Guidance on Empirical Analysis

This guide is intended for:

- Service agents acting under the auspices of their local regulatory authority, who are calibrating or placing meters into service with multiple linearization factors;
- Regulatory officials who witness the calibration or placing-in-service of meters with multiple linearization factors;
- Regulatory officials and service agents who are verifying the accuracy of meters with multiple linearization factors.

In theory, any properly performing meter system should be able to be calibrated with one calibration setting and remain in tolerance at any flow rate for one product, or group of similar products. Meter systems with mechanical calibrators operate in this manner. They have one calibration setting and are limited to dispensing only one product or one group of similar products. Accuracy is typically optimized at the normal flow rate for the most frequently dispensed product. This usually means there are slight errors at other flow rates, and for other products. These errors should be of no concern to the regulatory official if they are within applicable tolerances, but the device owner may wish to reduce these inaccuracies.

Modern meter registration technology allows accuracy to be optimized for multiple products at multiple flow rates through the use of linearization factors. Establishing, maintaining, and verifying these linearization factors can be time-consuming, however, because meter performance can be affected by system configurations. Differences in product density and viscosity can affect meter performance. Differences in storage tank size, location and plumbing configurations upstream of the meter may also affect meter technologies sensitive to flow profile configurations.

Device owners must weigh the benefits of optimization against the time commitment necessary to establish and maintain multiple linearization factors. It is the device owner's prerogative to determine whether each meter will be programmed with multiple flow rates and factors for each product, or with just one factor regardless of flow rate and product. If a meter is configured with only one linearization factor, it should be calibrated and verified exactly like a meter with a mechanical calibrator and register.

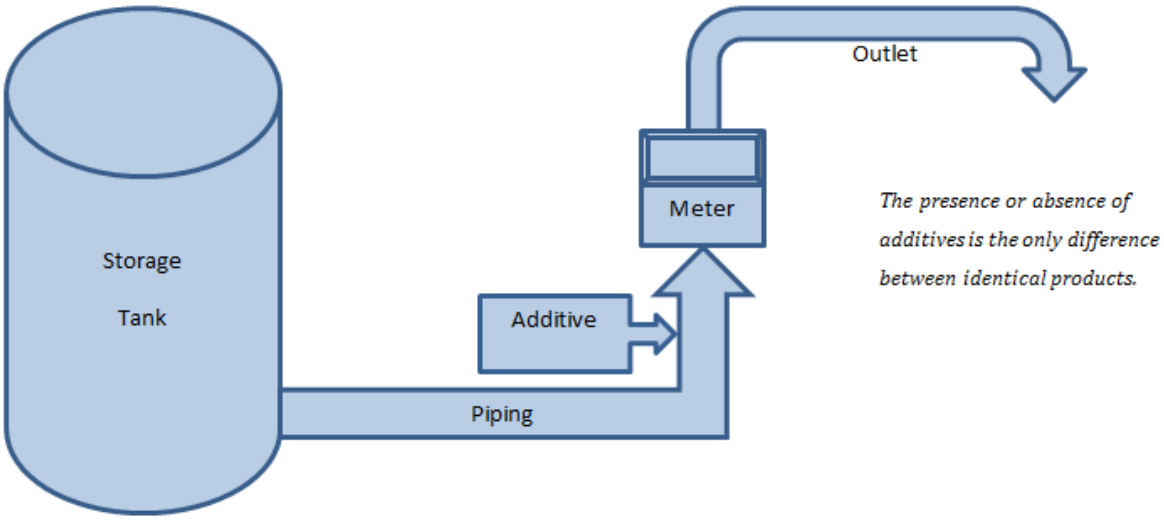
Meters with multiple linearization factors must initially be physically tested on each non-identical product at each configured flow rate in order to characterize the system and to determine the appropriate linearization factors. Using this initial data, regulatory officials can then determine which products can be treated as if they were identical and which as similar or discreet. The regulatory official may then also decide if and when empirical analysis may be used in conjunction with physical testing to reduce the time burden on subsequent calibrations and verifications.

The purpose of this guidance is to aid regulatory officials (and service agents acting under the auspices of their local regulatory authorities) in determining how and when empirical analysis can be properly utilized.

Initial Testing - Identical vs Similar vs Discreet Products

Products are considered identical when:

- The base product is the same; and
- The base product flows from the same storage tank; and
- The base product uses the same piping; and
- Any differences are due only to the injection of octane enhancer or corrosion inhibiters, dye, or similar additives that do not significantly change the product's properties.



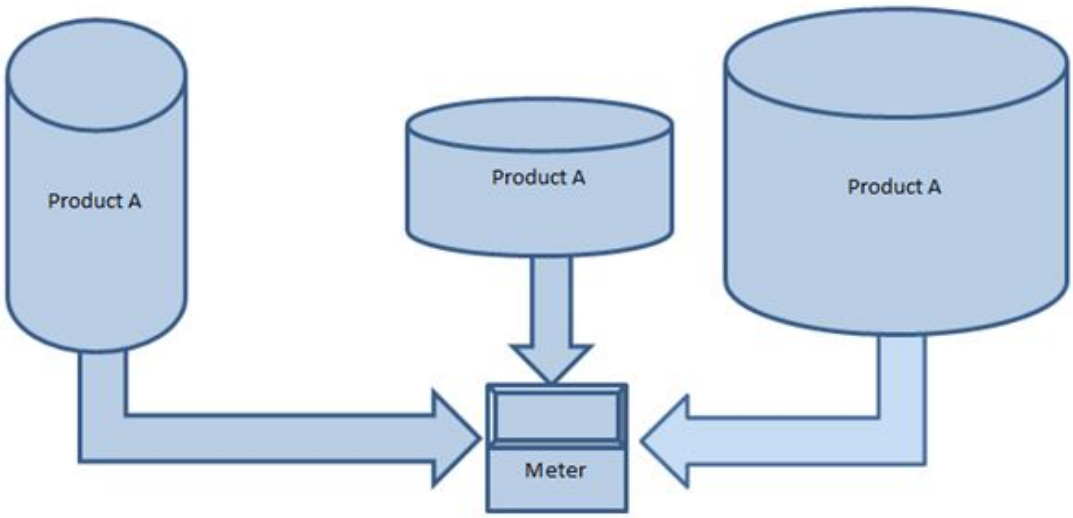
Identical products should be configured identically. Flow rates, and linearization factors at each flow rate, should be identical. Initially, only one product in a group of identical products needs to be physically tested, but it should be tested at all flow rates for which the meter is configured. On subsequent verifications, some of the flow rates may be verified empirically at the discretion of the regulatory official.

Consider, for example, a terminal meter which delivers taxed (clear) and untaxed (dyed) #2 diesel, drawn from the same tank, and delivered through the same piping. The red dye for the untaxed diesel is injected at the rack and there are no other differences between the products other than the dye. The meter is configured with the same slow flow rate, high flow rate, and intermediate flow rate for both products. It would be appropriate to physically test only the clear diesel on initial at all three flow rates. The linearization factors for the dyed product should be the same as the linearization factors of the clear product. If any adjustments were made to the clear product's linearization factors, the same adjustments should be made to the dyed products factors.

At future inspections, the regulatory official may decide that the clear diesel will be physically tested at high and low flow rate rates, and its linearization factor will be empirically verified at the intermediate flow rate. The dyed diesel will always be empirically compared to the clear diesel, and its linearization factors will always match those of the clear.

Products are considered similar when:

- They are the same grade of product but flow from different storage tanks; or
- They are the same grade of product but they reach the meter through different piping; or
- They are different products listed in the same Product Family on the meter's NTEP Certificate of Conformance, and they differ by –
    - No more than 10% in viscosity (for positive displacement, turbine and similar meters); or
    - No more than 10% in specific gravity (for mass flow meters).



The size and shape of storage tanks, the strength of different pumps, and the length and configuration of the plumbing, can affect the performance of some meters. Initial testing is needed to determine if the same product coming from different tanks can be considered to be similar, or if the product in each tank must be treated as if it was discreet.

Initial physical testing of the meter should be done with all non-identical products at all flow rates. The official with regulatory authority will use the initial test data to determine whether similar products can be treated as if they were identical on subsequent verifications and calibrations.

Initial data may show that the meter performs as if some products were identical. For example, different batches of gasoline with the same octane but drawn from different tanks may have identical linearization factors at every speed. Such products can be treated as if they are identical. [Note: Some meter technologies are sensitive to upstream flow dynamics caused by environmental factors like pump

horse power, tank shape and size, or plumbing configurations. Do not assume that the meter will perform identically with product of the same grade from different tanks. Verify through physical testing before making that determination.] Similar products which can be treated as if they were identical should be configured with the same flow rates and identical factors at each flow rate. Only one product in the group needs to undergo physical testing on subsequent verifications. Any adjustments made to the product being physically tested should be made to the other products in the group.

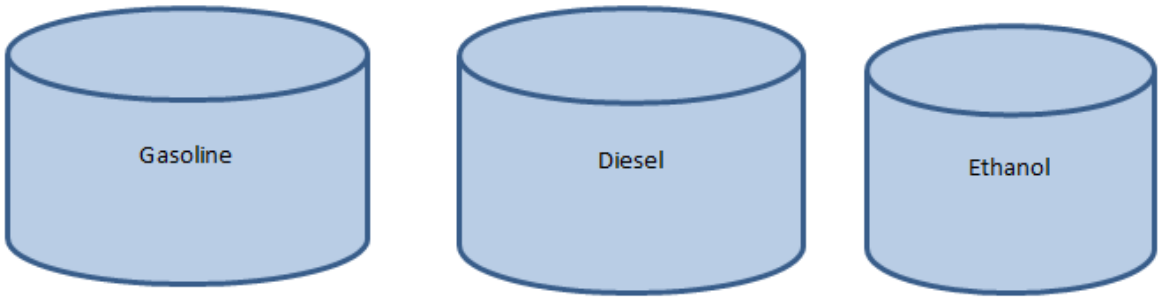
Initial testing may show that some products have optimal linearization factors which are not the same, but which are so close that the products can be treated as if they were identical. For example, consider a terminal meter which delivers sub-grade, mid-grade, and premium gasoline. Initial physical testing shows that the maximum difference between their optimal linearization factors at any flow rate is less than 0.05%. (One quarter of acceptance tolerance)

If the owner prefers to save time on subsequent verifications, the regulatory official would be justified in allowing the high and low factors to be averaged for every speed, and those factors to be input for all three products. These products could be treated as if they were identical on subsequent verifications. Only the intermediate product in the group would need to undergo physical testing on subsequent verifications. Any adjustments made to the product being physically tested should be made to the other products in the group.

If, however, the owner prefers to optimize accuracy and accepts that more physical testing will be required, each product can utilize its optimal linearization factor at each flow rate. The regulatory official must then determine if physical testing will be required for all products at all flow rates, or some combination of physical and empirical testing will be allowed.

Products are considered discreet when:

- They meet the criteria of similar products except that their optimal linearization factors differ from those of other products so much that they could not utilize the same factor as another product and still be in tolerance; or
- They are listed in the different Product Families on the meter's NTEP Certificate of Conformance; or
- They are different products listed in the same Product Family on the meter's NTEP Certificate of Conformance, and they differ by –
    - More than 10% in viscosity (for positive displacement, turbine and similar meters); or
    - More than 10% in specific gravity (for mass flow meters).



Discreet products are from different product families as listed on the NTEP certificate, are from the same product family but they differ by more than 10% in viscosity or specific gravity, or are similar but initial testing has determined that they cannot use the same linearization factors and still be in tolerance.

An example of a discreet product would be ethanol dispensed through a meter that is also configured to dispense various grades of gasoline. Discreet products must always be physically tested at all speeds initially. Regulatory officials may decide to allow empirical analysis on some speeds during subsequent verifications.

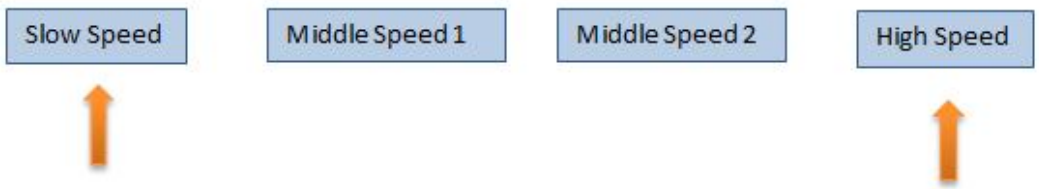
Empirical Analysis

Based on data analysis of the initial testing, the official with regulatory authority will determine if and when empirical analysis can be used on subsequent tests.

Acceptable Methods of Empirical Analysis

1. Evaluation between linearization factors on the same product.

   A product with unique linearization factors at different flow rates should not have linearization factors which are significantly different from adjacent factors. The regulatory official does not have to conduct physical testing at every flow rate, but should test the high and low flow rates at a minimum. The official can review the factors for flow rates which were not tested. Most meters have calibration curves which are roughly (not exactly) linear, so any factor which stands out as abnormally high or low should be physically verified.

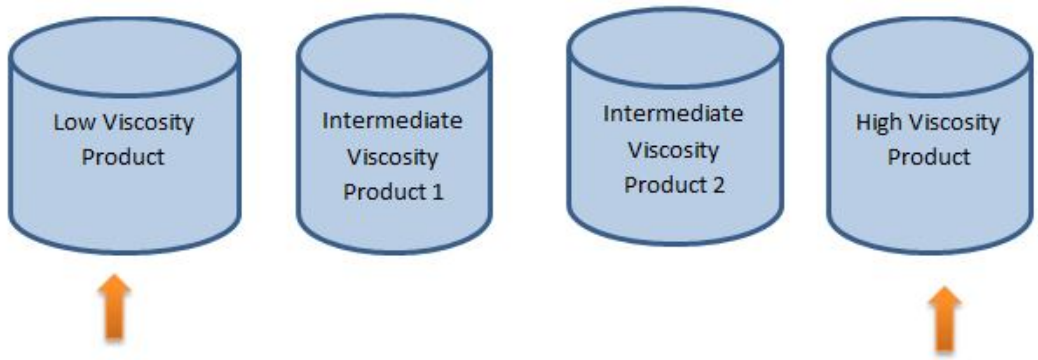


Test the slow speed first, and then the high speed. The factors for the middle speeds should be between the high and low speed factors. The factors should be roughly linear.

2. Evaluation between linearization factors on a group of similar products.

   If a group of similar products all have the same linearization factors, testing the highest and lowest viscosity products should be enough to determine whether the intermediate viscosity products will be in tolerance or not.

   If the similar products have different factors, test the high and low viscosity products. The linearization factors of the intermediate products should fall between the linearization factors for the two extreme products in a progression that mirrors the relation to the viscosities of the high/low viscosity products.



Test the highest and lowest viscosity products, and then evaluate the linearization factors of the intermediate products. All products should have the same linearization factors at every configured speed, or the intermediate products should have factors which fall between the factors of the high and low viscosity products.