

# Reliability Issues at Low I/O Ratios



Daryl Dunham



# Isobutane to Olefin Ratio

A key reactor parameter hydrofluoric acid alkylation is Isobutane-to-Olefin ratio (I/O).

Most units built in the 1970's were designed at 12 or 13 I/O ratio to achieve a high octane alkylate product.

With ethanol blending required in most gasoline produced in the United States, octane is not usually a priority for alkylate quality and I/O ratios have been reduced to achieve higher throughputs when settler or recycle limited.

# Reliability Issues

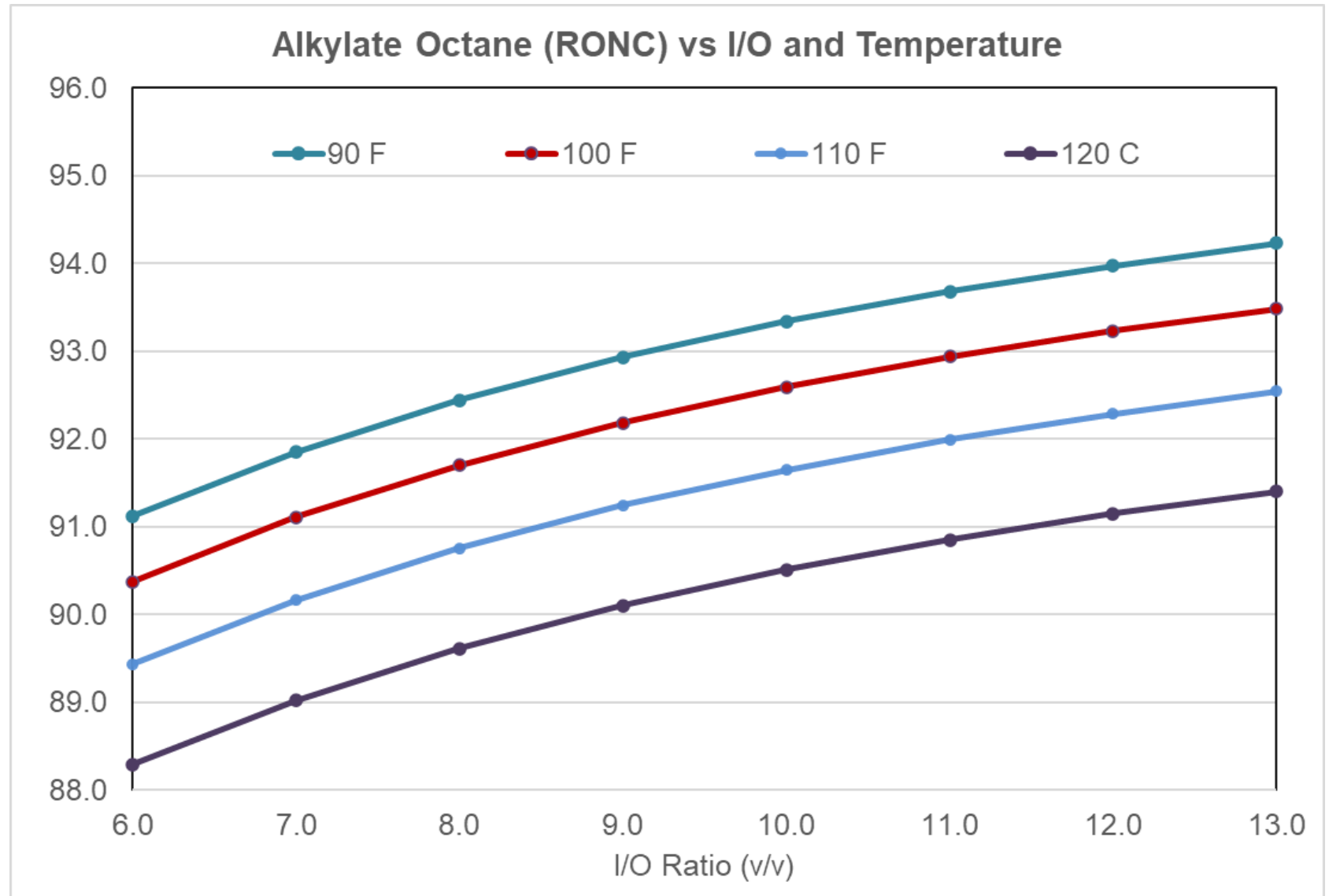
There are some reliability issues related to reducing I/O ratio:

1. Higher potential for acid carry over – corrosion in fractionating section
  - Carry over acid is more corrosive due to higher water than dissolved acid
2. Increased Acid Soluble Oil (ASO) formation – higher throughput in acid regeneration section
3. Lower ratio of acid-to-alkylate produced ratio – acid degrades faster
4. Higher ratio of alkylate-to-reactor effluent ratio – greater demand on alkylate cooling system

# Main Affect on Octane

At 100 deg F reactor temperature, dropping from 12 I/O to 6 – loses almost 3 octane numbers.

RONC = Research Octane Number Clear

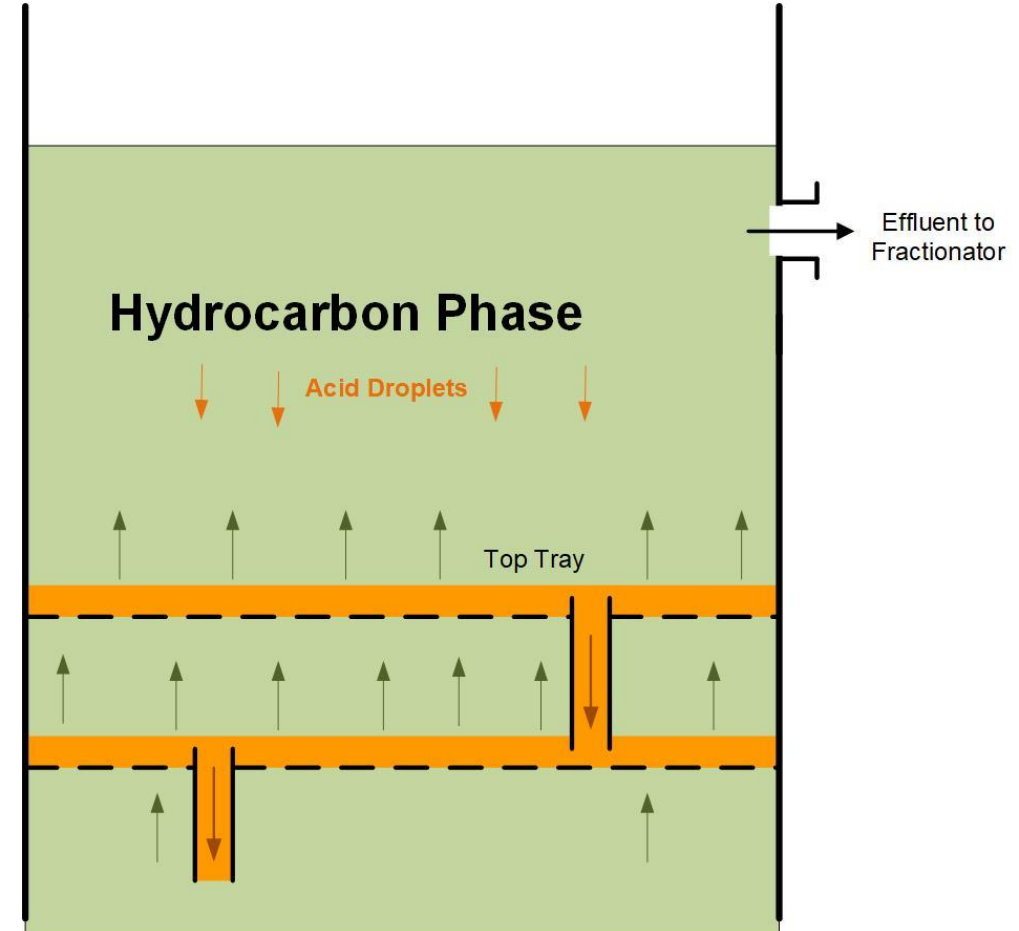


# Acid Settling

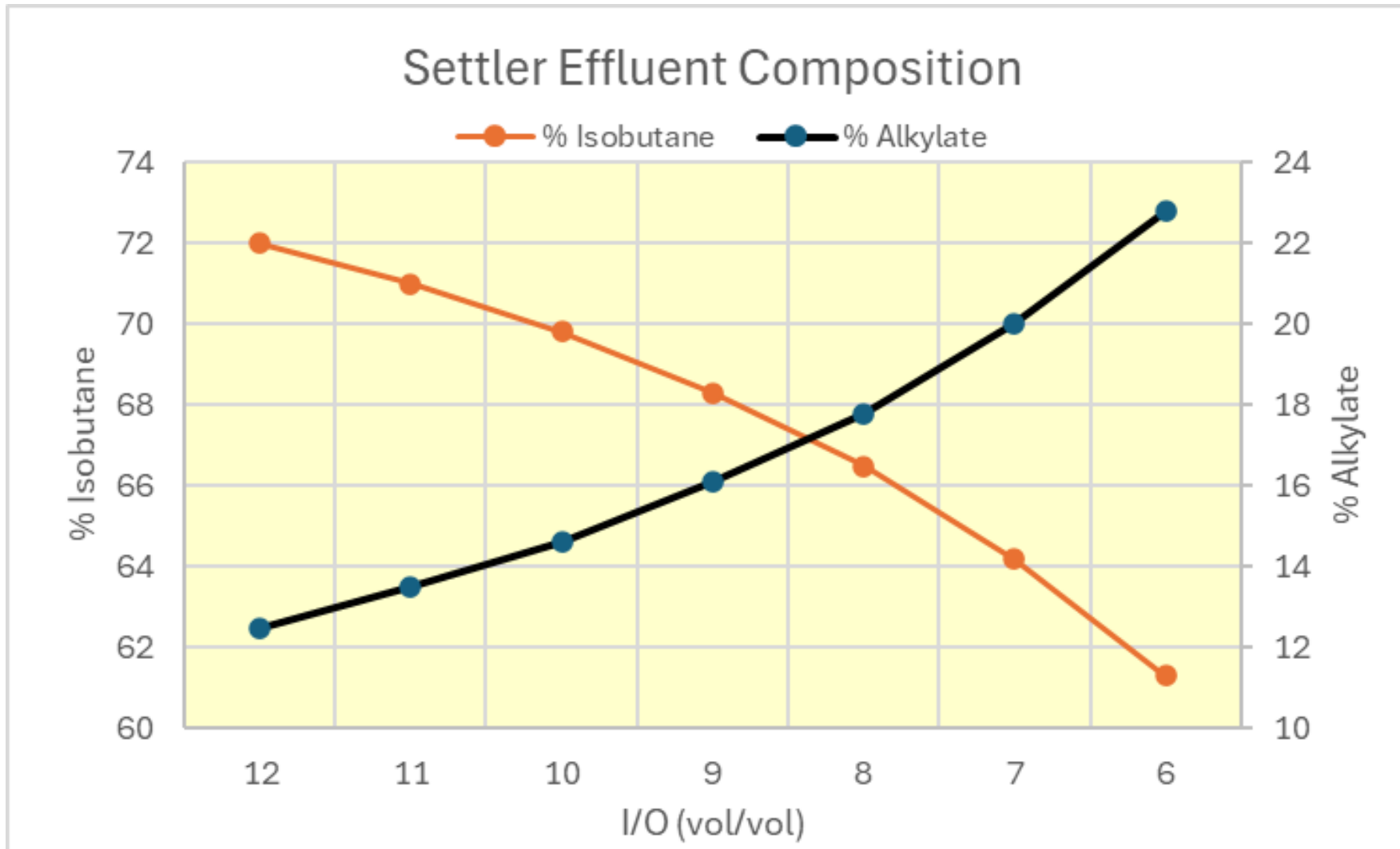
Acid droplets settle from the reactor effluent hydrocarbon in the acid settler by density difference.

In a vertical settler, there is a maximum hydrocarbon upward velocity at which a certain acid droplet will settle.

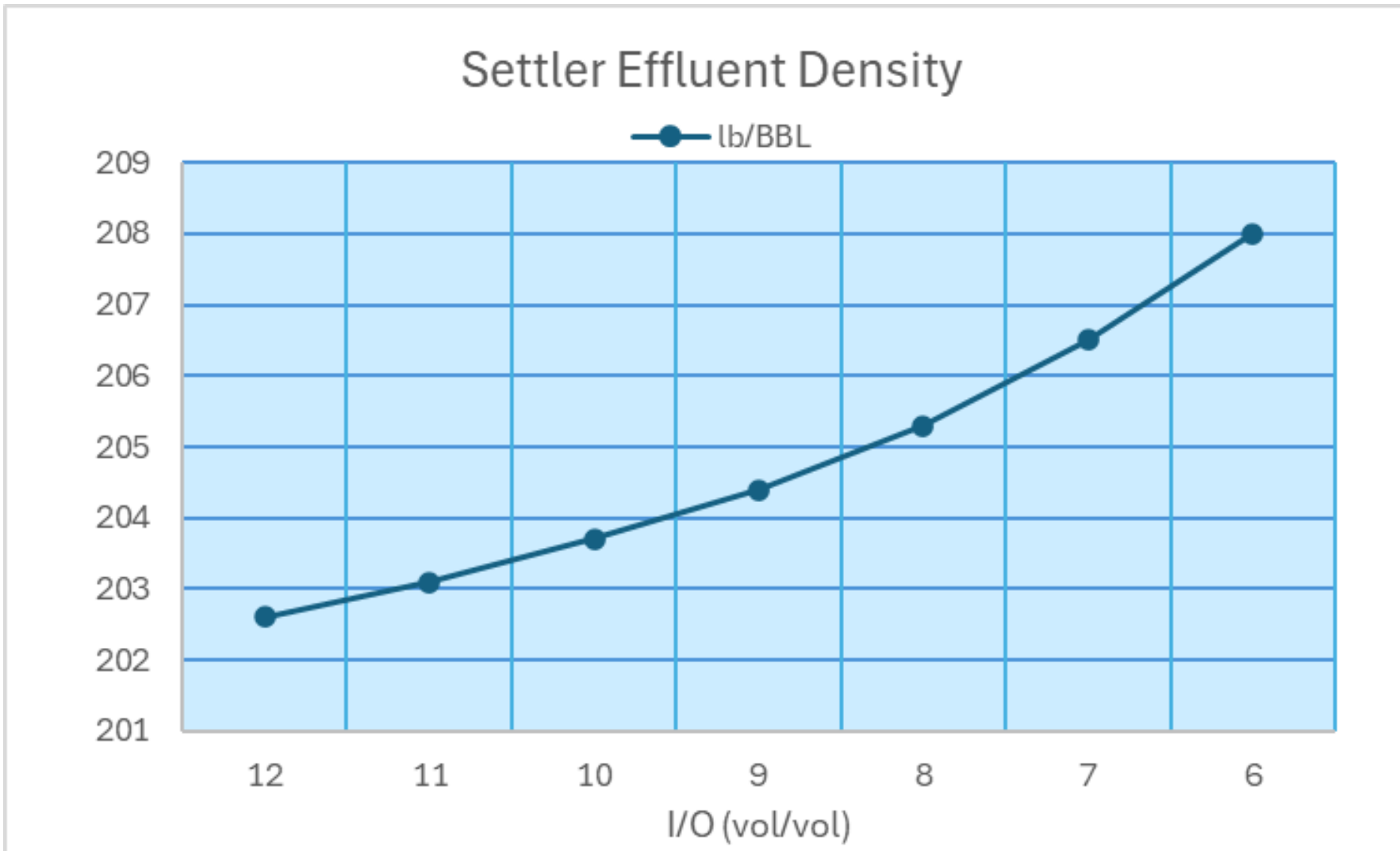
- This maximum velocity is calculated from Stokes law and depends on the acid density, hydrocarbon density, hydrocarbon viscosity and the droplet size (diameter).
- As I/O ratio decreases, effluent hydrocarbon density increases and hydrocarbon viscosity increases.



# I/O Affect on Settler Effluent



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# Settling – Stokes Law

$$V = g(\rho_H - \rho_L)d^2 / 18\mu$$

V = droplet settling velocity (cm/sec)

g= gravitational constant (980 cm/sec<sup>2</sup>)

$\rho_H$  = density of the acid (g/cm<sup>3</sup>)

$\rho_L$  = density of the hydrocarbon (g/cm<sup>3</sup>)

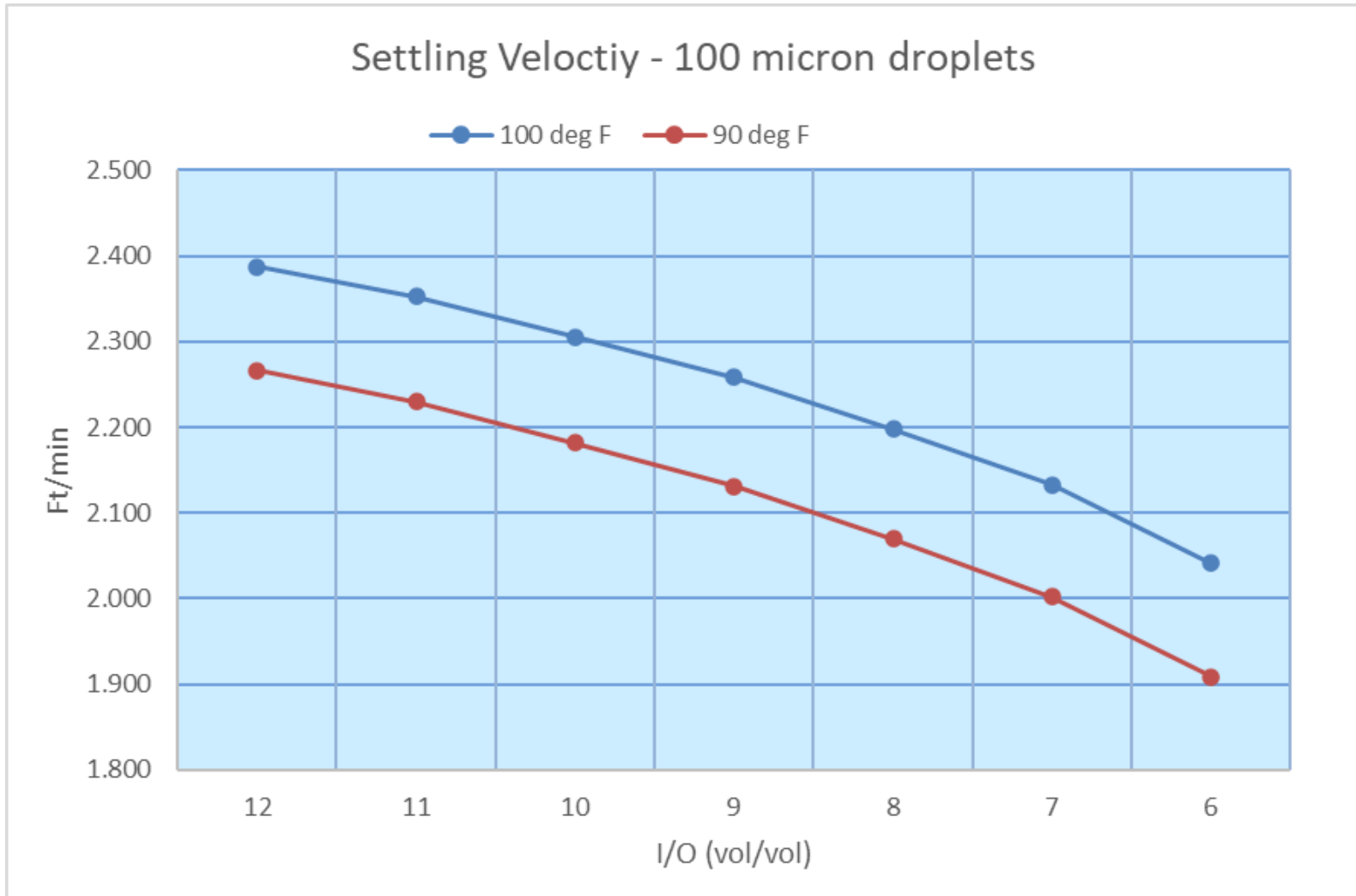
$\mu$  = hydrocarbon viscosity (g/cm-sec)

d = droplet diameter, cm (100 micron = 0.010 cm)

In a vertical settler, if upward hydrocarbon velocity exceeds settling velocity, larger droplets get carried over.

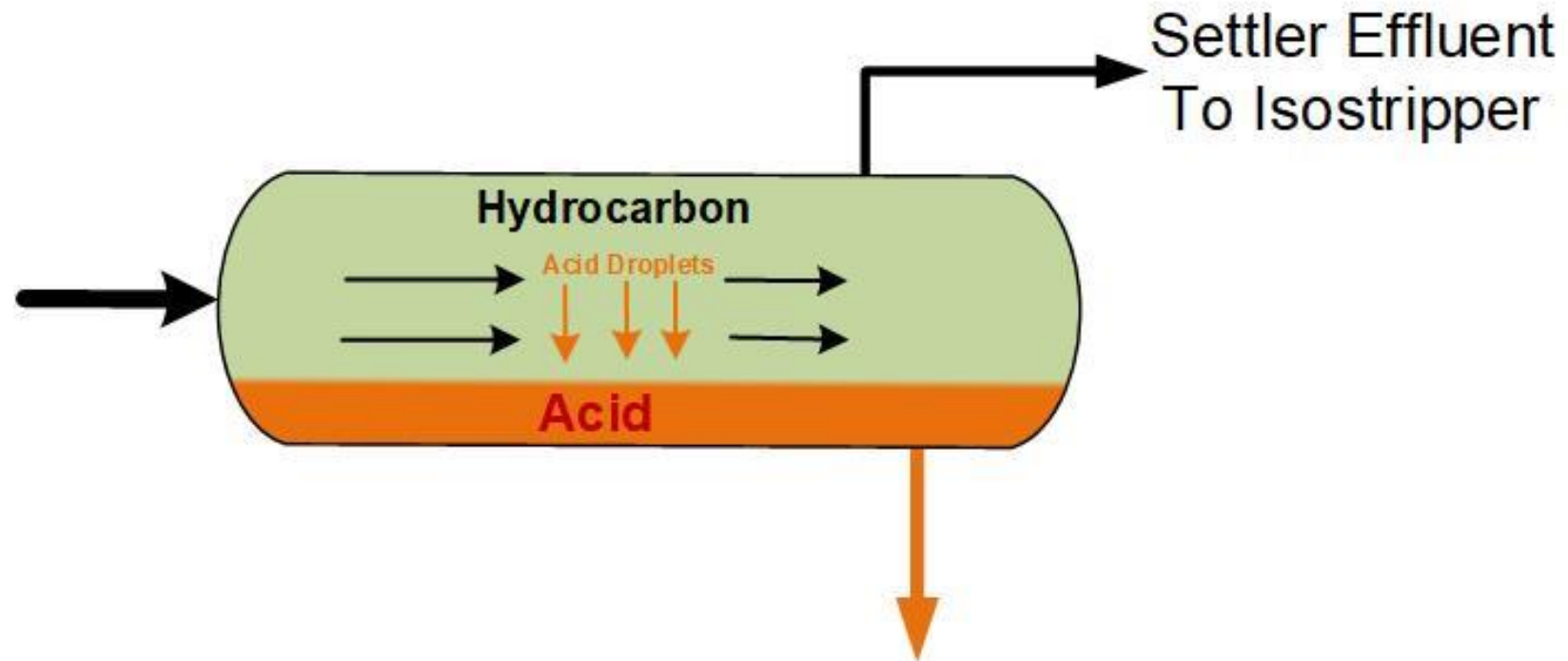
I/O Ratio	Settler Density Lb/ft <sup>3</sup>	Max Velocity Ft/min
12	34.92	2.39
11	35.02	2.35
10	35.15	2.31
9	25.29	2.26
8	35.46	2.20
7	35.66	2.13
6	35.97	2.04

# I/O Affect on Settling Velocity



At lower settler temperatures, hydrocarbon density and viscosity are higher

# Horizontal Settler



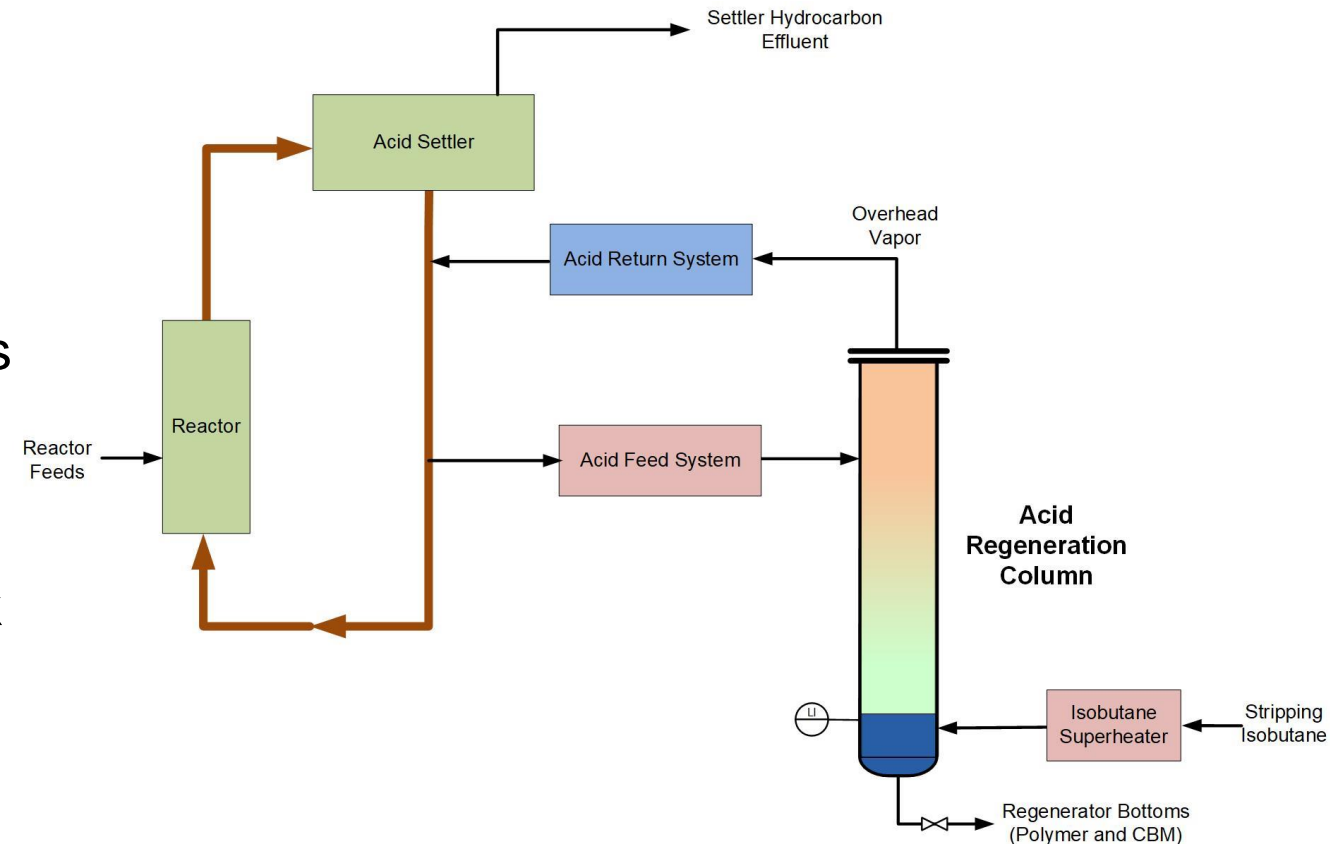
Hydrocarbon residence time must be high enough to allow time for acid droplets to settle.

Lower settling velocity at lower I/O ratios requires longer time.

# Acid Regeneration System

At lower I/O ratios, there is more demand on the acid regeneration system:

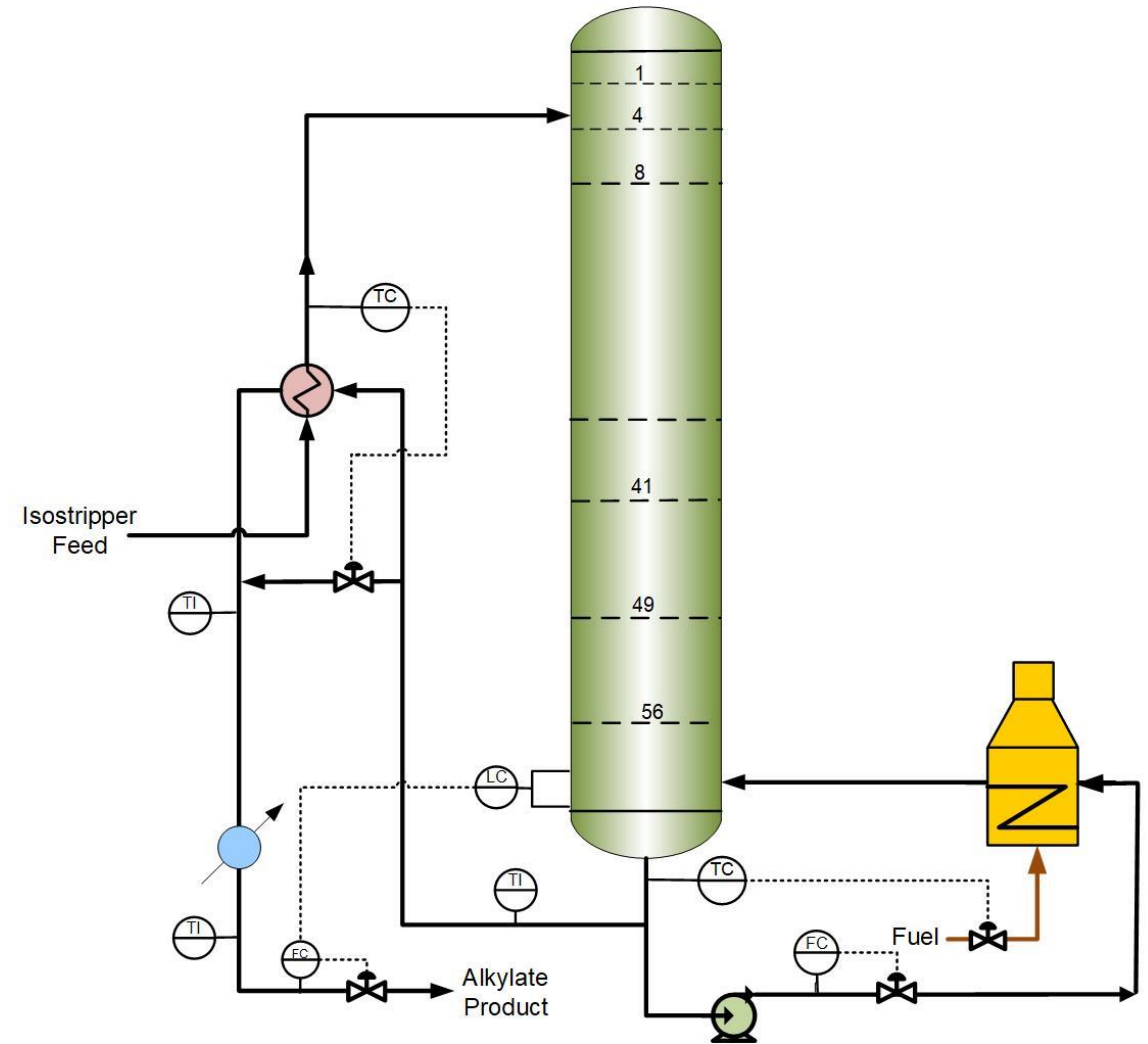
- More ASO is produced at low I/O.
- More alkylate is made with the same acid inventory, so the acid degrades faster.
- This requires higher acid and isobutane feed rates, higher overhead rate, and higher bottoms (polymer or ASO) rate.
- Corrosion and fouling can increase.
- The system may not have the capacity to reject ASO at the same rate that it is generated. (Risk of acid runaway).
- The system may not have catch-up capacity to recover from an upset such as high feed sulfur.



# Alkylate Rundown System

At lower I/O ratios, there is more demand on the alkylate product cooling system:

- Settler Effluent (Isostripper Feed) has higher alkylate content.
- Exchanging higher alkylate rate with same isostripper feed rate results in more alkylate being bypassed.
- The downstream alkylate water cooler must handle a higher alkylate rate at a higher temperature.
- Fouling and corrosion can increase on the water side of the alkylate cooler.
- Many refiners have added an air cooler to handle the higher temperature.





## CONTACT US:

 [becht.com/contact](https://becht.com/contact)  
 +1 (908) 580-1119  
  [/company/becht](https://www.linkedin.com/company/becht)

