A versatile automatic gas-sampling system

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Introduction

Commercially available equipment for automatic gas-sampling is both expensive and bulky. Air infiltration into refrigerated areas should ideally be measured with low-cost, portable, automatic gas-samplers, capable of operating in a wide range of ambient temperatures. This paper describes such a sampler. Although the need for portability limits the size of the equipment and therefore the volume of sampled gas, the consequent reduction in accuracy was not significant in this application. Depending on which tracer gas is used, its concentration in the sampled gas can be determined by infra-red spectroscopy or gas chromatography.

The portable gas-sampler was used to determine the infiltration of warm air into a number of single-storey cold-rooms with volumes from 4000 to 38 000 m³ and various types of door protection [1]. Infiltration was determined by measuring the rate of decay of the tracer gas SF₆ (sulphur hexafluoride). If the tracer gas becomes well mixed with the air in the room, the rate at which its concentration, c , decreases with time can be related to the rate of air change, r (i.e. the infiltration rate divided by the volume of the room) by:

$$\ln(c/c_0) = -rt$$

where c_0 is the initial concentration and t is the time after injection.

Sulphur hexafluoride can be detected by electron-capture gas chromatography at concentrations down to one part in 10¹³ [2]. It is completely harmless to people and products, relatively inexpensive, and thus ideal for tests in large rooms, such as meat cold-stores.

Description

The sampler mechanism consists of a rotating drum, or turntable, housing a number of vertically positioned, vacuum-sealed, 20 ml test-tubes. The turntable is mounted on a vertical axle, which is rotated in steps by a modified uniselector mechanism to position each sampling tube directly beneath a hypodermic needle (figure 1). For measurements of air infiltration into cold-stores 24 test-tubes are used. The hypodermic needle is connected via a flexible tube to a small diaphragm pump, which in turn is connected via tubing to the area from which the gas is to be sampled. A reciprocating mechanism, driven by a pulsed d.c. motor, moves the hypodermic needle downward to penetrate the rubber bung of the sample tube, thereby exposing it to the test atmosphere (figure 2). After a pre-set delay the needle is withdrawn upward from the self-sealing bung. The turntable is rotated in two steps to position the next sampling tube beneath the needle, and an LED starts flashing at 1 s intervals to indicate that timing is taking place.

Figure 1. Turntable mechanism.

Figure 2. Needle mechanism.

The timing interval is determined by the setting of a decade thumbwheel switch, each digit representing 10 min. Because the thumbwheel switch setting is 'read' at the start of each sampling interval, the interval can be changed during sampling, if required, by changing the switch setting. The sampler will automatically fill all the sample tubes and then stop, regardless of the time interval setting.

The microprocessor not only controls the timing intervals and stepping sequences, it also regulates the torque of the d.c. motor to reduce 'over run' after switch-off. A stand-by battery provides immunity against short-term power failures. A flow diagram is shown in figure 3 and an assembly listing is given in figure 4. Full documentation of the system is available from the authors.

There are six push-button control switches. The 'Auto' button starts the automatic sampling sequence; 'Start test', 'Stop test', 'Reset', 'Motor' and 'Step' buttons allow the operator to check that the automatic control system and mechanism are functioning correctly before the machine is operated in the automatic mode.

Start test

The Start test button is used to check that the mechanism is functioning correctly. In this mode the motor moves the needle down until it operates a microswitch at the bottom of its stroke. After a short pause the needle is moved up until it operates a microswitch at the top of its stroke. At this point the motor stops and the uniselector is stepped twice to position the next sample tube under the needle, after which the cycle is repeated. This 'fast test cycle' function runs continuously until the Stop test button is pressed.

Stop test

Operation of the Stop test button terminates the 'fast test cycle' at the end of a complete test cycle, at which point an LED glows to indicate that the mechanism and control system are ready for automatic sampling.

Reset

The Reset button can be used at any point in the sampling sequence to terminate the operation and restore the system to manual control.

Motor

When the Motor button is depressed, the motor actuating the needle movement turns slowly until the button is released.

Step

When the step button is depressed, the uniselector steps continuously to rotate the turntable.

Auto

The Auto button is depressed to start the actual sampling sequence. In this mode the Start test, Stop test, Motor and Step buttons are disabled.

Construction

The sampler is housed in two metal electrical-distribution cabinets (457 × 305 × 203 mm), each having a hinged door. The cabinets are mounted back-to-back, one containing the electronics and the diaphragm pump, the other containing the sampling tubes and the associated mechanism. The turntable can be tilted forward to enable the sampling tubes to be inserted or removed. Provision is made for the internal stowage of the mains-power lead. The cabinet housing the electronics is partially lined with 25 mm sheet polystyrene to retain some of the locally generated heat. The total weight of the equipment is 25.5 kg.

Applications

The device can be used for any application in which a gas is sampled to measure its concentration. The only service required is a mains-power supply. Minor circuit changes would enable the sampler to be battery powered. A simple modification to the rotating drum will cater for a different size of test-tube or vial. Commercial pre-evacuated tubes can provide a sampled gas volume accuracy of $\pm 1\%$ [1]. The sampler can also be used to pre-evacuate sampling tubes by connecting the hypodermic needle to a vacuum pump. The use of a side-entry syringe would allow the device to sample liquids from continuous processes or batch reactions. The physical size, versatility and low cost of the sampler should enable its use as a multi-purpose laboratory apparatus.

References

1. PHAM, Q. T. Air infiltration into cold stores. In *Proceedings of 22nd Meat Industry Research Conference* (Hamilton, New Zealand, 1982).
2. GRIMSRUD, D. T., SHERMAN, M. H., JANSSEN, J. E., PEARMAN, A. N. and HARRJE, D. T. *ASHRAE Transactions*, **86**, 1 (1980), 285.

Figures 3 and 4 follow.

Figure 3. Flow diagram.

6802 MICRO ASSEMBLER/DISASSEMBLER

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1000: $CO
1000— 8E LDS          $007F    SET UP P.I.A.s
1003— CE LDX          $8000    CLEAR OUTPUTS
1006— DF STX          10
1008— 86 LDA A        $FF
100A— A7 STA A        00, X
100C— A7 STA A        04, X
100E— 86 LDA A        $00
1010— A7 STA A        02, X
1012— A7 STA A        06, X
1014— C6 LDA B        $04
1016— E7 STA B        01, X
1018— E7 STA B        03, X
101A— E7 STA B        05, X
101C— E7 STA B        07, X
101E— 6F CLR          00, X
1020— 86 LDA A        $18      LOAD 24 SAMPLE COUNTER
1022— 97 STA A        20
1024— A6 LDA A        02, X    TEST AUTO PUSH BUTTON
1026— 84 AND A        $01
1028— 26 BNE          1048
102A— A6 LDA A        02, X    TEST MOTOR PUSH BUTTON
102C— 84 AND A        $08
102E— 27 BEQ          1035
1030— BD JSR          F120
1033— 20 BRA          1024
1035— A6 LDA A        02, X    TEST STEP PUSH BUTTON
1037— 84 AND A        $10
1039— 27 BEQ          1040
103B— BD JSR          F0F0
103E— 20 BRA          1035
1040— A6 LDA A        02, X    TEST START TEST PUSH BUTTON
1042— 84 AND A        $40
1044— 26 BNE          10C2
1046— 20 BRA          1024
1048— A6 LDA A        02, X    (START OF AUTOMATIC CYCLE)
104A— 84 AND A        $02      TEST NEEDLE UP
104C— 27 BEQ          102A
104E— A6 LDA A        06, X    READ THUMBWHEEL SWITCH
1050— 84 AND A        $0F      STORE 10 MINUTE INTERVAL COUNTER
1052— 27 BEQ          1024
1054— 97 STA A        17
1056— 86 LDA A        $07      LOAD MOTOR PULSE COUNTER
1058— 97 STA A        16
105A— CE LDX          $025C
105D— DF STX          18
105F— BD JSR          F120      CALL MOTOR PULSE DRIVE SUBROUTINE
1062— A6 LDA A        02, X    TEST NEEDLE DOWN
1064— 84 AND A        $04
1066— 27 BEQ          105F      SUBTRACT 30 SECONDS FROM SECONDS COUNTER
1068— 0C CLC
1069— 96 LDA A        19
106B— 80 SUB A        $1E
106D— 97 STA A        19
106F— 96 LDA A        18
1071— 82 SBC A        $00
1073— 97 STA A        18
1075— 86 LDA A        $38
1077— CE LDX          $FFFE    DELAY 30 SECONDS
107A— 09 DEX
107B— 26 BNE          107A
107D— 4A DEC A
107E— 26 BNE          1077
1080— BD JSR          F120      CALL MOTOR PULSE DRIVE SUBROUTINE
1083— A6 LDA A        02, X    TEST NEEDLE UP
1085— 84 AND A        $02
1087— 27 BEQ          1080
1089— BD JSR          F0F0      CALL STEP PULSE ROUTINE
108C— BD JSR          F0F0      CALL STEP PULSE SUBROUTINE
108F— DE LDX          10      PULSE AUTO LED
1091— 96 LDA A        19
1093— A7 STA A        04, X
1095— DE LDX          18      TEST SECONDS COUNTER ZERO
1097— 26 BNE          10B1
1099— D6 LDA B        17      COUNT DOWN 10 MINUTE INTERVAL COUNTER
109B— 5A DEC B
109C— D7 STA B        17
109E— 27 BEQ          10A7
10A0— CE LDX          $025C    RELOAD SECONDS (10 MINUTE) COUNTER
10A3— DF STX          18
10A5— 20 BRA          108F
10A7— DE LDX          10
10A9— 7A DEC          0020    COUNT DOWN 24 SAMPLE COUNTER

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Figure 4 (continued over).

10AC—	26	BNE		104E	
10AE—	7E	JMP		F000	LAST SAMPLE RETURN TO START
10B1—	CE	LDX		\$F3E9	DELAY 1 SECOND COUNT DOWN 1 SECOND
10B4—	01	NOP			REPEAT
10B5—	FF	STX		001A	
10B8—	09	DEX			
10B9—	26	BNE		10B4	
10BB—	DE	LDX		18	
10BD—	09	DEX			
10BE—	DF	STX		18	
10C0—	20	BRA		108F	(START OF TEST CYCLE)
10C2—	BD	JSR		F120	PULSE MOTOR
10C5—	A6	LDA	A	02, X	TEST NEEDLE DOWN
10C7—	84	AND	A	\$04	
10C9—	27	BEQ		10C2	
10CB—	C6	LDA	B	\$04	DELAY
10CD—	CE	LDX		\$0000	
10D0—	09	DEX			
10D1—	26	BNE		10D0	
10D3—	5A	DEC	B		
10D4—	26	BNE		10CD	
10D6—	BD	JSR		F120	CALL MOTOR PULSE SUBROUTINE
10D9—	A6	LDA	A	02, X	TEST NEEDLE UP
10DB—	84	AND	A	\$02	
10DD—	27	BEQ		10D6	
10DF—	BD	JSR		F0F0	CALL STEP SUBROUTINE
10E2—	BD	JSR		F0F0	CALL STEP SUBROUTINE
10E5—	A6	LDA	A	02, X	TEST CANCEL BUTTON
10E7—	84	AND	A	\$20	
10E9—	27	BEQ		10C2	
10EB—	7E	JMP		F000	RETURN TO START
10EE—	00	00			
10EF—	00	00			
10F0—	86	LDA	A	\$02	TURN STEP PULSE ON (STEP SUBROUTINE)
10F2—	A7	STA	A	00, X	
10F4—	CE	LDX		\$4000	DELAY
10F7—	BD	JSR		F110	
10FA—	86	LDA	A	\$00	TURN STEP PULSE OFF
10FC—	A7	STA	A	00, X	
10FE—	CE	LDX		\$4000	DELAY
1101—	BD	JSR		F110	
1104—	DE	LDX		10	
1106—	39	RTS			RETURN TO CALLER
1107—	00	00			
1108—	00	00			
1109—	00	00			
110A—	00	00			
110B—	00	00			
110C—	00	00			
110D—	00	00			
110E—	00	00			
110F—	00	00			
1110—	FF	STX		001A	DELAY
1113—	09	DEX			
1114—	26	BNE		1110	
1116—	DE	LDX		10	
1118—	39	RTS			
1120—	86	LDA	A	\$01	OUTPUT MOTOR PULSE (MOTOR DRIVE SUBROUTINE)
1122—	DE	LDX		10	
1124—	A7	STA	A	00, X	
1126—	96	LDA	A	16	TEST FOR END OF SECOND
1128—	26	BNE		1135	
112A—	86	LDA	A	\$07	START NEW SECOND
112C—	97	STA	A	16	
112E—	DE	LDX		18	COUNT DOWN SECONDS COUNTER
1130—	09	DEX			
1131—	DF	STX		18	
1133—	20	BRA		1138	
1135—	4A	DEC	A		COUNT DOWN END OF SECOND TIME
1136—	97	STA	A	16	
1138—	CE	LDX		\$0800	
113B—	FF	STX		0012	DELAY FOR ON TIME
113E—	09	DEX			
113F—	26	BNE		113B	
1141—	86	LDA	A	\$00	CANCEL MOTOR PULSE
1143—	DE	LDX		10	
1145—	A7	STA	A	00, X	
1147—	CE	LDX		\$1AD0	DELAY FOR OFF TIME
114A—	FF	STX		0012	
114D—	09	DEX			
114E—	26	BNE		114A	
1150—	DE	LDX		10	
1152—	39	RTS			RETURN TO CALLER

Figure 4. Assembly listing.