CONCAWE, EI, DGMK

Workshop on Microbial Growth in Fuel Supply and Distribution Systems

Brussels, March 16, 2011

Biological Problems in Captive Fleet Operations

Presented by:
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&
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Fuel Quality Services, Inc.

Introduction

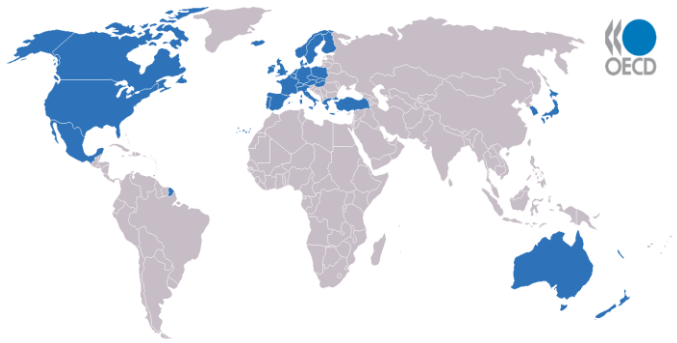
- Industrialized countries are generally the largest consumers of crude oil
- Total World Production
  - 85,472,000 bbl/day
- Total World Consumption
  - 85,534,000 bbl/day

= *Industrialized and Newly Industrialized Countries*

Andorra	Czech Republic	Hong Kong	Japan	New Zealand	Slovenia	Turkey
Australia	Denmark	Hungary	Latvia	Norway	South Africa	UK
Austria	Estonia	Iceland	Lithuania	Philippines	South Korea	USA
Belgium	Finland	India	Luxembourg	Poland	Spain	
Brazil	France	Ireland	Malaysia	Portugal	Sweden	
Canada	Germany	Israel	Mexico	San Marino	Switzerland	
China	Greece	Italy	Netherlands	Slovakia	Thailand	

Introduction

- OECD member countries account for 2/3 of the daily global oil consumption (2007 ~54 MM bbl)
- During the 1990's the demand for crude oil by the OECD only grew by 11% whereas demand in the non-OECD grew by 35%



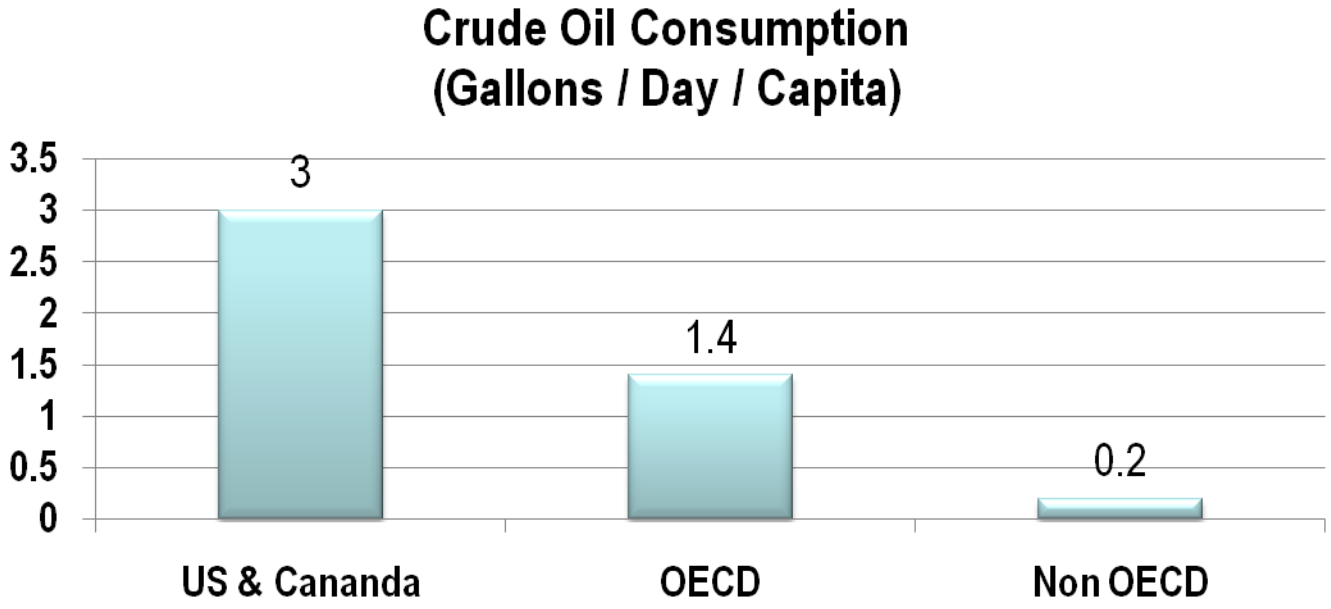
OECD – Organization for Economic Cooperation and Development

OECD Countries (30)

Australia	Finland	Ireland	New Zealand	Spain
Austria	France	Italy	Norway	Sweden
Belgium	Germany	Japan	Poland	Switzerland
Canada	Greece	Luxembourg	Portugal	Turkey
Czech Republic	Hungary	Mexico	Slovakia	UK
Denmark	Iceland	Netherlands	South Korea	USA

Introduction

- Developed economies use fuel more intensively than developing economies. For example:

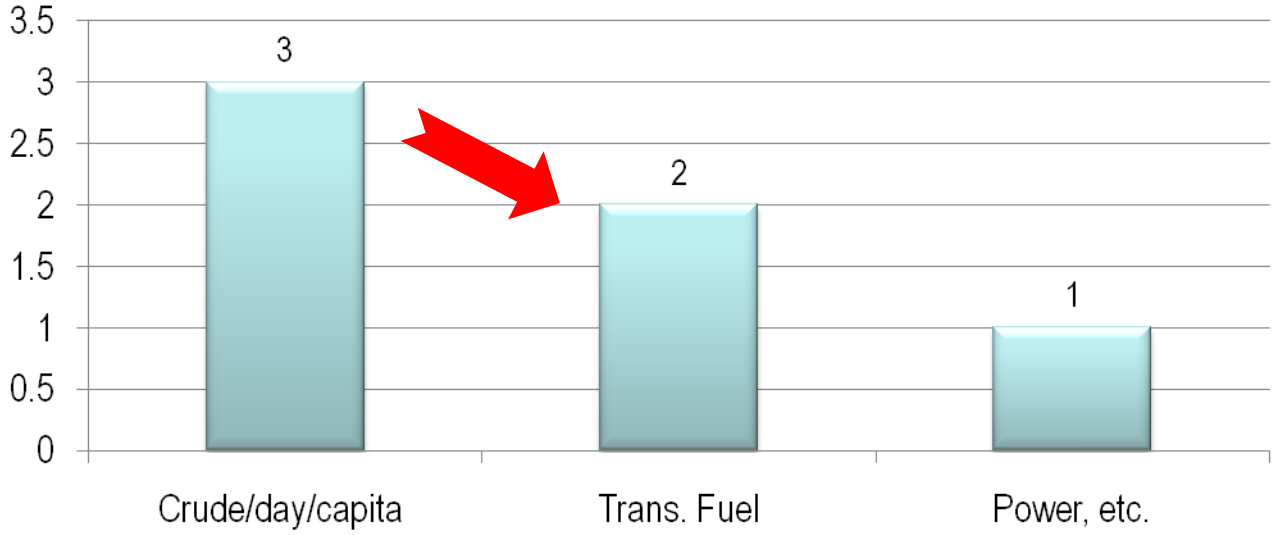


Introduction

- The United States and Canada use crude oil more for transportation than for heat and power
- For the rest of the OECD and non-OECD, the emphasis is on power and heat and much less on transportation
- The demand for crude oil is derived from the demand for the finished and intermediate products crude oil products

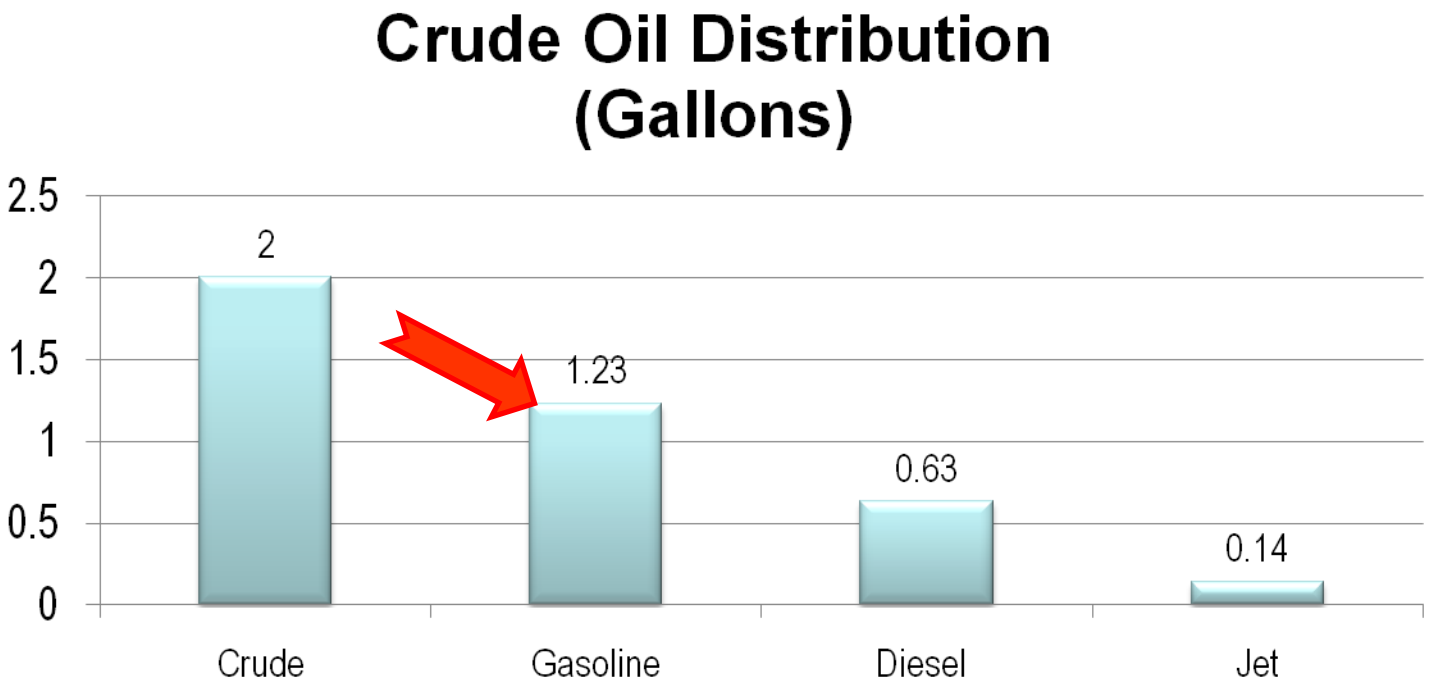
Introduction

In the United States, 2/3 of the crude oil is used for transportation fuels and 1/3 is for power and other petroleum related activities



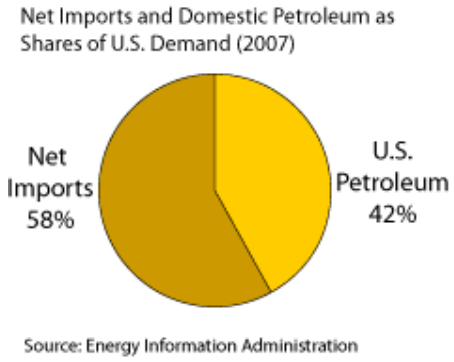
Introduction

U.S distribution of crude oil for transportation fuels

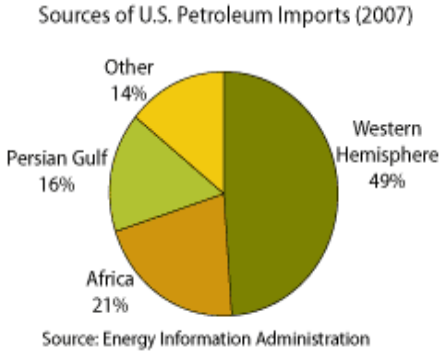


Introduction

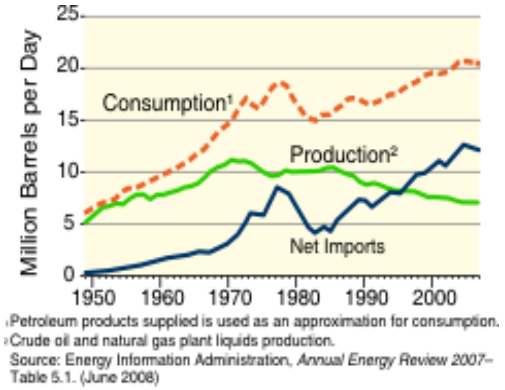
Although the U.S. is the third largest crude oil producer, most of the petroleum we use is imported.



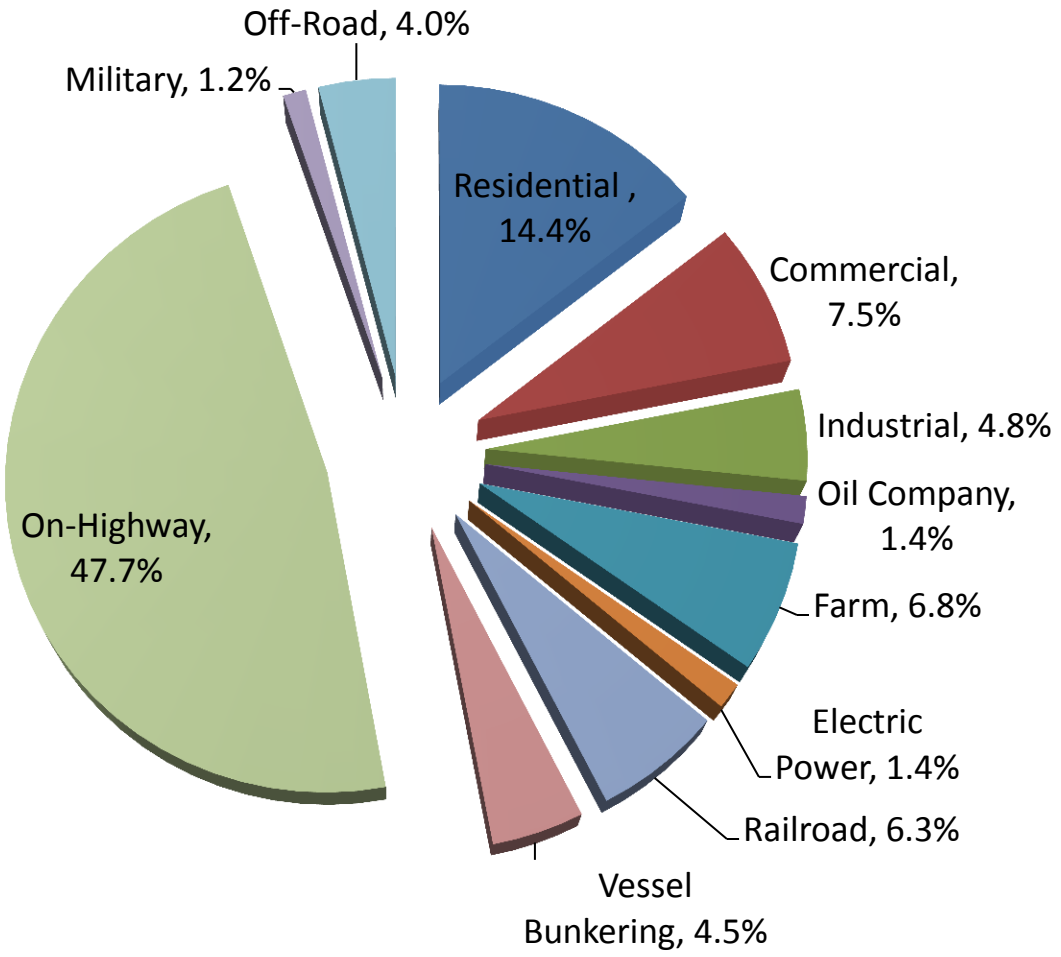
Western Hemisphere nations provide about half of our imported petroleum.



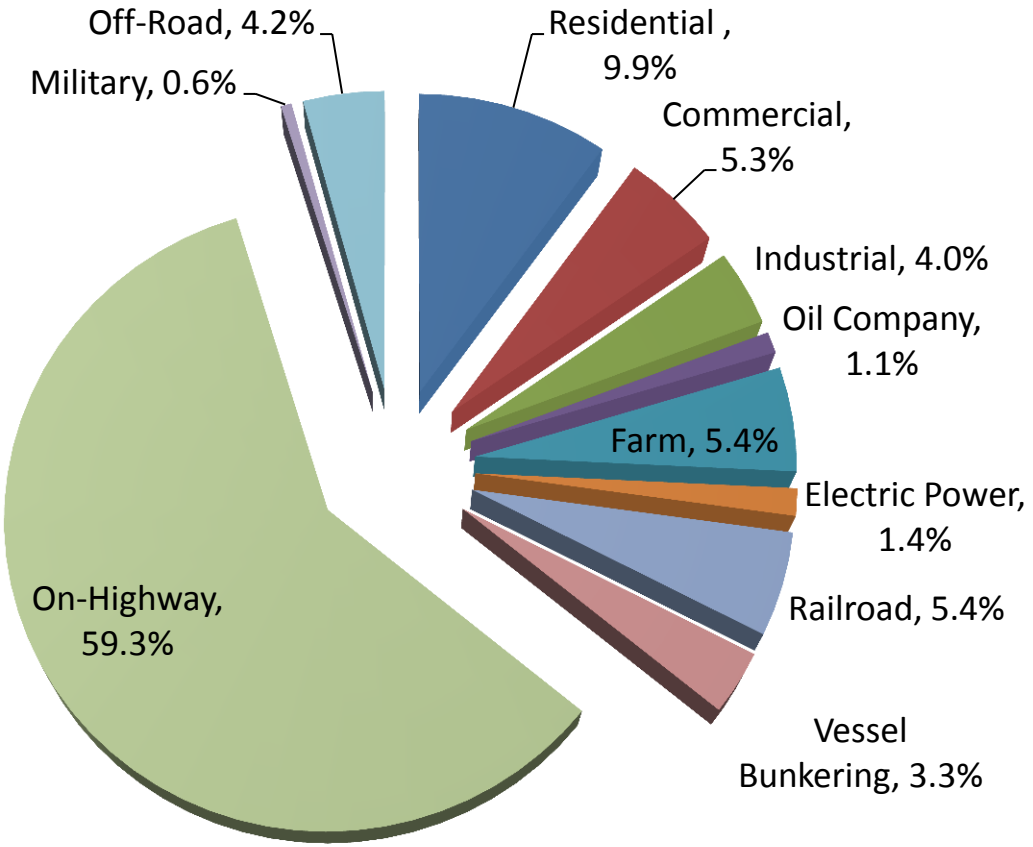
Net imports have generally increased since 1985 while U.S. production fell and consumption grew.



Diesel Fuel Sales 10 Year Average 1988-1997



Diesel Fuel Sales 10 Year Average 1998-2008



Changes in Diesel Fuel Sales1988-2008

	1988-1997	1998-2008	Change
On-Highway	47.7%	59.3%	+11.6
Residential	14.4%	9.9%	-4.5%
Commercial	7.5%	5.3%	-2.2%
Farm	6.8%	5.4%	-1.4%
Railroad	6.3%	5.4%	-0.9%
Industrial	4.8%	4.0%	-0.8%
Vessel Bunkering	4.5%	3.3%	-1.2%
Off-Road	4.0%	4.2%	+0.2%
Oil Company	1.4%	1.1%	-0.3%
Electric Power	1.4%	1.4%	0%
Military	1.2%	0.6%	-0.6%

Microbial Contamination of Fuel Storage and Distribution

1. Microbes are present in crude oil.

2. Microbes move along the distribution system.

3. The refining process sterilizes the fuel products

4. Microbial contamination initiated when moisture and microbial spores enter refinery storage tank via the ventilation system. Stay time insufficient to remove water and microbes.

Movement of Microbial Contamination in Fuel Storage and Distribution

5. After refining fuel cools along the distribution system condensing water and microorganisms to form active pools/biofilms distributing microorganisms and their corrosive metabolites downstream to ASTs and USTs

6. Poor ballast stripping sends water and microbes with offloaded fuel.

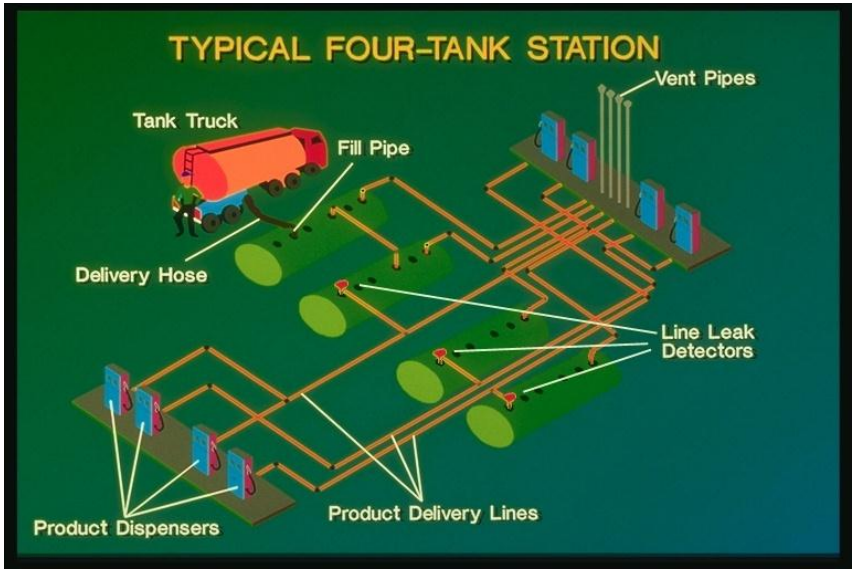
7. Pipelines and storage tanks are contaminated from upstream product tenders,

Microbial Contamination of Downstream Retail Market

External Sources of Contamination

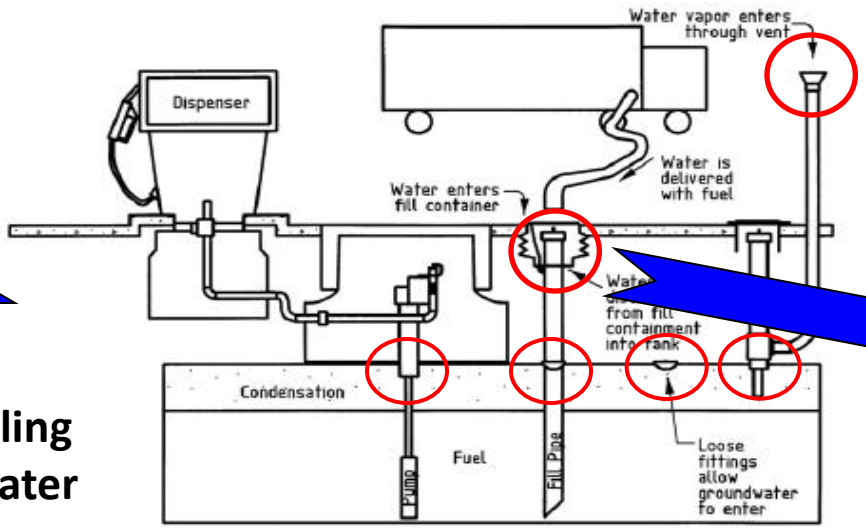
Installation of new UST:

- Ballasting of UST during installation
- Water contaminates USTs,
- PEI/RP100-2000



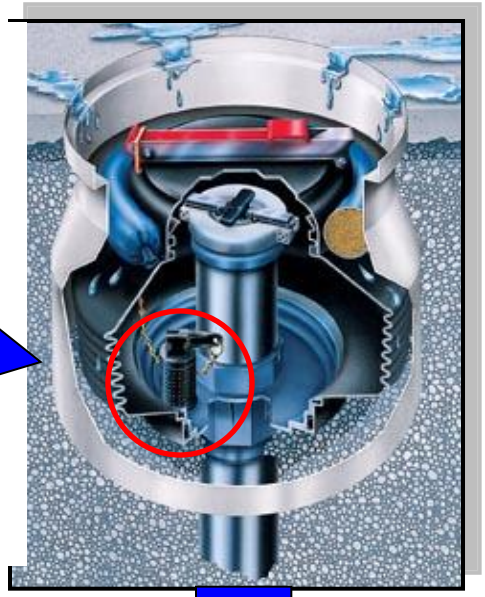
External Sources of Contamination

Existing UST



Rising/falling ground water

Steel Tank Institute: "Keeping Water Out of Your Storage System," March 2004



H_2O

contaminants into tank

Global Organizations That Acknowledge Impacts of MIC

Ground Transportation

- ASTM D975, ASTM D6751, ASTM D7467, ASTM D4814

Aviation

- ASTM D1655, ASTM Manual 5, IATA
- Airframe (Boeing/Airbus) OEMs - Aircraft Maintenance

Military

- MIL-SPEC-53021

Industry

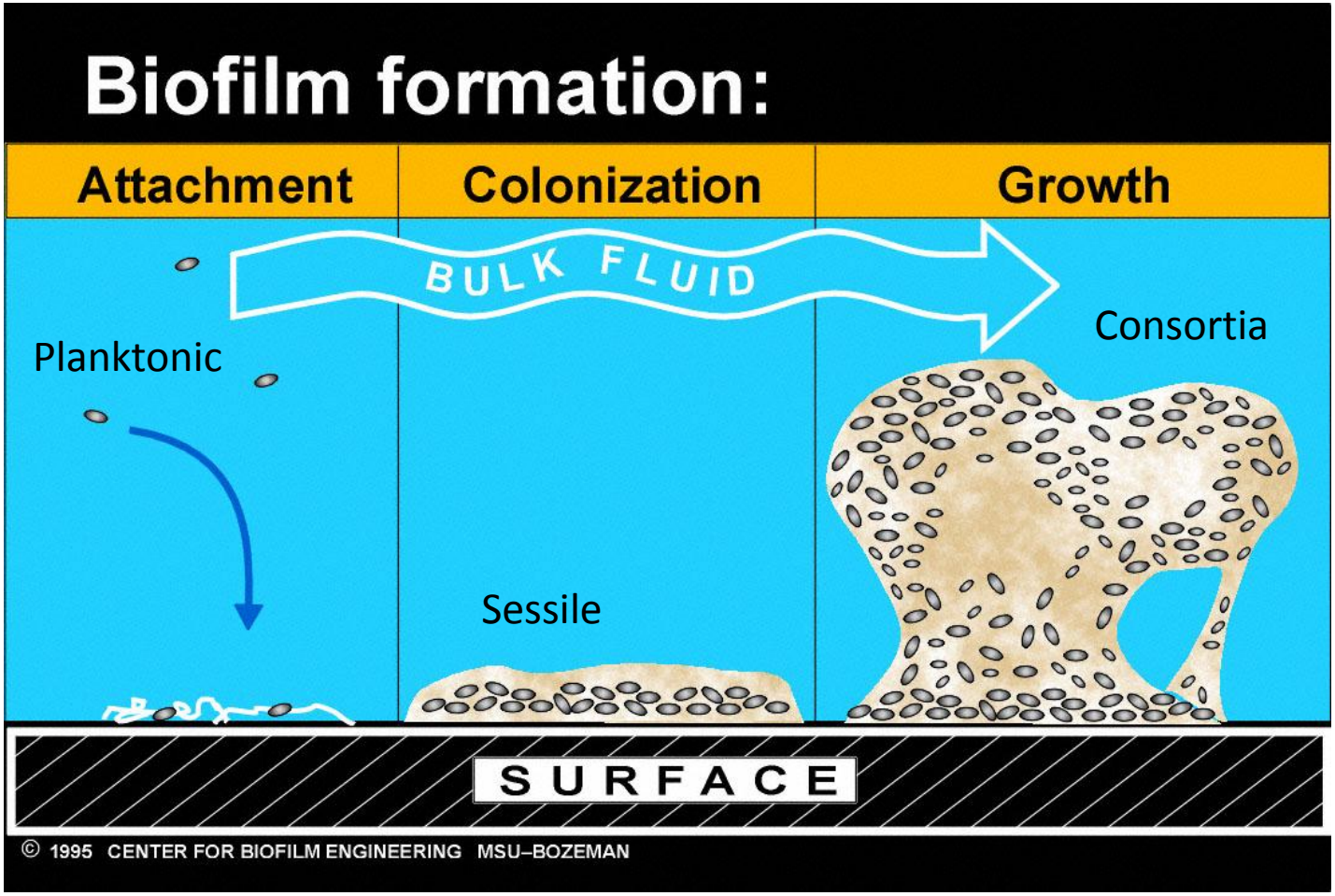
- API, CSA, DFOG, DOT, NBB, Oil Heat, PEI, STI, USEPA-OUST

Source and Distribution of Microorganisms

Microbial Contamination of Fuel Storage and Distribution

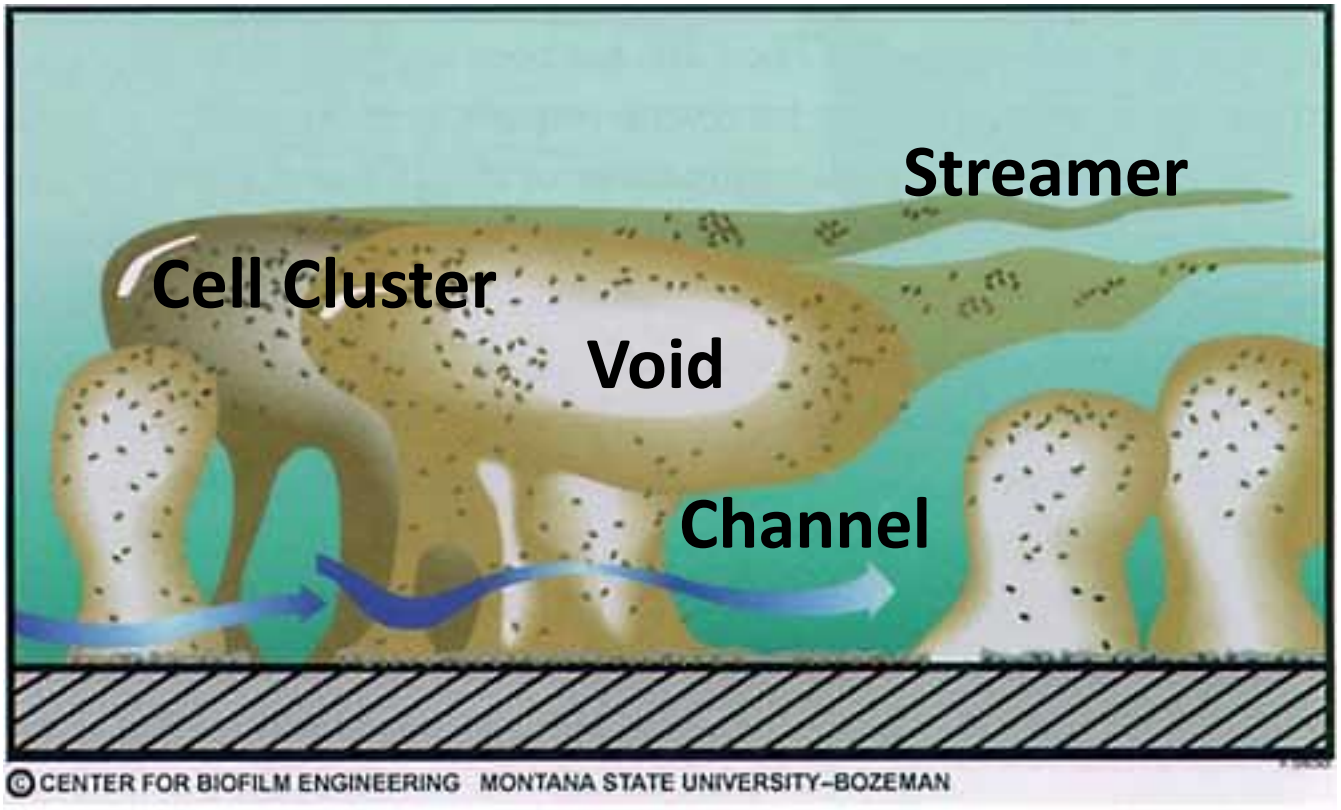
- Microbial Contamination Pathways
  - Present in the environment soil
  - Vents – Air, Water, Dust
  - Tanks with Floating Roofs that Leak
  - Ships Ballast / Seepage Water
  - Transfer Piping
  - Cross Contamination Between Fuel System Tankage

Initiation of Microbial Contamination in Fuel Storage



Conceptual Model of A Mature Biofilm Based on CLSM

Confocal Laser Scanning Microscopy – 3D Perspective



Examples Contaminated Fuels

Gasoline

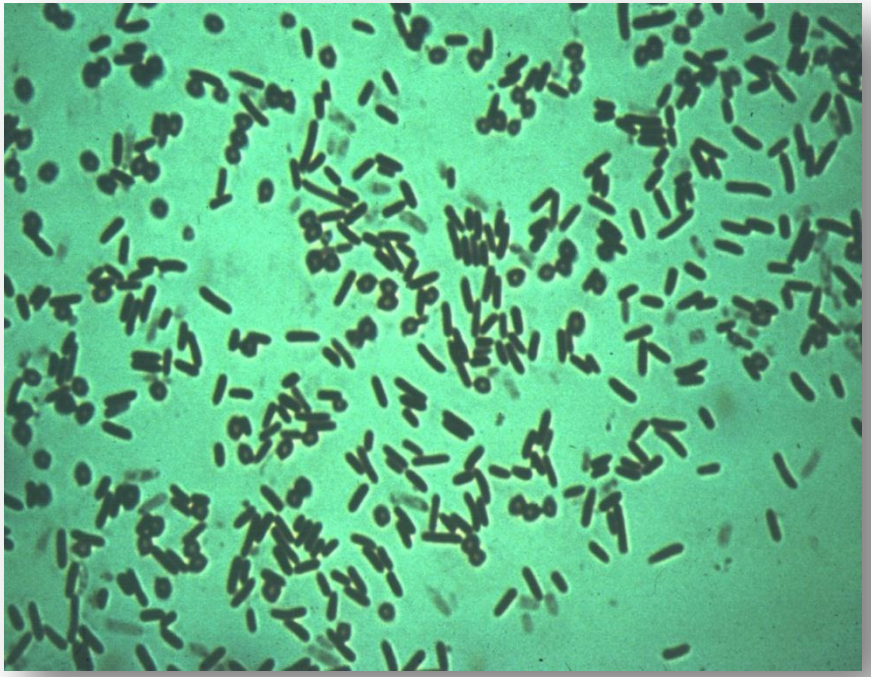
Aviation Fuel

Biodiesel (B20)

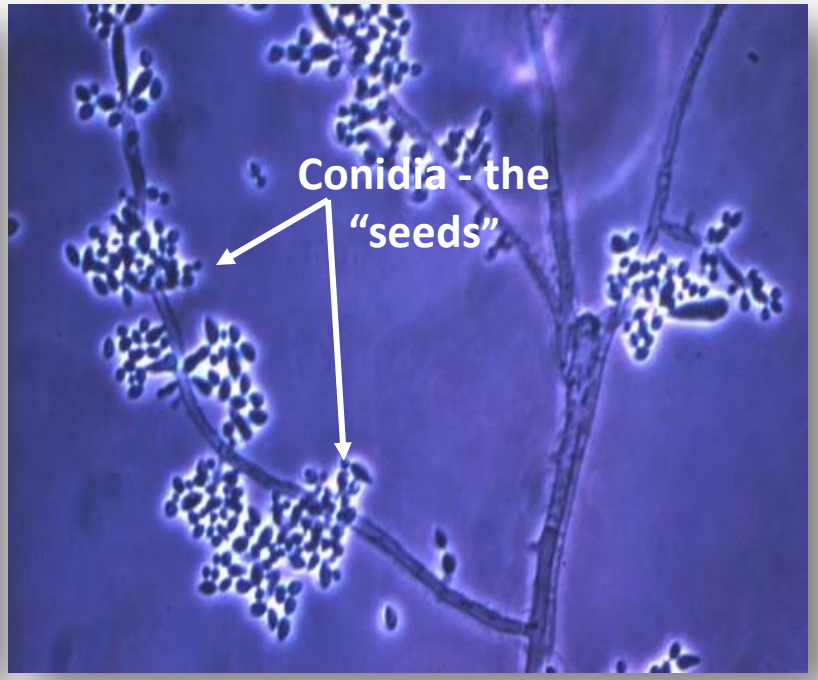
Diesel

Source: Fuel Quality Services, Inc.

Examples of Fuel Microorganisms



Bacteria
Prokaryote



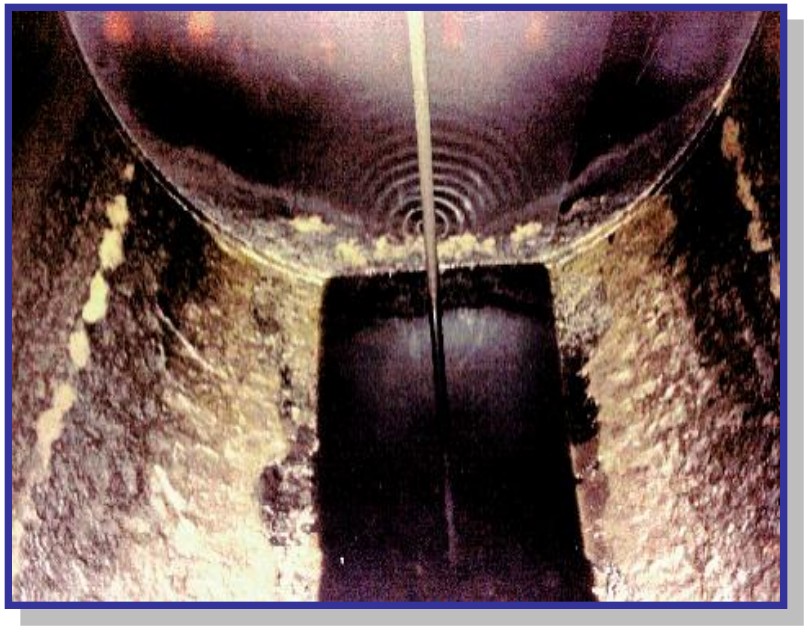
Fungi
Eukaryote

Diesel Fuel Tank
“Bug”Contamination

Contaminated Strainer

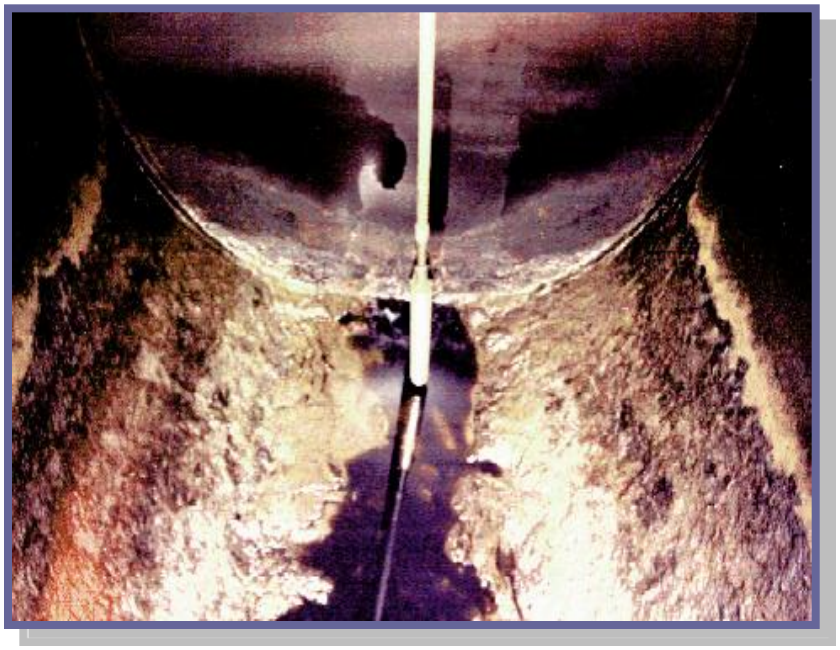
Fuel Storage and Distribution

UST Microbial Contamination



Fill End

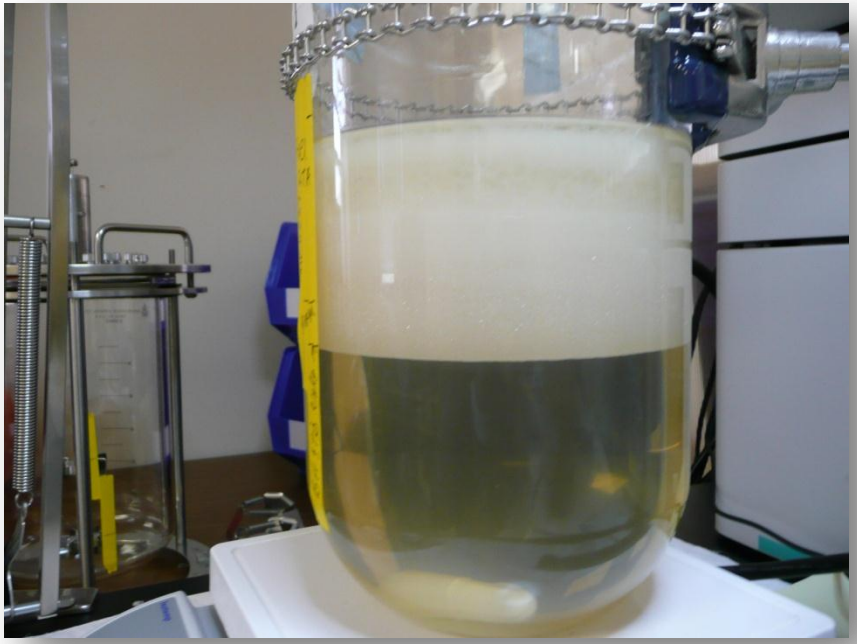
Pump End

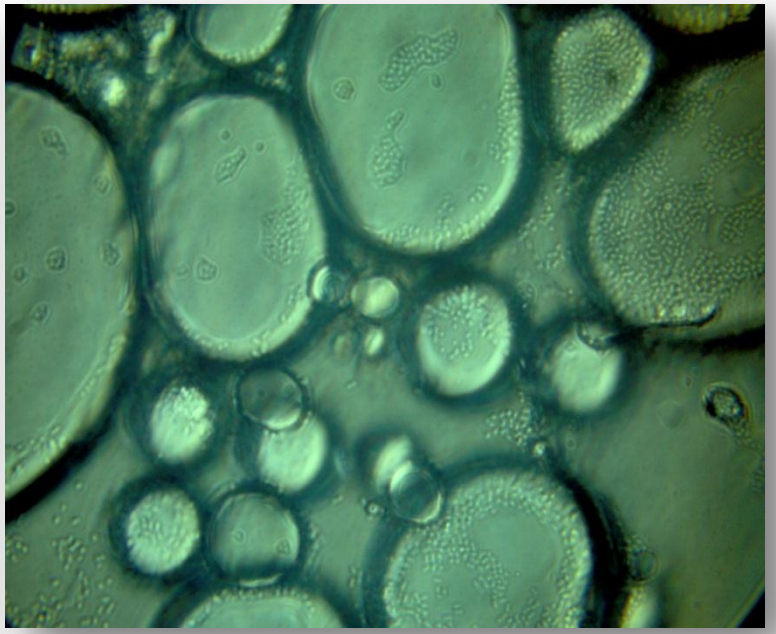


Source: Fuel Quality Services, Inc., 8000 gallon distillate fuel tank interior view, circa 1988

MIC Tank Corrosion

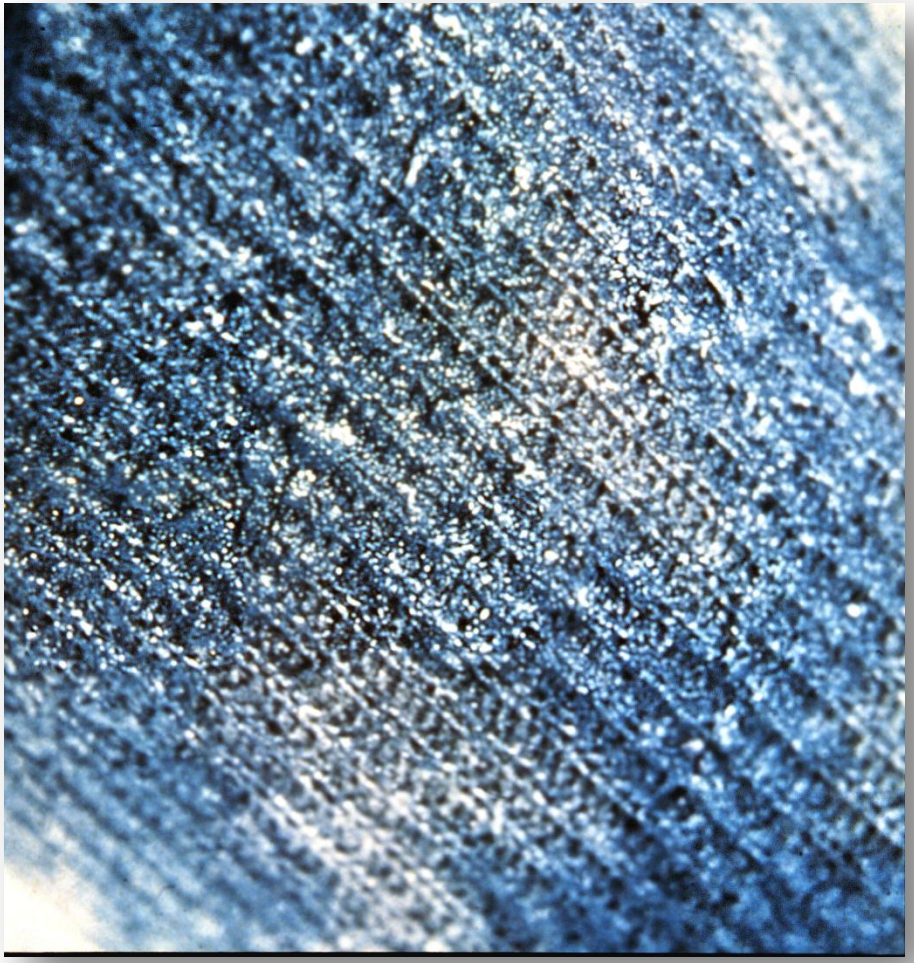
Microbial Activity
Water/Fuel Interface



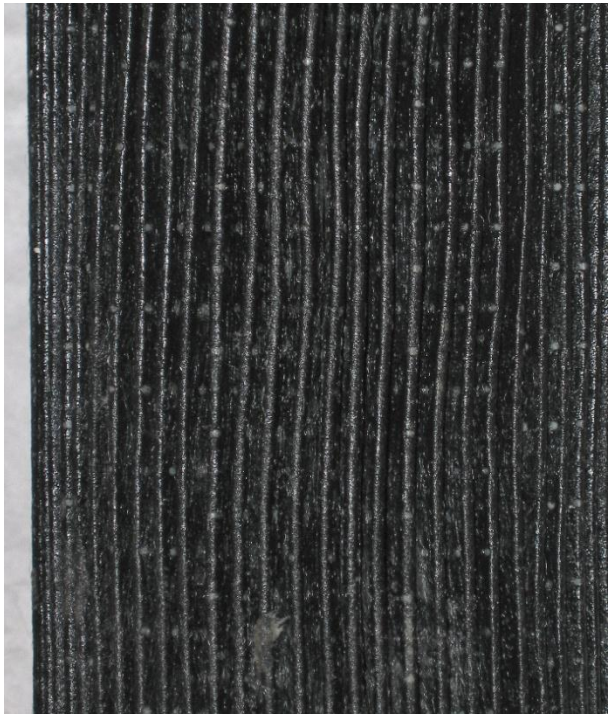


Source: Fuel Quality Services, Inc.

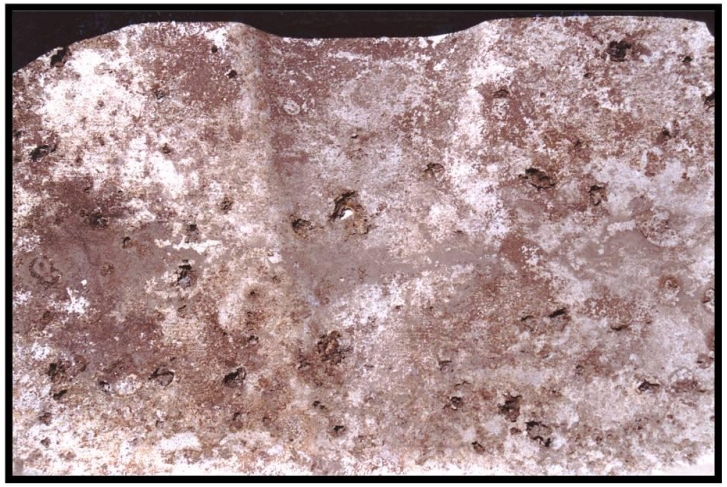
Biologically Contaminated Sock filter



Examples of Filter Plugging



Examples of Corrosion Saddle Tank Sumps



Potential Biodiesel Quality Issues

Chemical By-Product	Effect
Free Glycerin	Corrodes non-ferrous metals, soaks cellulose filters, sediments on moving parts and lacquering resulting in filter clogging and Injector coking
Mono- & di- Glycerides	Issues similar to glycerin
Free Fatty Acid	Causes swelling of some elastomers, nitrile rubbers to soften, swell or harden and crack resulting in potential fuel leakage. Provides electrolytes and hastens the corrosion of zinc, salts of organic acids, organic compounds formed corrosion of FIE, filter plugging and sediment formation on parts.

Source: Diesel Fuel Injection Equipment Manufacturers Common Position Statement

Potential Biodiesel Quality Issues

Chemical By-Product	Effect
Methanol Carryover	Corrodes aluminum & zinc, Corrosion of FIE low flash point
Process Catalysts	Potassium and sodium compounds solid particles potentially blocking injection nozzles.

Source: Diesel Fuel Injection Equipment Manufacturers Common Position Statement

Problems with B20 due to Out of Specification B100

Source: Fuel Quality Services, Inc.

Unexplained Accelerated Corrosion in ULSD Systems

Discussion

- Problems associated with accelerated corrosion of mild carbon steel in the fuel system several years after introduction ULSD September 2006.
- Issues originally identified by PEI and STI
- This investigation now under the auspices of Clean Diesel Fuel Alliance (CDFA) chaired by API.
- Issue discussed at ASTM workshop July 2010. Next work shop December 2011.

Discussion

- CDFA has contracted with Battelle National Laboratory to conduct study:
  - Task 1. Evaluate existing survey and historical field inspection data
  - Task 2. Test the Working Hypothesis
  - Task 3- Analyze results and develop conclusions
  - Task 4- Prepare draft and final project reports

Discussion

- Number of theories
  - Mechanical/Electrical:
    - Electrolysis from lack of proper grounding for submersible turbine pump (STP)
  - Chemical:
    - Presence hydroperoxides
    - Excess corrosion inhibitor
    - Lack of corrosion inhibitor
    - ULSD vs. LSD

Discussion

- Number of theories
  - Microbial
    - Low levels of sulfur level <15ppm vs. 500ppm
    - Aerobic vs. anaerobic microorganisms
- What we do know:

Fuel Phase		**Water Phase**			
Formate ppm	Acetate ppm	pH	Conductivity uS/cm	Formate ppm	Acetate ppm
<0.3	30	-	-	-	--
<0.3	35	4.5	22,000	260	19,000

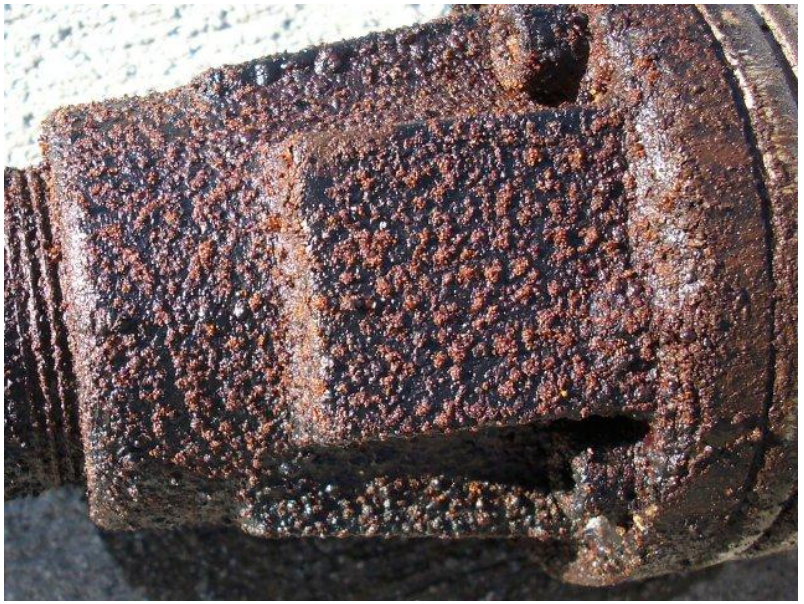
ULSD STP Manifold & 4” Riser

ULSD Column Pipe

ULSD Column Pipe

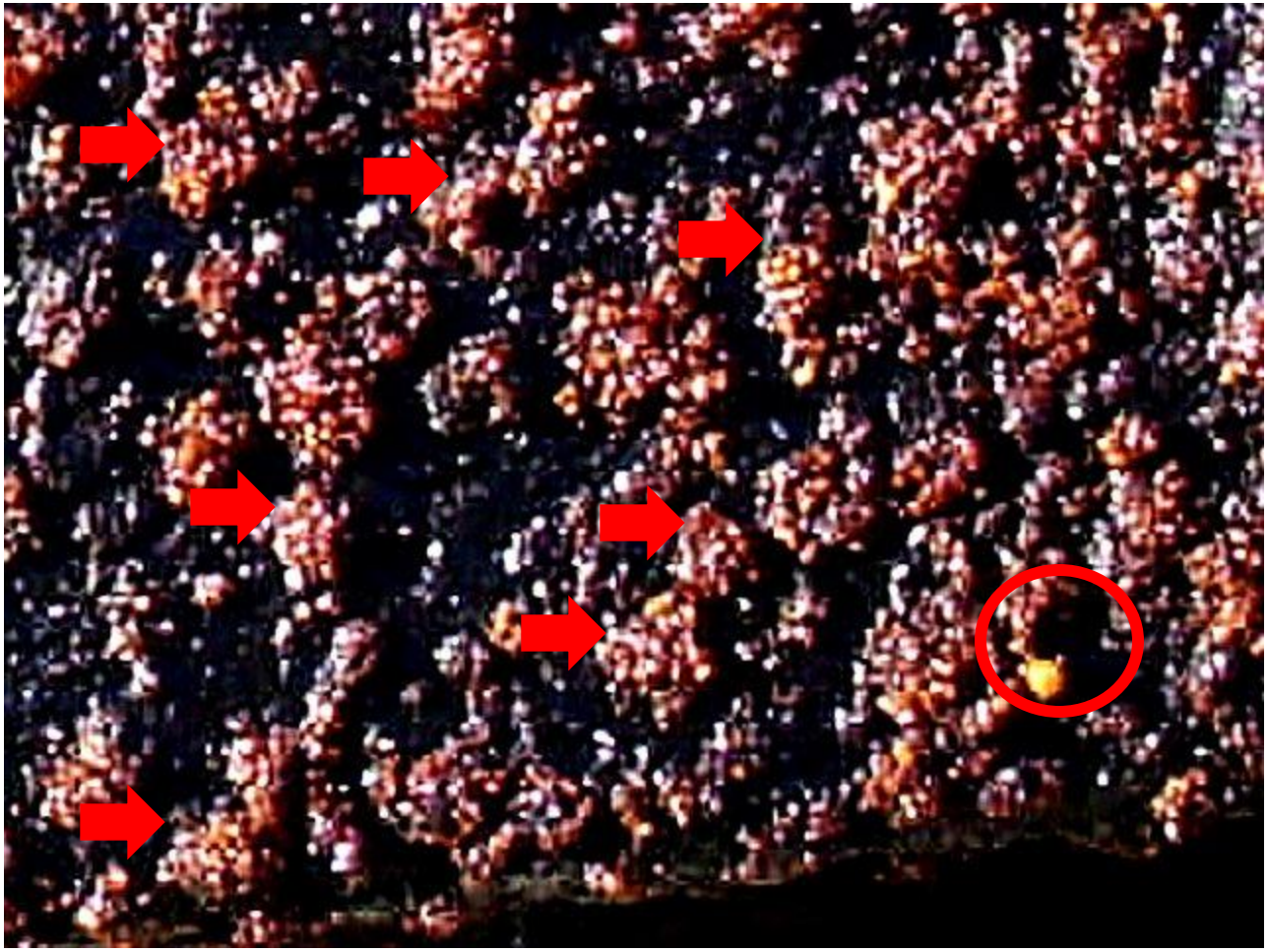
ULSD Pump Motor Assembly

STP Reducer Fitting



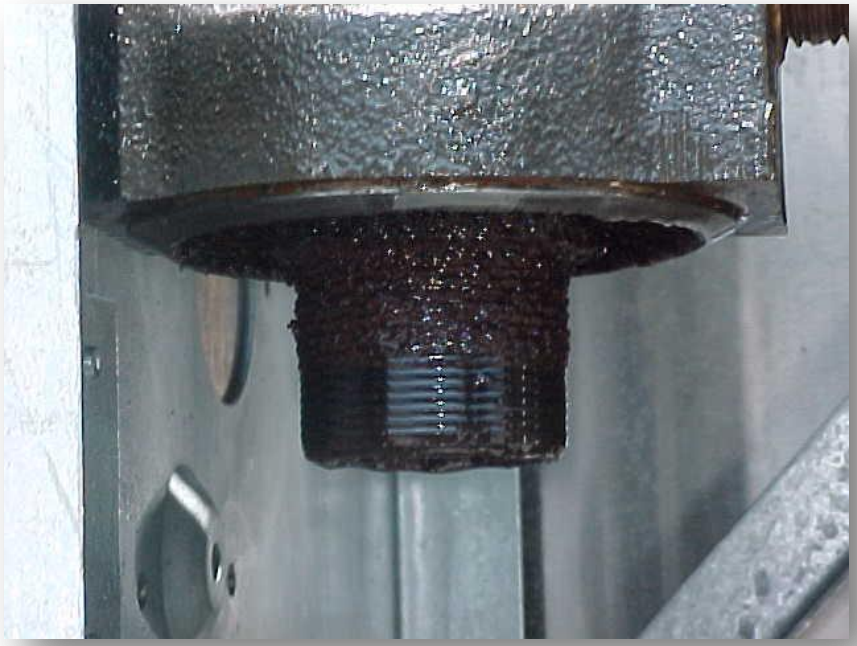
Close Up of STP Reducer Fitting

STP Reducer with Carbuncles and Reduced Sulfur Potential for SRB?

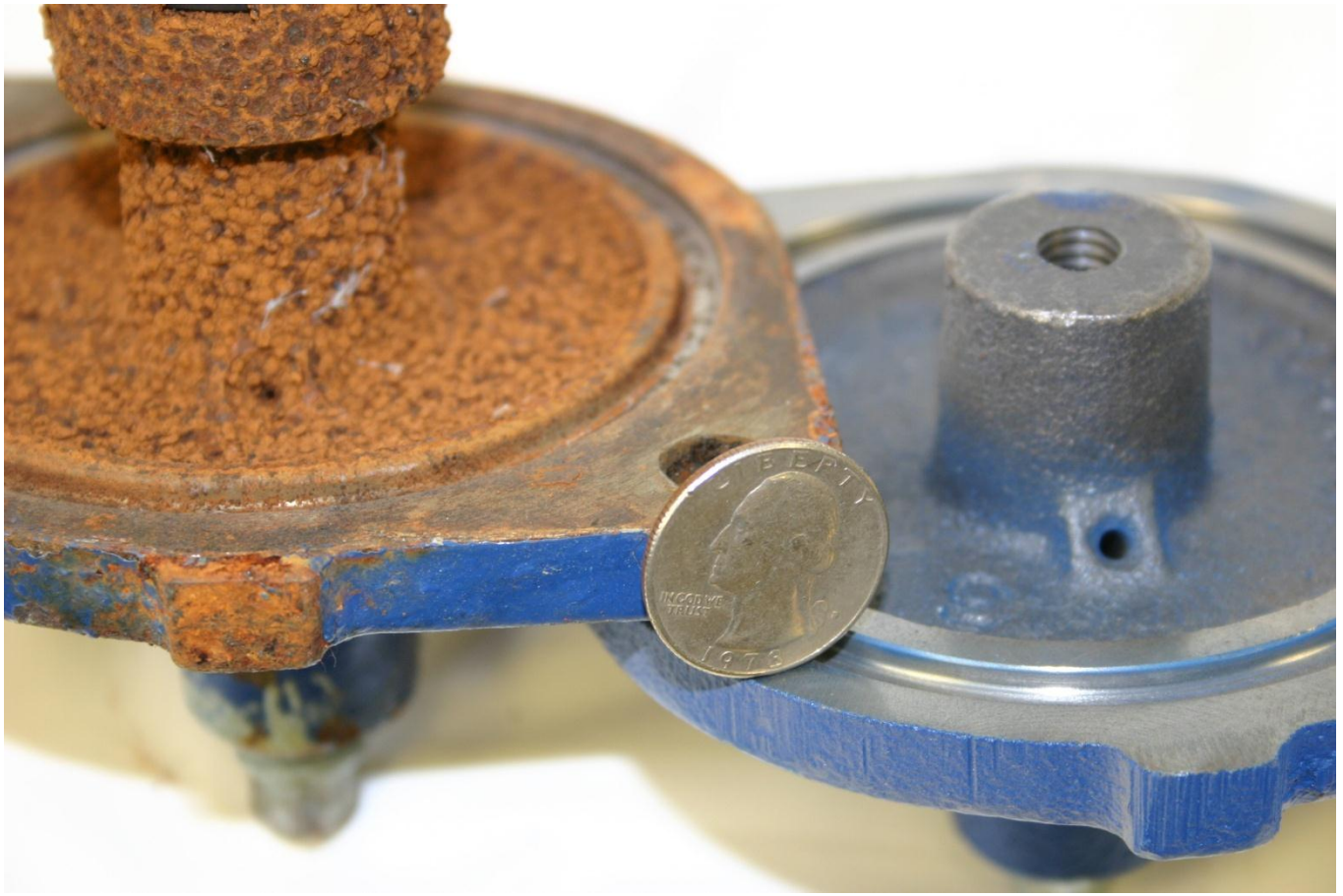


ULSD Corrosion Product

ULSD Dispenser



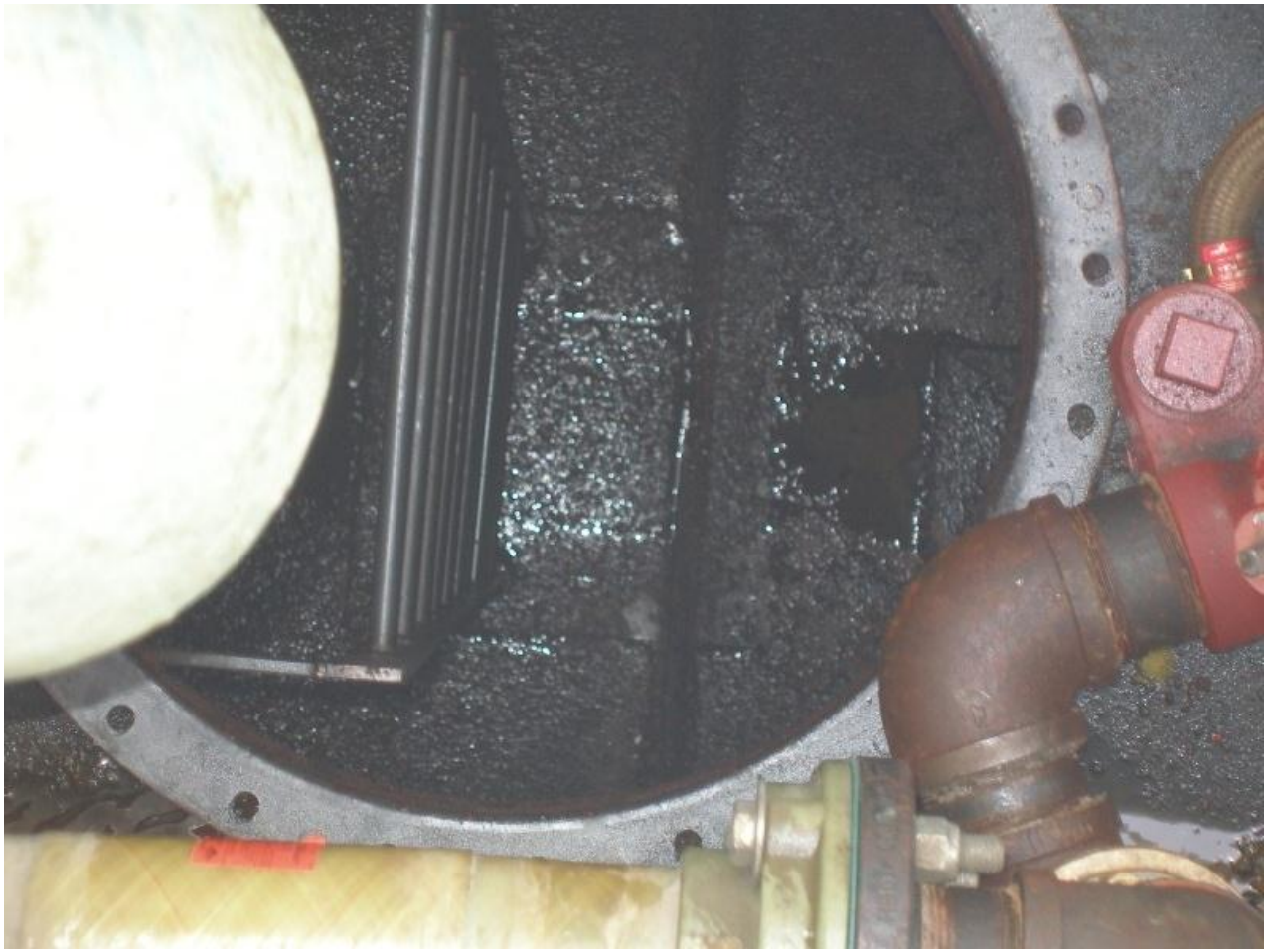
FE Petro Equipment



Old vs New


LIBERTY

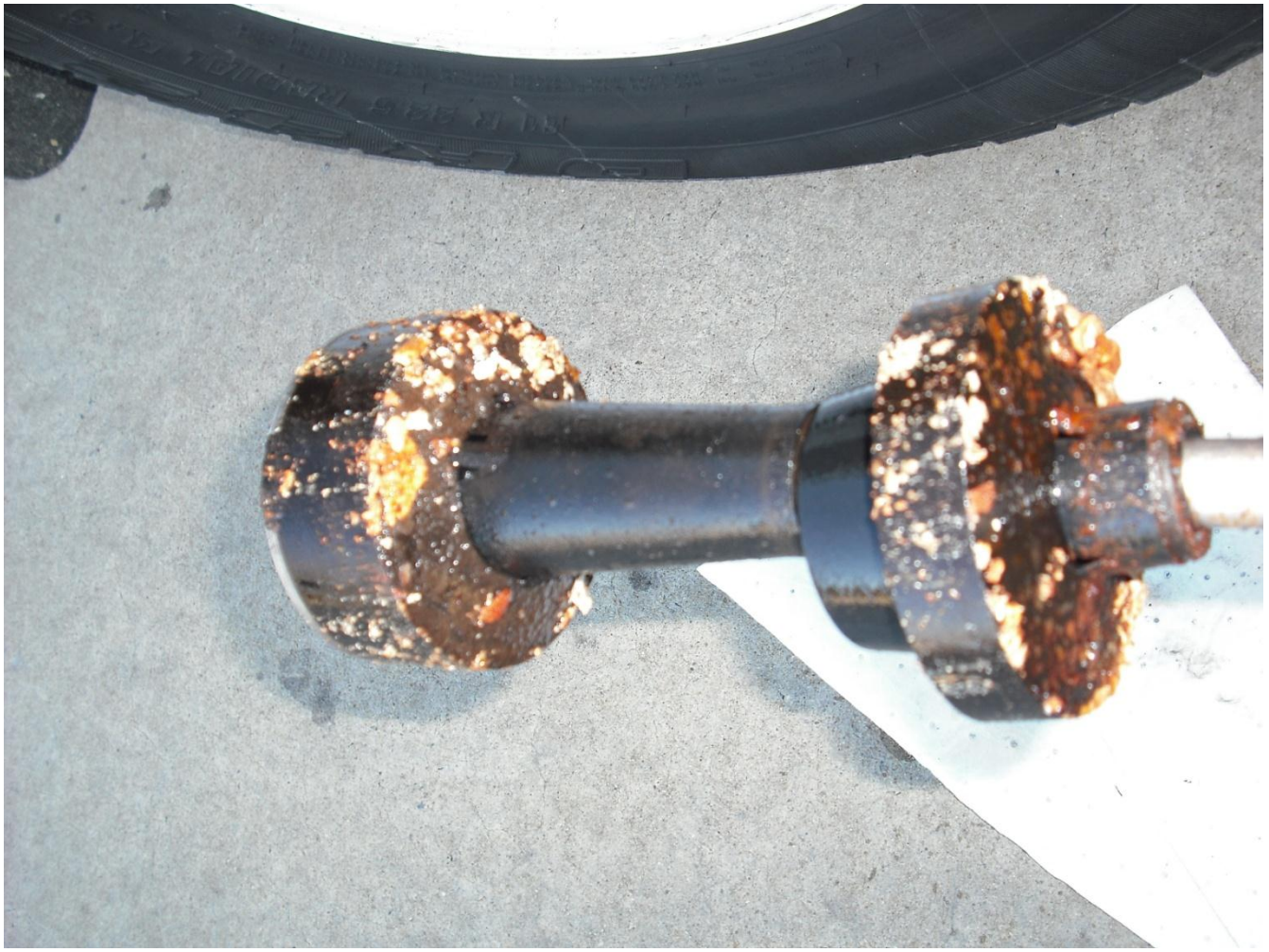
Black “gunk” in tank



Tank Bottom

ULSD Fuel Tank ATG

Encrusted ATG

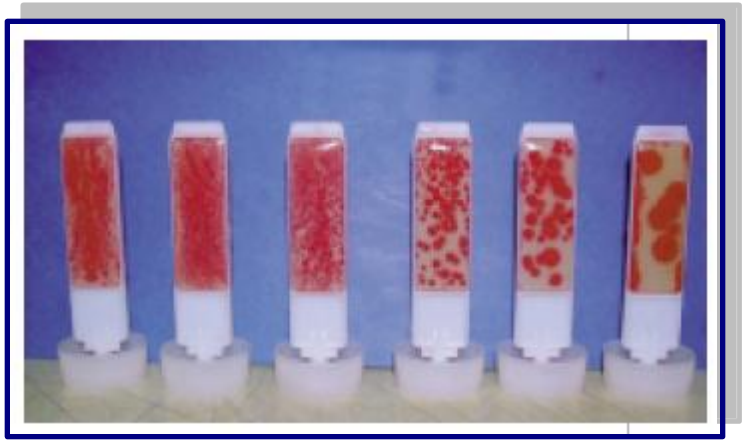


Sampling and Detection

Sample Devices

Semi Quantitative Dip Slide

- Used only for water samples.
- The test is a plastic slide with a nutrient agar to the growth of bacteria and fungi.
- The dip slide is inoculated with a water sample and monitored for growth during the incubation period.
- The numbers of colonies are estimated by comparing the dip slide to a chart.
- Done in-house and less expensive.

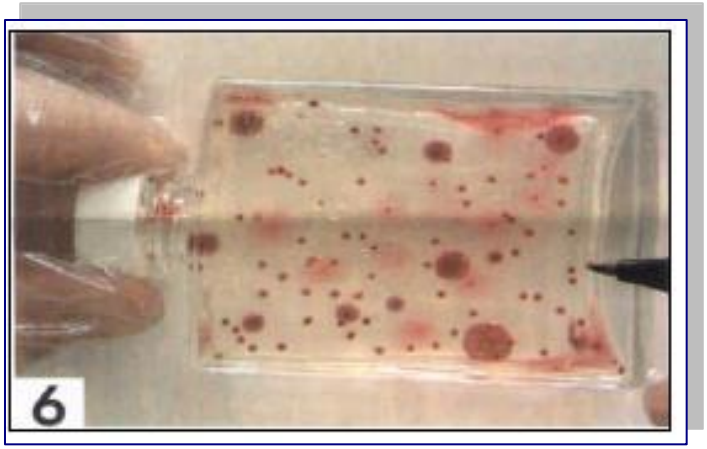


Semi Quantitative Dip Pad

- Used for fuel and water samples.
- The test is a plastic slide with a nutrient agar to the growth of bacteria and fungi.
- The dip pad is inoculated with a water sample and monitored for growth during the incubation period.
- The numbers of colonies are estimated by comparing the dip slide to a chart.
- Done in-house and less expensive.

Dual Use Thixotropic Gels

- The MicrobMonitor2® is a semi-quantitative test used to detect aerobic microorganisms in fuel and water.
- The test consists of a clear nutrient gel in a rectangular glass bottle that contains an indicator.
- A known volume of sample is added to the test bottle and incubated.
- The test bottle is examined while incubation and colonies are counted



ATP Bioluminescence

- Rapid ATP Assay utilizes bioluminescence to quantify the concentration of ATP associated with the microorganisms present in fuel and fuel/water mixtures,
- The test results estimate the microbial load in samples of up to 1 liter fuel with a quantitative result in less than 10 minutes.

Questions?

remediation

biological

MIC

corrosion

biocide

fuel

water

testing