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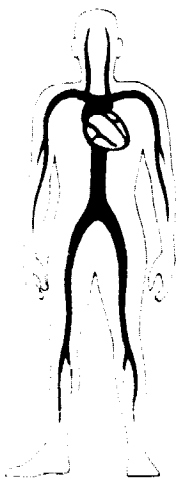

TECHNOLOGY INCORPORATED
LIFE SCIENCES DIVISION

SPECIAL REPORT

ON THE

METABOLIC RATE MEASUREMENT SYSTEM

Prepared for the NASA Johnson Space Center
Environmental Physiology Laboratory

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TECHNOLOGY INCORPORATED
Life Sciences Division
Houston, Texas

SPECIAL REPORT

Metabolic Rate Measurement System

Enviromental Physiology Laboratory
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center

Contract NAS 9-14880

Project 0175-80

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for

The Metabolic Rate Measurement System

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INTRODUCTION

The Metabolic Rate Measurement System (MRMS) is an uncomplicated and accurate apparatus for measuring oxygen consumption and carbon dioxide production of a test subject. From this one can determine the subject's metabolic rate for a variety of conditions, such as resting or light exercise.

MRMS, like its predecessor (Metabolic Measurement - X75 Ident. No. 55005-0), utilizes an LSI/11-03 microcomputer to monitor and control the experimental apparatus. However, accuracy and efficiency have been improved by utilizing more refired equipment and techniques. Future plans include configuring the LSI/11 to communicate with a larger central computer. This will also be done with several other LSI/11 controlled experiments, such as the Skin Temperature System so that as much data as possible can be collected and stored in highly efficient manner.

GENERAL DESCRIPTION

To measure the oxygen consumed and the carbon dioxide produced for a test subject, a somewhat constant flow of ambient air is pulled through the face mask and mixed with the subject's expired air. A mass spectrometer is used to determine the concentrations of gases in both the inspired and expired air. These concentrations as well as temperature, pressure and flow rate are monitored by a Digital Equipment Corporation LSI-11 Microcomputer. The computer programs, which are written in Fortran and reside on a floppy diskette, automatically calibrate this equipment, control the sampling of the various parameters, calculate the minute volumes of the gases, and display the results on the teletype.

The LSI-11 measures the gas concentrations from the Mass Spectrometer, as well as the temperature and pressure measurements by means of an ADAC 1030 A/D converter. A parallel interface board provides the communication link from the flow meter output, and to the solenoid valve controls.

The ADAC 1030 accepts up to 16 analog input signals. Output is an integer in the range 0-2047. Channel selection as well as gain are programmable. The counts are converted to a value signifying a measurement (such as ℓ/min, deg. cent. etc.) by means of the linear equation value = slope * counts + intercept. The slope and intercept values are determined by calibration techniques.

The temperature and pressure transducers are assumed constant devices, and so were calibrated once during hardware assembly.

The measurements from the Mass Spectrometer are calibrated during experimentation. Two calibration gases, of precisely known composition, are analyzed to provide slopes and intercepts.

The selection of gas (cal. gas 1, cal. gas 2, exhaled or ambient) picked up by the mass spectrometer probe is controlled by a set of solenoid valves. A digital control device converts the interface board signal to the 110 v. signal needed to actuate the proper valve.

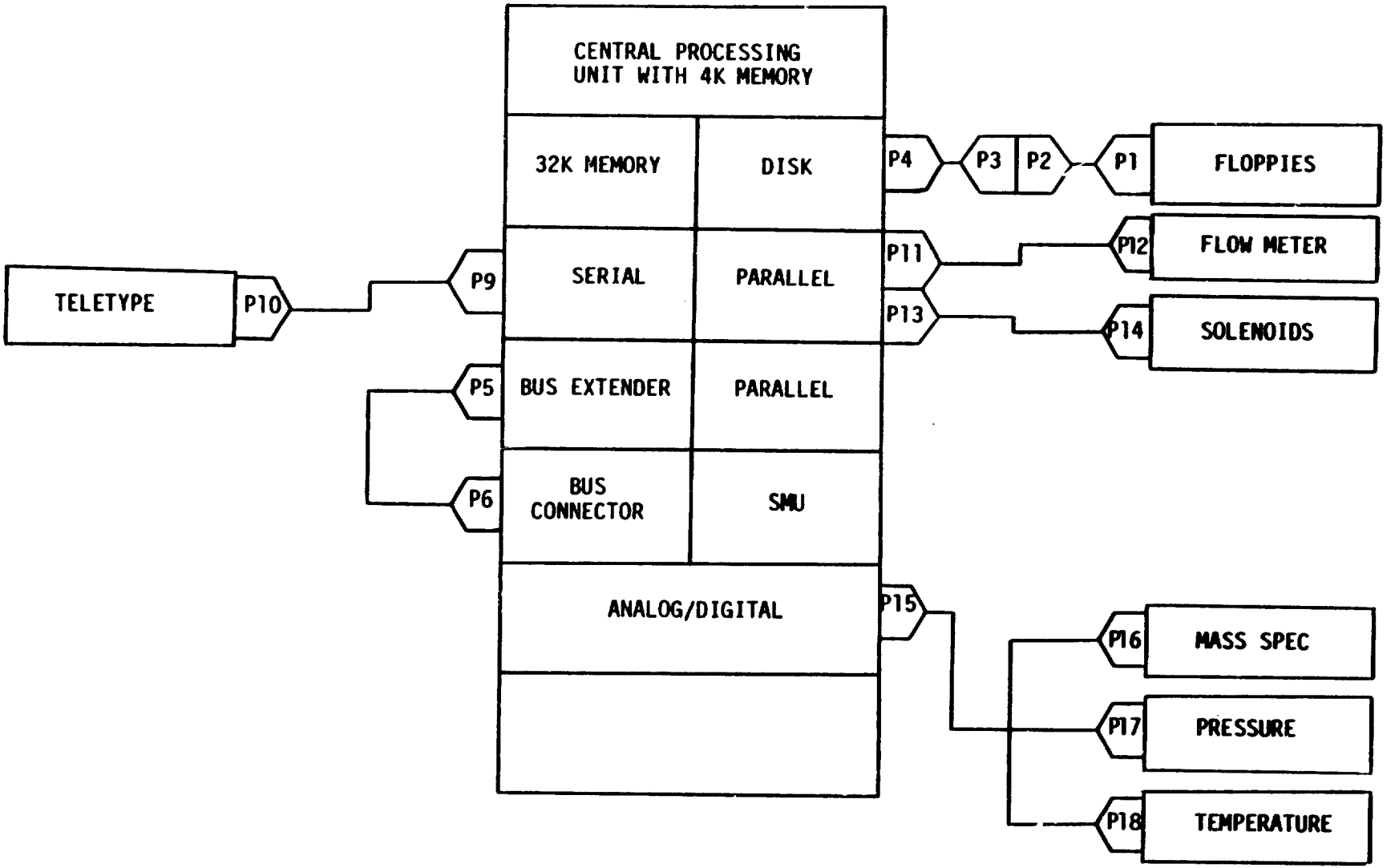
To measure flow, a turbine-like transducer sends a signal to an amplifier/signal conditioner, which generates a square wave. This is sent to a frequency counter which then generates a BCD signal on the parallel interface as well as displaying the results on the LED display. The flow measurement system was also calibrated during hardware assembly. The flow is governed by a variac controlled exhaust fan.

A complete block diagram of hardware arrangement appears in the hardware description.

Board Configuration of the LSI-11 Microcomputer

Slot Location	DEC Module No.	Device No.	Description
1	M7264	KD11-F	Microprocessor with 4K RAM
2A	M8044	MSV11-D	32K words x 16 bit memory
2C	M7946	RXV11-A	Dual floppy disk drive controller
3A		DLV11	Serial line interface for teletype
3C & 4C	M7941	DRV11	Parallel line interface
4A	M9400YE	BCV1B	First backplane terminator & bus extender
5A	M9401YE		Bus continuity card
5C		MLSI-SMU	System monitoring unit
6			16 channel A/D & 2 channel D/A interface

		A	B	C	D
First Backplane	1	CPU with 4K memory			
	2	32K memory		disk controller	
	3	serial interface		parallel interface	
	4	bus extender		parallel interface	
	5	bus connector		SMU	
Second Backplane	6	analog to digital converter			
	7				
	8				

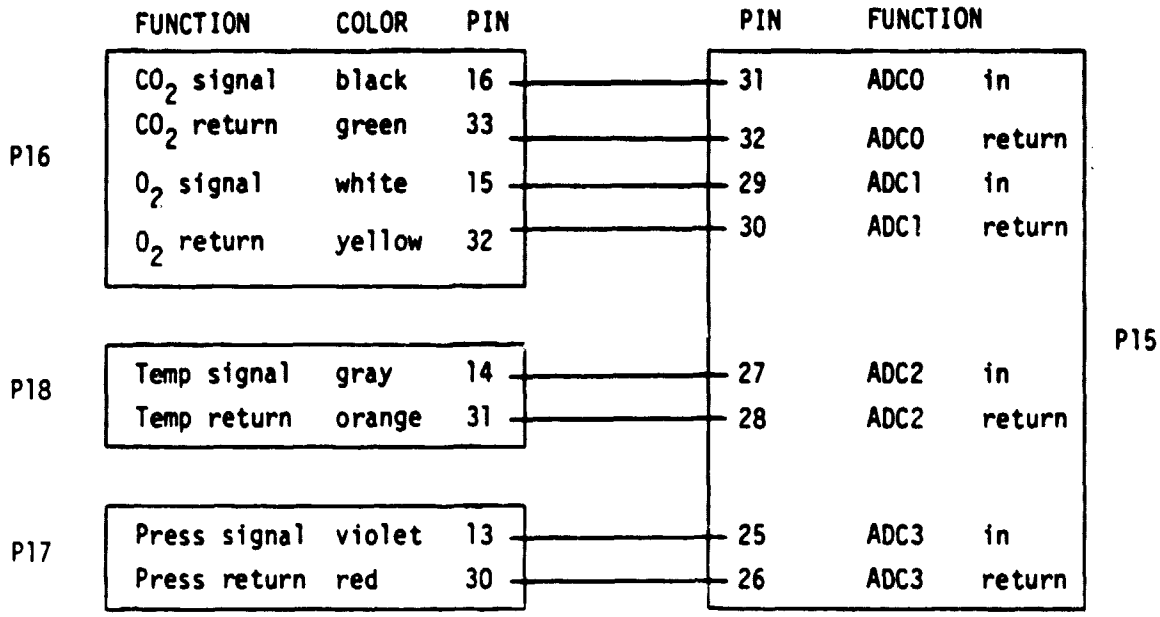


BLOCK DIAGRAM OF HARDWARE SHOWING
DATA CABLES

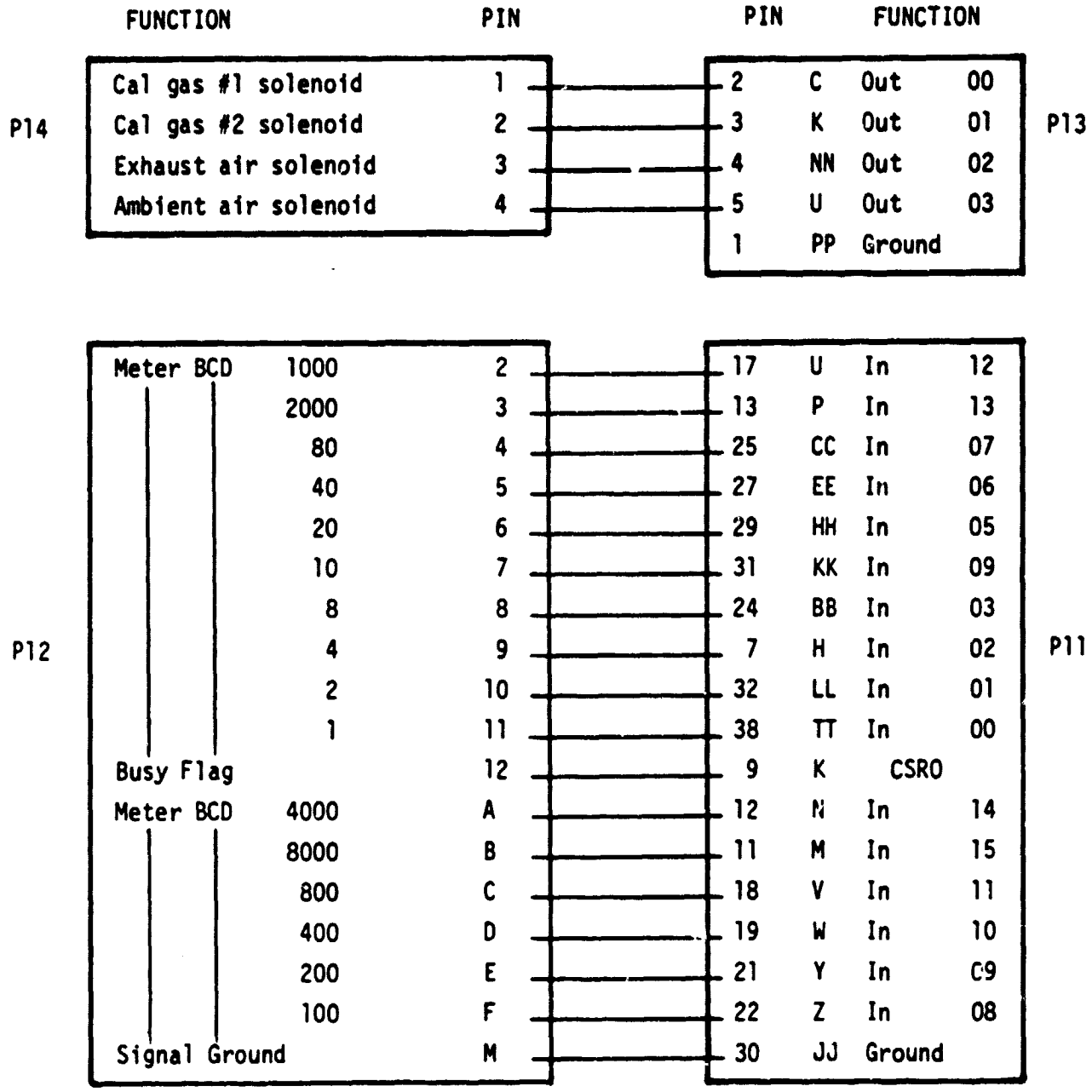
CABLE RUNNING LIST FOR ANALOG/DIGITAL INTERFACE

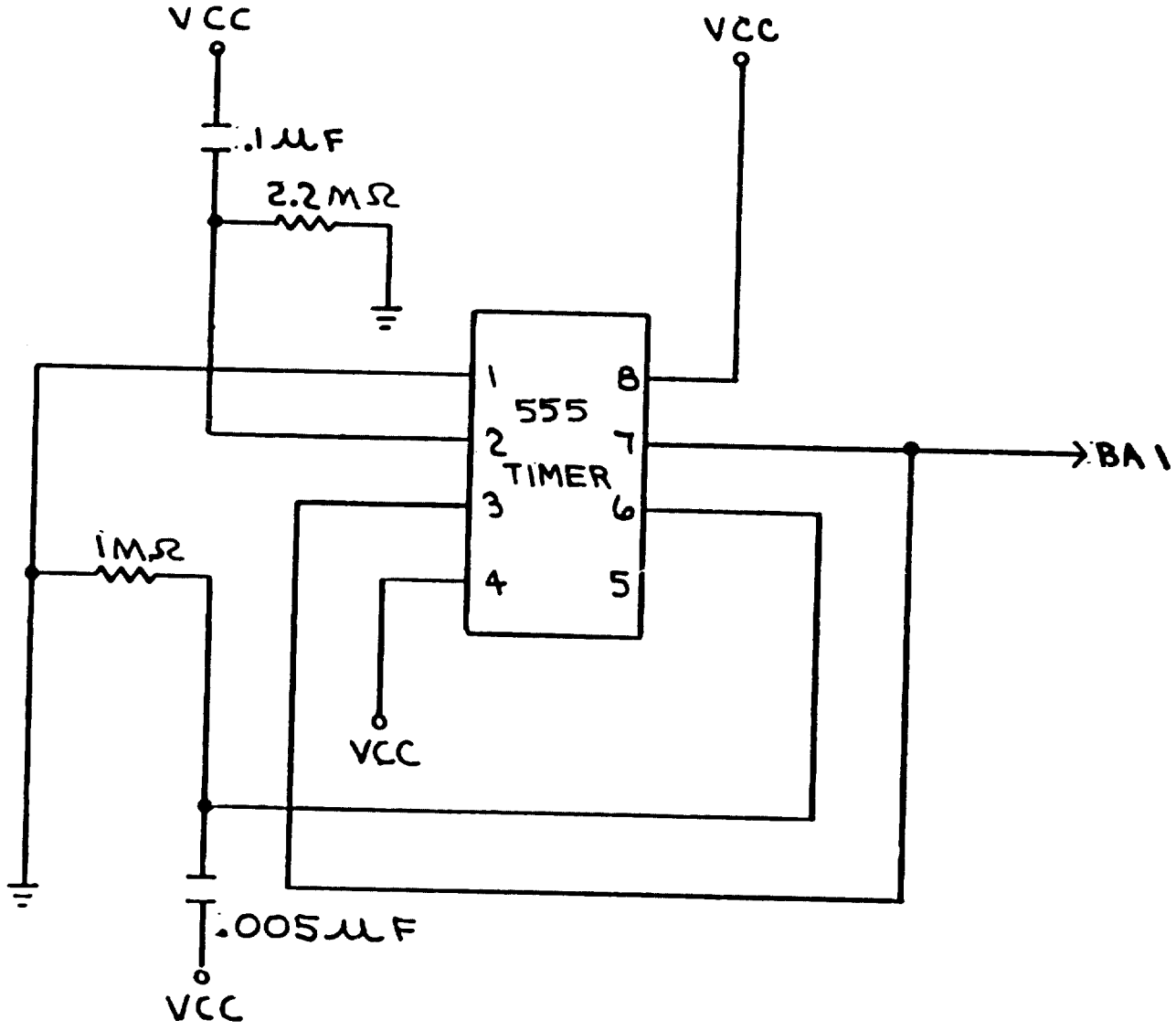
Cannon DD505 50 pin Ribbon Cable Mounted Connector

Cannon DD50P Mating Connector on PC Board

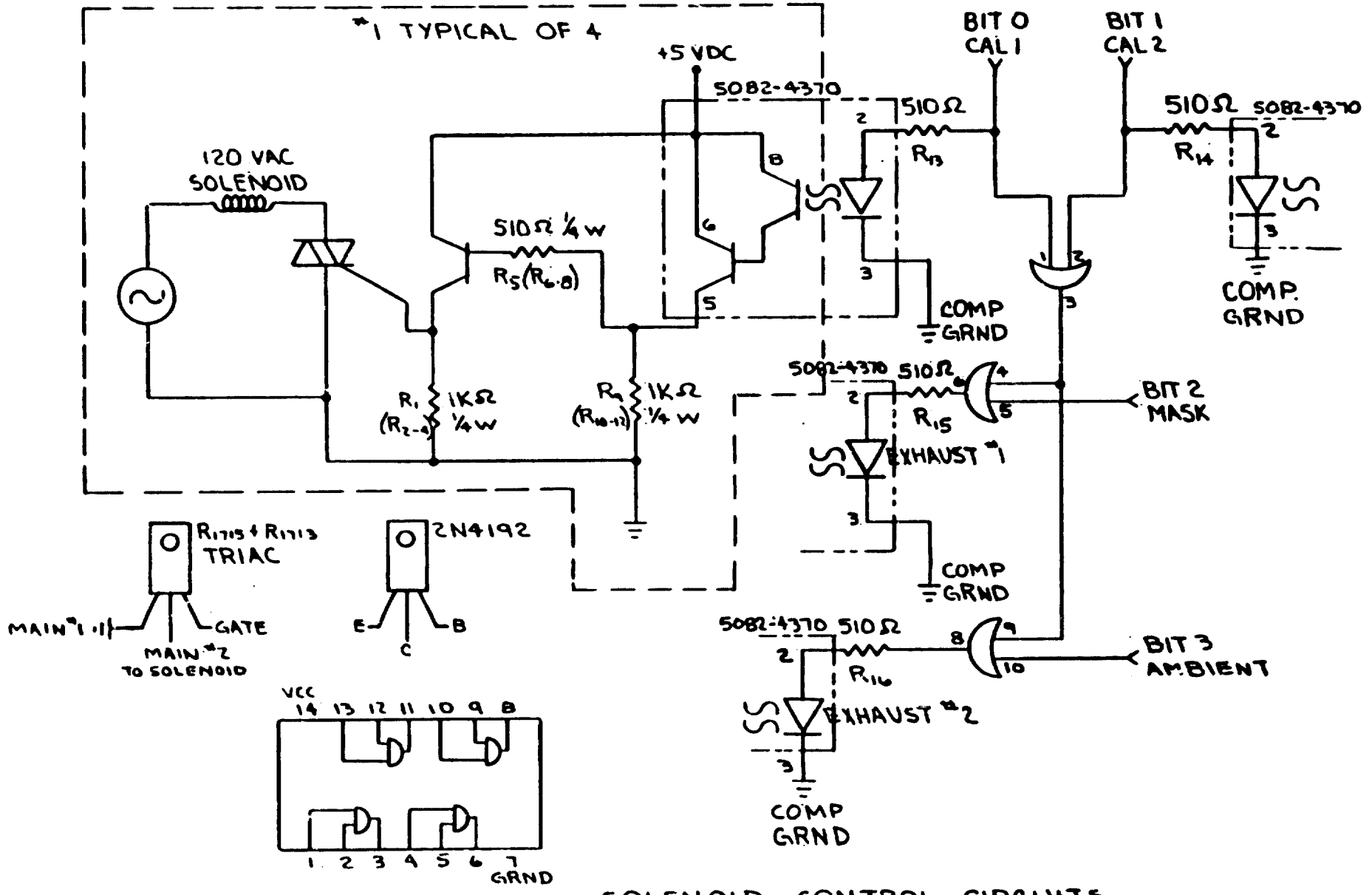


CABLE RUNNING LIST FOR PARALLEL INTERFACE

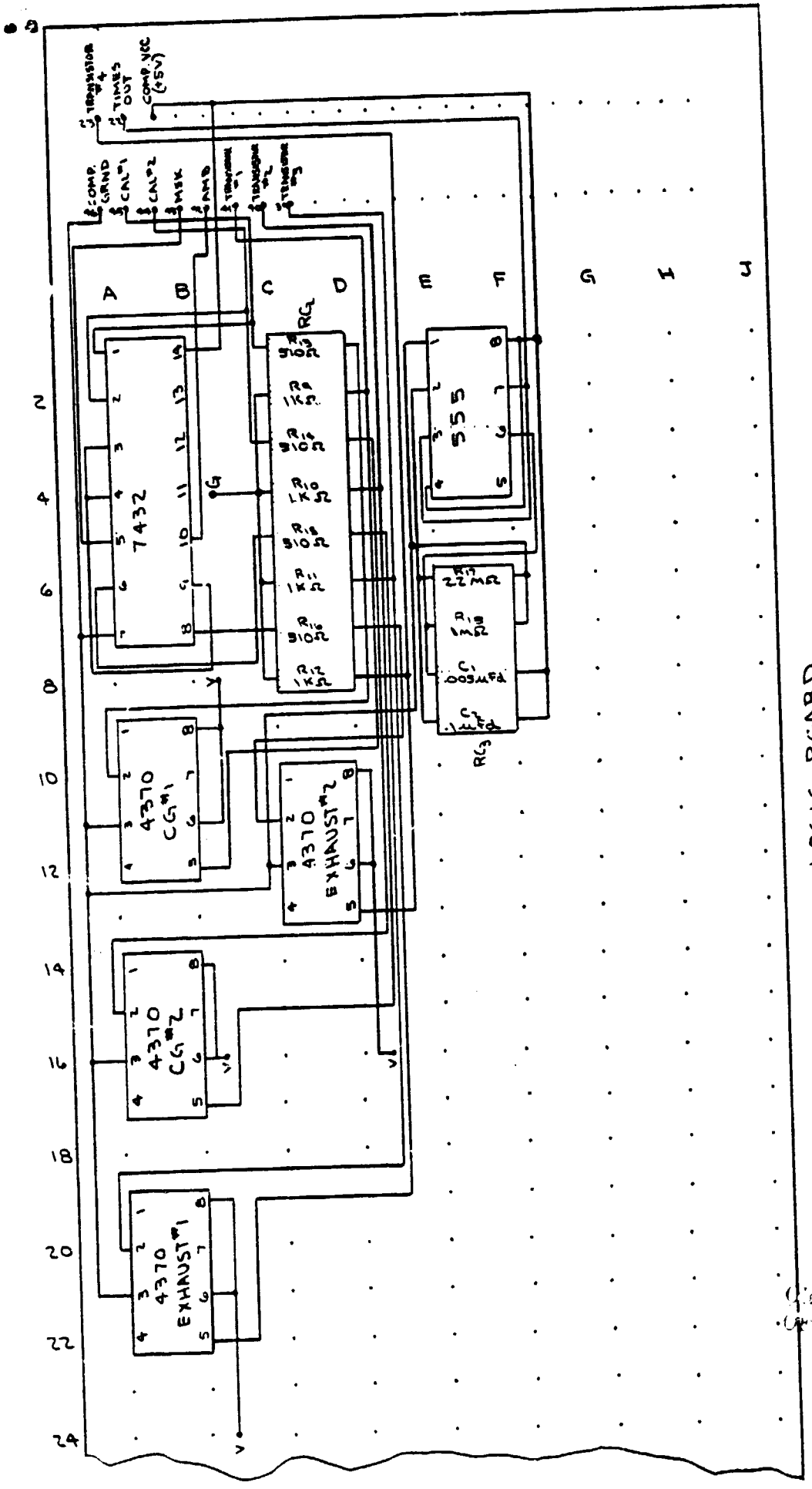




START UP CIRCUIT FOR LSI-11 MICROCOMPUTER



SOLENOID CONTROL CIRCUITS



LOGIC BOARD
START UP CIRCUIT &
PART OF SOLENOID
CONTROL CIRCUIT

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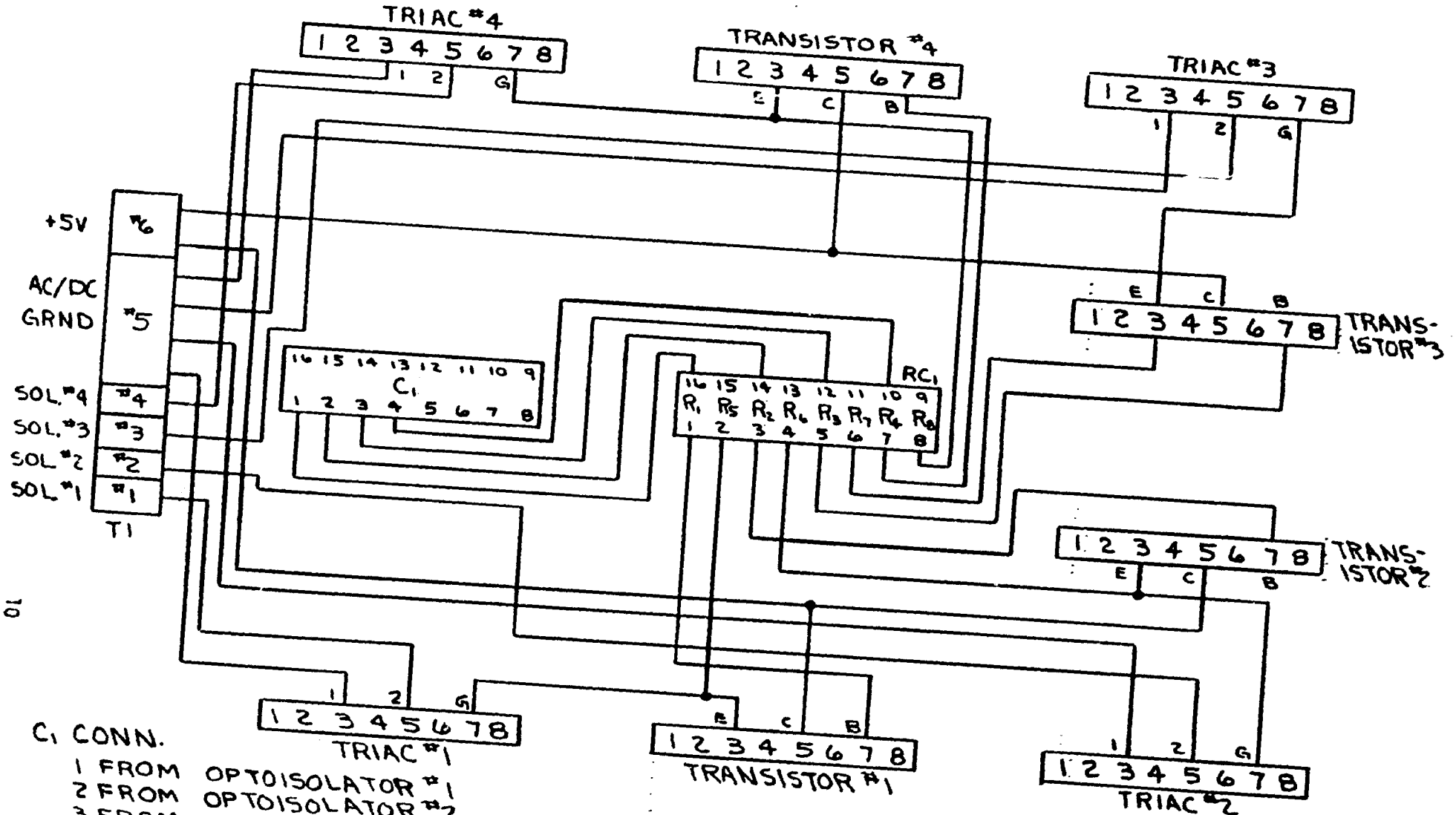
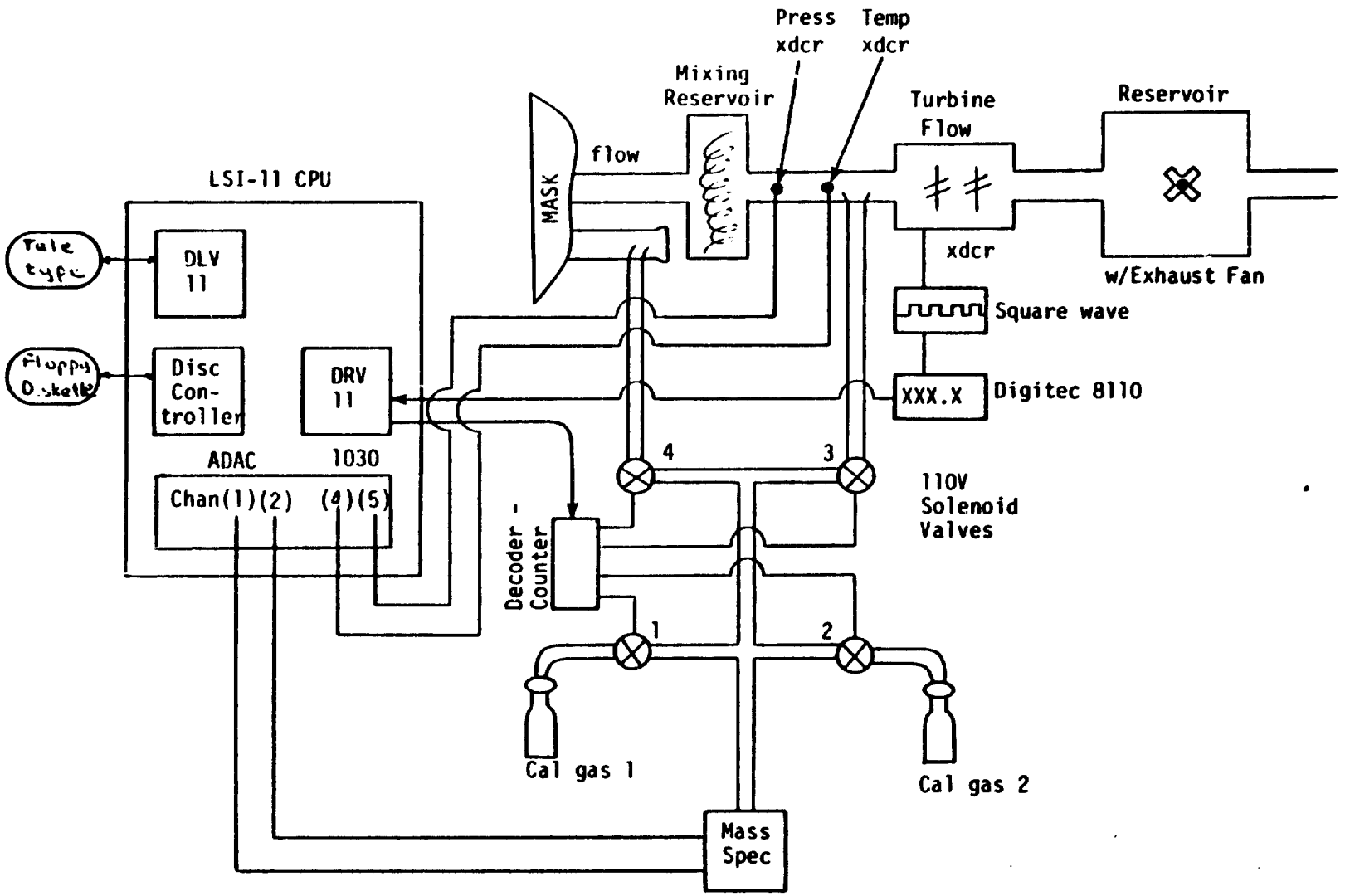


C1 CONN.
1 FROM OPTOISOLATOR #1
2 FROM OPTOISOLATOR #2
3 FROM OPTOISOLATOR #3
4 FROM OPTOISOLATOR #4

R_1-R_4 510 Ω
R_5-R_8 1K Ω

TRIAC-TRANSISTOR BOARD PICTORIAL
(PART OF SOLENOID CONTROL CIRCUIT)


Press xdcr
Temp xdcr
Mixing Reservoir
Turbine Flow
Reservoir
MASK
flow
LSI-11 CPU
DLV 11
xdcr
w/Exhaust Fan
Square wave
Disc Con-troller
DRV 11
XXX.X
Digitec 8110
ADAC
1030
Chan(1)(2)
(4)(5)
4
3
110V Solenoid Valves
Decoder - Counter
1
2
Cal gas 1
Cal gas 2
Mass Spec

SOFTWARE DESCRIPTION

The software package is developed in and supported by RT-11 v3B operating system. The real-time test program is written in Fortran and operates in phases that are user controlled. Although this requires user intervention, it permits software design so as to minimize the number of subroutines and associated overhead.

The main phases of the real-time test program operate in the following manner.

Calibration: Open solenoid valve for a cal. gas and flow for 30 seconds to clear tubing. Average 100 readings each for O_2 and CO_2 concentrations. Repeat for other cal. gas. Calculate slopes and intercepts. Print results.

Test data: Set valve for ambient gas flow for 7 seconds to clear tubing. Then sample ambient data continuously for the next 8 seconds. Set valve for exhaled gas flow for 7 seconds to clear tubing. Then sample exhaled data continuously for the next 38 seconds. During the duty cycles (8 sec./ ambient, 38 sec./exhaled), no other operations other than data gathering are performed. Averaging, computational calculations, and printing are done during the 7 sec. wait cycles. This 60 second cycle is repeated until user intervenes.

The resulting program provides good flexibility of initial conditions as well as high sampling rates and efficient use of CPU capability.

OPERATION

1) Insure cal gases are operational; verify proper hose connection (gas 1 with hose #1, etc.); bottle has sufficient operating pressure; pressure is adjusted properly (4-8 psi is sufficient).

2) Insure mask hoses are properly connected. Hose to tank and tank to flow meter/fan are color coded for proper connection. Capillary tube connects to Inlet connection.

3) Insure mass spectrometer is properly configured. Probe is connected to Mass Spectrometer connection. Proper inlet is selected and unit is "ON". Verify mode is % and output signal cables are connected to converter patch panel. (NOTE: A filter/amplifier box may be inserted between the mass spectrometer and the patch panel.)

4) Verify the patch panel connections are attached to the proper channel

Ch. 1: O_2 signal
2: CO_2 signal
4: Temp. signal
5: Press. signal

5) Load floppy diskette into disk drive; Disk ENVIRE contains the RT-11 v3B operating system as well as program into ENVIRE .SAV and data file DATCON .VAL.

6) Turn on power to teletype, turn on power to CPU and other hardware.

7) The teletype should print "$". To boot the system; clear the INTRPT light (depress the key once), type "DX" and carriage return. The

system will then boot up ready to accept commands.

8) Type "R ENVIRE" <CR>. Envire prints adequate instructions for operator actions required. Appendix D is a hard copy printout containing expanded comments about options etc.

APPENDIX A

PHYSIOLOGICAL EQUATIONS

Indices: $i \rightarrow$ cal gas 1 or 2

$j \rightarrow 1=O_2, 2=CO_2$

Given $\%(i,j) = m(j) * \xi(i,j) + b(j)$

where $\%$ → cal gas percentage

ξ → mass spec output, read as counts from A/D

then $$m(j) = \frac{\%(2,j) - \%(1,j)}{\xi(2,j) - \xi(1,j)}$$

$$b(j) = \%(1,j) - m(j) * \xi(1,j)$$

Respiratory Quotient $$Rq = \frac{\Delta CO}{\Delta O}$$

CO_2 Production $\Delta CO = \{STP * f\ell * [\rho_e(2) - r_2 * \rho_e(3)]\}$ averaged

O_2 Consumption $\Delta O = \{STP * f\ell * [r_1 * \rho_e(3) - \rho_e(1)]\}$ averaged

Temp/Press. Correction $$STP = \left[\left(\frac{273.15}{273.5 + T}\right) * \left(\frac{P}{760}\right)\right]$$ averaged

Gas Concentration $\rho_k(j) = m(j) * \xi(k,j) + b(j)$

where k denotes ambient or exhaled concentration

and $\rho_k(\text{nitrogen}) = 100. - \rho_k(1) - \rho_k(2)$

Ratio factor $$r_j = \left[\frac{\rho_{amb}(j)}{\rho_{amb}(N_2)}\right]$$ averaged

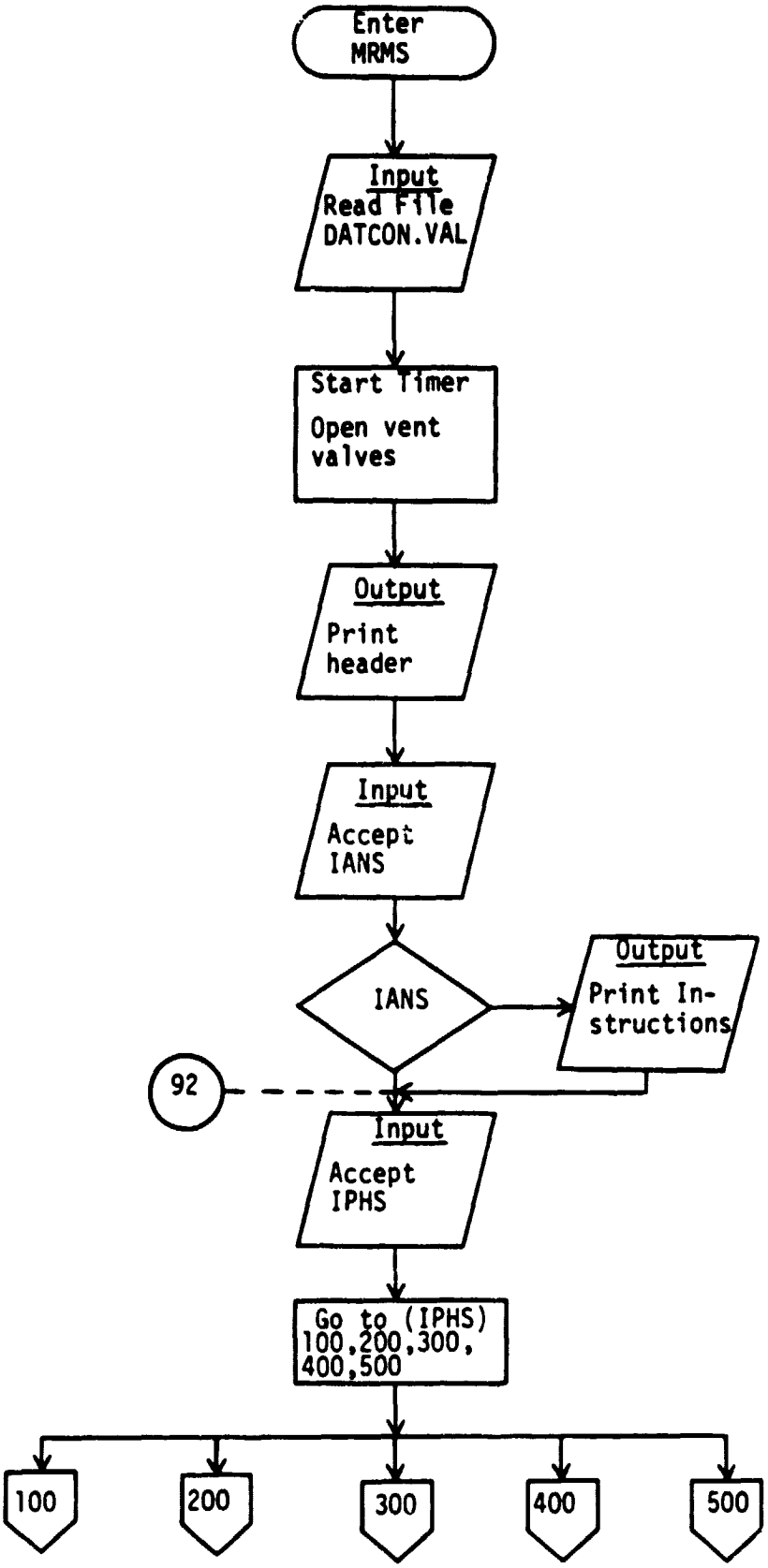
Flow $f\ell$ measured in litres/minute

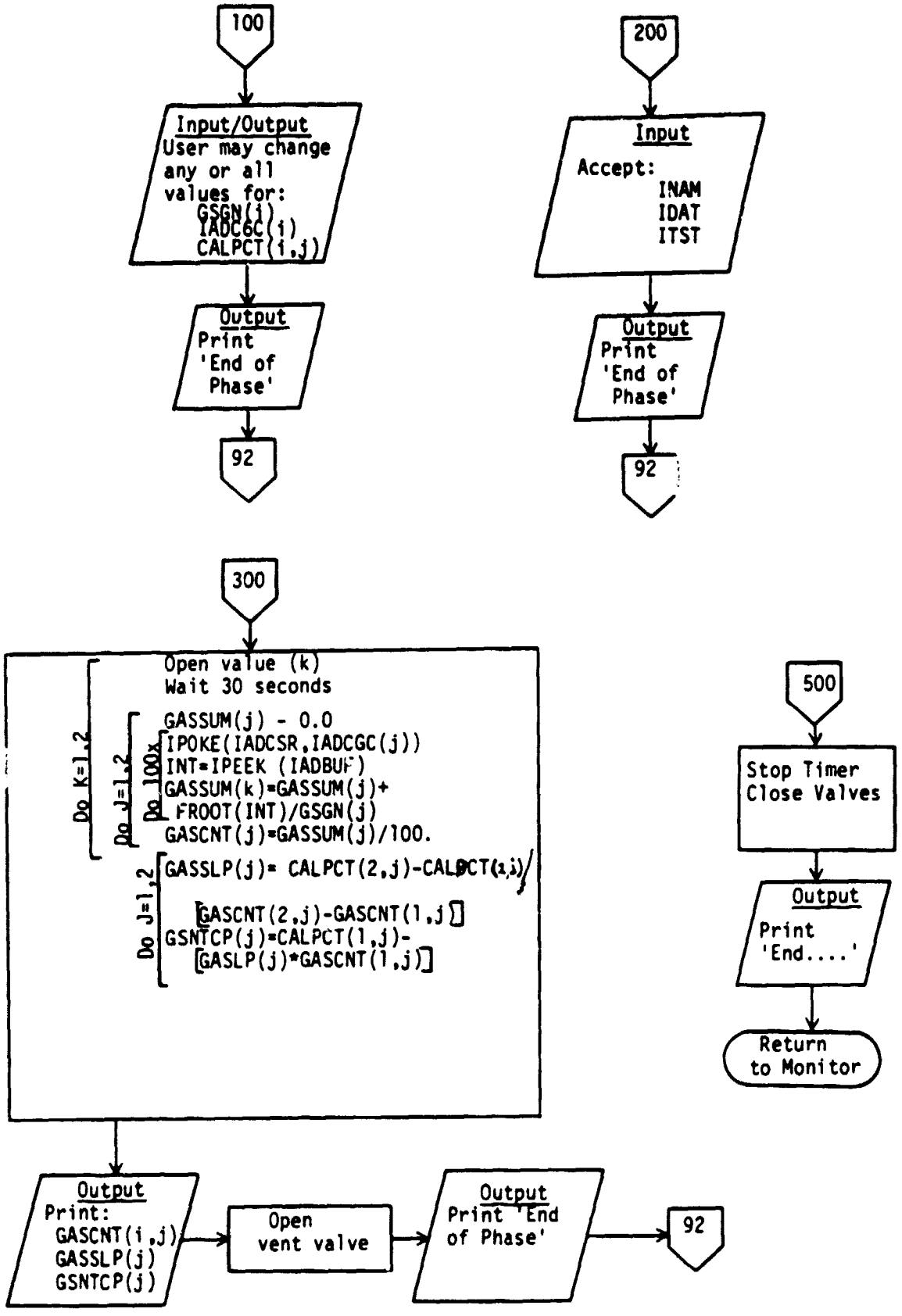
STP and rj are calculated and then averaged during the ambient duty cycle as described in the Software Description section.

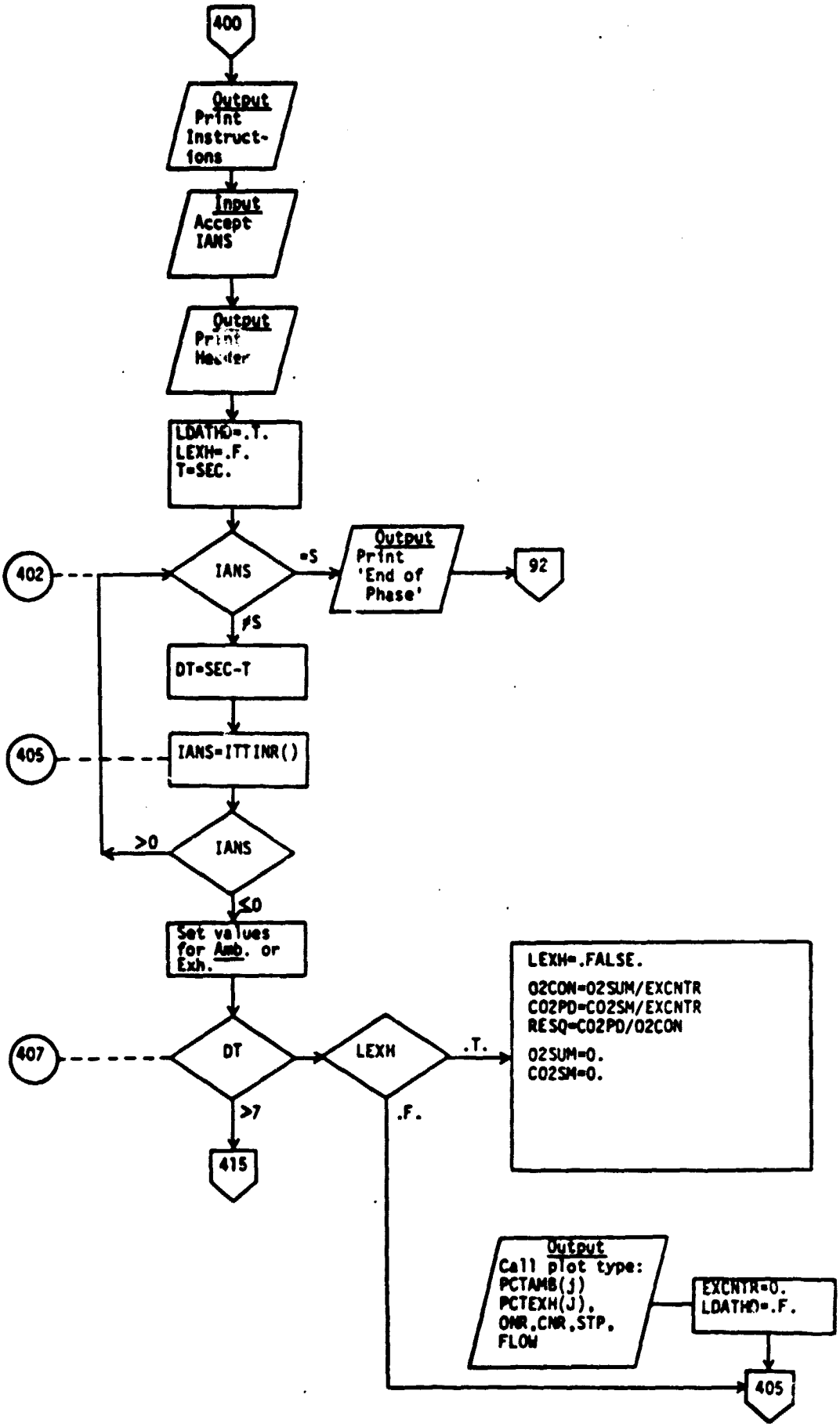
f_ℓ and $\rho_e(j)$ are measured and a value for $\Delta CO'$ and $\Delta O'$ is calculated. Due to experimental restriction, it is necessary that the ambient measurements (STP and r_j) be considered constant, at least during the exhaled duty cycle. The values of $\Delta CO'$ and $\Delta O'$ are averaged (to get ΔCO and ΔO), as described in the Software Description section. Rq reflects a single value, for the minute of data sampled.

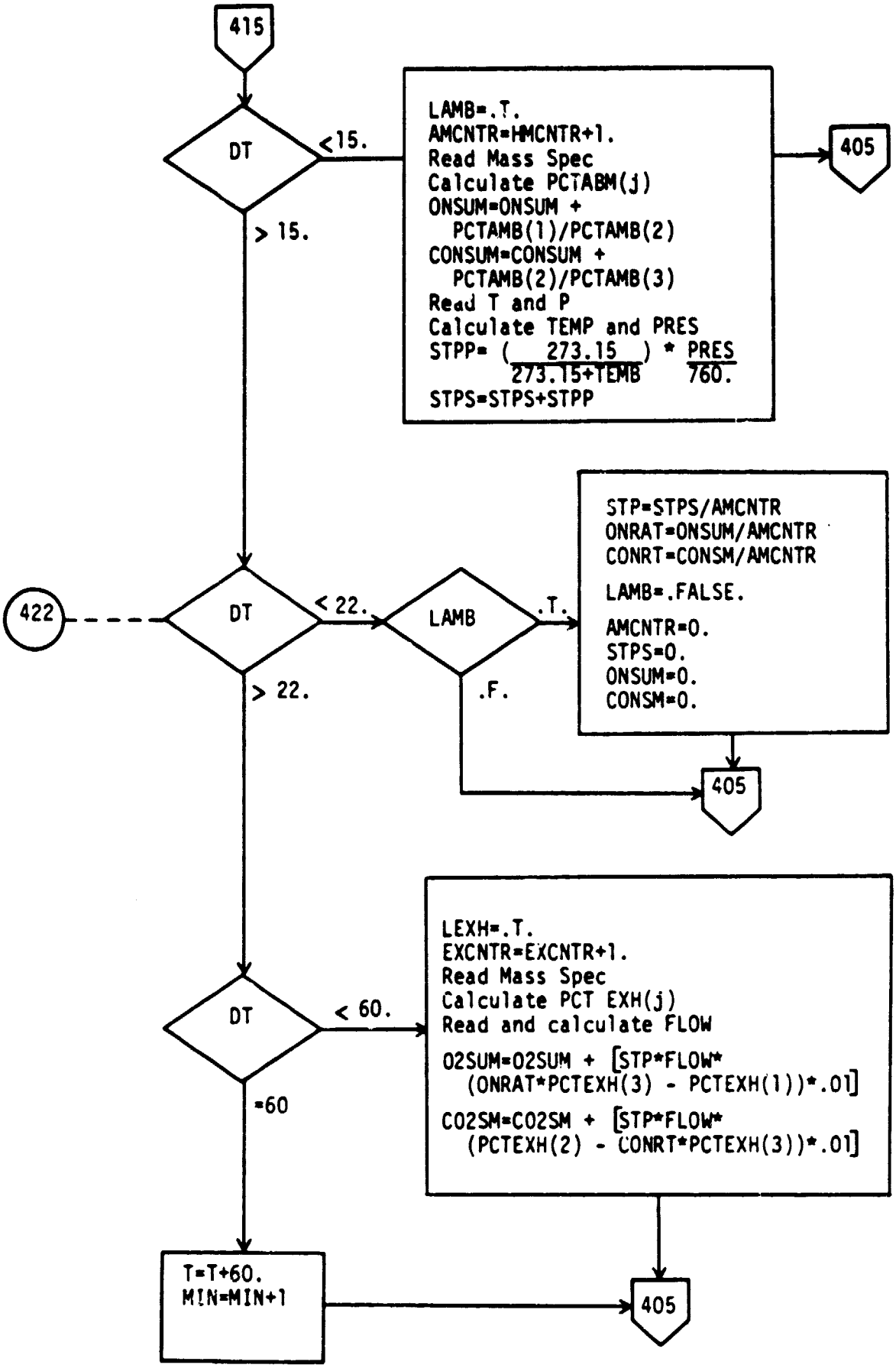
APPENDIX B

PROGRAM FLOW DIAGRAM


Enter MRMS
Input
Read File
DATCON.VAL
Start Timer
Open vent valves
Output
Print header
Input
Accept IANS
IANS
Output
Print In-structions
92
Input
Accept IPHS
Go to (IPHS) 100,200,300, 400,500
100
200
300
400
500


100
Input/Output
User may change any or all values for:
GSGN(i)
IADC6C(i)
CALPCT(i,j)
Output
Print 'End of Phase'
92
200
Input
Accept:
INAM
IDAT
ITST
Output
Print 'End of Phase'
92
300
Open value (k)
Wait 30 seconds
Do K=1,2
GASSUM(j) - 0.0
Do J=1,2
Do 100x
IPOKE(IADCSR,IADCGC(j))
INT=IPEEK (IADBUF)
GASSUM(k)=GASSUM(j)+
FROOT(INT)/GSGN(j)
GASCNT(j)=GASSUM(j)/100.
Do J=1,2
GASSLP(j)= CALPCT(2,j)-CALPCT(1,j)/
GASCNT(2,j)-GASCNT(1,j)
GSNTCP(j)=CALPCT(1,j)-
GASLP(j)*GASCNT(1,j)
Output
Print:
GASCNT(i,j)
GASSLP(j)
GSNTCP(j)
Open vent valve
Output
Print 'End of Phase'
92
500
Stop Timer
Close Valves
Output
Print 'End....'
Return to Monitor


400
Output
Print
Instruct-
ions
Input
Accept
IANS
Output
Print
Header
LDATH=.T.
LEXH=.F.
T=SEC.
402
IANS
=S
Output
Print
'End of
Phase'
92
≠S
DT=SEC-T
405
IANS=ITTINR()
>0
IANS
≤0
Set values
for Amb. or
Exh.
407
DT
LEXH
.T.
LEXH=.FALSE.
O2CON=O2SUM/EXCNTR
CO2PD=CO2SM/EXCNTR
RESQ=CO2PD/O2CON
O2SUM=0.
CO2SM=0.
>7
.F.
415
Output
Call plot type:
PCTAMB(j)
PCTEXH(j),
ONR,CNR,STP,
FLOW
EXCNTR=0.
LDATH=.F.
405


415
DT
<15.
LAMB=.T.
AMCNTR=HMCNTR+1.
Read Mass Spec
Calculate PCTABM(j)
ONSUM=ONSUM +
PCTAMB(1)/PCTAMB(2)
CONSUM=CONSUM +
PCTAMB(2)/PCTAMB(3)
Read T and P
Calculate TEMP and PRES
STPP= (273.15 / 273.15+TEMB) * PRES / 760.
STPS=STPS+STPP
405
> 15.
422
DT
< 22.
LAMB
.T.
STP=STPS/AMCNTR
ONRAT=ONSUM/AMCNTR
CONRT=CONSM/AMCNTR
LAMB=.FALSE.
AMCNTR=0.
STPS=0.
ONSUM=0.
CONSM=0.
405
> 22.
.F.
DT
< 60.
LEXH=.T.
EXCNTR=EXCNTR+1.
Read Mass Spec
Calculate PCT EXH(j)
Read and calculate FLOW
O2SUM=O2SUM + [STP*FLOW*
(ONRAT*PCTEXH(3) - PCTEXH(1))*.01]
CO2SM=CO2SM + [STP*FLOW*
(PCTEXH(2) - CONRT*PCTEXH(3))*.01]
=60
T=T+60.
MIN=MIN+1
405

APPENDIX C

PROGRAM LISTINGS

```
FORTRAN IV      V02.1-1     FRI 28-MAR-80 01:05:09

      C
0001          PROGRAM MRMS
      C
      C
      C
0002       10 FORMAT (/,17X,
     *       'M R M S',//,
     *       5X,'REAL-TIME TEST PROGRAM TO SUPPORT THE',//,
     *       5X,'METABOLIC-RATE-MEASUREMENT-SYSTEM.',//,
     *       5X,'ENVIRONMENTAL PHYSIOLOGY LAB,',//,
     *       5X,'TECHNOLOGY INCORPORATED ',///)
      C
      C         KEN KOESTER
      C         REVISION 1
      C
      C
      C           TYPE
0003          IMPLICIT LOGICAL (L)
0004          LOGICAL*1 IYS,INO,ISTP,IANS
      C
      C           SIZE
0005          DIMENSION IDAT(3),INAM(15),IMOD(15)
0006          DIMENSION CALPCT(2,2),PCIAMB(3),PCIEXH(3)
0007          DIMENSION GASSLP(2),GSNTCP(2),GSGN(2)
0008          DIMENSION GASCNT(4,2),GASSUM(2)
0009          DIMENSION IVLVMD(5),IADCGC(5)
      C
      C           COMMON
0010          COMMON/PLOTR/LDATHD,MIN,O2CON,CO2PO,
     *            RESQ,TEMP,PRES,EXCNTR,LAVG,FLOW,ISCL
0011          COMMON/TIME/SEC
      C
0012          EXTERNAL TICK
      C
      C           DATA
0013          DATA IYS/1HY/,INO/1HN/,ISTP/1HS/,IBL/"07/
0014          DATA IVLVMD/"01,"02,"04,"10,"14/
0015          DATA IADCSR/"176770/,IADBUF/"176772/,IDRVBF/"167772/
0016          DATA STPS/0./,O2SUM/0./,CO2SM/0./,CAMAX/0./
0017          DATA AMCNTR/0./,EXCNTR/0./,ONSUM/0./,CONSM/0./
0018          DATA SEC/0./,MIN/0/
      C
      C
      C           READ DATA CONSTANTS
0019          OPEN(UNIT=2,TYPE='OLD',NAME='DX0:DATCON.VAL')
0020          READ(2,60)((CALPCT(I,J),J=1,2),I=1,2),
     *            (GSGN(I),I=1,2),(IADCGC(M),M=1,4)
      C
0021          ISCL=2
12    C
11    C*          START PROG CLOCK
10  0022          ISR=INTSET("104,4,0,TICK)
 9  0023          CALL IPOKE("172542,10000)
 8  0024          CALL IPOKE("172540,"113)
 7
 6
 5
 4
 3
```

```
FORTRAN IV      V02.1-1     FRI 28-MAR-80 01:05:09

C*
C       OPEN VALVES FOR VENTING
0025        CALL IPOKE(IDRVBF,IVLVMD(5))
C
C           TYPE HEADER & INSTRUCTIONS
0026        TYPE 10
0027        TYPE 12
0028        ACCEPT 13,IANS
0029        IF(IANS.EQ.INO) GO TO 92
C
C           GET PHASE & BRANCH
0031     90 CONTINUE
0032        TYPE 14
0033     92 ACCEPT 15,IPHS
0034        IF(IPHS.GT.0) GO TO 94
0036        ACCEPT 15,IPHS
0037     94 GO TO (100,200,300,400,500) IPHS
C
C
C----------PHASE 1  DATA CONSTANTS
0038    100 CONTINUE
C
0039        TYPE 50
C
C           CHECK GAS GAINS
0040        DO 110 I=1,2
0041        TYPE 52,I,GSGN(I)
0042        ACCEPT 13,IANS
0043        IF(IANS.NE.IYS) GO TO 110
0045        TYPE 54
0046        ACCEPT 53,VALUE
0047        GSGN(I)=VALUE
0048    110 CONTINUE
C
C           CHECK PROGRAMMABLE GAINS
0049        DO 120 M=1,4
0050        TYPE 56,M,IADCGC(M)
0051        ACCEPT 13,IANS
0052        IF(IANS.NE.IYS) GO TO 120
0054        TYPE 54
0055        ACCEPT 57,INT
0056        IADCGC(M)=INT
0057    120 CONTINUE
C
C           CHECK CAL-GAS %'S
0058        DO 130 I=1,2
0059        DO 130 J=1,2
0060        TYPE 58,I,J,CALPCT(I,J)
0061        ACCEPT 13,IANS
0062        IF(IANS.NE.IYS) GO TO 130
0064        TYPE 54
0065        ACCEPT 59,VALUE
0066        CALPCT(I,J)=VALUE
0067    130 CONTINUE
```

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FORTRAN IV      V02.1-1    FRI 28-MAR-80 01:05:09

      C
      C       SET SCALE VALUE
0068          TYPE 62
0069          ACCEPT 13,IANS
0070          IF (IANS.EQ.IYS) GO TO 140
0072          ISCL=1
0073          TYPE 63
0074      140 CONTINUE
      C
      C           END OF PHASE 1--GET NEW PHASE
0075          TYPE 22,IPHS
0076          GO TO 92
      C
      C
      C----------PHASE 2  HEADER INFORMATION
0077      200 CONTINUE
0078          TYPE 16
0079          ACCEPT 17,(IDAT(M),M=1,3)
0080          TYPE 18
0081          ACCEPT 19,(INAM(M),M=1,15)
0082          TYPE 20
0083          ACCEPT 19,(IMOD(M),M=1,15)
      C
      C           END OF PHASE 2--GET NEW PHASE
0084          TYPE 22,IPHS
0085          GO TO 92
      C
      C
      C----------PHASE 3  CALIBRATION
0086      300 CONTINUE
      C
0087          TYPE 24
      C
0088          DO 315 K=1,2
      C
      C         OPEN VALVE(K)--WAIT 30 SECONDS
0089          CALL IPOKE(IORVBF,IVLVMD(K))
0090          T=SEC
0091      303 DT=SEC-T
0092          IF(DT.LT.30.0) GO TO 303
      C
      C         ANALYZE EACH TYPE FOR 100 SAMPLES
0094          DO 315 J=1,2
0095          GASSUM(J)=0.0
      C
0096          DO 305 M=1,100
0097          CALL IPOKE(IADCSR,IADCGC(J))
0098          INT=IPEEK(IADBUF)
0099          GASSUM(J)=GASSUM(J)+FLOAT(INT)/GSGN(J)
0100      305 CONTINUE
      C
0101          GASCNT(K,J)=GASSUM(J)/100.
0102      315 CONTINUE
      C
```

```
FORTRAN IV      V02.1-1     FRI 28-MAR-80 01:05:09

      C       GET SLOPES & INTERCEPTS
0103          DO 320 J=1,2
0104          GASSLP(J)=(CALPCT(2,J)-CALPCT(1,J))
             *     /(GASCNT(2,J)-GASCNT(1,J))
0105          GSNTCP(J)=CALPCT(1,J)-(GASSLP(J)*GASCNT(1,J))
0106      320 CONTINUE
      C
0107          TYPE 261
0108          TYPE 26,(GASCNT(I,1),I=1,2),GASSLP(1),GSNTCP(1)
0109          TYPE 262
0110          TYPE 26,(GASCNT(I,2),I=1,2),GASSLP(2),GSNTCP(2)
      C
      C             END OF PHASE 3--GET NEW PHASE
0111          CALL IPOKE(IDRVBF,IVLVMD(5))
0112          TYPE 22,IPHS
0113          GO TO 92
      C
      C
      C----------PHASE 4  TEST-DATA
0114      400 CONTINUE
      C
0115          TYPE 30
0116          ACCEPT 13,IANS
      C
0117          TYPE 32,(INAM(J),J=1,15),(IDAT(J),J=1,3),(IMOD(J),J=1,15)
0118          LDATHD=.TRUE.
0119          LEXH=.FALSE.
0120          LAVG=.FALSE.
0121          MIN=0
0122          T=SEC
      C
0123      402 IF(IANS.EQ.ISTP) GO TO 495
      C
      C       START TIMER
0125      405 DT=SEC-T
      C       CHECK FOR USER REQUEST
0126          IANS=ITTINR(DMY)
0127          IF(IANS.EQ.ISTP) GO TO 402
      C       SET VALVE CONFIGURATION
0129          IV=4
0130          IF(DT.GT.15.) IV=3
0132          CALL IPOKE(IDRVBF,IVLVMD(IV))
      C       CHECK TIME PHASE
0133      407 CONTINUE
0134          IF(DT.GT.7.) GO TO 415
      C       DT<7:  MAKE CALC'S &
      C        PRINT RESULTS; THEN IDLE...
0136          IF(.NOT.LEXH) GO TO 405
      C
12    0138          LEXH=.FALSE.
11    C
10    0139          O2CON=O2SUM/EXCNTR
9     0140          CO2PD=CO2SM/EXCNTR
8     0141          RESQ=CO2PD/O2CON
7
6
5
4
3
```

```
FORTRAN IV      V02.1-1    FRI 28-MAR-80 01:05:09

      C
0142          O2SUM=0.
0143          CO2SM=0.
      C
0144          CALL PLOT
      D       TYPE 80,((PCTAMB(J),PCTEXH(J)),J=1,3),ONR,CNR,STP,FLOW
      D  80 FORMAT(X,10E9.3)
0145          EXCNTR=0.
0146          LDATMD=.FALSE.
      C
0147          GO TO 405
      C
      C       DT>7, CHECK NEXT PHASE
0148     415 CONTINUE
0149          IF(DT.GT.15.) GO TO 422
      C       DT<15: COLLECT AMBIENT DATA
0151          LAMB=.TRUE.
0152          AMCNTR=AMCNTR+1.
      C             GAS FRACTIONS
0153          DO 417 J=1,2
0154          CALL IPOKE(IADCSR,IADCGC(J))
0155          INT=IPEEK(IADBUF)
0156          GASCNT(3,J)=FLOAT(INT)/GSGN(J)
0157          PCTAMB(J)=(GASSLP(J)*GASCNT(3,J))+GSNTCP(J)
0158     417 CONTINUE
0159          PCTAMB(3)=100.0-PCTAMB(2)-PCTAMB(1)
0160          IF(CAMAX.LT.PCTAMB(2)) CAMAX=PCTAMB(2)
      C             RATIO FACTORS
0162          ONSUM=ONSUM+(PCTAMB(1)/PCTAMB(3))
0163          CONSM=CONSM+(PCTAMB(2)/PCTAMB(3))
0164          PCTSM=PCTSM+PCTAMB(2)
      C             TEMP
0165          CALL IPOKE(IADCSR,IADCGC(3))
0166          INT=IPEEK(IADBUF)
0167          TEMP=((.4885*FLOAT(INT))-5.)/10.
      C             PRESS
0168          CALL IPOKE(IADCSR,IADCGC(4))
0169          INT=IPEEK(IADBUF)
0170          PRES=((4.8851*FLOAT(INT))+.007)/10.
      C
0171          STPP=(273.15/(273.15+TEMP))*PRES/760.
0172          STPS=STPS+STPP
      C
0173          GO TO 405
      C
      C       DT>15, CHECK NEXT PHASE
0174     422 CONTINUE
0175          IF(DT.GT.22.) GO TO 460
      C       DT<22: AVG AMBIENT DATA;
      C        ZERO INTEGRATORS; THEN IDLE...
0177          IF(.NOT..AMB) GO TO 405
      C
0179          LAMB=.FALSE.
      C
```

```
FORTRAN IV      V02.1-1     FRI 28-MAR-80 01:05:09

0180            STP=STPS/AMCNTR
0181            ONRAT=ONSUM/AMCNTR
0182            CONRT=CONSM/AMCNTR
0183            PCTCAV=PCTSM/AMCNTR
0184            IF((CAMAX-PCTCAV).GT.2) LAVG=.TRUE.
0186            IF(LAVG) TYPE 13,IBL
      D         ONR=ONRAT
      D         CNR=CONRT
      C
0188            AMCNTR=0.
0189            STPS=0.
0190            ONSUM=0.
0191            CONSM=0.
0192            PCTSM=0.0
0193            CAMAX=0.0
      C
0194            GO TO 405
      C
      C         DT>22, CHECK LAST PHASE
0195      460 CONTINUE
0196            IF(DT.LT.60.) GO TO 462
0198            T=T+60.
0199            MIN=MIN+1
0200            GO TO 405
      C
      C           DT<60.: COLLECT EXHALED DATA
0201      462 LEXH=.TRUE.
0202            EXCNTR=EXCNTR+1.
      C                   GAS FRACTIONS
0203            DO 467 J=1,2
0204            CALL IPOKE(IADCSR,IADCGC(J))
0205            INT=IPEEK(IADBUF)
0206            GASCNT(4,J)=FLOAT(INT)/GSGN(J)
0207            PCTEXH(J)=(GASSLP(J)*GASCNT(4,J))+GSNTCP(J)
0208      467 CONTINUE
0209            PCTEXH(3)=100.0-PCTEXH(1)-PCTEXH(2)
      C                   FLOW
0210            CALL IPOKE("167770,1)
0211            IVAL=IPEEK("167774)
0212            CALL IPOKE("167770,0)
0213            FLOW=CON3CO(IVAL,1)*1.52
      C
0214            O2SUM=O2SUM+(STP*FLOW*((ONRAT*PCTEXH(3))-PCTEXH(1))*.01)
0215            CO2SM=CO2SM+(STP*FLOW*(PCTEXH(2)-(CONRT*PCTEXH(3)))*.01)
      C
0216            GO TO 405
      C
      C
0217      495 CONTINUE
12    0218        CALL IPOKE(IDRVBF,IVLVMD(5))
11    0219        TYPE 22,IPHS
10    0220        ACCEPT 15,IPHS
 9    0221        IPHS=IPHS
 8    0222        GO TO 92
 7
 6
 5
 4
 3
```

```
FORTRAN IV      V02.1-1     FRI 28-MAR-80 01:05:09

      C
      C
      C----------PHASE 5  TERMINATION
0223    500 CONTINUE
      C
      C*       STOP CLOCK
0224        CALL IPOKE("172540,"000)
      C*
0225        TYPE 40
0226        CALL IPOKE(IDRVBF,"00)
      C
      C
0227        STOP 'BYE'
      C
      C
0228     12  FORMAT (X,'TO GET INSTRUCTION, ',
     *       'TYPE Y & RETURN',/,X,
     *    'TO PROCEED, TYPE N & RETURN  ',$)
      C
0229     13 FORMAT (A1)
      C
0230     14 FORMAT (X,//,X,'TEST LOAD M-R-M-S HAS 5 PHASES',
     *       //,5X,'1  DATA CONSTANTS--ALLOWS USER',
     *       /,' MODIFICATION OF SELECTED DATA CONSTANTS',
     *       /,' (GAS GAINS,CAL-GAS %'S, ETC.).',
     *       /,' OTHERWISE PROGRAM USES DEFAULT VALUES.',
     *      //,5X,'2  INITIALIZATION--ENTER HEADER INFORMATION',
     *      //,5X,'3  CALIBRATE--DETERMINE SLOPES & INTERCEPTS',
     *       /,' FOR DATA CURVES BY SAMPLING 2 CAL. GASES',
     *       //,5X,'4  TEST-DATA--SAMPLES TEST-DATA CONTINUOSLY',
     *    /,' UNTIL USER TERMINATES',
     *       //,5X,'5  TERMINATE--RETURNS CONTROL TO MONITOR',
     *   //,3X,'VERIFY CAL GASES ARE OPEN',
     *   /,3X,'AND MASS SPEC IS FUNCTIONAL',
     *      ///,10X,'ENTER # & RETURN  ',$)
      C
0231     15 FORMAT (I1)
      C
0232     16     FORMAT (X,//,10X,'PHASE 2  INITIALIZATION',//,
     *       2X,'DATE : (MM/DD/YY)  ',$)
      C
0233     17 FORMAT (I2,X,I2,X,I2)
      C
0234     18 FORMAT (2X,'SUBJECT NAME :  ',$)
      C
0235     19 FORMAT (15A2)
      C
0236     20 FORMAT (2X,'TEST NO. ',$)
      C
0237     22 FORMAT (X,/,5X,'END OF PHASE ',I3,/,
     *       '  ENTER NEW PHASE # ',$)
      C
0238     24 FORMAT(X,//,10X,'PHASE 3  CALIBRATION')
      C
```

```
FORTRAN IV      V02.1-1     FRI 28-MAR-80 01:05:09

0239     26  FORMAT(4X,'CIS=1',4X,'CIS=2',8X,'SLOPE',
               *       7X,'INTCPT',/,2(3X,F8.2),2X,2(3X,F9.3))
0240    261  FORMAT(/,22X,'OXYGEN')
0241    262  FORMAT(/,18X,'CARBON DIOXIDE')
        C
0242     30  FORMAT(X,//,10X,'PHASE 4  TEST-DATA',
               *       /,5X,'TO INITIATE:',
               *       /,5X,'ADVANCE PAGE AS DESIRED,',
               *       /,5X,'THEN RETURN,',
               *       /,5X,'TERMINATE AT ANY TIME',
               *       /,5X,'BY ENTERING $ & RETURN,',$)
        C
0243     32  FORMAT(X,'NAME:  ',15A2,15X,'DATE:  ',
               *       2(I2,'/'),I2,15X,'TEST MODE:  ',15A2)
        C
0244     40      FORMAT (X,//,10X,'END OF REAL-TIME TEST',
               *     /,5X,'CONTROL RETURNS TO SYS. MONITOR...',
               *  //,5X,'BE SURE TO CLOSE CAL GASES',
               *  /,5X,'AND RETURN MASS SPEC TO STANDBY')
        C
0245     50  FORMAT(X,//,10X,'PHASE 1  DATA CONSTANTS',
               *     /,5X,'TO LEAVE VALUE UNCHANGED, ENTER',
               *     /,5X,'N & RETURN,  TO CHANGE ENTER Y',
               *  /,5X,'& RETURN, GET "NEW VALUE" PROMPT,',
               *  /,5X,'ENTER NEW VALUE & RETURN',/)
        C
0246     52  FORMAT(5X,'GSGN(',I1,')=',F4.1,$)
        C
0247     54  FORMAT(3X,'NEW VALUE =',$)
        C
0248     53  FORMAT(F4.1)
        C
0249     56  FORMAT(5X,'IADCGC(',I1,')= "',O5,$)
        C
0250     57  FORMAT(O5)
        C
0251     58  FORMAT(5X,'CALPCT(',I1,',',I1,')=',F6.2,$)
        C
0252     59  FORMAT(F6.2)
        C
0253     60  FORMAT(4F6.2,2F4.1,4O5)
        C
0254     62  FORMAT(5X,'SET SCALE = 0=.5 ? ',$)
        C
0255     63  FORMAT(5X,'SCALE SET = 0=5. ! ')
        C
        C
0256         END
        C
```

```
FORTRAN IV      STORAGE MAP FOR PROGRAM UNIT MRMS

LOCAL VARIABLES, .PSECT $DATA, SIZE = 000636 (  207. WORDS)

NAME   TYPE  OFFSET    NAME   TYPE  OFFSET    NAME   TYPE  OFFSET
AMCNTR R*4   000332    CAMAX  R*4   000326    CONRT  R*4   000546
CONSM  R*4   000342    CO2SM  R*4   000322    DMY    R*4   000514
DT     R*4   000504    I      I*2   000456    IADBUF I*2   000306
IADCSR I*2   000304    IANS   L*1   000454    IBL    I*2   000302
IDRVBF I*2   000310    IND    L*1   000277    INT    I*2   000474
IRMS   I*2   000466    ISR    I*2   000464    ISTR   L*1   000300
IV     I*2   000520    IVAL   I*2   000556    IYS    L*1   000276
J      I*2   000460    K      I*2   000476    LAMB   L*4   000522
LEXH   L*4   000510    M      I*2   000462    ONRAT  R*4   000542
ONSUM  R*4   000334    O2SUM  R*4   000316    PCTCAV R*4   000552
PCTSM  R*4   000526    STP    R*4   000536    STPP   R*4   000532
STRS   R*4   000312    T      R*4   000500    VALUE  R*4   000470

COMMON BLOCK /PLOTR /, SIZE = 000050 (   20. WORDS)

NAME   TYPE  OFFSET    NAME   TYPE  OFFSET    NAME   TYPE  OFFSET
LOATHD L*4   000000    MIN    I*2   000004    O2CON  R*4   000006
CO2PD  R*4   000012    RESQ   R*4   000016    TEMP   R*4   000022
PRES   R*4   000026    EXCNTR R*4   000032    LAVG   L*4   000036
FLOW   R*4   000042    ISCL   I*2   000046

COMMON BLOCK /TIME  /, SIZE = 000004 (    2. WORDS)

NAME   TYPE  OFFSET    NAME   TYPE  OFFSET    NAME   TYPE  OFFSET
SEC    R*4   000000

LOCAL AND COMMON ARRAYS:

NAME      TYPE    SECTION OFFSET  ******SIZE****** DIMENSIONS
CALPCT    R*4 VEC $DATA   000102  000020 (    8.) (2,2)
GASCNT    R*4 VEC $DATA   000202  000040 (   16.) (4,2)
GASSLP    R*4     $DATA   000152  000010 (    4.) (2)
GASSUM    R*4     $DATA   000242  000010 (    4.) (2)
GSGN      R*4     $DATA   000172  000010 (    4.) (2)
GSNICP    R*4     $DATA   000162  000010 (    4.) (2)
IADCGC    I*2     $DATA   000264  000012 (    5.) (5)
IDAT      I*2     $DATA   000000  000006 (    3.) (3)
IMOD      I*2     $DATA   000044  000036 (   15.) (15)
INAM      I*2     $DATA   000006  000036 (   15.) (15)
IVLVMD    I*2     $DATA   000252  000012 (    5.) (5)
PCTAMB    R*4     $DATA   000122  000014 (    6.) (3)
PCTEXH    R*4     $DATA   000136  000014 (    6.) (3)

SUBROUTINES, FUNCTIONS, STATEMENT AND PROCESSOR-DEFINED FUNCTIONS:

NAME   TYPE  NAME   TYPE  NAME   TYPE  NAME   TYPE  NAME   TYPE
CONBCD R*4   FLOAT  R*4   INTSET I*2   IPEEK  I*2   IPOKE  I*2
ITTINR I*2   PLOT   R*4   TICK   R*4
```

```
FORTRAN IV       V02.1-1     FRI 28-MAR-80 00:40:55

0001            SUBROUTINE TICK(ID)
                C
0002            COMMON/TIME/SEC
                C
0003            SEC=SEC+1.
                C
0004            RETURN
0005            END
```

```
FORTRAN IV       STORAGE MAP FOR PROGRAM UNIT TICK

LOCAL VARIABLES, .PSECT $DATA, SIZE = 000002 (     1. WORDS)

NAME    TYPE  OFFSET      NAME    TYPE  OFFSET      NAME    TYPE  OFFSET
ID      I*2   000000

COMMON BLOCK /TIME  /, SIZE = 000004 (     2. WORDS)

NAME    TYPE  OFFSET      NAME    TYPE  OFFSET      NAME    TYPE  OFFSET
SEC     R*4   000000
```

```
FORTRAN IV       V02.1-1     MON 31-MAR-80 10:13:44

0001          SUBROUTINE PLOT
          C
0002          LOGICAL LDATHD,LAVG
0003          LOGICAL*1 ISCAL,IPL,IMN,IO,IC,IST,IBL,IGD
          C
0004          DIMENSION ISCAL(56),SCAL(2)
          C
0005          COMMON/PLOTR/LDATHD,MIN,O2CON,CO2PD,
             *     RESQ,TEMP,PRESS,EXCNTR,LAVG,FLOW,ISCL
          C
0006          DATA IPL/1H+/,IMN/1H-/,IBL/1H /
0007          DATA IO/1HO/,IC/1HC/,IST/1H*/
0008          DATA OXYPR/0.0/,CO2PR/0.0/,RSQPR/0.0/
0009          DATA SCAL/10.0,100.0/
          C
          C       PRINT COL. TITLES ONCE
0010          IF(.NOT.LDATHD) GO TO 8
0012          GO TO (10,100) ISCL
0013       10 TYPE 11
0014          GO TO 4
0015      100 TYPE 101
          C     GO TO 4
0016        4 CONTINUE
0017          RMIN=0.0
          C
          C       SET SCALE LINE BY BRUTE FORCE
0018          DO 5 I=1,56
0019        5 ISCAL(I)=IMN
0020          DO 6 I=1,51,10
0021        6 ISCAL(I)=IPL
          C
0022        8 CONTINUE
0023          JDIS=(O2CON*SCAL(ISCL))+.5
0024          JC=IFIX(JDIS)+1
          C
0025          CDIS=(CO2PD*SCAL(ISCL))+.5
0026          JC=IFIX(CDIS)+1
          C
0027          ISV1=ISCAL(JO)
0028          ISV2=ISCAL(JC)
0029          ISCAL(JO)=IO
0030          ISCAL(JC)=IC
          C
0031          IF(JC.EQ.JO) ISCAL(JJ)=IST
          C
0033          IGD=IBL
0034          IF(LAVG) IGD=IST
0036          TYPE 20,MIN,TEMP,PRESS,FLOW,O2CON,CO2PD,RESQ,
             *  IGD,(ISCAL(J),J=1,56),EXCNTR
0037          ISCAL(JO)=ISV1
12  0038      ISCAL(JC)=ISV2
11        C
10  0039      IF(LAVG) GO TO 9
9   0041      RMIN=RMIN+1.0
8
7
6
5
4
3
```

```
FORTRAN IV      V02.1-1     MON 31-MAR-80 10:13:44

0042          OXYPR=OXYPR+O2CON
0043          CO2PR=CO2PR+CO2PO
0044          RSQPR=RSQPR+RESQ
      C
0045          IF(RMIN.LT.15.0) RETURN
0047          OXYAVG=OXYPR/RMIN
0048          CO2AVG=CO2PR/RMIN
0049          RSQAVG=RSQPR/RMIN
      C
0050          OXYPR=0.
0051          CO2PR=0.
0052          RSQPR=0.
0053          RMIN=0.
      C
0054          TYPE 30,OXYAVG,CO2AVG,RSQAVG
      C
0055        9 CONTINUE
0056          LAVG=.FALSE.
0057          RETURN
      C
0058       11 FORMAT(/,1X,'MIN T(CG) P(MG) F(L/M)  O2-CON',
     *     '  CO2-PO  RES-Q',5X,'0.',8X,'1.',8X,'2.',
     *     8X,'3.',8X,'4.',8X,'5.',7X,'SMPLS')
      C
0059      101 FORMAT(/,1X,'MIN T(CG) P(MG) F(L/M  O2-CON',
     *     '  CO2-PO  RES-Q',5X,'0 ',8X,'.1',8X,'.2',
     *     8X,'.3',8X,'.4',8X,'.5',7X,'SMPLS')
      C
0060       20 FORMAT(2X,I2,3(1X,F5.1),X,3(2X,F6.3),4X,1A1,
     *     5A1,1X,F5.0,/)
      C
0061       30 FORMAT(5X,'15-MIN. AVERAGES  ',3(2X,F6.3),/)
      C
      C
0062          END
```

FORTRAN IV STORAGE MAP FOR PROGRAM UNIT PLOT

LOCAL VARIABLES, .PSECT $DATA, SIZE = 000210 (68. WORDS)

NAME	TYPE	OFFSET	NAME	TYPE	OFFSET	NAME	TYPE	OFFSET
CDIS	R*4	000146	CO2AVG	R*4	000166	CO2PR	R*4	000112
I	I*2	000136	IBL	L*1	000102	IC	L*1	000104
IGD	L*1	000130	IMN	L*1	000101	IO	L*1	000103
IPL	L*1	000100	IST	L*1	000105	ISV1	I*2	000154
ISV2	I*2	000156	J	I*2	000160	JC	I*2	000152
JO	I*2	000144	ODIS	R*4	000140	OXYAVG	R*4	000162
OXYPR	R*4	000106	RMIN	R*4	000132	RSQAVG	R*4	000172
RSQPR	R*4	000116						

COMMON BLOCK /PLOTR /, SIZE = 000050 (20. WORDS)

NAME	TYPE	OFFSET	NAME	TYPE	OFFSET	NAME	TYPE	OFFSET
LDATHD	L*4	000000	MIN	I*2	000004	O2CO	R*4	000006
CO2PD	R*4	000012	RESQ	R*4	000016	TEMP	R*4	000022
PRESS	R*4	000026	EXCNTR	R*4	000032	LAVG	L*4	000036
FLOW	R*4	000042	ISCL	I*2	000046			

LOCAL AND COMMON ARRAYS:

NAME	TYPE	SECTION	OFFSET	SIZE	DIMENSIONS
ISCAL	L*1	$DATA	000000	000070 (28.)	(56)
SCAL	R*4	$DATA	000070	000010 (4.)	(2)

SUBROUTINES, FUNCTIONS, STATEMENT AND PROCESSOR-DEFINED FUNCTIONS:

NAME	TYPE	NAME	TYPE	NAME	TYPE	NAME	TYPE	NAME	TYPE
IFIX	I*2								

```
FORTRAN IV       V02.1-1     FRI 28-MAR-80 00:39:53

0001          FUNCTION CONBCD(IVAL,NDD)
              C
0002          IBCD=IVAL
0003          IONE=(IBCD.AND."000017)
0004          I1=IONE
              C
0005          IBCD=IBCD/16
0006          ITEN=(IBCD.AND."000017)
0007          I10=ITEN*10
              C
0008          IBCD=IBCD/16
0009          IHUN=(IBCD.AND."000017)
0010          I100=IHUN*100
              C
0011          IBCD=IBCD/16
0012          ITOU=(IBCD.AND."000017)
0013          I1000=ITOU*1000
              C
0014          ITOT=(I1000+I100+I10+I1)
0015          DEC=10.**NDD
              C
0016          CONBCD=FLOAT(ITOT)/DEC
              C
0017          RETURN
0018          END
```

FORTRAN IV STORAGE MAP FOR PROGRAM UNIT CONBCD

LOCAL VARIABLES, .PSECT $DATA, SIZE = 000040 (16. WORDS)

NAME	TYPE	OFFSET		NAME	TYPE	OFFSET	NAME	TYPE	OFFSET
CONBCD	R*4	000004	EQV	DEC	R*4	000034	IBCD	I*2	000010
IHUN	I*2	000022		IONE	I*2	000012	ITEN	I*2	000016
ITOT	I*2	000032		ITOU	I*2	000026	IVAL	I*2 @	000000
I1	I*2	000014		I10	I*2	000020	I100	I*2	000024
I1000	I*2	000030		NDD	I*2 @	000002			

SUBROUTINES, FUNCTIONS, STATEMENT AND PROCESSOR-DEFINED FUNCTIONS:

NAME	TYPE	NAME	TYPE	NAME	TYPE	NAME	TYPE	NAME	TYPE
FLOAT	R*4								

RT-11 LINK V05.00 LOAD MAP MON 31-MAR-80 10:15:30
ENVIRE.SAV TITLE: MRMS IDENT: FORV02

SECTION	ADDR	SIZE	GLOBAL	VALUE	GLOBAL	VALUE	GLOBAL	VALUE
. ABS.	000000	001000	(RW,I,GBL,ABS,OVR)					
			$RF2A1	000000	.VIR	000000	$USRSW	000001
			$NLCHN	000006	$HRDWR	000006	$SYSV$	000011
			$WASIZ	000152	SLRECL	000210	$TRACE	004737
OTS$I	001000	021744	(RW,I,LCL,REL,CON)					
			$$OTSI	001000	ADF$IM	001000	ADF$PM	001006
			ADF$MM	001012	ADF$SM	001022	SUF$IM	001042
			SUF$SM	001050	SUF$PM	001100	SUF$MM	001104
			$CVTFB	001134	$CVTFI	001134	$CVTCB	001150
			$CVTCI	001150	$CVTDB	001150	$CVTDI	001150
			CIC$	001162	CID$	001162	CLC$	001162
			CLD$	001162	$DI	001162	CIF$	001172
			CLF$	001172	$RI	001172	CIL$	001300
			CLI$	001304	$CVTIF	001306	$CVTIC	001322
			$CVTID	001322	CCI$	001334	CDI$	001334
			$IC	001334	$ID	001334	CFI$	001350
			$IR	001350	RCI$	001434	GCO$	002450
			FCO$	002456	ECO$	002462	DCO$	002470
			DIF$PS	003412	DIF$MS	003416	DIF$IS	003430
			$DIVF	003436	DIF$SS	003450	$DVR	003450
			DII$PS	003454	DII$MS	003462	DII$IS	003466
			DII$SS	003470	$DVI	003470	MUI$PS	003512
			MUI$MS	003520	MUI$IS	003524	MUI$SS	003526
			$MLI	003526	$OTI	003574	$$OTI	003576
			$$SET	005456	$XFI	005752	XFI$	005764
			$PWRI	005764	IOR$	006242	AND$	006246
			EQV$	006254	XOR$	006256	OCI$	006272
			ICI$	006300	SECI	006314	OCO$	006474
			ICO$	006502	SCMKER	006700	$IOEXI	006724
			$EOL	006752	EOL$	006754	MOF$IS	007070
			MOF$OS	007076	MOF$SM	007104	MOF$SP	007114
			ADI$SS	007120	ADI$SA	007124	ADI$SM	007130
			ADI$IS	007134	ADI$IA	007140	ADI$IM	007144
			ADI$MS	007150	ADI$MA	007154	ADI$MM	007160
			IFR$	007164	$IFR	007170	$$IFR	007174
			IFR$$	007226	IFW$	007250	$IFW	007254
			$$IFA	007260	IFA$$	007316	MOI$SS	007366
			MOL$SS	007366	MOI$SM	007372	MOI$SA	007376
			MOI$IS	007402	MOL$IS	007402	REL$	007402
			MOI$IM	007406	MOI$IA	007412	MOI$MS	007416
			MOI$MM	007422	MOI$MA	007426	MOI$OS	007432
			MOI$OM	007436	MOI$OA	007442	MOI$IS	007446
			MOI$IM	007454	MOI$IA	007462	MOI$IP	007470
			MOI$SP	007472	MOI$PP	007500	MOI$MP	007504
			MOI$PS	007514	MOI$PM	007522	MOI$PA	007530
12			MOI$OP	007536	MOI$IP	007544	ISN$	007554
11			$ISNTR	007560	LSN$	007574	$LSNTR	007600
10			$OSTMI	007734	$OSTM	007740	RET$L	011056
9			RET$F	011062	RET$I	011070	RET$	011072
8			$STPS	011126	STP$	011134	$STP	011134
7			FOO$	011140	$EXIT	011160	$OTIS	011304
6			$$OTIS	011306	TVL$	011426	$TVL	011426
5			TVF$	011434	$TVF	011434	TVD$	011442
4			$TVD	011442	TVQ$	011450	$TVQ	011450
3			TVP$	011456	$TVP	011456	TVI$	011464
			$TVI	011464	MUF$PS	011620	MUF$MS	011624
			MUF$IS	011636	$MULF	011644	MUF$SS	011656

```
                                    $ALR    011656  $CLOSE  011662  $ERRTN  012326

                                    $ERRS   012434  $FCHNL  016126  $FID    016762
                                    $$FID   016766  $GETFI  020116  $INITI  020154
                                    $$OPCL  020266  $$$ERR  020400  $$$DIS  020422
                                    $PUTRE  020520  IRR$    021026  $IRR    021032
                                    IRW$    021056  $IRW    021062  $GETIN  021436
                                    $SETIN  021454  DEF$    021562  $DEF    021566
                                    $PUTBL  021656  $GETBL  022066  $EOFIL  022252
                                    $EOF2   022266  SAVRG$  022306  THRD$   022464
                                    $WAIT   022466  $VRINT  022530  $DUMPL  022532
                                    SAVR4$  022660
OTS$P   022744  000050   (RW,D,GBL,REL,OVR)
SYS$I   023014  000350   (RW,I,LCL,REL,CON)
                                    INTSET  023014  IPEEK   023216  IPOKE   023226
                                    ITTINR  023236  $CMPLT  023246
USER$I  023364  000000   (RW,I,LCL,REL,CON)
$CODE   023364  013420   (RW,I,LCL,REL,CON)
                                    $$OTSC  023364  TICK    034506  PLOT    034532
                                    CONBCD  036434
OTS$O   037004  001040   (RW,I,LCL,REL,CON)
                                    $$OTSO  037004  $OPEN   037004
SYS$O   040044  000366   (RW,I,LCL,REL,CON)
$DATAP  040432  004224   (RW,D,LCL,REL,CON)
OTS$D   044656  000052   (RW,D,LCL,REL,CON)
OTS$S   044730  000002   (RW,D,LCL,REL,CON)
                                    $AOTS   044730
SYS$S   044732  000066   (RW,D,LCL,REL,CON)
                                    $SYSLB  045014  $LOCK   045016  $CRASH  045017
$DATA   045020  001110   (RW,D,LCL,REL,CON)
USER$D  046130  000000   (RW,D,LCL,REL,CON)
.$$$$.  046130  000000   (RW,D,GBL,REL,OVR)
PLOTR   046130  000050   (RW,D,GBL,REL,OVR)
TIME    046200  000004   (RW,D,GBL,REL,OVR)
        046204  000210   (RW,I,LCL,REL,CON)
                                    $GETRE  046204  STTYIN  046260

TRANSFER ADDRESS = 023364, HIGH LIMIT = 046414 =  9868. WORDS
```

```
T-11 LINK  V05.04A      Load Map          Mon 31-Mar-80 10:15:30
ENVIRE.SAV        Title:  MRMS     Ident:  FORV02

Section  Addr    Size     Global  Value    Global  Value    Global  Value

. ABS.   000000  001000     (RW,I,GBL,ABS,OVR)
                          $RF2A1  000000   .VIR    000000   $USRSW  000001
                          $NLCHN  000006   $HRDWR  000006   $SYSV$  000011
                          $WASIZ  000152   $LRECL  000210   $TRACE  004737
OTS$I    001000  021744     (RW,I,LCL,REL,CON)
                          $$OTSI  001000   ADF$IM  001000   ADF$PM  001006
                          ADF$MM  001012   ADF$SM  001022   SUF$IM  001042
                          SUF$SM  001050   SUF$PM  001100   SUF$MM  001104
                          $CVTFB  001134   $CVTFI  001134   $CVTCB  001150
                          $CVTCI  001150   $CVTDB  001150   $CVTDI  001150
                          CIC$    001162   CID$    001162   CLC$    001162
                          CLD$    001162   $DI     001162   CIF$    001172
                          CLF$    001172   $RI     001172   CIL$    001300
                          CLI$    001304   $CVTIF  001306   $CVTIC  001322
                          $CVTID  001322   CCI$    001334   CDI$    001334
                          $IC     001334   $ID     001334   CFI$    001350
                          $IR     001350   RCI$    001434   GCO$    002450
                          FCO$    002456   ECO$    002462   DCO$    002470
                          DIF$PS  003412   DIF$MS  003416   DIF$IS  003430
                          $DIVF   003436   DIF$SS  003450   $DVR    003450
                          DII$PS  003454   DII$MS  003462   DII$IS  003466
                          DII$SS  003470   $DVI    003470   MUI$PS  003512
                          MUI$MS  003520   MUI$IS  003524   MUI$SS  003526
                          $MLI    003526   $OTI    003574   $$OTI   003576
                          $$SET   005456   $XFI    005752   XFI$    005764
                          $PWRI   005764   IOR$    006242   AND$    006246
                          EQV$    006254   XOR$    006256   OCI$    006272
                          ICI$    006300   $ECI    006314   OCO$    006474
                          ICO$    006502   $CHNER  006700   $IOEXI  006724
                          $EOL    006752   EOL$    006754   MOF$IS  007070
                          MOF$OS  007076   MOF$SM  007104   MOF$SP  007114
                          ADI$SS  007120   ADI$SA  007124   ADI$SM  007130
                          ADI$IS  007134   ADI$IA  007140   ADI$IM  007144
                          ADI$MS  007150   ADI$MA  007154   ADI$MM  007160
                          IFR$    007164   $IFR    007170   $$IFR   007174
                          IFR$$   007226   IFW$    007250   $IFW    007254
                          $$IFW   007260   IFW$$   007316   MOI$SS  007366
                          MOL$SS  007366   MOI$SM  007372   MOI$SA  007376
                          MOI$IS  007402   MOL$IS  007402   REL$    007402
                          MOI$IM  007406   MOI$IA  007412   MOI$MS  007416
                          MOI$MM  007422   MOI$MA  007426   MOI$OS  007432
                          MOI$OM  007436   MOI$OA  007442   MOI$1S  007446
                          MOI$1M  007454   MOI$1A  007462   MOI$IP  007470
                          MOI$SP  007472   MOI$PP  007500   MOI$MP  007504
                          MOI$PS  007514   MOI$PM  007522   MOI$PA  007530
                          MOI$OP  007536   MOI$1P  007544   ISN$    007554
                          $ISNTR  007560   LSN$    007574   $LSNTR  007600
                          $OSTMI  007734   $OSTM   007740   RET$L   011056
                          RET$F   011062   RET$I   011070   RET$    011072
                          $STPS   011126   STP$    011134   $STP    011134
                          FOO$    011140   $EXIT   011160   $OTIS   011304
                          $$OTIS  011306   TVL$    011426   $TVL    011426
                          TVF$    011434   $TVF    011434   TVD$    011442
                          $TVD    011442   TVQ$    011450   $TVQ    011450
                          TVP$    011456   $TVP    011456   TVI$    011464
                          $TVI    011464   MUF$PS  011620   MUF$MS  011624
                          MUF$IS  011636   $MULF   011644   MUF$SS  011656
                          $MLR    011656   $CLOSE  011662   $ERRTB  012326
                          $ERRS   012433   $FCHNL  016126   $FIO    016762
```

```
                                $$PIO   016766  $DEIP1  020116  $INIT1  020134
                                $$OPCL  020266  $$$ERR  020400  $$$DIS  020422
                                $PUTRE  020520  IRR$    021026  $IRR    021032
                                IRW$    021056  $IRW    021062  $GETIN  021436
                                $SETIN  021454  DEF$    021562  $DEF    021566
                                $PUTBL  021656  $GETBL  022066  $EOFIL  022252
                                $EOF2   022266  SAVRG$  022306  THRD$   022464
                                $WAIT   022466  $VRINT  022530  $DUMPL  022532
                                SAVR4$  022660
OTS$P     022744  000050         (RW,D,GBL,REL,OVR)
SYS$I     023014  000350         (RW,I,LCL,REL,CON)
                                INTSET  023014  IPEEK   023216  IPOKE   023226
                                ITTINR  023236  $CMPLT  023246
USER$I    023364  000000         (RW,I,LCL,REL,CON)
$CODE     023364  013420         (RW,I,LCL,REL,CON)
                                $$OTSC  023364  TICK    034506  PLOT    034532
                                CONBCD  036434
OTS$O     037004  001040         (RW,I,LCL,REL,CON)
                                $$OTSO  037004  $OPEN   037004
SYS$O     040044  000366         (RW,I,LCL,REL,CON)
$DATAP    040432  004224         (RW,D,LCL,REL,CON)
OTS$D     044656  000052         (RW,D,LCL,REL,CON)
OTS$S     044730  000002         (RW,D,LCL,REL,CON)
                                $AOTS   044730
SYS$S     044732  000066         (RW,D,LCL,REL,CON)
                                $SYSLB  045014  $LOCK   045016  $CRASH  045017
$DATA     045020  001110         (RW,D,LCL,REL,CON)
USER$D    046130  000000         (RW,D,LCL,REL,CON)
.$$$$.    046130  000000         (RW,D,GBL,REL,OVR)
PLOTR     046130  000050         (RW,D,GBL,REL,OVR)
TIME      046200  000004         (RW,D,GBL,REL,OVR)
          046204  000210         (RW,I,LCL,REL,CON)
                                $GETRE  046204  $TTYIN  046260

Transfer address = 023364, High limit = 046414 =  9862. words
```

APPENDIX D

TERMINAL PRINTOUT

```
$DX
RT-11SJ (S)V03B-00

.SET TT:SCOPE

.SET USR NOSWAP

.ASS DX1 DK

.RUN DX0:ENVIRE.SAV

                M R N S

    REAL-TIME TEST PROGRAM TO SUPPORT THE

    METABOLIC-RATE-MEASUREMENT-SYSTEM,

    ENVIRONMENTAL PHYSIOLOGY LAB,

    TECHNOLOGY INCORPORATED


TO GET INSTRUCTION, TYPE Y & RETURN
TO PROCEED, TYPE N & RETURN  Y


TEST LOAD M-R-N-S HAS 5 PHASES

    1  DATA CONSTANTS--ALLOWS USER
MODIFICATION OF SELECTED DATA CONSTANTS
(GAS GAINS,CAL-GAS %'S, ETC.).
OTHERWISE PROGRAM USES DEFAULT VALUES.

    2  INITIALIZATION--ENTER HEADER INFORMATION

    3  CALIBRATE--DETERMINE SLOPES & INTERCEPTS
FOR DATA CURVES BY SAMPLING 2 CAL. GASES

    4  TEST-DATA--SAMPLES TEST-DATA CONTINUOSLY
UNTIL USER TERMINATES

    5  TERMINATE--RETURNS CONTROL TO MONITOR

  VERIFY CAL GASES ARE OPEN
  AND MASS SPEC IS FUNCTIONAL


        ENTER # & RETURN  1
```

```
      . SE 1  DATA CONSTANTS
  TO LEAVE VALUE UNCHANGED, ENTER
  N & RETURN.  TO CHANGE ENTER Y
  & RETURN, GET "NEW VALUE" PROMPT,
  ENTER NEW VALUE & RETURN

  GSGN(1)= 1.0N
  GSGN(2)= 1.0N
  IADCGC(1)= "  431N
  IADCGC(2)= " 1031N
  IADCGC(3)= " 2001N
  IADCGC(4)= " 2401N
  CALPCT(1,1)= 14.29N
  CALPCT(1,2)=  4.87N
  CALPCT(2,1)= 20.60N
  CALPCT(2,2)=  0.06Y
NEW VALUE =.05
  SET SCALE = 0-.5 ? N
  SCALE SET = 0-5. !

  END OF PHASE   1
ENTER NEW PHASE # 2
```

These parameters are read from a data file, DATCON .VAL prior to any program execution. Phase I allows the user to alter these values if necessary.

GSGN(j) → The gain factor to correct for any hardware gains or A/D programmable gains.

IADCGC(k) → Octal code used to program the A/D converter. Contains channel selection and gain information. Refer to ADAC 1030 User's Manual.

CALPCT(i,j) → cal gas concentrations.


```
      PHASE 2  INITIALIZATION

DATE : (MM/DD/YY)  03/28/80
SUBJECT NAME :  KEN KOESTER
TEST NO. TESTMODE

  END OF PHASE   2
ENTER NEW PHASE # 3


      PHASE 3  CALIBRATION

                OXYGEN
 CTS-1      CTS-2        SLOPE      INTCPT
  291.43     415.17        0.051     -0.571

              CARBON DIOXIDE
 CTS-1      CTS-2        SLOPE      INTCPT
  996.79      14.83        0.005     -0.023

  END OF PHASE   3
ENTER NEW PHASE # 4
```

PHASE 4 TEST-DATA
TO INITIATE:
ADVANCE PAGE AS DESIRED,
THEN RETURN.
TERMINATE AT ANY TIME
BY ENTERING S & RETURN.

NAME: KEN KOESTER DATE: 3/28/90 TEST MODE: TESTMODE

MIN	T(CG)	P(HG)	F(L/M)	O2-CON	CO2-PR	RES-Q	0. 1. 2. 3. 4. 5.	SMPLS
1	26.1	766.0	116.7	1.045	0.806	0.771	+-------C-B--------+--------+--------+--------+--------+-----	3913.
2	26.1	763.1	120.2	1.075	0.886	0.824	+--------C+O-------+--------+--------+--------+--------+-----	3915.
3	26.2	760.9	116.1	0.637	0.597	0.938	+------*---+--------+--------+--------+--------+--------+-----	3909.
4	25.7	765.5	110.5	0.302	0.302	0.997	+---*------+--------+--------+--------+--------+--------+-----	3910.
5	26.2	765.5	119.0	0.435	0.488	1.121	+---OC-----+--------+--------+--------+--------+--------+-----	3909.
6	26.6	771.4	112.2	0.358	0.503	0.901	+----CO----+--------+--------+--------+--------+--------+-----	3909.
7	26.2	764.0	111.0	0.394	0.471	0.793	+----CB----+--------+--------+--------+--------+--------+-----	3909.
8	26.6	770.4	110.7	0.468	0.428	0.916	+---CO-----+--------+--------+--------+--------+--------+-----	3904.
9	27.5	760.9	115.2	0.388	0.357	0.919	+---*------+--------+--------+--------+--------+--------+-----	3907.
10	26.6	767.4	110.2	0.427	0.397	0.929	+---*------+--------+--------+--------+--------+--------+-----	3905.
11	27.0	766.0	111.0	0.382	0.319	0.836	+--CO-----+--------+--------+--------+--------+--------+-----	3911.
12	26.8	773.8	108.7	0.404	0.341	0.844	+--CO-----+--------+--------+--------+--------+--------+-----	3906.
13	26.9	761.1	112.6	0.482	0.447	0.928	+---CO-----+--------+--------+--------+--------+--------+-----	3906.
14	27.1	770.9	118.6	0.369	0.352	0.954	+---*------+--------+--------+--------+--------+--------+-----	3908.
	15-MIN. AVERAGES			0.550	0.491	0.911		
15	26.9	767.9	108.7	0.441	0.425	0.964	+---*------+--------+--------+--------+--------+--------+-----	3909.
16	26.6	764.0	112.0	0.431	0.362	0.839	+---*------+--------+--------+--------+--------+--------+-----	3908.
17	27.0	765.0	123.0	0.711	0.641	0.901	+-----CO---+--------+--------+--------+--------+--------+-----	3913.
18	26.9	766.5	93.5	1.821	1.405	0.771	+---------+---C---B-+--------+--------+--------+--------+-----	3915.
19	26.5	758.2	96.1	2.228	2.149	0.964	+---------+--------+CO------+--------+--------+--------+-----	3914.
20	28.5	753.3	97.0	2.370	2.475	1.044	+---------+--------+---BC----+--------+--------+--------+-----	3920.
21	27.3	766.5	109.6	2.548	2.696	1.058	+---------+--------+----O-C--+--------+--------+--------+-----	3916.
22	27.2	765.0	117.6	2.660	2.861	1.076	+---------+--------+------B-C+--------+--------+--------+-----	3918.

23	27.1	746.8	122.4	1.937	2.399	1.239	3927.
24	26.5	767.9	85.3	2.805	2.901	1.034	3923.
25	27.0	767.9	97.9	1.267	1.981	1.564	3922.
26	27.1	767.9	101.4	0.904	1.324	1.465	3918.
27	27.4	763.1	121.6	0.703	0.977	1.389	3911.
28	27.4	767.0	123.6	0.687	0.854	1.244	3911.
29	27.2	765.5	123.4	0.661	0.764	1.155	3912.
	15-MIN. AVERAGES			1.478	1.614	1.114	
30	27.3	781.6	122.5	0.635	0.693	1.093	3914.
31	26.6	767.4	103.4	0.649	0.680	1.048	3917.
32	27.5	766.0	1[illegible].2	0.545	0.519	0.953	3908.
33	27.2	767.0	120.2	0.582	0.535	0.920	3909.
34	27.4	768.4	114.8	0.554	0.492	0.893	3910.

6

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END OF PHASE 4
ENTER NEW PHASE # 5

END OF REAL-TIME TEST
CONTROL RETURNS TO SYS. MONITOR...

BE SURE TO CLOSE CAL BASES
AND RETURN MASS SPEC TO STANDBY
STOP -- BYE

APPENDIX F

CALIBRATION AND VERIFICATION

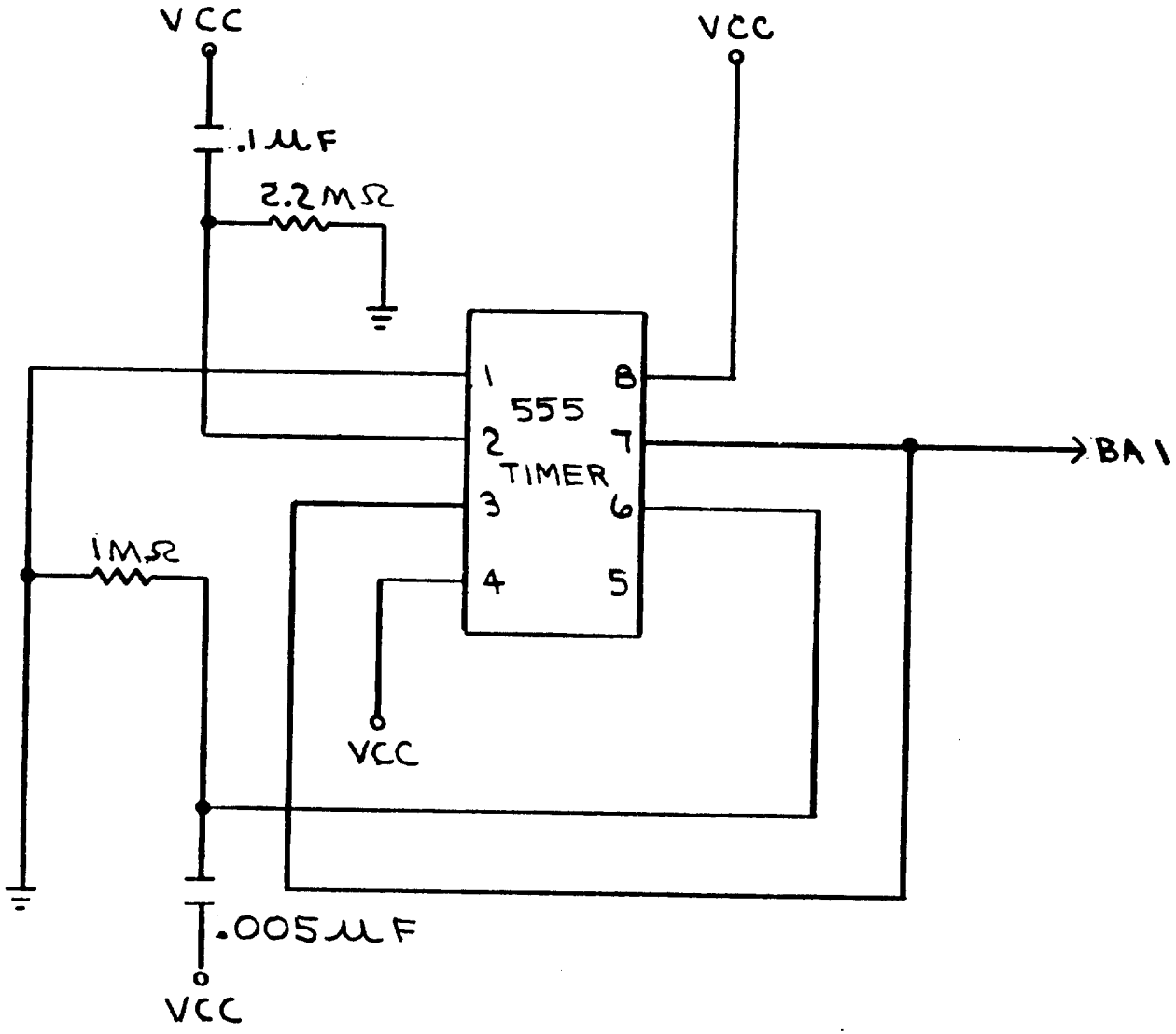
Verification and calibration was done utilizing an alcohol lamp in a vented chamber. The chamber was connected in place of the breathing mask.

Net alcohol weight loss	20.10 grams
Given that 1 gram of alcohol combines with 1.459 litres O_2,	
Net O_2 consumed	29.326 litres
Time Duration	63 minutes
Net rate of O_2 consumption	ΔO=.4655 litres/min.
Average experimental value obtained	ΔO=.4567 litres/min.
	1.9% error

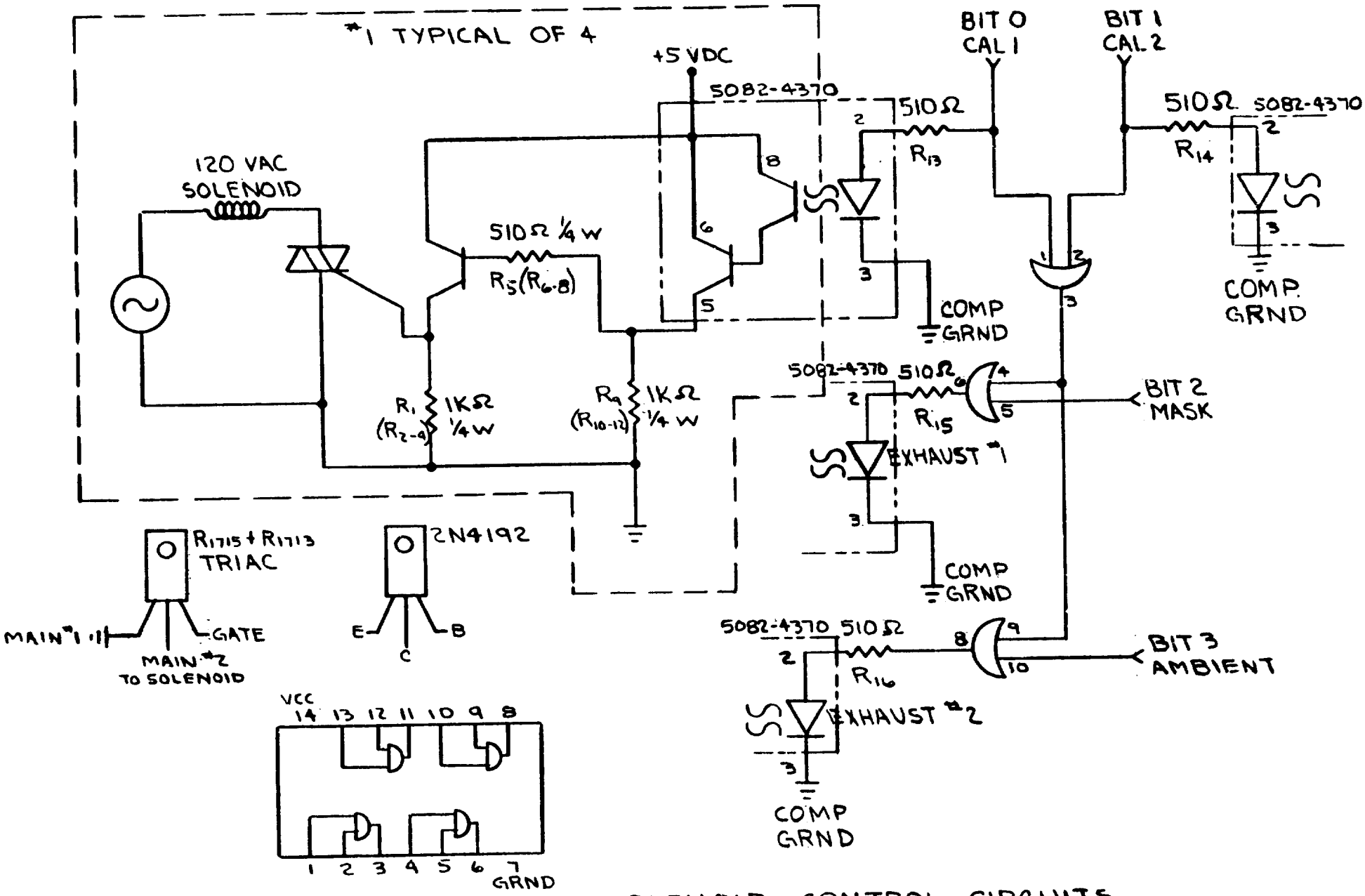
Given that Rq known = .6667

average Rq observed = .6502

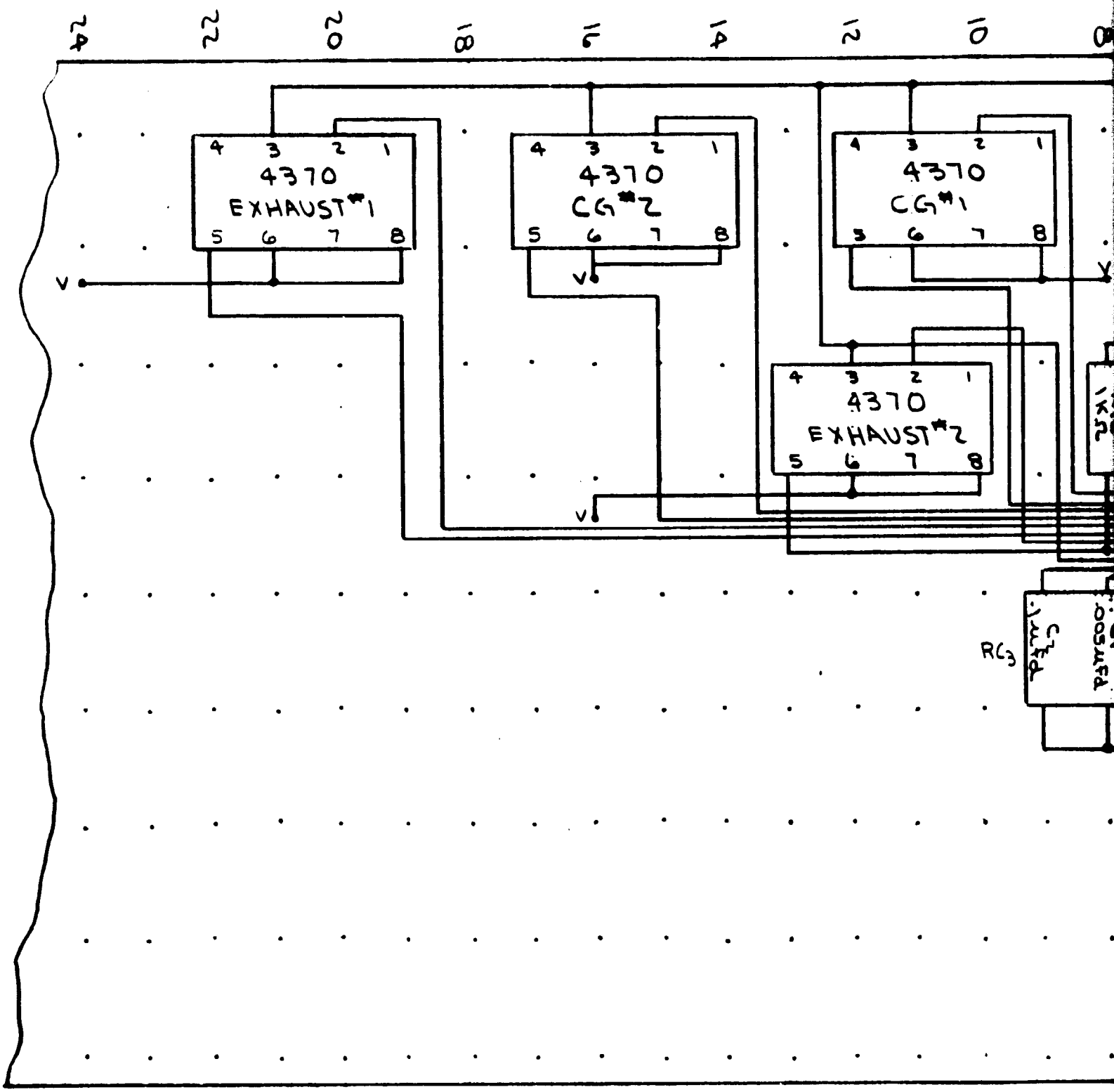
2.4% error



START UP CIRCUIT FOR LSI-11 MICROCOMPUTER



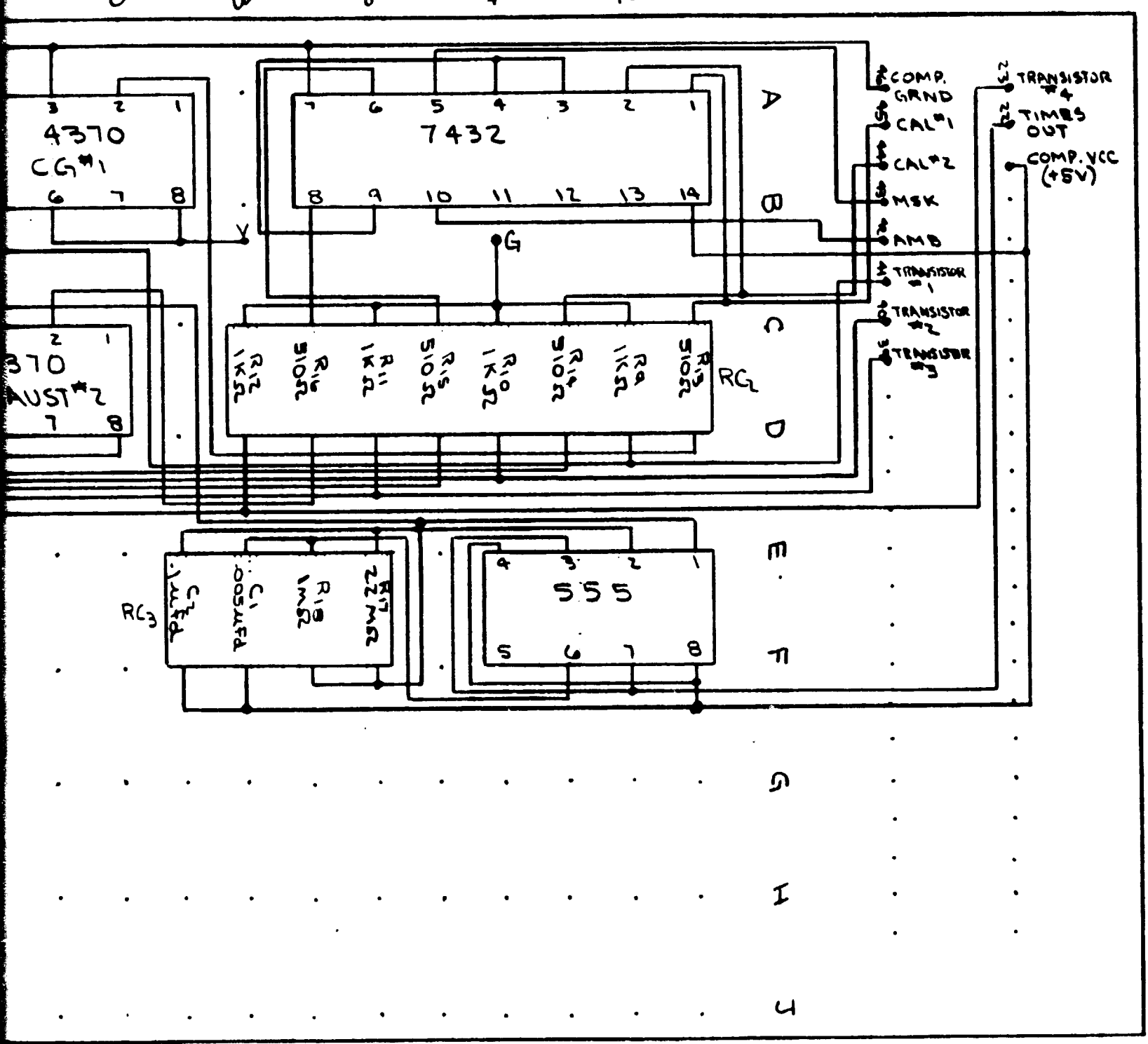
SOLENOID CONTROL CIRCUITS



LOGIC BOARD
START UP CIRCU
PART OF SOLEN
CONTROL CIRC

ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME



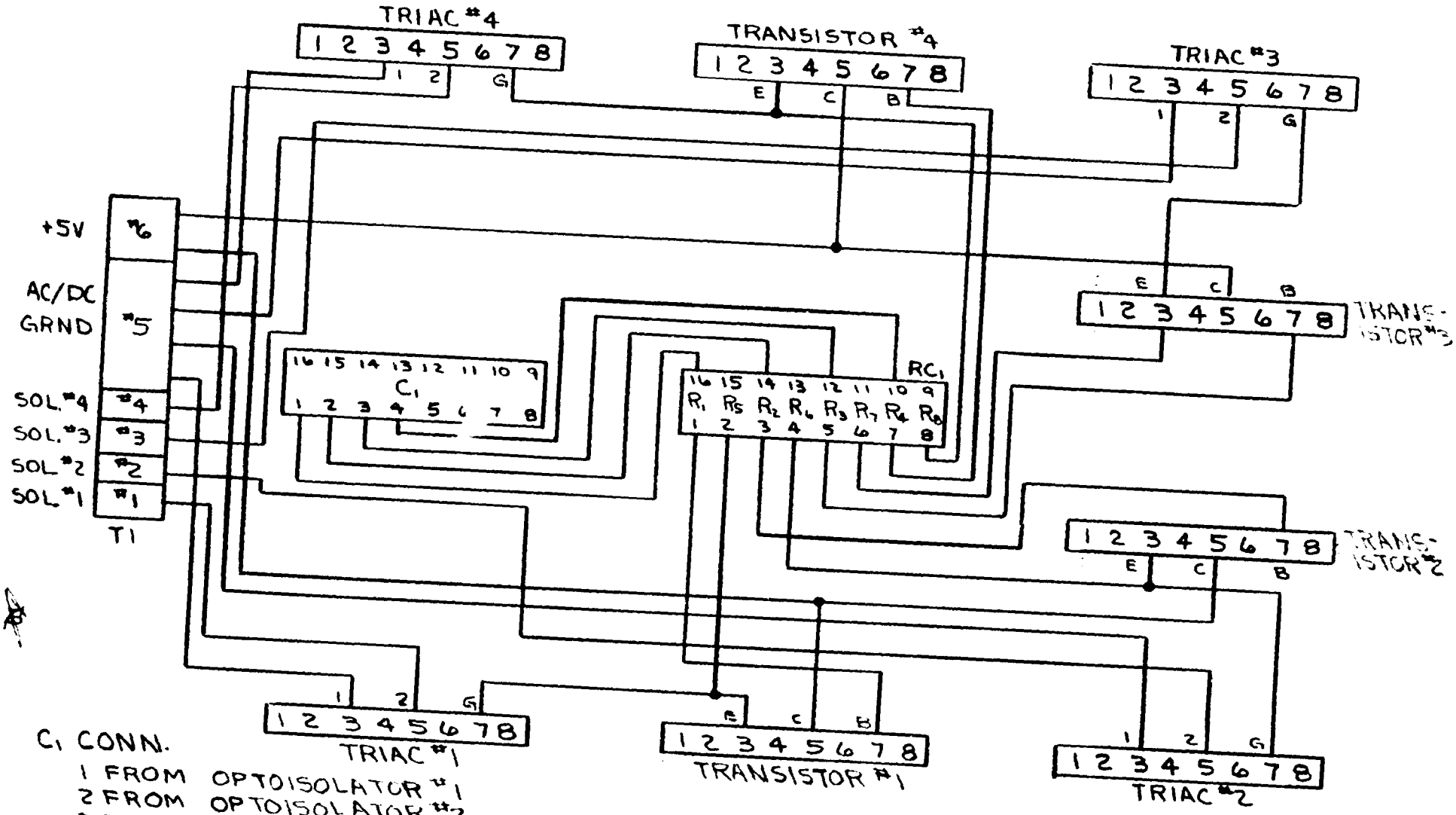
OGIC BOARD

RT UP CIRCUIT &

RT OF SOLENOID

ONTROL CIRCUIT

FOLDOUT FRAME 2



C1 CONN.

1 FROM OPTOISOLATOR #1
2 FROM OPTOISOLATOR #2
3 FROM OPTOISOLATOR #3
4 FROM OPTOISOLATOR #4

R_1-R_4 510 Ω
R_5-R_8 1K Ω

TRIAC-TRANSISTOR BOARD PICTORIAL
(PART OF SOLENOID CONTROL CIRCUIT)