The Effects of Fuel Dilution with Biodiesel on Lubricant Acidity, Oxidation and Corrosion – a Study with CJ-4 and CI-4 PLUS Lubricants

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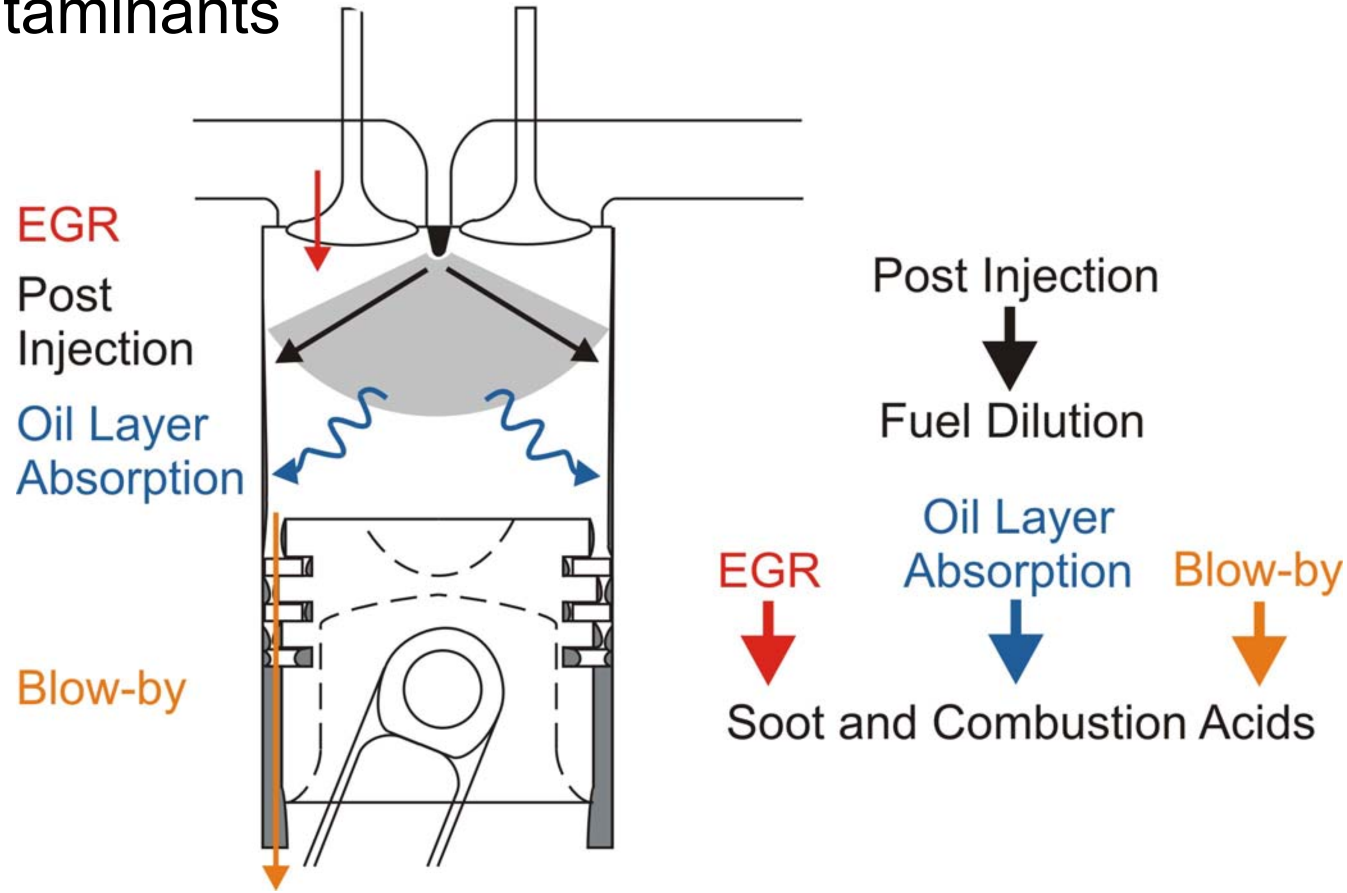
Sources of Lubricant Contamination

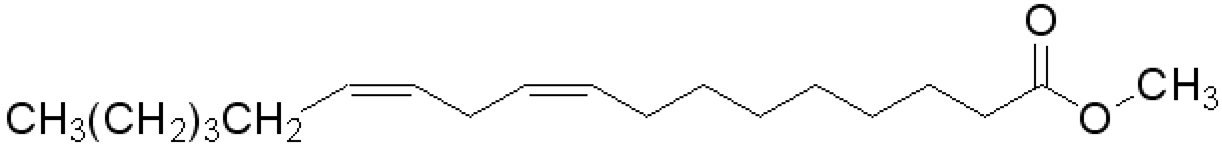
- The combustion chamber is the source of most oil contaminants



Fuel Dilution Concerns for 2007+ Engines and Lubricants

- The aftertreatment regeneration strategy in some engines increases opportunity for fuel to mix with lubricant
- Interest in the widespread use of Biodiesel fuel

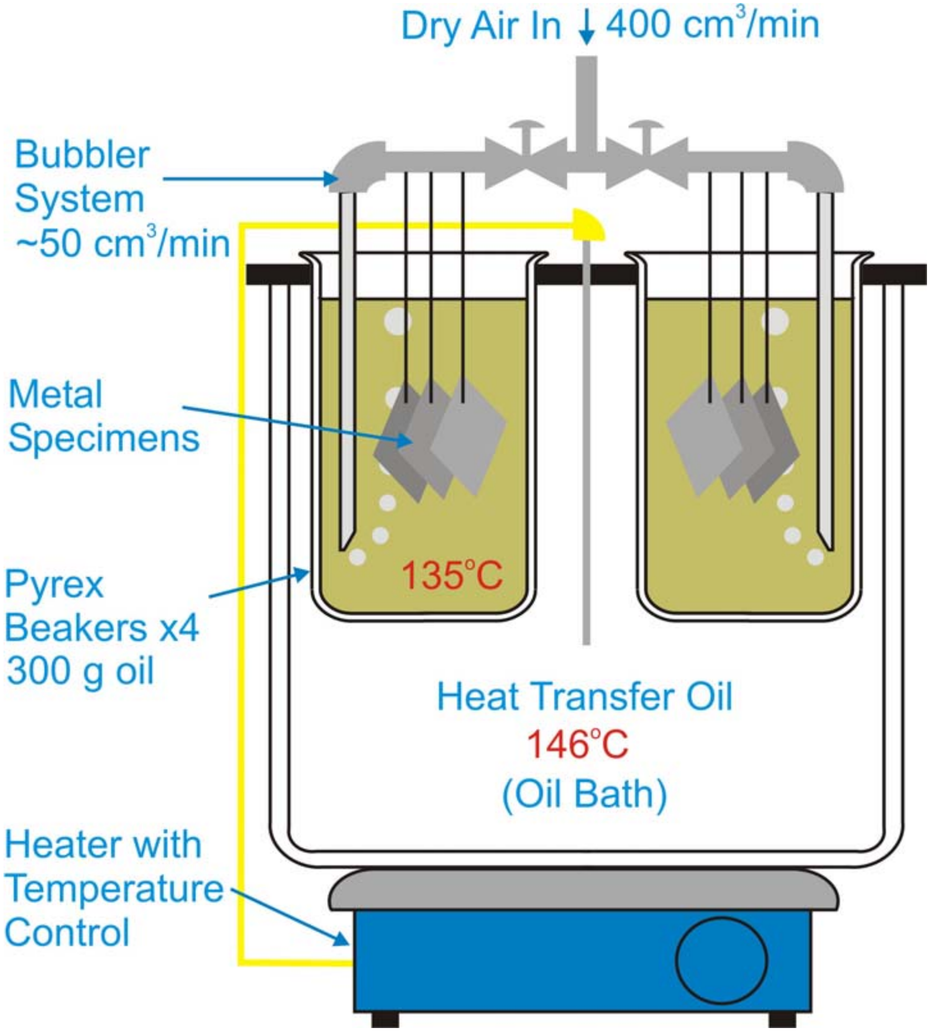
- Known concerns with biodiesel fuel:
  - Poor oxidation stability in storage
  - Acidic attack on fuel system components
  - Viscosity increase due to polymerization of fuel molecules
  - Distillation characteristics lead to higher fuel dilution levels
  - Polar methyl ester may interfere with ZDDP effectiveness



Experimental Objectives

1. Investigate the effects of fuel dilution with biodiesel on lubricant degradation and corrosion of engine components
2. Examine the relative effectiveness of CJ-4 (low ash) and CI-4+ lubricants in protecting components from fuel-borne acids and corrosion

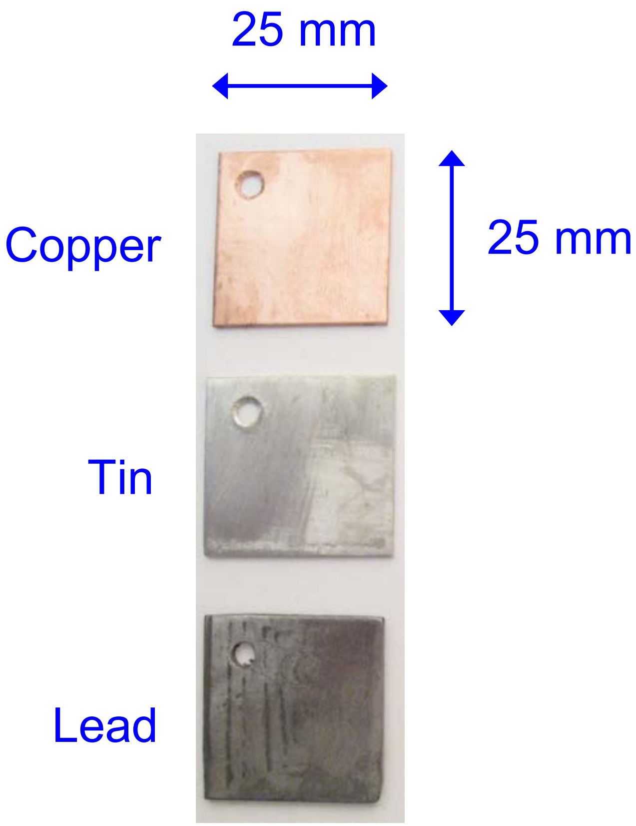
Test Method



- Bench-scale oxidation test based on ASTM D6594
- Mixtures of fuel and oil heated at 135°C for 160hrs
- Stressed lubricant analyzed for degradation
- Corrosion of metal specimens examined

Corrosion Test Specimens

- Copper, tin and lead specimens simulate engine bearings
- Prepared prior to each test by:
  - Polishing surfaces to remove oxide layers
  - Washing in acetone to rinse away metallic dust
- Corrosion quantified by measuring metallic concentrations in the oil with ICP



Test Matrix

- Two lubricants were used:
  - CJ-4 (Low Ash)
  - CI-4+
- Examined 14 cases:
  - 0%, 5% and 10% by mass of fuel mixed with oil
  - Diluted with ULSD, B-20 and B-100
- Six 0% fuel dilution cases also used as controls

	Lubricant	
Fuel Dilution	CJ-4	CI-4+
0%	X	X
5% ULSD	X	X
10% ULSD	X	X
5% B-20	X	X
10% B-20	X	X
5% B-100	X	X
10% B-100	X	X

Controls
3x 0% Fuel Dilution CJ-4
3x 0% Fuel Dilution CI-4+

Fuel and Lubricant Properties

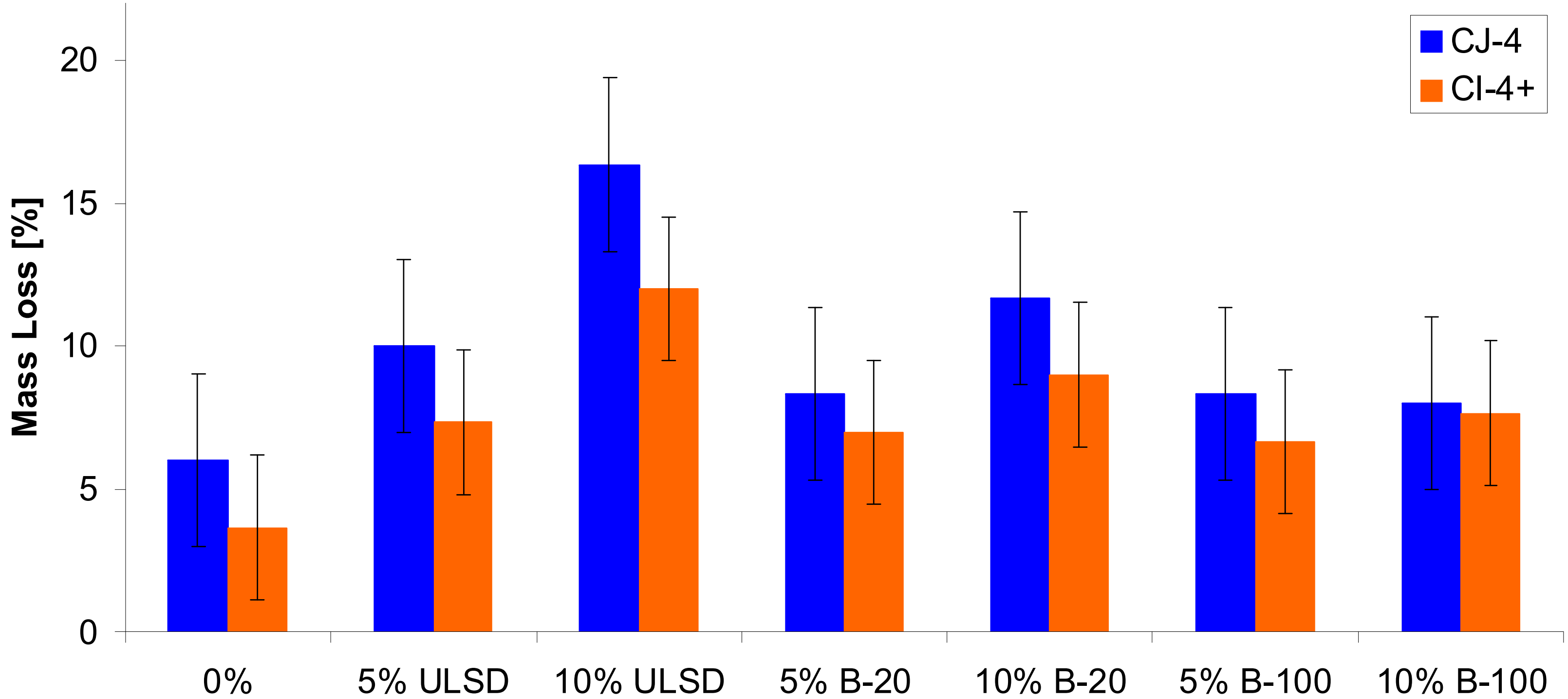
Lubricant Properties:

API Service	CJ-4	CI-4+
API Gravity	29.1	28.9
Viscosity @ 40°C [cSt]	125	146
Viscosity @100°C [cSt]	15.7	14.9
Sulfated Ash (D874) [%]	1.0	1.35
TBN (D2896) [mg KOH/g]	9.6	10.2

Biodiesel Properties:

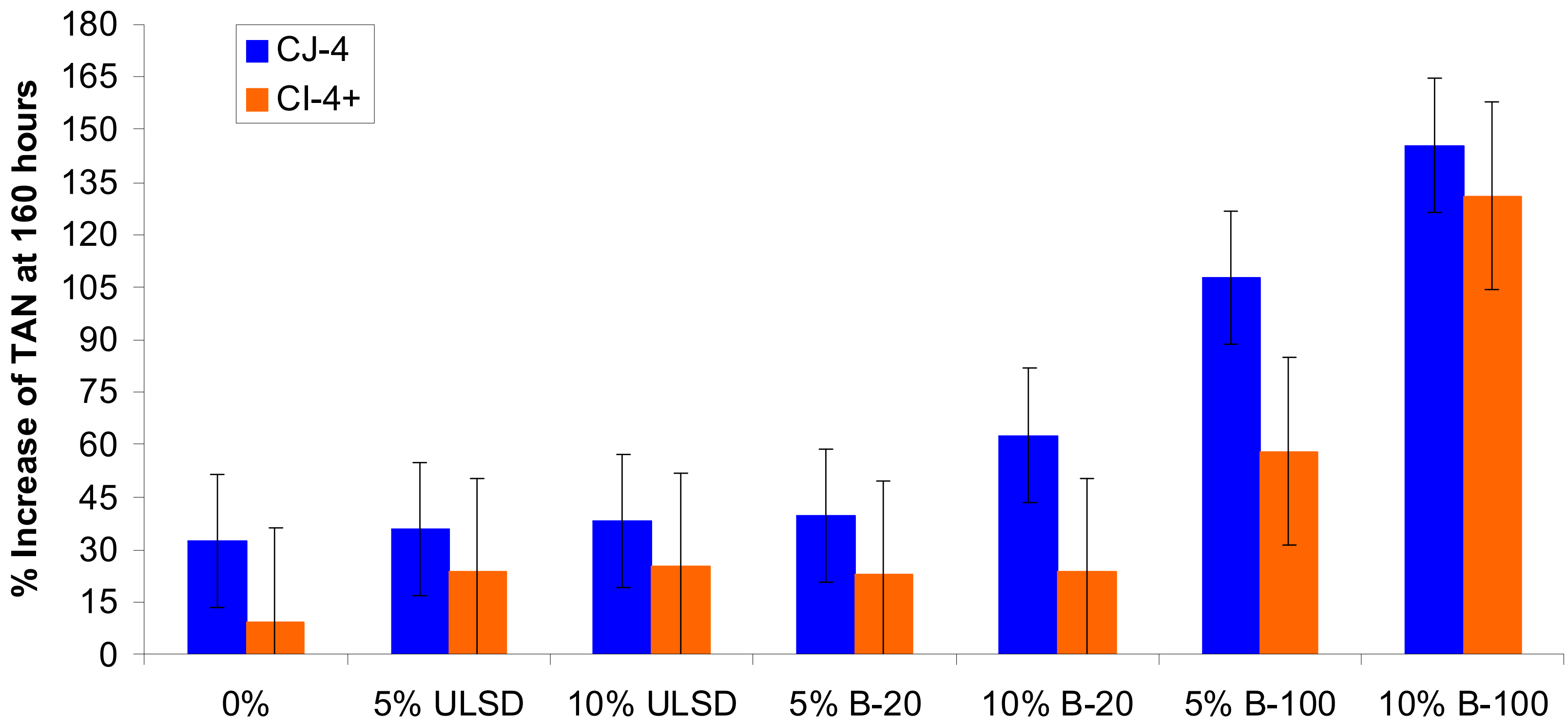
Property	Value	Limit (D6751)
Type	Soy Methyl Ester (SME)	
TAN [D664]	0.22	0.5

Mass Loss Due to Evaporation



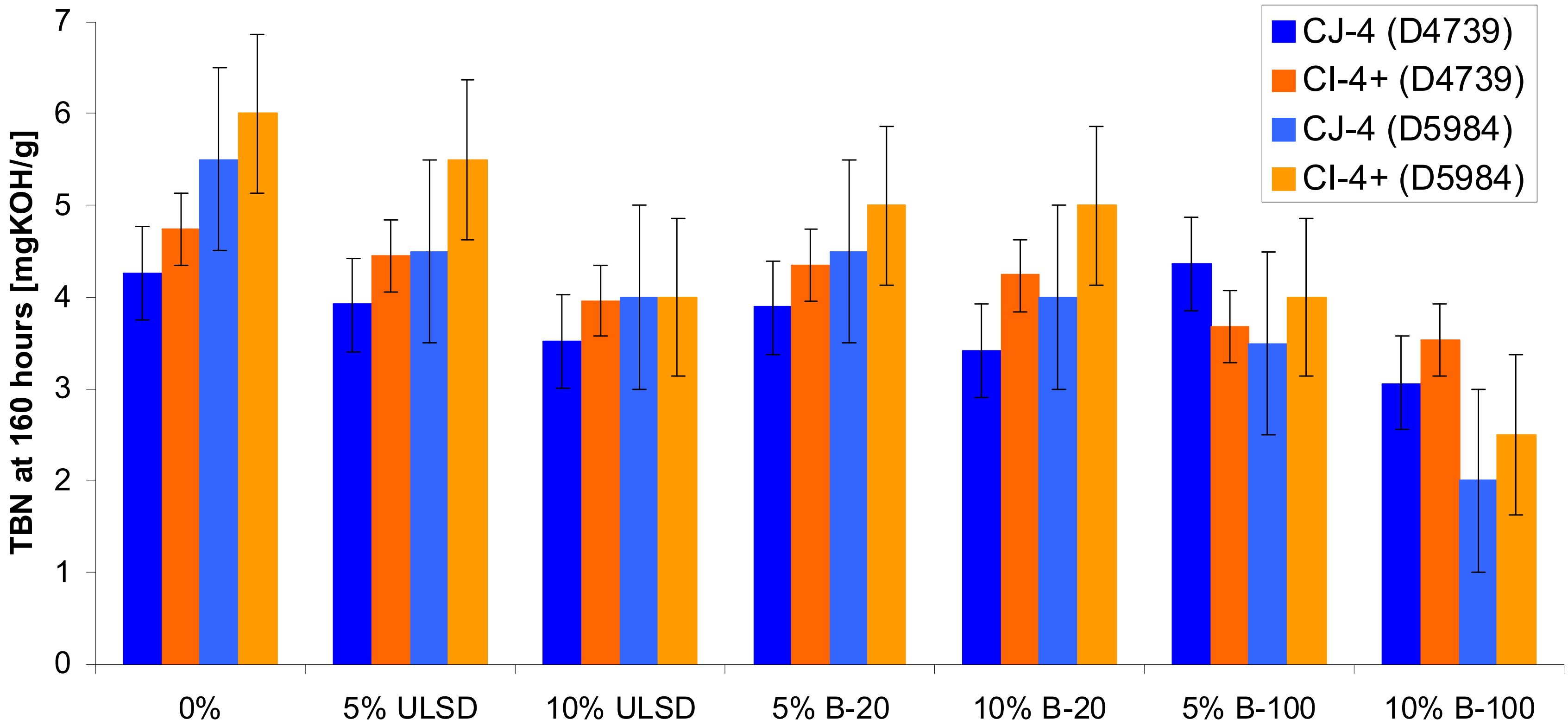
- Reduced mass loss is seen in the B-100 cases due to the higher B-100 boiling point
- Higher fuel dilution levels are expected in engines fueled with biodiesel

Increase in Acidity



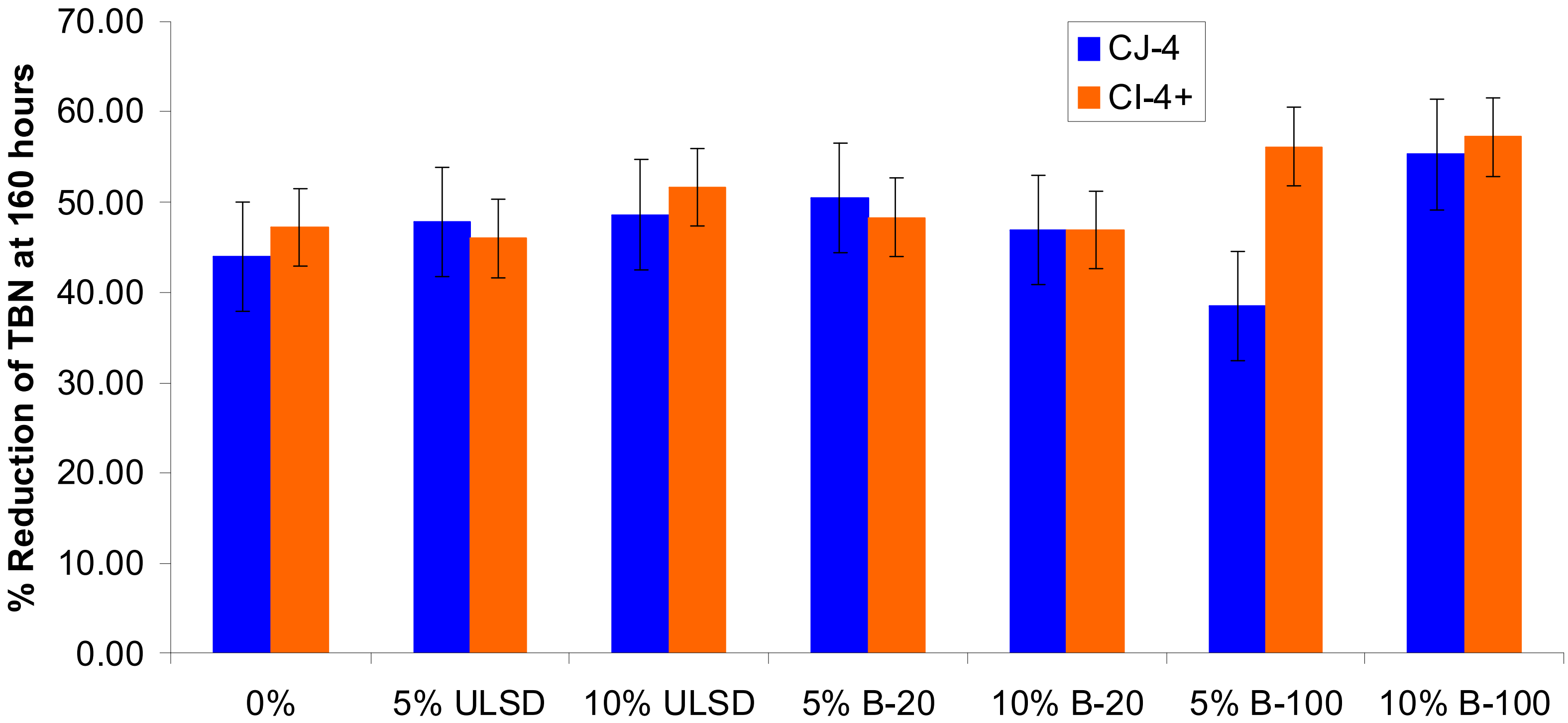
- Fuel dilution with B-100 significantly increases the acidity of the stressed lubricants
- TAN increases at a faster rate in the CJ-4 lubricant

Total Base Number Retention



- Fuel dilution with B-100 results in higher TBN depletion for both lubricants

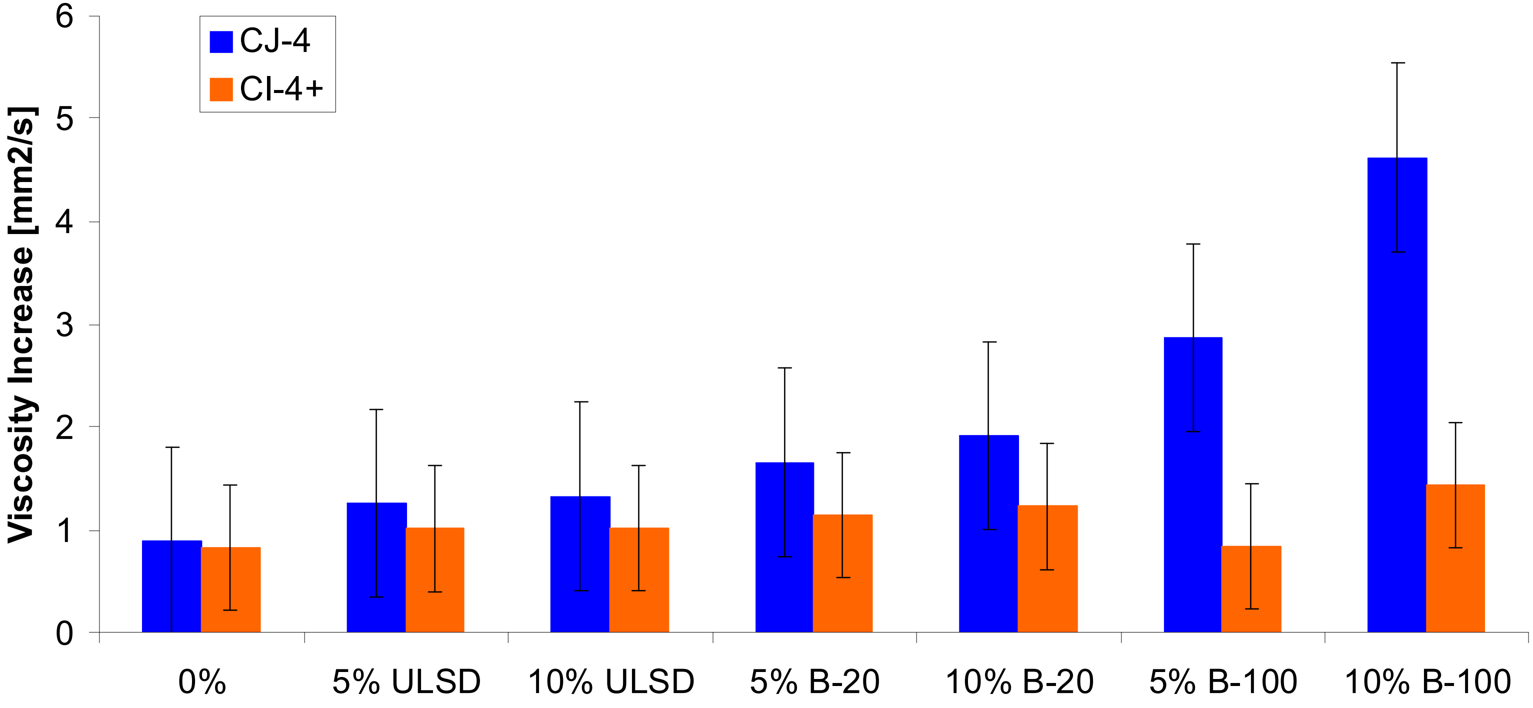
Percent Reduction in TBN



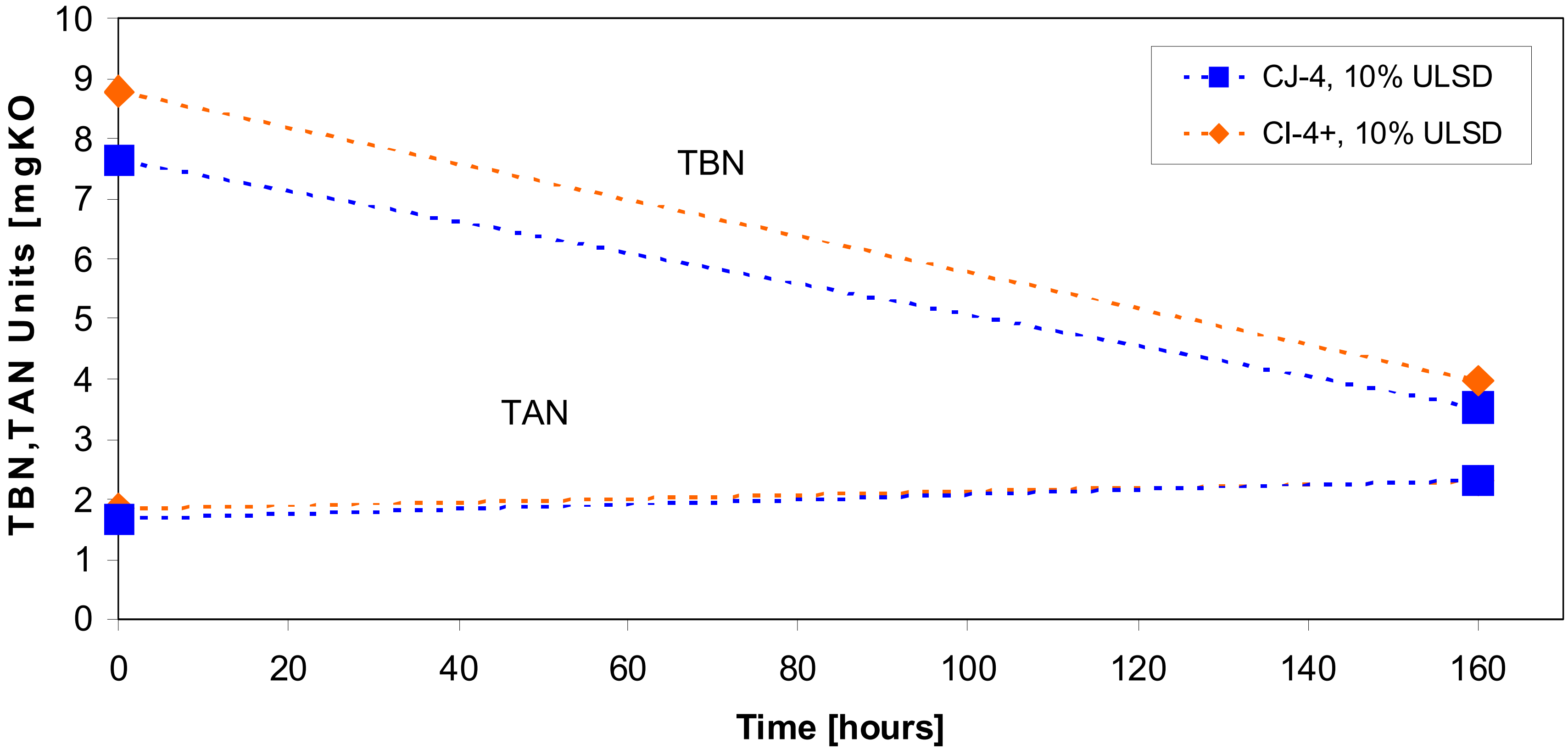
- Accounting for different initial TBN levels, fuel dilution with biodiesel only slightly increases TBN depletion
- The rate of TBN depletion is similar for the CJ-4 and CI-4+ lubricants

Viscosity Increase

- Adding fuel to fresh lubricants results in an initial decrease in viscosity
- Dilution with B-100 significantly increases CJ-4 viscosity at 160 hrs
- Viscosity increase shows similar trends as TAN increase

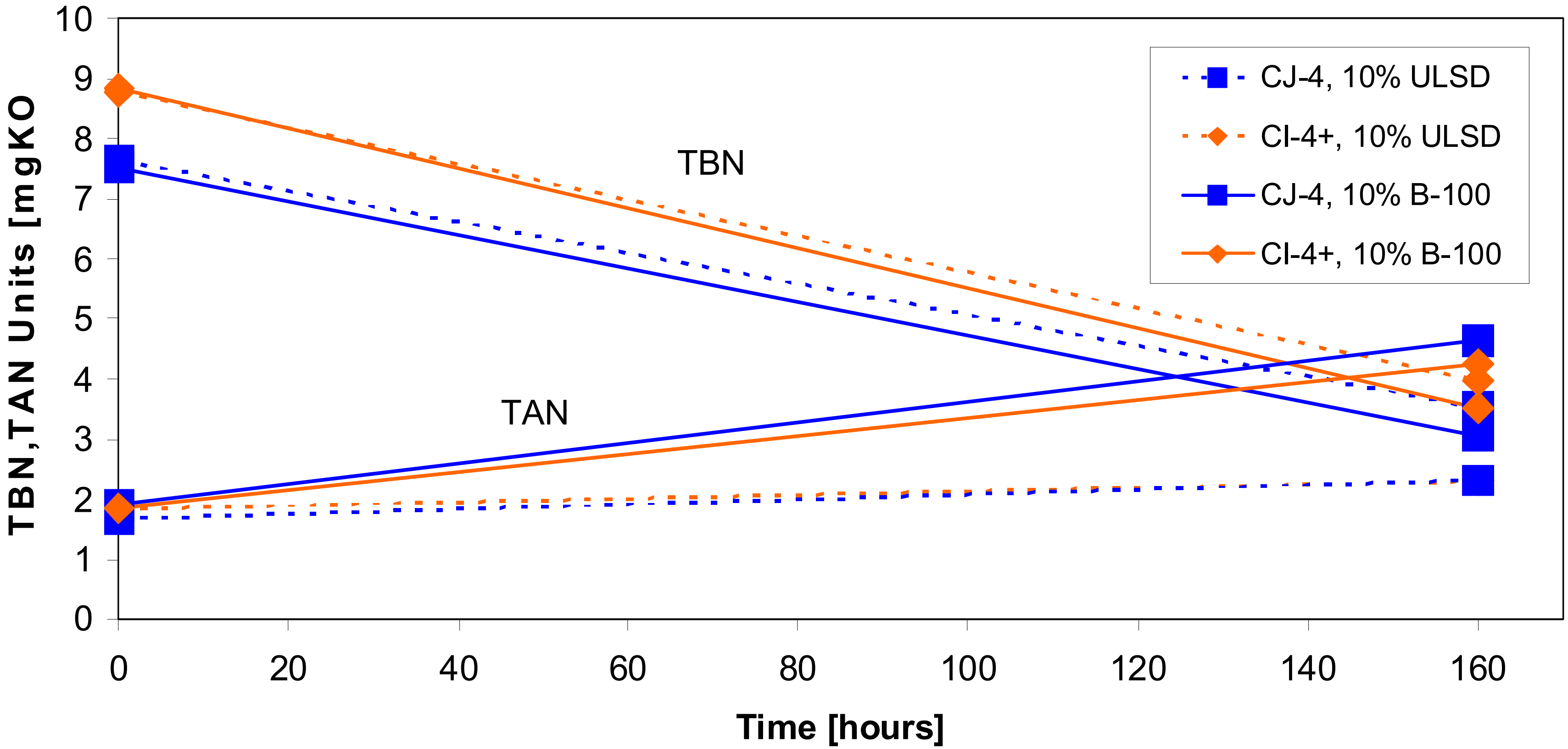


TBN and TAN Crossover



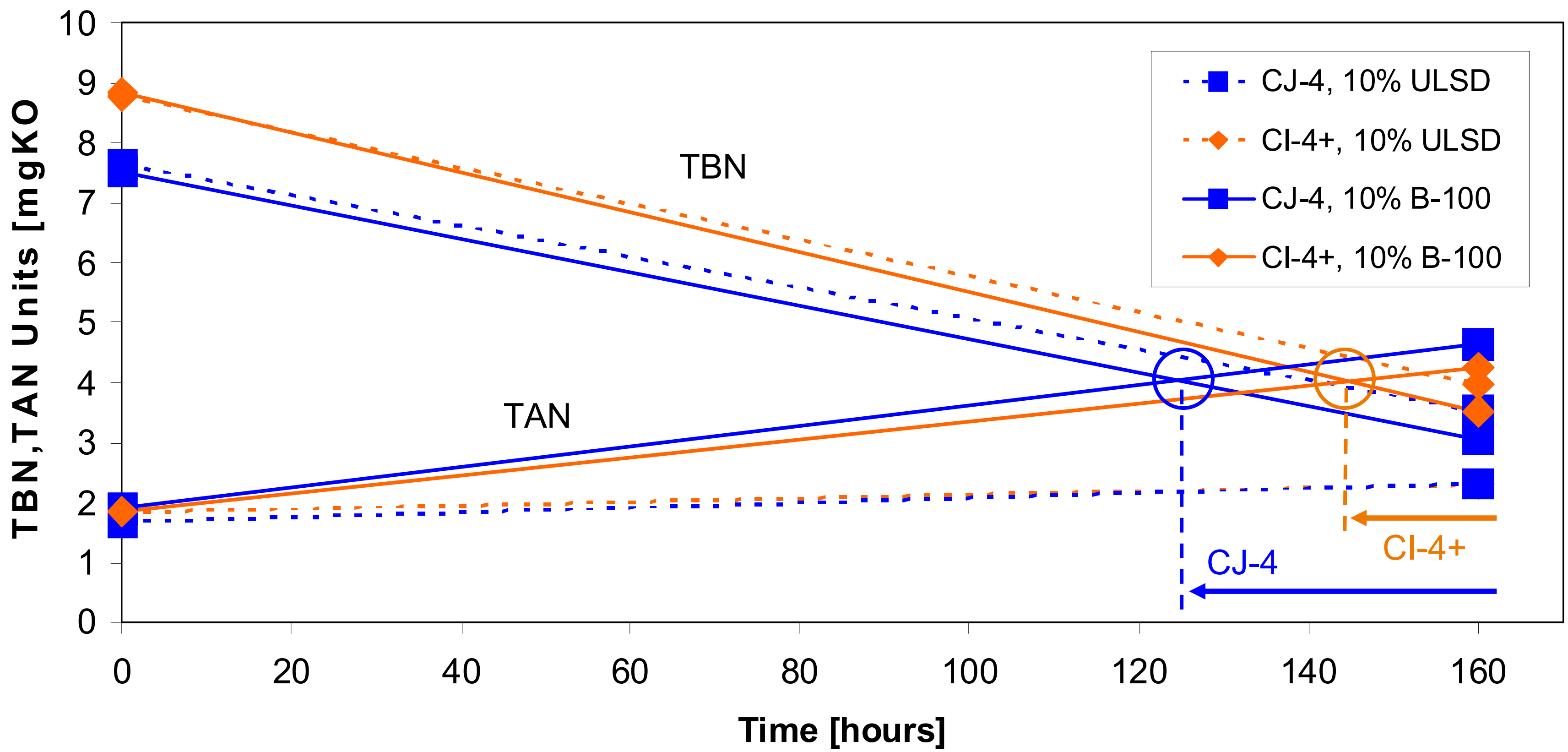
- TAN never exceeds TBN for the cases with no fuel dilution and the cases diluted with only ULSD fuel

TAN and TBN Crossover



- Dilution with biodiesel significantly increases the TAN at 160 hours

TBN and TAN Crossover



- TAN crosses TBN earlier in the tests with the CJ-4 oil
- This observation alone would seem to indicate that corrosion in the CJ-4 oil will be higher than with CI-4+ oil

Corrosion

Unused | 0% | 5% ULSD | 5% B-20 | 5% B-100

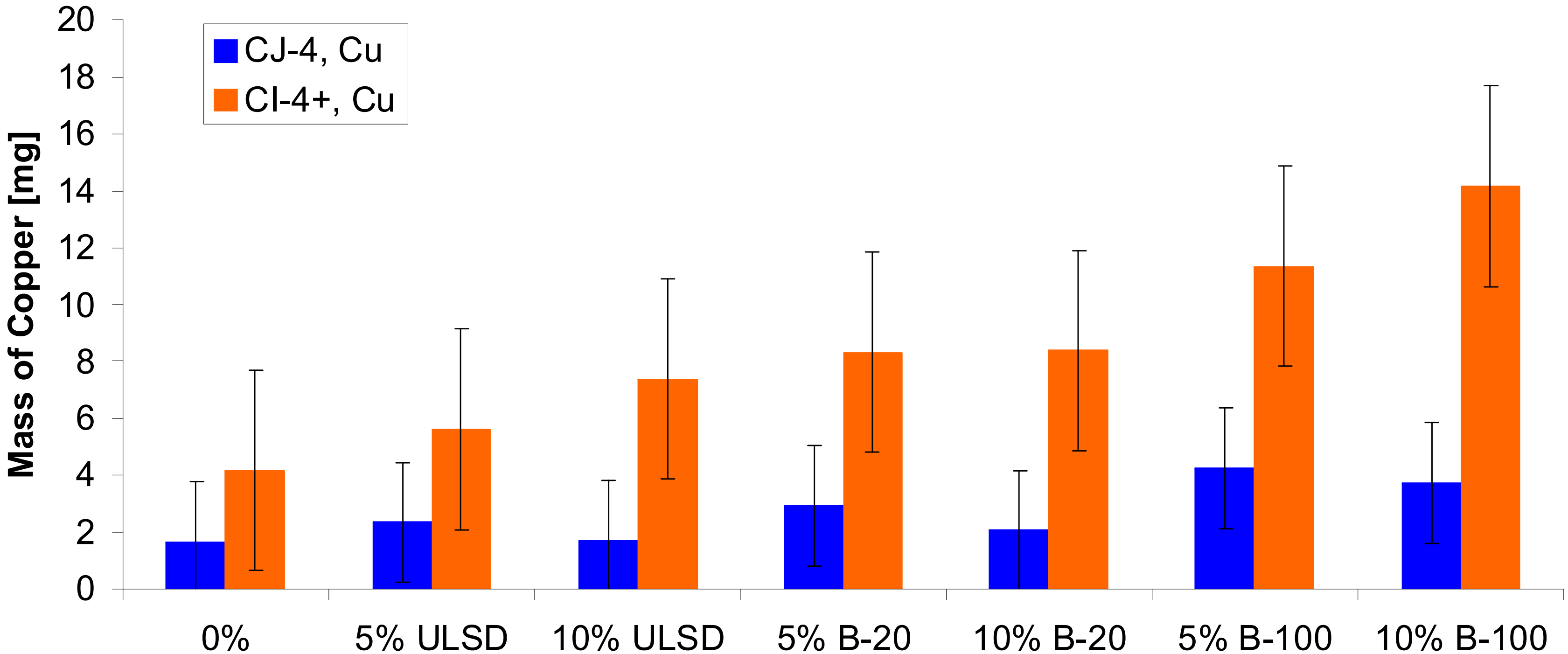
Copper →

Tin →

Lead →

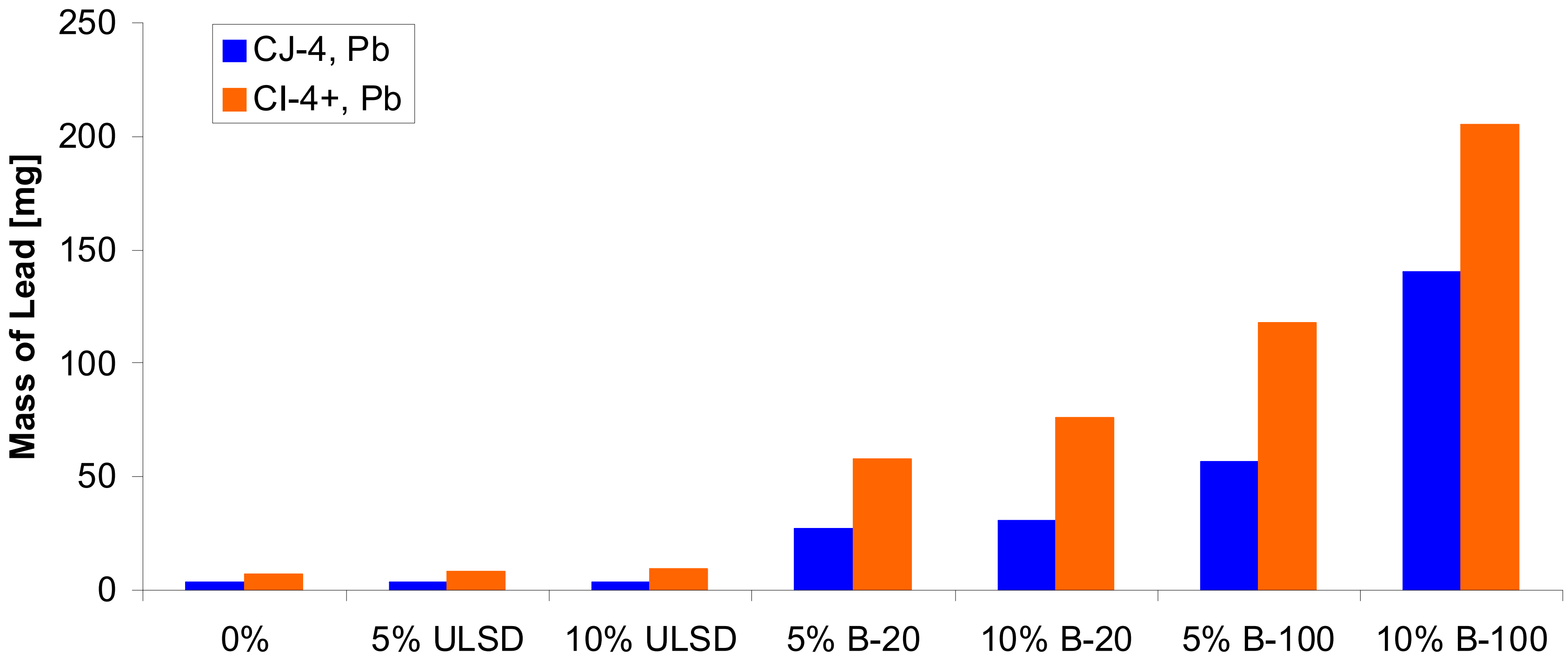
Increasing Biodiesel Concentration in the CJ-4 Lubricant

Copper Corrosion



- CJ-4 lubricant reduces corrosion of copper in all cases
- Copper corrosion increases substantially in the CI-4+, B-100 cases
- Low to zero levels of tin found in stressed oil

Lead Corrosion



- A 10 times increase in lead corrosion is observed in the B-100 cases
- The CJ-4 lubricant appears to give improved corrosion protection

Conclusions

- Higher fuel dilution levels are expected with biodiesel fuel
- In this test, fuel dilution appears to reduce TBN retention and ultimately increase viscosity of the stressed oil
- Dilution with B-100 further decreases TBN and increases TAN, reduces lubricant life and increases viscosity
- B-100 substantially increases corrosion of lead (10x) and copper in the stressed lubricant
- Reduced corrosion was observed with the CJ-4 oil, although acidity was increased
- TBN and TAN crossover was an unreliable indicator of relative lubricant performance

Acknowledgements

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