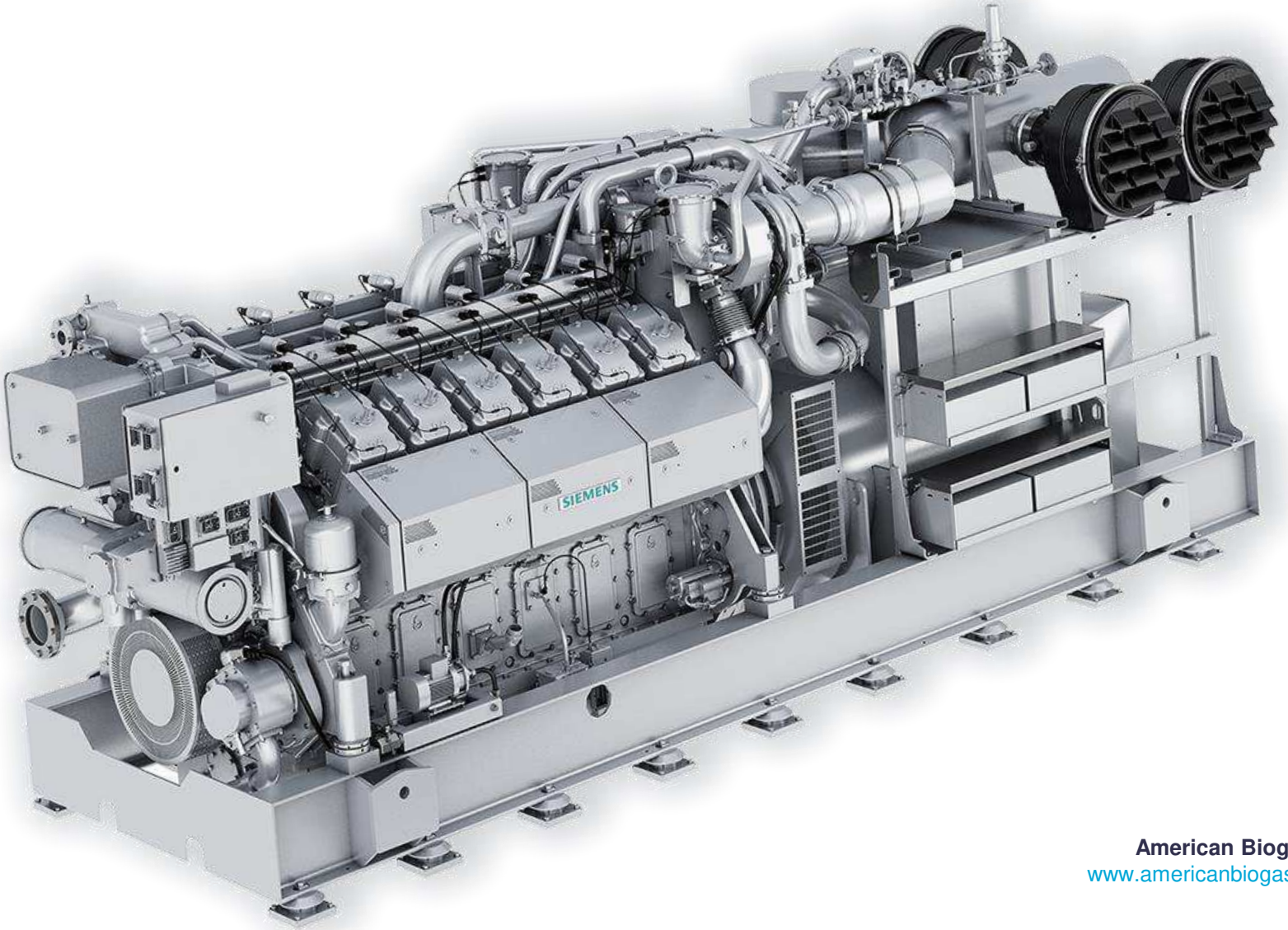
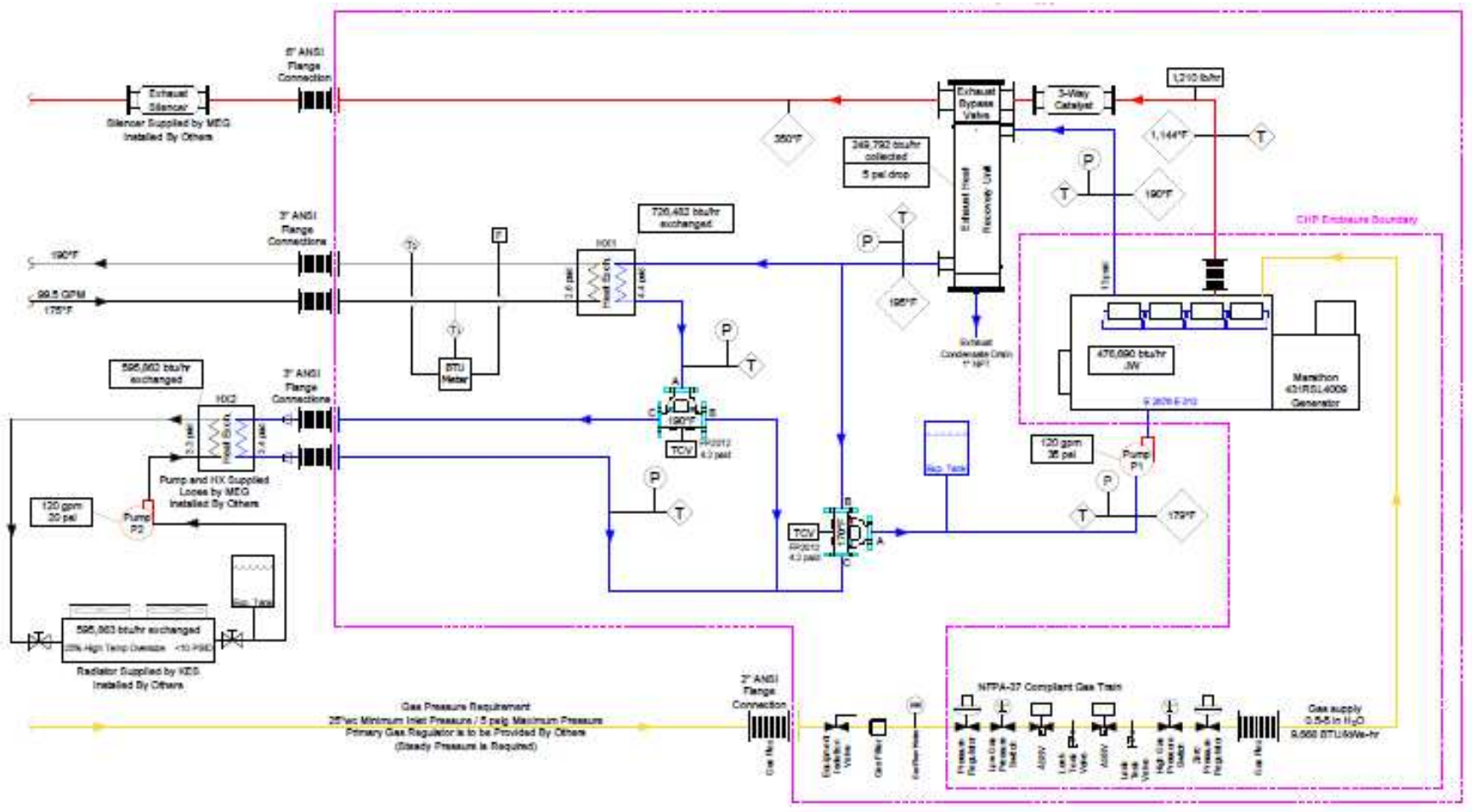
Engine and CHP Maintenance

Presented by Clarke Energy USA

June 2019

Engine Maintenance


SIEMENS


Exhaust Silencer
Silencer Supplied by MEG
Installed By Others
8" ANSI Flange Connection
3" ANSI Flange Connections
3" ANSI Flange Connections
3" ANSI Flange Connection
Exhaust Bypass Valve
3-Way Catalyst
1,210 lb/hr
1,144°F
350°F
249,792 btu/hr collected
5 psi drop
Exhaust Heat Recovery Unit
190°F
720,482 btu/hr exchanged
HX1
Heat Exch
2.6 psi
4.4 psi
190°F
99.5 GPM
175°F
BTU Meter
595,863 btu/hr exchanged
HX2
Heat Exch
3.3 psi
3.4 psi
Pump and HX Supplied Loose by MEG Installed By Others
120 gpm
20 psi
Pump P2
595,863 btu/hr exchanged
Radiator Supplied by KDS Installed By Others
Exhaust Condensate Drain
CHP Enclosure Boundary
476,690 btu/hr JW
Marathon 431RSL4000 Generator
TCV
190°F
TCV
170°F
Rad. Tank
120 gpm
35 psi
Pump P1
175°F
Gas Pressure Requirement
25"wc Minimum Inlet Pressure / 5 psig Maximum Pressure
Primary Gas Regulator is to be Provided By Others
(Steady Pressure is Required)
3" ANSI Flange Connection
NFPA-37 Compliant Gas Train
Gas supply
0.5-5 in H2O
9,568 BTU/kWe-hr


HGM240


KRAFTPOWER
DRESSER-RAND


EXIT
D-R


630296


KN 80-6
KRAFT ENERGY SYSTEMS
COMBINED HEAT AND POWER

Engine and CHP Maintenance

- Overview
- What goes into a successful project
- Outside factors affecting the gen-set
- What affects maintenance and operations
- Common problems
- Availability and reliability factors
- Proactive Monitoring

Overview

- Engine Maintenance
  - Scheduled Maintenance
  - Corrective Repairs

- Heat Recovery Equipment
  - Exhaust Heat Exchanger
  - Radiators

Requirements for a Successful Project

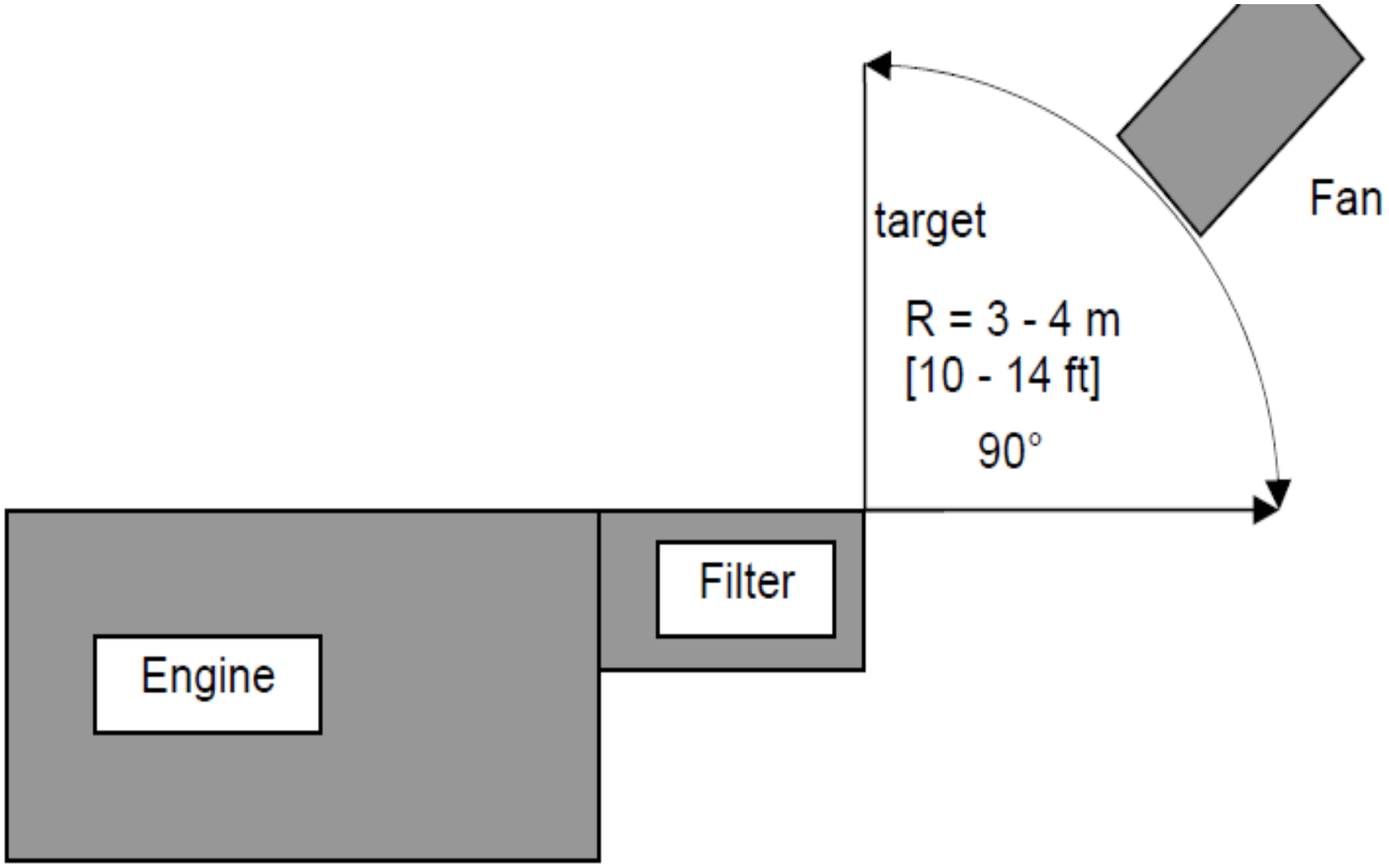
Proper….

- Design
  - Application, sizing
  - Ventilation
- Planning
- Installation
  - Install per manufacturer's technical specifications
  - Verify mechanical interfaces are correct
  - Verify electrical interfaces are correct
  - Verify ancillary equipment is installed correctly

Common Failures/Improper Installation

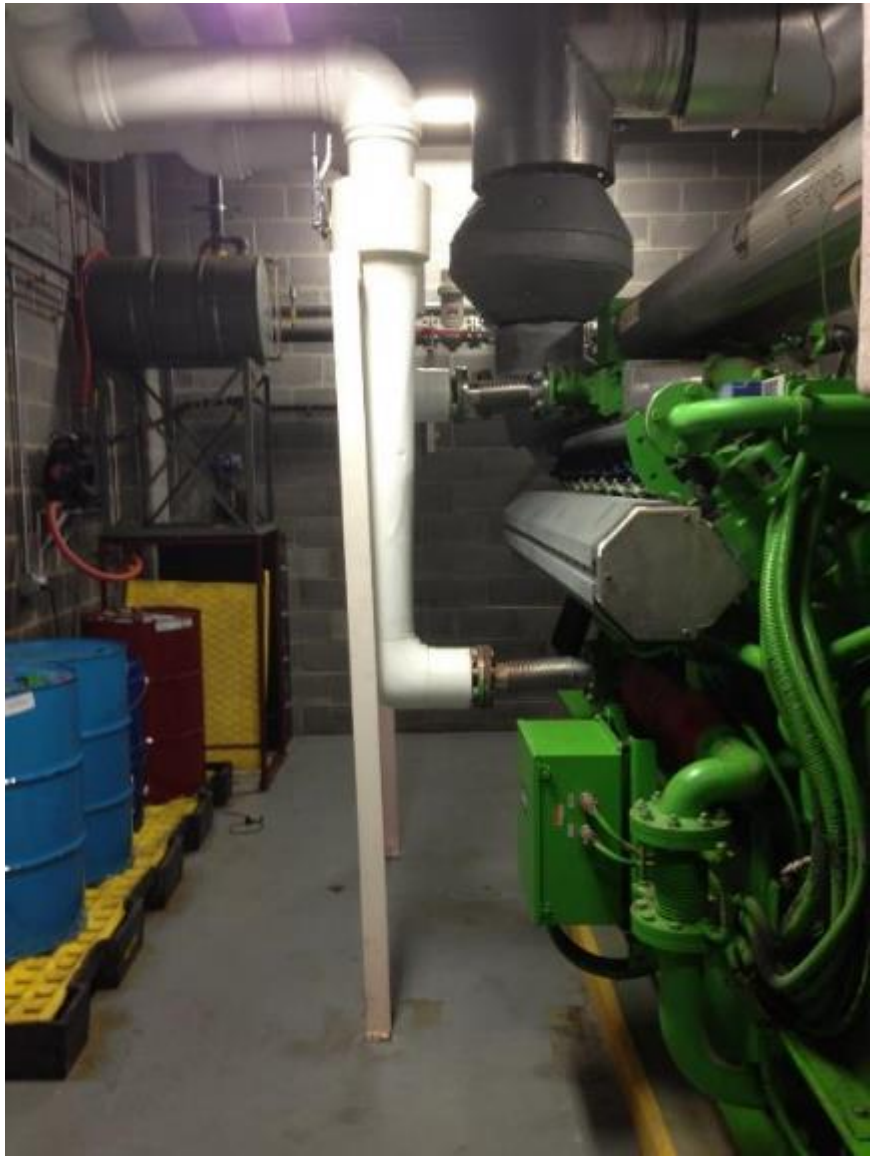
- Ventilation Design
- Mechanical Interface Installation
- Electrical Interface Installation
- Gas Supply Design / Installation
- Neutral ground Resistor

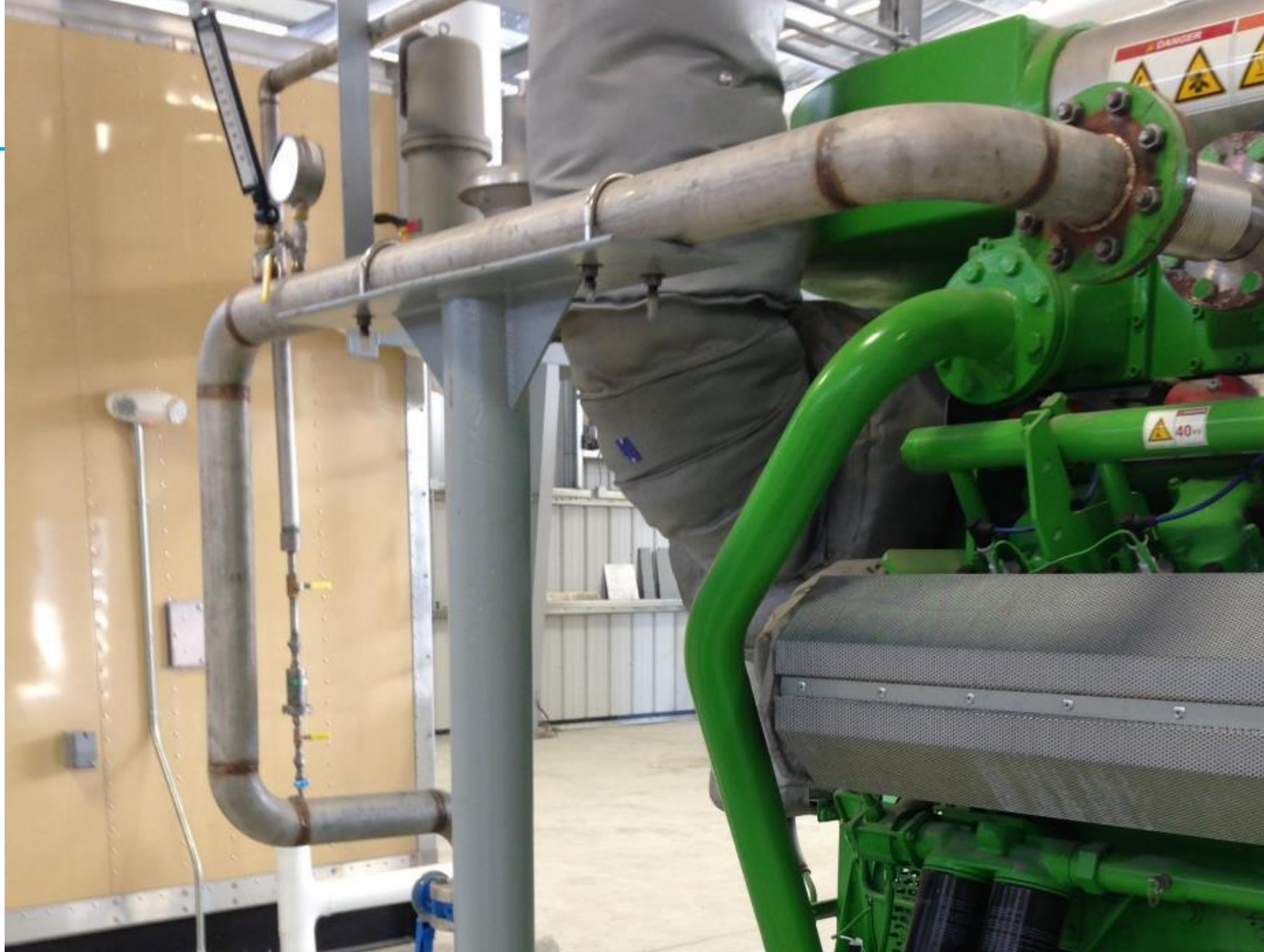
Ventilation Design



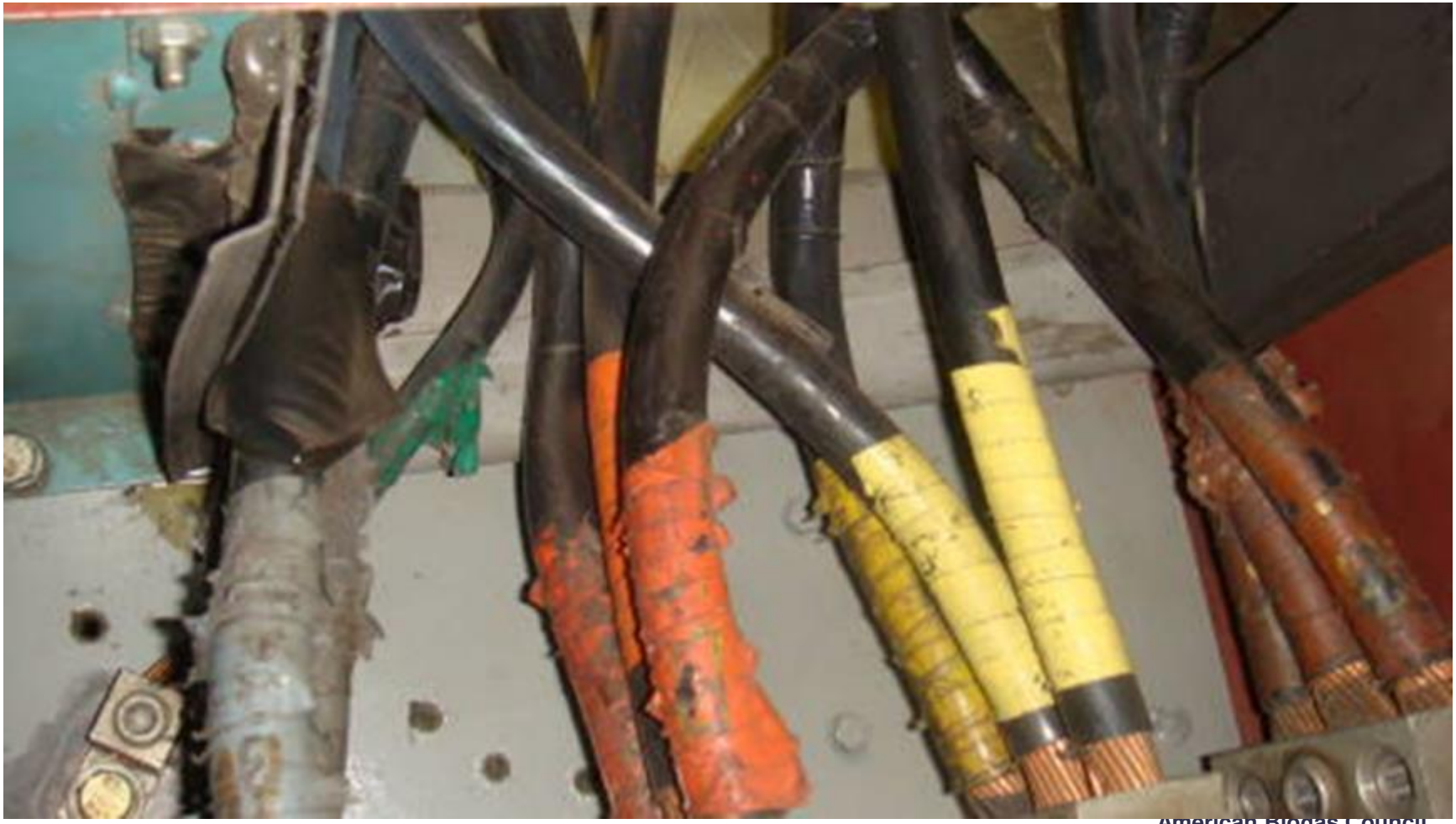
Piping interfaces need flex connections

Improper support leads to deflection




DANGER

Electrical Interfaces



Wear Dust Indicative of an Issue

Rubber buffers and cables wearing

Scheduled Maintenance

- **Daily inspections** – operator tasks
- **Oil changes:** oil analysis determines frequency of changes
- **Spark plug changes:** Gas quality, maintenance, load and capacity factor affect life of plugs
- **Inspection(s):** Usually includes valve lash and recession readings
- **Overhauls:** Top end, minor or major, complete overhauls

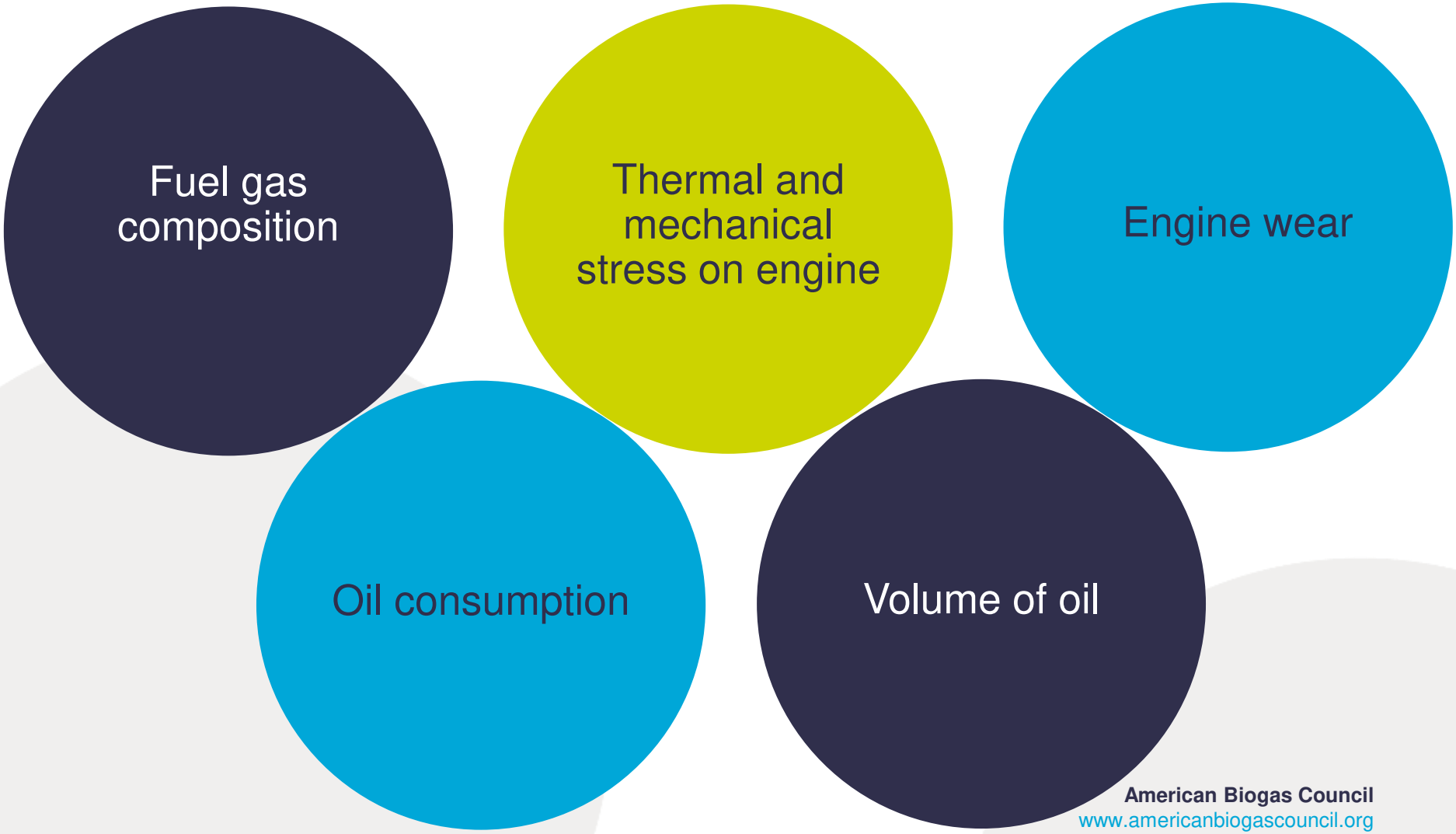
Daily Inspection

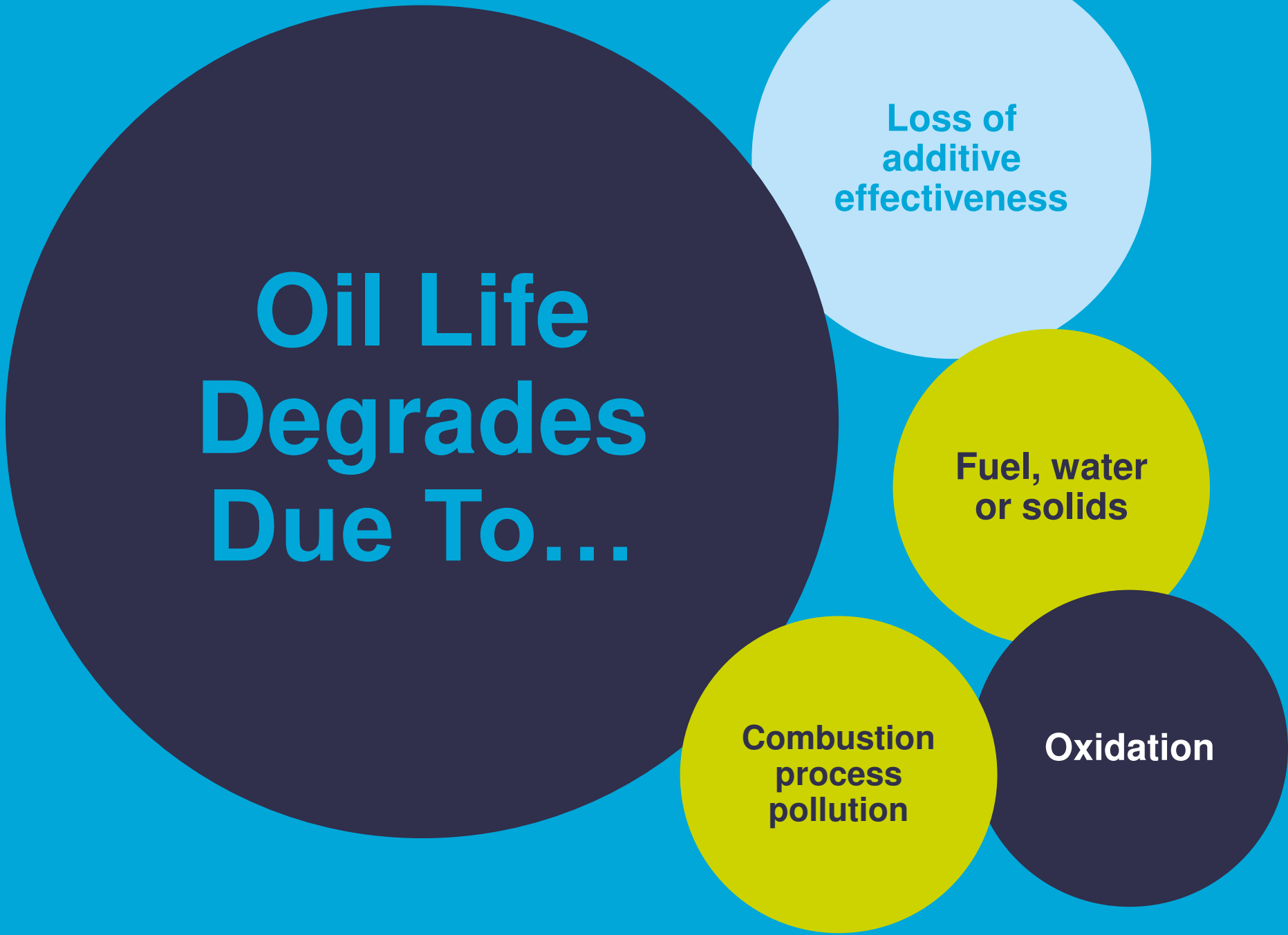
- Visual inspection of the module
- Look for problems: Leaks, insulation or ignition charred, unusual vibration, oil level
- Listen for unusual sounds: mixture line leaks, exhaust leaks, hunting, bearing noise, tuning of the engine
- Monitor / analyze daily readings: View trend screens
- Venting of coolant circuits: Help to determine if you have combustion gas leaking into coolant circuit.
- Draining of exhaust pipe: Could be indicative of an exhaust heat exchanger leak

Engine Oil

- Oil costs run in thousands of dollars / year for consumption and oil changes
- The oil costs in biogas applications can more than double those of natural gas applications, due to increased frequency of oil changes required
- Cleaning the gas on the front end can save on back end oil costs IC-G-D-30-003e - Digester Gas Fuel Specification.pdf

Oil life is affected by…




Oil Life Degrades Due To…
Loss of additive effectiveness
Fuel, water or solids
Combustion process pollution
Oxidation

Oil Life in Biogas Applications

- The fuel can be a main contributor oil life
- Sulfur in the gas can corrode engine parts
- Alkaline additives are added to the oil to fight against the acid created by sulfur and other contaminants
- When the additive reserve has been used up, the oil has to be changed.
- Oil change intervals are based on periodic oil analysis

Oil Analysis

- Viscosity
- TBN
- TAN
- pH
- Oxidation
- Nitration
- Water content
- Wear metals
- Silicon
- Chlorine

Spark Plug Maintenance

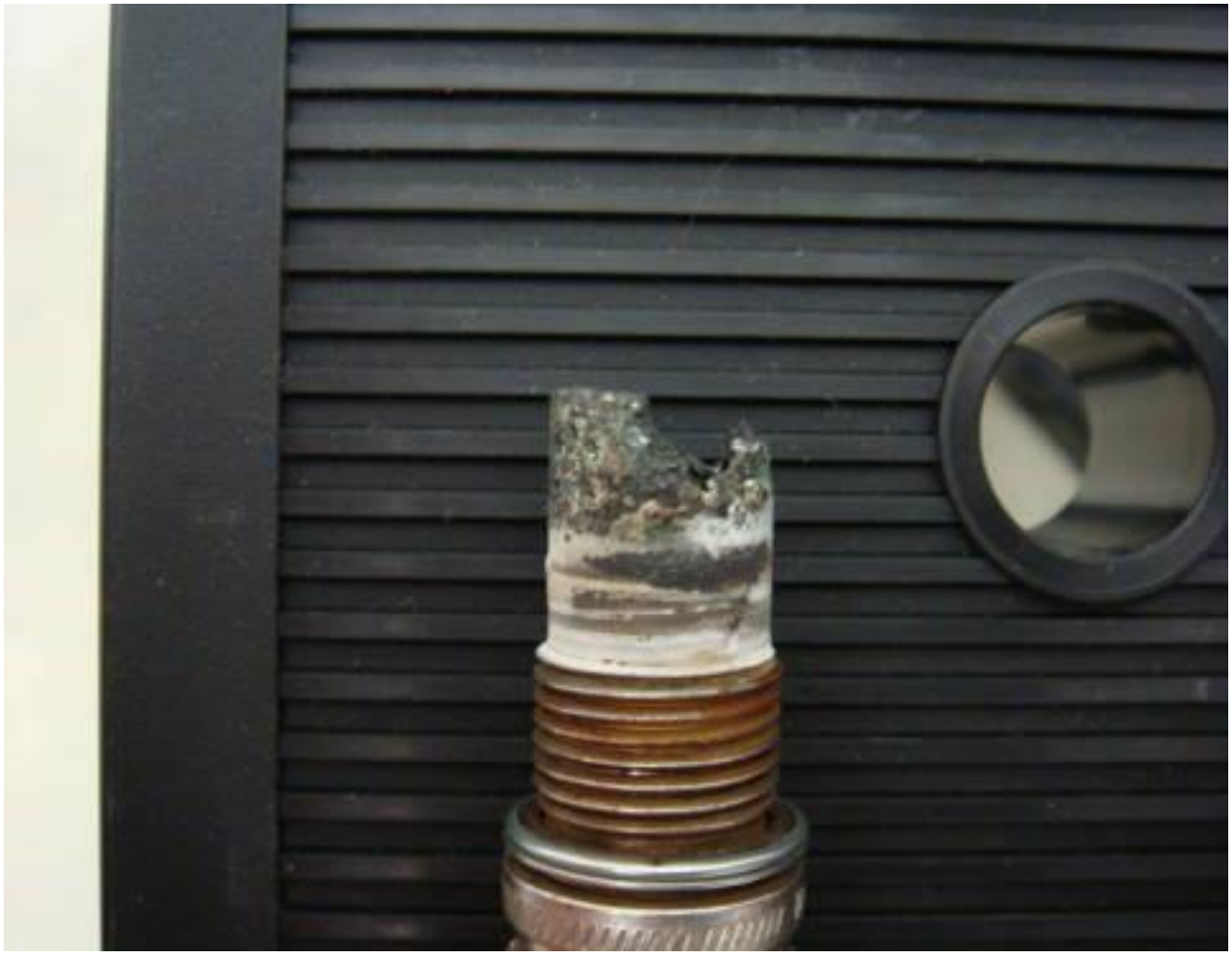
- ↑ up-time, increasing revenues, less negative impact on digester issues
- Proper maintenance is important to meet emissions requirements and efficiencies.
- Spark plugs can be expensive. Proper maintenance extends the life of the plug, lowering maintenance costs
- Proper maintenance decreases the stress and peak loading on components of the engine.

Spark Plug Variations

Spark Plug Maintenance

Spark Plug Maintenance

Failed Spark Plug



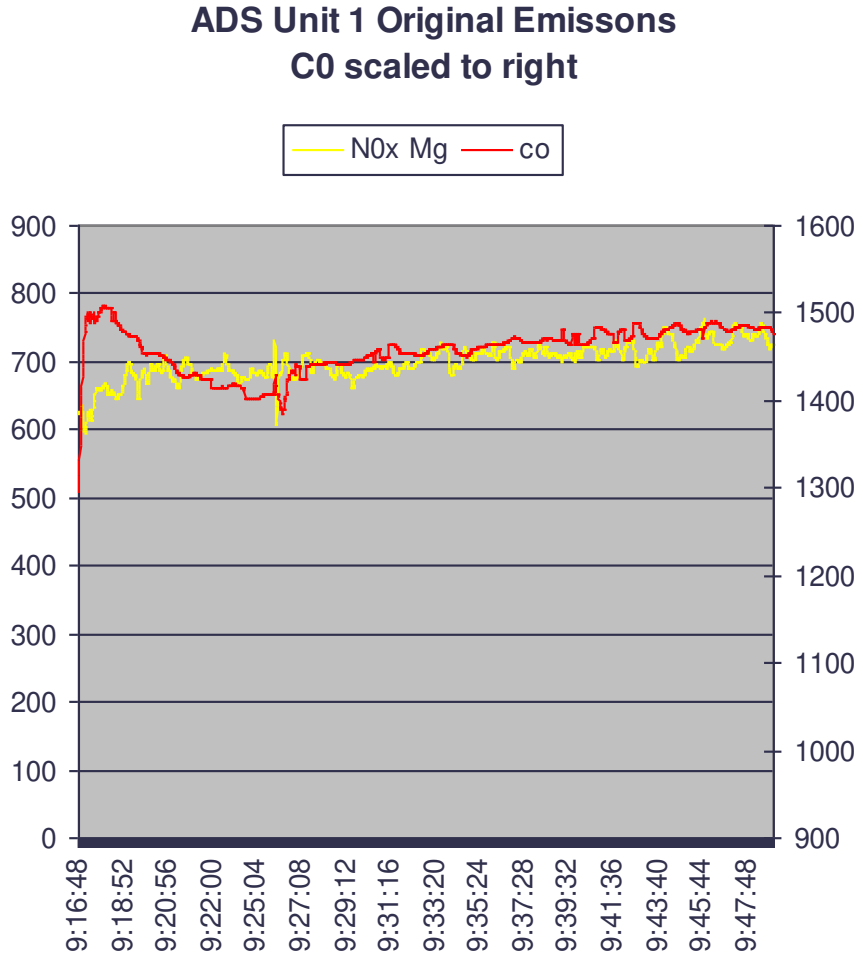
Piston damage due to knocking

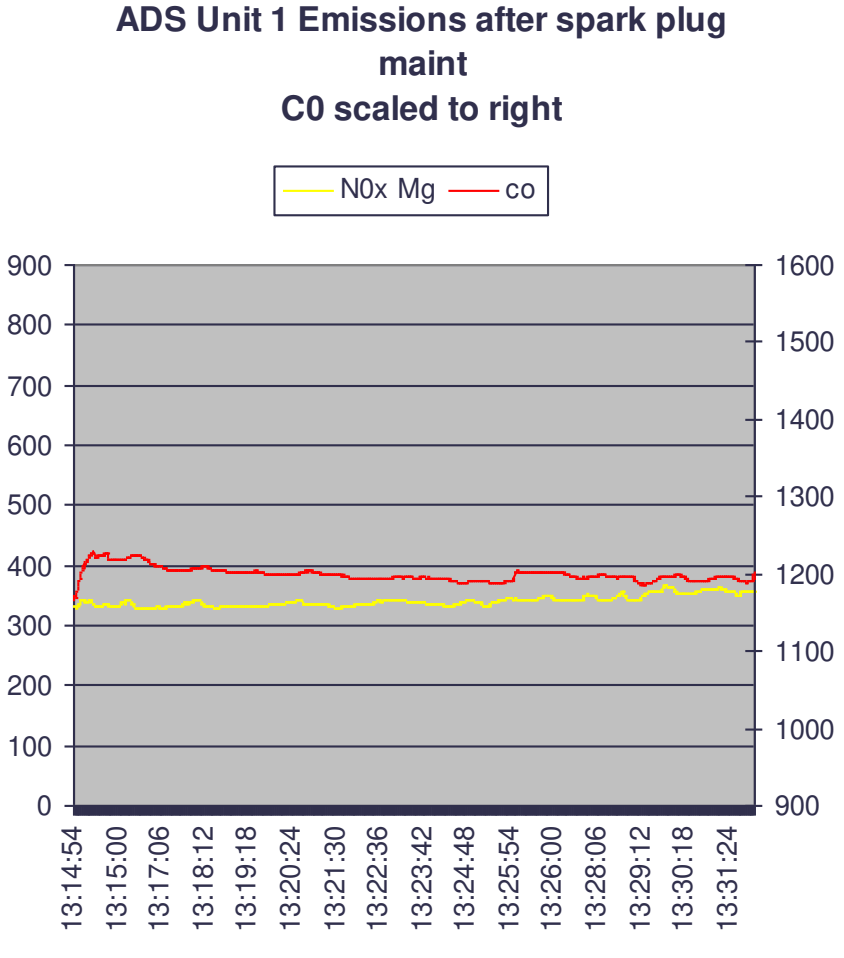
Spark Plug Maintenance Tips

- Record kV readings of the spark plugs at full load once a week and track readings to determine life cycle. Proactively change plugs based on that information.
- Replace spark plugs as a set to control unscheduled outages and to minimize down time due to faulty plugs
- Utilize a swing set of spark plugs and track operating hours
- Do not bead blast to remove build-up on plug, as it removes the precious metal on the electrode and lessens the life of the plug. Use a brass wire brush to clean

Swing set of spark plugs

Proper plug maintenance reduces emissions





Ignition Maintenance Tips

- Prevent the spark plug wire from the coil to the spark plug socket from contacting engine parts. Over time, the friction from vibration will wear the insulation away and cause faulty ignition and misfiring.
- Keep the inside and outside of the spark plug insulator clean to prevent faulty ignition.
- Look for deterioration of the spark plug insulator due to high heat or exhaust leaks.

Heat damaged candlestick

Failed spark plug insulator

Timing Adjustments

- Timing adjustments are occasionally needed to tune the engine properly, to meet emissions.
- Seasonal adjustments may be required due to high ambient conditions
- Retarding timing causes ↑ exhaust gas temps, ↑ load on the exhaust manifold, turbocharger

Outside Factors Affecting the Gen-Set

- Digester production / operations
- Gas Quality
- Gas Pressure
- Gas contaminants; sulfur, siloxanes, chlorine
- Condensate in the gas
- Electrical load / harmonics, location within the grid

Outside Factors Affecting the Gen-Set

Ambient conditions – too cold, too hot

Other engines on same gas supply

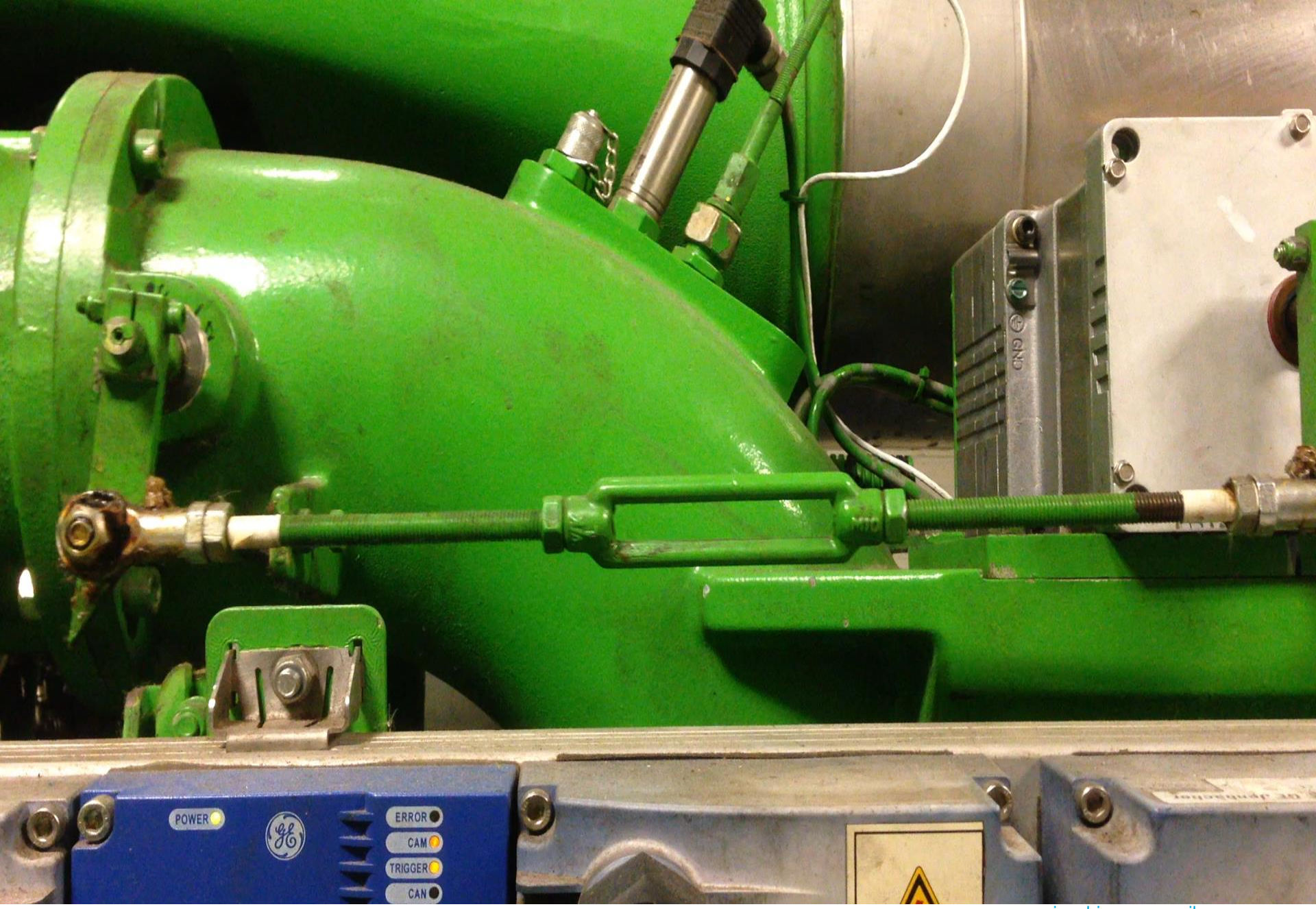
Exhaust heat recovery equipment / silencer

Factors That May Affect Life Cycle Costs

- Gas Quality: Type of gas, natural gas, biogas, landfill gas
- Gas specification: Is the gas within manufacturer's specifications?
- Engine operates within the technical specification of the manufacturer
- Proper Maintenance
- Load factor of the engine
- Start / Stop Frequency

To Maximize Up-time

- Steady state operations is preferred
- Maintain gen-set according to manufacturer's spec's
- Keep appropriate spares on-hand
- Keep appropriate tooling on-hand
- Self-perform on certain tasks; spark plug maintenance, oil changes, emissions tuning


POWER
ERROR
CAM
TRIGGER
CAN
GND

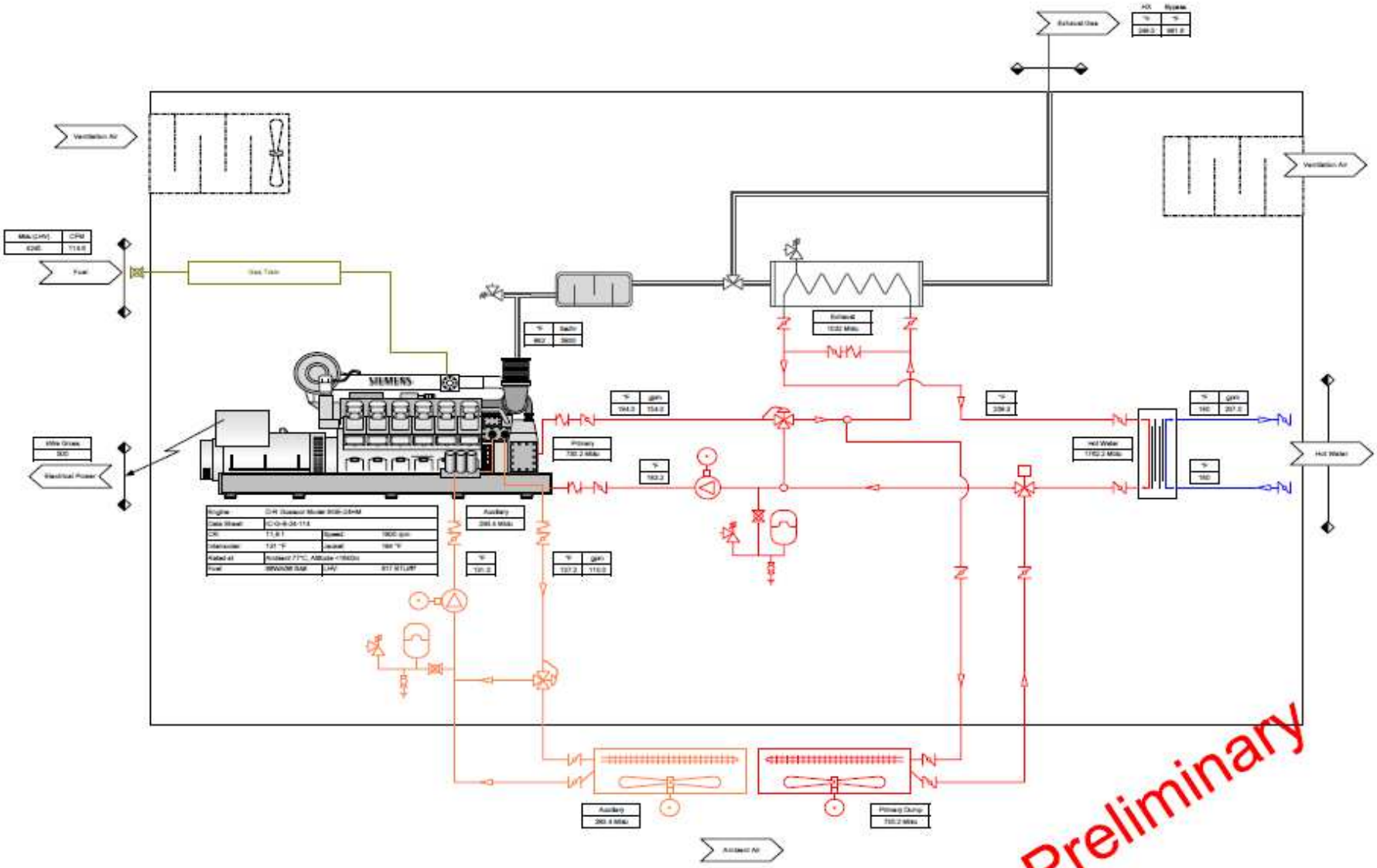
Exhaust Heat Exchanger

- Fire-tube where the exhaust flows through the tube
- In biogas plants, this can become clogged on the gas side of the tubes, due to gas quality
- It's necessary to monitor the exhaust and cooling water temperatures
- Monitor / record exhaust backpressure before and after cleaning the heat exchanger, delta P across heat exchanger
- Depending on severity, may be able to clean tubes with a Goodway machine

Predictive Maintenance – Monitoring

- Know your engine and systems
- Daily rounds, logs, analysis – use all your senses
- Oil Analysis
- Emissions Readings and Adjustment
- Vibration Analysis
- Meggher Readings / Inspections
- Alignment

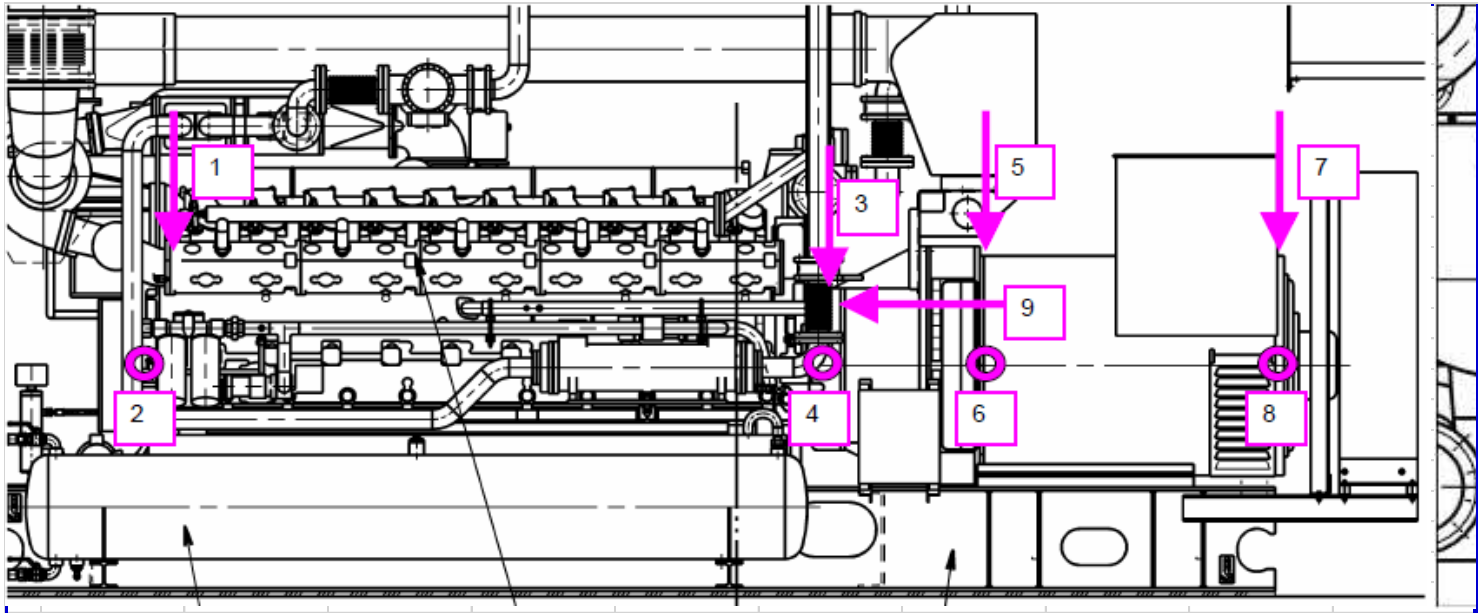
Know Your System



Electric Starters

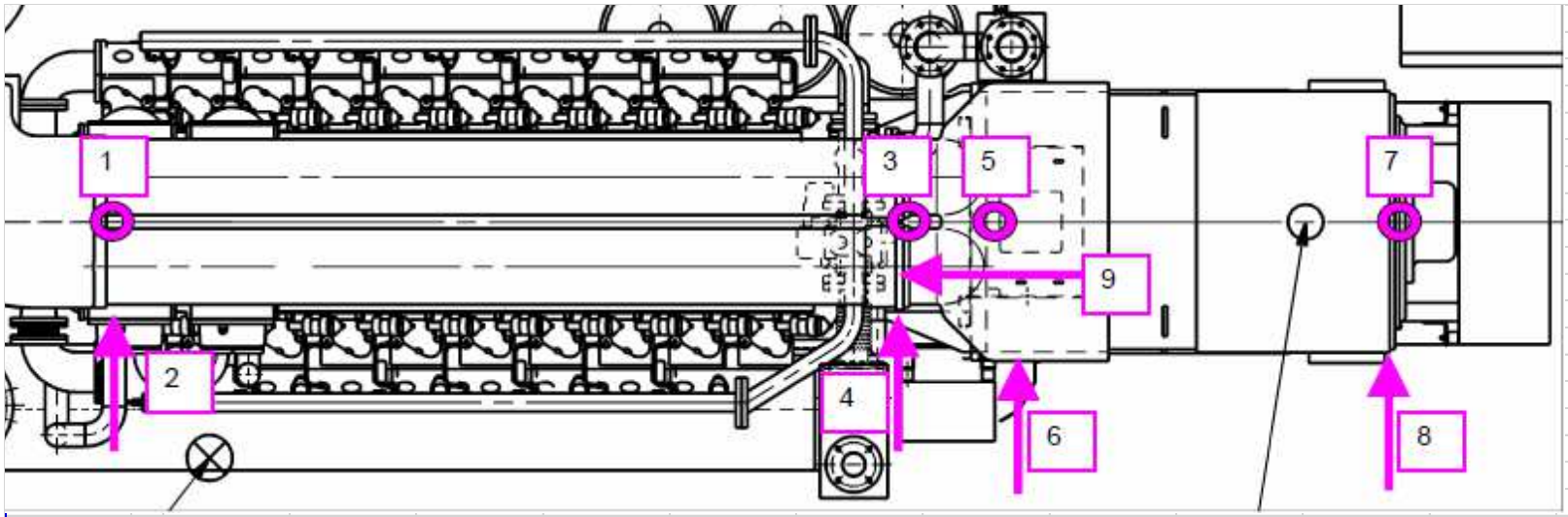
- Biogas engines may have issues with start repeatability as gas quality varies from start to start.
- This requires the starter to work harder than in a natural gas application.
- More frequent start attempts and longer starter engagement durations can increase the chance of starter failures.
- More frequent and longer start durations,↓the battery voltage and ↑ amperage to the starter. This can cause electrical failures of the starter coils, etc.
- Keep a spare set of batteries accessible and a spare starter on hand

Vibration Measuring Points – Side View



		mm/s	m/s²
1	Vertical measured at the top of the crankcase		
2	Horixontal measured at the foot of the crankcase		
3	vertical measured at the top of the flywheel housing		
4	Horizontal measured at the side of the flywheel housing		
5	vertical measured at the top of the generator drive end flange of vent housing		
6	horizontal measured at the side of the the generator drive end flange of vent housing		
7	vertical measured at the top of the generator non drive end flange		
8	horizontal measured at the top of the generator no drive end flange		
9	horizontal measurement at the flywheel hosing of the engine in axial direction		
→	To be measured: the velocity in Milimeters per second (mm/s) and the acceleration in m/s²		

Vibration Measuring Points – Top View



		mm/s	m/s²
1	Vertical measured at the top of the crankcase		
2	Horixontal measured at the foot of the crankcase		
3	vertical measured at the top of the flywheel housing		
4	Horizontal measured at the side of the flywheel housing		
5	vertical measured at the top of the generator drive end flange of vent housing		
6	horizontal measured at the side of the the generator drive end flange of vent housing		
7	vertical measured at the top of the generator non drive end flange		
8	horizontal measured at the top of the generator no drive end flange		
9	horizontal measurement at the flywheel hosing of the engine in axial direction		
→	To be measured: the velocity in Milimeters per second (mm/s) and the acceleration in m/s²		

Vibration Analysis

- Take readings at the same load consistently, preferably at full load
- Take velocity and acceleration readings
- Document properly
- Monitor / review for changes in the readings
- Training in vibration analysis
- Vibration pen

Low Risk – Biggest Reward

Self – Perform on the following…

- Operations
- Provide your own fluids – oil and anti-freeze
- Oil Sampling and Analysis
- Oil and Filter Changes
- Spark Plug Maintenance
- Inspection Requirements

- Valve Lash and Recession Readings

Risk – Reward Analysis

Self-performing Maintenance Tasks

Risk – potential cost of self-performing

- Not your core competency
- Personnel safety
- Takes you away from operator tasks
- Time and manpower constraints
- Proper tooling
- Overhauls are less frequent. You can invest in training to do it. But, by time you have to do it again, the training is lost. This increases the chance for failure.
- Accountability for engine performance

Reward – potential benefit of self-performing

- Potential savings on labor and travel costs, decreasing maintenance expense
- Potential savings from markup on oil
- Changing oil and filters, low risk
- Changing spark plugs, low risk
- Valve adjustments, recession readings, moderate risk
- Overhauls; top end, major and complete, high risk compared to the potential reward
- Accountability for engine performance

Camshaft Failure

Camshaft lobe failure

- Improper Lubrication
- Incorrect valve adjustment

The Risk

Maintenance Tasks that Operators CAN Do

- Daily Rounds / Operations
- Inspections
- Spark Plug Maintenance
- Lube Oil Sampling and Analysis
- Lube Oil Changes
- Filter Changes
- Some Troubleshooting
- Valve Adjustments and Recession Readings – Risk / Reward
- Head Changes – Risk / Reward Analysis
- Turbochargers – Risk / Reward Analysis

Maintenance Tasks Operators Should NOT Do!

- Overhauls
  - Top End (pistons, liners, heads)
  - Bottom End (conrods, main bearings)
  - **Catastrophic damage may result!**

→→

- Valve Adjustments

  Proper training or expertise required
- Personnel Safety
  - Electrical High Voltage
  - Arc flash training requirements
- Any task which is not a core competency

Common Reasons for Failure - Conrods

- Insufficient personnel training / expertise
- Mixing rod caps from one conrod to another
- Improper torque
- Bearing slipped during assembly
- Foreign material into oil supply
- Re-use of connecting rod bolts, yield strength
- Incorrect part installed

Connecting Rod Cap

Catastrophic Failure - Parts

- Parts may be specific to a particular engine serial number
- Need to order from that engine's specific parts book

Common mistakes…

- Ordering parts from a parts manual for similar engine model but not for the specific engine serial number (multiple engines at one site, engine replacements)
- Incorrect part number provided by the manufacturer
- No process developed for verifying parts
- Re-using parts past their yield strength (conrod bolt)

Common Causes of Catastrophic Failure

- Negligence or human error
- Not adhering to manufacturer's maintenance schedule
- Poor lubrication
- Foreign material in lube oil, in engine
- Fuel supply contamination: sulfur, siloxanes, condensate

Self-perform – Safety

Gas Quality: Condensate

- The gas supply to the engine should be moisture and condensate free.
- Condensate cannot be compressed in the cylinder and damage will occur
- Condensate causes corrosion and may be acidic, clogging and eating away at components
- Slugs of condensate may occur at startup and full load shutdowns

Condensate

- Signs of condensate first appear in piping and fittings.
- Investigate signs before they cause major engine damage
- Water vapor will turn into condensate as it enters high pressures of the engine

Gas Pre-Treatment to Prevent Water Vapor

- Install the proper digester process
- Allow the gas to cool and / or expand
- Install knock-outs to remove the condensed vapor after cooldown
- Cyclone separator or filtering
- Drain gas line upstream of engine prior to start
- Insulate / heat trace piping. Helps to prevent condensate and to prevent pipes from freezing

Condensate evident in gas supply

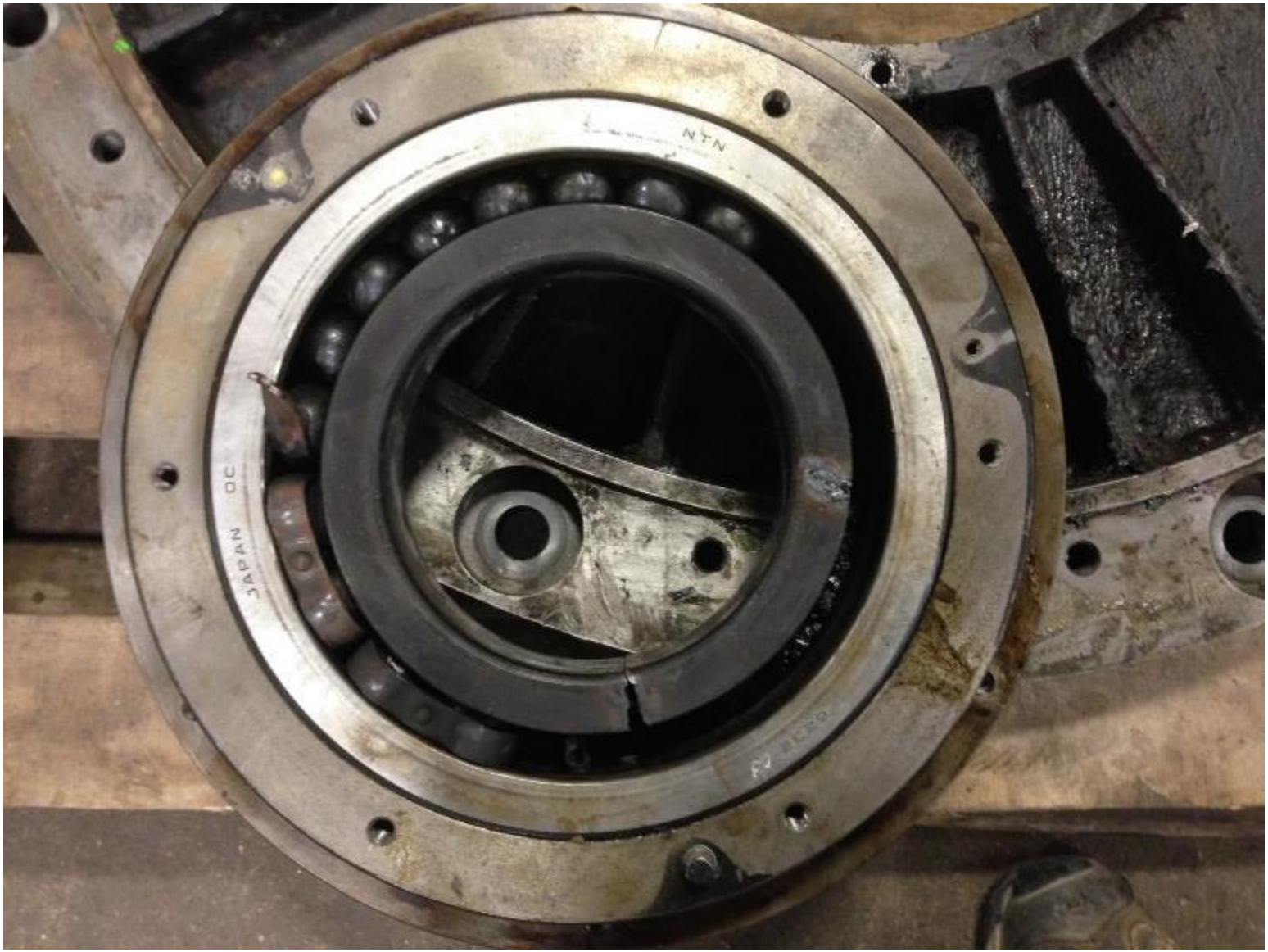
Condensate contamination main gas solenoid


50
100
150
160
0
mbar
DUNGS

Condensate through the exhaust

- Water can enter the engine through the exhaust as well
  - Exhaust heat exchanger leak
  - Intercooler water-side leak
  - Through the stack due to weather

Generator Bearing Maintenance



Service Agreement Pricing

- Various options

  - Scheduled maintenance only Engine and Heat Recovery

    - Scheduled and Corrective Maintenance CHP

    - Lube oil, no lube oil

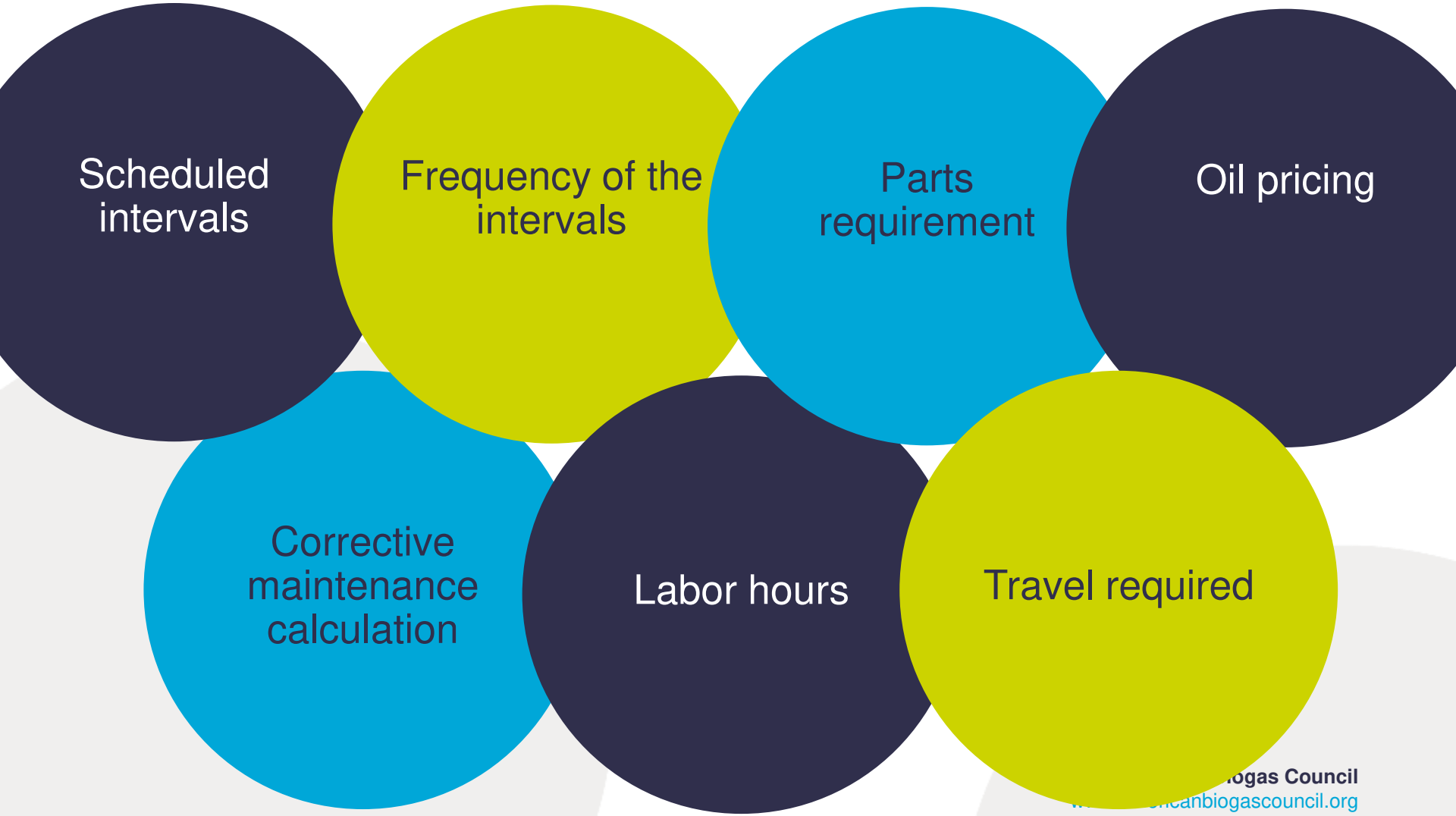
    - The term of the agreement is adjustable

- $ / operating hour or $ / kW billing rate
- Range is somewhere between $0.015 / kW to $0.035 / kW

  - The smaller the unit the larger the per kW cost usually

  - The smaller the unit, the smaller the $ / OPH cost

Factors Contributing to CSA Pricing



Summary

- Maintenance costs are a considerable factor in the total cost of ownership of a CHP plant
- There are many ways to customize a service agreement to best fit the customer's proforma for a successful project
- The customer has choices for service and should analyze the risk / reward of the different choices available
- The customer can elect to self-perform on maintenance tasks to improve on the cost of maintenance

Questions?