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Control of baker's yeast production based on ethanol measurement - a poster presentation

*Abstract*

This report contains a poster presentation of some results on substrate control of fed-batch cultivation of baker's yeast. The substrate feed rate was controlled based on ethanol measurement in the broth. A PID regulator around an exponential basic dosage scheme was used. Molasses was used as subtrate. Results are shown from four cultivations in a 8 liters reactor.

The poster was presented at 1st IFAC symposium on 'Modelling and Control of Biotechnological Processes', in Noordwijkerhout, The Netherlands, 11-13 December 1985.

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# CONTROL OF BAKER'S YEAST PRODUCTION BASED ON ETHANOL MEASUREMENT - A POSTER PRESENTATION

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## O B J E C T I V E S

Biosensors are becoming commercial. Here an ethanol sensor is used for control of the substrate flow during a fed-batch cultivation of baker's yeast.

### Background

Baker's yeast production in a fed-batch reactor can be improved using feedback control of substrate dosage.

The metabolism of yeast is very sensitive to variations in the substrate supply. Oversupply of substrate gives ethanol, which even if it is consummed, results in a loss in the over all yield.

Different ways to track the exponential increase in substrate demand, have been investigated in the literature. The main ideas have been:

* Precalculated dosage schemes
* Feedback from the respiratory quotient
* Feedback from the substrate or the ethanol concentration
* Feedback from the pH-balance or the heat production

The ethanol concentration is a sensitive indicator of the metabolic state of the yeast and thus the actual substrate demand.

# METHODS

The fermentor used was Chemoferm FLC-B-8 with a working volume of 6 ℓ. The fermentor is equipped with control units for pH, $pO_2$, stirrer speed and temperature. An LSI-11 computer was used for control and monitoring of the process. Programs are written in PASCAL extended with a realtime kernel.

## Cultivation conditions

The following substances were fed to the fermentor:

* Molasses (the substrate)

* NaOH for pH control

* Stirrer speed (rpm) for control of dissolved oxygen (DO)

* Antifoam

Sufficient phosphates, minerals and vitamins were given at the start of the fed-batch cultivation.

## Regulation of the substrate feed rate

The substrate feed rate was controlled using a precalculated exponential dosage scheme. Corrections from that scheme were done using feedback from the ethanol signal. The regulator was a well tuned PID regulator with fixed parameters. The regulator parameter were changed manually as indicated in the diagrams.

## The membrane gas semiconducter ethanol sensor system

The ethanol concentration was continuously measured in the broth. The volatile ethanol diffuses through a silicone membrane tube into a flowing stream of dried nitrogen gas.

The gas stream passes by a semiconducter sensor (Figaro sensor). A signal is obtained due to chemisorbtion of ethanol on the surface of the semiconducter.

Below is shown the gas flow mixing system. The gas flow was carefully controlled using feedback from flow metres.

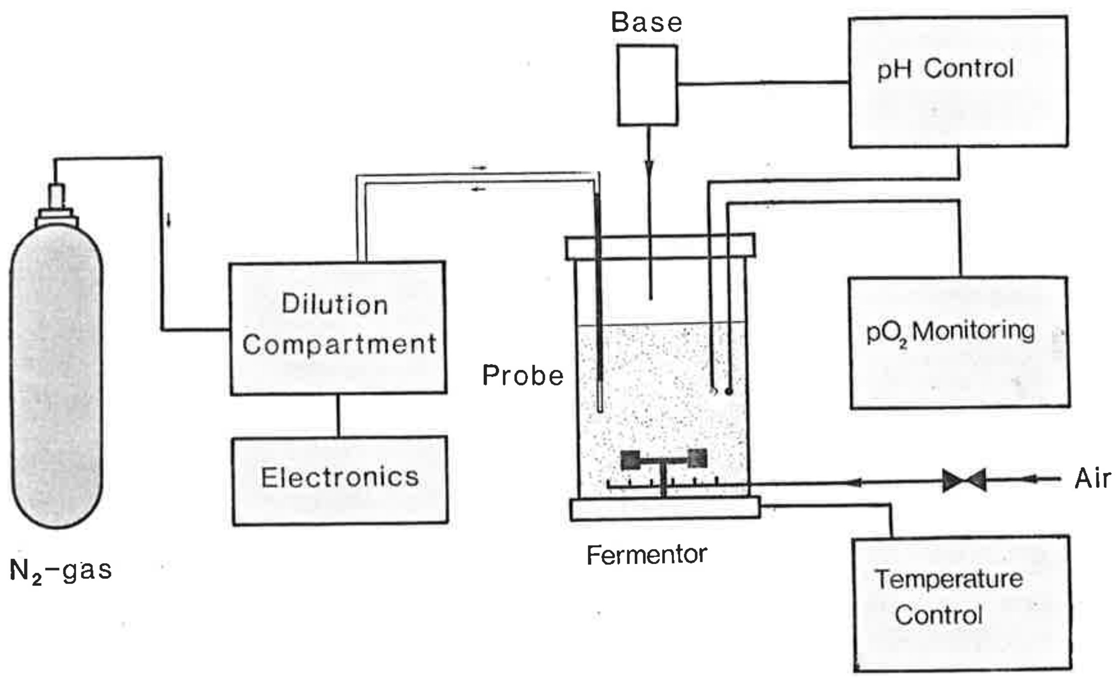



FIGURE 2. ETHANOL MONITORING OF AN AEROBIC CULTIVATION OF BAKER'S YEAST WITH A MEMBRANE GAS SENSOR EQUIPPED WITH ORDINARY DEVISES FOR FERMENTATION CONTROL.

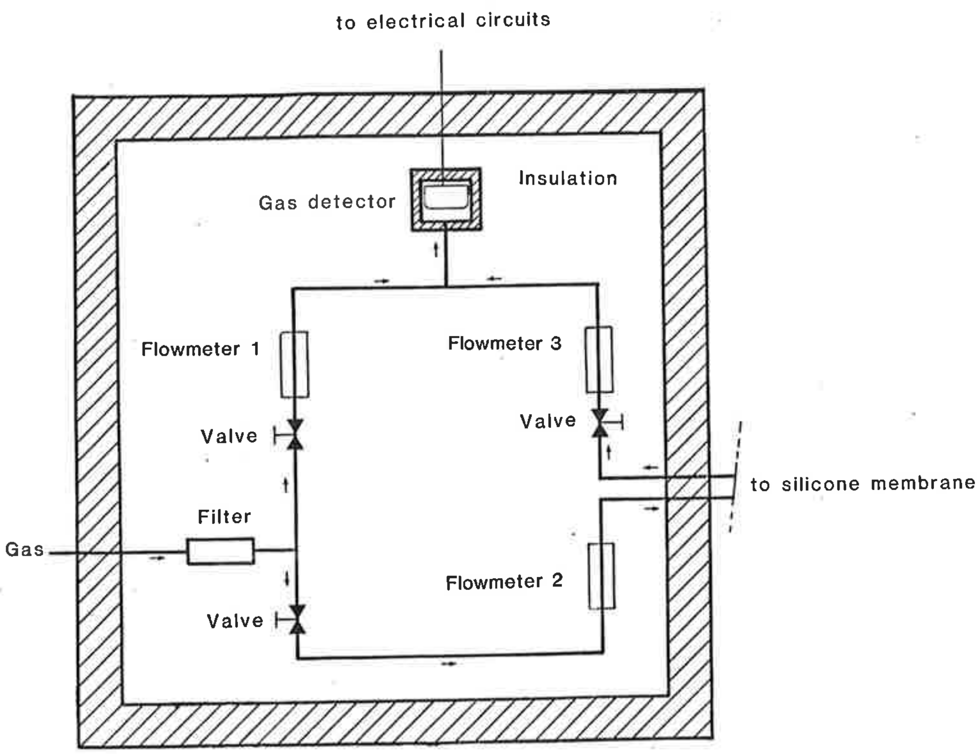
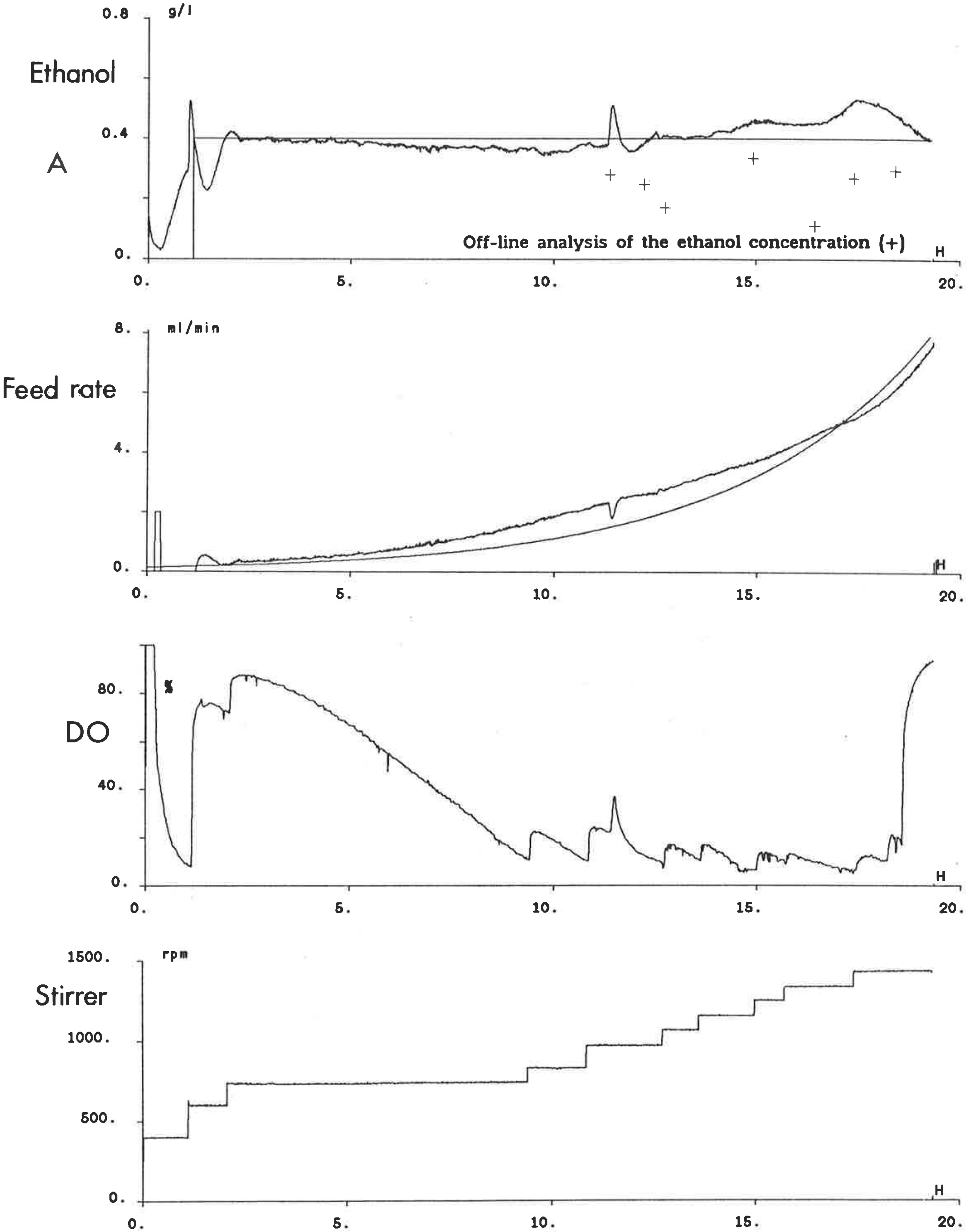
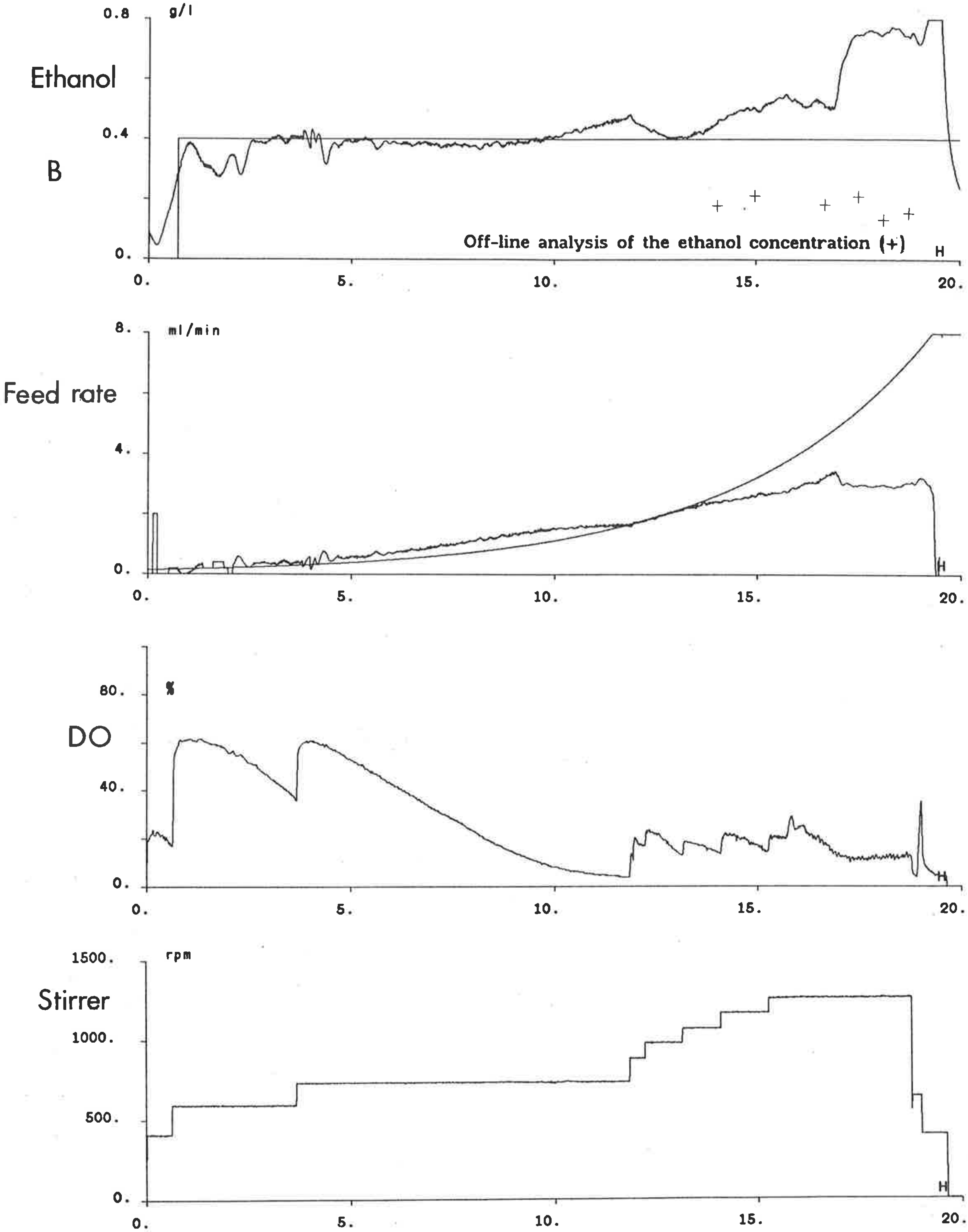
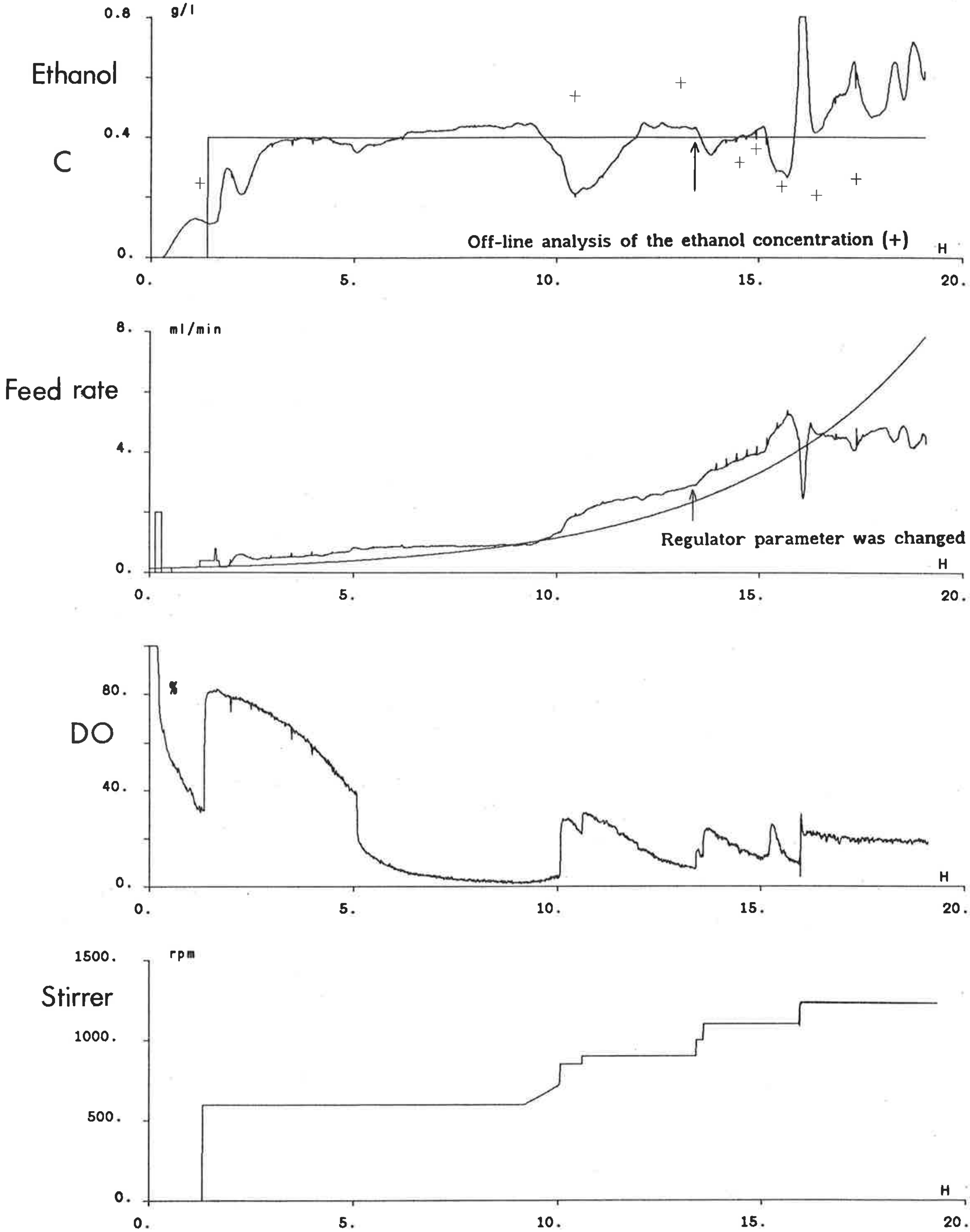



FIGURE 3. MAMBRANE GAS SENSOR WITH THE DILUTION SYSTEM. THE THREE FLOW METERS ARE TUNED TO GIVE A DILUTION DEGREE OF 2 - 1000 TIMES.

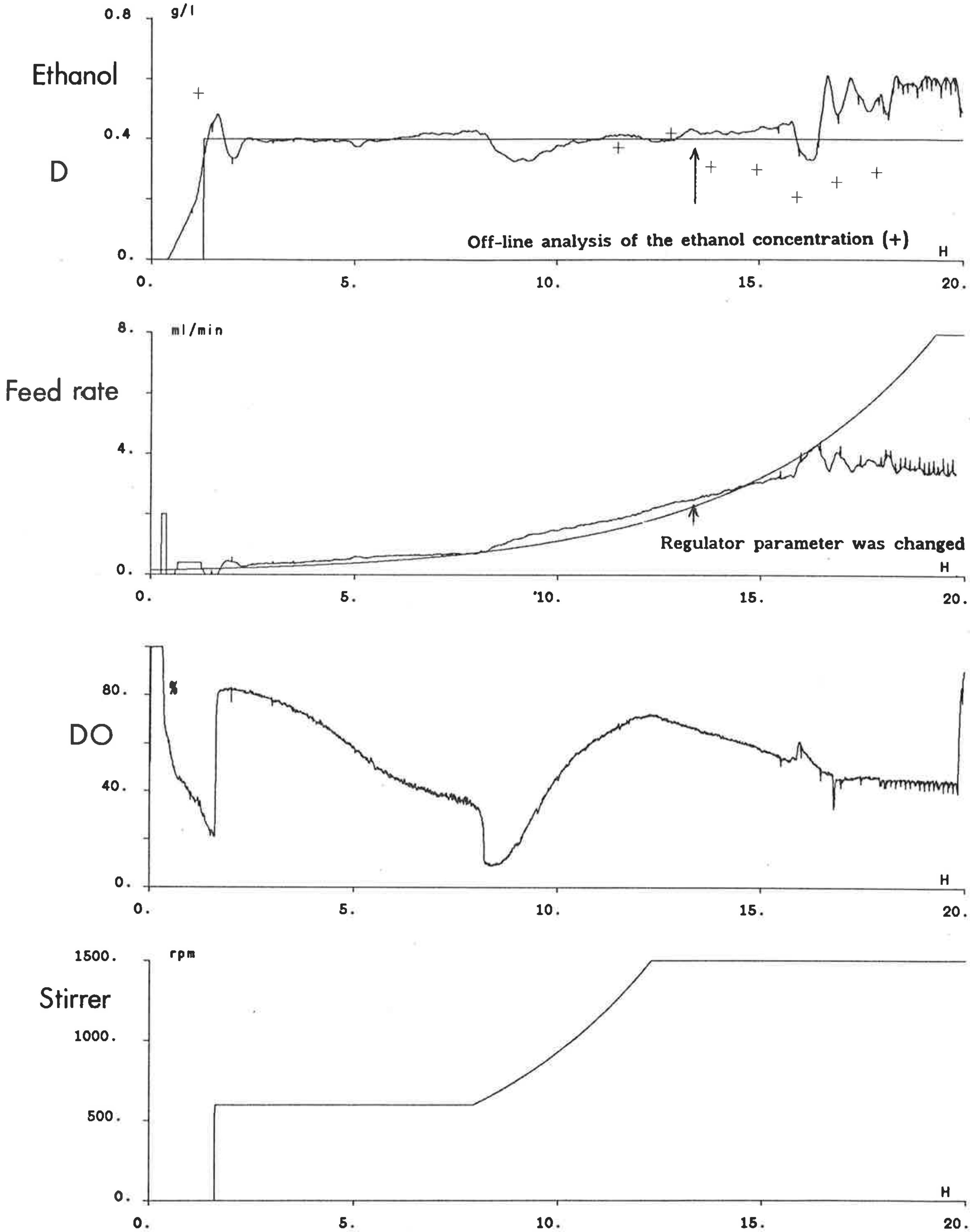

Ethanol
A
0.8
0.4
0.
g/l
Off-line analysis of the ethanol concentration (+)
H
0.
5.
10.
15.
20.
Feed rate
8.
4.
0.
ml/min
H
0.
5.
10.
15.
20.
DO
80.
40.
0.
%
H
0.
5.
10.
15.
20.
Stirrer
1500.
1000.
500.
0.
rpm
H
0.
5.
10.
15.
20.



Ethanol
B
g/l
0.8
0.4
0.
Off-line analysis of the ethanol concentration (+)
H
0.
5.
10.
15.
20.
Feed rate
ml/min
8.
4.
0.
H
DO
%
80.
40.
0.
Stirrer
rpm
1500.
1000.
500.
0.



Ethanol
C
0.8
g/l
0.4
0.
Off-line analysis of the ethanol concentration (+)
H
0.
5.
10.
15.
20.
Feed rate
8.
ml/min
4.
0.
Regulator parameter was changed
H
0.
5.
10.
15.
20.
DO
80.
%
40.
0.
H
0.
5.
10.
15.
20.
Stirrer
1500.
rpm
1000.
500.
0.
H
0.
5.
10.
15.
20.


0.8
g/l
Ethanol
0.4
D
0.
Off-line analysis of the ethanol concentration (+)
H
0.
5.
10.
15.
20.
8.
ml/min
Feed rate
4.
0.
Regulator parameter was changed
H
0.
5.
10.
15.
20.
80.
%
DO
40.
0.
H
0.
5.
10.
15.
20.
1500.
rpm
Stirrer
1000.
500.
0.
H
0.
5.
10.
15.
20.

## RESULTS

Here are shown the results from four cultivations A-D. Reproducibility of growth rate and yield are given in the table below. Two important signals, E and DO, and the corresponding control variables, feed rate and stirrer speed, are shown for the four cultures, A-D. The E - feed rate loop was closed, while the DO - stirrer speed loop was open.

The cultivations were pairwise done on the identical substrate during the same week. Cultivation A and B were done week 8519, and C and D were done during week 8547.

### Reproducibility of growth rate and yield

Measurements of cell mass were done at the start of the fed-batch cultivation and regularly during the later half of the cultivation. From the measurements at the start and after 18 h of cultivation, the average growth rate ($\mu$) and yield (Y) was calculated.

| Cultivation | μ | Y |
|---|---|---|
| A | 0.202 | 0.255 |
| B | 0.198 | 0.250 |
| C | 0.190 | 0.293 |
| D | 0.205 | 0.301 |

Where

Y : [g yeast cells/g molasses] during 18 h.

$\mu$ : [$h^{-1}$] during 18 h.

### A few remarks on the performance of the ethanol control

The ethanol signal was kept near the set-point. Off-line measurements indicate a drift in the signal. It may be attributed to accumulation of volatile compounds like acetic acid, acetaldehyd or changes in the permeability of the silicone tubing.

Note the interaction between the two loops at low DO levels.

The regulator parameters were initially identically for all four cultivations. During cultivations C and D, the regulator parameters were changed as indicated in the diagrams. The gain was increased by 50% and the integral time and derivative time were decreased with about 40%.

## C O N C L U S I O N

Control of feed in baker's yeast production using ethanol sensors is an attractive technology.

### Control properties

Although

* process dynamics varies substantially

* the load disturbance is exponential

a well tuned PID regulator gives reasonable performance but there are potentials for improvements.

### Sensor system

The system is now stable and reliable.

The increasing difference between the sensor signal and the off-line determinations needs further attention.

It may be attributed to accumulation of volatile compounds like acetic acid, acetaldehyde or changes in the permeability of the silicon tubing.