## Introduction

In virtually every industry there are globally established standards, recommendations or best practice guides. They may be established by regulatory authorities or by industry user bodies. IBIA is the obvious organisation to represent the bunker industry and promote best practice in all aspects of bunker fuel management. It is the only user group representing bunkering and this is the latest in the series of IBIA Guides.

The guides are intended to reflect generic practice and to set objective standards; they are not intended to endorse any particular technology or any particular manufacturer or service provider.

The extent to which any operator chooses to implement the guides is a matter for the operator to determine, remaining consistent with good business practice and within the limits permitted by local regulatory authorities. Because shipping and bunker operations are very diverse, IBIA Guides endeavour to provide advice that is as broad based as possible and practicable.

## Objective of this document

To provide impartial technical guidance for IBIA members who are considering the use of in-line blending for the physical supply of bunker fuels. The guidance considers the issues that need review when deciding the most appropriate blending technology to meet the quality certification, operating profit and operational needs of an in-line blending facility and makes recommendations against each consideration. The purpose of this guide is to advise on the technical considerations and factors necessary to achieve the bunkering objectives.

## Background

Most bunker fuel is blended at some time in the process from the distillation unit to the point of delivery. This document considers the use of in-line blending at oil terminals, tank-farms, and on jetties and floating facilities such as barges and tankers. It covers the issues that enable suppliers to deliver a blended product that meets the quality specification (typically ISO8217) and environmental demands of their customers.

Fuels are blended (in tank or in-line) to achieve a number of goals:-

1. To ensure that the bunkers supplied to a customer meets the specification and requirements of the markets and environmental needs.
2. To optimise the cost of producing such a fuel by using the maximum quantity of low cost feedstock that produces a stable, homogeneous and compliant bunker fuel.

In a simple setup producers will blend a range of bunker fuels using a residual heavy, high viscosity component and a distillate or low viscosity component. In more complex scenarios producers can simultaneously blend a large number of fuel types together to meet a particular specification (for example using high and low sulphur residual fuel oil as part of the blend to meet MARPOL requirements).

As the demands for higher specification bunker fuels increase, it is expected the blending of bunkers will become more widespread and adopt more advanced technology, much as has been the case with motor fuel blending globally.

It should be noted that in-line blending does not solve any issues of blend incompatibility. If two blend components are not compatible, they will remain incompatible whether blended in a laboratory, tank or using an in-line blending system. However, unlike in-tank blending, in-line blenders can be configured to use high-shear mixing that closely resembles laboratory mixing. This can avoid incompatibility at the interface of the two products, which could otherwise cause effects such as waxing or asphaltene deposition.

In addition blending does not remove the need for representative sampling and analysis. In-line blending for some operations can represent an extremely cost effective and accurate method of producing high-quality bunker fuel at optimal cost, but any form of blending, in-line or tank is only as good as the quality of the feedstock provided. Whilst an in-line blending system with online analysers can accurately measure and control the batch quality for parameters such as density, viscosity, sulphur, CCAI (calculated carbon aromaticity index) and CII (calculated ignition index), it cannot currently cost effectively measure and control for parameters such as ash, flash point, micro-carbon residue, total sediment, $H_2S$, acid number, stability and most elements (i.e. aluminium, silicon, sodium and vanadium). By using an accurate analysis of the feedstock being blended (from representative samples) some systems can provide a calculated and traceable value for predictable parameters (such as density, temperature, sulphur and some elements) but not non-linear parameters (such as viscosity, flash point etc.). This further supports the need for validatory samples to be taken at the point of blending in order to resolve any quality dispute, should one occur.

It is not intended that this guide will cover the proper management of fuel or correct and representative sampling and analysis procedures to determine blend feedstock quality. These will be covered is subsequent guides and for the purposes of this guide it is assumed these are in accordance with recognised standards or best practice. There is no escaping the maxim: *garbage in = garbage out.*

## Definitions

***Heavy*** – fuel that is the heavier component in a blend typically a residual component(s) with a high density and sometimes viscosity.

***Cutter stock*** – Distillate or low-viscosity hydrocarbon feedstock used in a blend to change the quality, typically viscosity, of the final blended fuel.

***Homogeneous*** - means having the same qualities or properties throughout. For a blend this normally means that from beginning to end of the batch the quality is consistent.

***Feedstock/blend components*** - the components used to produce any blend.

***Fuel Blend Calculation –*** The properties of a blended fuel calculated from the properties of the individual fuel components and the ratio in which they are blended. The properties determined by calculation should be verified by subsequent laboratory analysis of commercial samples collected during bunkering.

***API/IP -*** American Petroleum Institute (API) and Institute of Petroleum (IP); two of the bodies that create the standards covering measurement – (see appendix) .

***Give-away –*** the percentage of additional feedstock (typically high cost) that is included within any blend to ensure the blend exceeds the required blended product specification. In bunker blending this is typically distillate and can have significant impact on the cost of the blend due to the cost differential between the heavy and light feedstock.

***Blend –*** to combine one or more different fuel components so as to produce a fuel, the properties of which are the aggregate properties of the blended fuels.

***Mixing –*** the action of homogenising the different components together to produce a fuel with the same properties throughout. Different products do not naturally mix even when flowing in a pipeline so it may be necessary to actively mix the components using additional energy.

***Ratio control*** – a method of in-line blending where the ratio/flow rate of each feedstock is continuously measured and controlled during the blending operation to ensure an accurate blend ratio within the limits of the accuracy of the measurement and control system.

***Analyser/quality trim control -*** a method of in-line blending where the ratio of each feedstock is continuously measured and adjusted during a blending operation based on the feedback from a parameter measurement (such as viscosity or density). The objective is to continuously optimise the blend to meet the specification, within the limits of the accuracy of the measurement, analyser and control system.

## Blending goals

The goal of bunker blending is to blend two or more feedstock to produce a finished product that meets the following criteria:-

1. Meets the desired specification requirements, typically ISO 8217.
2. Is homogeneous (well mixed) and of consistent quality for the whole batch (i.e. no segregation).
3. Produced at optimal cost.
4. Using the minimum justifiable capital expenditure (CAPEX).

## Types of blending

### In-line blending

In-line blending is defined as the continuous mixing together in real-time of a number of feedstock to produce a homogeneous and consistent product of defined quality. The process can either be fully automated with in-line measurement and control of flow, quality parameters and ratio, or a simple mechanical ratio control system, or a combination of both.

In-line blending has significant advantages when compared with in-tank blending; these are outlined briefly below. It is likely that any reader of this document has already accepted the functional and economic advantages of in-line blending over in-tank blending and is now progressing to the next stage, making a serious assessment of how to select the in-line blender best suited to their application; however, a brief description of in-tank blending helps place in-line blending in context.

### In-tank blending

In-tank blending involves the sequential (or simultaneous) measurement of each of the products to be blended into a blending/storage tank which is then mixed (which may take hours). A manual tank sample is taken and using this, the blended product is analysed for quality. Any required blend adjustments are then made, the blend is re-mixed and, if necessary, re-analysed to confirm quality. The batch is then either stored or dispatched to the delivery point. It is worth noting that for some facilities, the ability to blend, whether in-line or in-tank, may be limited by the range of feed stock available, either locally produced or received as incoming cargo, rather than a lack of available space or infrastructure.

The main drawbacks of in-tank blending are;-

1. Inflexibility – in-tank blending requires ‘spare’ storage capacity for pre-blended stock and significant production pre-planning.

2. Where feedstock quality varies (layering etc.) in-tank blending to a ratio often demands the production of a blend with a margin of error which results in unnecessary ‘give-away’ of expensive feedstock/cutter stock.
3. Blend ratios are based on a theoretical ratio which is not based on specific feedstock; this also results in blends with errors, either resulting in further give-away or, worse, off-specification product.
4. Possibly result in large capital lock-up in pre-blended stock.
5. Requires additional tank infrastructure when compared with in-line blending, for storing the blended product. Alternatively, in an existing facility, storage for blended product released by using in-line blending can be used to store a wider range of cost-saving feedstock.

## Factors/ Considerations When Selecting Blending Technology

Each factor will have an impact upon the capital cost and complexity of the in-line blending equipment as well as the performance and hence return on investment and operational saving. It is recommended that the factors below are carefully considered in light of the operational needs when selecting blending technology for any bunker application. Optimal performance can be achieved; however it is important that this is factored against a consideration of the value that this brings to operations, which is directly linked to throughput.

## Acceptability/amount of ‘give-away

All blending methods result in a ‘give-away’; however, the amount and acceptability of ‘give-away’ will depend on both the cost of the individual feedstock being blending and a combination of the factors below. Consideration needs to be given to the feedstock being used, the current cost of give-away and the potential CAPEX cost of any blender compared with the OPEX savings it provides.

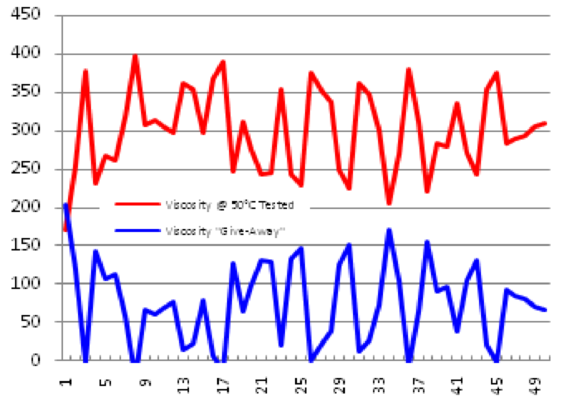


Figure 1 - Viscosity give-away - source Bunkerworld 2009

## Consistency of feedstock (viscosity. density, homogeneity etc.)

The consistency of feedstock is a key consideration when selecting blending technology, configuration and control philosophy. If the feedstock is of consistent quality and homogeneous, then apart from errors in the blend recipe/ratio calculation (see below), a ratio control in-line blender is likely to be suitable for such an application. In this case consideration needs to be given to the accuracy of the flow measurement and control system and the impact this will have on the ratio accuracy of the final blend. However where the feedstock is not consistent or homogeneous, or there is uncertainty about the accuracy of blend recipe calculation then an analyser/quality trim control blender is best suited for the application.

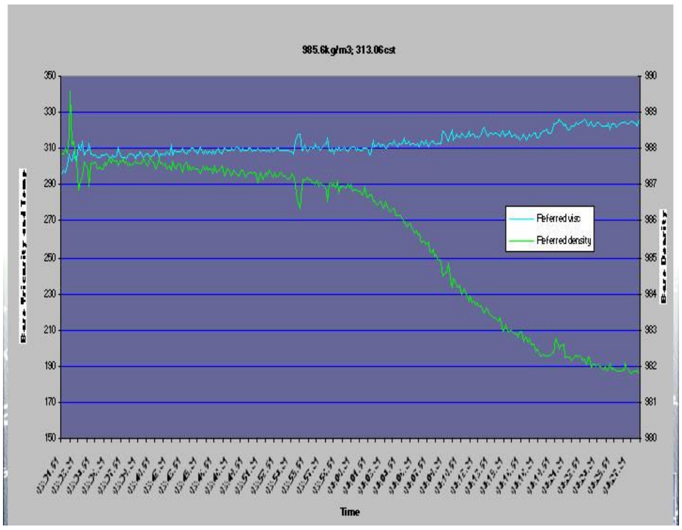


Figure 2 – Layering during tank discharge – source RMI

## Location (tank farm, barge, terminal, jetty etc.)

The precise location of an in-line blender within an installation can have a significant impact on the required configuration and it is important these issues are understood before project implementation. Can the blender be operated at the location, or is it more easily operated from a remote control room? Does the data from the blender need to be transferred to a central data system? What level of operator intervention is required? What are the alarms and safety systems in the event of system failure? How is the volume between the blender and point of loading managed?

Another point that will affect the cost and configuration of an in-line blender is the installation's 'area classification'. If the equipment is to be installed within a 'hazardous area' the electrical components and cabling etc. will all need to be certified to the appropriate zone rating.

## Blender flow meters – types and suitability

Flow measurement, either for the individual streams and/or the final blended product, can have a significant impact on the blend accuracy and control as well as the flexibility of a blender. A flow meter at the outlet of an in-line blender provides an accurate 'totalised' measurement for the delivered batch; however, this does not provide a measure of the individual feedstock flow rates.

Figure 3 - Barge mounted in-line blender – Source Jiskoot

Using a flow meter in every stream being blended provides an accurate and real-time volumetric measurement of each feedstock flow rate and an appropriate control system can use this to continuously correct the blend ratio/volume.

Mechanical in-line blenders use an alternative technique. They do not use discrete flow meters with electronic outputs, but use an 'inferred flow measurement' (usually differential pressure) which drives the mechanical control of the blend ratio.

For both systems the blend ratio is set on the basis of product specifications and/or analysis of the components to be blended.

Whether flow measurement is 'inferred' or made directly using a flow meter it is important to quantify any measurement errors and the effect that these may have on blend quality.

Figure 4 - barge mounted blender with PD flow meters – Source CBI

As the feedstock is almost always at different temperatures, flow measurement must be referenced to standard conditions (common pressure and temperature) to ensure accuracy of blend control, ratio or batch measurement as appropriate. In addition it is important to consider the pressure-drop, accuracy, linearity and repeatability of any flow meter used, not just at the maximum operating range, but at all blend ratios and of the start-up and shut down rates of the blender to ensure accurate control of the batch.

An important point to consider is that of entrained air and the effect that it may have on the flow meter technology, the accuracy of measurement and hence the performance of the in-line blender. It is expected that bunker fuel measurement will be the subject of a future IBIA guide.

## On-line analyser accuracy

On-line analysers can be used as part of an in-line blender to dynamically measure and control parameters such as viscosity, density and sulphur; these are the parameters most commonly utilised for fuel oil blending but others can be specified. An absolute requirement to ensure successful deployment of on-line analysers is the accurate measurement of the analysed property. To achieve this, the measuring device must be installed in a stable and representative environment. Care needs to be taken that the accuracy stated for the blender performance is understood. Accuracy of 'measured value' or 'calibrated range' is very different and has a significant impact on performance and hence cost optimisation.

**Figure 5 – Typical insertion on-line viscosity analyser – Source Emerson**

## Blender feedback control systems

Feedback control systems fall into two main categories:

- Single-term control (proportional only) systems – These can be electronic (using flow meters, control valves (or pump control) and a simple controller) or mechanical (using the differential pressure generated by the flow through a blender to maintain a ratio set manually). The instantaneous blend ratio is controlled but the system does not store or correct for any errors from the time they were identified (and correction started) until the ratio was corrected. As a result errors, that would need to be determined, will exist in the final blend ratio for both types of single-term control systems. The level of error will be based on the response time of the control, flow measurement and analyser (if fitted) systems combined with the amount of time the blend was 'off-spec' before the control system corrected the ratio.

- Three-term control PID (proportional, integral and differential) systems – The control system is electronic and uses closed-loop control between flow meters, control valves (or pump control), analysers (where fitted) and a suitable control system. The analyser input (where fitted) and real-time accumulated flow measurement of the individual streams in the blender are used to continuously adjust the ratio to meet specification. With three-term PID control; blend errors are 'stored' and corrected continuously during the batch. Three-term PID also provides control 'damping' so that the correct specification is achieved with the minimal delay and no risk of blender 'oscillation' during operation.

In addition, with any type of control system it is important to determine if any errors in temperature/volume correction are being applied to the total blend or component ratios. As each of the streams being blended is likely to be at a different operating temperature it is important to confirm how, and if, any temperature/volume correction is applied to the blend otherwise this can introduce errors that need to be determined.

When choosing the most appropriate control system for any application it is important to assess the cost of the equipment compared with any additional value or savings that each type of system might contribute to operating costs.

## Viscosity measurement and control to reference conditions

One of the primary measures of bunker fuel is viscosity at 50°c. However, bunker fuel is often not blended at 50°c; therefore, to be able to accurately determine the viscosity at reference conditions, stable measurement is required as well as an accurate method to 'refer' the measurement to reference conditions (50°c). Consideration should be given to the accuracy of the viscosity measurement (both at process and reference conditions) as well as considering the accuracy of the viscosity calibration curves used for the referral to reference conditions (normally ASTM D341).

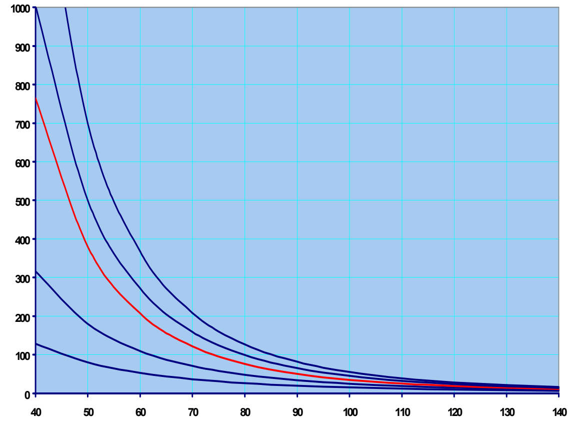


Figure 6 - Heavy fuel oil viscosity/temp index curves

## API/IP temperature volume correction

Temperature volume correction is required to ensure accurate volumetric delivery of blended product (at reference conditions) and that the volumetric ratio of each stream is at the same conditions to ensure the correct blend ratio and hence reduce give-away to the minimum. The standards normally used for this are API2540 and IP200.

## Certification requirement and ability to certify blender performance

Certification is important for a number of reasons:

1. Ensuring that the blender can produce any required documentation to verify the quality and quantity of the blended batch.
2. Ensuring that the blender and its equipment are certified to any required measurement standards.
3. Certification of the blender performance to meet the specification and operational requirements.

## Pressure-drop, throughput and range of recipes

Bunker delivery and loading rates can be key to maximise batch turn-around/throughput. Any incremental pressure-drop in pipe-work, loading arms or blending configuration can have a significant impact on operations and may require additional pumps. Pressure-drop is directly related to the square of flow rate and therefore careful consideration should be given to the pressure drop that any blending solution creates at all ratios and flow rates and the impact that this has on operations.

## Mixing to ensure homogeneity and analyser representivity

Batch homogeneity is a requirement of bunker fuel and to mix a blend requires energy. Mixing energy can be provided either by turbulence and pressure drop or can be mechanically added to the flow. Both methods are acceptable provided the impact of any resulting pressure-loss on operations is understood. The blending system should be capable of delivering a fuel that is fully mixed so that additional mixing is not required. Some possible mechanisms include:

*In-line blending*

- Jet mixing - a pump extracts and re-injects part of the flow to create high-shear mixing.
- Static mixing - multiple elements in the flow generate disturbance which may cause mixing.
- Pipeline components may create mixing disturbance, however this is not generally predictable.

*In-tank blending*

- Tank mixers – One or multiple motor driven impeller(s) in the tank.
- Re-circulation mixing – a pump re-circulates the tank contents, sometimes with an eductor.

Due to the high viscosities generally involved in bunker fuel blending it is not normally considered good practice to use air for mixing as this can cause entrained air bubbles which can create errors in delivered volume, measurement and handling.

The homogeneity of the blend is also of vital importance to the performance of any analyser so consideration needs to be given to mixing in relation to the installation location and stability of the analyser. Any analyser, such as a viscometer, will only provide measurements as representative as the fluids they are measuring, the refresh rate of the fluids and the location of the analyser in the system. Any error in analyser measurement caused by non-optimal installation or the effects of process variations will be directly reflected in the accuracy, quality, and hence cost, of the final blend.

**Figure 7 – Typical flow-through on-line viscosity analyser – Source Lemis**

## CAPEX of blending system

CAPEX is always an important consideration when acquiring any piece of equipment in a plant; however, it is usually not difficult to demonstrate the return on investment for an in-line blender by reference to the incremental revenue increase/cost reduction in terms of give-away such a system facilitates.

## Standard design – v – custom built

Blenders are available both to standard and custom designs. The benefits of a custom built blender are that it will be built specifically to cater for an application and range of feedstock/recipes enabling the blender and component performance to be optimised for that application. The incremental costs and longer delivery period of a custom built system are, for most applications, offset by the additional operating cost savings they deliver.

## Operational simplicity

Operational simplicity, ease of maintenance and suitability for installation location are all important criteria. Possibly of paramount importance is the simplicity with which operators are able to select batches, initiate operation, diagnose problems and ensure the correct documentation is produced by the blending system.

## Fuel blend calculations

Any form of blending on-demand directly to delivery may not permit the blend properties to be reported at the time of bunkering from a laboratory analysis of samples. Quality is therefore reported based on a combination of any parameters measured during the blend and a fuel blend calculation. This method is widely used in process plants and the calculation reports the various calculable properties of the blend based on the properties of the individual components and the ratio in which they are blended. It is essential to the accurate calculation of blend properties that all feedstock is homogeneous for the properties reported and that the feedstock analysis is representative.

On-line and subsequent laboratory sample measurements can be compared to the blend calculation results as a means of assurance that the calculation results are representative and reliable. Ideally the properties should be calculated using a recognised fuel blend calculator. Those from Shell, DNVPS and similar may be considered suitable. Where operations are registered and licensed by PSAs, the PSA may approve or suggest suitable blend calculators. Fuel quality should always be verified by commercial sample analysis and any unreasonable differences investigated for cause.

### Sampling for blended batches

Consideration needs to be given to the requirement to take either automatic or manual (drip) samples to verify the quality of the batch blended. Whilst both manual and automatic sampling are allowed under MARPOL Annex VI, automatic sampling is generally recognised as being of higher accuracy; however, consideration needs to be given to the location of the sampler, as a blender is unlikely to be installed at the receiving ship's manifold, which may be the preferred location for sampling.

Figure 8 – Automatic MARPOL sampler

## Performance testing/specification of in-line blending systems

When specifying any blending package it is important to pay attention to the business drivers behind the investment. Consideration should be given to whether this should be included in the specification and site acceptance testing for the blender. A concise, detailed and well written specification and a clear performance guarantee are the only way to ensure that an in-line blender delivers the required performance and return on investment. If for example the investment is justified upon the anticipated incremental saving made by achieving a certain level of final blend accuracy this should be included in the specification and acceptance criteria. It is also important when specifying the equipment and scope of a blender package that consideration is given to the up and downstream piping and process requirements, pressure drop, method of operation and other similarly crucial issues to ensure the system delivers the optimal return on investment. Finally it is extremely important that any prospective supplier of blending equipment is validated to determine their track-record and performance.

## References

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http://www.cbi.dk/blending.html

http://www.viscoanalyser.com

ISO 8217 – 2005 and 2010

ISO 3171

ISO 3170

API MPMS Chapter 5

MARPOL Annex VI

Process Measurement and Analysis – B G Liptak