TEST OF ON-LINE CHROMATOGRAPH ON THE GAS EXPORT METERING STATION, STATFJORD FIELD

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TEST OF ON-LINE GAS CHROMATOGRAPH ON THE GAS EXPORT METERING STATION, STATFJORD FIELD.

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S U M M A R Y

A three stage test program has been carried out, for proving the On-line Gas Chromatograph for fiscal accounting purposes. The following aspects have been studied:

- Mechanical Proving
- Availability
- Monitoring of Calibration and Operational Constants
- Analysing-accuracy
- Comparison against existing sampler/analysing system

Phase I:
The On-line GCs are found to be mechanically sound and they operate reliably. Changes to the calibration constants did not in some cases comply within the preset limits, mainly due to a weakness in some components.

Phase II:
Except for an overestimation of nitrogen content on two of the four On-line GC's, all analysis were found to be within the ASTM 1945 reproducibility limits. The allocation laboratory reproduced all components within the given limits.

Phase III:
Two of the On-line GCs are compared against the existing system, and preliminary results have shown an underestimation of the C6+ fraction. All other components have been within the limits throughout the periods stated.

1. Introduction.

This paper describes the experience and preliminary results of an ongoing test program for the On-line GC on the Statfjord field. The test program was initiated in order to investigate the possibility of utilizing the On-line Gas Chromatographs for allocation purposes. Little experience was available by use of On-line Gas Chromatographs on offshore installations. It was therefore neccesary to go through an acceptance test for verifying the system.

Background:
To provide a real time analysis of the exported gas, it was decided to install an On-line GC for Statfjord A, Statfjord B, Statfjord C and UK-offtake metering stations, (later called system A, B, C and D in random order).

The reasons for choosing a continious analysis system were:

- to ensure that gas quality spec's were met.

- to provide the pipeline operators with input for:
    1) pipeline leak detection system
    2) optimizing operations of the processing plant
    3) optimizing pipeline operations

- to furnish data to be used for calculating volume and energy flow.

- after a period of testing, include the On-line system in the allocation accounting procedure.

A three stage test program was initiated containing the following phases:

Phase I:
- Collecting of maintenance and reliability data. This has been compared against preset "limits".

Phase II:
- Compare the analysis results provided by the On-line GCs against certified gas samples, with respect to reproducibility and repeatability limits in the ASTM 1945.

Phase III:
- Compare composition analysis figures from the On-line GC against the existing sampling and analysing system.

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2. Description of the On-line GC system

The On-line GC system is a part of the Gas Export Metering Station (shown in fig. 1). It consists of the following main component parts:

- Bendix 002 Gas Chromatograph, including three columns each dedicated for separating groups of components.
  The carrier gas is high purity Helium

- Sample/handling system, low and high pressure cabinets providing two-stage pressure reduction (ref. fig 2).

- Cosasco Probe, located in a commom flow point on the inlet header.

- Control unit, supervising the following tasks:

  - introduce the sample into the proper column
  - control column switching
  - convert raw data from the detector
  - check components for preset limits
  - perform all calculations and communication with master computer.
  - control the calibration sequence.

3. Phase I

3.1 Introduction

This phase involved the mechanical proving and the operational reliability of the entire On-line GC system. To monitor the performance of the system, three main test criteria have been established: Downtime, RRF and RRT, ref sect. 3.2 - 3.4.

3.2 Downtime

This mode is defined as "a period when the GC does not give a representative result of the gas sample composition". Downtime periods are normally caused by changes in the sample/handling system, analyser problems or hardware/software corruptions.
The objective was to keep the monthly mean downtime to less than 1 hour per day; i.e. availability = 95.8 %.

Fig. 3 shows the downtime results for GC system "A", "B", "C" and "D" versus maximum allowable downtime, 100 % is equal to 1 hour (4 cycles downtime) per day. An observation period of 17 months is included in fig. 3.

For all GCs, the actual downtimes were outside the objective at the beginning of the test period. This was mainly due to fact that the technicians working with the equipment were at the beginning of the learning curve. Later months have also shown downtime figures outside the objective, but they were mainly due to the following:

- periods of long response time during alarm conditions.

- hardware faults in a control unit.

- faults in the temperature control unit in one GC cabinet.

- weak design of a restrictor providing constant reference flow through one of the GCs.

The distribution of the downtime duration is presented in fig. 4. The plot is based on data from GC system "C" during a six months period. The peak of 4 downtime cycles (1 hour) was due to the calibration of the system. The GC is automatically set to be calibrated 4 times per month, and is then out of service for one hour.

Approx. 70 % of the downtime had a duration of 1 hour or less and approx 5 % of the downtimes' exceeded 5 hours. The results shown in fig. 3 were typical for the remaining GCs.

3.3 Relative Response Factor (RRF)

Relative Response Factor (RRF) is a calibration constant, computed for each component during the calibration sequence. Calibration gas with known composition is then routed through the GC, and analyses are carried out.

When back in normal "analysing" mode, the sets of RRFs calculated during calibration, and the integrated peak areas are used to calculate gas composition.

Shift in the RRF-value indicates performance of the following GC components:

- columns
- pressure regulators
- detector (TDC, thermal conductivity detector)
- flow control
- temperature control

In addition, change of calibration gas can affect the RRF-values.

The objective of RRF stability was to be within +/- 3 % per 3 months.

Figs. 5 and 6 show the typical RRF development on GC system "B" and "C" over a period of 3 months for all components.

Some components were found to be outside the RRF objective, mainly due to the following:

- weak control of reference flow through a detector on system "B".
- weak temperature control in GC cabinet on system "B".

By proper maintenance and by corrrecting weak parts of the system, it is possible to achieve RRFs within the objective. Slight changes in the RRFs can be accepted as long as an optimal calibration interval is adopted

3.4 Relative Retention Time (RRT)

For each component, a fixed Relative Retention Time (RRT) through the columns, is established in the GC controller software. If no peaks are detected inside the preset "time-window", a "missing" alarm will be reported.

The objective is to keep the RRT for each component within +/- 4 secs for 3 months.
A six monthly test was carried out on GC system "B" and "C" and no significant shifts in the RRTs were observed. There was no need for changing the RRT-settings throughout the test period. If the "missing" alarm condition did occur, this was reflected in the downtime figures.

4. Phase II

4.1 Description

Phase II included comparison of the four On-line GCs on Statfjord against certified gas mixtures. For verifying and comparison, the onshore allocation GC has been included.

Analyses were carried out with the onshore GC, thereafter on the On-line GCs and finally back for verifying with the onshore GC.

The results have been checked for repeatability and reproducibility criteria in the current standard, ASTM 1945.

Two composition samples close to the typical gas export quality, have been investigated.

Typical Statfjord gas composition:

Methane	:	76.0 %
Ethane	:	11.0 %
Propane	:	8.0 %
I-Butane	:	0.5 %
N-Butane	:	2.0 %
I-Pentane	:	0.5 %
N-Pentane	:	0.5 %
C6+	:	0.5 %
Nitrogen	:	0.5 %
CO2	:	0.5 %

Certified gas bottles provided by Norsk Hydro were used as transfer samples between the On-line GCs and the onshore GC. Norsk Hydro is also used as the supplier of calibration mixtures to the onshore and offshore GCs.

The calibration gas is certified within the following accuracy:

- methane within a range   : +/- 0.5 %
- all other components within a range : +/- 1.0 %

- Onshore Gas Chromatograph

The test gas cylinders were analysed according to the existing allocation analysis procedure, based on ASTM 1945.

The following calibration checks are performed prior to analysing:

- unnormalized sum to be within 100 +/- 1 %.
- two concecutive analyses to be within the limits in ASTM 1945.

If it is outside the limits, the GC is re-calibrated. A sample analysis is only accepted if results are within the above limits. The analysis with the unnormalized sum closest to 100 % is normalized and reported in sect. 4.2.

- Offshore On-line Gas Chromatographs

The On-line GCs were calibrated prior to the analysis of the transfer samples. Two concecutive analyses must repeat within the ASTM 1945 limits. Based on the last calibration analyses, new updated sets off RRF were utilized in the GC software.
The transfer samples were connected and prepared as done for calibration. Two concecutive analyses must then repeat within the given limits, and the latest ones have been reported in sect. 4.2.

4.2 Results

Results from two certified mixtures are presented. Each mixture has been analysed on two occasions on the onshore GC, plus once on each On-line GC. The results are separated for each of the involved GCs, see fig. 7, 8 and 9.

The bar height shows the fraction of maximum allowable reproducibility calculated for each component as follows:

bar height = (analysis-certificate)*100 / max reproducibility.

The certificate value is provided by Norsk Hydro. The plots show the distribution for every component in the mixture. Maximum allowable reproducibility and repeatability values according to ASTM 1945, for this calibration gas specification, are as follows:

Component	Reproducibility	Repeatability
N2, CO2, iC4, iC5 and nC5	0.06 %	0.03 %
nC4	0.10 %	0.05 %
C2H6 and C3H8	0.20 %	0.15 %
CH4	0.60 %	0.30 %
C6 and above	10 % of amount	5 % of amount

- Onshore Gas Chromatograph

The results are presented in fig. 7. Every component has reproduced against the certificate within the above reproducibility and repeatabilty limits.

- On-line Gas Chromatographs

The results from the 4 GCs on Statfjord, system "A", "B", "C" and "D" is shown in fig. 8 and fig. 9. The following main performance characteristic were observed:

- overestimation of the nitrogen content by 65% - 75% of maximum allowable on three of the GCs.

- all analyses were within the ASTM 1945 repeatability limits.

- all analyses except single nitrogen results were within the ASTM 1945 reproducibility limits.

4.3 Discussion

The main finding of the test comparison was the general overestimaton of nitrogen content on system "B", "C" and "D". This was not found to be of the same extent on system "A". Several explanations have been examined.
The main reason for nitrogen overestimation seems to be changes in the nitrogen RRF during the period of testing, due to process corruptions (liquid carry-over) on the metering stations.

A small shift was observed in the hexane (C6) result between the first and second analysis on the allocation GC. This can be explained by utilizing a new calibration bottle in the time between.

5. Phase III

5.1 Description

Phase III of the test program includes a comparison between the On-line GC figures and the analysed results from the existing sampler system.
The existing flow proportional sampler system collects small amounts (0.5 ml) of gas into the sample cylinder after fixed increments of exported gas. The sample piston cylinder uses argon as a back-pressure gas, keeping cylinder pressure slightly above line pressure. Maximum filling volume of the cylinder is 800 ml.

After a sampling period of 14 days, the cylinder is removed and transported to the onshore allocation laboratory for analysis.

The station master computer is provided with every analysis from the On-line GC. This information is combined with exported volumes since the last analysis, and printed on a chromatograph report.

During phase III, the chromatograph reports on GC systems "B" and "C" are continiously logged by a PC. The reports are created approximately 4 times per hour per GC system. During a 14 days period, 1100 - 1300 single analyses are logged.

In order to compare the GC data against the allocation analysis result, they must be weighted with respect to flowrate, and corrected if there are any obvious errors.

5.2 Preliminary results

During phase III, twelve sampling periods will be compared. The results presented in fig 10 - fig 13, cover the first eight of these.

The comparison of the results is based on the reproducibiliy limits in ASTM 1945 as done for phase II. The following main observations have been found in phase III.

- underestimation of the C6+ fraction particular for system "C", in the beginning of the test period.

- C1 - C5, N2 and CO2 have been within the reproducibility limits in ASTM 1945 for both systems.

- small variations in gas export composition.

- no systematic offset between On-line GC and Onshore GC, except for the C6+ fraction.

5.3 Discussion

Phase III was determined to be the most difficult part of the test program, and initially no test criteria or accuracy objective was established. For comparison against phase II, the same reproduciblity limits have been used in phase III. The distinct underestimation of the C6+ fraction on both systems during the first months, has gradually become less, particular for system "B". System "B" is today within the reproducibility limits in ASTM 1945.

The effect of a different sampling point for the GC and the existing sampler have been tested, and no significant difference was observed. Based on the phase-envelope of the gas, we are close to the two-phase region through the sample/handling system. If any condensation of heavy ends has occured, this may cause underestimation of the C6+ fraction, resulting in large variations within the C6+ analysis data; however this has not been observed.

The underestimation of nitrogen found in phase II, is not observed to any extent in phase III.

6. Conclusion

Phase I:
The mean availability for the test period is approx. 97 %, which is satisfactory. The relative response factor has in some cases not been within the preset limits, and the problem has been investigated. Satisfactory explanations have been concluded and overall the phase I testing shows that the GC operates reliably.

Phase II:
Results from three On-line systems shows an overestimation of nitrogen. All the analysed hydrocarbon components (C1 - C6+) and CO2 have reproduced on the On-line systems to within the ASTM 1945.

The Onshore and On-line GC have repeated within the ASTM 1945 limits and the Onshore GC has reproduced every component within the limits.

Phase II demonstrated that the GC analysing accuracy is sufficient to develop an accepted On-line GC for allocation purposes.

Phase III:
Preliminary results indicate for the last periods that the two independent sampling/analysing systems (On-line GC versus existing flow proportional system) agree within the reproducibility in ASTM 1945. A further study of the observed C6+ underestimation will be carried out.

Following aspects should to be taken into consideration when utilizing an On-line GC system for allocation purpose:

- optimize calibration interval based on experience ie. monitor the performance

- use high quality calibration gas

- operational and maintenance procedure to be established

- consider the education of personnell

The advantage of on-line available GC data can be included in the flow calculations for new gas metering systems. By continious updating of critical gas data (Tc, Pc, back-up density, viscosity, isentropic exponent, Zref, etc), improved measurement performance will be expected.

7. References

G. Brown - Use of inline gaschromatograph for gas sales from an offshore platform. North Sea Flow Metering Workshop, NEL 1986.

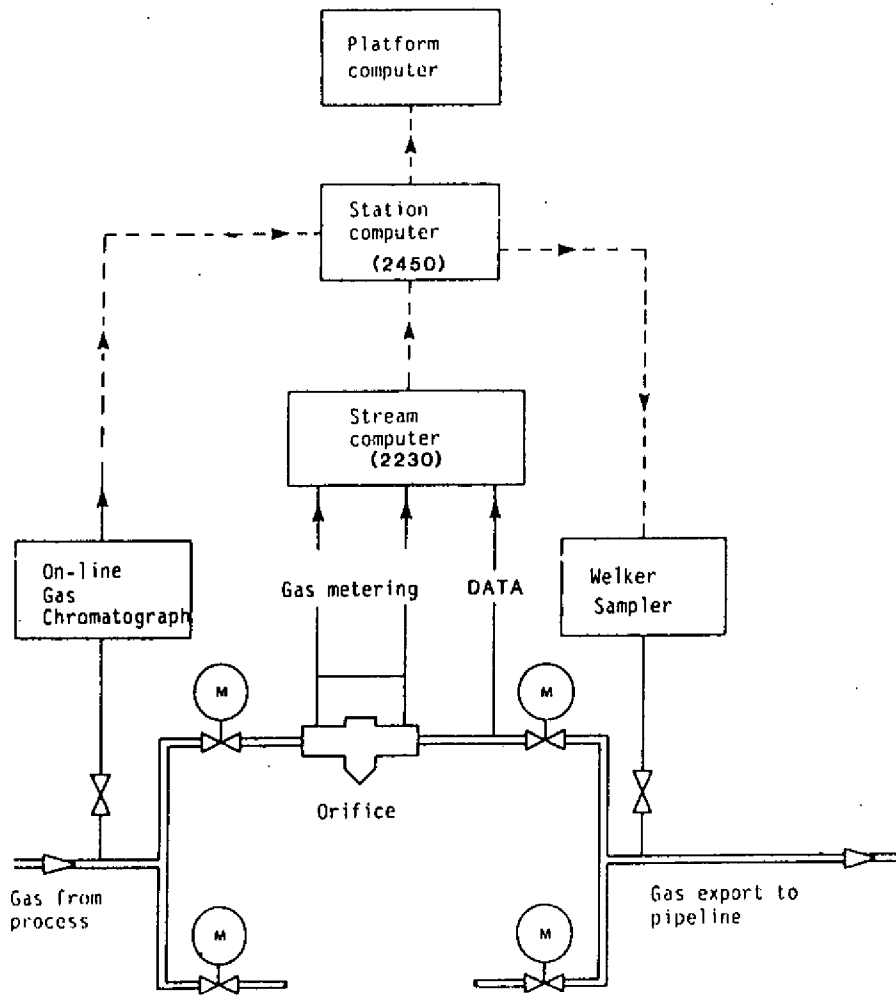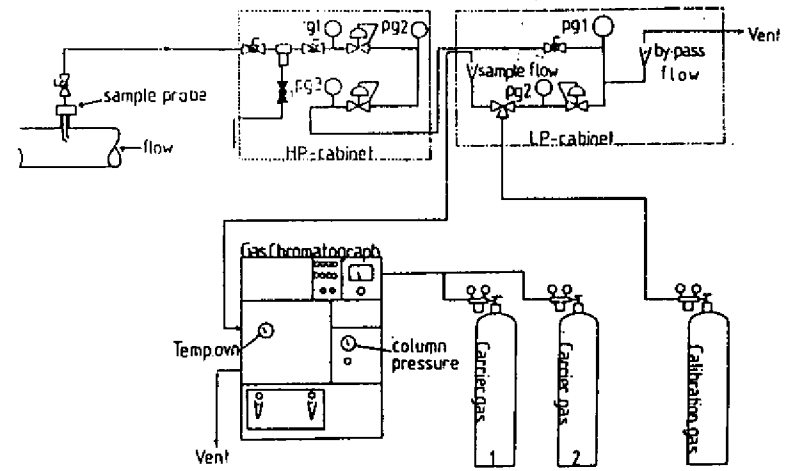ASTM Designation 1945 - 81. Analysis of natural gas by gas chromatography.

Fig..1   STATFJORD FIELD GAS
          EXPORT METERING
          STATION

Schematic drawing
of
sample handling system
STATFJORD FIELD GAS
CHROMATOGRAPH
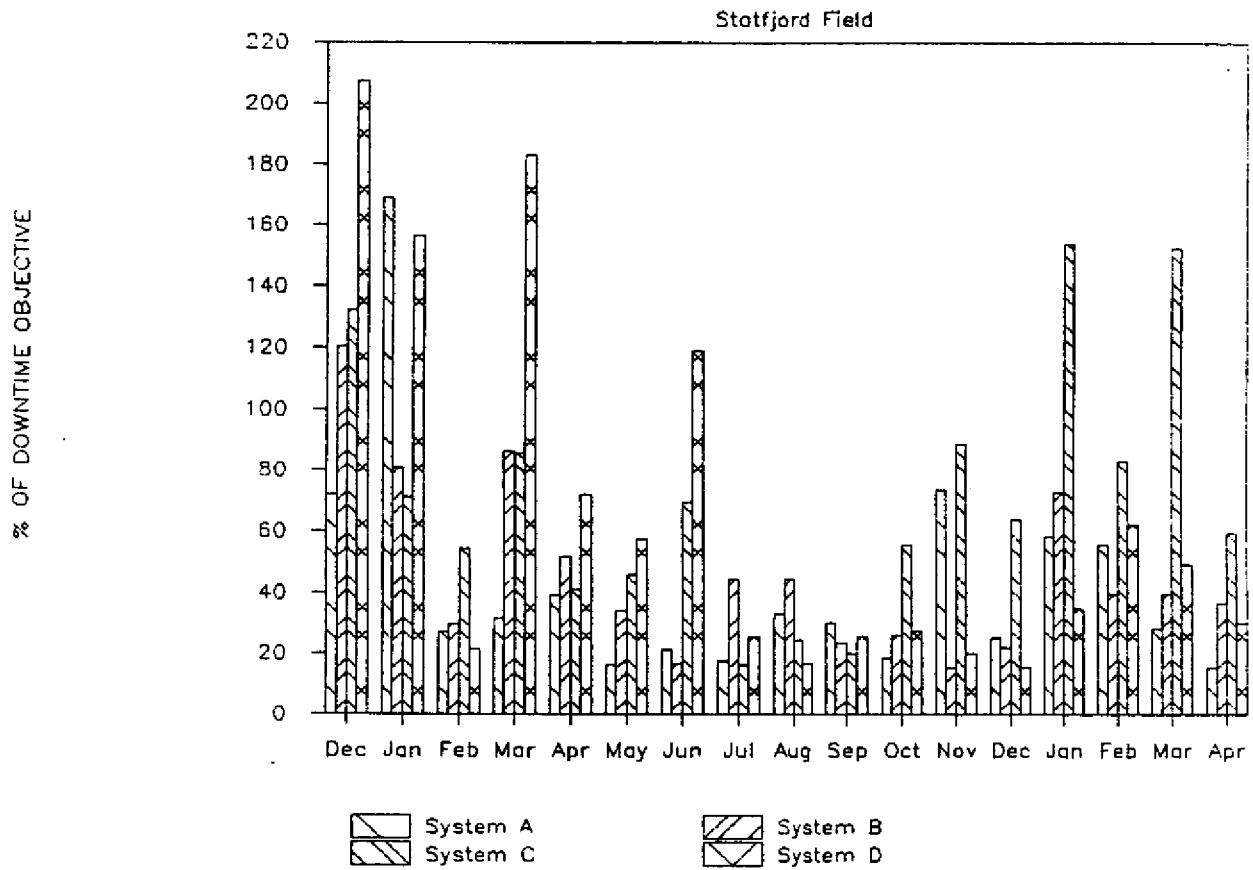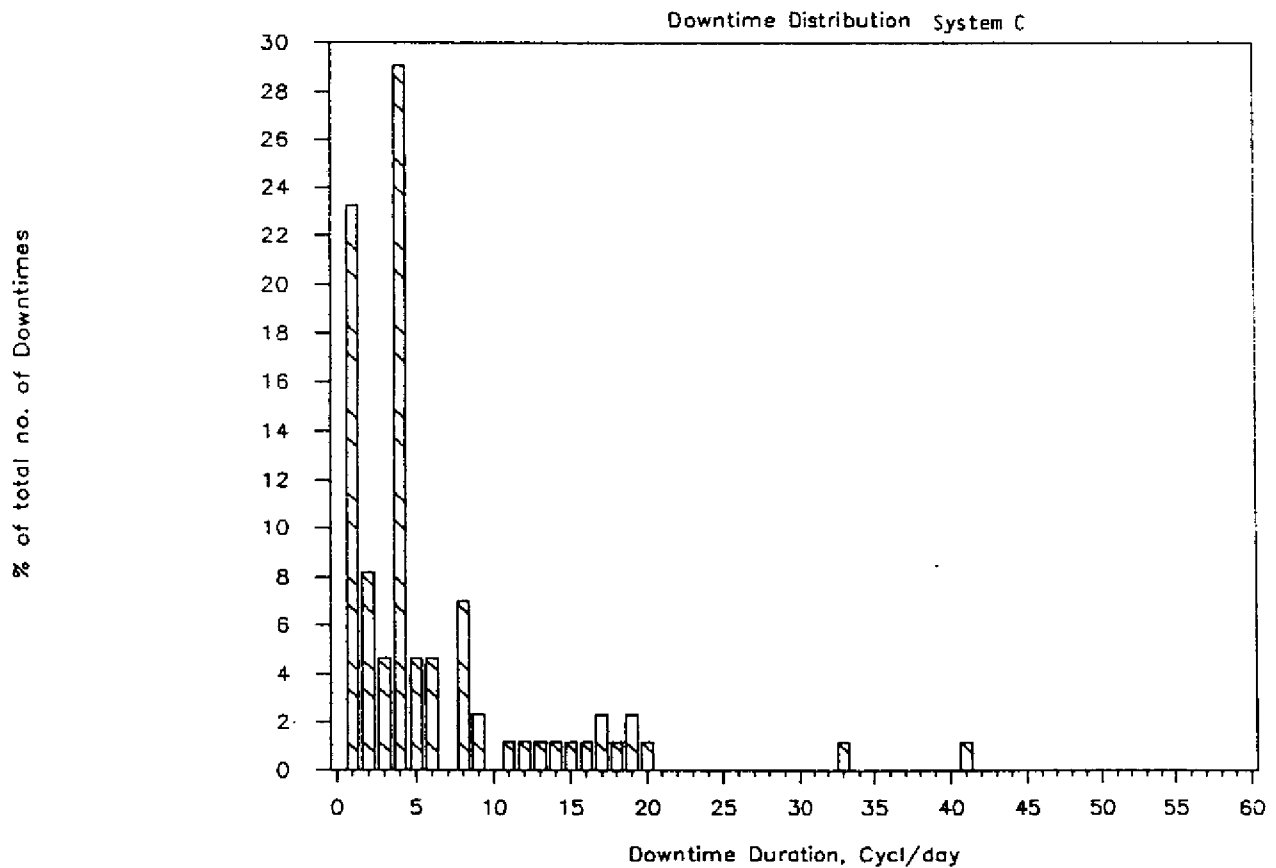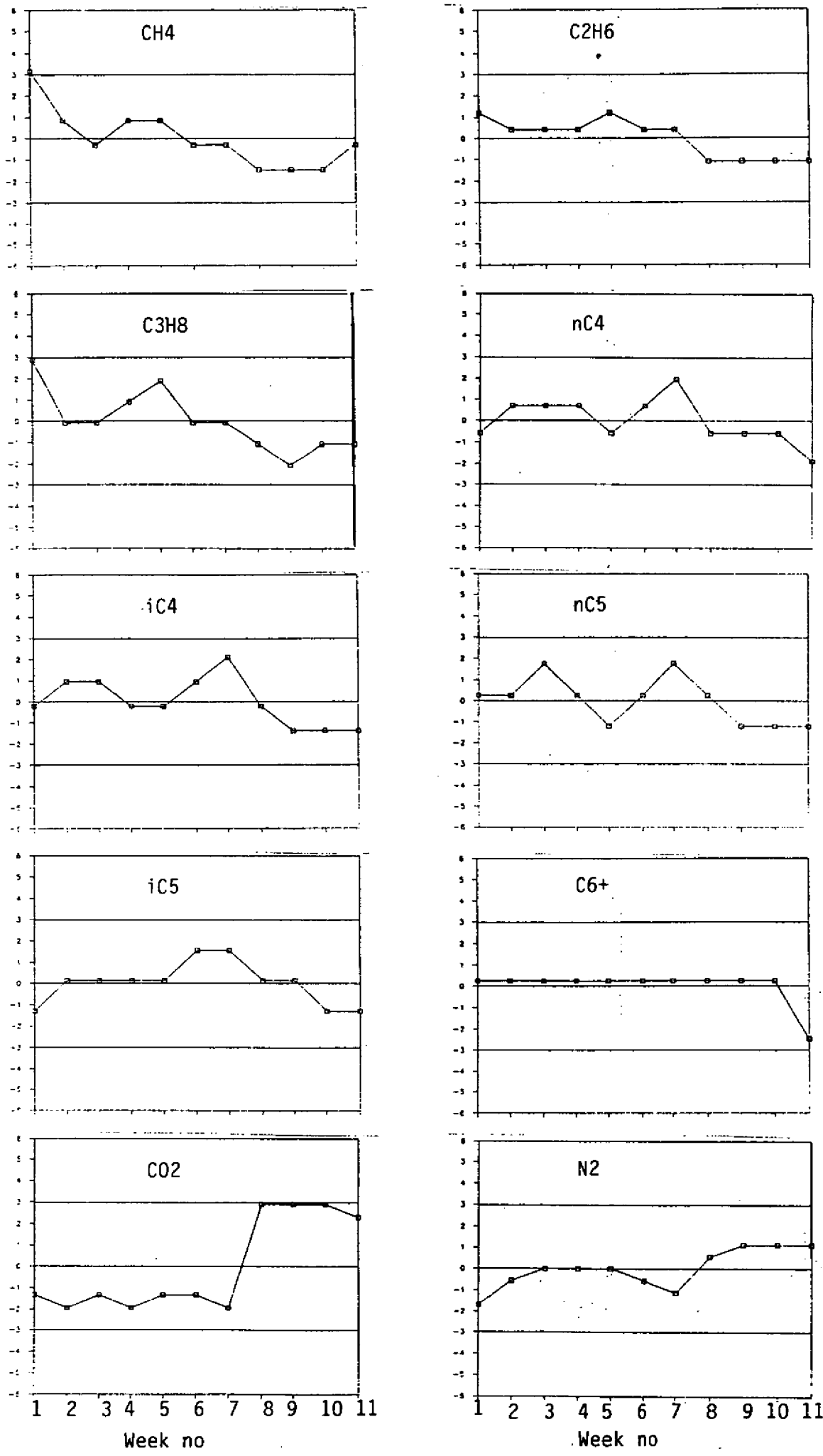
Fig. 2

Fig. 3   Downtime on the Gas Chromatographs

Statfjord Field

% OF DOWNTIME OBJECTIVE

System A
System B
System C
System D

Fig. 4   Gas Chromatograph

Downtime Distribution   System C

% of total no. of Downtimes

Downtime Duration, Cycl/day

14

Fig. 5 RRF versus % of mean, System B
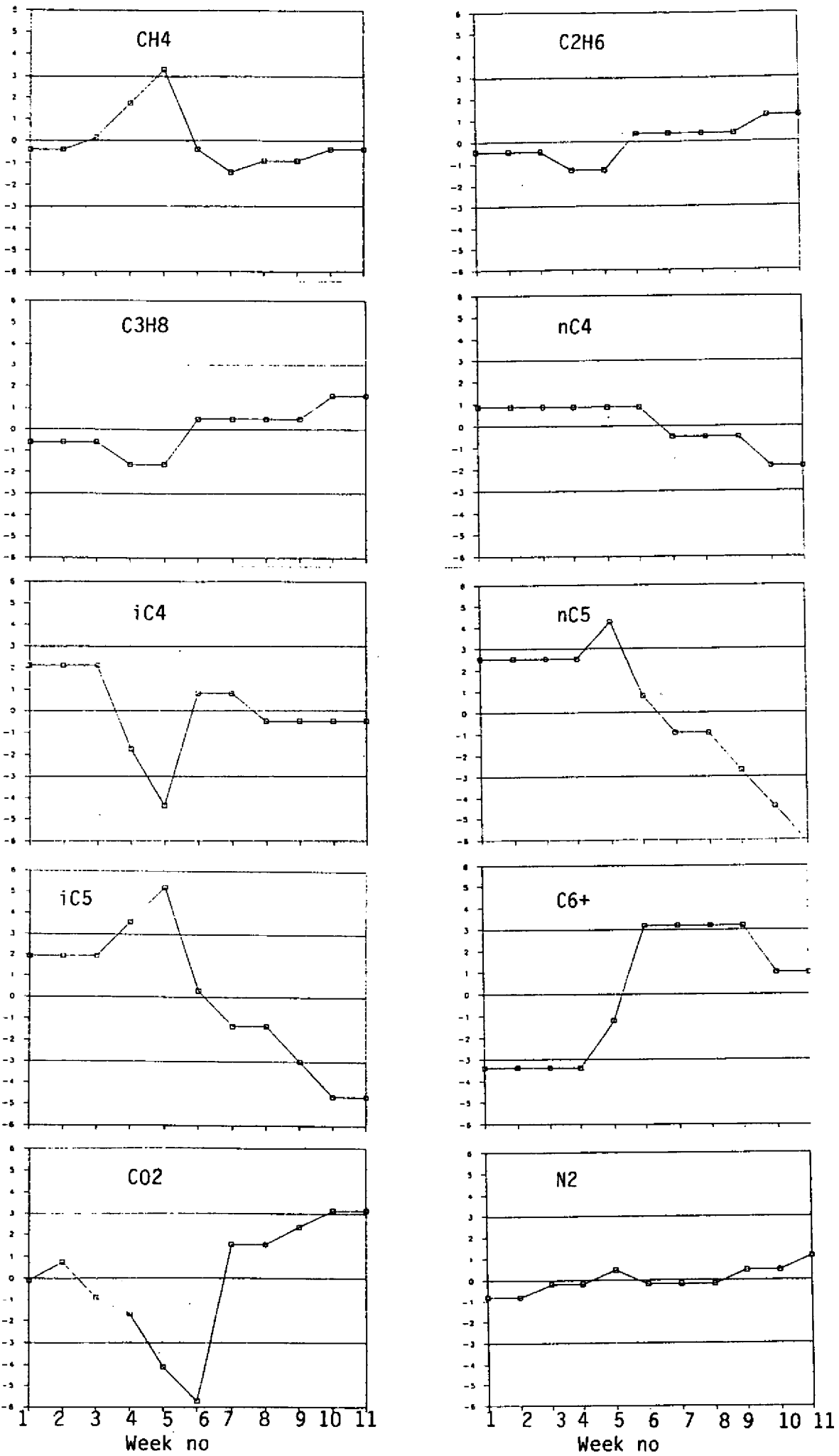
Fig. 6 RRF versus % of mean, System C

GAS CHROMATOGRAPH PHASE II
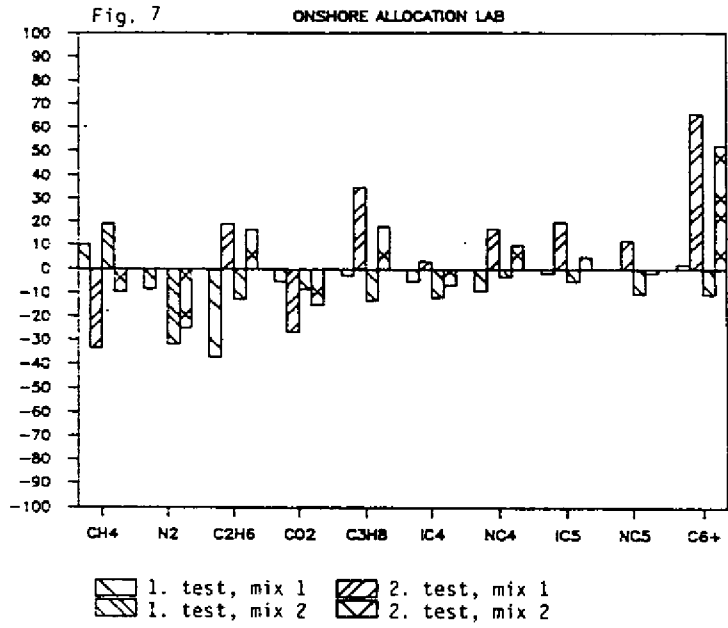
Fig. 7 — ONSHORE ALLOCATION LAB

Legend:
- 1. test, mix 1
- 1. test, mix 2
- 2. test, mix 1
- 2. test, mix 2

Fig. 8 — GC SYSTEM A and D

Legend:
- System D, mix 2
- System A, mix 2
- System D, mix 1
- System A, mix 1

Fig. 9 — GC SYSTEM B and C

Legend:
- System C, mix 2
- System B, mix 2
- System C, mix 1
- System B, mix 1
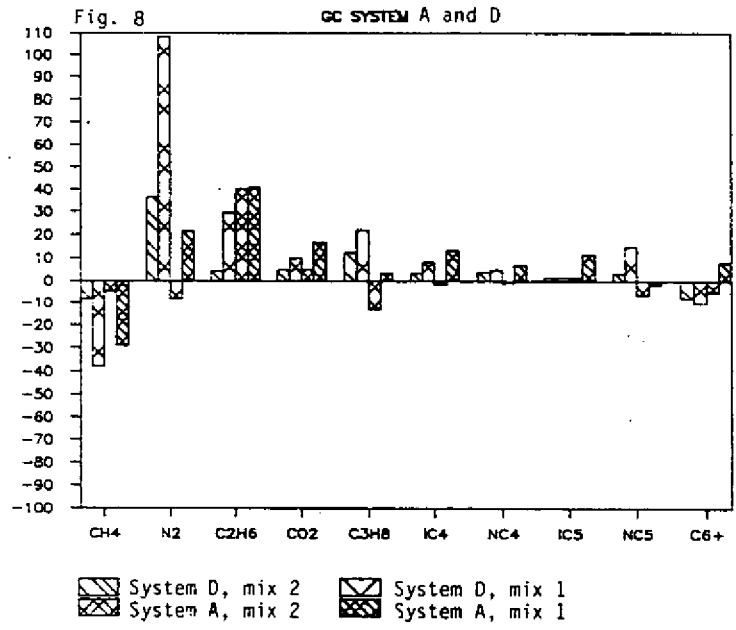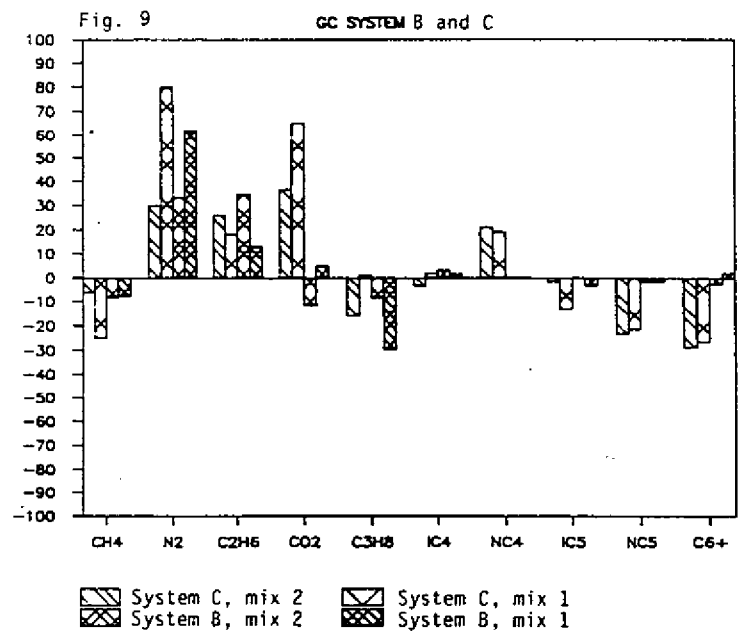
GAS CHROMATOGRAPH PHASE III

Fig. 10, System C

1. period   2. period   3. period   4. period
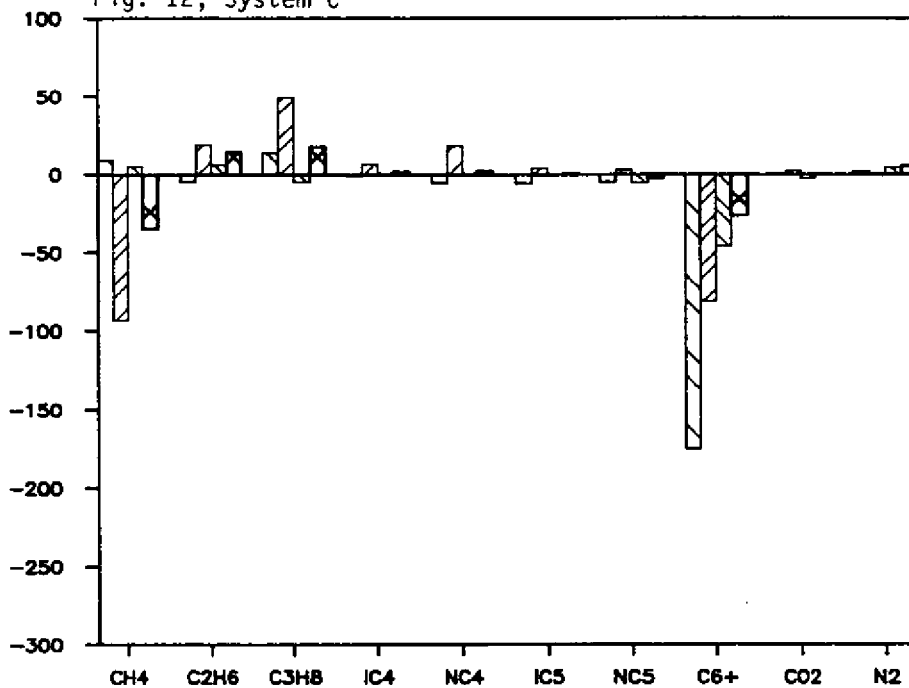

Fig. 11, System B

1. period   2. period   3. period   4. period

GAS CHROMATOGRAPH PHASE III
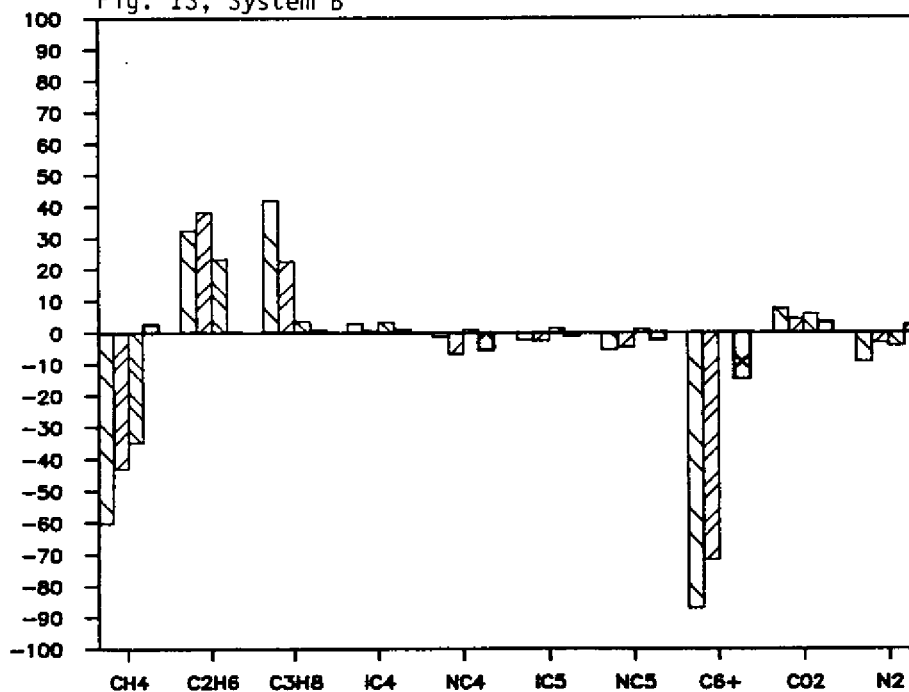

Fig. 12, System C

% OF MAX REPROD. ACC. TO ASTM 1945

5. period 6. period .7 period 8. period

Fig. 13, System B

% OF MAX REPROD. ACC. TO ASTM 1945

5. period 6. period 7. period 8. period