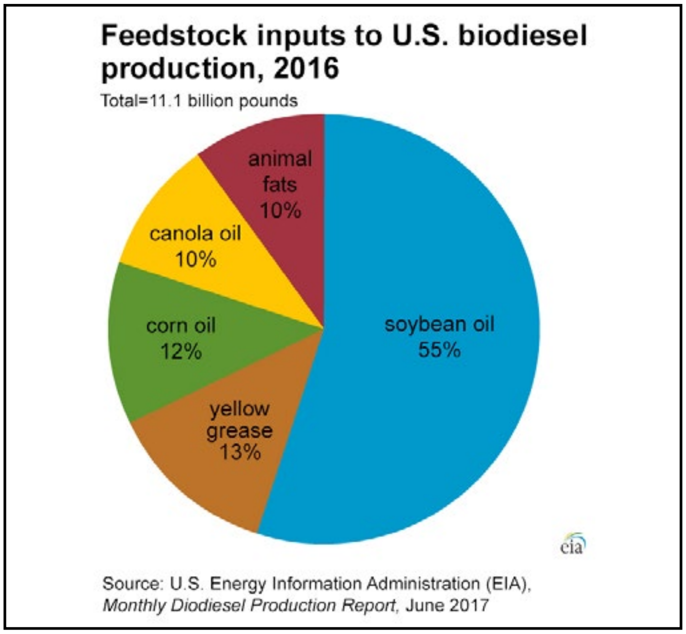
Biodiesel



Biodiesel is produced from a combination of plant oils, animal fats, and recycled cooking oil. Plant feedstocks include palm oil, sunflower oil, soybean oil, corn oil, and algae oil. Pure biodiesel (B100) is corrosive to brass, bronze, and copper. It is mildly corrosive to carbon steel, although stainless steel holds up very well to biodiesel.

Swelling of certain seals and gasket materials has been demonstrated with biodiesel. Studies have demonstrated nitrile rubber, polypropylene, polyvinyl, and Tygonare based seals are particularly prone to swelling in the presence of biodiesel while Teflon, nylon, and Viton based seals showed only negligible swelling over time. (Biodiesel Compatibility with Elastomers and Steel) When blended with diesel fuel to produce B20 (20% biodiesel) or B50, biodiesel is less corrosive and carbon steel is generally used for tanks and pipe material.

Heating of B100 will be necessary to ensure it can be pumped, filtered, and atomized. Steam heaters, electric heaters, heat tracing, insulated pipe, as well as proper burner fuel train construction will be required to ensure biodiesel of adequate viscosity is delivered to the oil burner. In most instances, steam atomization will be required—limiting it's use with hot water boilers.

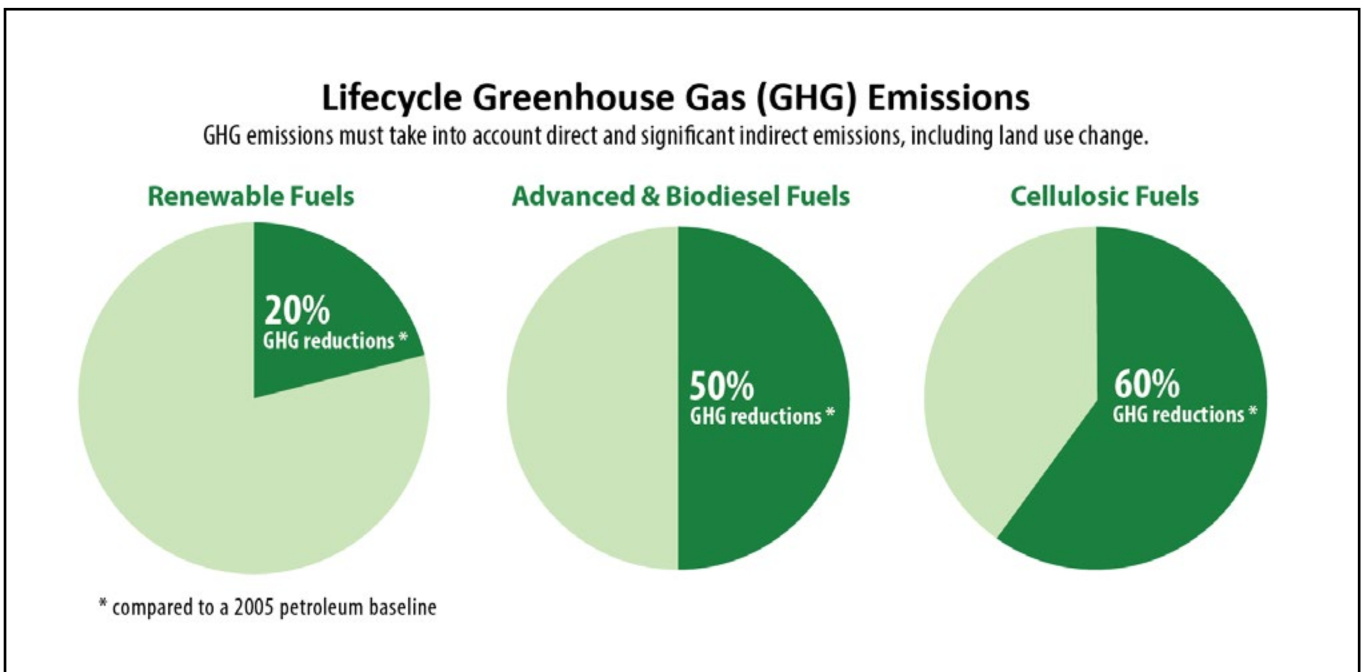
The primary issue with storing biodiesel is water removal. Biodiesel has been found to be 30 times as hygroscopic as diesel fuel. Tanks vented to atmosphere will condense water, which will become immersed with the biodiesel, and lead to sludge formation. Frequent filtration and de-watering is required to prevent biologic degradation.

Biodiesel's Physical Characteristics	
Specific gravity	0.88
Kinematic viscosity at 40°C	4.0 to 6.0
Cetane number	47 to 65
Higher heating value, Btu/gal	˜127,960
Lower heating value, Btu/gal	˜119,550
Density, lb/gal at 15.5°C	7.3
Carbon, wt%	77
Hydrogen, wt%	12
Oxygen, by dif. wt%	11
Boiling point, °C	315-350
Flash point, °C	100-170
Sulfur, wt%	0.0 to 0.0015
Cloud point, °C	-3 to 15
Pour point, °C	-5 to 10

Biodiesel Residual

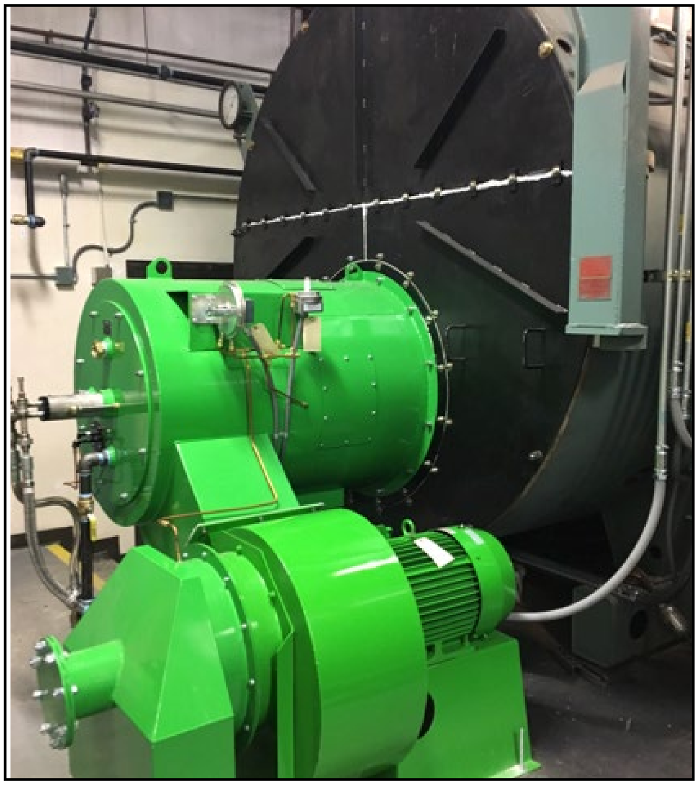
Biodiesel Residual (Heavy Esters)
Like a non-fossil No. 6 residual oil, heavy esters are the heavy ends produced from biodiesel refining. Feedstocks include recycled fats and oils such as used cooking oil, inedible corn oil, animal fat, and other vegetable oils. Heavy esters provide the same carbon reduction benefits of biodiesel at a lower cost of fuel. Heating value depends on the feedstock but averages 128,000 Btu/ gallon. (Diesel fuel averages 138,000 Btu/gallon). The boiler industry does not have much experience yet burning heavy esters, but it is anticipated the same methods of fuel heating, mixing, and filtering used for No. 6 fuel oil will be effective with biodiesel heavy esters.

Pump & heater system for heating and mixing heavy fuel oils



Renewable Fuel Oil

Renewable Fuel Oil (RFO) is usually made from commercial tree farm trimmings. A pyrolysis process is used to convert the wood waste into a liquid fuel that has about 70% of the heating value by volume as diesel fuel and a pH of about 2.5. The low pH requires that tanks, pipe, valves, and burner components be made of stainless steel. Carbon steel has been known to last just days in the presence of RFO. In addition, RFO is too viscous to burn at room temperature. It must be heated to approximately 140 – 150 deg. F to burn cleanly. Care must be taken with the material selection of atomizers and tips to ensure longevity of the burner components.



A 700 HP boiler converted to fire renewable fuel oil

Property	Analytical Method	Typical
Water Content	ASTM E203 (Karl Fisher titration)	<24 wt%
pH	ASTM E70-07	>2.5
Density @ 15 °C	ASTM D4052	10.0 lb/USgal
Specifc Gravity @ 15 °C		1.20
Kinematic Viscosity @ 40 °C	ASTM D445	25 cSt
Higher (Gross) Heating Value, Moisture Free	ASTM D240	9905 Btu/lb
Higher (Gross) Heating Value, As-Is	Calculated	7528 Btu/lb
Lower (Net) Heating Value	Calculated	6842 Btu/lb
Solids Content	ASTM D7579	0.1 wt%
Pour Point	ASTM D97	-13 °F
Elemental Analysis (moisture & ash free)		
Carbon	ASTM D5291	54.87 wt%
Hydrogen	ASTM D5291	6.67 wt%
Nitrogen	ASTM D5291	0.16 wt%
Sulphur	ASTM D4294	<0.05 wt%
Oxygen	Calculated, by difference	38.25 wt%
Ash	ASTM D482	<0.15 wt%

Ethanol

Ethanol is made by fermentation of agricultural crops such as corn, sugar beets, and sugar cane. It is also produced from agricultural residues including bagasse, barley straw, corn stover, sorghum stubble, rice straw, wheat straw, and wood residues. In the United States, most ethanol is produced from corn.

Because ethanol is required to be blended with gasoline, and it is more suited as an engine fuel, ethanol is rarely used as a boiler fuel. In rare circumstances where a chemical or pharmaceutical plant produces ethanol and it is not economical to sell, ethanol can be burned in the plant's boilers.

Because ethanol is so thin, some care needs to be taken when atomizing the fuel prior to burning. Air atomization or pressure atomization is recommended. Steam atomization will cause the fuel to vaporize prior to combustion, resulting in flame instability.

Table 2: Fuel properties

Property	*Gasoline*	*Ethanol*
Formula (liquid)	C_8H_{18}	C_2H_6O
Molecular weight (kg / kmol)	114.15	46.07
Density (kg/m^3)	765	785
Heat of vaporization (kJ/kg)	305	840
Specific heat (kJ/kg K) Liquid	2.4	1.7
Specific heat (kJ/kg K) Vapour	2.5	1.93
Lower Heating Value (kJ/kg)	44,000	26,900
Stoichiometric air–fuel ratio by mass	14.6	9.00
Research Octane Number	92	108.6
Motor Octane Number	85	89.7
Enthalpy of formation (MJ/kmol) Liquid	259.28	224.10
Enthalpy of formation (MJ/kmol) Gas	277.0	234.6

Ethanol is hygroscopic, and will attract water in vented tanks. Water concentrations over 2% will produce organic acids that attack soft metals such as those containing zinc, copper, aluminum, and lead. Carbon steel, stainless steel, and fiberglass hold up well against ethanol. Seals and gaskets made from natural rubber, polyurethane, PVC, polyamides, methyl-methacrylate plastics, and polyester-bonded fiberglass should not be used with ethanol. However, Buna-N, neoprene rubber, polypropylene, nitrile, Viton, Teflon, and thermoset reinforced fiberglass are compatible with ethanol.

E85 (85% Ethanol, 15% Unleaded Gasoline)

E10 is strictly a motor fuel. Because it has been mandated as an additive to gasoline since the 1980s, the fuel handling industry has a great deal of experience with the slightly corrosive nature of this ethanol blend. E85 is less corrosive than pure ethanol. But because both ethanol and gasoline are hygroscopic, they will attract condensed water vapor that will lead to the formation of corrosive acids. Because permanent storage tanks (both underground and aboveground) are required to be vented, there is an open path for water vapor to condense in tanks and enter the fuel. The amount of condensation will depend on the relative humidity of the air, and the temperature differential between the tank and the ambient air.

Turning the fuel quickly (burning the fuel before it sits and collects water) is the best way to keep the fuel dry and clean. If turning the fuel quickly isn't practical, frequent de-watering and filtration is necessary to preventing the formation of organic acids that lead to corrosive properties. Chemical additives can also be used to keep the water in solution and prevent the formation of acids and bacterial sludge.

B20 & B50

Biodiesel blends are becoming more common as engine fuels and boiler fuels. When blended with ULSD, the corrosive properties of pure biodiesel are significantly mitigated. A recent study tested the amount of swelling of nitrile rubber and Viton seals with different blends of biodiesel (B20, B50, and B100) and found an increase in swelling corresponding to an increase in biodiesel concentration. However, the same study found different concentrations of biodiesel had the same adverse effect on the hardness or elasticity of the seal material.

In general, B20 is only corrosive to copper containing metal alloys—and less so than B100. Carbon steel, stainless steel, aluminum, and titanium have been found to be resistant to B20 corrosion. Although less corrosive than B100 to gasket and seal materials, B20 should be investigated for each material prior to use. Although cloud points for B100 biodiesel can range from 27 deg. F to 53 deg. F, B20, when blended with ultra low sulfur diesel (ULSD) fuel, cloud points range from 14 deg. F to 23 deg. F depending on the cloud point of the ULSD used in the blend. Commercially available B20 will usually be made with a winter mix and a summer mix, meaning ULSD with a lower pour point will be added in winter months and colder climates.

Property	Diesel No. 2	B20	B50	B100
Density at 15 deg. C (kg/m^3)	859.3	861.7	865.5	871.6
LHV(MJ/kg)	42.19	41.17	39.66	37.13
K. Viscodity at 40 deg. C (mm^2/s)	4.33	4.49	4.58	4.73
Chemical Formula	$C_{14.7}H_{28.8}$	$C_{15.2}H_{29.7}O_{.4}$	$C_{16.7}H_{31.5}O_{.8}$	$C_{18.1}H_{34.9}O_2$
Molecular Weight	205.2	217.8	240.4	284.2
Stoich. Fuel/Air Ratio	1/14.6	1/14.3	1/13.5	1/12.5
Oxygen (% Wt)	0.00	2.33	5.73	11.26
Cetane Index	46.46	48.2	51.1	56.9
Initial Boiler Point	182	185	190.2	302
T50 (deg. C)	285	302	312.6	327
Final Boiling Point (deg. C)	384	371	364.5	348

		Viscosity Issues	Corrosion Issues	Degradation Issues	Combustion Issues	Notes
Fossil Fuels	Gasoline	A	B	B	B	RARELY USED AS A BOILER FUEL. HAS CORROSSION ISSUES, BUT BECAUSE OF IT'S WIDESPREAD USE THERE IS A GOOD SELECTION OF CORROSION RESITANT MATERIALS AVAILABLE.
	No.2 Diesel	B	B	B	A	MILDLY CORROSIVE, BUT A WIDE VARIETY OF CORROSION RESISTANT MATERIALS ARE AVAILABLE. VISCOSITY IS NOT AN ISSUE EXCEPT IN EXTREMELY COLD ENVIRONMENTS. PRONE TO DEGRADATION IF EXPOSED TO WATER. ULTRA LOW SULFUR DIESEL (ULSD) IS MORE PRONE TO BACTERIAL GROWTH THAN TRADITIONAL DIESEL FUEL.
	No. 6 Residual	C	A	A	C	MUST BE HEATED AND WELL-MIXED. BURNERS MUST BE SPECIALLY DESIGNED FOR HEAVY FUEL OIL.
Bio-Fuels	Biodiesel (B100)	C	C	C	B	CORROSIVE. HYGROSCOPIC (ATTRACTS WATER VAPOR FROM THE AIR) SUBJECT TO BACTERIAL GROWTH. MUST BE HEATED IN MOST CLIMATES.
	Biodiesel Residual (Heavy Esters)	C	B	B	C	MILDLY CORROSIVE. SUBJECT TO BACTERIAL GROWTH. MUST BE HEATED. BURNERS MUST BE SPECIALLY DESIGNED FOR HEAVY FUEL OIL.
	Ethanol (E100)	B	C	C	B	CORROSIVE. ATOMIZATION, METERING, AND FLAME SCANNING CAN BE ISSUES FOR ALCOHOL-BASED FUELS.
	RFO	C	C	B	C	MUST BE HEATED AND WELL-MIXED. CHEMICAL COMPATIBILITY OF TANKS, PUMPS, PIPING, AND BURNERS IS A MAJOR CONCERN. ATOMIZATION AND COMBUSTION IS DIFFICULT DUE TO HIGH WATER CONTENT OF FUEL.
Blended Fuels	B20	B	B	C	B	MILDLY CORROSIVE. SUBJECT TO BACTERIAL GROWTH. MUST BE HEATED OR CAREFULLY BLENDED IN COLD CLIMATES.
	B50	B	C	C	B	MILDLY CORROSIVE. SUBJECT TO BACTERIAL GROWTH. MUST BE HEATED OR CAREFULLY BLENDED IN COLD CLIMATES.
	E85	B	C	C	B	RARELY USED AS A BOILER FUEL. CORROSIVE. SUBJECT TO BACTERIAL GROWTH AND DEGRADATION WHEN ULSD IS USED AS A FEEDSTOCK.

		Seal or Gasket Material										Tank, Pipe, or Valve Material										
		CPVC	PP	PTFE	PVC	PVC GF	PVDF	ULTEM	EPDM	Viton	NITRILE	HASTALLOY	18-8 SST	316 SST	416 SST	TITANIUM	ALUMINUM	CARBON STEEL	304 SST	BRASS	BRONZE	COPPER
Fossil Fuels	Gasoline	X	X	A	C	C	A	A	X	B	A	A	A	A	A	X	A	A	A	X	B	X
	No. 2 Diesel	A	B	A	A	A	A	A	X	A	A	A	A	A	A	A	A	A	A	X	A	X
	No. 6 Residual		B	A	B	C	A		X	A	A	A	A	A		A	A	B	A	X	B	X
Bio Fuels	Biodiesel (B100)		B	A	X	X			B	B	X	A	A	A	A		B	B	A	X	X	X
	Biodisel Residual		B	A	X	X			B	B	X	A	A	A	A		B	B	A	X	X	X
	Ethanol	B	A	A	A	A	A	A	A	B	A	A		A	A	A	B	B	A	X	X	X
	RFO			A					X		X		A	A	A			C	A	X	B	X
Blended Fuels	E85 (85% ethanol)			A	C	C				B	A	A	A	A	A		B	A	A	B	A	X
	B20 (20% biodiesel)		B	A	C	C			A	A	C	A	A	A	A	A	A	A	A	B	B	B
	B50 (50% biodiesel)		B	A	X	X			B	B	X	A	A	A	A	A	A	A	A	C	C	C

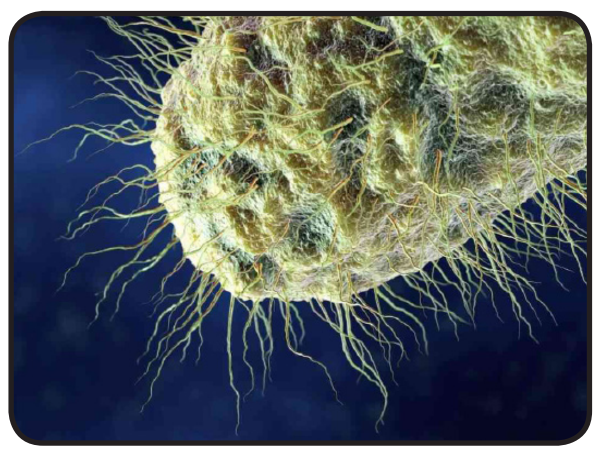
De-watering and Filtering to Prevent Microbial Build-up and Corrosion

Three stages of Filtration:
99% particulate removal that can clog vital components, and reduce reliability and service life.

Tank Turnover Time In Hours
(Rounded to Nearest Hour)

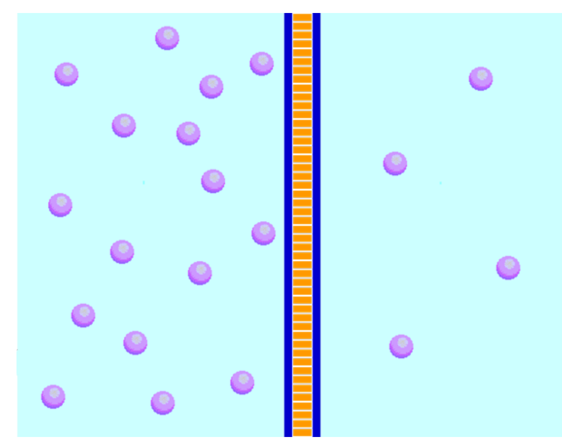
	Storage Tank Size (Gallons)					
	1,000	**2,000**	**4,000**	**8,000**	**16,000**	**20,000**
PF-501	6	11	22	44	89	111
PF-502	2	4	8	17	33	42
PF-503	2	3	7	13	27	33
PF-504	1	2	4	9	18	22
PF-505*	1	2	3	7	13	16

Stage 1: ***Fuel Straining*** removes large particulates.



MICROORGANISMS
Under normal circumstances, water is constantly being introduced to the fuel. Microorganism growth can then produce sludge.

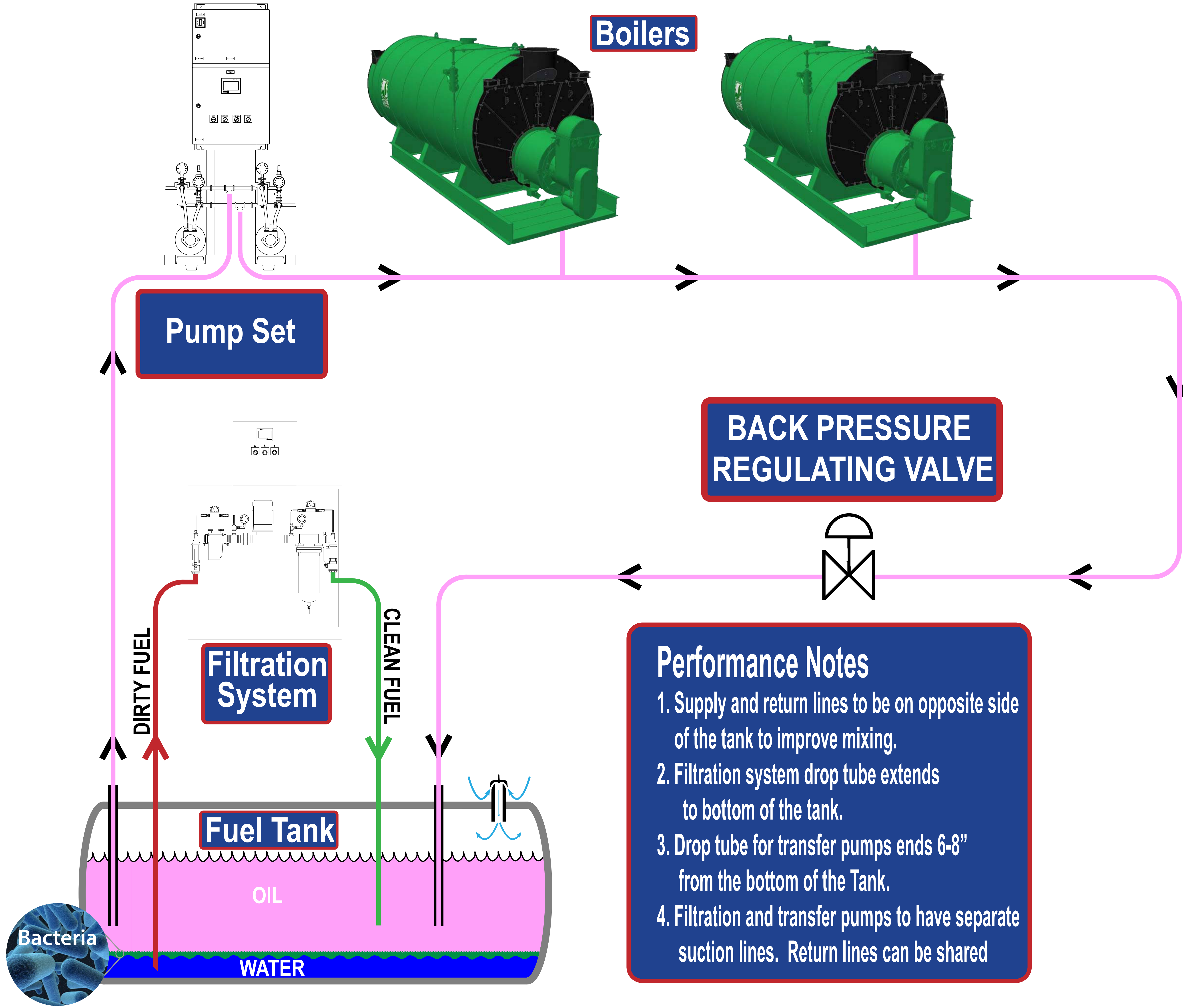
Stage 2: ***Filtration*** removes particulate to 5 micron



PARTICULATE CONTAMINATION
can also reduce reliability and service life of the diesel generator(s). Interchangeable filters can remove particles as small as 5 microns.

Stage 3: ***Water Removal*** eliminates water through special filter design.

SLUDGE
left in a system can cause tank, fuel line, strainer, pump and engine injectors to clog. Water induced corrosion (rusting) can reduce tank life expectancy and reliability of the emergency diesel generator or boiler.


Boilers
Pump Set
BACK PRESSURE
REGULATING VALVE
Filtration
System
DIRTY FUEL
CLEAN FUEL
Fuel Tank
OIL
WATER
Bacteria
Performance Notes
1. Supply and return lines to be on opposite side of the tank to improve mixing.
2. Filtration system drop tube extends to bottom of the tank.
3. Drop tube for transfer pumps ends 6-8” from the bottom of the Tank.
4. Filtration and transfer pumps to have separate suction lines. Return lines can be shared

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