KROHNE

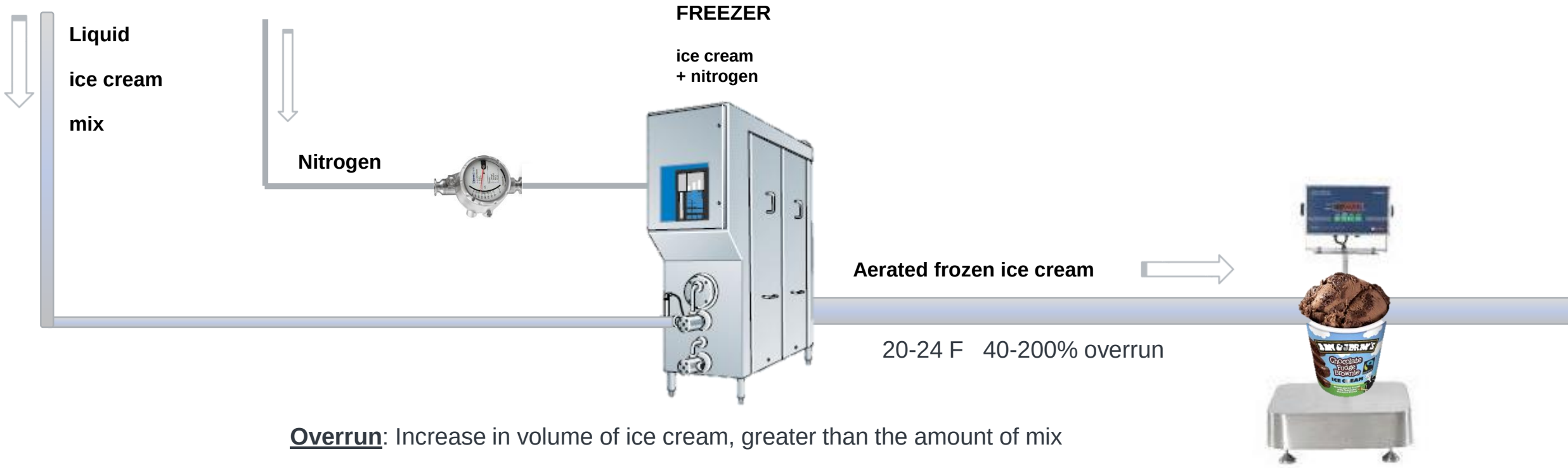
achieve more

IDFA
ice cream conference
04-2019

In-line ice cream overrun measurement

Process instrumentation and measurement solutions for the food industry

Overrun measurement



Overrun: Increase in volume of ice cream, greater than the amount of mix

For a **100% overrun**, **1 gal of mix** makes **2 gal of ice cream**

Maintain a constant overrun for:

- **Volume of production**
- **Texture**
- **Stabilisation**

Startup process

Warm up process ½ h to 1 h
- Stabilize in temperature
- Get the expected overrun

Liquid

ice cream

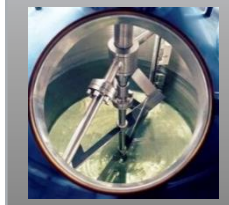
mix

Nitrogen

FREEZER

ice cream
+ nitrogen

Mixing tank with rework and fresh ice cream mix



Reworked and fresh liquid ice cream mix

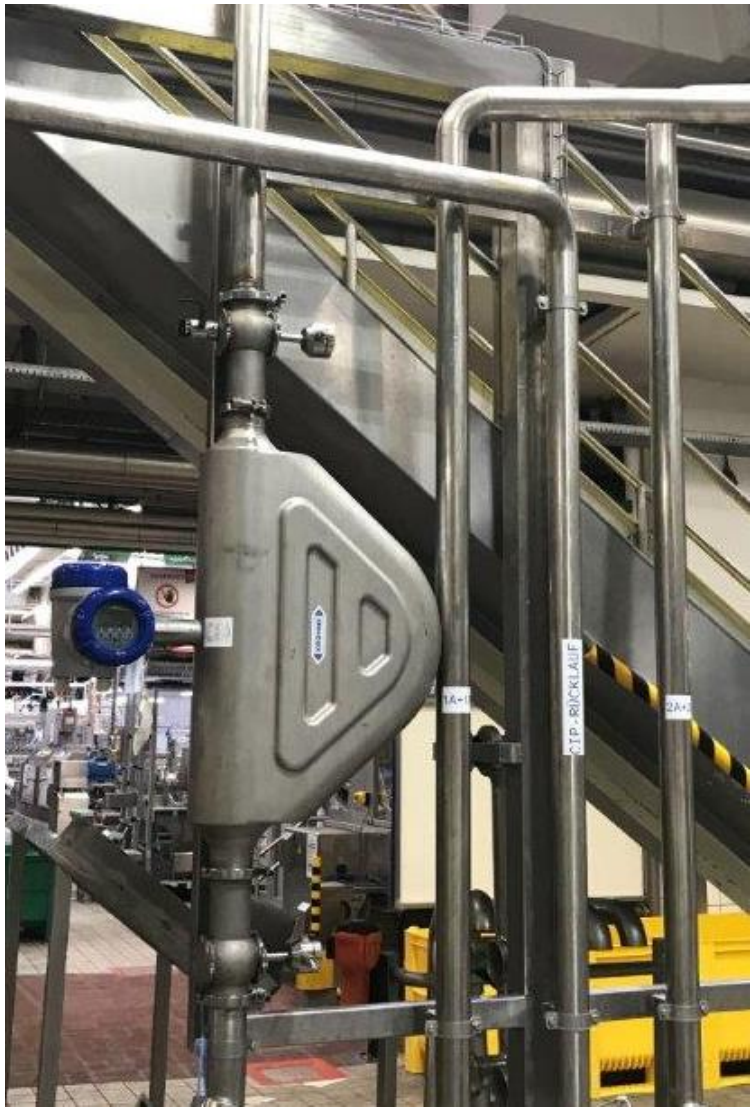
0-20% Overrun

Aerated frozen ice cream

Rework, aerated frozen ice cream

Solution proposed by Krohne

- Perform an in-line density measurement using a Coriolis flow meter on the frozen ice cream
- Combine it with a temperature and a pressure measurements
- Correlate these three measurements with the ice cream overrun



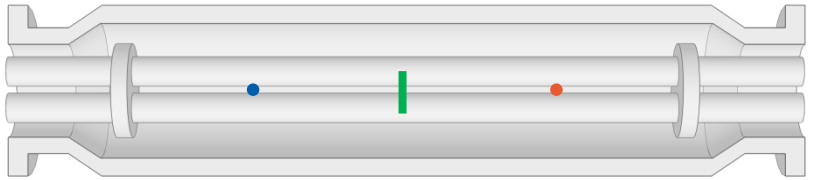
Benefits:

- Faster start-up
- Less waste or rework ice cream
- More consistent product

Coriolis measurement

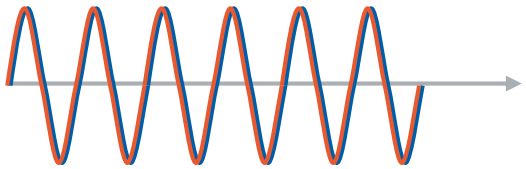
Principle

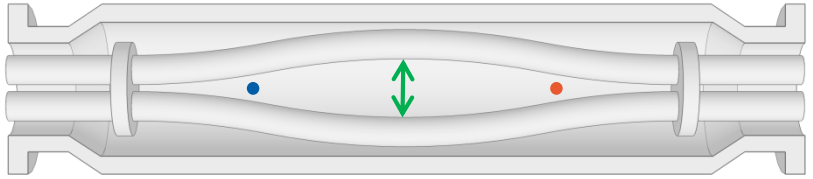
No Flow + No Driver Oscillation



- One driver
- Two sensors

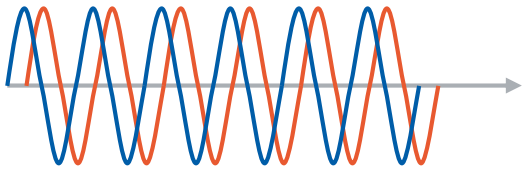
No Flow + Driver Oscillation

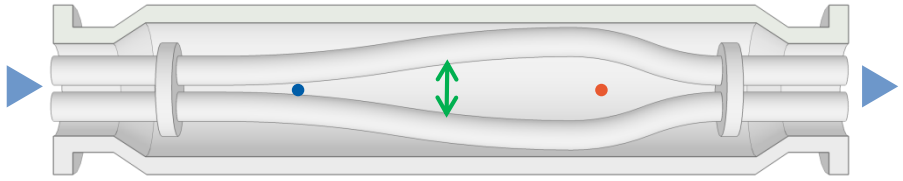




- Free oscillation frequency reversely proportional to the mass (RMS)
- Volume accurately known, with compensation for P and T

Flow + Driver Oscillation





- Phase shift proportional to the flow of that mass

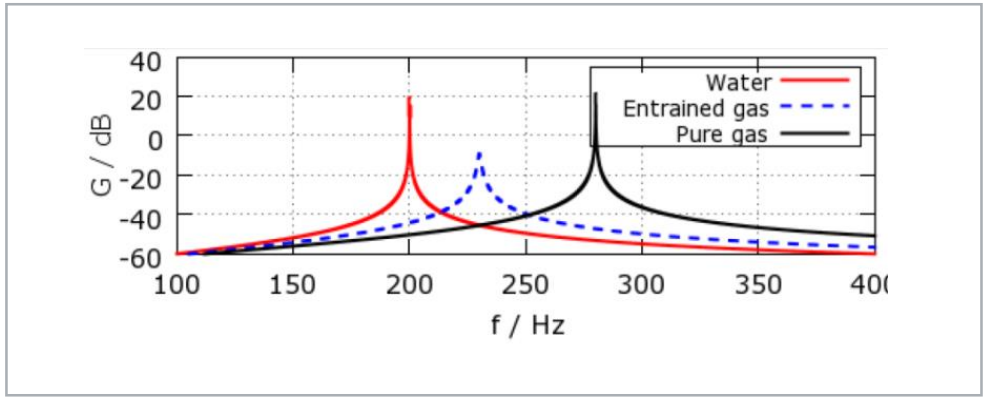
A Coriolis flow meter is a scale

Coriolis measurement

Entrained Gas Management (EGM™)

Diagrams represent effect of full, empty and entrained gas

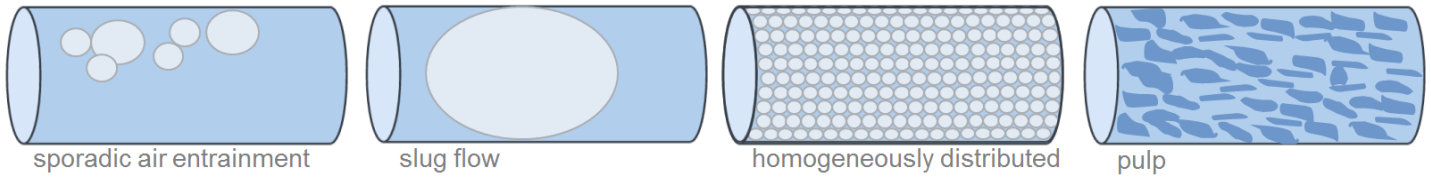
- Signal attenuation
- Rapid changes



- Synthesized drive control to maintain a signal with 2 phases
- Signal digitalized inside the sensor to account for fast changes of frequency

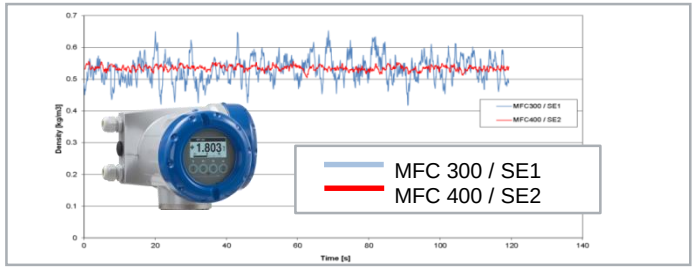
Coriolis measurement

Immune to 2-phase flow enabled by EGM™



Standard high performance

Mass: 0,1% of rate
(opt. 0,05%)
Density: 0,062 lb/ft3
local cal: 0,012 lb/ft3



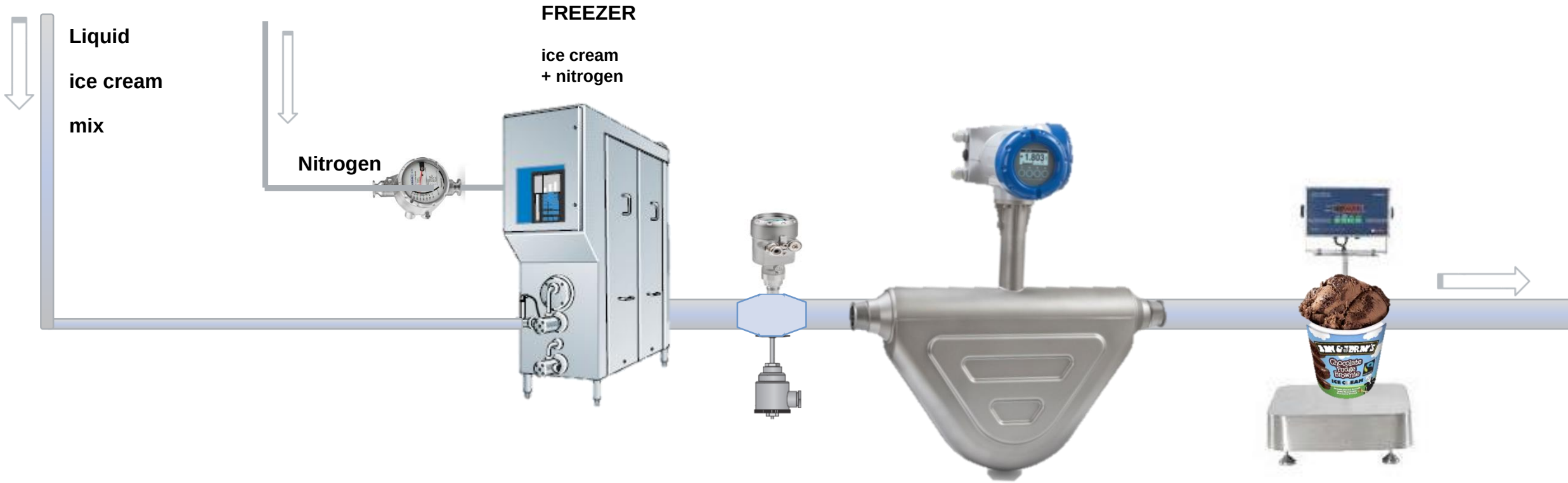
Accuracy depends on the 2 phase flow pattern:

- Air volume fraction
- Density of continuous phase
- Morphology of the dispersed phase
- Viscosity of the continuous phase

EGM™
Entrained Gas Management

Converter: enabler of EGM™
by synthesized drive control - superior density measurement

Overrun measurement

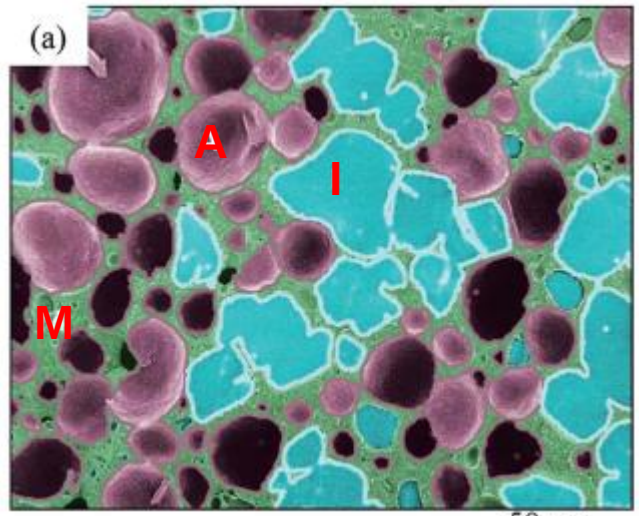


In-line **Density**, **Pressure** and **Temperature** to be correlated with the off-line **Density**

Density of ice cream

Ice cream is a 3 phases system:

- Solid: Ice — $\rho_{ice} = f(T)$
- Liquid: Matrix = cream mix, sugar, fat — Viscous media
- Gaz: Air — $\rho_{air} = f(P)$

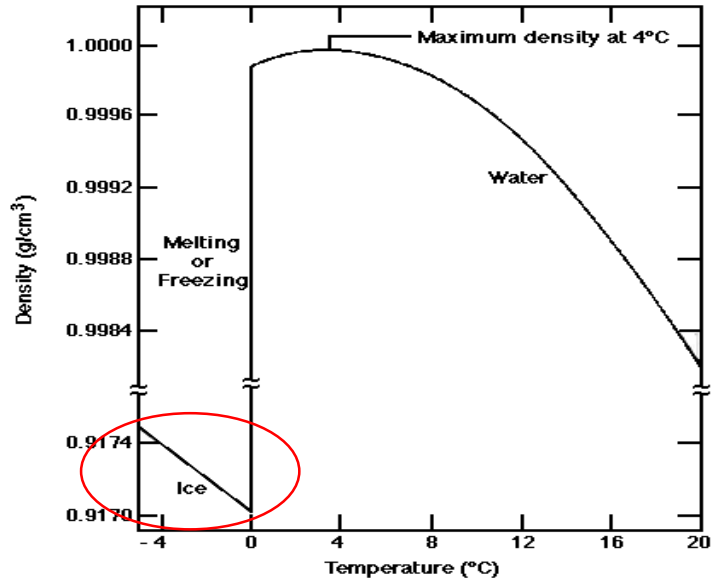


Enyu Guo et al. RSC Adv 2017

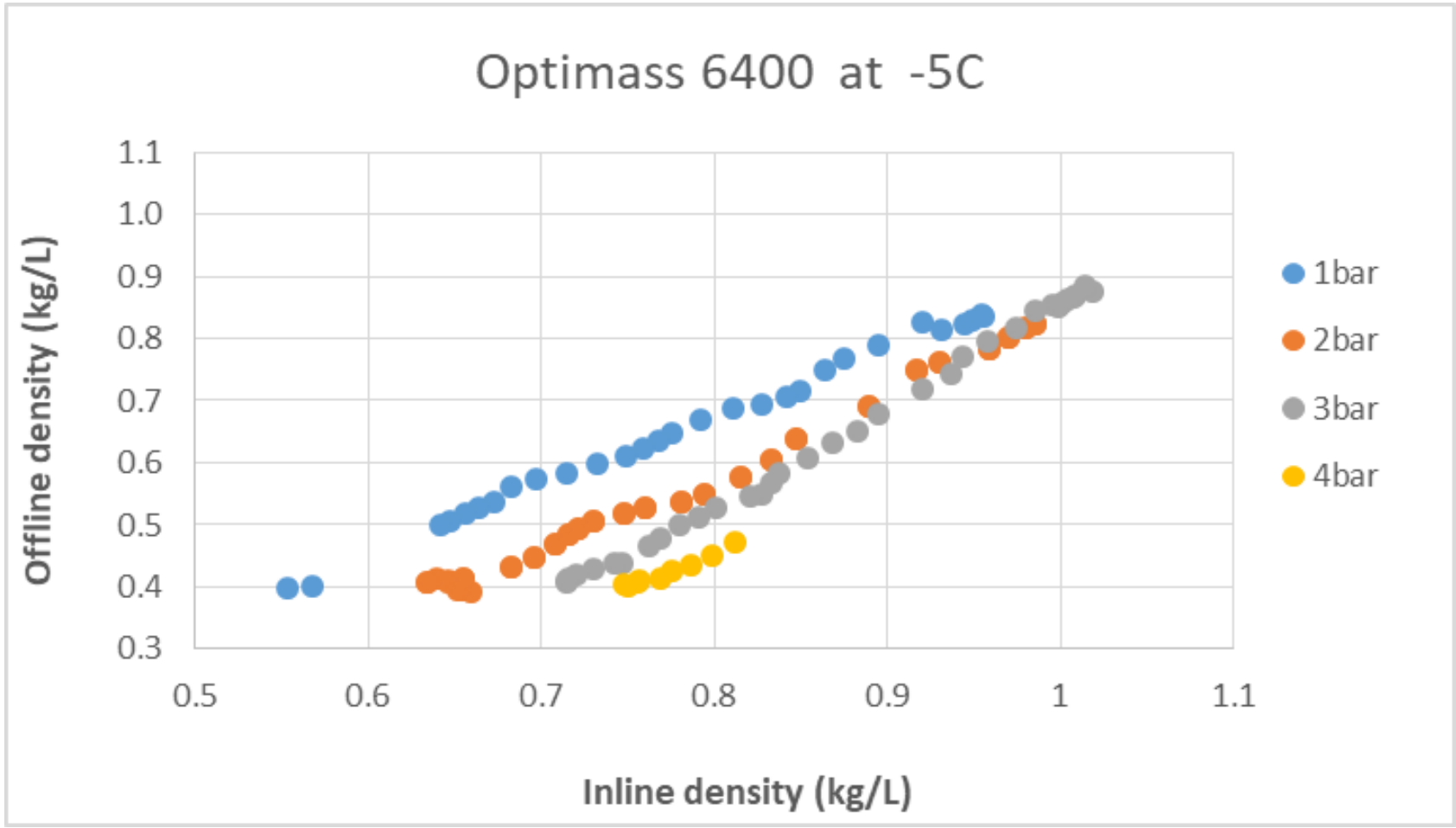
Density of ice cream is a combination of density of each phase:

$$\rho_{ice\ cream} = x_{v\_air}\ \rho_{air} + x_{v\_mix}\ \rho_{mix} + x_{v\_ice}\ \rho_{ice}$$

$$\rho_{ice\ cream} = f\ (Pressure, Temperature, Overrun)$$



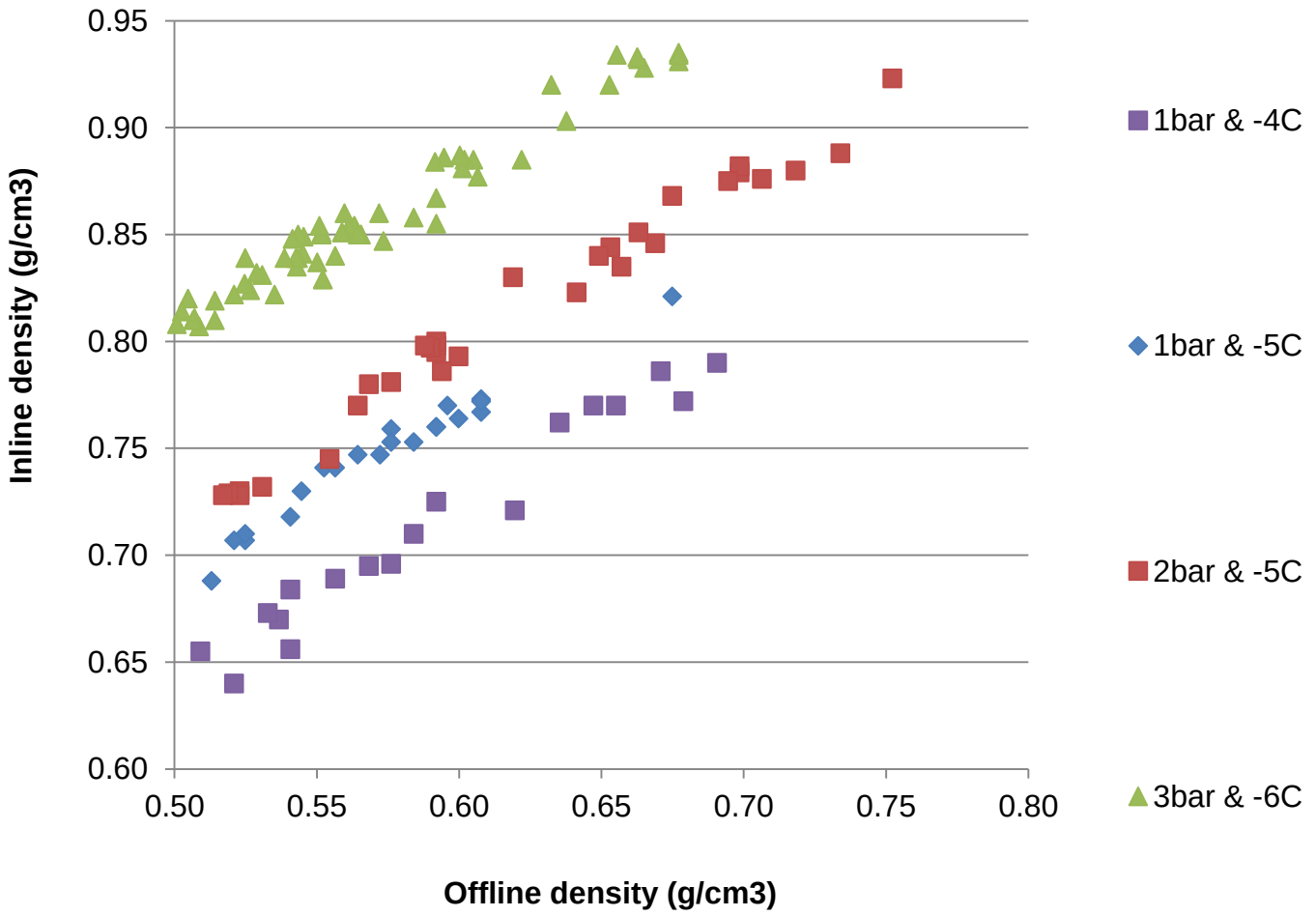
Pressure effect



Combined effects of temperature and pressure

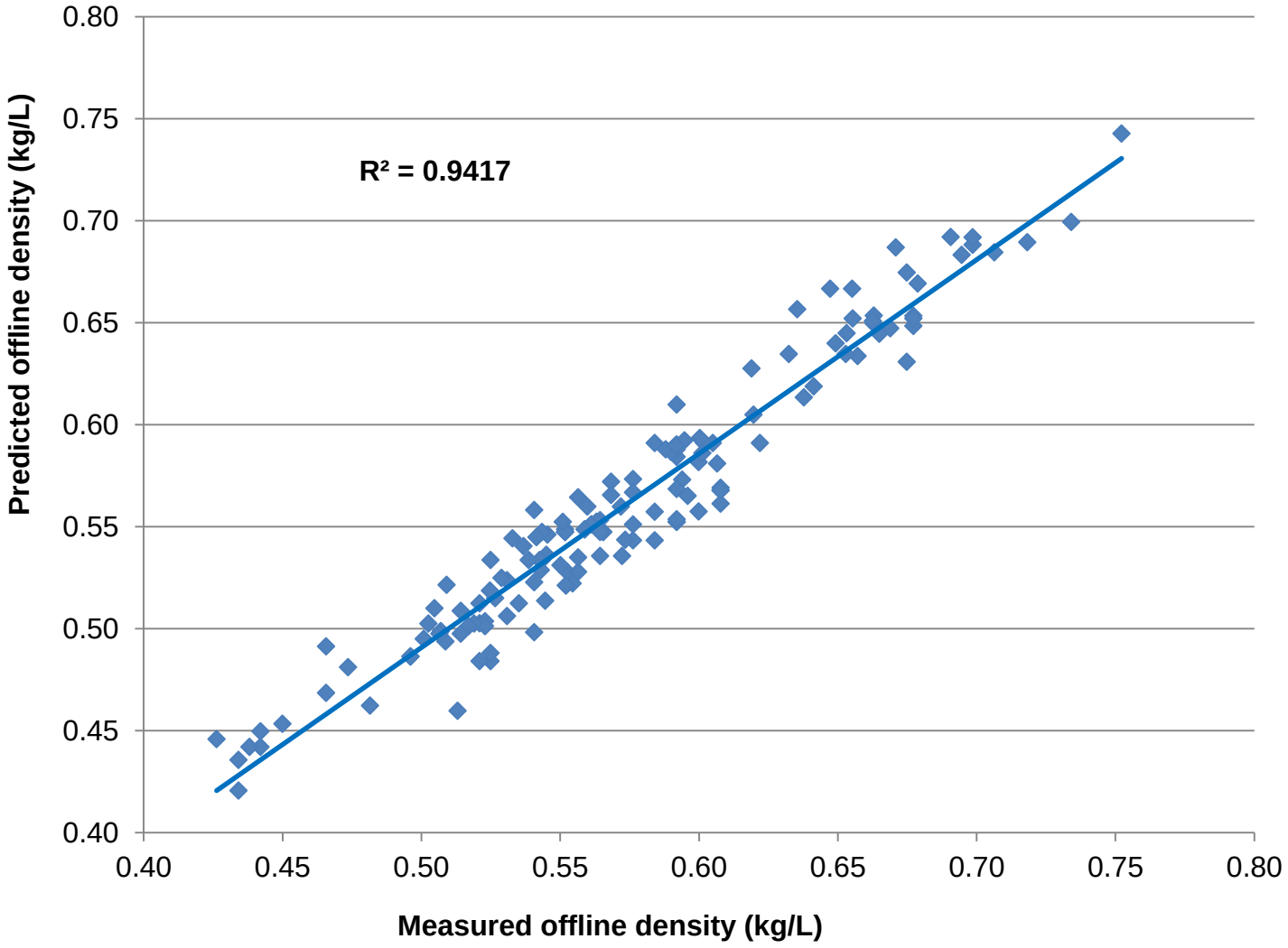
$\rho_{offline} = a\ \rho_{inline} + b$

a and **b** are both functions of P and T



Setting a correlation

By correlating the measured density in temperature and pressure, the off-line density, and then Overrun, can be predicted within an accuracy of 5%



Thank you for attention !

Whichever type of cool delight you make, KROHNE improves, how

- Molded

- Filled

- Extruded