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STANDARD LEAK CALIBRATION FACILITY SOFTWRE SYSTEM

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ACKNOWLEDGEMENTS

The SLCF calibration methods were designed by J. A. Basford, the system's principal scientist. Mr. Basford was also responsible for configuring the vacuum system hardware and mass spectrometer. D. W. Carver designed and built the computer's custom communications interface known as the Serdex. Mr. Basford's and Mr. Carver's design efforts will be documented in a design report currently in preparation to be distributed upon completion. The computer software was developed by S. K. McClain. Additional software documentation is listed in the References.

SUMMARY

A software system has been developed and implemented to support the Standard Leak Calibration Facility. The software system provides a number of functions which support the operation of the facility.

1. Interactive computer control of the vacuum system.
2. Dynamic color graphic display of the current vacuum system state.
3. Automatic logging of vacuum system control commands.
4. Automatic pump down of the vacuum subsystems.
5. Automatic power fail recovery.
6. Automatic calibration of typical-size leaks for total flow and purity.
7. Automatic calibration of small helium leaks for total helium flow.
8. Data archival and reporting capabilities.
9. Automatic depletion rate measurement.
10. Automatic mass spectrometer calibration.
11. Automatic magnet calibration.

Descriptions of each task supporting these functions are presented. Examples and pseudo-code listings are provided when appropriate.

STANDARD LEAK CALIBRATION FACILITY SOFTWARE SYSTEM

S. K. McClain

ABSTRACT

A Standard Leak Calibration Facility Software System has been developed and implemented for controlling, and running a standard Leak Calibration Facility. Primary capabilities provided by the software system include computer control of the vacuum system, automatic leak calibration, and data acquisition, manipulation, and storage.

INTRODUCTION

PURPOSE OF THE STANDARD LEAK CALIBRATION FACILITY

Calibrated leaks are used throughout the Oak Ridge Y-12 Plant as transfer standards of gas flow to calibrate mass spectrometer systems and mass detectors. The flow rates of gas emitted from these leaks covers the broad range from 1×10^{-14} mol/s to 6×10^{-9} mol/s. The Standard Leak Calibration Facility (SLCF) is a system that will calibrate the leaks for both total gas flow rate and gas purity. It is a complex instrument consisting of two independent vacuum systems with associated constant temperature baths, a sector mass spectrometer, and a selection of high-purity calibration gases. Computer control of the vacuum system, the mass spectrometer, and the acquisition, manipulation, and storage of data permits accurate, unattended calibration of up to 17 leaks at a time.

COMPUTER HARDWARE

The computer hardware configuration consists of a Digital Equipment Corporation (DEC) PDP-11/34a computer with 128K words of memory, cache, a floating point processor, extended instruction set, and two RL02 10-megabyte disk drives for online storage (Fig. 1). A battery backed-up clock, the TCU-150, is installed. Communication to external devices is accomplished through an 8-line MDB-DZ-11 asynchronous multiplexer. Connected to the multiplexer are a VT100 video display terminal and a Tektronix (Tek) 4027a color graphics terminal. The vacuum system hardware communicates with the computer through a custom-designed interface known as the Serdex. The Serdex interface, as

Y-GA 89M-11066

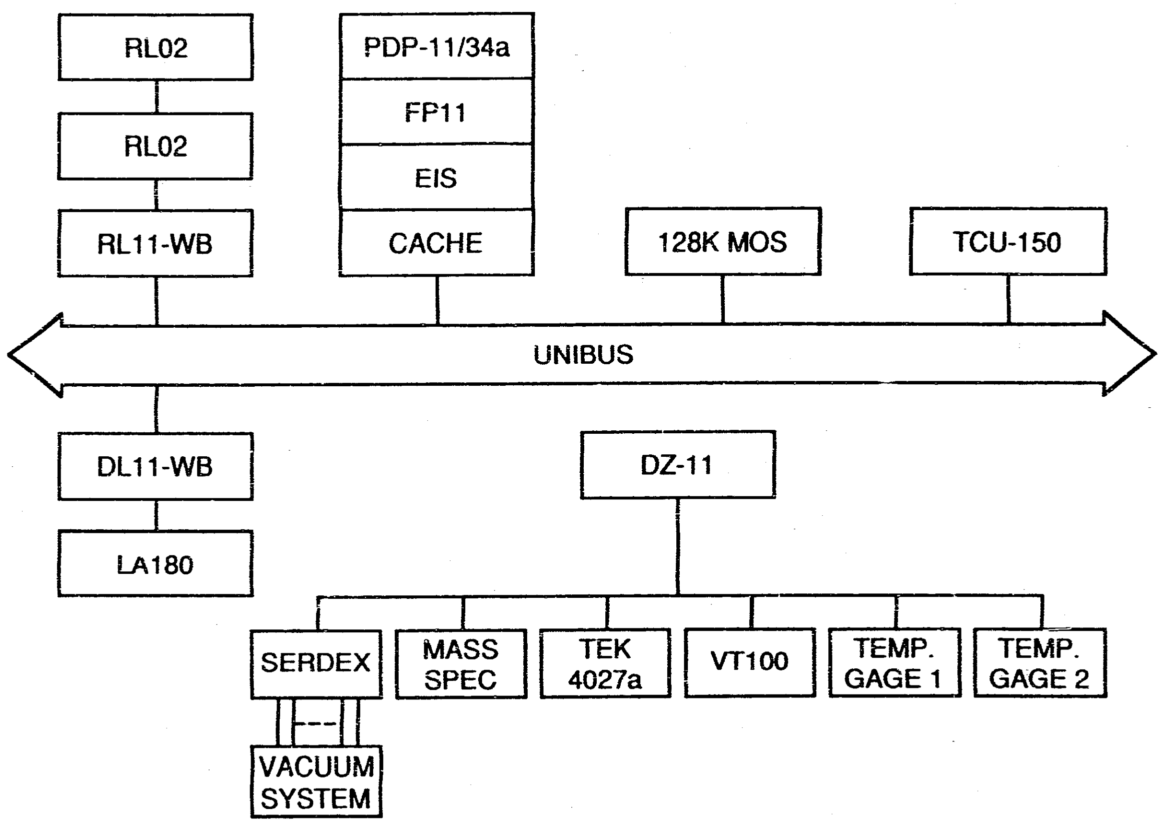

Fig. 1. Computer hardware configuration.

well as three serial communication lines to two temperature gauges, and the mass specrometer are connected to the computer through the MDB-DZ-11. An LA120 Decwriter serves as the computer console device and printer.

SOFTWARE SUMMARY

The computer is running the RSX-11M Version 4.1 operating system. In-house software written specifically for SLCF is coded primarily in Fortran-77. Where necessary, software is coded in Macro-11. Full advantage of DEC extensions to the Fortran-77 language has been taken since it is not necessary that the code be portable to other vendor's hardware. A summary of the seventeen tasks which compose the SLCF software system follows.

1. CAL   Calibration Task - typical-size leaks

   CAL performs the automatic calibration of typical-size leaks for total flow and purity.

2. CLS   Calibration Task - small-size leaks

   CLS performs the automatic calibration of small helium leaks for total helium flow.

3. DDM   Data Management Task

   DDM prints calibration data reports and transfers data from temporary storage to permanent storage.

4. DPR   Depletion Rate Measurement Task

   DPR measures the depletion rate of hydrogen through each of the four possible paths along which gases may flow from the vacuum system to the mass spectrometer during mass scans.

5. EMG   Emergency Main Control Task (non-graphics version)

   EMG serves the same purpose as LCF, but without the use of a graphics device. It is designed to be used in emergency situations when the SLCF must be operated but the graphics terminal is not operational.

6. LCF   Main Control Task (graphics version)

   LCF serves as the primary interface between the user and the vacuum system. It provides a graphic display of the vacuum system, depicting the current status of process flows, motors, valves, gauges, and station monitors.

Through LCF, the operator can manually and interactively control the state ofthe vacuum system. A simple online Help facility and automatic command logging functions are available.

7. LGF Log File Display Task

LGF generates a report of the commands logged in the log file.

8. MGC Magnet Calibration Task

MGC calibrates the mass spectrometer magnet.

9. MSC Mass Spectrome.er Calibration Task

MSC calibrates the mass spectrometer (i.e., it measures the sensitivity of each mass due to various gases).

10. PMPDN1 Pump Down Bath 1 Task

PMPDN1 automatically pumps down the Bath 1 vacuum subsystem.

11. PMPDN2 Pump Down Bath 2 Task

PMPDN2 automatically pumps down the Bath 2 vacuum subsystem.

12. PMPDN3 Pump Down Bath 3 Task

PMPDN3 automatically pumps down the high-purity gas calibration stand vacuum subsystem.

13. PRM Parameter Modification Task

PRM provides an easy way to review current parameter values and to make changes to parameters required by the calibration tasks: depletion rates, collection volume sizes, and mass scan parameters.

14. PWRUP Power Fail Restart Task

PWRUP attempts to pump down the vacuum system whenever electrical power has been restored after power loss.

15. REFGAU Gauge Monitoring Task (graphics version)

REFGAU continously monitors the vacuum system gauges in the graphics mode (with LCF).

16. RFGEMG Gauge Monitoring Task (non-graphics version)

RFGEMG continuously monitors the vacuum system gauges in the non-graphics mode (with EMG).

17. SLA Standard Leak Attachment Task

SLA prepares the vacuum system and the leaks for calibration. Operators may attach to the system new leaks to be calibrated, or they may repeat calibration of leaks attached during a previous run of SLA.

SOFTWARE DIAGRAM

A block diagram of the interactions between the primary task and data components of the SLCF appears in Fig. 2. Tasks are represented by squares and data are represented by ovals. Interconnecting arrows represent data flow or communication links. Notice that some interconnections are unidirectional while others are bidirectional.

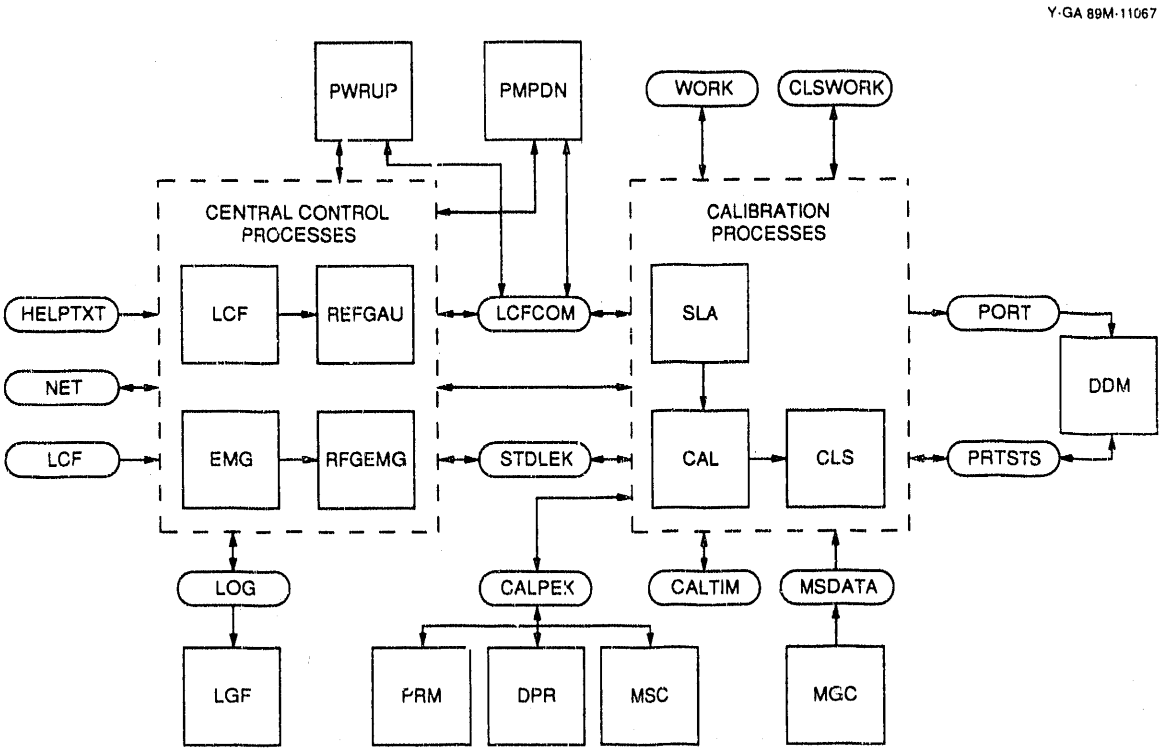

Fig. 2. Standard Leak Calibration Facility software block diagram.

PRESENTATION OF EXPERIMENTAL WORK

STATUS DISPLAY AND CONTROL TASK

The various software components of the SLCF software system represent a complex network of tasks which must be managed carefully. The Status Display and Control Task (SDC) aids task management in four ways:

1. Displays a list of tasks comprising the SLCF.
2. Denotes which tasks are currently active.
3. Provides for menu-selectable task initiation.
4. Prevents concurrent execution of conflicting tasks.

When executed, SDC will determine which tasks are currently active and create a display similar to the one in Fig. 3 which displays a list of all tasks that may be initiated by the operator. In the example, tasks CAL and LCF are currently active. SDC will warn the operator if an attempt is made to execute conflicting tasks concurrently. For example, SDC will not allow a bath to be pumped down at the same time leaks are being calibrated.

```
JUL 30, 1988 Status Display and Control Program (SDC)      Version 01

 1 - [CAL] Calibration Procedure (typical)                 <-- Active
 2 - [CLS] Calibration Procedure (small)
 3 - [DDM] Data Mangement Procedure
 4 - [DPR] Depletion Rate Measurement Procedure
 5 - [LCF] Main Control Task                                <-- Active
 6 - [LGF] Log File Procedure
 7 - [MGC] Magnet Calibration Procedure
 8 - [MSC] Mass Spec Calibration Procedure
 9 - [PMPDN1] Pumpdown Bath 1 Procedure
10 - [PMPDN2] Pumpdown Bath 2 Procedure
11 - [PMPDN3] Pumpdown Calibration Stand Procedure
12 - [PRM] Parameter Modification Task
13 - [SLA] Standard Leak Attachment Procedure

Enter 'R' to execute a task
Enter 'E' to EXIT:
```

Fig. 3. Status display and Control Task menu.

VACUUM SYSTEM CONTROL

Introduction

The various software components which provide the monitoring and control of the vacuum system will be presented. Vacuum system control is performed by the Main Control Task (LCF) and the Gauge Monitoring Task (REFGAU). The vacuum system pump down tasks include PMPDN1, PMPDN2, and PMPDN3. The Log File Display Task (LGF) produces a report of previously executed commands. Recovery from a power failure is handled by the Power Fail Restart Task (PWRUP). The Emergency Main Control Task (EMG) and the Emergency Gauge Monitoring Task (RFGEMG) perform the same functions as LCF and REFGAU, but without graphics.

Main Control Task (LCF/REFGAU)

Description. The main control task is in reality composed of two separate tasks, LCF and REFGAU, working in conjunction with one another. However, because the operation of REFGAU is completely transparent to the user, the main control task will be referred to in this report simply as LCF.

LCF serves as the primary interface between the user and the vacuum system. It provides a color graphic display of the vacuum system, depicting the current status of process flows, motors, valves, gauges, and subsystem monitors. Through LCF, the operator can manually and interactively control the state of the vacuum system. A simple online Help facility and automatic command logging functions are available.

System Diagram. LCF will generate a dynamic color display of the vacuum system similar to the diagram shown in Fig. 4. System components are described in the following paragraphs.

1. Valves

   The valves in the diagram are those devices shaped like two small triangles connected at a vertex. They are uniquely labeled V01 through V27, V30 through V34, V40 through V44, V50 through V64, V70 through V79, V80 through V83, and V85 through V92. The only exception to the unique labeling scheme is V77, which represents two valves physically tied together so that they are both in the same state always.

   Valves 30 and 31 are automatically closed whenever mechanical pump 1 (MP1) is turned on. They are automatically opened whenever it is turned off. Valves 40 and 41 are automatically closed whenever mechanical pump 2 (MP2) is turned on. They are automatically opened whenever it is turned off.

   Valves 51 and 52 are paired such that they are always in opposite states (i.e., opening one valve automatically closes the other). Valves 53 and 54, 55 and 56, 57 and 58, and 59 and 60 are paired in a similar fashion.

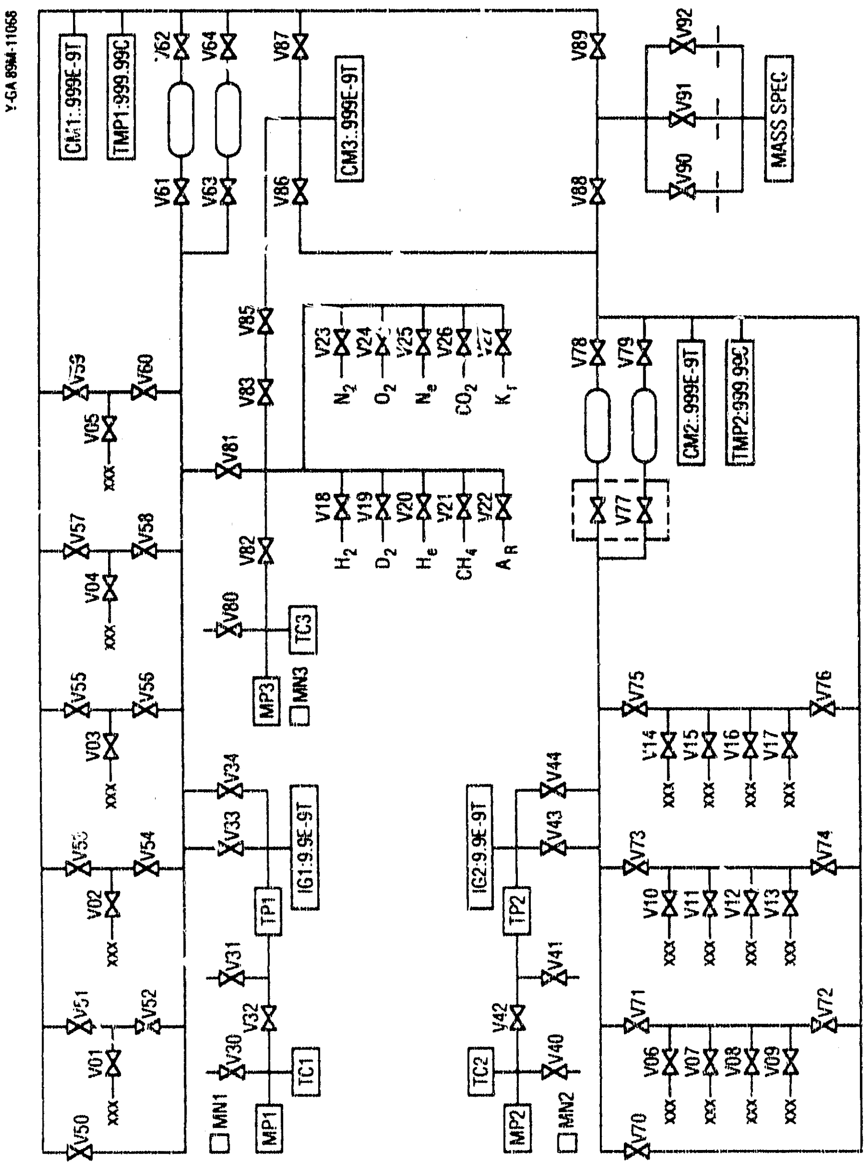

Fig. 4. Standard Leak Calibration Facility System diagram.

On the color display, a valve is outlined in white if it is closed, solid green if it is open, and solid red if its condition cannot be determined.

V01 through V17 are sometimes referred to as Port 1 through Port 17. This is because standard leaks can be attached at these locations. When possible, the diagram displays the type of leak currently attached at a given port.

2. Motors

The motors in the diagram are labeled MP1, MP2, MP3, TP1, and TP2. The MP indicates mechanical pumps and the TP indicates turbo pumps.

On the color display, a motor is outlined in white if it is off, solid green if it is running, and solid red if its condition cannot be determined.

3. Gauges

The gauges in the diagram are labeled IG1, IG2, CM1, CM2, CM3, TMP1, TMP2, TC1, TC2, and TC3. IG indicates ion gauges, CM indicates capacitance manometers, TMP indicates temperature gauges, and TC indicates thermocouple gauges. CM3 is not used in the current version of SLCF.

The ion gauges, temperature gauges, and capacitance manometers all display actual readings on the screen. If a gauge is on, its reading is displayed in black on a yellow background. If the gauge is off, the display is in white. If the gauge cannot be read due to a communications error, the display is in red.

The thermocouple gauges merely indicate above or below setpoint. A thermocouple is outlined in white if it is above setpoint, solid green if it is below setpoint, and solid red if its condition cannot be determined.

4. Monitors

The monitors, labeled MN1, MN2, and MN3, are hardware devices which automatically shut down a vacuum subsystem in the event of certain types of failures.

MN1 is the monitor for bath 1. It should be turned on whenever bath 1 is completely pumped down. When activated, the monitor will automatically shut down bath 1 if either TP1 shuts off or TC1 goes above setpoint.

MN2 is the monitor for bath 2. It should be turned on whenever bath 2 is completely pumped down. When activated, the monitor will automatically shut down bath 2 if either TP2 shuts off or TC2 goes above setpoint.

MN3 is the monitor for the calibration stand. It should be turned on whenever the calibration stand is completely pumped down. When activated, the monitor will automatically shut down the calibration stand if TC3 goes above setpoint.

A monitor is outlined in white if it is not activated, solid green if it is activated, and solid red if its condition cannot be determined.

5. Lines

The solid lines connecting the devices represent the interconnecting pipes. Lines are colored to represent the last known condition of the line. Colors are selected for lines according to the following order of precedence.

- WHITE if condition is unknown.
- RED if vented to atmosphere.
- PURPLE if opened to a gas on the calibration stand.
- BLUE if opened to a gas from a leak on one of the baths.
- ORANGE if being pumped on by a turbo pump.
- GREEN if being pumped on by a mechanical pump.

The oval areas between V61 and V62, V63 and V64, V77 and V78, and V77 and V79 represent volumes which serve as gas collection reservoirs. The volumes take on the same colors as the lines that connect to them.

The short, disconnected lines running perpendicular to the main lines near V33, V43, V90, V91, and V92 represent restrictions in the main line at the indicated location.

6. External Command Echo Box (Tasks Box)

Whenever an external task (such as a calibration program) wants to manipulate the vacuum system, it does so by sending a request to LCF to perform the service. The external command echo box (or tasks box), which does not appear in Fig. 4, but is positioned on the video screen below the system diagram and to the left side of the screen, always contains the most recent command sent to LCF by an external task. For example, if task CAL requested LCF to open valve 61, the following message would appear in the tasks box:

[...CAL ev:16] OPEN 61

The message indicates the name of the task sending the command (...CAL), the numeric identifier assigned to the task by LCF (ev:16), and the command to be executed (OPEN 61).

7. Command Line

Immediately below the tasks box is the command prompt. An operator may interactively manipulate the vacuum system by entering commands through the keyboard in response to this prompt. When a command is entered, LCF tags it with the current time and date.

Command Summary. There are fifteen unique commands which LCF will accept interactively from the keyboard.

1. HELP

The HELP command provides the operator with a quick, online description of each of the available LCF interactive commands.

Entering the command HELP generates a list of all legal commands.

```
Command: help
TOP      BOTTOM   OPEN     CLOSE   START   STOP    SHUT
SESAME   REDRAW   VERIFY   LOG     NOLOG   RECALL  BYEBYE
HELP
```

Entering the command HELP followed by a legal command name generates a description of the command. For example,

```
Command: help log
LOG      Maintain a record of the most current commands
         executed. Commands may be viewed with the RECALL
         option or by executing LGF. LOGGING should normally
         be in effect. To execute: LOG.
```

2. OPEN

The OPEN command followed by a legal valve number opens the specified valve.

3. CLOSE

The CLOSE command followed by a legal valve number closes the specified valve.

4. START

The START command followed by a legal pump name starts the specified mechanical pump or turbo pump. The START command followed by a legal monitor name activates the specified monitor. The START command followed by a legal ion gauge name turns on the filament of the specified ion gauge. The START command followed by a legal external task name executes the specified external task.

5. STOP

The STOP command followed by a legal pump name stops the specified mechanical pump or turbo pump. The STOP command followed by a legal monitor name deactivates the specified monitor. The STOP command followed by a legal ion gauge name turns off the filament of the specified ion gauge. The STOP command followed by a legal external task name terminates execution of the specified external task.

6. LOG

The most recent 500 commands executed by LCF are saved in a log file if the LOGGING option is enabled. LOGGING is enabled automatically every time LCF is started up. The operator can manually activate the LOGGING option by entering the LOG command.

7. NOLOG

The NOLOG command disables the logging option.

8. RECALL

The RECALL command displays the 10 most recent commands executed by LCF. The requester and the time at which LCF received the request are also displayed.

In the example below, the first two commands listed were requested from the keyboard while the last two listed were requested by external tasks.

```
Command: recall
30-JUL-88 10:18:01   [KEYBRD] START TP2
30-JUL-88 10:18:08   [KEYBRD] OPEN 33
30-JUL-88 10:18:11   [PMPDN2] OPEN 44
30-JUL-88 10:18:20   [PMPDN2] START IG2
.
.
.
```

9. REDRAW

The REDRAW command redraws the system diagram on the Tek 4026a graphics screen.

Occasionally, the graphics may become corrupted due to voltage surges or some other unusual occurrence. The REDRAW command can be used to redraw the picture without having to completely terminate and restart LCF.

10. VERIFY

The VERIFY command forces every device in the vacuum system to be polled for its current status.

Normally, the status of the vacuum system will be maintained correctly on the graphics display. However, if its condition ever becomes suspect, the VERIFY command can be used to quickly verify the integrity of the display.

11. SHUT

The SHUT command 'locks' or 'turns off' the keyboard so that most commands cannot be entered through the keyboard.

The only commands that can be entered on a 'locked' keyboard are: TOP, BOTTOM, SESAME, RECALL, and HELP.

12. SESAME

The SESAME command reverses the effect of the SHUT command (i.e., it 'unlocks' the keyboard).

13. TOP

The TOP command forces the top half of the available graphics display area to be viewed on the Tek 4027a screen.

14. BOTTOM

The BOTTOM command forces the bottom half of the available graphics display area to be viewed on the Tek 4027a screen.

15. BYE

The BYE command terminates execution of LCF. All active external tasks currently attached to LCF will also be terminated.

    Command: bye

Pump Down Tasks (PMPDN1/PMPDN2/PMPDN3)

The three pump down tasks automatically pump down the vacuum subsystems. The bath 1 subsystem pump down task, PMPDN1, the bath 2 subsystem pump down task, PMPDN2, and the calibration stand subsystem pump down task, PMPDN3, are presented in pseudo-code form in Appendix A, Appendix B, and Appendix C, respectively.

Log File Display Task (LGF)

All commands executed through the LCF main control task are temporarily stored in an internal log file if the LCF LOGGING option is enabled. In general, the last 500 activities performed by LCF are currently available in the log file. A listing of all or part of the log file can be obtained using the Log File Display Task (LGF). A sample log file listing is shown in Fig. 5.

Power Fail Restart Task (PWRUP)

The Power Fail Restart Task (PWRUP) is designed to attempt to pump down the vacuum system whenever electrical power has been restored after a power loss. This is accomplished in the following way.

1. Electrical power is supplied to the computer.
2. The computer automatically boots itself.
3. The computer automatically activates the main control task LCF.
4. The computer automatically activates PWRUP.
5. PWRUP interrogates the bath 1 subsystem monitor, MN1. If the monitor is off, PWRUP assumes bath 1 is not pumped down and starts task PMPDN1 to pump the bath down.
6. PWRUP interrogates the bath 2 subsystem monitor, MN2. If the monitor is off, PWRUP assumes bath 2 is not pumped down and starts task PMPDN2 to pump the bath down.
7. PWRUP interrogates the calibration stand subsystem monitor, MN3. If the monitor is off, PWRUP assumes the calibration stand is not pumped down and starts task PMPDN3 to pump the stand down.

The computer cannot know why electrical power has been lost or if the electrical power was actually lost to the vacuum system rather than just to the computer. Consequently, any time the computer is booted, it blindly attempts to pump down any vacuum subsystem for which the associated monitor is off. If the operating personnel do not want a particular subsytem to be pumped down (such as during maintenance), they must unplug the mechanical pump to that subsystem. Doing so will cause a harmless failure of the associated pump down task.

Emergency Main Control Task (EMG/REFEMG)

Description. The Emergency Main Control Task (EMG) serves the same purpose as the Main Control Task (LCF), but without the use of a graphic display. It is a 'stripped down' version of LCF to be used in emergency situations when the SLCF must be operated but the graphics terminal is not operational.

The entire operation of the SLCF is dependent upon the main control task. Because LCF requires the Tek 4027a graphics terminal, failure of the graphics device could render the entire computer system useless.

```
COMMAND LOG
-----------

07-JUL-88   12:55:11    [KEYBRD]    LOG
07-JUL-88   12:55:30    [KEYBRD]    START TP1
07-JUL-88   12:55:39    [KEYBRD]    START MN1
07-JUL-88   12:55:45    [KEYBRD]    START MN2
07-JUL-88   12:59:39    [...SLA]    CLOSE 50
07-JUL-88   12:59:40    [...SLA]    CLOSE 52
07-JUL-88   12:59:40    [...SLA]    CLOSE 54
07-JUL-88   12:59:41    [...SLA]    CLOSE 56
07-JUL-88   12:59:42    [...SLA]    CLOSE 58
07-JUL-88   12:59:44    [...SLA]    CLOSE 60
07-JUL-88   12:59:45    [...SLA]    CLOSE 61
07-JUL-88   12:59:46    [...SLA]    CLOSE 62
07-JUL-88   12:59:47    [...SLA]    CLOSE 63
07-JUL-88   12:59:47    [...SLA]    CLOSE 64
07-JUL-88   12:59:49    [...SLA]    CLOSE 81
07-JUL-88   12:59:50    [...SLA]    CLOSE  1
07-JUL-88   12:59:51    [...SLA]    CLOSE  2
07-JUL-88   12:59:52    [...SLA]    CLOSE  3
07-JUL-88   12:59:53    [...SLA]    CLOSE  4
07-JUL-88   12:59:55    [...SLA]    CLOSE  5
07-JUL-88   12:59:56    [...SLA]    CLOSE  6
07-JUL-88   12:59:57    [...SLA]    OPEN 52
07-JUL-88   12:59:58    [...SLA]    OPEN 58
07-JUL-88   12:59:59    [...SLA]    OPEN 60
07-JUL-88   13:00:00    [...SLA]    CLOSE 33
07-JUL-88   13:00:02    [...SLA]    STOP IG1
07-JUL-88   13:00:03    [...SLA]    STOP MN1
07-JUL-88   13:01:22    [...SLA]    STOP TP1
07-JUL-88   13:01:23    [...SLA]    OPEN 33
07-JUL-88   13:04:10    [...SLA]    CLOSE 70
07-JUL-88   13:04:11    [...SLA]    CLOSE 71
07-JUL-88   13:04:12    [...SLA]    CLOSE 72
07-JUL-88   13:04:12    [...SLA]    CLOSE 73
07-JUL-88   13:04:13    [...SLA]    CLOSE 74
07-JUL-88   13:04:14    [...SLA]    CLOSE 75
07-JUL-88   13:04:15    [KEYBRD]    NOLOG


End of Program
```

Fig. 5. Log file listing example.

Consequently, a version of the main control task (which can run on any dumb terminal) is needed. The Emergency Main Control Task (EMG) serves this purpose.

EMG is in reality composed of two tasks, EMG and REFEMG, working in conjunction with one another. However, because the operation of REFEMG is completely transparent to the user, the Emergency Main Control Task will be referred to in this report simply as EMG.

Command Summary. There are thirteen unique commands which EMG will accept interactively from the keyboard.

1. HELP

   The HELP command provides the operator with a quick, online description of each of the available EMG interactive commands.

   Entering the command HELP in isolation generates a list of all legal commands.

```
Command: help
OPEN    CLOSE   START   STOP    SHUT    STATUS   SESAME
VERIFY  LOG     NOLOG   RECALL  BYEBYE  HELP
```

Entering the command HELP followed by a legal command name generates a description of the command. For example,

```
Command: help log
LOG     Maintain a record of the most current commands
        executed.  Commands may be viewed with the RECALL
        option or by executing LGF.  LOGGING should normally
        be in effect.  To execute: LOG.
```

2. STATUS

The STATUS command reports the status of every device in the vacuum system.

```
Command: status
    1:closed  15:closed  30:open  50:open    70:closed  ...
    2:closed  16:closed  31:open  51:closed  71:closed  ...
    3:open    17:closed  33:open  52:closed  72:closed  ...
    .         .          .        .          .
    .         .          .        .          .
    .         .          .        .          .
      MP1:on    TP1:on     MN1:on   TC1:on     IG1:5.1E-07
      MP2:on    TP2:on     MN2:on   TC2:on     IG2:5.8E-06
      MP3:off              MN3:off  TC3:off
```

3. OPEN

The OPEN command followed by a legal valve number opens the specified valve.

4. CLOSE

The CLOSE command followed by a legal valve number closes the specified valve.

5. START

The START command followed by a legal pump name starts the specified mechanical pump or turbo pump. The START command followed by a legal monitor name activates the specified monitor. The START command followed by a legal ion gauge name turns on the filament of the specified ion gauge. The START command followed by a legal external task name executes the specified external task.

6. STOP

The STOP command followed by a legal pump name stops the specified mechanical pump or turbo pump. The STOP command followed by a legal monitor name deactivates the specified monitor. The STOP command followed by a legal ion gauge name turns off the filament of the specified ion guage. The STOP command followed by a legal external task name terminates execution of the specified external task.

7. LOG

The most recent 500 commands executed by EMG are saved in a log file if the LOGGING option is enabled. LOGGING is enabled automatically every time LCF is started up. The operator can manually activate the LOGGING option by entering the LOG command.

8. NOLOG

The NOLOG command disables the logging option.

9. RECALL

The RECALL command displays the 10 most recent commands executed by EMG. The requestor and the time at which EMG received the request are also displayed.

In the example below, the first two commands listed were requested from the keyboard while the last two listed were requested by external tasks.

```
Command: recall
30-JUL-88 10:18:01    [KEYBRD] START TP2
30-JUL-88 10:18:08    [KEYBRD] OPEN 33
30-JUL-88 10:18:11    [PMPDN2] OPEN 44
30-JUL-88 10:18:20    [PMPDN2] START IG2
.
.
.
```

10. VERIFY

The VERIFY command forces every device in the vacuum system to be polled for its current status.

Normally, the status of the vacuum system will be maintained correctly on the status display of EMG. However, if its condition ever becomes suspect, the VERIFY command can be used to quickly verify the integrity of the display.

11. SHUT

The SHUT command 'locks' or 'turns off' the keyboard so that most commands cannot be entered through the keyboard.

The only commands that can be entered on a 'locked' keyboard are: SESAME, RECALL, and HELP.

12. SESAME

The SESAME command reverses the effect of the SHUT command (i.e., it 'unlocks' the keyboard).

Only the first four letters of the SESAME command have to be entered for the command to execute properly.

13. BYE

The BYE command terminates execution of EMG. All active external tasks currently attached to the LCF will all be terminated.

MASS SPECTROMETER CONTROL

The Mass Spectrometer Library is a collection of object modules which perform a variety of data collection and control functions on the Micromass 3001 mass spectrometer (MM3001). These modules are used by those SLCF tasks which required the use of the mass spectrometer. The functions are listed below.

- CLOCK - Read MM3001 clock.
- CYCLE - Cycle MM3001 magnet.
- DI60S - Begin digital integrator read function with 60-s integration period.
- MSINIT - Initialize MM3001 for automated control.
- MSSTOP - Release the MM3001 from automated control.
- RAMP - Ramp MM3001 magnet.
- READDI - Read digital integrator with 0.2- or 1-s integration period.
- SCNPK - Scan peak.
- SETDI - Set digital integrator timing period.
- SETGN - Set digital integrator gain.
- ZMEAS - Measure MM3001 zero and noise levels.

STANDARD LEAK CALIBRATION

Introduction

The standard leak calibration software is responsible for performing four functions: (1) leak attachment, (2) total flow rate calibration and purity determination of typical-size leaks, (3) helium flow rate calibration of very small helium leaks, and (4) interactive modification of run parameters. The four tasks specifically designed to support the performance of these four functions will be presented.

The sequence of events which must occur for successful calibrations to be accomplished are listed below.

1. The operator runs the Parameter Modification Task (PRM) to adjust the run parameters if necessary.
2. The operator runs the Standard Leak Attachment Task (SLA).
3. SLA prepares the vacuum system for calibration.
4. If new leaks have been attached to the vacuum system, SLA initiates the Calibration Task for typical-size leaks (CAL) after 24 hours. If no new leaks were attached, SLA initiates CAL immediately.
5. CAL calibrates all typical-size leaks for total flow and determines their purity, storing the collected data in the port data files.
6. CAL initiates the Calibration Task for small-size leaks (CLS).
7. CLS calibrates all small helium leaks for helium flow rate, storing the collected data in the port data files.
8. Process terminates. The operator may now transfer the collected data to a permanent storage location.

Paramenter Modification Task (PRM)

Description. There are a number of parameters required by the calibration tasks which may have to be changed from time to time. The Parameter Modification Task (PRM) provides an easy way to make these changes or to review the current settings. The items which may be changed include depletion rates, collection volume sizes, and mass scan parameters. The PRM main menu, from which the operator selects the option to be executed, is shown in Fig. 6.

Modify Depletion Rates. The four hydrogen (H_2) depletion rates required by the calibration software can be modified using the 'modify depletion rates' option. When this operation is selected, PRM will display the current H_2 depletion rate value for each of the four possible paths from the vacuum system to the mass spectrometer (Fig. 7). The depletion rate path is identified by the bath from which the gas being scanned is located and the valve through which the gas enters the mass spectrometer. For example, the first depletion rate refers to a gas originating from bath 1 and flowing to the mass spectrometer through valve 90. As each depletion rate is displayed, the operator may enter a new value or hit return to keep the old value.

```
                    Parameter Entry Program (PRM)         Version 01

PRM Master Menu:

1 - Modify depletion rates
2 - Modify volumes
3 - Modify peak data
4 - Reset all parameters to defaults
5 - Reset depletion rates and volumes to default values
6 - Reset peak data to default values
7 - Print parameters summary

Enter selection (return to stop):
```

Fig. 6. PRM main menu.

```
                      Parameter Entry Program (PRM)         Version 02

Hydrogen depletion rate update
------------------------------

Enter new value (hit return to retain old value):

     Bath 1, valve 90 [-.002000] - -.002113
     Bath 1, valve 92 [-.002000] - -.002099
     Bath 2, valve 90 [-.003000] - -.003311
     Bath 2, valve 92 [-.003000] - -.003013

Update parameter file? y
```

Fig. 7. PRM modify depletion rate option example.

The operator will not normally use PRM to change the depletion rate values. Running the Depletion Rate Measurement task (DPR) automatically calculates the system's depletion rates and updates the parameter file.

Modify Volumes. There are four calibrated volumes attached to the vacuum system which must be certified. If any of these volumes are changed or recertified, the new values can be entered using the 'modify volumes' option. When this option is selected, PRM will display the current value for each of the four volumes (Fig. 8). Volumes are identified by the two valves between which they are attached. For example, the first volume is the one located between valves 61 and 62. As each volume value is displayed, the operator may enter a new value or hit return to keep the old value.

```
                    Parameter Entry Program (PRM)          Version 01

Volumes update
--------------

Enter new value (hit return to retain old value):

     Valves 61/62 [ 105.500] -  105.533
     Valves 63/64 [ 938.600] -  938.560
     Valves 77/79 [  54.600] -   54.588
     Valves 77/78 [3000.000] - 3001.020

Update parameter file? y
```

Fig. 8. PRM modify volumes option example.

Modify Peak Data. A collection of data is required by the mass scan software for each peak included in the mass spectrum. These data can be adjusted interactively using the 'modify peak data' option. For each peak, the following data are maintained.

- Peak Number - The peaks are numbered 0 through 13 for identification purposes.
- Gas Name - The gas name of the peak.
- Mass Number - The mass number of the peak.
- Port Number - The port number on the calibration stand to which the reference gas cylinder is attached. If there is no such reference gas, the port number is zero.
- Peak Center - The approximate location of the peak center.
- Peak Halfwidth - The approximate half-width of the peak.
- Peak Sensitivity - The sensitivities of the peak to other gases.

Although these items may occasionally require interactive modification,the 'modify peak data' option is seldom used. The mass name, mass number, and port number should not change. The peak center and peak half-width are maintained automatically by the mass scan programs and should not normally require modification by the operator. The peak sensitivities are determined automatically by the Mass Spectrometer Calibration Task (MSC).

This option works very much like the one previously discussed. After selecting a peak number, PRM will display the current value for each of the data items (Fig. 9). As each item is displayed, the operator may enter a new value or hit return to keep the old value.

Reset All Parameters to Defaults. Every parameter has a default value associated with it. Selecting the 'reset all parameters to defaults' option will reset all parameters to their default values.

```
                    Parameter Entry Program (PRM)         Version 01

Peak data update
----------------

Enter peak number (return to stop): 1

Enter new value (hit return to retain old value):

     Peak no.  1 mass name                [H2              ] - H2
     Peak no.  1 mass number              [               2] - 2
     Peak no.  1 port number              [              18] - 18
     Peak no.  1 center                   [        0.616740] - .618
     Peak no.  1 halfwidth                [        .0009000] - .8
     Peak no.  1 sensitivity due to H2    [           0.000] - 13.303
     Peak no.  1 sensitivity due to D2    [           0.000] - .062

Update parameter file?  y
```

Fig. 9. PRM modify peak data option example.

Reset Depletion Rates and Volumes to Default Values. Selecting the 'reset depletion rates and volumes to default values' option will reset the depletion rate and the volume parameters to their default values without affecting the current peak data values.

Reset Peak Data to Default Values. Selecting the 'reset peak data to default values' option will reset the peak data parameters to their default values without affecting the current depletion rate or volume values.

Print Parameters Summary. The 'print parameters summary' option generates a video display or a hardcopy printout of the current parameter values. An example of the hardcopy printout is shown in Fig. 10.

Standard Leak Attachment Task (SLA)

Description. The Standard Leak Attachment Task (SLA) prepares the vacuum system and the leaks for calibration. Operators may attach to the system new leaks to be calibrated or they may repeat calibration of leaks attached during a previous run of SLA. A pseudo-code description of the leak attachment procedure is presented in Appendix D.

Procedure. A summary of the procedure for attaching leaks follows.

1. Initiate SLA.

```
                    Calibration Parameters Summary
                          30-JUL-88  14:06

H2 depletion rates:  Bath 1, valve 90 - -0.002113
                     Bath 1, valve 92 - -0.002099
                     Bath 2, valve 90 - -0.003311
                     Bath 2, valve 92 - -0.003013

Volumes:  Valves 61/62 -  105.533
          Valves 63/64 -  938.560
          Valves 77/79 -   54.588
          Valves 77/78 - 3001.020
```

	Mass	Name	Port	Center	Half-width	Sensitivity
0	0	Zero	0	0.400000	.0000000	
1	2	H2	18	0.618000	.0008000	13.303 due to H2
						.062 due to D2
2	3	HD	0	0.654506	.0006044	10.762 due to HD
3	4	He	20	0.753800	.0007946	2.997 due to He
4	4	D2	19	0.756243	.0007658	8.221 due to D2
5	16	CH4	21	1.466907	.0015355	16.977 due to CH4
6	18	H2O	0	1.607179	.0016685	3.488 due to H2O
7	20	Ne	25	1.693449	.0018096	3.488 due to Ne
						2.758 due to Ar
8	28	N2	23	2.007884	.0020854	20.895 due to N2
						2.634 due to CO2
9	32	O2	24	2.147915	.0023005	10.223 due to O2
10	40	Ar	22	2.404116	.0025804	24.895 due to Ar
						0.162 due to Kr
11	41	Oils	0	2.436712	.0026011	3.488 due to Oils
						0.490 due to Kr
12	44	CO2	26	2.524067	.0026207	22.599 due to CO2
13	84	Kr	27	3.511536	.0040939	14.744 due to Kr

Fig. 10. PRM calibration parameters hardcopy report example.

SLA may print a warning message at the beginning of its run.

Warning message 1: "At least one port is awaiting calibration. Running SLA at this time will terminate the current calibration cycle."

This message indicates that CAL and CLS have not executed since the last time SLA was run. Consequently, running SLA at this time will cancel the calibration cycle for those leaks currently waiting to be calibrated.

Warning message 2: "At least one port is awaiting transfer of data to permanent storage. Running SLA at this time will cause the current temporary data to be lost."

The second warning message indicates that calibration data collected during the last calibration cycle has not been transferred to a permanent storage location. Running SLA at this time will cause that data to be lost.

2. Select port number.

SLA will present a display similar to the one in Fig. 11. For each port, the display shows the M-number, gas type, and approximate flow rate of the currently attached leak.

```
                      Standard Leak Attachment (SLA)       Version 00

1 - M-0140710  HD   1.2E-09 *            10 - M-0053321  Ar   5.2E-09
2 - M-0116637  D2   3.0E-10 *            11 - M-0000000  **   0.0E-01
3 - M-0380617  CH4  2.5E-10 *            12 - M-0000000  **   0.0E-01
4 - M-0440754  HD   2.0E-09 *            13 - M-0000000  **   0.0E-01
5 - M-0086768  D2   6.0E-10              14 - M-0177577  He   4.0E-12 *
6 - M-0325510  H2   5.0E-10              15 - M-0126878  He   1.0E-12 *
7 - M-0648842  HD   3.5E-09              16 - M-0000000  **   0.0E-01
8 - M-0155769  D2   5.0E-10              17 - M-0116545  He   1.5E-10 *
9 - M-0000000  **   0.0E-01

Port number
```

Fig. 11. SLA port selection screen.

The operator should select the number of any port to which he would like to attach a new leak for calibration, or he should select a port which contains a leak that was attached in a previous session of SLA but is to be recalibrated.

There are three rules which must be obeyed when attaching leaks.

(1) Helium leaks less then 5×10^{-12} mol/s should only be attached to Ports 14, 15, or 16 to insure accurate calibration.

(2) Port 17 should always contain a helium leak in the range 3×10^{-11} mols/s to 3×10^{-10} mol/s. This leak is required for accurate calibration of small helium leaks.

(3) The helium leak at Port 17 should be recalibrated on a monthly basis.

3. Enter leak data.

   SLA will list current values for the leak at the selected port and ask the operator whether to recalibrate the currently attached leak. If recalibration is not desired, the operator must enter the M-number, gas name, and approximate flow rate of the new leak (Fig. 12).

```
                    Standard Leak Attachment (SLA)        Version 00

5 - M-0086768 D2    6.0E-09

Recalibrate currently attached leak? n

Enter M number M-0116857
Enter gas name H2
Enter flow rate (moles/sec) 6.0E-10

Port number   -  5
M-number      -  M-0116857
Gas           -  H2
Flow rate     -  6.0E-10 moles/sec

Accept entry? y
```

Fig. 12. SLA leak data entry.

4. Repeat steps (2) and (3) until all ports to be calibrated in the current run have been selected.

   After the leak data are entered, the port selection display (Fig. 11) will reappear. The display will be updated to reflect the most recently entered data. An asterisk will appear to the right of the flow rate of each port selected for calibration.

   The operator should continue entering data in this manner until all leaks to be calibrated have been selected. After the data for the last leak have been entered, the operator should hit return in response to the 'port number' prompt.

5. Verify inputs.

   SLA will display a summary listing of the calibration requests, similar to the one in Fig. 13. The column on the left lists the ports for leaks to be calibrated. The column on the right lists the ports to which new leaks are to be attached.

   The operator should review the summary to verify that it is correct. Selection to proceed to the next phase of SLA, to modify requests, or to terminate SLA immediately is made by entering 1, 2, or 3, respectively.

PORTS TO BE CALIBRATED				NEW LEAK ATTACHMENTS		
Port	ID	Gas		Port	ID	Gas
1	M-0140710	HD		1	M-0140710	HD
2	M-0116637	D2		2	M-0116637	D_2
3	M-0380617	CH4		5	M-0116857	H2
4	M-0440754	HD		14	M-0177577	He
5	M-0116857	H2		15	M-0126878	He
14	M-0177577	He				
15	M-0126878	He				
16	M-0116545	He				

Enter 1-Proceed, 2-Modify, 3-Terminate

Fig. 13. SLA calibration request summary.

6. Attach new leaks to system.

   SLA will begin preparing the vacuum system for standard leak attachment. After a few minutes, SLA will request the operator to close the manual valves of the old leaks at those ports where new leaks are to be attached, and then to attach the new leaks to those ports (Fig. 14).

7. Open manual valves.

   SLA will request the operator to open the manual valves to the new leaks which have been attached to the vacuum system baths.

8. SLA completes attachement procedure.

   SLA will continue preparing the vacuum system for leak calibration. It requires no additional operator involvement.

9. Summary report.

   Upon completion, SLA will print a summary of its activities similar to the one in Fig. 15. The left column of the summary lists all ports which now contain leaks to be calibrated. The right column lists all ports to which new leaks have been attached. at the bottom of the report is the approximate time at which the next phase of the calibration sequence will begin.

Calibration Task - Typical-Size Leaks (CAL)

The Calibration Task (CAL) performs total flow rate calibrations and determines the purity of standard leaks with a total flow rate greater than 5×10^{-12} mol/s. A pseudo-code description of CAL is presented in Appendix E.

```
                    Standard Leak Attachment (SLA)         Version 00

After closing the appropriate manual valves:

Attach M-0140710 to port  1
Attach M-0116637 to port  2
Attach M-0116857 to port  5
Attach M-0177577 to port 14
Attach M-0126878 to port 15

Enter 'READY' when leaks are attached: ready
```

Fig. 14. Standard Leak Attachment request.

```
                    Standard Leak Attachment (SLA)         Version 00

                   SLA Session Summary          18-JUL-88  10:35
Ports to be calibrated                     New leak attachments
 1     M-0140710   HD                        1    M-0140710   HD
 2     M-0116637   D2                        2    M-0116637   D2
 3     M-0380617   CH4                       5    M-0116857   H2
 4     M-0440754   HD                       14    M-0177577   He
 5     M-0116857   H2                       15    M-0126878   He
14     M-0177577   He
15     M-0126878   He
17     M-0116545   He

CAL is scheduled to run 24 hours from 10:35, Jul 18, 1988
```

Fig. 15. SLA session summary report.

CAL is automatically scheduled for initiation by SLA. If new leaks were attached to the system, CAL initiates 24 h after SLA completes, to allow time for the vacuum system to clean up; otherwise, it initiates within one minute. At its completion, CAL automatically initiates the Small Leak Calibration Task (CLS).

CAL runs for a maximum of 24 h. During that time, every typical-size leak will be calibrated at least once. The larger leaks may have time to calibrate either two to three times during the 24-h period.

CAL stores on disk a complete record of the data collected during a run. At the end of the run, CAL prints a summary similar to the one in Fig. 16. For each leak calibrated, the summary displays the average leak rate and its standard deviation. A warning flag is also displayed

```
CAL SUMMARY: 30-JUL-88  10:35:55

Port  1: M-0140710  HD Flow = 1.35E-09 mol/s Stdv = 8.40E-13
Port  2: M-0116637  D2 Flow = 2.87E-10 mol/s Stdv = 5.12E-13
Port  3: M-0130717 CH4 Flow = 2.94E-10 mol/s Stdv = 6.26E-13
Port  4: M-0140754  HD Flow = 1.68E-09 mol/s Stdv = 2.49E-12
Port  5: M-0116857  H2 Flow = 6.51E-10 mol/s Stdv = 1.45E-10 <-WARNING
Port 17: M-0116545  He Flow = 1.47E-10 mol/s Stdv = 3.24E-13
```

Fig. 16. CAL summary example.

if the results are suspect. The Data Management Task (DDM) can be run to determine the exact reason for the warning message. There are four conditions that will cause CAL to display a warning.

1. A questionable value has been received from a CM gauge.
2. A questionable value has been received from the mass spectrometer.
3. The calibrated leak rate differs by more than 100% of the estimated leak rate.
4. The standard deviation is more than 1% of the average flow rate.

The presence of a warning flag does not necessarily indicate incorrect calibration results. More importantly, the absence of a warning flag does not necessarily indicate correct calibration results. The operator must evaluate of the results of every calibration to judge its trustworthiness.

Calibration Task - Small-Size Leaks (CLS)

The Small Leak Calibration Task (CLS) performs partial flow rate calibrations of helium leaks with helium flow rates less than 5 x 10 mol/s. A pseudo-code description of CLS is presented in Appendix F.

CLS is initiated automatically by CAL and runs for a maximum of 24 h. During that time, every small-size helium leak will be calibrated by three different methods at least once. The larger leaks may have time to calibrate either two or three times during the 24-h period. The three calibration methods are designated Method A, Method B, and Method C.

CLS stores on disk a complete record of the data collected during a run. At the end of the run, CLS prints a summary similar to the one in Fig. 17. For each leak calibrated, the summary displays the average leak rate for each method and the standard deviation for Method C, which is generally considered the most reliable result. A warning flag is also displayed if CLS is suspicious of the results. The Data Management Task (DDM) can be run to determine the exact reason for the warning message. There are three conditions which will cause CLS to display a warning.

```
CLS SUMMARY:  31-JUL-88  10:35:55

Port 14: M-0177577  He   Method A flow rate = 4.29E-12 mol/s
                         Method B flow rate = 3.03E-13 mol/s
                         Method C flow rate = 4.32E-12 mol/s
                         Stdv (Method C)    = 0.00E-00
Port 15: M-0126878  He   Method A flow rate = 1.66E-12 mol/s
                         Method B flow rate = 2.11E-13 mol/s
                         Method C flow rate = 1.44E-12 mol/s
                         Stdv (Method C)    = 0.00E-00
```

Fig. 17. CLS summary example.

1. A questionable value has been received from the mass spectrometer.
2. The calibrated leak rate differs by more than 100% of the estimated leak rate.
3. The standard deviation is more than 1% of the average flow rate.

The presence of a warning flag does not necessarily mean the calibration results are incorrect. More importantly, the absence of a warning flag does not necessarily mean the results are correct. The operator must evaluate the results of every calibration to judge its trustworthiness.

Port Data Files

A complete record of the data collected by the calibration tasks is stored in a collection of files called the port data files. There exists exactly one port data file for each of the ports on the two baths. The data in the port data files are temporary, because each time a leak is calibrated the data from the previous calibration in the associated port file are overwritten. Consequently, if the operator wants to keep the calibration data, he must transfer them from the port data files to a permanent storage location before performing another calibration.

DATA MANAGEMENT

The calibration tasks store collected data in the port data files. Because the port data files are temporary, there must be a way for the operator to transfer the data to permanent storage facilities. Also, a mechanism is needed for printing reports containing all of the data collected for a particular leak. The Data Management Task (DDM) serves both of these needs.

Only a subset of the data from a temporary port data file is transferred to the permanent data file. The permanent file contains only critical data items such as leak number, flow rate, calibration date, temperature, and purity information.

Data reports can be generated from either the temporary port data files or from the permanent data files. Sample listings of the two reports which may be generated from the temporary data files are shown in Figs. 18 and 19. The quality of the data in the examples is poor, but the report formats are adquately demonstrated. The listing in Fig. 19 is only a partial report. Reports generated from the permanent data files are similar, but abbreviated, because only a subset of the data is stored permanently.

FACILITY MAINTENANCE

Introduction

From time to time, the vacuum system and mass spectrometer will require calibration to ensure accurate measurements. There are three tasks designed to meet this need, the Depletion Rate Measurement Task (DPR), the Magnet Calibration Task (MGC), and the Mass Spectrometer Calibration Task (MSC).

Depletion Rate Measurement Task (DPR)

The Depletion Rate Measurement Task (DPR) measures the depletion rate of hydrogen through each of the four possible paths where gases may flow from the vacuum system to the mass spectrometer during mass scans. The results are automatically stored in a local data file for subsequent use by the calibration tasks. DPR is presented in pseudo-code form in Appendix G.

DPR calculates four depletion rates, one for each path a gas may travel from vacuum system to mass spectrometer during a mass scan.

- Depletion rate 1 - From Bath 1 thru valve 90
- Depletion rate 2 - From Bath 1 thru valve 92
- Depletion rate 3 - From Bath 2 thru valve 90
- Depletion rate 4 - From Bath 2 thru valve 92

Magnet Calibration Task (MGC)

The Magnet Calibration Task (MGC) calibrates the mass spectrometer magnet. The results are automatically stored in a local data file for subsequent use by the mass scanning software.

Mass Spectrometer Calibration Task (MSC)

The Mass Spectrometer Calibration Task (MSC) calibrates the mass spectrometer, measuring its sensitivity of each mass due to various gases. The results are automatically stored in a local data file for subsequent use by the calibration tasks. MSC is presented in pseudo-code form in Appendix H.

Data Management (DDM) SEP 07, 1988 Port 11 Data Page 1 of 1

M-D14-710 HD	Leak rate: 1.32E-09 mol/s	Temp : 23.01 C	
	Std dev : 1.05E-12	Cal date: 27-AUG-88 21:16	
	Trials : 3	Version : 01	

Gas	Mass	Background amps	Intensity amps	Pressure % volume
H2	2	3.103520E-3	4.315534E+0	32.90
HD	3	7.755000E-5	5.971300E+0	52.78
D_2	4	9.519999E-6	2.347978E+0	24.65
CH_4	16	6.123300E-4	3.476602E-4	0.02
H_2O	18	1.030215E-2	3.454099E-3	0.11
Ne	20	3.994000E-5	4.524000E-5	0.00
N_2	28	3.571840E-3	7.357611E-3	0.04
O_2	32	2.987500E-4	1.813800E-4	0.00
Ar	40	3.690300E-4	2.387000E-4	0.00
Oils	41	1.781020E-3	1.099490E-3	0.04
CO_2	44	2.935800E-3	9.521849E-3	0.07
Kr	84	1.973100E-4	2.048900E-4	0.00
			sum =	110.60

	Trial 1	Trial 2	Trial 3
Calibration method:	1	1	1
Calibrated flow (mol/s):	1.32E-09	1.32E-09	1.32E-09
Calibration time:	27-AUG-38/20:01	27-AUG-88/21:01	27-AUG-88/21:16
Temperature (C):	23.00	23.01	23.01
Volume (cc):	105.500	105.500	105.500
Estimated flow (mol/s):	1.30E-09	1.32E-09	1.32E-09
CMz (T):	8.68E-04	8.72E-04	8.70E-04
CMa (T) / Ta (s):	3.54E-01/ 1174.	1.67E-01/ 554.	1.72E-01/ 568.
CMb (T) / Tb (s):	1.60E-01/ 1226.	7.91E-02/ 605.	8.13E-02/ 621.

Fig. 18. Data Management Task typical-size leak report example.

```
Data Management (DDM) SEP 20, 1988       Port 15 Data             Page 1 of 2

M-0116844    He       Leak rate:  3.32E-07 mol/s   Temp     :  22.98 C
                      Std dev   :  0.00E-01        Cal date: 19-SEP-88 11:10
                      Trials    : 1                Version : 01
------------------------------------------------------------------------------
                       Method A    Method B    Method C
                       --------    --------    --------
Average (mol/s)    :   8.65E-12   -3.56E-14    3.32E-07
Standard deviation:    0.00E-01    0.00E-01    0.00E-01

                                    Trial 1
                                --------------
Calibrated flow A (mol/s):          8.65E-12
Calibrated flow B (mol/s):         -3.56E-14
Calibrated flow C (mol/s):          3.32E-07
Calibration time:               19-SEP-80/11:10
Temperature (C):                       22.98
Estimated flow (mol/s):             2.50E-14
He reference flow (mol/s):          1.40E-10
BASE:                             1.615700E+01
H1:                               7.147741E+00
STDV1:                            1.800492E-01
H2:                               7.589400E+00
STDV2:                            8.876482E-02
H3:                              -1.819229E-03
STDV3:                            1.364210E-03
Ha:                               7.682242E+00
                                  7.722460E+00
                                  7.759762E+00
                                  7.801561E+00
                                  7.770160E+00
                                  7.771521E+00
STDVa:                            5.304633E-02
                                  4.384129E-02
                                  7.608525E-02
                                  2.697310E-02
                                  5.508134E-02
                                  6.740868E-02
RX1:                              1.250640E+01
RX2:                              7.371199E+00
                                  7.606102E+00
                                  7.919302E+00
                                  8.178600E+00
                                  8.369001E+00
                                  8.565500E+00
   .
   .
   .
```

Fig. 19. Data Management Task small-size leak report example.

MSC measures the sensitivities of 13 masses to various gases.

Sensitivity of mass	Due to gas
2	H2
2	D2
3	HD
4	He
4	D2
16	CH4
18	H2O
20	Ne
20	Ar
28	N2
28	CO2
32	O2
40	Ar
40	Kr
41	Oils
41	Kr
44	CO2
84	Kr

APPENDICES

APPENDIX A. PUMP DOWN BATH 1 PROCEDURE (PMPDN1)

PMPDN1 - Main

```
BEGIN

close valves 50,52,54,56,58,60,61,62,63,64,87, and 89;
start MP1;
wait up to 2 minutes for TC1;
if timeout then [stop MP1; terminate];

open valve 32;
start TP1;
wait up to 4 minutes for TP1;
if timeout then [stop TP1; close valve 32; stop MP1; terminate];

wait 1 min;
start IG1;
start MN1;
wait up to 15 minutes for  5E-7 Torr;
if timeout then terminate;

stop IG1;
stop MN1;
open valve 34;
wait 1 min;
wait up to 15 minutes for TC1 and TP1;
if timeout then [start MN1; terminate];

start MN1;
start IG1;
wait up to 15 minutes  for 5E-7 Torr;
if timeout then terminate;

stop IG1;
stop MN1;
wait 10 s;
open valves 50,52,54,56,58,60,61,62,63, and 54;

wait 1 minute;
wait up to 2 minutes for TC1 and TP1;
if timeout then [start MN1; terminate];

start MN1;
start IG1;
wait up to 15 minutes for 5E-7 Torr;
if timeout then [close valves 50,61,62,63,64;
                 close valves 1,2,3,4, and 5;
                 terminate];
```

APPENDIX A. PMPDN1 (continued)

PMPDN1 - Main (continued)

```
stop IG1;
open valve 33;
wait 30 seconds;
start IG1

END.
```

APPENDIX B. PUMP DOWN BATH 2 PROCEDURE (PMPDN2)

PMPDN2 - Main

```
BEGIN

close valves 70,71,72,73,74,75,76,77,78,79,86, and 89;
start MP2;
wait up to 2 minutes for TC2;
if timeout then [stop MP2; terminate];

open valve 42;
start TP2;
wait up to 4 minutes for TP2;
if timeout then [stop TP2; close valve 42; stop MP2; terminate];

wait 1 min;
start IG2;
start MN2;
wait up to 15 minutes for 5E-7 Torr;
if timeout then terminate;

stop IG2;
stop MN2;
open valve 44;
wait 1 minute;
wait up to 15 minutes for TC2 and TP2;
if timeout then [start MN2; terminate];

start MN2;
start IG2;
wait up to 15 minutes for 5E-7 Torr;
if timeout then terminate;

stop IG2;
stop MN2;
wait 10 seconds;
open valves 70,71,72,73,74,75,76,77,78, and 79;

wait 1 minute;
wait up to 2 minutes for TC2 and TP2;
if timeout then [start MN2; terminate];

wait 1 minute;
wait up to 2 minute for TC1 and TP1;
if timeout then [start MN1; terminate];
```

APPENDIX B. PMPDN2 (continued)

PMPDN2 - Main (continued)

```
start MN2;
start IG2;
wait up to 15 minutes for 5E-7 Torr;
if timeout then [close valves 50,70,71,72,73,74,75,76,77,78, and 79
                 close valves 6,7,8,9,10,11,12,13,14,15,16, and 17
                 terminate];

stop IG2;
open valve 43;
wait 30 seconds;
start IG2

END.
```

APPENDIX C. PUMP DOWN CALIBRATION STAND PROCEDURE (PMPDN3)

<u>PMPDN3 - Main</u>

```
BEGIN

close valves 81,82,83, and 85;
start MP3;
wait 2 minutes;
wait up to 10 minutes for TC3;
if timeout then [stop MP3; terminate];

start MN3

END.
```

APPENDIX D. STANDARD LEAK ATTACHMENT PROCEDURE (SLA)

SLA - Main

```
BEGIN

close all ports to which new leaks are to be attached;
tell operator to close manual valves and attach new leaks;
if there are leaks to be calibrated on bath 1 then BATH1:=true;
if there are leaks to be calibrated on bath 2 then BATH2:=true;

if BATH1 then
  [ close valves 50,52,54,56,58,60,61,62,63,64, and 81;
    close valves 1,2,3,4, and 5;
    if there is a new leak at valve 1 then open valve 52;
    if there is a new leak at valve 2 then open valve 54;
    if there is a new leak at valve 3 then open valve 56;
    if there is a new leak at valve 4 then open valve 58;
    if there is a new leak at valve 5 then open valve 60;
    close valve 33; stop IG1; stop MN1; stop TP1;
    for each new leak on bath 1 do
      [ open valve to new leak; wait 10 seconds;
        wait up to 1 minute for TC1;
        if timeout then [TCTO;
                          if TCTO is not successful then terminate] ];
    start TP1;
    open valve 33; wait 5 seconds;
    wait up to 4 minutes for TC1 and TP1;
    if timeout then [LKTO; terminate];
    start MN1 ];

if BATH2 then
  [ close valves 70,71,72,73,74,75,76,77,78, and 79;
    close valves 6,7,8,9,10,11,12,13,14,15,16, and 17;
    close valve 43; stop IG2; stop MN2; stop TP2;
    if there is a new leak at valves 6,7,8, or 9 then open valve 71;
    if there is a new leak at valves 10,11,12, or 13 then open valve 73;
    if there is a new leak at valves 14,15,16, or 17 then open valve 75;
    for each new leak on bath 2 do
      [ open valve to new leak; wait 10 seconds;
        wait up to 1 minute for TC2;
        if timeout then [TCTO;
                          if TCTO is not successful then terminate] ];
    start TP2;
    open valve 43; wait 5 seconds;
    wait up to 4 minutes for TC2 and TP2;
    if timeout the [LKTO; terminate];
    start MN2 ];
```

APPENDIX D. SLA (continued)

SLA - Main (continued)

```
wait 30 seconds;

if BATH1 then
  [ start IG1; wait up to 30 minutes for 5E-7 Torr;
    if timeout then [error message; terminate] ];

if BATH2 then
  [ start IG2; wait up to 30 minutes for 5E-7 Torr;
    if timeout then [error message; terminate] ];

wait for operator to acknowledge that he is prepared to open the
  manual valves;

if BATH1 then [close valve 33; stop MN1; stop IG1];
if BATH2 then [close valve 43; stop MN2; stop IG2];

notify the operator to open the manual valves;
wait for the operator to acknowledge that he has opened the manual
  valves;

if BATH1 then
  [ start TP1; wait up to 2 minutes for TP1 and TC1;
    if timeout then [TPATO;
                     if TPATO is not successful then terminate];
    start MN1 ];

if BATH2 then
  [ start TP2; wait up to 2 minutes for TP2 and TC2;
    if timeout then [TPATO;
                     if TPATO is not successful then terminate];
    start MN2 ];

wait 30 s;

if BATH1 then
  [ start IG1; wait up to 30 minutes for 5E-6 Torr;
    if timeout then [IGTO;
                     if IGTO is not successful then terminate] ];

if BATH2 then
  [ start IG2; wait up to 30 minutes for 5E-6 Torr;
    if timeout then [IGTO;
                     if IGTO is not successful then terminate] ];
```

APPENDIX D. SLA (continued)

SLA - Main (continued)

```
if BATH1 then
  [ stop MN1; stop IG1;
    open valves 52,54,56,58,60,61,63,64;
    open all valves on bath 1 attached to which are leaks to be
      calibrated;
    wait 30 s;
    wait up to 2 minutes for TP1 and TC1;
    if timeout then [TPBTO; terminate];
    start MN1; start IG1; wait up to 30 minutes for 5E-6 Torr;
    if timeout then [IGBTO;
                     if IGBTO is not successful then terminate] ];

if BATH2 then
  [ stop MN2; stop IG2;
    open valves 70,71,72,73,74,75,76,77,78,79;
    open all valves on bath 2 attached to which are leaks to be
      calibrated;
    wait 30 s;
    wait up to 2 minutes for TP2 and TC2;
    if timeout then [TPBTO; terminate];
    start MN2; start IG2; wait up to 30 minutes for 5E-6 Torr;
    if timeout then [IGBTO;
                     if IGBTO is not successful then terminate] ];

if BATH1 then [stop IG1; stop MN1; open valve 33];
if BATH2 then [stop IG2; stop MN2; open valve 43];

wait 30 seconds;

if BATH1 then [start IG1; start MN1];
if BATH2 then [start IG2; start MN2]

END.
```

APPENDIX D. SLA (continued)

SLA - Procedure TCTO

```
BEGIN

Close valve at which error occurred;

if error occurred on bath 1 then
  [ open valve 33;
    start TP1; wait up to 4 minutes for TP1;
    if timeout then [error message; start MN1; return not successful];
    wait up to 30 seconds for TP1 and TC1;
    if timeout then [error message; start MN1; return not successful];
    start MN1;
    wait 30 seconds
    start IG1; wait up to 20 minutes for 5E-7 Torr;
    if timeout then [error message; return not successful];
    stop IG1; stop MN1; stop TP1;
    close valve 33;
    return successful ];

if error occurred on bath 2 then
  [ open valve 43;
    start TP1; wait up to 4 minutes for TP2;
    if timeout then [error message; start MN2; return not successful];
    wait up to 30 seconds for TP2 and TC2;
    if timeout then [error message; start MN2; return not successful];
    start MN2;
    wait 30 seconds;
    start IG2; wait up to 20 minutes for 5E-7 Torr;
    if timeout then [error message; return not successful];
    stop IG2; stop MN2; stop TP2;
    close valve 43;
    return successful ];

END.
```

APPENDIX D. SLA (continued)

SLA - Procedure LKTO

```
BEGIN

close all ports on the bath on which the error occurred to which new
  leaks are attached for calibration;
error message;

if error occurred on bath 1 then
  [ wait up to 2 minutes for TP1;
    if timeout then error message;
    start MN1 ];

if error occurred on bath 2 then
  [ wait up to 2 minutes for TP2;
    if timeout then error message;
    start MN2 ];

return

END.
```

APPENDIX D. SLA (continued)

SLA - Procedure TPATO

```
BEGIN

Tell the operator to press the reset button;
wait 30 s;

if error occurred on bath 1 then
  [ stop TP1; start TP1; wait up to 2 minutes for TP1 and TC1;
    if not timeout then return successful;
    close all valves on both baths to which are attached leaks to be
      calibrated;
    start TP1;
    wait up to 2 minutes for TP1; if timeout then error message;
    if BATH2 then [start TP2; wait up to 2 minutes for TP2;
                   if timeout then error message ];
    start MN1;
    if BATH2 then start MN2;
    return not successful ];

if error occurred on bath 2 then
  [ stop TP2; start TP2; wait up to 2 minutes for TP2 and TC2;
    if not timeout then return successful;
    close all valves on bath 2 to which are attached leaks to be
      calibrated;
    start TP2; wait up to 2 minutes for TP2;
    if timeout then error message;
    start MN2;
    return not successful ];

END.
```

APPENDIX D. SLA (continued)

SLA - Procedure IGTO

```
BEGIN

if error occurred on bath 1 then
  for each valve on bath 1 to which a new leak was attached do
    [ close valve;
      wait 2 minutes for IG1 to reach 5E-6 Torr;
      if not timeout then [error message; return successful];
      open valve ];

if error occurred on bath 2 then
  for each valve on bath 2 to which a new leak was attached do
    [ close valve;
      wait 2 minutes for IG2 to reach 5E-6 Torr;
      if not timeout then [error message; return successful];
      open valve ];

error message;
return not successful

END.
```

APPENDIX D. SLA (continued)

SLA - Procedure IGBTO

```
BEGIN

if error occurred on bath 1 then
  for each valve on bath 1 to which a leak is being calibrated do
    [ close valve;
      wait 2 minutes for IG1 to reach 5E-6 Torr;
      if not timeout then [error message; return successful];
      open valve ];

if error occurred on bath 2 then
  for each valve on bath 2 to which a leak is being calibrated do
    [ close valve;
      wait 2 minutes for IG2 to reach 5E-6 Torr;
      if not timeout then [error message; return successful];
      open valve ];

error message;
return not successful

END.
```

APPENDIX D. SLA (continued)

SLA - Procedure TPBTO

```
BEGIN

error message;
close all port valves on bath on which error occurred;
wait 30 seconds;

if error occurred on bath 1 then
          [open valve 33; start MN1; start IG1];

if error occurred on bath 2 then
  [open valve 43, start MN2; start IG2]

END.
```

APPENDIX E. CALIBRATION PROCEDURE FOR TYPICAL-SIZE LEAKS (CAL)

CAL - Main

```
{For leaks in the range 5E-12 mol/s thru 6E-9 mol/s.}

BEGIN

close valves 1,2,3,4, and 5;
close valves 6,7,8,9,10,11,12,13,14,15,16, and 17;
close valves 70,71,73,75, and 77;


REPEAT

  CALPRT := Port to be calibrated;
  if CALPRT is on bath 1 then [BATH1:=true; BATH2:=false]
     else [BATH1:=false; BATH2:=true];
  if CALPRT=1 then [UPVLV:=51; LOVLV:=52];
  if CALPRT=2 then [UPVLV:=53; LOVLV:=54];
  if CALPRT=3 then [UPVLV:=55; LOVLV:=56];
  if CALPRT=4 then [UPVLV:=57; LOVLV:=58];
  if CALPRT=5 then [UPVLV:=59; LOVLV:=60];
  if (CALPRT>=6) and (CALPRT<=9) then [UPVLV:=72; LOVLV:=71];
  if (CALPRT>=10) and (CALPRT<=13) then [UPVLV:=74; LOVLV:=73];
  if (CALPRT>=14) and (CALPRT<=17) then [UPVLV:=76; LOVLV:=75];

  if BATH1 then [stop MN1; stop IG1];
  if BATH2 then [stop MN2; stop IG2];

  if BATH2 then close UPVLV;
  open LOVLV;
  open CALPRT; wait 2 minutes; close CALPRT;
  if BATH2 open UPVLV;

  if BATH1 then [start MN1; start IG1];
  if BATH2 then [start MN2; start IG2];

  T-calprt := 0;      {Timer for each port-to-be-calibrated}
  Re := estimated leak rate in moles/sec;
  if BATH1 then
    [ if (5E-12 <= Re <= 5E-10) then Te-calprt := 8E-9/Re minutes;
      if (Re > 5E-10) then Te-calprt:=8 min ];
  if BATH2 then
    [ if (5E-12 <= Re <= 4E-10) then Te-calprt := 8E-9/Re minutes;
      if (Re > 4E-10) then Te-calprt:=10 minutes];
  store Re,Te-calprt

UNTIL all 'typical'-ports-to-be-calibrated have been checked;
```

APPENDIX E. CAL (continued)

CAL - Main (continued)

```
if bath 1 contains a 'typical' port to be calibrated then
  [close valves 81,87, and 88;
   open valves 50,52,54,56,58,60,61,62,63,64, and 89];
if bath 2 contains a 'typical' port to be calibrated then
  [open valves 70,71,72,73,74,75,76,77,78,and 79];


REPEAT

  choose CALPRT having the minimum wait time remaining of all ports
    which have not yet been calibrated;
  open all port valves to which 'small' leaks are attached;
  wait until T-calprt > Te-calprt;
  if (T-calprt > 1.5*Te-calprt) then
            reset T-calprt as before
  else
    [close all port valves to which 'small' leaks are attached;
     assign BATH1, BATH2, UPVLV and LOVLV as before;
     CALIBRATE(CALPRT)];

  if (CALPRT can be calibrated again within 24 hours from the start of
     CAL)
     and
     (CALPRT has been calibrated less than three times)
  then place CALPRT on list of leaks remaining to be calibrated

UNTIL all ports have been calibrated;

if bath 1 contained a 'typical' port to be calibrated then
  open valves 50,52,54,56,58,60,61,62,63, and 64;
if bath 2 contained a 'typical' port to be calibrated then
  open valves 70,71,72,73,74,75,76,77,78, and 79


END.
```

APPENDIX E. CAL (continued)

CAL - Procedure CALIBRATE

```
BEGIN

Get capacitance manometer zero reading CMz-calprt;
store CMz-calprt;

open UPVLV;
if BATH2 then [close LOVLV; close valves 72,74, and 76 except UPVLV];

if a background scan is to be performed then
[
  if BATH2 then [close valve 89; open valve 88; wait 30 seconds];

  if BATH1 then [close valves 50,61,63, and 88; open valve 89];
  if BATH2 then close valves 70,77, and 78;

  open valve 90;
  start depletion rate timer Tdep;

  BACKGROUND; store background;

  if BATH1 then [open valves 50,61, and 63; wait 15 seconds];
  if BATH2 then [open valves 70 and 77; wait 15 seconds];
  close valve 90
];


if BATH1 close valves 50,61,62,63,64, and 89;
if BATH2 close valves 70,77,78,79, and 88;

open CALPRT; wait 15 seconds; close CALPRT;
Ta-calprt := T-calprt; wait 20 seconds;
Get capacitance manometer reading CMa-calprt;

if BATH1 then if (CMa-calprt < 1 Torr) then CALMETHOD1 else CALMETHOD2;
if BATH2 then if (CMa-calprt < 1 Torr) then CALMETHOD1 else ERR2;
```

APPENDIX E. CAL (continued)

CAL - Procedure CALIBRATE (continued)

```
if a mass scan is to be performed then
[
  if no ERRx has been performed then
  [
    close UPVLV;
            if CALMETHODx is successful then
    [
      if BATH2 then [open valve 88; wait 20 seconds];
      if BATH1 then open valve 89;
      if CALMETHOD1 was used then CMx := CMb-calprt;
      if CALMETHOD2 was used then CMx := CMd-calprt;
      if CMx <0.05 Torr then open valve 92
              else open valve 90;
      Start depletion rate timer Tdep;
      wait 10 seconds;
      MASS-SCAN; store mass-scan
    ]
  ]
];

if BATH1 then [close valves 90 and 92; open valves 61,62,63,64;
               open valves 50,52,54,56,58,60, and 87];
if BATH2 then [close valves 90 and 92; open valves 70,71,72,73,74,
                                                   75,76,77,78, and 79];
wait 1 minutes;

return

END.
```

APPENDIX E. CAL (continued)

CAL - Procedure CALMETHOD1

```
BEGIN

open CALPRT;
if BATH1 open valve 62; if BATH2 open valve 79;
wait 15 seconds; close CALPRT;
Tb-calprt := T-calprt; wait 20 seconds;
get capacitance manometer reading CMb-calprt;
zero correct CMa-calprt and CMb-calprt;
apply correction curves to CMa-calprt and CMb-calprt;
store CMa-calprt, Tb-calprt, CMb-calprt;

Calculate leak rate R-calprt (moles/sec):

                       (CMa-calprt)(CMb-calprt)V(1.6035E-5)
R-calprt : =-------------------------------------------------------------
            ((CMa-calprt)(Tb-calprt)-(CMb-calprt)(Ta-calprt))(T+273.16)

where T (C) is the temperature of the bath and V (cc) is the volume,
      Bath 1: V := Volume of bottle 1 (between valves 61 & 62)
      Bath 2: V := Volume of bottle 3 (between valves 77 & 79);

VOLUME := V;
store R-calprt, T, VOLUME;
if CMb-calprt >0.4 Torr then [open valve 64; wait 10 seconds];

return

END.
```

APPENDIX E. CAL (continued)

CAL - Procedure CALMETHOD2

```
BEGIN

open valve 62; wait 20 seconds;
get capacitance manometer reading CMc-calprt;
if CMc-calprt > 1 Torr then [ERR1; return];
open CALPRT; open valve 64; wait 15 seconds; close CALPRT;
Td-calprt := T-calprt;
wait 20 s;
get capacitance manometer reading CMd-calprt;
zero correct CMc-calprt and CMd-calprt;
apply correction curves to CMc-calprt and CMd-calprt;
store CMc-calprt, Td-calprt, CMd-calprt;

Calculate leak rate R-calprt (moles/s):

            (CMc-calprt)(CMd-calprt)(V1+V2)(1.6035E-5)
R-calprt := -----------------------------------------------------------
            ((CMc-calprt)(Td-calprt)-(CMd-calprt)(Ta-calprt))(T+273.16)

where T (C) is the temperature of bath 1 and
      V1 := Volume of bottle 1 (between valves 61 & 62)
      V2 := Volume of bottle 2 (between valves 63 & 64);

VOLUME := V1+V2;
store R-calprt, T, VOLUME;

return

END.
```

APPENDIX E. CAL (continued)

CAL - Procedure ERR1

```
BEGIN

error notification 'leak rate out of range';
close CALPRT;
close valve 33; open valves 50,61,62,63, and 64;
wait 10 minutes for IG1 < 5E-7;
if timeout then [error message; terminate];
open valve 33;
return

END.
```

APPENDIX E. CAL (continued)

CAL - Procedure ERR2

```
BEGIN

error notification 'leak too large or leak rate estimate too large';
close CALPRT;
close valve 43; open valves 70 and LOVLV;
wait 10 minutes for IG2 < 5E-7;
if timeout then [error message; terminate];
open valve 43;
return

END.
```

APPENDIX E. CAL (continued)

CAL - Procedure BACKGROUND

```
BEGIN

{depletion rate := drh2 * sqrt (2./m),
            where drh2 = depletion rate of hydrogen,
                     m = peak mass begin scanned}

cycle magnet;
ramp magnet to zero peak;
set digital integrator to 0.2-second timing; get
digital integrator ZERO and NOISE readings;

for all peaks to be measured
  BEGIN
  locate center of peak;
  BKGRND:=(measured_intensity - ZERO)*exp(depletion_rate*Tdep)
  END;

END.
```

APPENDIX E. CAL (continued)

CAL - Procedure MASS-SCAN

```
BEGIN

{depletion rate := drh2 * sqrt (2./m),
            where drh2 = depletion rate of hydrogen,
                     m = peak mass begin scanned}

set digital integrator to 0.2-second timing;

for all peaks to be measured
  BEGIN
  locate center of peak;
  INTENSITY:=(measured_intensity - ZERO)*exp(depletion_rate*Tdep)
  END;

for all peaks measured INTENSITY:=INTENSITY-BKGRND;

{if CALMETHOD1 was used then
     partial pressure : = (intensity/sens/CMb-calprt)*100.
  if CALMETHOD2 was used then
     partial pressure : = (intensity/sens/CMd-calprt)*100.}

END.
```

APPENDIX F. CALIBRATION PROCEDURE FOR SMALL-SIZE LEAKS (CLS)

CLS - Main

```
 {For helium leaks in the range (less than) 5E-12 mol/second down to
  1E-14 mol/second.

  Leaks may be attached to ports 14, 15, and 16 only.  A helium standard
  of about 1E-10 mol/s must be attached to port 17.}


BEGIN

close valves 6,7,8,9,10,11,12,13,14,15,16, and 17;
close valves 70,72,74,77,86, and 89;
open valve 88;

close valve 76; open valve 75;
open all 'small'-ports-to-be-calibrated;
wait 10 minutes;


REPEAT

  CALPRT := Port to be calibrated;
  Estrat := estimated leak rate of CALPRT in moles/seconds;
  Rrate := leak rate of He at port 17 in moles/seconds;
  Te-calprt := 12*(Rrate/Estrat) seconds;
  close CALPRT;
  T-calprt := 0     {Timer for each port-to-be-calibrated}

UNTIL all 'small'-ports-to-be-calibrated have been checked;

open valves 17 and 77;

REPEAT

  choose CALPRT having the minimum wait time remaining of all ports
    which have not yet been calibrated;
  wait until T-calprt > Te-calprt;
  close valve 75; open valve 76;
  CALIBRATE(CALPRT)

  if (CALPRT can be calibrated again within 24 hour from the start of
     CLS)
      and
     (CALPRT has been calibrated less than three times)
  then place CALPRT on list of leaks remaining to be calibrated
```

APPENDIX F. CLS (continued)

CLS - Main (continued)

UNTIL all 'small'-ports-to-be-calibrated have been calibrated;

open valves 70,71,72,73,74,75,76,77,78, and 79

END.

APPENDIX F. CLS (continued)

CLS - Procedure CALIBRATE

```
BEGIN

close valves 78 and 79;
open valve 91;
wait 2 minutes;

TEMP := Bath 2 temperature;

measure zero and noise levels of mass spectrometer with 0.2-second
  integration;

scan to find mass 4;
down range gain 2 decades;
ramp to zero location and measure BASE with 60-second integration; ramp
  to mass 4;
measure mass 4 five times (subtracting BASE) on 60-second integration
  timing;

calculate mean average H1 and standard deviation STDV1;

start a 60-second integration period;
open CALPRT; TMF := T-calprt;
complete integration period taking reading RX1;
RX1 := RX1-BASE;

measure mass 4 five times (subtracting BASE) on 60-second integration
   timing;

calculate mean average H2 and standard deviation STDV2;

HRU := RX1-H1;
Ra := Rrate*((H2-H1)/H1);
```

APPENDIX F. CLS (continued)

CLS - Procedure CALIBRATE (continued)

```
close 17;
wait 5 minutes;

measure mass 4 five times (subtracting BASE) on 60-second integration
  timing;

calculate mean average H3 and standard deviation STDV3;

Rb := Rrate*(H3/H1);

open valve 17;
EXP:=0;

REPEAT

  close valves 77,76,88,91,CALPRT;
  open valve 75;
  wait 2 minutes;

  close valve 17;
  T17:=0;    {T17 is a timer}
  open valves 77,76,78,CALPRT;

  EXP:=EXP+1;    {Timer setpoint}
  Wait until T17=EXP minutes;

  close valves 77 and 75;
  open valve 17;
  wait 30 s;
  close valve 17; stop T17;
  wait 30 s;
  close valve CALPRT;
  open valves 17,77,88, and 91;
  close valve 78;
  wait 90 s;

  measure mass 4 five times (subtracting BASE) on 60-second integration
    timing;

  calculate mean average Ha and standard deviation STDVa;

  start a 60-second integration period; open CALPRT;

  complete integration period taking reading RX2;
  RX2 := RX2-BASE;
```

APPENDIX F. CLS (continued)

CLS - Procedure CALIBRATE (continued)

```
  HR(EXP) := (RX2-Ha);  TR(EXP) := T17;

UNTIL EXP=6;

perform a least-squares fit deriving coefficients (HU1,HU2), where
  HU1 is the slope and HU2 is the intercept, of a straight line
  representing HR versus TR;

TU := (HRU-HU2)/HU1;

Rc-calprt := Rrate*TU*(Vol/TMF)*V4

  where Vol is the volume of the area between the leak and the port
    valve, and V4 is the volume of the bottle between valves 77 and 78;


close valves CALPRT,76, and 91;
open valves 17,75,77,78,79, and 88;

END.
```

APPENDIX F. CLS (continued)

CLS - Least Squares Fit Method

For the first order polynomial: $y = A + Bx$

Intercept: $$A = \frac{(\Sigma x^2)(\Sigma y) - (\Sigma x)(\Sigma xy)}{n(\Sigma x^2) - (\Sigma x)^2}$$

Slope: $$B = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n(\Sigma x^2) - (\Sigma x)^2}$$

Correlation coefficient: $$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{n\Sigma x^2 - (\Sigma x)^2)\,(n\Sigma y^2) - (\Sigma y)^2)}}$$

where n is the number of sample data points.

Note: The equation form

$$y = A \bullet e_{(B \bullet x)}$$

can be transformed into a linear form in the following way:

$$\ln y = \ln A + Bx$$

APPENDIX G. DEPLETION RATE CALCULATION PROCEDURE (DPR)

DPR - Main

```
{Measure depletion rates of hydrogen.

  dep1 - H2 flow from bath 1 thru valve 90
  dep2 - H2 flow from bath 1 thru valve 92
  dep3 - H2 flow from bath 2 thru valve 90
  dep4 - H2 flow from bath 2 thru valve 92}

BEGIN

perform FILL_BOTTLE_a;
VLV := 90;
perform GET_RATE_BATH_1;
dep1 := DPR;

if (CM1_final <0.2 Torr) then perform FILL_BOTTLE_b;
VLV := 92;
perform GET_RATE_BATH_1;
dep2 := DPR;

VLV := 90;
perform FILL_BOTTLE_c;
perform GET_RATE_BATH_2;
dep3 := DPR;

VLV := 92;
perform GET_RATE_BATH_2;
dep4 := DPR

END.
```

APPENDIX G. DPR (continued)

DPR - Procedure FILL BOTTLE a

```
BEGIN

if (MN1=off) or (MN3=off) then [error message; terminate];

close valves 81,83,86,87,88,89;
stop MN3; open valve 82; wait 5 s;
wait up to 2 minutes for TC3;
if timeout then [error message; terminate];
start MN3;

close valve 82;
close valves 50,52,54,56,58,60,61,63;

stop MN1; stop IG1; stop TP1;
open valves 81,83,85;
start TP1; wait 5 seconds;

wait up to 2 minutes for TP1 and TC1;
if timeout then [close valves 81,83,85;
                 error message; terminate];

start MN1; start IG1;
wait up to 30 minutes for 5E-7 Torr;
if timeout then [close valves 81,83,85; error message; terminate];

close valves 81,85;
open valve 18; wait 5 seconds; close valves 18,83;

open valves 50,52,54,56,58,60,61,62,63,64,87,89;
wait 10 seconds;
wait up to 5 minutes for 5E-7 Torr;
if timeout then [error message; terminate];

get capacitance manometer zero reading CM1z;
close valves 50,61,63;
open valve 85; wait 10 seconds;
CM1_temp := CM1 - CM1z;

close valves 85,62,64;
```

APPENDIX G. DPR (continued)

DPR - Procedure FILL BOTTLE a (continued)

```
CNT:=0;
REPEAT

  CM1a := CM1_temp;

  stop MN1; stop IG1;
  open valves 50,89; wait 15 seconds;
  wait up to 15 s for TP1 and TC1;
  if timeout then [error message; open valve 61,62; terminate];
  start MN1; start IG1;

  wait up to 10 minutes for 5E-7 Torr;
  if timeout then [error message; stop MN1; stop IG1;
                   open valves 61,62; wait 2 minutes;
                   start MN1; start IG1; terminate];

  CNT:=CNT+1;

  if (CM1a > 1 Torr) then
    [if (CNT = 8) then [error message; terminate];
     stop MN1; open 61; wait 10 seconds;
     wait up to 15 s for TP1 and TC1;
     if timeout then [error message; open valve 62; terminate];
     start MN1;
     close valves 50,61,89; open valves 62,64; wait 20 seconds;
     CM1_temp := CM1 - CM1z; close valves 62,64]

UNTIL (CM1a =< 1 Torr);

if (CM1a <0.1 Torr) then [error message; terminate]

END.
```

APPENDIX G. DPR (continued)

DPR - Procedure FILL BOTTLE b

```
BEGIN

open valves 62,64;
wait 5 seconds;
close valves 62,64;
open valve 50;
wait 15 seconds;

start IG1;
wait up to 10 minutes for 5E-7 Torr;
if timeout then [error message; stop MN1; stop IG1;
                 open valves 61,62; wait 2 minutes;
                 start MN1; start IG1; terminate];

END.
```

APPENDIX G. DPR (continued)

DPR - Procedure GET RATE BATH 1

```
BEGIN

close valves 50,87;
open valves 62,VLV;
wait 5 seconds;

CM1_initial := CM1 - CM1z;
CM1_final := CM1_initial;

CNT := 0;
REPEAT

  wait 10 seconds;
  CNT := CNT + 1;
  if (CNT > 100) then [error message; terminate];
  read CM1, maintaining values for linear least-squares fit;
  CM1_final := CM1-CM1z;

UNTIL (CM1_final < CM1_initial/2.0) and (CNT >= 20);

solve linear least-squares fit:  CM1 = A * exp(B*t),
                                       where A = constant,
                                             B = depletion rate,
                                             t = time in seconds;

close valve 62,VLV

END.
```

APPENDIX G. DPR (continued)

DPR - Procedure FILL BOTTLE C

```
BEGIN

stop MN1; stop IG1;
open valve 50;
close valves 70,72,74,76,77,78;
open valves 79,88;

wait 30 seconds;

wait up to 2 minutes for TP1 and TC1;
if timeout then [close valves 79,88; wait 30 seconds; start MN1;
                 error message; terminate];

start MN1; wait 30 seconds; start IG1;
wait up to 5 minutes for 5E-7 Torr;
if timeout then [error message; terminate];

wait 60 seconds;
get capacitance manometer zero reading CM2z;

close valve 50

END.
```

APPENDIX G. DPR (continued)

DPR - Procedure GET RATE BATH 2

```
BEGIN

open valves 88,89,64;
wait 5 seconds;
close valves 64,89;
open valve VLV;
wait 5 seconds;

CM2_initial := CM2 - CM2z;
CM2_final := CM2_initial;

CNT := 0;
REPEAT

  wait 10 seconds;
  CNT := CNT + 1;
  if (CNT > 100) then [error message; terminate];
  read CM2, maintaining values for linear least-squares fit;
  CM2_final := CM2-CM2z;

UNTIL (CM2_final < CM2_initial/2.0) and (CNT >= 20);

solve linear least-squares fit:  CM1 = A * exp(B*t),
                                       where A = constant,
                                             B = depletion rate,
                                             t = time in seconds;

close valves VLV,88;

END.
```

APPENDIX H. MASS SPECTROMETER CALIBRATION PROCEDURE (MSC)

MSC - Main

```
{Determine sensitivities of the masses interest.}

BEGIN

{Set up arrays:  MASS - mass, NAME - mass name,
                  PORT - location on calibration gasses stand.}

mass[1]:=2;   name[1]:='H2';     port[1]:=18;
mass[2]:=3;   name[2]:='HD';     port[2]:=0;
mass[3]:=4;   name[3]:='He';     port[3]:=20;
mass[4]:=4;   name[4]:='D2';     port[4]:=19;
mass[5]:=16;  name[5]:='CH4';    port[5]:=21;
mass[6]:=18;  name[6]:='H2O';    port[6]:=0;
mass[7]:=20;  name[7]:='Ne';     port[7]:=25;
mass[8]:=28;  name[8]:='N2';     port[8]:=23;
mass[9]:=32;  name[9]:='O2';     port[9]:=24;
mass[10]:=40; name[10]:='Ar';    port[10]:=22;
mass[11]:=41; name[11]:='Oils';  port[11]:=0;
mass[12]:=44; name[12]:='CO2';   port[12]:=26;
mass[13]:=84; name[13]:='Kr';    port[13]:=27;

depletion_rate := depletion rate of H2 flow from bath 1 thru
                  valve 90;


perform BACKGROUND;

for i := 1 to 12 do
          if (i#2) and (i#6) and (i#11) then perform GET_SENSITIVITY;

'sensitivity of mass 3 due to HD' := ('sensitivity of mass 2 due to H2'
                          + 'sensitivity of mass 4 due to D2')/2;
'sensitivities of mass 18 due to H2O' :=
                          function1('sensitivity of mass 28 due to N2')
'sensitivities of mass 41 due to Oils' :=
                          function2('sensitivity of mass 28 due to N2')

END.
```

APPENDIX H. MSC (continued)

MSC - Procedure GET-SENSITIVITY

```
BEGIN

if (MN1=off) or (MN3=off) then [error message; terminate];

close valves 81,83,86,87,88,89;
stop MN3; open valve 82; wait 5 seconds;
wait up to 2 minutes for TC3;
if timeout then [error message; terminate];
start MN3;

close valve 82;
close valves 50,52,54,56,58,60,61,63;

stop MN1; stop IG1; stop TP1;
open valves 81,83,85;
start TP1; wait 5 seconds;

wait up to 2 minutes for TP1 and TC1;
if timeout then [close valves 81,83,85;
                 error message; terminate];

start MN1; start IG1;
wait up to 30 minutes for 5E-7 Torr;
if timeout then [close valves 81,83,85; error message; terminate];

close valves 81,85;
open valve port[i]; wait 5 seconds; close valves port[i],83;

open valves 50,52,54,56,58,60,61,62,63,64,87,89;
wait 10 seconds;
wait up to 5 minutes for 5E-7 Torr;
if timeout then [error message; terminate];

get capacitance manometer zero reading CM1z;
close valves 50,61,63;
open valve 85; wait 10 seconds;
CM1a := CM1 - CM1z;
close valves 85,62,64;
```

APPENDIX H. MSC (continued)

MSC - Procedure GET-SENSITIVITY (continued)

```
CNT:=0;

WHILE CM1a >0.4 Torr DO

  [
  stop MN1; stop IG1;
  open valves 50,89; wait 15 seconds;
  wait up to 15 s for TP1 and TC1;
  if timeout then [error message; open valves 61,62; terminate];
  start MN1; start IG1;

  wait up to 10 min for 5E-7 Torr;
  if timeout then [error message; stop MN1; stop IG1;
                   open valves 61,62; wait 2 minutes;
                   start MN1; start IG1; terminate];

  CNT:=CNT+1;

  if (CNT = 10) then [error message; terminate];
  stop MN1; open valve 61; wait 10 seconds;
  wait up to 15 seconds for TP1 and TC1;
  if timeout then [error message; open valves 61,62; terminate];
  start MN1;
  close valves 50,61,89; open valves 62,64; wait 20 seconds;
  CM1a := CM1 - CM1z; close valves 62,64
  ];


wait 1 minute;
close valves 50,87;
open valves 62,89; wait 10 seconds;
open valve 90;
start depletion rate timer Tdep;

d_rate := depletion_rate * sqrt(2.0/mass[i])

for every sensitivity of mass[i] due to a name[j] do
  [ PERFORM SCAN_MASS;
    'sensitivity of mass[i] due to name[j]' :=
                   'intensity of mass[j]'/(CM1a * exp(d_rate * Tdep));

close valve 90;
open valves 61,63,64;
open valves 50,87

END.
```

APPENDIX H. MSC (continued)

MSC - Procedure BACKGROUND

```
BEGIN

cycle magnet;
ramp magnet to zero peak;
set digital integrator to 0.2 seconds timing;
get digital integrator ZERO and NOISE readings;

for all peaks to be measured
  BEGIN
  locate center of peak;
  'background of mass[i]' := measured_intensity - ZERO
  END

END.
```

APPENDIX H. MSC (continued)

MSC - Procedure SCAN MASS

```
BEGIN

set digital integrator to 0.2 seconds timing;
locate center of peak 'mass[j]';
'intensity of mass[j]' := INT - 'background of mass[j]' - ZERO

END.
```

APPENDIX I. MASS SCAN PROCEDURE

The Standard Leak Calibration Facility (SLCF) is concerned with a mass spectrum of 13 gasses:

ID	Gas	Mass
1	H_2	2
2	HD	3
3	He	4
4	D_2	4
5	CH_4	16
6	H_2O	18
7	Ne	20
8	N_2	28
9	O_2	32
10	Ar	40
11	Oils	41
12	CO_2	44
13	Kr	84

SENSITIVITIES

In order to correctly determine the intensity and percent composition of each mass in the spectrum, it is necessary to know the sensitivities of each of the masses. The table below shows the sensitivities required by LCF.

DUE TO GAS

SENSITIVITY OF MASS	H_2	HD	He	D_2	CH_4	H_2O	Ne	N_2	O_2	Ar	Oils	CO_2	Kr
2	X			X									
3		X											
4			X										
4				X									
16					X								
18						X							
20							X			X			
28								X				X	
32									X				
40										X			X
41											X		X
44												X	
84													X

The mass sensitivities are determined by the mass spectrometer calibration program (MSC).

(continued next page)

APPENDIX I. MASS SCAN PROCEDURE (continued)

MASS SPECTRUM

The corrected mass spectrum is determined in the following way.

(1) Make a background scan, B, where b_i is the background intensity at mass i.

(2) Make a foreground scan, F, where f_i is the foreground intensity at mass i.

(3) Subtract the background from the foreground, generating the scanned foreground, F_s , where f_{s_i} is the scanned foreground of mass i. $F_s = F - B$, that is, $f_{s_i} = f_i - b_i$, for all i.

(4) Given the following:

dpr_i = depletion rate of mass i, expressed as a positive number.
$dtime_i$ = depletion time of mass i.
$sens_{i/j}$ = sensitivity of mass i due to gas j.
cm = capacitance manometer pressure.
N = number of masses.

Determine F_c, where f_{c_i} is the percent composition of mass i, as follows:

```
FOR i := N down to 1 DO
  BEGIN
  FOR j := N down to i+1 DO
    IF SENS_i/j > 0 THEN
      BEGIN
      in := (sens_i/j * cm * (f_c_j/ 100)) / (exp(dpr_j * dtime_i));
      f_s_i := f_s_i - in

      END;
  f_c_i := (100 * f_s_i * exp(dpr_i * dtime_i)) / (cm * sens_i/i)

  END.
```

REFERENCES

1. McClain, S. K., *Standard Leak Calibration Facility Software Reference Manual*, Y/DW-833, Martin Marietta Energy Systems, Oak Ridge Y-12 Plant, September 1988.

2. McClain, S. K., *Standard Leak Calibration Facility Software User's Guide*, Y/DW-834, Martin Marietta Energy Systems, Oak Ridge Y-12 Plant, September 1988.

END

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