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"The KO210 Flow Metering Control System"

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THE KO210 FLOW METERING CONTROL SYSTEM

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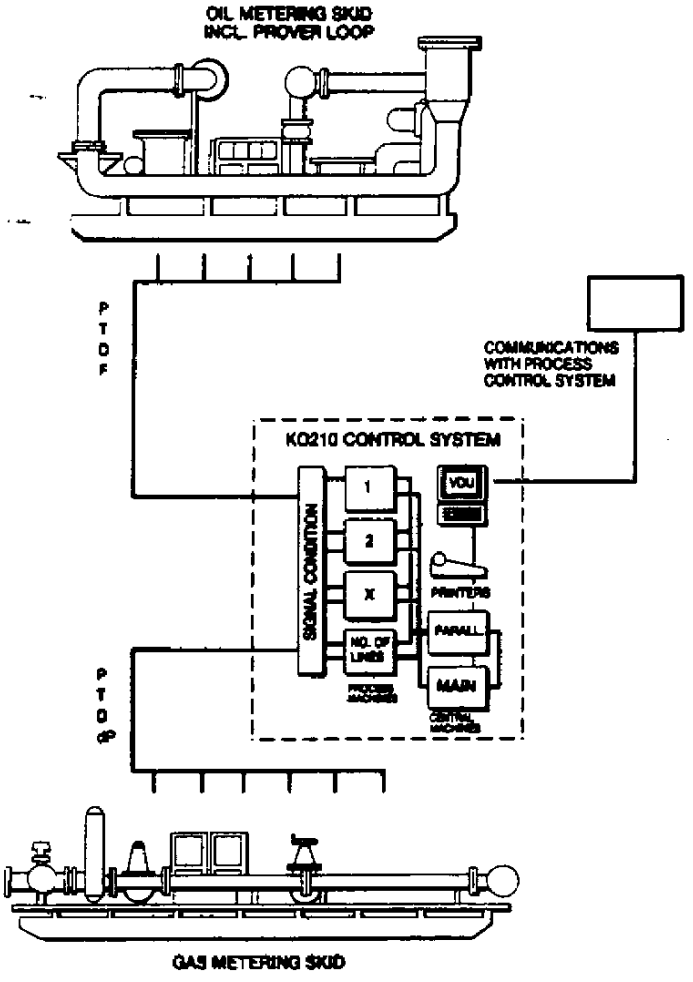
1 INTRODUCTION

The KO210 Fiscal Metering Control System is a hierarcial, two level computer system. The first level of the system is the Process Machine (PM) performing all interfacing with the metering skids, i.e. all input/output signals are connected to the Process Machine. In a typical installation with both oil and gas metering skids, one common Process Machine can monitor and control one gas line, one oil line including the prover. However, it can be configured as one Process Machine for each metering line.

The other level is the Central Machine (CM) which communicates with all Process Machines of an installation. The Central Machine comprises the Control System main data storage and performs the operator interactions. The Central Machine also performs stations totalising, statistical data computation and it performs the reporting on printers.

The Central Machine can be configured either as two redundant computers with one in charge and the other as standby, or as a single computer according to actual requirements.



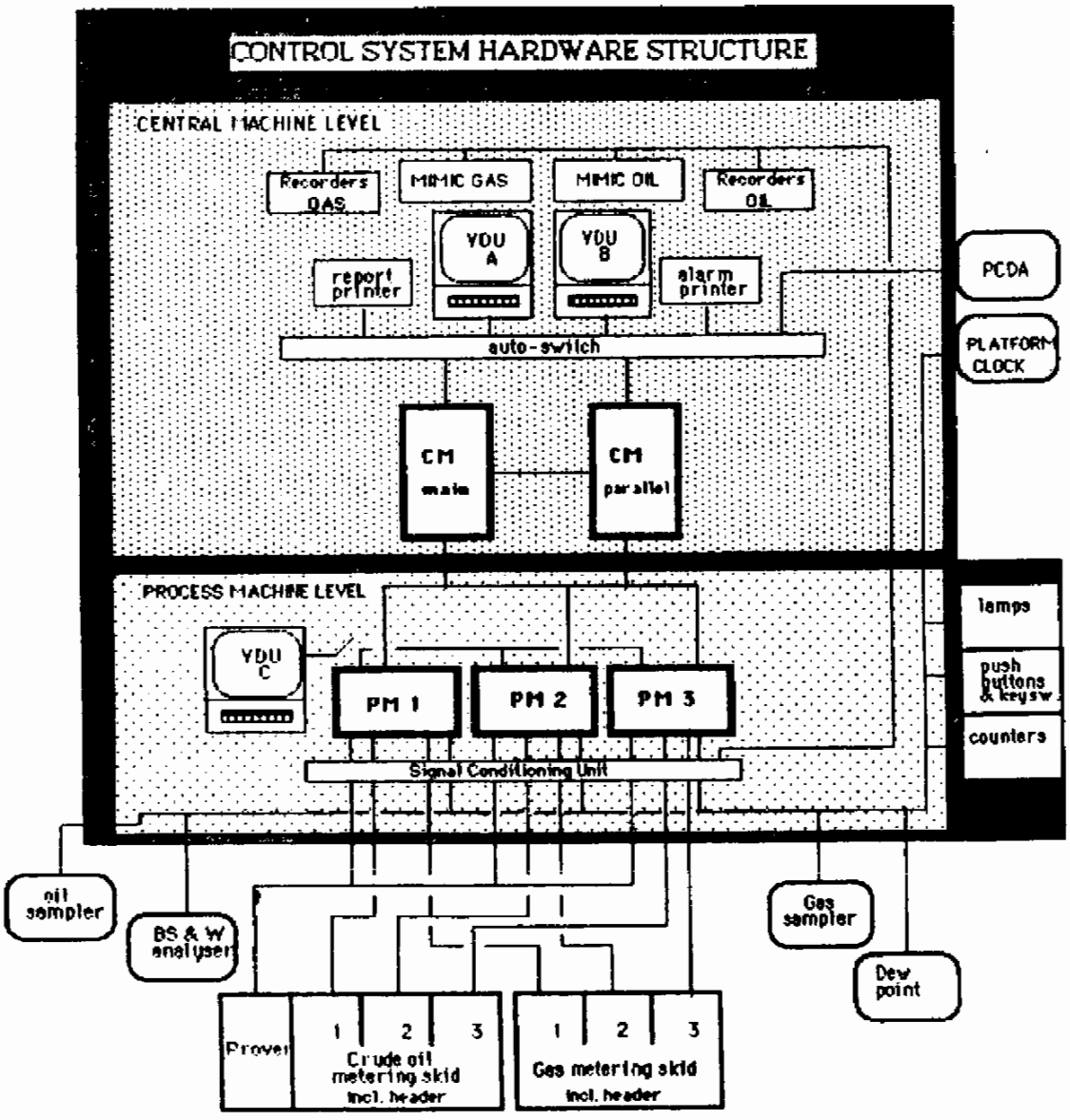
Flow Metering System Structure

2 CONTROL SYSTEM DESCRIPTION

The sketch below indicates a control system equipped with customer requested, additional facilities such as mimic panels and pen recorders. The "process" in this case, is an oil skid with three metering lines (including turbine meters prover) and a gas skid with three orifice based metering lines.

The metering stations are also interfaced with flow proportional samplers, BS&W analyser, Dew point analyser, external (Platform) clock and a Process Control (PCDA) system.

The Control System comprises three Process Machines, two Central Machines, two printers, a monochrome VDU and two colour VDU's. The printers and colour VDU's are connected to the Main Central Machine and the Parallel Central Machine through an automatic switch.



Example of a Flow Metering Control System for two metering stations.

2.1 PROCESS MACHINE FUNCTIONS

A single Process Machine will in the case described above, handle the signal readings and fiscal computation for one oil metering line and one gas metering line. It also interfaces to all signals of the turbine meter prover and will control the proving for the turbine meter of its oil metering line. Each Process Machine is connected to common station equipment, such as BS&W and Dewpoint analysers, flow proportional samplers, and in this actual case, a platform clock. A Process Machine transmits its data simultaneously to both Central Machines.

PROCESS MACHINE FUNCTION OVERVIEW

- COMMUNICATIONS WITH TWO CENTRAL MACHINES
- INFORMATION/DATA DISPLAY
- PARAMETER ENTERING FACILITIES
- ERROR LOGGING
- PROCESS EVENT LOGGING
- ALARM LOGGING
- WATCHDOG
- SAMPLER CONNECTION
- LINE INTERLOCKING FACILITIES
- LINE CALIBRATION MODE
- PROVING SEQUENCING OIL LINE
- CHECKSUM VERIFICATION
- ACCUMULATION
- BACKUP DENSITY CALCULATION
- FLOW CALCULATIONS
- VALVE SEQUENCING (OPEN/CLOSE LINE)
- SIGNAL LIMIT CHECKING (ALARMING)
- INSTRUMENT INPUT/OUTPUT SIGNAL HANDLING

All instruments of a metering line are interfaced with the Process Machine through dedicated input/output (I/O) modules. Depending on the signal type, the I/O module in question will perform signal handling as required. Data is made available for the Process Machine CPU, by the I/O module, for limit checking, calculations and storage once a second, in general, (digital signals are available 10 times a second).

Analogue input signals (pressure, temperature, differential pressure) are converted to digital form by an Analogue Input Module with a resolution of 14 bits and an accuracy better than 0.02%, including resolution and input resistance accuracy figures.

A densitometer is connected to a Pulse Input Module which counts the pulses continously and transfers the frequency to the Process Machine CPU with an accuracy better than 0.01%.

Turbine meter signals are handled by a Turbinemeter Pulse Counter Input Module which counts the two pulse trains individually. Pulse security handling is performed in accordance with ISO 6551, level A.

During turbinemeter proving, pulses from the turbinemeter will be handled by a Proving Pulse Counting Input Module which will perform pulse interpolation according to ISO 7278/3 (double timing method), when required. Number of pulses is available for the Process Machine CPU for each trial.

Within each second, the Process Machine will perform the following calculations according to fiscal standards for both a gas and an oil line:

- volume flows
- mass flow
- increment of volumes
- increment of mass
- accumulated volumes
- accumulated mass
- density
- backup density

The calculations are made using 64 bit real number representation of: 11 bit exponent, 52 bit fraction part and one sign bit. This gives a real number representation of 15 significant digits.

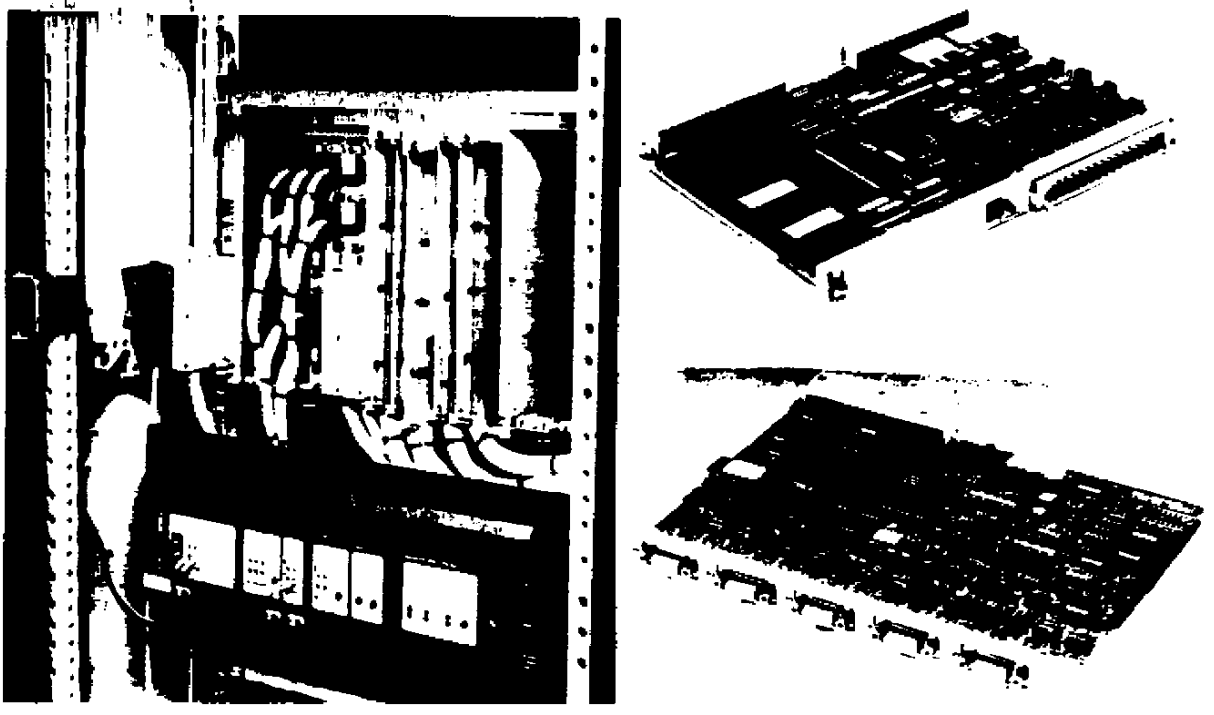
2.2 PROCESS MACHINE HARDWARE

The Process Machine hardware is based on the well proven Sicomp MMC216 microcomputer family from Siemens. Those computers are used in a wide range of applications such as:

* onshore industry installations for:
  - water treatment control
  - pig flesh quality determination
  - airport runway light control
  - steel production control (one system is a multi-computer installation with as much as 80 CPU's).

* marine/offshore installations on:
  - naval vessels
  - metering systems

The hardware construction of the MMC216 computer is a traditionally microcomputer structure with an internal powerful 16 bits bus located in a subrack with power supplies, fans, backup battery and free slots for insertion of CPU, memory and I/O modules. The Process Machine has good computing performance utilizing Intel types of processors including additional numeric data processor.



Process Machine with some typical modules

Most of the Process Machine modules are of the Sicomp type. However, some of the I/O modules are of the Siemens Simatic S5 type since the Simatic and the Sicomp computers are based on almost the same internal bus. The selection of I/O modules are made from a functionality, an industrial experience and a price point of views. The I/O modules are powered by dual redundant power supplies.

The modules of the Process Machine are of the double Europa format.

2.3 PROCESS MACHINE SOFTWARE

A Process Machine comprises software for performing all tasks concerned with metering and control of one gas line, one oil line, turbinemeter prover and communications with two Central Machines simultaneously. In addition, the Process Machine has operator interaction software for data information and manipulation purposes. All signal scanning and calculations are performed within one second.

The data acquisition, scaling and limit check unit performs all signal input and output via the appropriate I/O module. It scales the read-in signal according to the signal engineering unit representation. It also does alarm checking, such as limit violation or rate of change checking. Scaled data is put into the data base, while alarms or events are put into the alarm/event list.

The oil calculation unit and the gas calculation unit perform fiscal calculations according to actual procedures and regulations and enter the results into dedicated registers. Both flows, increments and accumulations of volumes and masses are determined. Implemented algoritms are: gas calculations according to ISO 5167 and oil calculations as described in "IP Petroleum Measurement Paper, no. 2". However, the system is designed for special customer preferences to be installed.

Oil density can be entered as a fixed number, as calculated according to the method of Costald or based on densitometer readings. Gas density can be entered as a fixed number, as calculated according to AGA 8, as calculated according to the KATZ method or based on densitometer readings. Automatic selection of density to be used can be established.

The prover control unit calculates all data related to one round trip trial of proving. The result is placed in the data base for transmittal to the Central Machines and for display on the Process Machine. This unit also performs the prover loop valve sequencing before and after proving, as well as it does pressure, temperature and flow supervision during the stabilisation period.

The communications unit sends data to the Central Machines and it also receives data from those computers and distributes it to the correct data area of the Process Machine data base.

The operator interaction unit gives an operator the possiblities for inspection of the Process Machines database as well as it provides facilities for data manipulation, i.e. line control, proving, sampling and parameter changing.

The checksum control unit calculates and compares checksums for both fiscal algoritmns and data area containing parameters influencing on the calculation results. Alarm will be rised upon any discrepancy.

2.4 CENTRAL MACHINE FUNCTIONS

A Central Machine is connected to all Process Machines by dedicated communication cables, one cable from each Process Machine to each Central Machine. The Central Machine acts as the Control Systems main data base, i.e. it contains all correct information. The Central Machine performs all station totalising of flows and accumulated values. It also calculates average values, the proportional sampling frequency, and it performs the proving management (which line to prove and how many trials to do) and also performs report printing at predefined intervals.

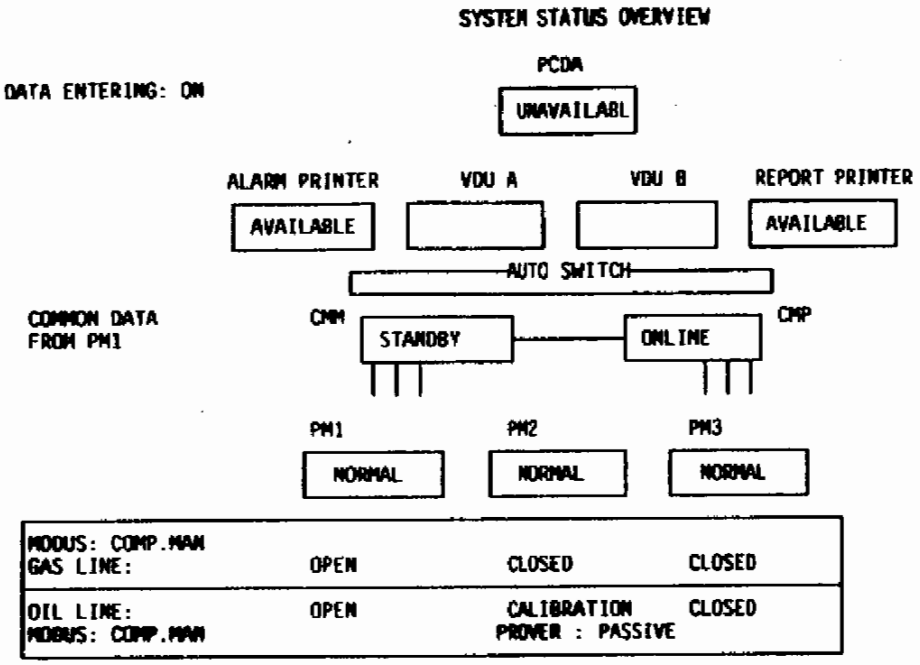
CENTRAL MACHINE FUNCTION OVERVIEW

- PCDA (OR OTHER EXTERNAL) COMMUNICATIONS
- GAS CHROMATOGRAPH CONNECTION
- COLOUR MIMIC DISPLAYS
- PARAMETER ENTERING FACILITIES
- LOGGING OF OPERATOR ENTERED DATA
- PRINTING OF DATA
- PREPARATION AND AUTOMATIC PRINTING OF REPORTS
- ERROR LOGGING
- ALARM LOGGING AND PRINTING
- PROCESS EVENT LOGGING AND PRINTING
- CONTROL SYSTEM CONTROL
- SAMPLING MANAGEMENT
- PROVING MANAGEMENT
- PROVING QUEUE HANDLING
- AVERAGE CALCULATIONS OF SELECTED VALUES
- STATION TOTALISING
- STATION ALARMING
- DEVIATION CHECKS BETWEEN OPEN LINES OF A STATION
- OPEN/CLOSE LINES IN COMPUTER AUTO MODE
- WATCHDOG
- COMMUNICATIONS WITH ALL CONNECTED PROCESS MACHINES

External communication connections to the Control System will be to the Central Machine.

The Central Machine monitors parameter deviation between open lines and will rise alarm if necessary. It opens and closes metering lines of a station depending on flow variations.

The Central Machine supervises the complete Control System status, and will take actions depending on disturbances introduced to the system. In a configuration as described earlier, comprising dual Central Machines and three Process Machines covering one gas and one oil metering station, the information used for making decisitions are showed in the two displays below, the System Status and the Computer Status Overviews.



System Status Overview Display

COMPUTER STATUS OVERVIEW

PICTURE ONLY AVAILABLE ON CM BEING IN STATUS

ONLINE

ALL INFORMATION REPRESENTS THIS CM'S VIEW OF THE ACTUAL SITUATION

TIME PERIOD BY PLATFORM CLOCK: OFF

PLATFORM CLOCK SIGNAL VALUE: WINTER

COMPUTER	STATUS	COMMUNICATION	WATCHDOG STATUS	CONNECTIONS
CMM	STANDBY	CMP:NORMAL PM1:NORMAL PM2:NORMAL PM3:NORMAL	CMM:NORMAL CMP:NORMAL PM1:NORMAL PM2:NORMAL PM3:NORMAL	PCDA:********** APRN:********** RPRN:********** PLATF.CLOCK STS: NORMAL
CMP	ONLINE	CMM:NORMAL PM1:NORMAL PM2:NORMAL PM3:NORMAL	CMM:NORMAL CMP:NORMAL PM1:NORMAL PM2:NORMAL PM3:NORMAL	PCDA:UNAVAILABL APRN:AVAILABLE RPRN:AVAILABLE PLATF.CLOCK STS: NORMAL
PM1	NORMAL	CMM:NORMAL CMP:NORMAL	CKS:NORMAL I/O:NORMAL	ERR:OFF PWR:NORMAL
PM2	NORMAL	CMM:NORMAL CMP:NORMAL	CKS:NORMAL I/O:FAILED	ERR:OFF PWR:NORMAL
PM3	NORMAL	CMM:NORMAL CMP:NORMAL	CKS:NORMAL I/O:NORMAL	ERR:OFF PWR:NORMAL

Computer Status Overview Display

The backup Central Machine will automatically take over as the in-charge Central Machine based on predefined takeover criteria. A takover will be performed mainly for two reasons, either its told by the other Central Machine to take over, or it determines itself that the other is not performing its duties.

The main parameters for decision making, is the watchdog signals, the communication status and the metering line status.

As examples, the following two cases are given. The system status before any disturbances is assumed as described by the two overview displays:

case 1: Disturbance: communication between PM1 and CMP fails.
Action : CMM enters ONLINE status and CMP enters STANDBY status. Printers, VDU's and external connections are switched automatically from CMP to CMM. Totalising and sampling will not be influenced. Alarm is rised.

case 2: Disturbance: PM1 fails.
Action : both gas and oil metering lines are kept open until the oil and gas metering lines of PM3 are opened automatically by the system monitoring task. Then lines of PM1 are closed. Common data will be routed to PM3. Alarm is rised.

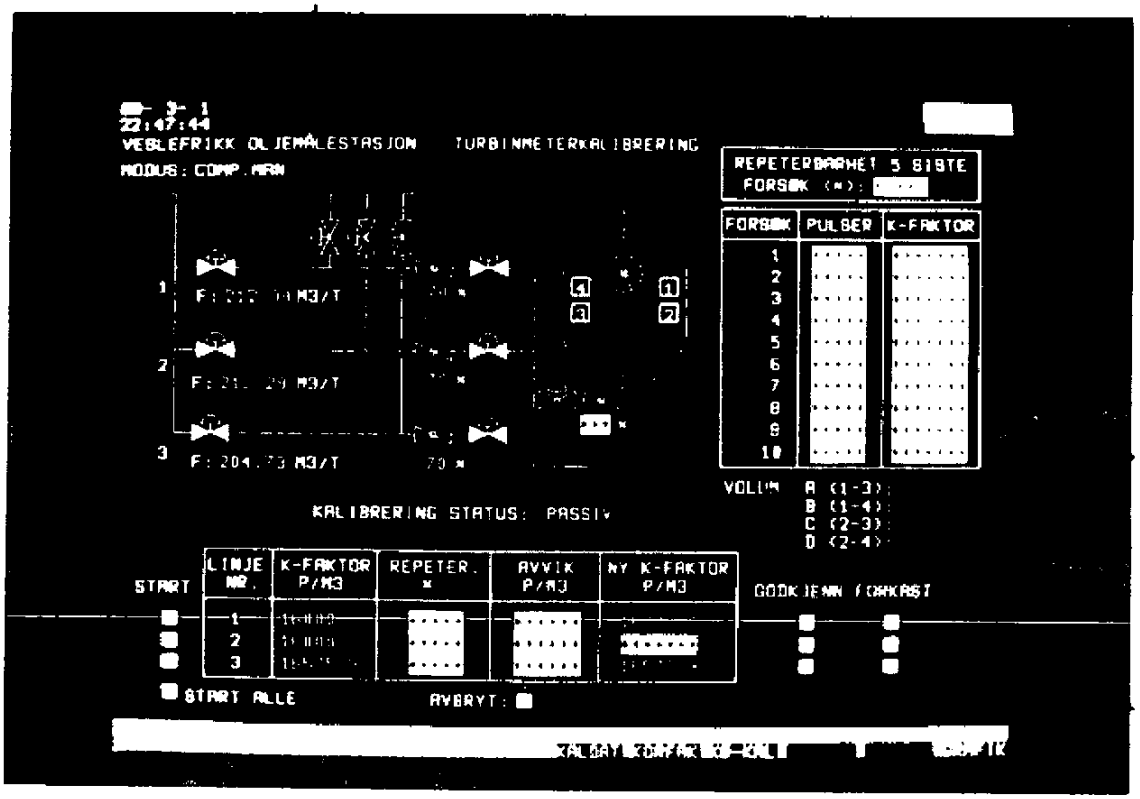
3 CONTROL SYSTEM OPERATIONS

A major contribution for a Flow Metering Control System to do correct metering is to be equipped with a good man-machine interface. The K0210 Flow Metering Control System comprises facilities for easy to use and consistent parameter alterisation, quick process status understanding and good report printing.

Although the system used as an example of this paper comprises several operation equipment, the system can be operated from one single VDU.

The system information is grouped in three main categories: the mimic colour pictures, the parameter entering menues and the reports. All three categories are available at the Central Machine level, whilst the Process Machines supports the menues with some extentions.

An important aspect of an information display is that it contains all data associated with a function and only that. An example of that is the turbinemeter proving control mimic picture.



Turbinemeter proving control picture

Parameter entering menues are available for lookup at any time, but data can only be changed if the access key is switched on. Each parameter is displayed with its currently used value and with an explanatory text along with it. Parameters which logically are related will be grouped together in one menu. An example is shown below. Menues are identically while displayed by a Central Machine or a Process Machine.

89-03-01 23:23 PM NO: 02

PROVER DATA

Volume for one round trip at std. cond.:	Current val	New val
Volume A (1-3).....(Sm3):	1.238353	1.238353
Volume B (1-4).....(Sm3):	1.309503	1.309503
Volume C (2-3).....(Sm3):	1.219373	1.219373
Volume D (2-4).....(Sm3):	1.289783	1.289783
Maximum flow deviation.....(m3/t):	95.3	95.3
Flow transmitter period.....(s):	13	13
Pressure deviation prover - line.....(barg):	4.53	4.53
Temp. deviation prover - line.....(DegC):	7.53	7.53
Time to stabilise.....(min):	3	3
Period to first detector.....(s):	23	23
Period to second detector.....(s):	43	43
Period before 4-w valve is turned.....(s):	3	3

Press ESC for return to previous menu

Menu for entering proving related parameters.

Parameters common for all Process Machines will be sent to all of those it concerns. If a Process Machine is unavailable at the time the parameter is changed, the Central Machine will registrate that and update the Process Machine as soon as it becomes available.

The RAM of the Process Machine is battery backed up. If, however, a situation occurs, f.i. a Process Machine replacement, where the configuration data of a Process Machine is lost, the configuration including latest parameter update will automatically be downloaded from the Central Machine at power up of the Process Machine.

The system also supports displays for maintenance and detailed data investigations. Each single prosess signal or calculated value of the data base can be investigated using a specific dislay. For analogue input signals as shown in the figure below, the information available includes both the analogue to digital converters internal representation (the decimal count value) of the signal and the digital (16 bits) representation of the signal in addition to the scaled value in engineering units.

```
89-03-01 23:23                                              PM NO: 02

                          ----------------
                            POINT DISPLAY
                          ----------------

  TAG no..... :  21-TE108A
  Description :  01: LINE TEMPERATURE
  Signal no.. :  2
  Unit....... :  DegC

                          Value    Status      Alarm     Lock
  Current val :          50.085   ##########   ####      alarm
                           9841
                0010011001110001

  Alarm limits
  High instr. :          101.00                 gen
  High limit. :
  Low limit.. :
  Low instr.. :           -1.00                 gen

Press ESC for return to previous menu
```

Process Machine single point display.

The Process Machine´s system functions comprises facilities such as computer time alteration, list of alarm history (the other alarm list includes only active alarms at the time it is displayed), internal computer program error logging display, forced data base configuration upload/download to/from the Central Machine and a status display of all input/output modules of the actual Process Machine.

```
89-03-01 23:23                                              PM NO: 02

                          --------------------
                            I/O-MODULE STATUS
                          --------------------

  Type                      Address        Status

  Digital in              CE00:0008        OK
                          CE00:0010        FAILED
  Digital out             CE00:0008        OK
                          CE00:0010        FAILED
  Analogue in             CE00:0040        OK
                          CE00:0080        FAILED
  Analogue out            CE00:0020        FAILED
  Counters                CE00:0100        FAILED
                          CE00:0140        FAILED
                          CE00:0180        FAILED
  Watchdog                CE00:0400        FAILED

Press ESC for return to previous menu
```

Process Machine Input/Output Module Status Display.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.