

# THE USE OF TOTAL ORGANIC CARBON ANALYSERS TO MONITOR SUGAR CONTAMINATION IN BOILER FEED CONDENSATE

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## Abstract

The recent installation of two high pressure boilers at Hulett Refineries has increased the need for a more sensitive and reliable means of continuously monitoring boiler feed condensate for sugar contamination. The conductivity based system which relies on higher ash levels in the contaminating streams for good sensitivity has proved unreliable at the refinery due to the low ash content in all process streams. The paper describes a redesigned condensate handling system based on the use of total organic carbon analysers, and the system control logic adopted to compensate for the longer response time required by these instruments.

## Introduction

One of the main concerns of boiler operators in a sugar factory is the possibility of gross sugar contamination in any of the return process condensates destined for boiler feed. A sensitive and reliable sugar trace monitoring system is essential if such a situation is to be avoided. For many years Hulett Refineries has used the conventional conductivity based measuring system with little success. The problem with conductivity measurement is the dependence on reasonably high ash levels in the measured stream for good sensitivity. Unlike a raw sugar factory where the contaminating streams have much higher ash contents, in a sugar refinery the ash level in the impurest stream is too low for good sensitivity. Consequently the system at the refinery has often only responded to either gross contamination or second cycle condensate, where the sugar has decomposed due to high temperature after passing through the boiler drums. Hulett Refineries has managed to tolerate this situation because of the relatively low 14 bar operating pressure of the boilers. The recent installation of two new boilers with an operation pressure of 30 bar has increased the need for a more sensitive and reliable monitoring system. After a considerable period of on-line testing, a total organic carbon analyser proved to be the most cost effective instrument to satisfy the requirements. Together with the analyser, a completely redesigned condensate handling system was required to compensate for the seven minute sample response time required by this instrument.

## Condensate Monitoring System

Boiler feed condensate is derived from four main sources in the refinery. Each of these streams had previously been equipped with a conductivity monitor positioned upstream of the condensate collection tank. An additional monitor was used to check the quality of combined condensate leaving the collection tank, prior to the main boiler feed storage tank. Due to the relatively high cost of the total carbon analyser, monitoring of the combined condensate rather than individual streams was chosen. In designing the new condensate handling system to suit the requirements of this instrument, the main criterion for consideration was the provision of sufficient residence time in the primary collection tank to compensate for the seven minute sample response time of the analyser. A second analyser was incorporated in the system as an on-line backup, as well as to provide continuity whilst routine calibration is being carried out on the other instrument.

Figure 1 shows the general arrangement of the new handling system. The individual condensate streams are fed into a single

flash vessel positioned above the primary collection tank. The outlet from the flash vessel extends to the bottom of the collection tank in order to minimise short circuiting to the tank outlet. A composite sample is pumped from the outlet of the flash vessel into a high velocity loop, via the Laboratory, to the first analyser and back to the tank. The first analyser 'A' provides the opportunity to preview the condensate quality entering the primary collection tank and rejects out of specification water at that point. The seven minute response time of the analyser however means that 12 cubic metres of contaminated condensate will have entered the primary collection tank before rejection is triggered. The primary collection tank, with an operating volume of 60 cubic metres and residence time of 35 minutes, is designed to handle the 12 cubic metre overshoot at a 50 ppm level of sugar contamination, enabling the total mix to be kept within the 10 ppm maximum limit set. The second analyser 'B' samples the well mixed contents in the primary collection tank, and through a programmable logic controller to which both analysers are linked, the output from the tank is either allowed to continue to boiler feed or is stopped. Output is once again resumed when the contents have been sufficiently diluted to within the 10 ppm limit.

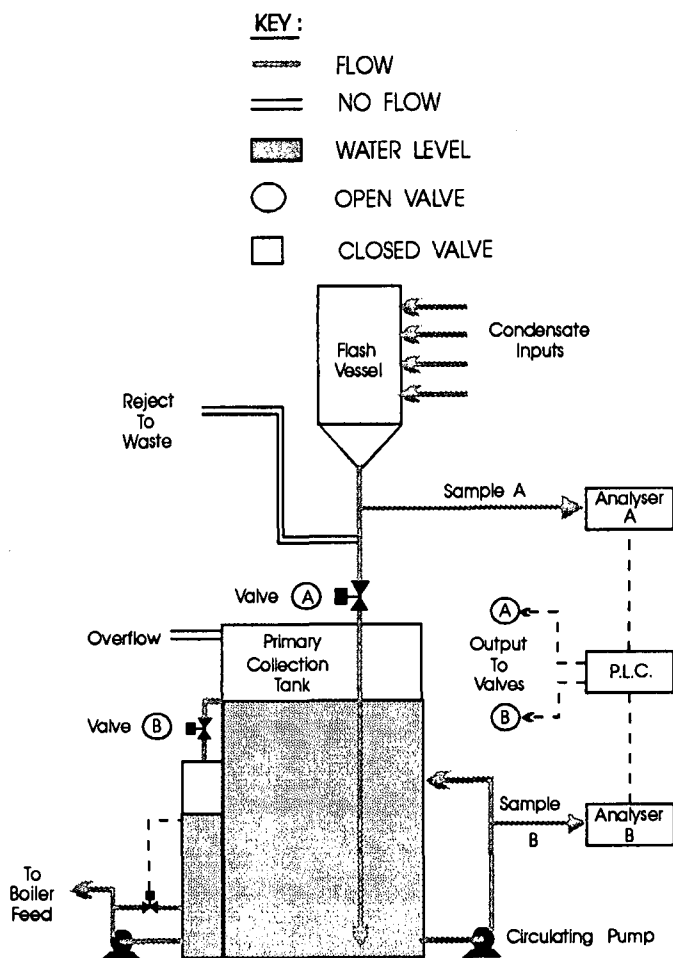
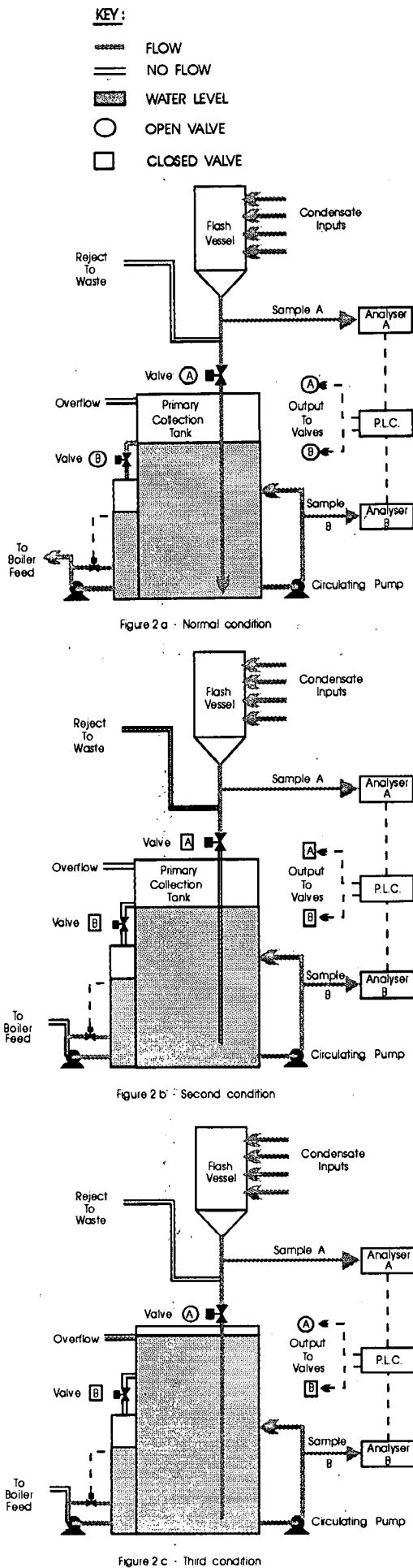


FIGURE 1 General arrangement.



Figures 2a, 2b and 2c illustrate the three possible operating situations of the system. These are each described as follows:

Figure 2a represents normal uneventful operation where both condensate samples being measured by analysers A and B are within the prescribed contamination limits. Condensate flows through the flash vessel and primary collection tank into the pump suction compartment and away to the main boiler feed storage tank.

Figure 2b illustrates the situation where the level of sugar contamination at the outlet of the flash vessel has exceeded the set point. In this situation, the control logic immediately closes valve A causing all incoming condensate to be rejected to waste. Valve B is simultaneously closed which ensures that the short duration of contaminated condensate which entered the primary collection tank is held in the system until analyser B has had time to measure the level of contamination in the total mixture. Should the measured value be acceptable, the control action reverts back to the normal condition illustrated in Figure 2a, once the quality of incoming condensate being monitored by analyser A is back to normal.

Figure 2c shows the second condition for Figure 2b where the condensate mixture in the primary collection tank has a contamination level above set point, after analyser A has re-accepted the quality of incoming condensate. In this situation valve B remains closed as long as the mix remains unacceptable. The condensate level in the primary collection tank rises and overflows to waste. When sufficient displacement has occurred for the diluted mixture to fall once again within the quality limit, valve B opens and the system changes back to normal operation.

### Total Carbon Analyser

#### Design

The instrument is of the conventional auto-analyser design. A fixed speed peristaltic pump delivers a continuous sample of water together with reagent to an ultraviolet oxidizer where organic matter is converted into carbon dioxide. The gas is stripped from the oxidizer by a metered volume of oxygen and passes through an infrared detector which produces a 4 to 20 mA signal proportional to the concentration of carbon dioxide measured. This signal is transmitted as a percentage of the maximum calibrated value to a digital display and chart recorder. The output signal is also used to drive a set of relays which can be set by a variable potentiometer to trigger anywhere along the 4 to 20 mA output range. This is used to provide the high and low values to a programmable logic controller for switching valves in the field. Figure 3 is a flow diagram showing various operating stages of the total carbon analyser.

It is worth noting that the original total carbon analyser tested was designed to analyse various sample streams in a batch mode, using a personal computer to provide the necessary intelligence. It was also designed to remove inorganic carbon from a sample prior to analysis. The disadvantage of the multi-stream feature to Hulett Refineries was the much longer response time due to the need for flushing between samples. In addition, the low level of carbonates in refinery condensates eliminated the need for the inorganic carbon stripping stage. The analyser was therefore modified to the simpler design previously described, to suit the refinery's need.

#### Chemistry

A single reagent, potassium persulphate is used. The persulphate ( $S_2O_8^{2-}$ ) ion in the presence of ultraviolet light, oxidises all dissolved organic carbon to carbon dioxide. The concentration of carbon dioxide generated is used as an indirect measure of the total organic carbon present in the sample.

FIGURE 2 Operating logic.

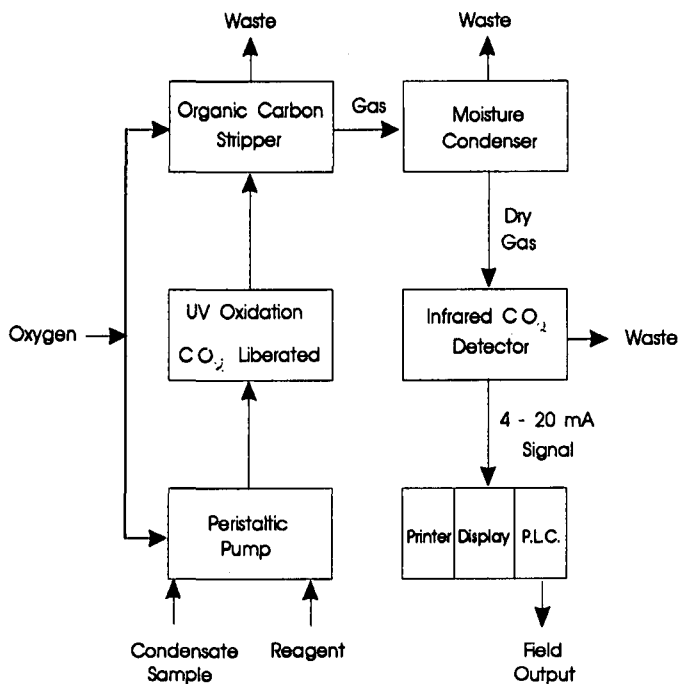


FIGURE 3 Analyser flow diagram.

### Calibration

When using the analyser for sugar trace measurement, the concentration of carbon dioxide generated is used as an indirect measure of the sugar present in the sample. Calibration is carried out in the following manner:

The instrument is set from 'RUN' to 'CALIBRATE' mode, and is fed with distilled water to check, and adjust the zero if necessary. A standard sucrose solution (made with distilled water) is applied to check and adjust any drift from original calibration. Finally, a standard sucrose solution made up in sucrose free factory condensate is used to set the instrument's high alarm/output level. For analyser 'A' which monitors the condensate from the flash vessel this second standard contains 20 ppm sucrose, while for analyser 'B' which monitors the contents of the primary collection tank the standard contains 10 ppm.

In practice, checking the zero and verifying instrument response are carried out every day, and resetting of the high alarm/output value is done if the background interference of factory condensate has changed.

### Operating Experience

#### Background interference

Mention was made under the heading 'Calibration' of the use of sucrose standards made up in sucrose-free factory condensate. Because these instruments measure total organic carbon and not sucrose specifically, the presence of other organic compounds in the background influence the measured value and consequently the accuracy of sucrose estimation, hence the use of standards made up in sucrose-free condensate to set the alarm/reject point.

It is found that heat exchangers operating on vapour generated from refinery liquor produce condensate containing exceptionally high non-sucrose organic material. This gives rise to a high background effect resulting in frequent and spurious rejection of all the condensate streams entering the flash vessel. Consequently, this particular condensate bypasses the monitoring system, and other operating measures at the evaporator station are used to minimise the possibility of heavy contamination from this source.

A high background effect is also noted during the three day period immediately following a 36 hour month-end maintenance stoppage. Sweetwater which has been in storage over a stoppage seems to be the most likely cause, as fairly high traces of ethanol have been measured in condensate during this period. To cater for this, the high sugar alarm/reject setting is checked twice daily until the background returns to normal.

#### Condensate handling

The condensate handling system and control logic have operated well without any problems and have not required any modifications from the original design.

#### Analyser problems

Some initial problems were experienced with these instruments as outlined below:-

- Moisture entering the infrared analysing chamber with the gas caused both measurement problems and damage to chamber internals. Heat generated by the oxidising reaction creates water vapour which must be condensed and removed from the gas before it enters the measuring chamber. A 'U' tube at the rear of the analyser is designed to allow condensate to gravitate to waste, whilst permitting moisture-free carbon dioxide to be carried to the detector. Unfortunately the original design had a flaw in that the condensate drain was set too high, allowing entrainment into the detector. Water, being infrared sensitive, affected measurement and damaged the gold plated reflector unit. A change in design solved this problem.
- Rupturing of pump tubing caused internal leaking of condensate and reagent, resulting in instrument down time. An internal leak detecting circuit was incorporated to give early warning of leaks before any damage can be caused. A policy of replacing the complete set of pump tubes each operating month has helped overcome the problem.
- Small suspended scale particles in the continuous factory condensate sample to the analysers caused pump tube blockage and probably contributed to tube failure as well. This was overcome by coupling the pump suction tube in the sample flow chamber to a suitably sized sintered glass filter. As long as the sintered glass is cleaned occasionally so as not to allow sample starvation to the instrument, the system works well.
- On the positive side, the detecting system has been very effective in preventing condensate with an unacceptably high sugar trace level from entering the boiler feed water tank. To-date, since commissioning the new system, several such incidents testify to this statement.

### Capital and Operating Costs

#### Capital costs

The purchase price of the analysers amounted to R 54 000 each and the modification which was made to the condensate handling system cost a further R 150 000.

#### Operating costs

The additional operating costs to the refinery for condensate monitoring, compared with the previous system, come mainly from the running cost of the analysers. These costs so far have been limited to reagent and regular replacement of peristaltic pump tube sets. These costs, per month, are tabled below:

Reagent cost	=	R 40
Oxygen cylinder	=	R 24
Pump tube sets	=	R 132
Total	=	R 196

### **Conclusions**

The seven minute sample response time required by the modified analysers being used is still longer than ideal, but seems the best performance achievable for continuous operation and the type of chemistry being used. The main disadvantage of long response time is the more complex and costly handling system needed to compensate for this feature.

The major disadvantage in using the total organic carbon principle for indirectly measuring sugar traces is the variable background effect caused by other non-sugar organic material in the condensate. Fortunately for the refinery, the background effect is fairly stable during normal factory operation and only changes for a short period following the monthly maintenance stoppage. The effect of this predictable trend is therefore minimised by the action taken during a refinery start. A larger proportion of condensate streams with a high background during normal operation, such as the refinery's vapour heat exchangers, would obviously result in this principle of measurement being inappropriate.

The use of total carbon analysers for monitoring boiler feed condensate at Hulett Refineries has proved to be a more sensitive and reliable method than the previous conductivity system in preventing sugar contamination of boiler feed water. Due to the short period that these instruments have operated since commissioning the system, little is known at this stage of any major maintenance costs which may lie ahead. The routine operating costs however have proved to be inexpensive relative to the important function these analysers are performing at the refinery.

### **Acknowledgements**

The authors wish to thank the management of Hulett Refineries Limited for permission to publish this paper and express their appreciation to all the members of the project team at the refinery who were responsible for the design, construction and commissioning of this successful project.