

Inline Beer Monitor: Alcohol, Real and Original Extract Determination in the Brewing Process using Density/Sound Velocity Measurement

1 Introduction

After fermentation, beer consists of three components: alcohol, extract and water. In order to determine the concentration of all these components, two suitable, physically independent properties of the beer have to be measured. Several methods can be applied to determine the exact composition, i.e. combinations of refraction and density, sound velocity and refractive index or sound velocity and density measurement.

This report describes one of the most accurate and powerful methods for alcohol, real and original extract determination.

The new DSRn 427S density/sound velocity transducer with stainless steel housing combines density, sound velocity and temperature measurements in one compact unit. It meets the highest demands for accuracy and reliability required for optimum measurement of the alcohol content, real and original extract concentration (Fig 1).



Fig. 1 DSRn 427S density/sound velocity transducer with stainless steel housing

2 Measuring principle

The DSRn 427S density/sound velocity transducer consists of a U-tube density meter with an integrated sound velocity sensor (Fig. 2).

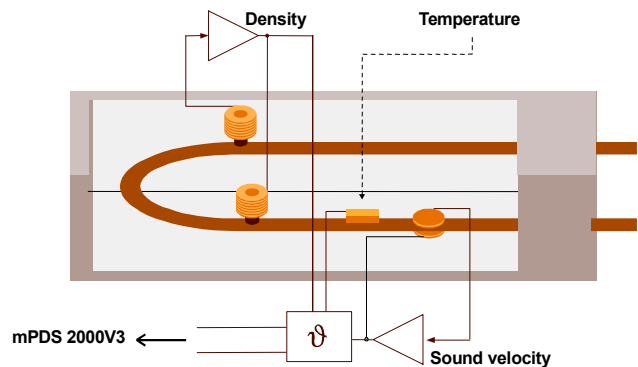


Fig. 2 DSRn 427S density/sound velocity transducer

The density of the beer is determined by measuring the period of oscillation of the oscillating U-tube.

The sound velocity is measured over a fixed distance between a transmitter generating ultrasonic pulses, and a receiver. The propagation speed is determined with a repeatability of 0.01 m/s.

Both the density of the sample and the propagation speed through the sample change with temperature. Therefore, it is necessary to make a high-precision temperature measurement directly at the U-tube.

3 The beer diagram

With increasing alcohol concentrations the density decreases but the sound velocity increases (Fig. 3).

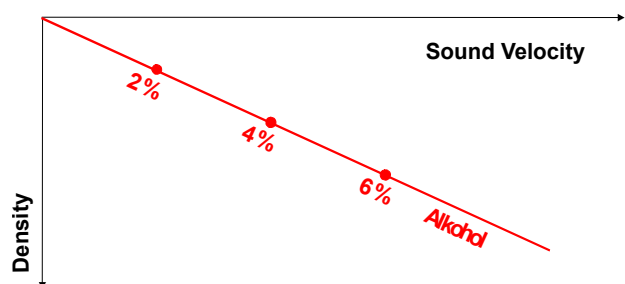


Fig. 3: Alcohol line



Process Application Note

On the other hand, increasing sugar concentration increases both density and sound velocity. Since beer extract is not a sugar solution but a mixture of various substances, the extract line will not exactly coincide with the sugar line (Fig. 4).

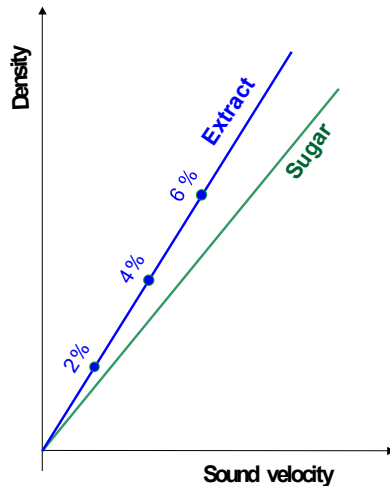


Fig. 4: Extract line and sugar line

Combining alcohol and extract lines in a system of coordinates yields a plane between the alcohol and extract lines that covers all alcohol/extract/water mixtures (Fig. 5).

High selectivity and sensitivity are given by the almost perfect 90° angle between the extract and alcohol line. This is unique in comparison to all other methods (like density/refractive index or refractive index/sound velocity). The combination of density and sound velocity measurements enables a particularly accurate determination of alcohol and extract.

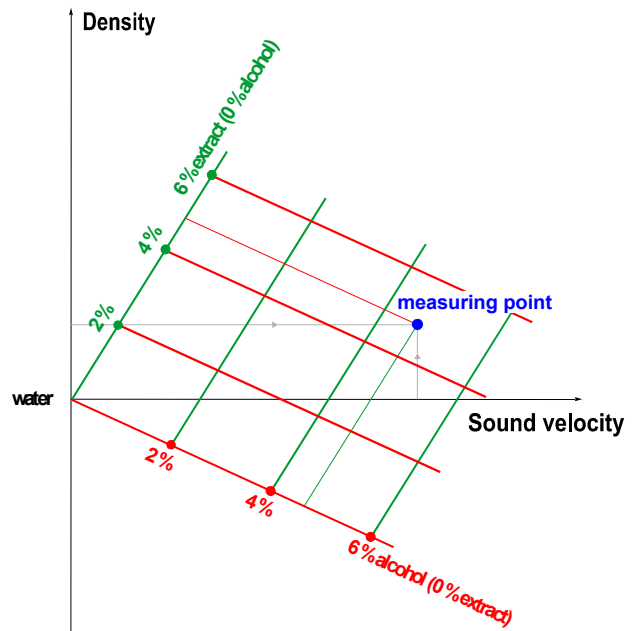


Fig. 5: Diagram for beer analysis

The software automatically calculates alcohol, real and original extract content from density, sound velocity and temperature using a set of polynomial formulas. The formulas are valid for the entire concentration range of current beers.

4 Example of a typical installation

The basic instrumentation for an Inline Beer Monitor consists of the DSRn 427S density/sound velocity transducer with integrated Inline Pump or Inline Adapter and an mPDS 2000V3 evaluation unit (Fig. 6).

An optional Profibus DP Adapter allows you to connect the evaluation unit mPDS 2000V3 to any process computer or PLC via Profibus DP.

For optimum system performance it is recommended to add an inline CO₂ analyzer. The CARBO Inline measures the CO₂ content and eliminates the CO₂ influence on the density and sound velocity measurements. At the same time it can be used to control the carbonization.

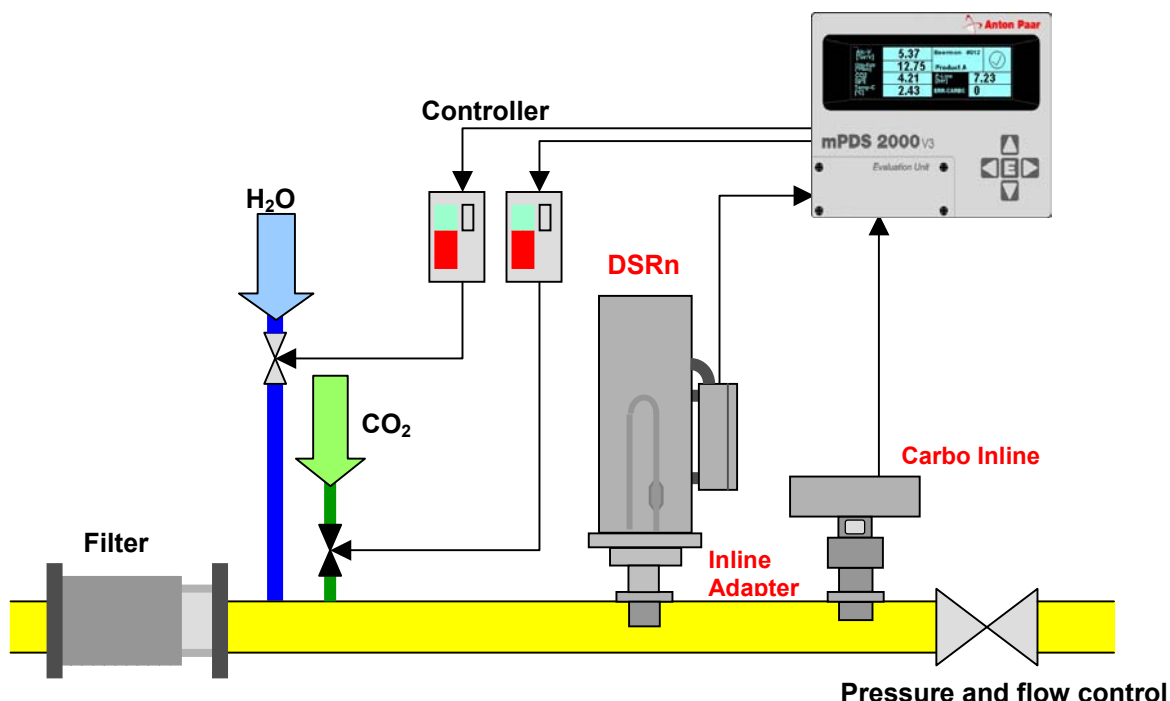


Fig. 6 : DSRn 427S/Carbo Inline/mPDS 2000V3 In-line Beer Monitor

5 Measuring range

Alcohol content	0 to 12 % v/v
Real extract	0 to 8 °Plato
Original extract	0 to 25 °Plato

Alcohol content	±0.02 % v/v
Real extract	±0.02 °Plato
Original extract	±0.04 °Plato

6. Accuracy of the density/sound velocity method

To achieve the highest accuracy it is necessary to compare each beer type to the laboratory reference method and, if necessary, make adjustments during instrument start-up. A maximum of 255 different types of beer can be selected within the mPDS 2000V3.

After the product-specific adjustment, the accuracy of alcohol and extract values depends on the accuracy of the transducer and on the stability of a number of process and sample parameters.

- Accuracy of density/sound velocity measurement**

With reference to the transducers' reproducibility and their different effects on alcohol/extract values, the following accuracy is yielded:

- CO₂ influence**

If not compensated by means of a CO₂ analyzer, fluctuations in the CO₂ content of ±0.5 g/l will cause variations of:

Alcohol content	±0.03 % v/v
Real extract	±0.03 °Plato
Original extract	±0.07 °Plato

An average CO₂ content is corrected by the measuring system. The remaining fluctuations still cause an error, which is not negligible.

Accuracy (sum all influences) without Carbo Inline transducer:

Alcohol content	±0.04 % v/v
Real extract	±0.04 °Plato
Original extract	±0.08 °Plato

Process Application Note

Installing a CARBO Inline leads to a considerable reduction of the error:

Alcohol content	± 0.02 % v/v
Real extract	± 0.02 °Plato
Original extract	± 0.04 °Plato

7 Installation sites

• After the beer filter

The Inline Beer Monitor can determine the original extract content and alcohol content of the beer after the beer filter.

This measurement is used for

- continuously monitoring beer quality
- controlling beer dilution (high gravity blending)
- separating first and last runnings for recovery
- switching from drain to recovery tank and from recovery tank to pressure tank

• Before the filler

The Inline Beer Monitor can determine the original extract content and alcohol content before the filler.

This measurement is used for

- continuously monitoring beer quality
- separating first and last runnings
- separating different beer types

• At discharge bays for tank trucks

To optimize line performance, beer is often transported by truck from the brewing location to a filling plant, where beer is pumped into storage tanks. Measuring alcohol, original extract, CO₂ and oxygen at discharge is critical for the acceptance of goods.

8 DSRn 427S Inline Installation

The new transducer with stainless steel housing can be installed in a bypass or directly in the main line, using an Inline Pump or Inline Adapter. Both Inline Pump and Inline Adapter can be connected to the transducer, forming a compact unit.

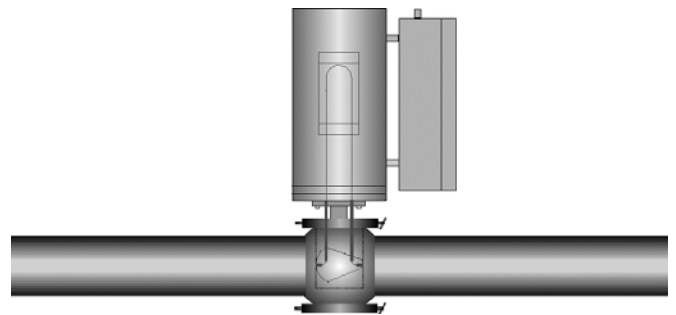


Fig. 7 Installation with Inline Adapter (top view)

The Inline Adapter is immersed in the main line so that the liquid is forced to flow through the connected transducer. The flow speed in the main line must be at least 1 m/s (Fig 7).

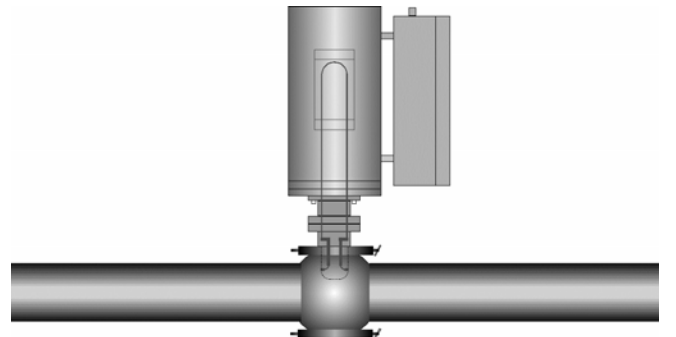


Fig. 8 Installation with Inline Pump

Using the Inline Pump the measurement is independent of the flow speed in the main line. It can also be used for flow-stop conditions. The Inline Pump is a hermetically sealed radial pump, built into a compact housing. The speed can be set, allowing adaptation to different samples (Fig 8).



9 Summary

The well-proven density/sound velocity method provides a highly accurate measurement of the alcohol, real and original extract content. The main constituents alcohol/water and extract/water are mathematically separated and the concentration values are determined.

The influence of variations of temperature, pressure and degree of fermentation on the measured results are well compensated. Variations in dissolved CO₂ content cause the most significant reduction in accuracy of the measurement. Therefore, the CO₂ content of the beer should preferably be measured with an Inline CO₂ analyzer and can thus be compensated as well.

The Inline Beer Monitor can even be used for the measurement of "non-alcoholic" beers.

10 References

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