

IMPLEMENTATION OF TOXIC GAS MONITORS WITH COMPUTER LOGIC CIRCUIT

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ABSTRACT

The inherent problems with toxic gas monitors with continuous tape movement are the low resolution due to the tape background and the high operating cost caused by the requirement for frequent tape changes. This paper presents an incremental tape movement technique to alleviate the problems associated with the continuous tape movement.

INTRODUCTION

Toxic gas detectors can be constructed with one of several commercially available paper tape cassettes. These tapes will respond by changes in surface color (referred to as stain level) when they are exposed to a particular gas. Commercial paper tapes are chemically treated to be compatible with the gas to be monitored and therefore, by a proper selection of paper tape cassettes, one can monitor a variety of gases such as hydrogen chloride, phosgene, isocyanate, ammonia, chlorine, and hydrazine.

The basic configuration of a gas monitor is as shown in Figure 1. The gas to be monitored is drawn through the tape by a low pressure diaphragm pump. Stain levels are detected by an opto-electric circuit consisting of a light source and two photo cells (reference and signal) as shown in Figure 2. The photocells are mounted side by side on an optic block so that the reflected lights from the blank and the exposed parts of the tape are viewed by the reference and signal photocells, respectively (Figure 3). The light source, whose intensity is equivalent to stain level of blank tape (zero stain), is provided by a pair of lamps connected in series (Figure 2). Since the reference photocell is mounted so as to view the reflected light from the blank tape, its internal resistance varies as a function of zero strain, thereby controlling the output of the differential amplifier U1. Thus, whenever there is a change of tape background, the intensity of the light source will change due to the change of internal resistance of the reference photocell.

The output of the signal photocell (transducer) viewing the reflected light from the exposed part of the tape gives the gas concentration with respect to the zero strain level. To obtain a high resolution for the voltage range (mV range) provided by the transducer, an amplifier (U2) with a minimum predetermined gain is



FIGURE 1. BLOCK DIAGRAM OF TOXIC GAS MONITOR

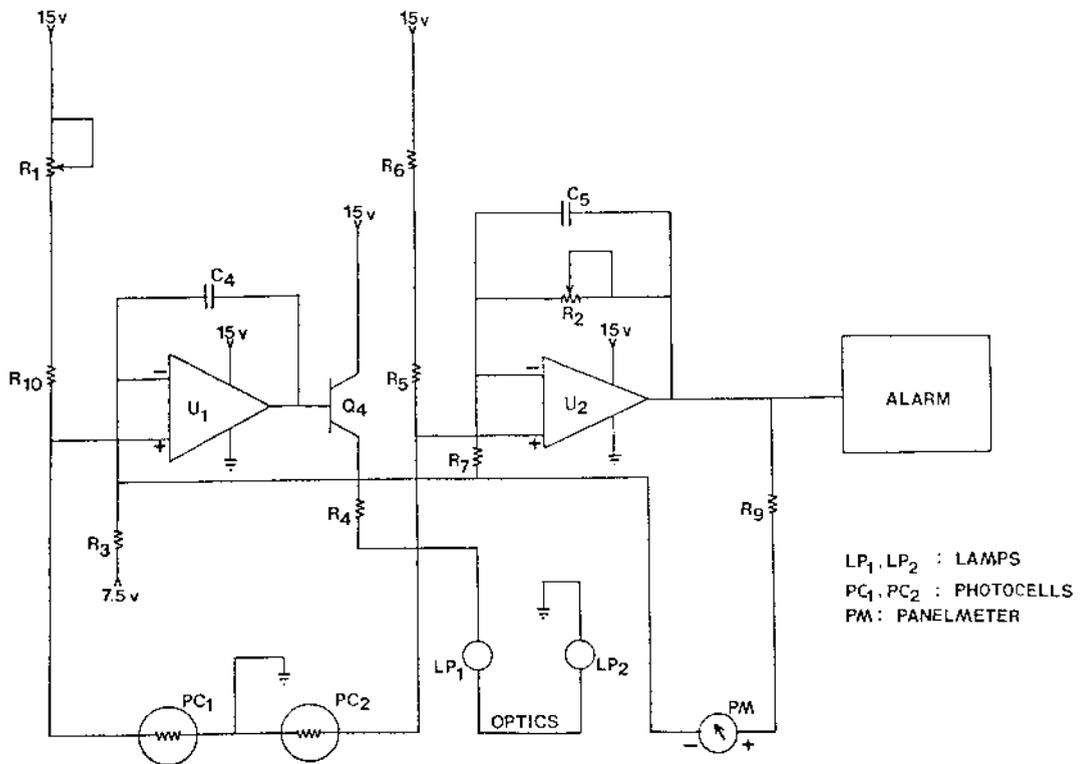


FIGURE 2. OPTO-ELECTRIC CIRCUIT

interfaced with the transducer output. The amplifier output drives an alarm circuit and a panel meter as shown in Figure 2. Whenever gas concentration exceeds the tolerance level, the transducer output activates a buzzer in the alarm circuit. The panel meter is calibrated to monitor gas concentration directly.

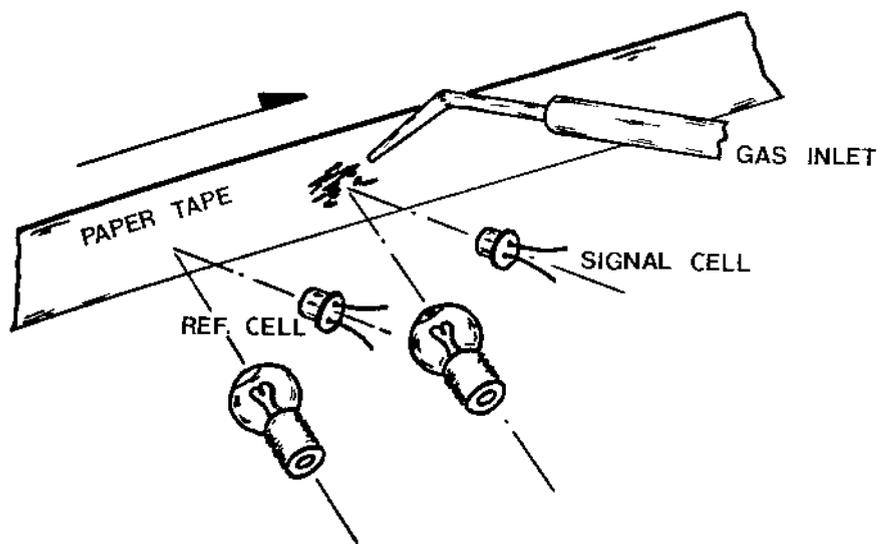


FIGURE 3. OPTIC BLOCK

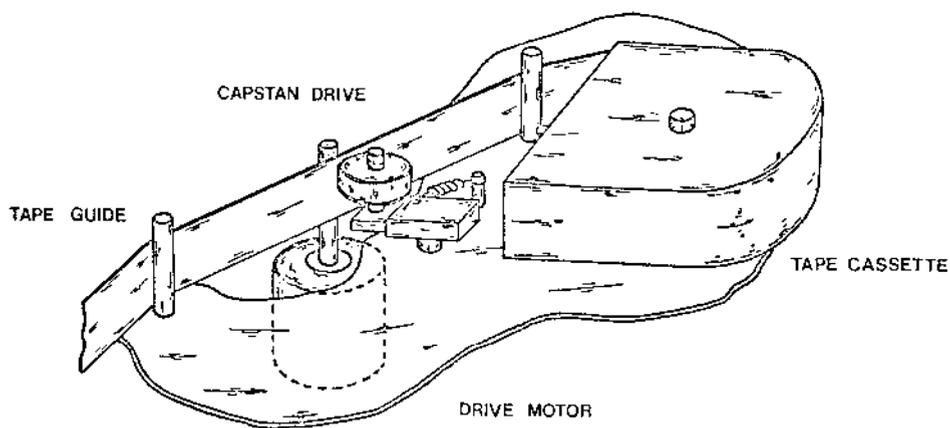


FIGURE 3A. TAPE TRANSPORT SYSTEM

Tape stain levels are irreversible and therefore, a motorized tape transport system is employed to advance unexposed tape sections in front of the photocells mounted on the optic block. Most of the commercial toxic gas monitors are implemented with continuous tape movement using a slow speed motor turning a capstan drive along with a rubber pinch roller to provide enough friction for smooth tape advancement as shown in Figure 3a. The whole system is usually housed in a "Nema Box" type enclosure to prevent the tape from being exposed to the external environment.

Monitors with continuous tape movement must be calibrated in the laboratory by means of stain cards with two artificial stain spots. With the stain spot for zero stain facing the photocells, the variable resistor (R1) associated with the reference photocell must be adjusted for zero panel meter reading. The same procedure must be repeated with the gain spot and resistor R2, associated with signal photocell for full scale deflection of panel meter.

The problems associated with the commercial toxic gas monitors are due to the continuous tape movement and the tape background noise. In addition to the requirement for frequent tape changes, the tape movement rate must be low enough to provide an exposed part of the tape with sufficient stain reaction time. The zero stain problem with the continuous tape movement is due to the heterogeneous nature of paper tape for a given chemical composition. Due to the fact that no two spots of tape have the same background, the practice of using a reference cell gives gas concentration readings with respect to zero stain for the spot facing the reference cell. Also the practice of using a reference cell will lead to the possible problem of spot overlap. Whenever gas with high toxic level is monitored, the stain formed at the spot facing the signal photocell will grow and reach the spot facing the reference cell thereby increasing the zero stain level. This increased zero stain level will result in a low concentration reading.

This paper presents an incremental tape technique which, when added to the existing monitors with continuous tape movement, will alleviate the inherent problems associated with continuous tape movement monitors.

INCREMENTAL TAPE TECHNIQUE HARDWARE

The problems associated with the continuous tape movement can be eliminated by the use of an incremental tape circuit. In the incremental tape technique, the tape is advanced and held at the optic block for a predetermined time (referred to as sample time). Since the tape is held stationary during the sample time, sufficient time is provided for stain formation. Also, at the beginning of the sample time, the signal from the signal transducer is treated as zero stain thereby completely eliminating the problem associated with the heterogeneous nature of tape.

Incremental tape logic is achieved by the use of a computer logic circuit (Figure 4). It is interfaced with the opto-electric circuit, panel meter, and the alarm circuit through a 3PDT switch as shown in Figure 5. The 3PDT switch can be set in one of two positions (RESET, RUN). When the switch is in the RESET position, the incremental circuit is isolated from the system and the zero stain and gain adjustments are made as in the case of continuous tape movement. The system is controlled by the computer logic circuit when the switch is in the RUN position. During the RUN mode, the amplified analog signal from the opto-electric section of

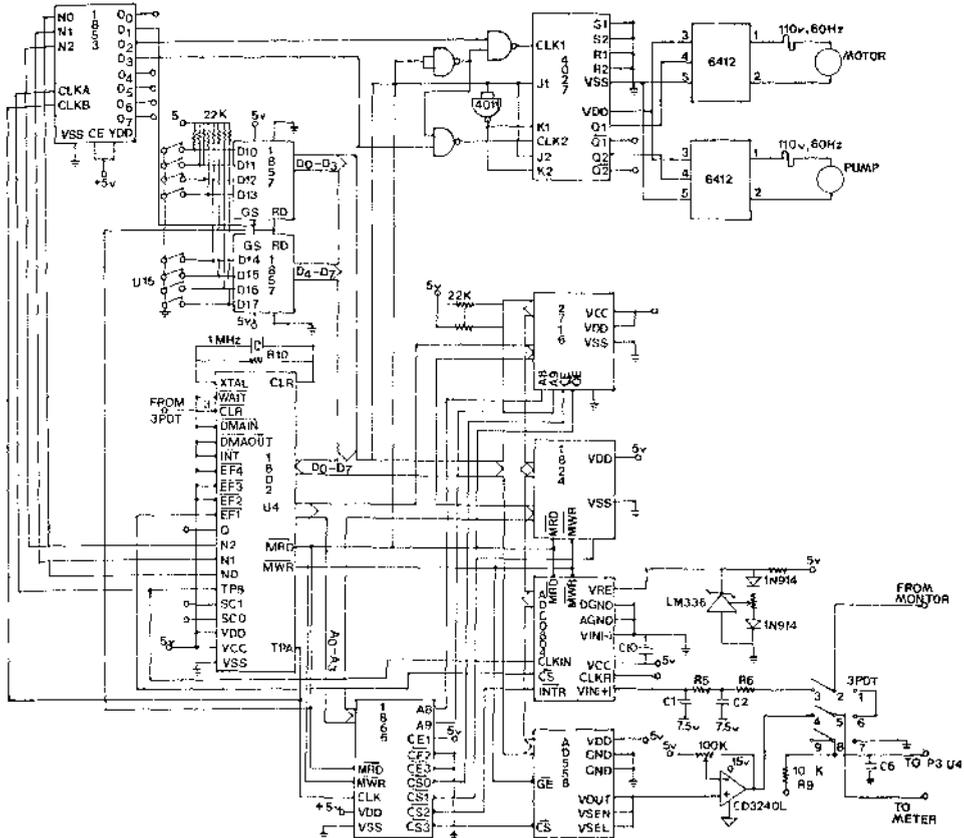


FIGURE 4. INCREMENTAL TAPE LOGIC CIRCUIT

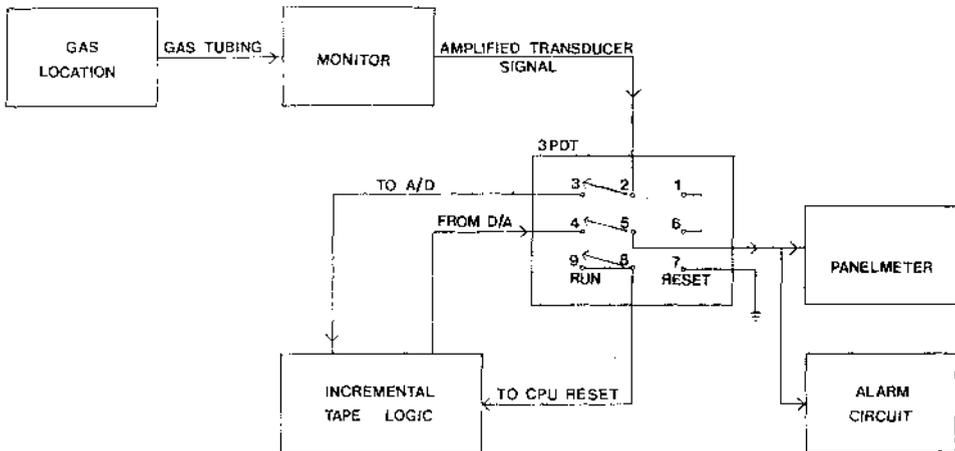


FIGURE 5. BLOCK DIAGRAM OF TOXIC GAS MONITOR WITH INCREMENTAL TAPE LOGIC

the system is fed to the computer circuit by the use of an analog to digital converter (A/D). The A/D is interfaced with the processor by a hand shake data transfer technique in order to compensate for their speed difference. The status of analog to digital conversion is indicated by the output INTR of the A/D. Upon sensing an active INTR signal, the processor will read the gas concentration in digital form from the A/D. Since the A/D has a resolution of eight bits, there are 256 possible digital readings. In order to read the digital data from the A/D as the direct measurement of the amplified analog signal, a reference voltage of 2.56 volts is provided for the A/D as shown in Figure 4. For this direct digital stain measurement, the digital ground and panel meter reference voltages must be the same. The incremental tape circuit uses 2K bytes of EPROM (implemented with INTEL's IC2716) for program storage and 32 bytes of RAM memory (implemented with RCA's IC1824) for data storage. The processed digital stain data from the processor is converted back to analog form by the use of a digital to analog converter (D/A) in order to drive the panel meter. The A/D and the D/A are located in the memory map so that they can be addressed by the device-select pulses generated by the memory address decoder (implemented with RCA's IC1866). The I/O address decoder, implemented with RCA's IC1853, generates device-select pulses for driving one input and a pair of output devices. The input device is used for selecting the sample time and it consists of a pair of 4 bit tri-state buffers (IC 1857) and an 8 position dip switch. The computer logic circuit uses the output devices in order to switch the motor and pump. The output devices consist of a dual D-Flip flop and a pair of solid state relays (CRYDUM's DC/AC 6412). With the exception of the EPROM, A/D, and the D/A, the incremental tape circuit is implemented with CMOS devices because of their high noise immunity and low power consumption.

SOFTWARE

The important aspect of a toxic gas monitor with incremental tape movement is that it is a software-controlled hardware. Sufficient time and effort must be spent for developing software in order to utilize the instrument effectively. The program logic begins with the initialization of stain and device pointers. The sample time is then read and stored in one of the buffers located in RAM memory. Two locations of RAM memory (Stain buffers) are reserved under the labels 'OSTAIN' and 'NSTAIN' in order to give gas concentration levels of the last and the current sample intervals, respectively. The stain buffers are reset before the start of first sample interval. The sample interval logic consists of tape advance and monitor routines. The order of functions to be performed in the tape advance routine is as follows:

- A. Turn pump off and motor on.
- B. Enter a time delay routine for advancing the tape.
- C. Turn motor off.
- D. Enter a time delay routine for suppressing motor noise.
- E. Read and save zero stain in the ZSTAIN buffer.
- F. Load the stain buffers in order to start the next sample interval.
- G. Load the panel meter with the content of NSTAIN buffer and reset NSTAIN.
- H. Activate the pump and enter a time delay routine for suppressing pump noise.

At the completion of tape advance routine, the pump draws gas samples through the fresh tape to form stain. The processor enters a monitor routine in

order to read stain for the rest of the sample interval. The duration of this interval is controlled by the sample interval time that was read and saved in RAM memory during the tape advance routine. In the monitor routine, the processor samples the A/D continuously. The zero stain is subtracted from the A/D readings to generate gas concentration levels. The instantaneous maximum of any two consecutive positive gas concentration levels is always saved in the NSTAIN buffer. Thus, at the end of the monitor routine, the content of NSTAIN buffer represents the toxic level of the gas sample. When the monitor routine is completed, the control is transferred to the tape advance routine of the next sample interval. The flow chart and the listing of the software are as shown in Figure 6 and Figure 7.

```

OSTAIN    EQU R2
NSTAIN    EQU R3
ZSTAIN    EQU R4
ATOD      EQU R5
DTON      EQU R6
PUMP      EQU 3
MOTOR     EQU 2
TIME      EQU 1
  Initialize Stain Pointers
    DISABLE
    IDLE
    LDI 00H; PLO OSTAIN
    LDI 04H; PHI OSTAIN
    LDI 05H; PLO NSTAIN
    LDI 04H; PHI NSTAIN
    LDI 0A1H; PLO ZSTAIN
    LDI 04H; PHI ZSTAIN
  Initialize Device Pointers
    LDI 00H; PLO ATOD
    LDI 081H; PHI ATOD
    LDI 00H; PLO DTON
    LDI 00H; PHI DTON
  Read and Store Sample Time
    SEX R3
    INP TIME
    PLO R3

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FIG. 6 INCREMENTAL TAPE TECHNIQUE PROGRAM

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  Initialize Stain
    LDI 00H
    STR OSTAIN
    STR NSTAIN
  Enter Tape Advance Routine
LOOP12   SEX R0
         OUT PUMP           Pump Off
         DC 01H
         OUT MOTOR         Motor on
         DC 00H
         LDI 80H; PLO R8    Wait for tape advance

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LOOP2    LDI 80H; PLO R9
LOOP1    DEC R9
          GLO R9
          BNZ LOOP1
          DEC R8
          BNZ LOOP2
          OUT MOTOR           Motor off
          DC 01H
          LDI 20H; PLO R8     Time delay for motor noise
LOOP4    LDI 80H; PLO R9
LOOP3    DEC R9
          GLO R9
          BNZ LOOP3
          DEC R8

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FIG. 6. INCREMENTAL TAPE TECHNIQUE PROGRAM (Continued)

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          GLO R8
          BNZ LOOP4
          Read and Save Zero Stain
          STR ATOD           Enable A/D
LOOP5    BN1 LOOP5           Wait for End of Conversion
          LDN ATOD
          STR ZSTAIN
          LDN NSTAIN
          STR OSTAIN
          STR DTOA
          LDI 00H
          STR NSTAIN
          Enter Monitor Routine
          OUT PUMP           PUMP ON
          DC 00H
          LDI 20H; PLO R8     Time Delay for Pump Noise
LOOP7    LDI 80H; PLO R9
LOOP6    DEC R9
          GLO R9
          BNZ LOOP6
          DEC R8
          GLO R8
          BNZ LOOP7
          GLO RF             Retrieve Sample Time
          PLO R8
LOOP11   LDI 0FFH
          PLO R9
LOOP10   DEC R9
          STR ATOD           Enable A/D
          BN1 LOOP8           Wait for EOC
LOOP8    LDN ATOD           Read A/D
          SEX ZSTAIN         Subtract zero stain

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	SM	
	BM LOOP9	Skip on no stain
	PLO RE	Save Stain level
	SEX NSTAIN	Check for increase in stain level
	SM	
	BM LOOP9	Skip on no stain increase
	GLO RE	Redefine new stain when there is
	STR NSTAIN	stain increase
	SEX OSTAIN	Check if current stain is greater
	SM	than meter reading
	BM LOOP9	
	GLO RE	Update meter if NSTAIN is greater
	STR DTOA	than display
LOOP9	GLO R9	
	BNZ LOOP10	
	GLO R8	
	BNZ LOOP11	
	LBR LOOP12	
	END	

Fig. 6. INCREMENTAL TAPE TECHNIQUE PROGRAM (Continued)

CONCLUSION

The incremental tape circuit described in this paper is designed to monitor a single sample point. But, this computer logic circuit can be easily expanded to monitor gases from multiple sample points. When monitoring gas concentration levels from multiple points, the monitor is stationed at a central location. The gas samples from various locations are brought to the monitor by the tubing arrangement as shown in Figure 8. The solenoid valves (S1, S2, S3, . . . Sn) are actuated by the monitor. The pump P1 is always on in order to purge gas samples through the main tubing; whereas, the pump P2 is controlled by the monitor to draw gas samples only when needed. Normally, the monitor operates in parallel mode. In the parallel mode, all the solenoid valves are open and a gas mixture from all the locations is purged through the main tubing. The gas mixture thus formed is monitored using a procedure similar to the one for single point sampling. If a significant toxic level is detected, the monitor will enter a sequential mode. In the sequential mode, individual sample points are monitored to identify the location or the locations having high level concentration. Significant cost reduction can thus be achieved by monitoring multiple sample locations with a single gas monitor. Also, in the incremental tape technique, the requirement for frequent change of tape can be minimized by reusing the tape for more than one sample time if the toxic level is not significant. In most of the personal gas monitoring systems, it is required to document time weighted average (TWA) of toxic gas level for a given period of time. This can be easily achieved by interfacing a real time clock circuit and a non-volatile memory system (such as disk drive) with the incremental tape circuit.

The most important aspect of the incremental tape technique is that it is implemented with a computer logic circuit. Computer logic circuits are software-controlled and therefore, by a proper selection of program logic, functions such as

multiple sample point monitoring, tape reuse, and TWA can be easily achieved without major changes in the hardware.

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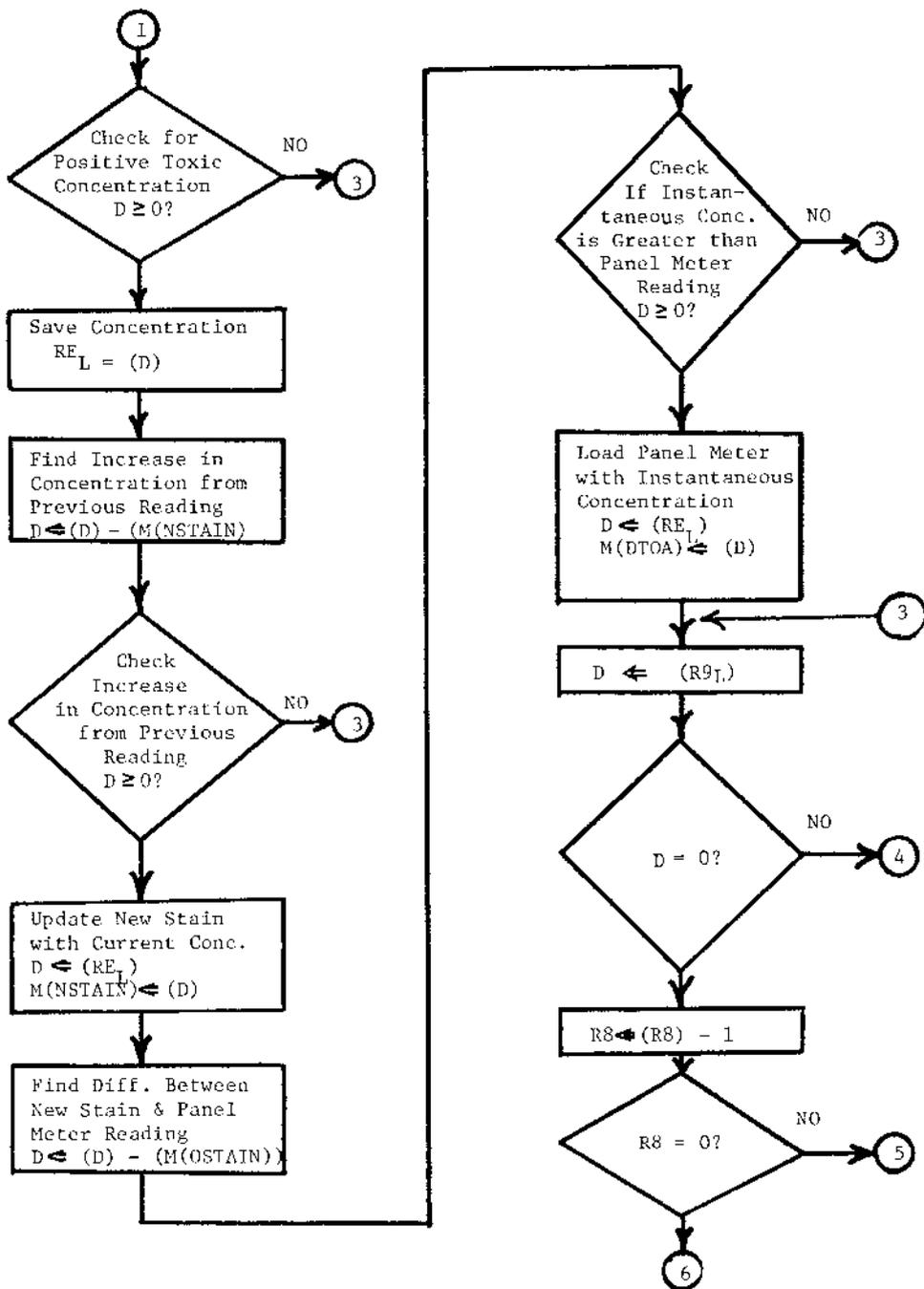


Figure 7. FLOW CHART FOR INCREMENTAL TAPE TECHNIQUE

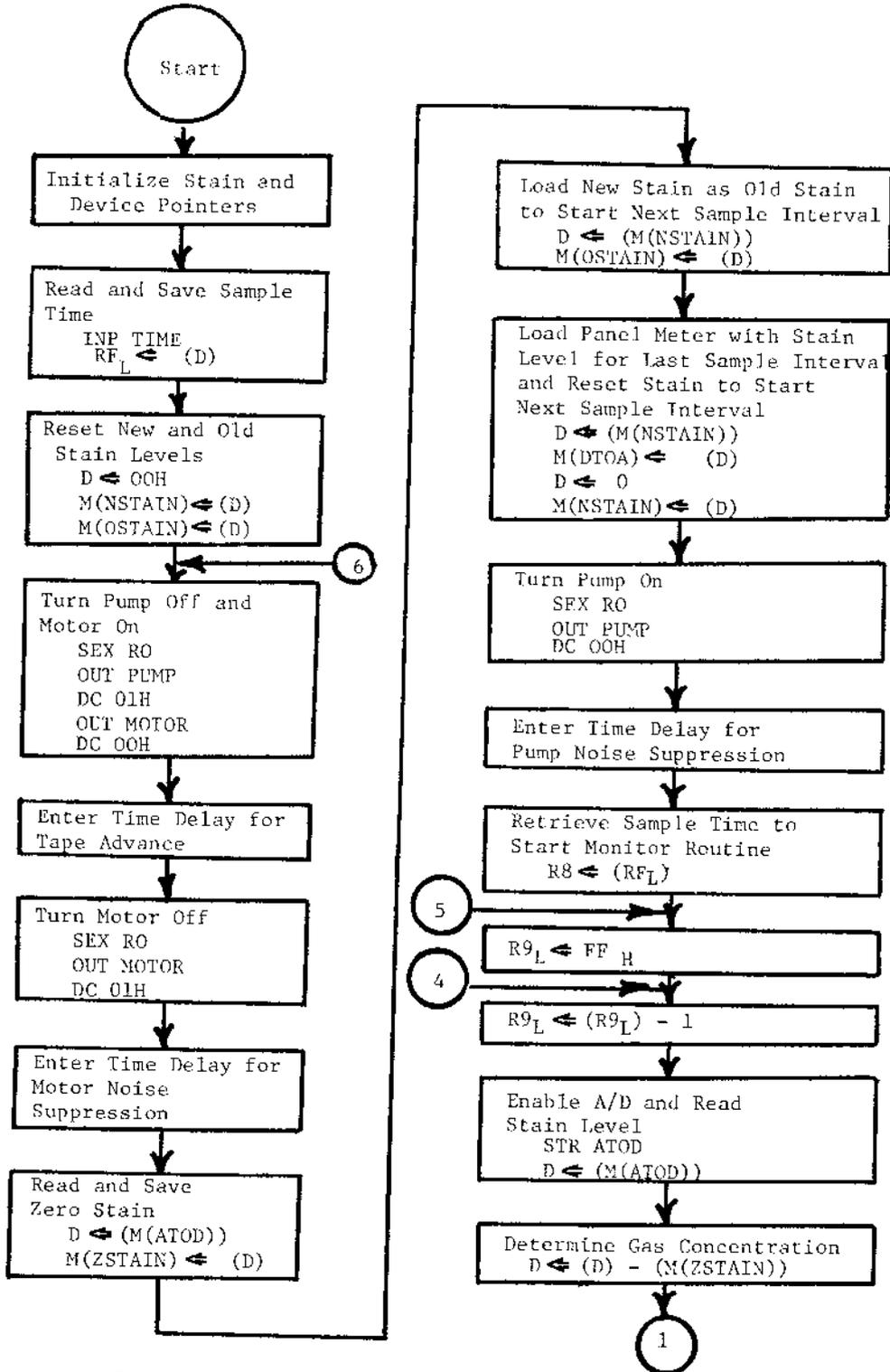


Figure 7. FLOW CHART FOR INCREMENTAL TAPE TECHNIQUE (Continued)

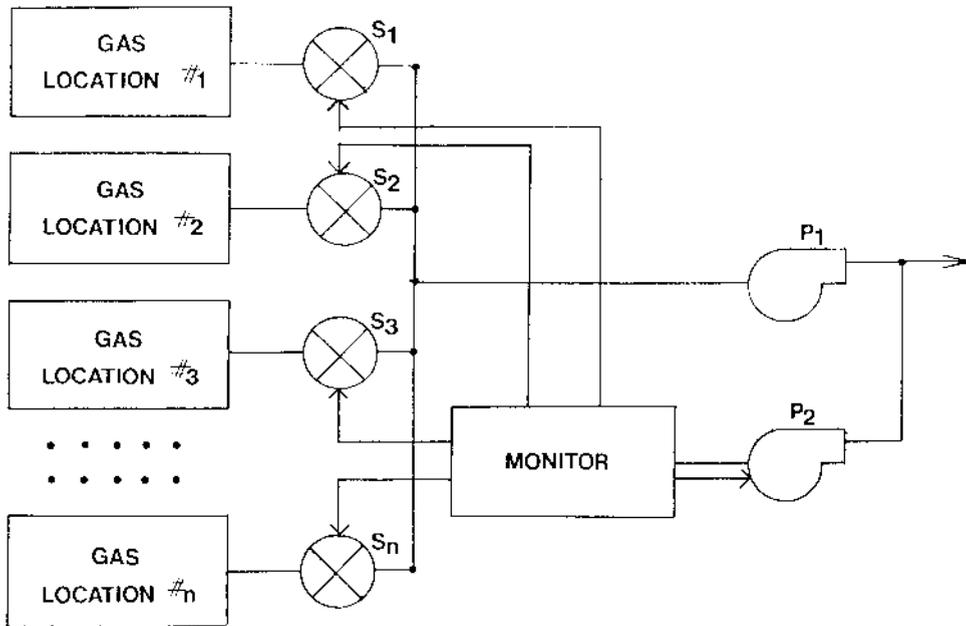


FIGURE 8. BLOCK DIAGRAM OF TOXIC GAS MONITOR WITH MULTIPLE SAMPLE POINTS