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Make your gasoline more valuable with butane blending

Butane blending—blending butane into a finished gasoline with the goal of increasing the volume—is a well-known technique that has been used in the gasoline business for many years. Butane is injected because it is cheap (~$36/bbl) and due to its positive properties [high Reid vapor pressure (RVP) and high octane].

Due to favorable economics, blending butane and/or naphtha into commercial pipeline gasoline—i.e. (conventional gasoline) CG87 or CG93 to downgrade it to CBOB (conventional before oxygenate blend) regular or CBOB premium—is being considered.

Alternatively, bio-ethers such as ethyl tert-butyl ether (bio-ETBE) or methyl tert-butyl ether (bio-MTBE) can be blended. With the bio-fuels market anticipated to grow by ~40% in the next 10 yr, blending bio-oxygenates could prove to increase profits. Most of these bio-fuels are well used in Europe and Latin America, so why not invest more in the U.S.?

Case 1. **TABLE 1** shows the downgrading of a CG93 to CBOB A4 by injecting butane and naphtha, generating a profit of $0.92/bbl. In this example, 3.74 vol% of butane is being blended with naphtha on top of CG93 to produce CBOB A4. All specs are met with a profit of almost $1/bbl.

Case 2. **TABLE 2** shows the downgrading of a CG87 to CBOB A4 by injecting butane and naphtha, generating a profit of $3.7/bbl. In this example, 4.56 vol% of butane is being blended with naphtha (light and medium) on top of CG87 to produce CBOB A4. All specs are met with a profit of almost $4/bbl.

Both cases show that blending butane is a lucrative business.

Case 3. **TABLE 3** shows the downgrading of a CG87 to CBOB A4 by injecting butane and naphtha, and bio-ETBE, generating a profit of $ 0.77/bbl. The recipe to make CBOB A4 is shown in **TABLE 3,** using butane, naphtha, CG87 and bio-ETBE. All specs are met with a profit of $0.77/bbl. All the blend component prices are from January 2022.

How butanization works. Typical butanization levels vary from 1%–3%. Adding lower RVP naphtha lowers the CG93

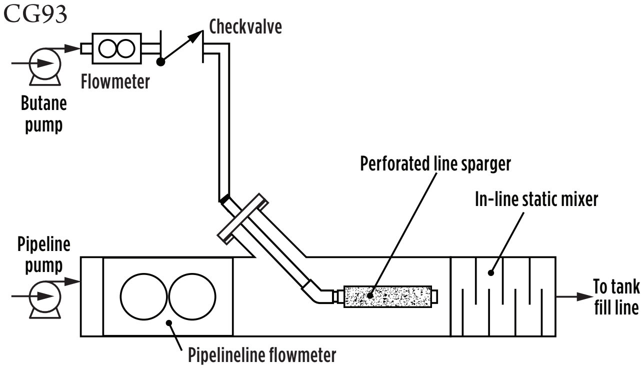

FIG. 1. Inline butane sparging blending.

TABLE 1. Downgrade CG93 to CBOB A4, with a profit of $0.92/bbl

	Recipe		Inventory, bbl			Price
Component	Vol%	bbl	Initial	Final	Remaining	$/bbl
n-Butane	3.74	3,500	0	100,000	96,500	50.51
Natural gasoline	0	0	0	100,000	100,000	76.38
Light naphtha	42.78	40,000	0	100,000	60,000	75.12
Medium naphtha	0	0	0	0	0	75.78
Heavy naphtha	0	0	0	0	0	76.44
MTBE	0	0	0	0	0	62.43
ETBE	0	0	0	0	0	91.34
CG87 reg	0	0	50,000	50,000	50,000	87.03
CG93	53.48	50,000	0	0	-50,000	92.15

RVP, making it possible to add even more butane for a total of 3%–10% additional volume increase over the CG93 volume, depending on the properties of blending butane and naphtha available.

The cheapest and fastest way to implement the butanization scheme is to inject butane into the tank filling line as the product is being pumped into the tank. The disadvantage is that the properties of the gasoline being pumped into the tank are not well known; therefore, the butanization amount will be conservative and not economically optimum.

The next cheapest way to implement the butanization scheme is to sequentially inject butane into the tank filling line after the gasoline product has been pumped into the tank. The advantage here is that a tank sample can be taken and its properties analyzed. This allows the determination of the maximum amount of butane that can be injected without throwing the gasoline product off spec. The disadvantage is that it takes much longer time to sample and analyze the tank, do the butane injection calculations, physically add the butane, circulate the tank to ensure homogeneity, sample the tank again, and ensure it is on spec.

A final option is to implement an inline blender that simultaneously adds butane and naphtha to a stream of pipeline gasoline. By using an online analyzer measuring RVP and potentially other properties, operators can exploit every degree of freedom to maximize the injection of butane and naphtha while maintaining an on-spec blended product. Additionally, the use of an inline static mixer ensures the homogeneity of the blend, reducing or eliminating the time needed to circulate a tank for homogenization. The disadvantage is the higher cost of installation (approximately $500,000–$750,000).

BUTANE AND/OR NAPHTHA BLENDING SCHEMES

Injection of butane and/or naphtha into the tank fill line. Physically, butane and/or naphtha are injected via a specially designed sparger—a pipe with holes drilled in it—that sticks in the middle of the filling line (**FIG. 1**).

TABLE 2. Downgrade CG87 to CBOB A4, with a profit of $3.7/bbl

	Recipe		Inventory, bbl			Price
Component	**Vol%**	**bbl**	**Initial**	**Final**	**Remaining**	**$/bbl**
n-Butane	4.56	4,200	0	100,000	95,800	50.51
Natural gasoline	28.2	0	0	0	0	76.38
Light naphtha	13.02	26,000	0	100,000	74,000	75.12
Medium naphtha	0	12,000	0	100,000	88,000	75.78
Heavy naphtha	0	0	0	100,000	100,000	76.44
Alky	0	0	0	0	0	96.75
Heavy Reforate	0	0	0	0	0	113.05
Isom	0	0	0	0	0	80.74
MTBE	0	0	0	0	0	97
ETBE	0	0	0	0	0	107
CG87 reg	54.23	50,000	0	100,000	50,000	87.03
CG93	0	0	0	0	0	92.15

TABLE 3. Downgrade GC87 to CBOB A4 by using bio-ETBE, with a profit of $0.77/bbl

	Recipe		Inventory, bbl			Price
Component	**Vol%**	**bbl**	**Initial**	**Final**	**Remaining**	**$/bbl**
n-Butane	6.45	6,452	0	100,000	93,547.80	50.51
Natural gasoline	0	0	0	100,000	100,000	76.38
Light naphtha	0	0.01	0	100,000	99,999.99	75.12
Medium naphtha	33.43	33,425.78	0	100,000	66,574.22	75.78
Heavy naphtha	0	0	0	100,000	100,000	76.44
Alky	0	0	0	100,000	100,000	96.75
Heavy Reforate	0	0	0	100,000	100,000	113.05
Isom	0	0	0	100,000	100,000	80.74
MTBE	0	0	0	0	0	97
ETBE	13.09	13,090.03	0	100,000	86,909.97	107
CG87 reg	47.03	47,031.99	0	100,000	52,968.01	87.03
CG93	0	0	0	0	0	92.15

The butane and/or naphtha lines are each provided with check valves to prevent the "flashing" of butane pushing back against the gasoline in the fill line. An inline static mixer (approximately $7,000–$8,000) is also required to ensure blend homogeneity to cut down on circulating the tank (to be determined by testing the degree of homogeneity achieved with and without circulation (4 hr, 8 hr, 16 hr), and then interpolating/extrapolating as needed.

This scheme will produce a pressure drop of approximately 10%, so sufficient pumping capacity must be provided. The quantity of butane injected is measured with a butane flowmeter (turbine or Coriolis- type, at a cost of $5,000–$12,000, depending on type).

A variation of this scheme is to inject butane sequentially using the same scheme, where the amount of butane injected is measured with a butane tank gauge (on the bullet). This saves the cost of a butane flowmeter but prolongs the blending time, and it can require additional homogenization time via circulation.

Injection of butane and/or naphtha directly into the product tank. In this scheme, butane is sequentially injected into the tank filling line after the gasoline product has been pumped into the tank. This means that a tank sample can be taken and its properties analyzed, allowing the determination of the maximum amount of butane that can be injected without throwing the gasoline product off spec. A disadvantage is that it takes much longer to homogenize the tank sample and analyze the tank, calculate the amount of butane to be injected, physically add the butane, circulate the tank to ensure homogeneity, sample the tank again, and ensure it is on spec. This can easily add approximately 24 hr to the cycle from beginning to end to "final" the product tank.

The scheme (shown in **FIG. 2**) determines the amount of injected butane as measured with a butane tank gauge (on the bullet); if not, a butane flowmeter will be required at additional cost.

Although this scheme uses a high-efficiency vortex nozzle mixer, it is not as time-efficient as the first scheme mentioned here with the sparger and static mixer; therefore, additional circulation time must be allocated before taking tank samples. The time can be determined experimentally.

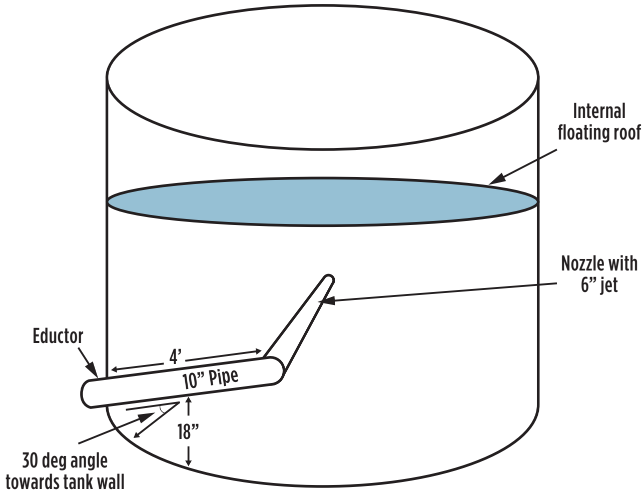

FIG. 2. Sequential butane blending.

Inline blending of butane and/or naphtha into the product tank. This scheme allows for precision blending of the maximum possible amounts of butane and naphtha to maximize gross profit per barrel. The price for this is the additional cost of a skid-mounted inline blender, an online RVP analyzer and blending software. A typical design is shown in **FIG. 3.**

The typical cost of the inline blender with three streams [P/L gasoline, butane and natural gas liquids (NGL)] ranges from $300,000–$700,000 (~$150,000 per meter run, plus $150,000 for an analyzer, plus blending software). Typical performance is within the ASTM precision of measurement (r = 0.2 ON, RVP

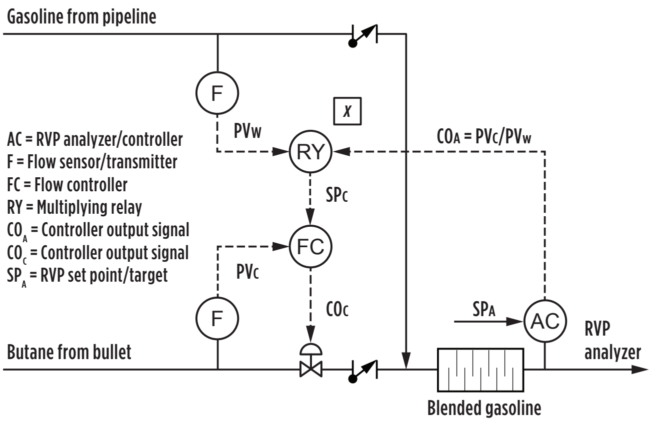

FIG. 3. Inline blending of butane.

TABLE 4. Calculation of butane properties from GC compositional analysis

Sphere 235	GC	From ASTM DS 4B			Calculation per ASTM D2598		
Component	**Vol%**	**RVP**	**RON**	**MON**	**RVP-bbl**	**RON-bbl**	**MON-bbl**
Propane	0.998	188	101.8	97.1	187.624	101.5964	96.9058
I-Butane	8.882	72.6	100.1	97.6	644.8332	899.0882	866.8832
n-Butane	78.345	51.7	93.8	89.6	4,050.44	7,348.76	7,019.71
I-Butene	0.269	63.3	97.4	80.8	17.0277	26.2006	21.7352
I-Pentane	7.066	20.4	92.3	90.3	144.1464	652.1918	638.0598
n-Pentane	2.8	15.6	61.7	62.6	43.68	172.76	175.28
					RVP	RON	MON
Results	**98.36**				**51.73**	**93.44**	**89.66**

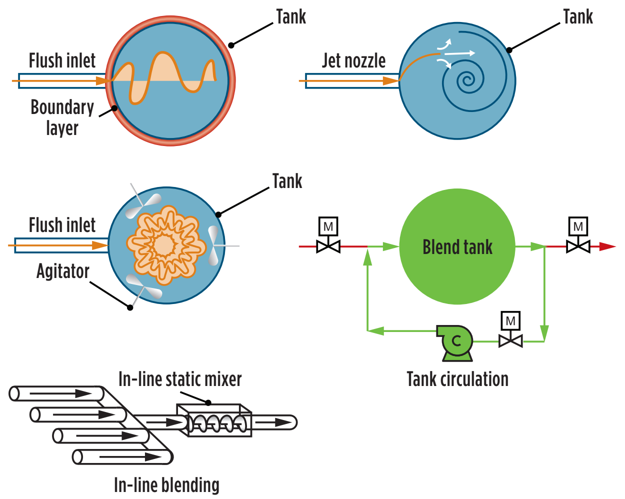

FIG. 4. Tank mixing techniques.

r = 0.16 psi). Because it is prefabricated, it can be installed, started up and commissioned within 2 wk–3 wk after delivery.

OTHER CONSIDERATIONS

Accuracy of gasoline, butane and naphtha properties. The measurement of gasoline and naphtha properties can be done directly by any competent third-party lab. The measurement of butane properties is based on ASTM D2598 gas chromatographic analysis of components, so it is vital to get a representative sample of the blending butane and calculate the properties (see **TABLE 4**). Using chemical handbook properties is not recommended.

Property analyzers. It is highly recommended to acquire table-top RVP and (possibly) multi-property analyzers that also measure research octane number (RON), motor octane number (MON), RVP, specific gravity (SG), etc., and allow quick analysis of samples in minutes, whether tank samples or pipeline samples.

It is equally important to take samples per ASTM D5842 practice to ensure sample integrity. Samples should be taken in ASTM recommended sample bottles and stored in a cold room/refrigerator until ready to use.

Tank homogenization. Many techniques exist for homogenizing the contents of a tank to meet U. S. Environmental Protection Agency (EPA) homogeneity requirements of a maximum 6° API difference between the top third, middle and lower third of the liquid level in a tank (**FIG. 4**). This requires a 95% homogeneity.

Jet nozzle mixing is quite effective, depending on the type of nozzle—the recommended nozzle is an "eductor-type" jet nozzle. An inline blender with a static mixer is highly effective; however, a cheap inline static mixer requires a relatively expensive inline blender.

The use of electric motor-driven "propeller-type" mixers or agitators is quite effective, but this takes a long time compared with the other methods. If not already installed, this is not recommended.

Tank circulation works well but requires additional expenses in the form of two different tank lines (i.e., fill lines, suction line), a pump and manifolding with isolation valves. Achieving 95% homogeneity requires approximately one tank turnover—for example, a 20,000-bbl tank with a 1,000-bph pump capacity will take approximately 20 hr (20,000 bbl/1,000 bph = 20 hr).

Project management. It is easy to fall into a trap of do-it-yourself being less expensive than having a single point of responsibility. Conversely, the extra 10%–15% cost is worth it to ensure the work is accomplished on time and within budget.

The single most crucial factor is the selection of experienced vendors/contractors that are willing to provide performance guarantees against a 10%–15% contract value retention until performance is demonstrated via a site acceptance test (typically a 2-wk duration). HP

ELISEO CURCIO is Principal Consultant at Blend Tiger, a consulting company working in the blending business and financial modeling. He previously worked as Vice President and CFO at Refinery Automation Institute (RAI), where he transformed the business and increased revenue, as well as created a blending training platform that is considered one of the best in the business. Mr. Curcio is an optimization and modeling specialist with more than 10 yr of experience in the areas of gasoline, diesel, crude and bunker blending, ethanol non-linear property correlations and octane boost, and naphtha and butane blending. He collaborates often with traders and brokers developing custom algorithms within refineries and terminals to boost optimization. He previously worked at Catholic University of Louvain (Belgium) in advanced modeling and optimization in the membrane area. Mr. Curcio holds BS and MS degrees in chemical engineering with high honors from the University of Calabria, Italy.