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ABSTRACT

The report describes a microcomputer-controlled instrument intended for operational measurement on experimental water loop. On the basis of pressure and temperature input signals the instrument calculates the specific weight, γ, and for ten operator-selectable measuring channels it calculates the mass flow, G(kp/s), or the voluminal flow Q(m^3/h). On pressing the appropriate push-buttons the built-in display indicates the values of pressure (p) and temperature (t), as well as the values of the specific weight γ calculated therefrom. For ten individually selectable channels the instrument displays either the values of the pressure differences of the measuring throttling elements ($\sqrt{\Delta p_i}$), or the values of G_i or Q_i as obtained calculationally. In addition, on pressing the Σ-push-button it summarizes the values of G_i and Q_i for the selected channels. The device is controlled by type 8085 microprocessor, the analogic unit MP 6812 being used as the A/D convertor. Instrument algorithm indicates also some errors which concern both the faults of the input signals and the mistakes in the calculation.

1. INTRODUCTION

The water loop built in Škoda Works, Plzeň, operates with different pressures and temperatures. In some cases it is necessary to measure the mass flow rate, while other situations necessitate to know the voluminal flow rate of water. It should be taken into consideration that varying water parameters are connected with a variation of its specific weight on which are both values of the flow rate dependent. Therefore a flow meter has been developed and built whose working algorithm is controlled by a microcomputer.

In ten selected points of the water loop there have been placed ten throttling elements connected to differential manometers whose sensors provide data about the pressure loss, the data being given in the form of $\sqrt{\Delta p_i}$. Further input signals for the flow meter is the pressure signal p and temperature signal t which serve for determining the specific weight γ.

In mathematical terms, individual quantities are defined as follows:

Specific weight :

$$\gamma = A_o + B_o p + t(A_1 + B_1 p + t/A_2 + B_2 p + tA_3/) \qquad /1/$$

where γ (kg/m^3)...specific weight of water
p(Pa).......water pressure
t(^{o}C).......water temperature
$A_o \div A_3$,.......constants
$B_o \div B_2$.......constants

Equation /1/ approximates the dependence $\gamma = f(p,t)$ within the region $t = 40 \div 320$ ^{o}C, $p = 0.1 \div 18$ MPa with a relative error $|\Delta\gamma/\gamma| < 0.7\%$.

$$\text{Mass flow} \quad G_i = K_i \frac{\sqrt{\Delta p_i \cdot \gamma}}{3600} \qquad /2/$$

where G_i(kg/s).....mass flow
Δp_i(kPa).....pressure drop on throttling element of the i-th measuring channel
K_i..........constant of the i-th measuring channel
γ(kg/m^3)....specific mass

Voluminal flow $Q_i = K_i \sqrt{\frac{\Delta p_i}{\gamma}}$ /3/

where $Q_i (m^3/h)$......voluminal flow,

other symbols are the same as in eq. /2/.

2. FUNCTIONAL DESCRIPTION

On the front panel of the device are placed 3 rows of push-buttons and a four-digit display.

The first row of the mutually exclusive push-buttons enables the operator to select the quantity which he wishes to be displayed. The display can show the values of p, t, and that of γ obtained calculationally therefrom. These values are independent on the selected channel. Moreover, the display can show the value of $\sqrt{\Delta p_i}$, G_i or Q_i for the i-th channel selected. The row contains also independent push-buttons Σ and TEST which are dealt with hereinafter.

The second row contains ten push-buttons excluding mutually each other. These buttons serve for selecting the channel to be measured.

The third row contains the mains push-button and the resetting one (i.e. the button which sets the program to beginning).

The display consists of numeric indicators for displaying numbers in a region from 0.001 up to 9999 as well as symbols of errors discussed later. The right section of the display accommodates LEDs indicating the dimension of the displayed quantity.

Input signals are fed via a connector situated on the rear panel of the instrument. A view of the instrument prepared for building into a panel switchboard is shown on fig. 1.

3. HARDWARE OF THE INSTRUMENT

The circuit scheme of the instrument is presented on fig. 2. The input signals are differential, maximum voltage is +5 V, and they are led onto the inlets of the A/D convertor of the type MP 6812 as delivered by the firm Analogic. The convertor cooperates with the microprocessor as a specialized peripheral equipment. The microcomputer consists of a microprocessor (type 8085, firm Intel), two memories EPROM (type 8755 with a capacity of 2 kB), a memory (RAM-type, 8155) with a capacity of 256 B and an address decoder type 8205. The memory packages accommodate also programmable I/O ports. Manual inputs from channel selectors (TK) and from the selectors of the displayed quantity (TD) are led onto input ports in the modules M1 and M2. The display is controlled by the output ports from module M3 (control of digits) and M1 (control of decimal indicator). The selector of displayed quantity has an additional push-button called "TEST" enabling to check the instrument without connecting the input signals by feeding the internal voltages onto one inlet of the convertor. Simultaneous pressing of the push-buttons Σ and TEST displays the magnitude of internal voltages on converter inlets in volts.

4. PROGRAM OF THE INSTRUMENT

The basic flow chart is shown on fig. 3. The input signals are converted into a floating-point format which serves for performing the calculations. The format is of three-byte type and of the shape $x = a \cdot 2^b$, the mantissa being of two-byte type and the exponent of one-byte type.

Furthermore, individual sections of the functional diagram are briefly described.

4.1. Section "PREPARATION"

It serves to programmed setting of I/O ports in the packages M1 ÷ M3 and determines which port will operate as an input port and which as the output one.

4.2. Section "READING"

It provides 3 functions:

a) reading the input variables p, t, $\sqrt{\Delta p_i}$ from converter's input and their storing into microcomputer memory

b) reading the code of the selected channel from input push-buttons TK

c) reading the requirement imposed on the displayed value from the input push-buttons TD.

4.3. Section "THE DETERMINATION OF CHANNEL NUMBER"

This section performs the following functions:

a) it checks whether some push-button of channel selection is pressed down; if not, the device indicates an error

b) it calculates number of the selected channel on the basis of read channel code

c) it is checked whether channel number has not been changed; if so, the new value is read after the corresponding waiting loop is passed through

d) the address of the normalizing constant as well as the constant of selected channel are calculated.

4.4. Section "NORMALIZING OF VALUES"

This section converts measured signals p, t, Δp_i into a normalised shape used in further calculation.

4.5. CALCULATING SECTIONS

These are program sections for calculating γ, G_i and Q_i by means of equations /1/, /2/, and /3/.

If there occurs during the calculation a mistake involving overflowing, a negative number under the square-root sign, etc., a symbol of error is sent on the display.

4.6. SUMMATION SECTION

During the operation of the water loop it is sometimes required to know the sum of flow rates in several points. The instrument provides this information after pressing the push-button designated "Σ". The device then sums the flow rates of individual, successively selected channels (in each summing cycle each channel can be selected only once). Therefore, the summing section of the program performs the following functions:

a) it checks whether summation is required or not

b) if summation is not required, it resets the auxiliary variables of the summation unit

c) if summation is required, it checks whether the selected channel number is changed. If there has occurred no change, the summation unit does not operate. If a change has occurred, it checks whether channel number has occurred in the summing cycle for the first time. If so, it adds the values of G_i to ΣG_i and Q_i to ΣQ_i, and it will remember the new selected number. In opposite case it provides an information of error.

4.7. DISPLAY

a) on the basis of the code of displayed value selector it determines the displayed value

b) it transfers the value from the floating-point format into another one which is suitable for display (4 decadic ciphers and decimal point), and these data are sent on the output ports of the display

c) it indicates some incorrect states of the instrument. An error is indicated in the field of the first cipher by a sign ⌴, and in the fields of the 3rd and 4th ciphers it produces a two-digit code whose meaning is as follows:

00...measured value of the input quantity is zero

01...displayed number is outside the display range

02...no measuring channel is selected

03...error originating during calculation (division by zero, radical of a negative number, etc.)

04...repeated pressing of the same push-button during summation cycle

05...in simultaneous pressing of push-button TEST and the quantity of p, t, or $\sqrt{\Delta p_i}$ is not selected.

4.8. WAITING LOOP

It ensures that the information is not fed onto display more frequently then once in a second, and that there is no flickering of the display.

The program of the instrument has been debugged on the MDS 221 (firm Intel) development system and incorporated into 2 EPROM memories, type 8755. The program is so divided that the main program including all special subroutines are recorded into the first memory, while in the second memory are standard subroutines for converting binary numbers into floating-point format, and for mathematical operations with these numbers (multiplying, division, finding the square root of a number, summation, etc.). One cycle of the program lasts approx. 100 ms, while length of the program is approx. 3 kB.

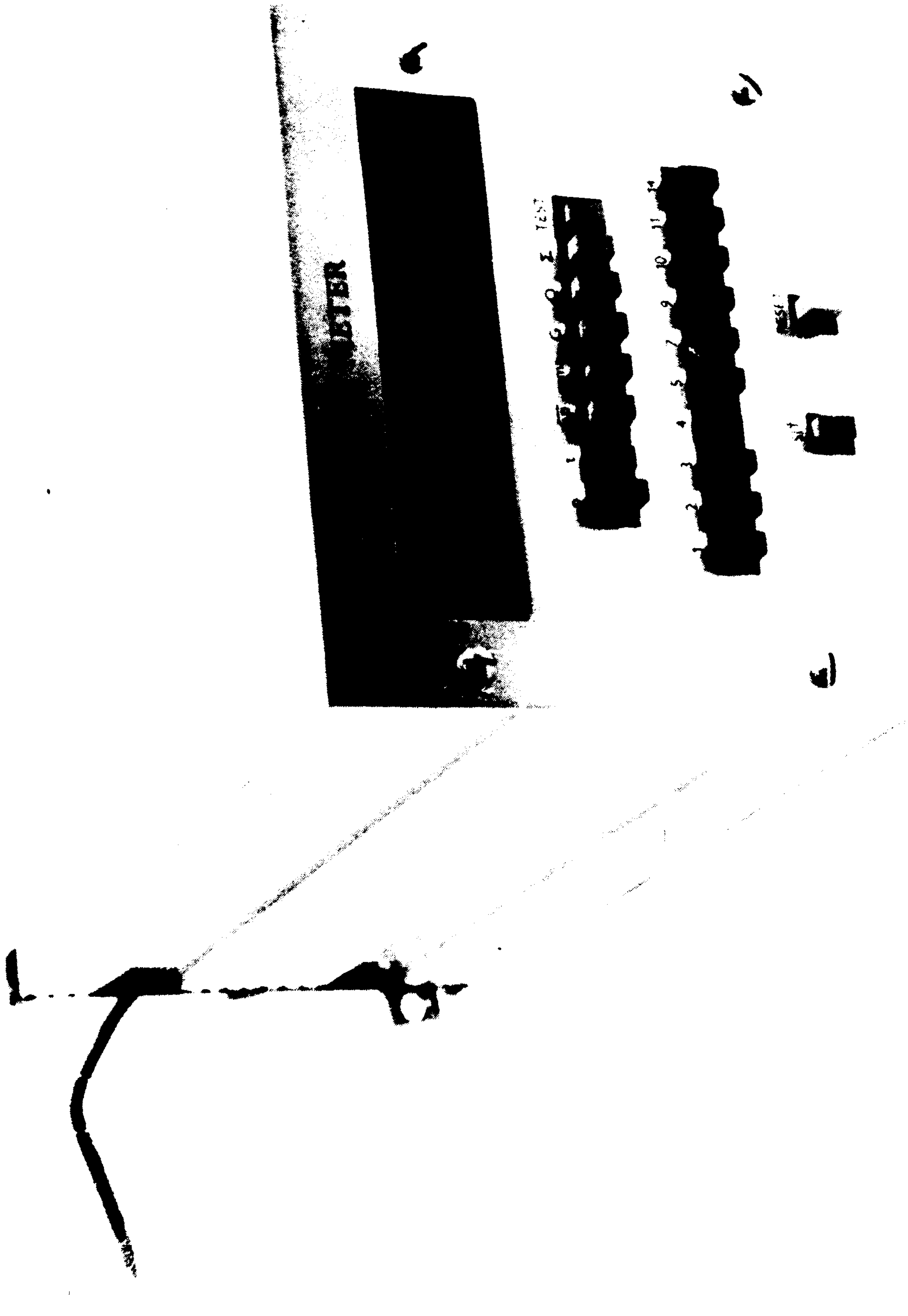
5. STRUCTURAL ARRANGEMENT

The circuits of the instrument are accommodated in two plates arranged one over the other. The bottom plate accommodates 4 packages of the microcomputer while the upper one carries the converter and other auxiliary circuits. The back part of the mechanical section houses the supply. The size of the instrument is 160 x 140 x 280 mm. The input signals are fed onto a connector placed on the rear wall of the instrument.

6. CONCLUSIONS

This report describes a microprocessor-controlled instrument intended for operational measurement on experimental water loop. The instrument has been built using the microprocessor type 8085 and it is now installed in the control room of the water loop where it undergoes long-term tests.

Fig. 1.



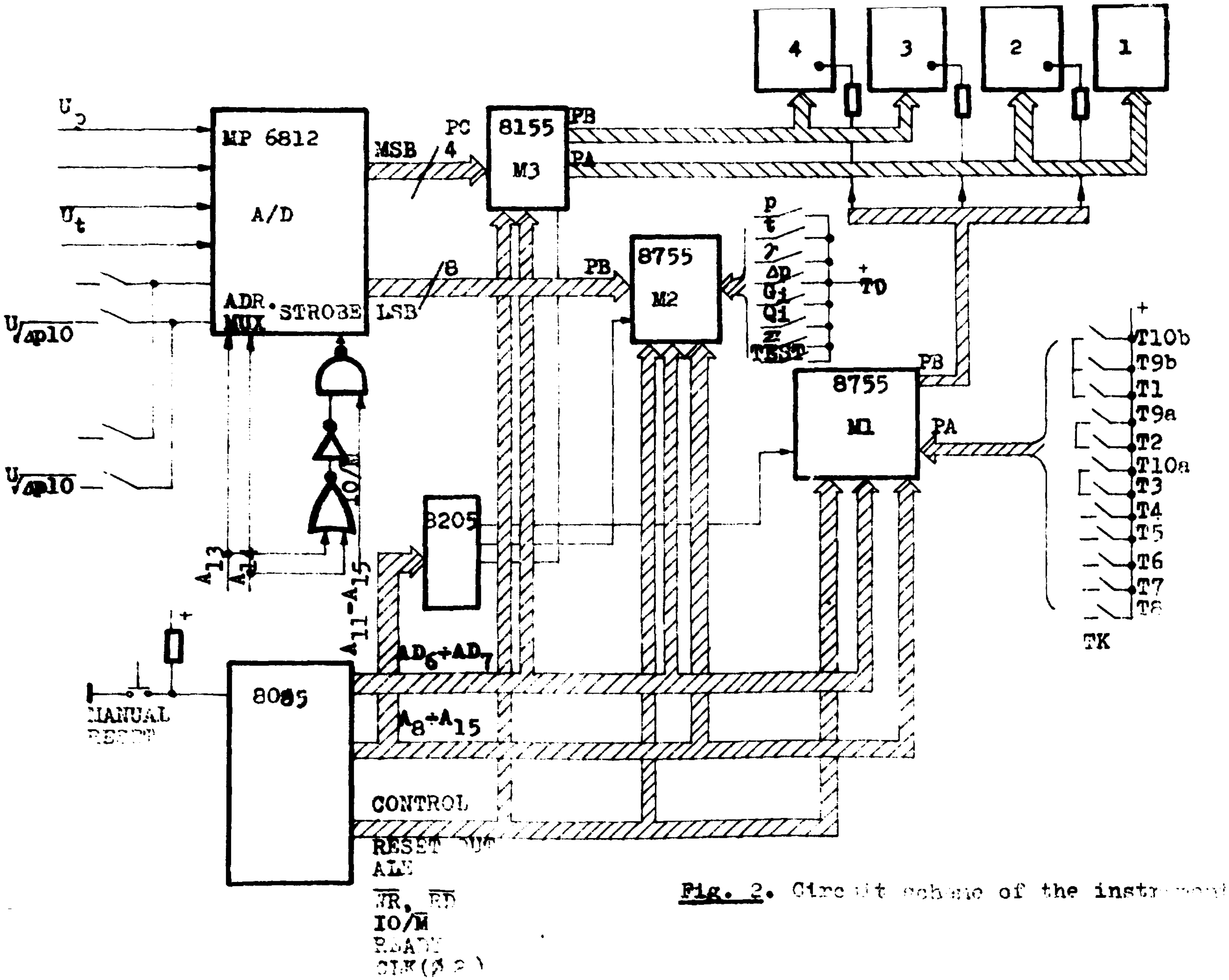


Fig. 2. Circuit scheme of the instrument

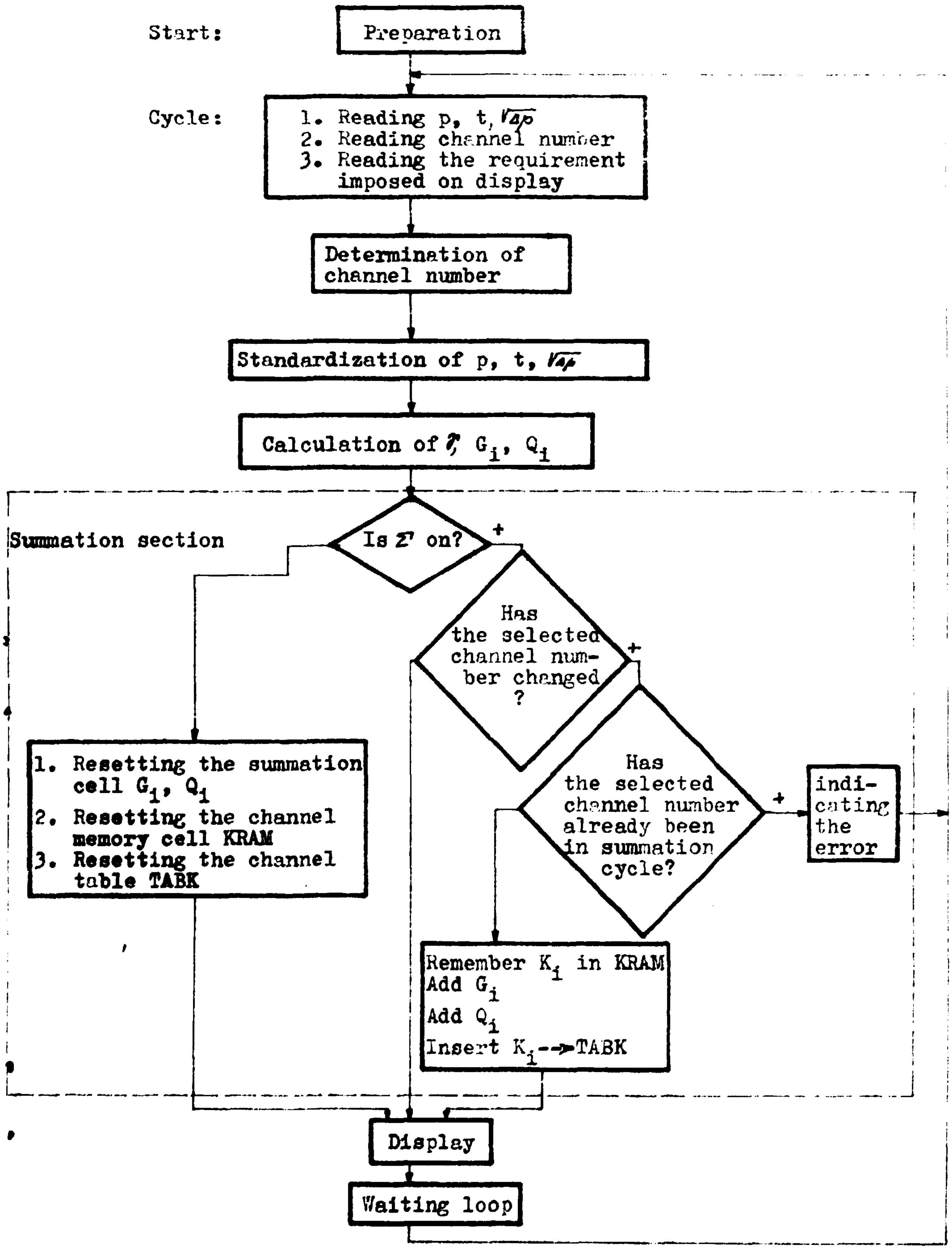


Fig. 3. Basic flow chart of the instrument