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**Development of an In-line CIP Sensor.**

by

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## Abstract

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Masters of Technology in Food Engineering

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The need to spend a few hours cleaning milk powder plants at least once every 24 hours is the cause of a significant amount of downtime for a plant. This downtime is worth millions of dollars of lost production time to the New Zealand dairy industry each year.

Optimisation of the cleaning-in-place (CIP) systems used to clean milk powder factories has been limited by the lack of a method for measuring the amount of fouling throughout a plant without dismantling equipment for visual inspection. A sensor that could measure the amount of fouling remaining on a plant surface during CIP would allow cleaning rates and cleaning times to be determined for each cleaning cycle. Areas of intense fouling within the plant could also be mapped out using such a sensor.

Research was conducted to develop a method for using a heat flux sensor to measure the amount of fouling remaining on a stainless steel surface during CIP. A pilot plant was built to replicate the pre-heating and fouling processes in a milk powder plant. The pilot plant had a cleaning-in-place system that cleaned the plant in a manner as similar as possible to that used in the dairy industry.

Results from pilot plant trials showed that the heat flux sensor reflected changes in the fouling mass during cleaning. The heat transfer coefficient was low in the presence of fouling on the measured surface. As fouling was removed during CIP the overall heat transfer coefficient would increase. The probe allowed the estimation of the cleaning rate and cleaning time of the measured surface. The extent of fouling removed during cleaning could also be determined. Cleaning was found to be a relatively rapid process. Fouling layers of about 1 mm thickness took about 5 minutes of washing with 1.0% w/w caustic to become almost visually clean. Visual observations of a fouling layer during cleaning showed that cleaning was a process of attrition of the fouling surface. No lumps of fouling were seen breaking off the fouling layer during cleaning.

Accurate and fast-responding temperature sensors to measure the CIP fluid tem-

perature were found to be essential to the performance of the CIP monitoring system. When commercial Resistance Temperature Detectors (RTDs) mounted in a stainless steel sheath were used to measure the CIP fluid temperature the slow response time of the RTDs caused anomalies in the heat transfer coefficient trace. Heat loss from the RTD tip to its surroundings was also found to cause offset in temperature measurements. These anomalies were not seen when naked thermocouples were used to measure the CIP fluid temperature.

The effect of changes in the thermophysical properties of the CIP solutions on the heat transfer coefficient during cleaning was also investigated. Changes in temperature were found to have the largest effect on the heat transfer coefficient. A method for compensating the heat transfer coefficient trace for changes in CIP fluid temperature was developed. The compensation was justified by predictions calculated from fundamental heat transfer theory. The concentration of soil or nitric acid did not significantly affect the heat transfer coefficient. The addition of caustic soda to the process fluid caused a very small decrease in the heat transfer coefficient.

An industrial trial of the heat flux sensor was made at Kiwi Coop. Dairies Ltds Pahiatua Milk Powder Factory. The heat flux sensor was attached to the pipe directly following the direct steam injection unit (DSI) used to pre-heat milk before it entered the evaporator. The heat transfer coefficient was measured using the heat flux sensor and an existing RTD temperature probe measuring the process fluid temperature downstream of the direct steam injection unit. The CIP monitoring system was able to measure the build up of fouling during milk processing. However instability in the DSI during CIP lead to fluctuating process fluid temperatures during CIP making accurate measurement of the heat transfer coefficient impossible. A fast-response temperature sensor close to the heat flux sensor would have been needed for an accurate measurement. The existing RTD was however of a type similar to those that had given problems in earlier laboratory experiments.

Much of the data collected from the heat flux sensor and the process fluid temperature sensor at Pahiatua contained significant noise or interference. The cause of this interference is unknown but it was likely due to electrical interference from powerful electrical devices within the plant. Amplification of the signal from the heat flux sensor is therefore recommended for industrial environments along with special attention to signal wire sheilding.

To my parents.

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