone as a oil quality indicator.

Indicators of Oil Degradation

- Poor system performance can indicate oil quality issues with contamination or water.
  - Regularly replacing servovalves may indicate contamination
- Oil which is dark with a strong odor may indicate a need to replace the oil
  - Acquire sample and submit for analysis
- Oil which is cloudy white or yellow indicates air or water in the oil
  - Immediate action is required when there is water in the oil to prevent additional damage to other components
  - Water can be indicated by fluid level rising on the sight gage when no oil has been added to the system due to water being ingested into the reservoir through failed heat exchanger.

Oil Quality

» To reduce the amount of particle contamination ingested into the oil

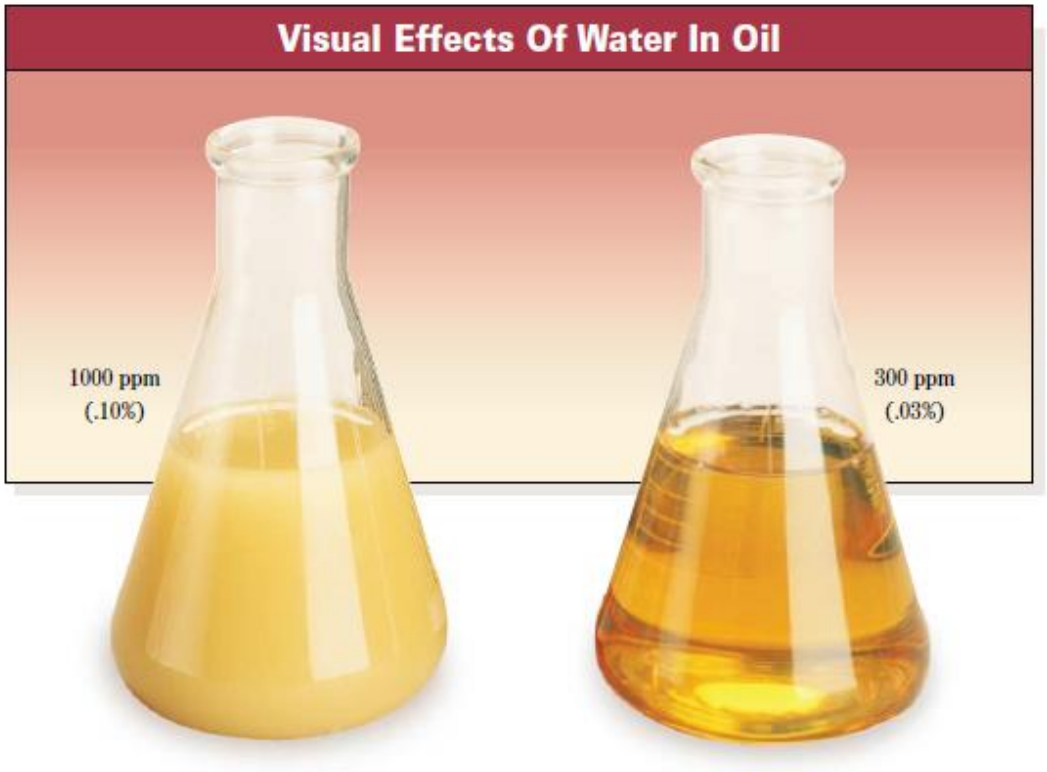
- Wipe clean any fittings prior to removing cap or hose
- This includes HPU, HSM, Actuator, Load frame, or any other area that comes in contact with hydraulic fluid
- Use lint free cloths when working on HPU or areas such as actuator pistons, end caps, or seals that come in contact with hydraulic fluid
- Verify filter elements are not dirty.
- Dirty filters typically bypass oil allowing contaminated oil to go around the filter and not trap particle contamination.

Oil Quality

- Operating the HPU at an elevated temperature will degrade the oil. Nitration and Oxidation values rise.
  - SilentFlo water valve factory adjusted for reservoir temperature of 43°C (110°F)
  - SilentFlo reservoir recommended operating temperature 43°C–49°C (110°F–120°F).
- Do not bypass or alter oil temperature limit
  - SilentFlo maximum temperature shut down limit set for 55°C (131°F)

Oil Quality

- Water in the oil is indicated by a cloudy white appearance
  - Water will damage servovalves, control valves, delaminate nylon, and cause other unpredictable results



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* Parker Handbook of Hydraulic Filtration

Oil Quality

- Water in oil is commonly caused by a failed heat exchanger
  - Immediately stop all tests and shut down all systems
  - Isolate failure
  - Replace failed components
  - Replace hydraulic oil
  - Flush all systems with clean oil to help dislodge any remaining oil with water contamination
  - Replace oil as necessary to eliminate water contamination
  - Verify water is removed using oil sample

FSE Oil Sample Method

- The only approved method for MTS service engineers to obtain an oil sample is with the use of the Fluid Inline Sampling Tool (FIST).
  - To learn how to use the FIST tool see module 72 – RM Fluid Care Video Manaul
- FIST's have been distributed to FSE's. If you do not have a FIST available, contact your manager.
- Use of this tool will help to eliminate false contamination readings due to inconsistent oil collection methods.

Oil Sample

- MTS uses the MobilServ Oil analysis program. The HPU should be operating at full pressure and at normal operating temperature when taking an oil sample.
- The sample is shipped in pre-labeled shipping container. (Fluid Analysis bottles purchased by customer through order services will have special shipping instructions)
- After sample is analyzed, a report is created by MobilServ.
- If results show an elevated contamination level the FSE will work with the customer to correct the issue.

Oil Sampling

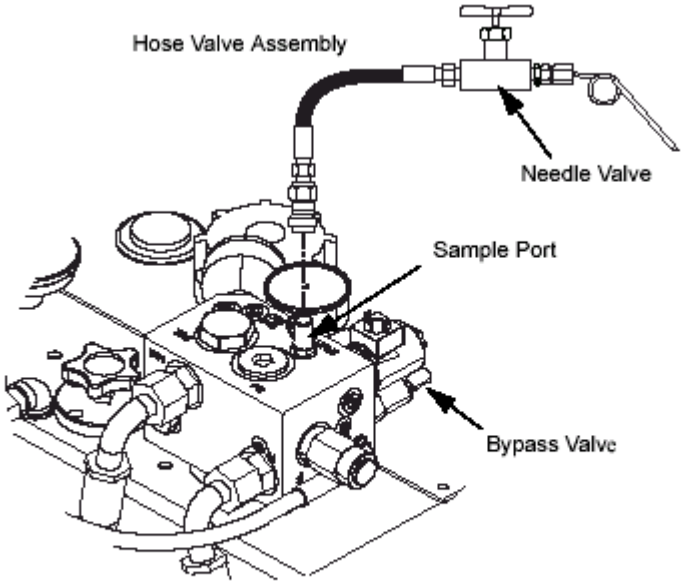
- For sampling procedure see Fluid Care video manual in the Routine Maintenance – Fluid Care training module

- Fluid Care procedures located on Fluid Care page of service QMS site
  - FS-OP 4404
  - FS-OP 4405
  - FS-OP 4406

Customer Oil Sample Method

- MTS has available a customer fluid sample kit P/N 055-589-601
  - Acquires sample using high pressure port
  - Be sure to flush the bottle minimum of three times with system oil

- This kit is not approved for FSE use for Fluid Care



Control Manifold

Oil Analysis

- MTS has selected the MobilServ service to provide oil sample analysis
- The following sections explain the oil analysis results
- A sample analysis report can be found using the link below.
  - Link to Example MobilServ Oil Analysis Report

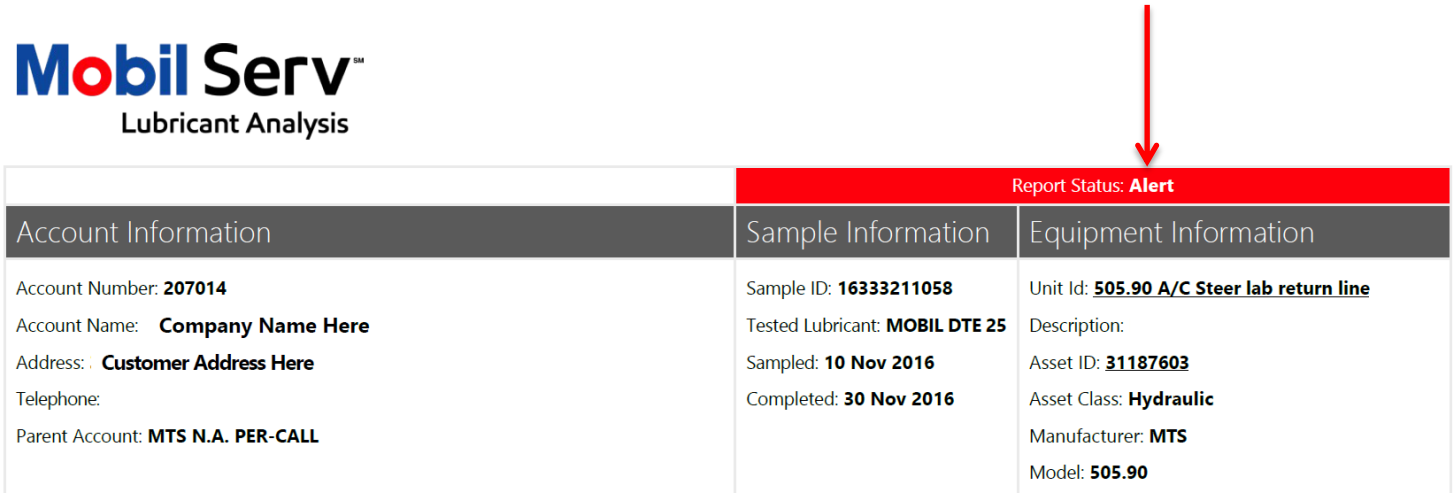
Oil Analysis Results

- After the oil sample is processed, the results are sent to the MTS fluid care administrator for the region
- The Fluid Care Administrator will forward the report to the following:
  - TSC
  - Service Sales
  - Preferred FSE (if listed in SFDC) and/or FSE (if known from Outlook request form, etc)
- If the report is Fluid Care (FC noted at end of Unit ID), it is also sent to sh.fluidcare@mts.com
- The TSC should forward the report to the FSE, if the FSE is not already copied on the email.
- The TSC (or FSE) should be forwarding the report to the customer.
- A FSE can log onto the MobilServ web site and download an oil analysis report if it was not received through another method.
  - For additional details on acquiring the sample or the MobilServ web site see module 72 – RM Fluid Care

Oil Analysis Results

- The header of the MobilServ lubricant analysis contains the customer information and the oil sample general information

- There is also a quick visual status in the header of the report of the oil quality using the indicators: Normal, Caution, or Alert



Mobil Serv℠
Lubricant Analysis

Report Status: **Alert**

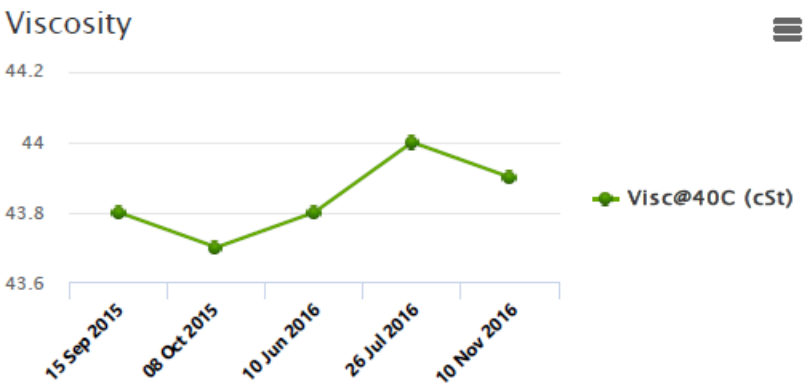
Account Information	Sample Information	Equipment Information
Account Number: **207014**	Sample ID: **16333211058**	Unit Id: **505.90 A/C Steer lab return line**
Account Name: **Company Name Here**	Tested Lubricant: **MOBIL DTE 25**	Description:
Address: **Customer Address Here**	Sampled: **10 Nov 2016**	Asset ID: **31187603**
Telephone:	Completed: **30 Nov 2016**	Asset Class: **Hydraulic**
Parent Account: **MTS N.A. PER-CALL**		Manufacturer: **MTS**
		Model: **505.90**

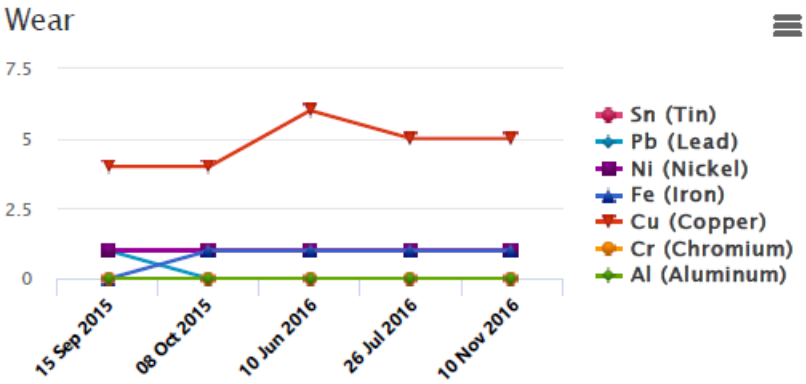
This sample requires attention because of the Alert status

Oil Analysis Results

» The data section of the report contains detailed results as well as previous samples and trending graphs from the same sample point.

Sample Info	Report Status	Caution	Normal	Alert	Caution	Alert
	Sample ID	15268461021	15299447036	16180322027	16228237034	16333211058
	Tested Lubricant	MOBIL DTE 25	MOBIL DTE 25	MOBIL DTE 25	MOBIL DTE 25	MOBIL DTE 25
	Sampled	15 Sep 2015	08 Oct 2015	10 Jun 2016	26 Jul 2016	10 Nov 2016
	Completed	30 Sep 2015	29 Oct 2015	29 Jun 2016	17 Aug 2016	30 Nov 2016
	Equipment Age	9530	9750	11043	11400	12300
	Equipment UOM	Hours	Hours	Hours	Hours	Hours
	Oil Age	9530	9750	11043	11400	12300
	Oil UOM			Hours	Hours	Hours
	Make-up Volume					
	Volume UOM					
	Oil Changed	No	No	No	No	No
	Filter Changed	No	No	No	No	No
Lubricant	Contamination Rating	Caution	Normal	Alert	Caution	Alert
	Equipment Rating	Normal	Normal	Normal	Normal	Normal
	Nitration (Ab/cm)	0	0	1	1	0
	Oil Rating	Normal	Normal	Normal	Normal	Normal
	Oxidation (Ab/cm)	1	1	1	1	1
	Particle Count >4um	1535	249	6601	947	4869
	ISO Code (4/6/14)	18/13/10	15/13/9	20/17/17	17/13/9	19/16/16
	Particle Count >6um	62	58	749	75	469
	Particle Count>14um	8	5	671	4	332





Oil Analysis Results

» For details of the cause of alerts see the Data sections of the report

All parameters within limits

Lubricant	Contamination Rating	Normal
	Equipment Rating	Normal
	Nitration (Ab/cm)	0
	Oil Rating	Normal
	Oxidation (Ab/cm)	1
	Particle Count >4um	249
	ISO Code (4/6/14)	15/13/9
	Particle Count >6um	58
	Particle Count>14um	5
	PQ Index	0
	UC Rating	1
	Visc@40C (cSt)	43.7
	Water (Vol%)	0.021

Follow up Action Required

Lubricant	Contamination Rating	Alert
	Equipment Rating	Normal
	Nitration (Ab/cm)	1
	Oil Rating	Normal
	Oxidation (Ab/cm)	1
	Particle Count >4um	6601
	ISO Code (4/6/14)	20/17/17
	Particle Count >6um	749
	Particle Count>14um	671
	PQ Index	0
	UC Rating	1
	Visc@40C (cSt)	43.8
	Water (Vol%)	0.022

Oil Analysis Results

- Contamination Rating includes
  - Particle Count
  - Water Contamination
- Oil Rating includes
  - Nitration
  - Oxidation
  - Additive Content

Lubricant	Contamination Rating	Caution	Normal	Alert	Caution	Alert
	Equipment Rating	Normal	Normal	Normal	Normal	Normal
	Nitration (Ab/cm)	0	0	1	1	0
	Oil Rating	Normal	Normal	Normal	Normal	Normal
	Oxidation (Ab/cm)	1	1	1	1	1
	Particle Count >4um	1535	249	6601	947	4869
	ISO Code (4/6/14)	18/13/10	15/13/9	20/17/17	17/13/9	19/16/16
	Particle Count >6um	62	58	749	75	469
	Particle Count>14um	8	5	671	4	332
	PQ Index	0	0	0	0	0
	UC Rating	1	1	1	1	1
	Visc@40C (cSt)	43.8	43.7	43.8	44.0	43.9
	Water (Vol%)	0.021	0.021	0.022	0.028	0.017

Oil Analysis Results

- If particle count is above desired values
  - Verify filters are clean and not in bypass mode
  - Look for sources of contamination
  - Change oil and filters as necessary

		Normal	Caution	Alert
Particle Count >4u		0-640	641-2500	>2500
Particle Count >6u		0-160	161-320	>320
Particle Count >14u		0-10	11-80	>80

	Contamination Rating	Normal
		Normal
		0
		Normal
	Oxidation (Ab/cm)	1
Lubricant	Particle Count >4um	249
	ISO Code (4/6/14)	15/13/9
	Particle Count >6um	58
	Particle Count>14um	5

Particle Count within Limits

	Contamination Rating	Alert
		Normal
		1
		Normal
	Oxidation (Ab/cm)	1
Lubricant	Particle Count >4um	6601
	ISO Code (4/6/14)	20/17/17
	Particle Count >6um	749
	Particle Count>14um	671

Particle Count exceeding Limits

Oil Analysis Results

- Water content (Vol%)
  - Normal – Less than 0.05
  - Caution – 0.05 to 0.099
  - Alert – Above 0.099

- If water content is above limit look for source of water
  - Heat exchanger failure
  - Condensation
  - Poor oil storage – Water ingested into barrel of new oil

Lubricant	Contamination Rating	Normal
	Equipment Rating	Normal
	Nitration (Ab/cm)	0
	Oil Rating	Normal
	Oxidation (Ab/cm)	1
	Particle Count >4um	249
	ISO Code (4/6/14)	15/13/9
	Particle Count >6um	58
	Particle Count>14um	5
	PQ Index	0
	UC Rating	1
	Visc@40C (cSt)	43.7
	Water (Vol%)	0.021

Oil Analysis Results

- Nitration
  - Evidenced by characteristic odor - oxidized (smells like electrical burn)
  - Leads to formation of lacquer and varnish
  - Normal – Less than 3
  - Caution – 3 to 5
  - Alert – Above 5

	Contamination Rating	Normal
	Equipment Rating	Normal
	Nitration (Ab/cm)	0
Lubricant	Oil Rating	Normal
	Oxidation (Ab/cm)	1
	Particle Count >4um	249
	ISO Code (4/6/14)	15/13/9
	Particle Count >6um	58
	Particle Count>14um	5
	PQ Index	0
	UC Rating	1
	Visc@40C (cSt)	43.7
	Water (Vol%)	0.021

Oil Analysis Results

- Oxidation
  - Provides the condition or stability of the oils
  - Indication of the start of the base oil degradation
  - Normal – Less than 3
  - Caution – 3 to 4
  - Alert – Above 4

- PQ Index
  - Measurement of the relative level of ferrous wear particles
  - Normal – Less than 20
  - Caution – 20 to 40
  - Alert – Above 40

	Contamination Rating	Normal
	Equipment Rating	Normal
	Nitration (Ab/cm)	0
	Oil Rating	Normal
	Oxidation (Ab/cm)	1
Lubricant	Particle Count >4um	249
	ISO Code (4/6/14)	15/13/9
	Particle Count >6um	58
	Particle Count>14um	5
	PQ Index	0
	UC Rating	1
	Visc@40C (cSt)	43.7
	Water (Vol%)	0.021

Oil Analysis Results

- Viscosity
  - Alert at +/- 20% of reference value
- UC Rating
  - Relative rating of sediment on a scale of 1 to 8
- Additive Elements
  - Monitor to assess a fluid's suitability for further use

Lubricant	Contamination Rating	Normal
	Equipment Rating	Normal
	Nitration (Ab/cm)	0
	Oil Rating	Normal
	Oxidation (Ab/cm)	1
	Particle Count >4um	249
	ISO Code (4/6/14)	15/13/9
	Particle Count >6um	58
	Particle Count>14um	5
	PQ Index	0
	UC Rating	1
	Visc@40C (cSt)	43.7
	Water (Vol%)	0.021

Additive (ppm)	Ba (Barium)	0	0	0	0	0
	Ca (Calcium)	121	128	124	109	115
	Mg (Magnesium)	2	4	3	4	5
	P (Phosphorus)	486	505	539	431	496
	Zn (Zinc)	743	761	690	587	693

Oil Analysis Results

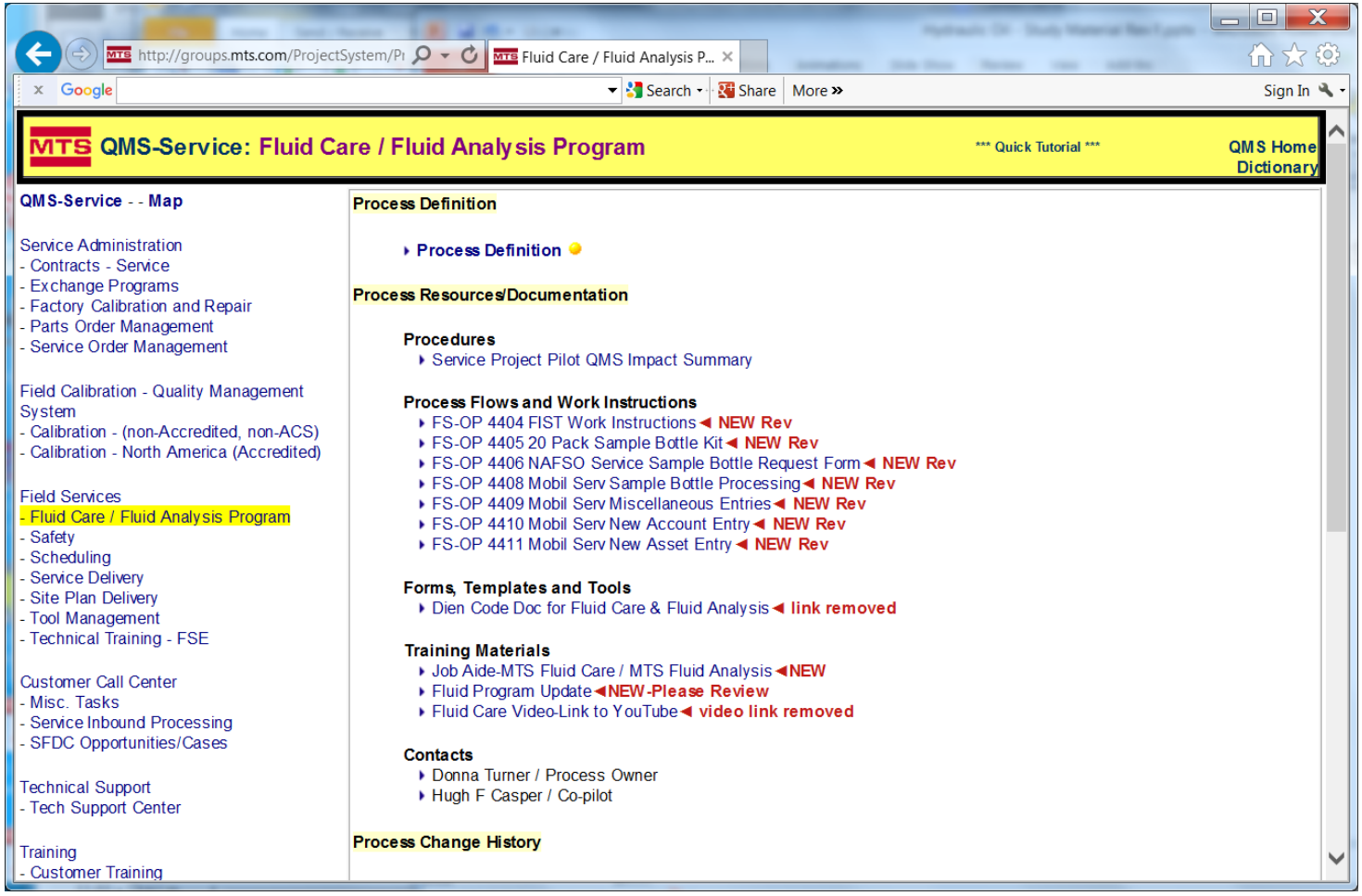
- Contaminant Elements
  - Elements that are not contained in new oil and are generated from an external source
  - Silicon and Sodium are typical contaminate metals coming from dirt/dust
- Wear Elements
  - Metals that comprise the working components of the equipment
  - For basic hydraulic equipment the wear metals are copper, iron and lead

Contaminant (ppm)	**B (Boron)**	0
	K (Potassium)	0
	Na (Sodium)	0
	Si (Silicon)	1

Wear (ppm)	**Al (Aluminum)**	0
	Cr (Chromium)	0
	Cu (Copper)	4
	Fe (Iron)	0
	Mo (Molybdenum)	0
	Ni (Nickel)	1
	Pb (Lead)	1
	Sn (Tin)	0

Oil Analysis Results

» For additional information on Oil Analysis see the Service QMS Fluid Care Page



Control limits for Oil Integrity

Characteristic	Normal	Borderline	Unsatisfactory
Viscosity@100 F	215-240	256-276	>276
Particle Count	16/13/9	17/15/11	18/16/13
Water, % by Wt.	<.05	0.05-.1	>1.0
Iron, ppm	< 30	30-50	>50
Silicon, ppm	<15	15-30	>30
Copper, ppm	<40	40-100	>100
TAN mg	<1.4	1.4-1.6	>2.6
Ultra Centrifugation	1-3	4-6	7-8
Oxidation	<3	3-4	>4

HPU Oil Change

- Press the stop button to turn off the HPU.
  - Use appropriate Lock Out / Tag Out procedures
- Remove the filler cap and screen
- Use a transfer pump to remove the used oil
  - Place transfer pump in filter bypass mode
  - Customer responsible for disposal
- Replace the filter element(s)

HPU Oil Change

- Add new oil to the reservoir
  - Use a transfer pump
  - Filter the oil to 3-10 micron
- Reinstall filler cap and screen
- Turn on HPU
- Run in high pressure and check for leaks
- Verify that dirty filter indicator extinguishes

Solvent Flushing the Hydraulic System

- Using a solvent to flush a hydraulic system is discouraged except for in cases of extreme contamination such as heavy varnish deposits or severely overheated oil which has turned to a thick consistency.

- MTS has identified Colfax as a recommended varnish removal vendor. Colfax is also recommended by Exxon Mobil.

- Flushing with a solvent dislodges contamination and passes it through the system
  - Never flush using a solvent with servovalves installed. The contamination will get trapped in the servovalve which will then require servovalve replacement
  - Replace servovalves with flushing blocks for a solvent flush

Fluid Disposal

- It is the customer responsibility to dispose of used hydraulic fluid
  - Must be disposed of in accordance with local, national, or international laws and regulations