

Stillwater Mining Company

Engine Maintenance Program



Stillwater Mine's DPM reduction plan includes emissions testing, and maintaining 375 pieces of underground mobile equipment.

- Engines ranging from 24 hp to 400 hp
- Deutz, Cat, Cummins, Yanmar, Toyota, Perkins, Daihatsu

Our DPM services are included on the calendar schedule we use for preventative maintenance.

- Emissions testing is done every 56 days, which is every other PM service.
- Production equipment will soon be emissions tested every 28 days.

There are two rotating PM crews, made up of 7 mechanics each.

- All are trained on the ECOM gas analyzers, located in 3 of our underground shops, and one at the surface shop
- Trained on Six System engine and emissions-based maintenance
- Training has been done quarterly by Sean McGinn, of McGinn Integration Inc.

Our Engine PM Tools



- **Magnehelic Gauges**
- **Pressure Gauges**
- **IR Temp Gun**
- **Laser Tachometer**
- **Intake Pressure Test Kit**



- **Ecom Analyzer and UGAS**
- **Networked Emissions Database**

What We Measure & Check

Intake

- Restriction iwg
- Boost Pressure psi
- Pressure leak test
- Restriction based filter replacement

Exhaust

- Emissions
- Engine RPM stall speeds
- O₂, CO, NO, NO₂, NO_x, CO₂, Smoke #, Temp, MEQI
- $MEQI = CO/25 + NO/25 + NO_2/3$
- Backpressure iwg
- DPF & DOC efficiency %
- Leaks, Fire Hazards, Insulation, etc.

Fuel Injection

- Transfer pump pressure
- Injector cutout (electronic)
- Filtration / Contamination

Lubrication

- Oil Pressure
- Oil Level
- Filtration / Contamination
- Oil Analysis

Cooling

- Engine Coolant Delta T
- Coolant Level
- Charge Air Boost Temp
- Cleaning / Inspection
- Fan, Belts, Radiator, etc.

ECOM AC Gas Analyzer

- Located in every shop where PMs are performed. We also have one complete unit used as a spare while any are out for repair.
- Measures oxygen, carbon monoxide, nitrogen oxide, nitrogen dioxide, gas temp, gas pressure and performs smoke test.
- Stores the six system engine preventive maintenance form (EPM).
- UGAS software uses intuitive gauge display and integrated testing protocol for easy readout and repeatable testing method for all users
- Emissions database enables you to search and print historical reports on any equipment previously tested.



UGAS 1.0

Sampling Information

User name : 3800 Mechanics
Vehicle : UT132
RPM : 2500 RPM
Fuel : Diesel
Code : ODOC
Memo : DOC Catalyst Outlet
Time : 3:52:12 AM
Date : 10/15/2005
Sample Duration : 1.00

Sampling Results

Description	Previous test	Current test	TV	Unit
O2	5.5	15.2	12.0	%
CO	3.0	109.6	200.0	PPM
NO	490.9	331.4	700.0	PPM
NO2	116.8	2.0	50.0	PPM
CO2	11.4	4.2	8.0	%
T. Gas	986.3	471.2	700.0	Deg F
MEQI	58.7	18.3	50.0	Certif
NOx	607.7	333.4	750.0	PPM

Target values preset by user.
Used previous base line numbers
to come up with TV

Shows previous test results for
easy comparisons



Six System Concept

- Intake System
- Exhaust System
- Fuel Injection System
- Cooling System(s)
- Lubrication System
- Fuel and Lube Quality Management

- Note actions required based on emissions and diagnose / repair – if actions required re-do emissions test at finish to verify

➤ ACTIONS:



Intake System

- Measure and record intake restriction: _____ iwg
- Measure and record turbo boost pressure: _____ psi (full throttle - stall)
- DO NOT replace intake filters if less than 20 iwg restriction
- CAREFULLY remove filter and inspect for proper function of pre-cleaner and make necessary repairs – Clean out pre-cleaner and housing carefully
- Install plug filter and pressure test intake with regulator @ 10 psi – check for and repair all leaks on both suction and charge sides
- Carefully re-install old (or new) filters before starting engine
- ACTIONS:



Exhaust System

- Measure and record backpressure: _____ iwg (max 30 iwg)
- Attach emissions printouts inlet/outlet & DOC efficiency from above
- Inspect clamps, connections, flanges for leaks and repair as required
- Inspect turbo, piping, deflectors
- Inspect insulation, check for fire hazards, repair as required
- ACTIONS:



Fuel System

- Service water separator and-or drain water from bottom fitting on tank
- Fuel transfer pump pressure @ idle _____ psi @ full throttle _____ psi
- Replace primary and secondary fuel filters and bleed system
- Visual inspection for tank contamination, condition of lines, hoses, cooler
- ACTIONS:



Cooling System

- Measure temperature differential across radiator _____ degrees (min 30°F)
- Measure turbo charge air temp at cooler outlet _____ degrees (max 120°F)
- Verify operation of thermostats cycling with IR temp gun
- Visual inspection of radiator, fan , belts, leaks,
- Air cooled engines:
 - Verify cylinder temperatures
 - Verify engine oil cooler temperature differential

- Intake restriction and turbo boost psi
- Exhaust back pressure
- Fuel pressures
- Radiator and charge air temperatures
- Comment sections for any action taken

- Verify condition of belts, drive, blower, sensors and alarms

➤ ACTIONS:

Lubrication

- Engine oil pressure @ idle _____ psi @ full throttle _____ psi
- Drain oil and take sample (from drain not filters)
- Replace lube filters (do not pre-fill on bench)
- Fill crankcase with new oil – run/stop engine and verify proper level
- Visual inspection for external leaks, internal leaks (consumption) at exhaust or turbo, crankcase breather blow-by

➤ ACTIONS:

Electronic Controlled Engines

- Engine/Trip Data – Print and re-set Trip Data
- ECM total hours _____ ECM trip hours _____
- Total Idle _____ % Trip Idle _____ %
- Total fuel _____ gals Trip fuel _____ gals
- Diagnostic Menu – Cylinder Cutout – Automatic @1000 RPM and Print
- Diagnostic Menu – Fault Codes – Verify and Clear Inactive

➤ ACTIONS:

• Engine oil pressures

• Comment sections

• Print form and store in equipment file

PRINT

EXPORT

CLEAR FORM

Common Problems

- Basics – intake leaks on both suction and charge sides – fuel injection problems sourced to primary side filtration / contamination, etc.
- DPF failures – root cause failure analysis determines manufacturer / application / engine related sources of failure

Daily Engine Maintenance

Includes passive and active soot trap maintenance

When excessive back pressure is realized, soot trap is cleaned or replaced.

If there is no significant reduction on outlet smoke test, soot trap is replaced.

Operators utilizing the active Titan filters, normally replace the filters themselves (5 units).

Several means of off-board filter regeneration.



DCL Titan X1600-A020-RS Burner

Capable of reaching 1200 degrees F

Less than 2 hour regeneration time

**Larger filters require multiple
regeneration cycles**

Not ventilated to the outdoors

Does not capture soot or ash

LUBRIZOL CombiClean Burner

**Uses three step cleaning process
Vacuum – Heat – Vacuum**

3 hour cleaning cycle

Captures soot in shop vac



2006 12 21

Euclid Kiln

Bake filters at 950 degrees for 5 hours

Can cook several filters at once

Usually does not require more than one cooking cycle

Ventilated to the outdoors



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Next Steps

- Fully electronic Engine PM stores all performance data, checks, and actions taken to database (not just emissions history)
- More effort on base lining all engine performance metrics for each engine / vehicle / emission control combination
- Expand emissions database to include maximum, minimum and TWA average values during 60 second stall tests (currently TWA only)