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LASER TRANSMISSOMETER
INSTALLATION, ALIGNMENT AND INSTRUCTION MANUAL
(INCLUDING FINAL REPORT)

Jul 78

Prepared for
Agency for Defense Development
Republic of Korea

Prepared by
BLOCK ENGINEERING, INC.
19 Blackstone St.
Cambridge, MA 02139

Also see Test Plan Dwg. #8001289
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# Laser Transmissometer System Specifications

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<td>Double Ended, Separate Transmitter and Receiver</td>
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<td>Based on HP9825A programmable desk top calculator</td>
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| Meteorological Monitors                | Temperature: Climet #015  
Pressure: Climet #502  
Relative Humidity: Climet #016-43  
Wind Speed: Climet #011-28  
Wind Direction: Climet #012-6C  
Rain Gauge: Belfort #5-405HA  
Rate of Rainfall: Belfort #6069A |
| Measurement wavelengths                | 0.6328µm, HeNe laser  
1.06µm, Nd:YAG laser  
10.6µm, CO₂ laser |
| Laser Sources                          | He-Ne - Hughes #3221  
Nd-YAG - General Photonics #2-10  
CO₂ - GTE Sylvania #941-P |
| Water Cooling Requirements             | Single closed-loop water cooler General Photonics #400 |
| Measurement Range                      | 0.1 - 2.0 km |
| Modulation Frequency                   | 1200 Hz Nominal, Laser Precision CTX534 Variable Speed Chopper |
| Signal Detectors; 6 Total              | 0.6328µm, Silicon PIN  
1.06µm, Silicon PIN  
10.6µm, LiTaO₃ Pyroelectric |
| Demodulator Reference Source           | He-Ne Transmitter |
| Signal Channel Time Constant           | 1 sec (fixed) and 1 msec (fixed), selectable. |
| System Radiometric Sensitivity         | S/N ≥ 1×10⁴ all signal channels |
LASER TRANSMISSOMETER (Cont'd.)

SYSTEM SPECIFICATIONS

Gain Range

Three receiver channels have 2 gain states (front panel & calculator controlled)

Transmitter Aperture (f/13.33) 15cm. dia.

Transmitter Throughput

0.6328 μm, 4.14x10^{-9} cm^2 ster
1.06μm, 9.87x10^{-8} cm^2 ster
10.6μm, 1.58x10^{-6} cm^2 ster

Transmitter Monitor Aperture 0.6 cm^2

Receiver Aperture (F/5) 50cm. dia.

Receiver F.O.V. 2mr full angle

Receiver Sighting Reflex, with reticle

Data Processing System

Data Input Channel 6 Detector outputs
7 Meteorological Sensor Outputs

A/D Converter 12 bits

A/D Input Voltage Range ±10 volts

Scan Rate 2 sec, Fixed

Digital Signal Integration Selectable 2,3,4, etc./scans

Time Delay between channel to channel sampling 0.01 sec, nominal

Data Output Digital Tape Cassette
Printer/Plotter

Tape Capacity ~3400 Scans
LASER TRANSMISSOMETER (Cont'd.)

SYSTEM SPECIFICATIONS

Printer Output Format

3 transmission plots versus time. Numerical value of transmission versus time plus 7 meteorological sensor outputs and the absolute time will be output in tabular format adjacent to the transmission plots.

Data Output Base

Calculator determined; based on digital integration interval.

Miscellaneous Specifications

Power 100V, 20A, 60 Hz
Receiver Environment -20°C to +40°C
Transmitter Environment +15°C to +30°C
Electronics Chassis 19" rack mount
Transmission cable length 2000 m
1. **GENERAL**

The laser transmissometer described herein has been built for making continuous precision atmospheric transmission measurements at three laser wavelengths over an extended period of time.

This manual should be thoroughly read before any attempt is made to operate the system.

1.1 **EQUIPMENT SUPPLIED**

The complete system may be divided into five sections each section consisting of the following equipment.

1. Desk Console
   a. Hewlett-Packard 9825A
   b. H-P Multiprogrammer 6940-B
   c. H-P Printer 9871-A
   d. Laser Transmissometer Controller
   e. Climet Translator 060
   f. GTE Sylvania CO₂ Laser Power Supply Model 941P
   g. General Photonic Closed Loop Water Cooler Model-400.
2. Transmitter Optical Head
   a. 0.6328μm laser
   b. 1.06μm laser
   c. 10.6μm laser
   d. 3 reference detectors with preamplifiers
   e. chopper assembly
   f. Transmitter optics.

3. Receiver Optical Head
   a. 3 receiver detectors with preamplifiers
   b. Receiver optics

4. 2000 meters of interconnecting cable.

5. Meteorological Equipment
   a. Climet Wind Speed Transmitter, Model 011-28
   b. Climet Wind Direction Transmitter, Model 0126C
   c. Climet Temperature Sensor, Model 015-3
   d. Climet Pressure Transducer, Model 502
   e. MRI Tipping Bucket Rain Gauge, Model 302
   f. Motor Aspirated Temperatures and Dewpoint Shield, Model
   g. 
   h. 
   i. All necessary interconnecting cables.

1.2 INSPECTION

Carefully examine all equipment for possible damage which may have occurred during transit. If any damage is observed, refer to instructions below.
1.3 CLAIM FOR DAMAGE IN SHIPPING

The instrument should be visually inspected and tested for proper operation as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filled with the carrier. A full report of the damage should be made out and forwarded to Block Engineering, Inc. who will then advise you of the disposition of the equipment and arrange for repair or replacement. Include the model and serial numbers in any correspondence regarding this instrument.

1.4 RETURN FOR REPAIR INSTRUCTIONS

If any fault develops, the following steps should be taken:

1. Notify Block Engineering, Inc. giving full details of that difficulty; include model and serial numbers. Upon receipt of this information, Block Engineering, Inc., will reply with either service or shipping instructions. DO NOT return any equipment without prior acknowledged notification.

2. If the equipment is to be returned to Block Engineering, Inc., pack it in its original containers or according to the shipping instruction, and forward it prepaid to the address given below. Unless otherwise instructed, arrange shipment via air freight. If the original shipping containers have been discarded, the instrument should be packed in strong exterior containers (preferably wood) and surrounded by at least two inches of foam rubber or similar shock absorbing material.

3. Address Shipping Container as follows:
   Block Engineering, Inc.,
   19 Blackstone Street
   Cambridge, Massachusetts 02139
2. HARDWARE DESCRIPTION GENERAL

The system built by Block Engineering, Inc. for this application utilizes a laser transmitter and a remote receiver (up to 2km) with a sufficiently large aperture such that the three laser beams are completely contained, even in the presence of scintillation. The three laser beams are projected along a common boresight axis through the transmitter telescope which is focussed at the plane of the receiver aperture. The transmitted radiation is modulated with a chopper and then monitored at the transmitter aperture to allow correction for laser amplitude fluctuations by ratioing with the received radiation.

2.1 TRANSMITTER OPTICS

As can be seen in the Drawing BEI 650468, radiation is generated by the three lasers, S1, S2, and S3. The S1 beam is 4mm in diameter, but the S2 and S3 beams are smaller, and so S2 and S3 are expanded by the beam expanders EX2 and EX1. The three beams are combined using the beamsplitters BS1, BS2, and BS3. BS3 is designed to reflect 90% of the 0.6328 micron laser radiation but transmit other visible radiation to permit viewing through the system optics by personnel. BS2 is designed to reflect over 90% of the 1.06 micron laser radiation, but transmit 90% of all visible radiation. BS1 is designed to reflect 36% of all radiation, absorbing or transmitting the remainder. BS1 transmits radiation from about 2 to 14 microns, and therefore transmits about 40% of the S1 laser radiation, reflecting about 60% to the absorber BB1. Two beam adjusting mirrors, M8 and M9, are used to position and align the S1 laser beam to the other beams.

2-1
The three beams are combined after BS1, and proceed through the chopper C1, which modulates the radiation at 1.2kHz. The beams are reflected by the flat mirrors M1 and M2 to the focussing mirror M3. This beam diverges from the focal point, through the flat mirror M4 to the primary collimator mirror M5. The collimator beam is transmitted from the instrument through the aperture at the opposite end.

A very small part of the beam is intercepted by the prism mirror P1, which deflects this portion of the radiation through the flat mirrors M6 and M7 to the beamsplitters BS4, BS5, and BS6. These beamsplitters are made of identical materials and coatings to BS1, BS2, and BS3, respectively. The S1 radiation is transmitted through BS4 to the detector lens L1, which focuses the energy onto detector D1, a pyroelectric long wavelength detector. The S2 radiation is reflected by BS5 to lens L2 and focuses onto detector D2, a Si photodiode optimized for red and near infrared radiation. The S3 radiation is reflected by BS6 to lens L3 and focused onto detector D3, an identical type to D2.

2.2 RECEIVER OPTICS

Drawing BEI 650469 shows the receiver optical system. Radiation is received by the large paraboloid primary mirror M1, which focuses this radiation at a point just past the diagonal prism mirror M2. The radiation is transferred through the spherical mirror M3 to a focus at the detector lenses. This converging beam is folded by flat mirrors M4, M5, and M6. Beamsplitters BS1, BS2, and BS3 are identical to transmitter beamsplitters BS1, BS2, and BS3, respectively, and the characteristics are described in the transmitter discussion.
The detector lenses L1, L2, and L3 and the detectors D1, D2, and D3 are identical to those in the transmitter with the same designation. Filter F1 is used to reject extraneous infrared radiation outside of the laser wavelength range. Filter F2 blocks the laser radiation so that viewing by personnel during operation is possible. Filter F3 is a ground glass viewing screen, permitting ease of alignment of the receiver to the He-Ne laser beam. A small retroreflector is mounted at the center of the aperture to provide a return flash when the He-Ne beam is incident on the aperture. An eyepiece and reticle are also provided to help in verifying the alignment.

2.3 OPTICAL SURFACES

All mirrors in this system are aluminized first surface mirrors protected by a silicon monoxide overcoat. DO NOT TOUCH MIRRORS, LENSES, OR BEAMSLITTER SURFACES. Although these surfaces can be cleaned, acids from some persons fingers are strong enough to etch these surfaces in a few hours, and cleaning will not remove such marks. Since the optical elements are exposed to ambient air, the collection of oil and other aerosols, as well as dust particles will tend to gradually reduce the system transmission. Cleaning of all surfaces is recommended every six months, or more frequently if contamination is severe. Each mirror coating will withstand up to about ten cleanings before recoating might become necessary, unless unusual severe treatment has been given to them.
2.4 OPTICAL CLEANING

Mirrors, lenses, and beamsplitters can be cleaned by using alcohol and fine lens tissue. Alcohol should be kept clean in a container which permits ejection of a gentle jet or spray onto the optical surface. The surface should be rinsed in the spray without touching the surface with the tissue, collecting the used liquid in a tissue held below the bottom edge. Do not reuse the liquid! Then wet a clean tissue held loosely in one hand, and let the wet tissue contact the optical surface over as large an area as possible while still holding the edge of the tissue. Carefully pull the tissue across the surface without applying any pressure on the tissue area in contact with that surface. The tissue may be used once on either side, and then must be discarded. This process may be repeated once or twice until the mirror, lens or beamsplitter is clean. Rubbing the surface of a mirror will probably damage the coating, but is not as likely to damage the lenses or beamsplitters, if done gently.

If alcohol does not seem to remove the contaminant material on the surface, acetone may be used with the same procedure, but this must be done more quickly, since the evaporation of acetone is much more rapid, leading to spot formation. If large amounts of dust or debris are found on the mirror, it is best to remove the mirror from the mounting and wash it carefully under a gentle stream of water. The tissue may be used as before to dislodge deposits. After cleaning with water, alcohol or acetone must be used to remove all traces of the water so as to avoid mineral deposition. A similar cleaning can be done with a mild mixture of liquid household detergent (Joy or equivalent) and water, followed by a water rinse and alcohol or acetone cleanup.
2.5 ELECTRONIC DESCRIPTION, GENERAL

The transmissometer system can be divided into three sections, the transmitter, receiver and the control desk console.

The transmitter houses the three lasers, the chopper assembly and the three detector-preamplifier combinations. These three detectors provide the reference signal used in the transmission calculation. Furthermore, the silicon detector used for the He-Ne laser also provides the reference signal required for synchronously demodulating the six optical channels. There is also a temperature controller in the transmitter that is used to maintain the three detectors at a constant temperature slightly above the normally expected ambient.

The receiver has three matching detector-preamplifiers, one to match each one located in the transmitter. A remotely controlled (from the electronics controller) gain change amplifier for each channel has been included in the receiver for optimizing the signal to noise under varying conditions. The receiver also contains the current drivers and transformers needed to properly interface the 2000 meters of cable connecting the receiver to the control desk console which is located back at the transmitter.

The desk console contains the H.P. 9825 desk calculator, the power supply for the CO₂ laser, CLIMET meteorological signal conditioner, and the transmissometer controller. The H.P. desk calculator, power supply for the CO₂ laser and Climet signal conditioner all have detailed manuals supplied by their respective manufacturers and therefore will not be discussed in detail in this manual. The transmissometer controller contains the a.c. to d.c. regulated power supplies and all the signal conditioning
electronics needed to amplify, demodulate and filter the electrical signals from the transmitter and receiver. The controller also acts as a buffer between the receiver and transmitter and the A/D converter located in the multiprogrammer.

2.5.1 Transmitter Electronics

The transmitter utilizes EG&G HAV-1000 silicon photovoltaic detector/amplifier combinations. One of the two detectors is used for the He-Ne and the other is used for YAG laser. These silicon detectors are used in the photovoltaic mode and are packaged with their own optimized preamplifiers. The only additional circuitry required is power supply de-coupling capacitors and an external feedback network. The value of the feedback resistor capacitor combination controls the gain and bandwidth of the preamplifier.

A pyroelectric detector P-1 72G, by Molectron, is used for the CO$_2$ laser channel. This detector is also packaged with its own integral preamplifier which incorporates a FET as its input stage. As configured in this system the detector/preamplifier combination is used in the current mode. By using the detector in this mode the voltage at the detector terminals is held at zero while causing a current proportional to the received optical power to flow through the feedback resistor. This current through the feedback resistor generates the signal voltage at the amplifier output. Again the feedback resistor capacitor combination controls the gain and bandwidth of the preamplifiers.

Each of the three detectors have a heating element attached to their respective mounting brackets. There is one temperature controller which supplies the necessary power to each of the three heating elements. Since the thermal load on each detector
assembly is approximately the same it is possible to monitor the temperature of one detector assembly and use this information to control all three assemblies. The absolute temperature of each assembly is not critical, but the temperature should remain constant so that the operating point of the detectors does not change due to ambient temperature changes. Since the characteristics of the pyroelectric detector show the strongest dependance on temperature the control thermistor for the three detector assemblies is mounted on the pyroelectric detector assembly.

The temperature controller uses a bridge type circuit with the control thermistor in one arm of the bridge. An operational amplifier is used to amplify and integrate the error voltage generated across the bridge. The output of the amplifier is used to control the drive current to the power transistor which is in series with the heating elements. The temperature of the controller may be adjusted by changing the value of R-3 if a higher or lower set point is required.

The He-Ne and YAG lasers which are part of the transmitter only require 115Va.c. since they each have their own internal power supplies. The main power switch located on the front panel of the desk console controls the line voltage to both of these lasers. The CO₂ laser receives its power from a separate high voltage supply. This high voltage power supply is located in the desk console for mounting convenience.

The final item in the transmitter is the chopper assembly. A d.c. motor is used for the chopper. This motor receives its power from a regulated d.c. power supply located in the Electronic Controller. A resistor has been placed in series with the motor and the power supply in order to adjust its speed.
2.5.2 Receiver Electronics

The three detectors and their respective preamplifiers are exactly the same as the detector preamplifier combinations described in Section 1.1. The temperature controller is also the same and therefore the description given in Section 1.1 is also applicable.

In order to optimize the signal to noise under varying atmospheric conditions between the transmitter and the receiver an additional amplifier has been included in the receiver. This amplifier has two possible gain states, 1X and 16X. The gain is controlled through the Electronic Controller either by the switch labelled GAIN if it is in HIGH or LOW or via the computer when the switch is in AUTO. Control for the gain change is brought to the receiver via the CO$_2$ channel transmission line.

The transmission lines which interconnect the receiver and the Electronic Controller are driven through impedance matching transformers by appropriate current drivers.

Regulated power is provided to the receiver electronics by a d.c. to d.c. converter at the receiver. The input power to this converter is brought from the Electronics Controller via the YAG and He-Ne transmission lines. It is important that the length of cable (2000m) supplied with the system always be connected between the Electronics Controller and the Receiver because of the voltage drop across the 2000m of cable. Too little cable would not drop the voltage sufficiently and could damage the d.c. to d.c. converter. Too much cable would cause a larger voltage drop across the cables and if this additional voltage drop became too large the regulator could fall out of regulation.
2.5.3 Electronic Controller

The Electronic Controller contains six almost identical channels, two for each laser, one for the receiver signal and the other for the transmitter signal. Each channel contains an input buffer amplifier, a demodulator and two low pass filters.

Each output of the two low pass filters of each channel are available on the front panel bnc connectors labeled CH1, CH2, and CH3, depending upon which time constant has been selected by the user. A 1 second time constant is available along with a 10 millisecond time constant. The 1 second time constant is the only one available to the computer for sampling, but with an oscilliscope or DVM either output can be monitored at the front panel.

In addition to 6 channels the controller also contains the necessary electronics to generate the reference signal for the demodulators. This signal is generated from the transmitted He-Ne laser signal. By passing the He-Ne signal through a high gain amplifier a reference signal (approximately a square wave) is generated. The square wave generated from the He-Ne signal is used to alternately change the gain of the amplifier from +1 to -1 therefore causing full wave rectification or demodulation of the signal.

2.5.4 Electronic Schematics

A complete set of reduced schematics are included here for convenience.

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<th>Ecom System Block Diagram</th>
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<td>System Power</td>
<td>33 200 019</td>
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</tbody>
</table>
Transmitter:

Head Electronics 34 750 084
Electronics Console 35 750 086
LPF (Low Pass Filter) 33 720 014
Demodulator 33 720 013
Temp Controller 33 300 012
Power Supply 33 200 043
Gain Range 32 120 018

Receiver:

Receiver Electronics 34 750 085
Receiver Gain Shift Logic/
Level Snifter 33 600 066
Receiver Temp Controller 32 300 011
2 POLE BESSEL LPF

<table>
<thead>
<tr>
<th>T</th>
<th>R1, R2</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>15EC</td>
<td>49.9K</td>
<td>4.69pF</td>
<td>2292pF</td>
</tr>
<tr>
<td>10MS</td>
<td>49.9K</td>
<td>0.47pF, 0.225pF</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
1. * INDICATES METAL FILM RESISTORS 1% ±1%
Notes:
1. All resistors are 1/2 watt unless otherwise indicated.
**NOTES:**

* INDICATES METAL FILM RESISTOR ± 1% 1/8 W
3. SOFTWARE DESCRIPTION

All software is written in HPL, the BASIC-like language of the HP 9825. Extensive use is made of the language extensions provided by the String/Advanced Programming ROM (read only memory) and the General I/O Extended I/O ROM. This manual assumes that the reader is familiar with the HP 9825 calculator and HPL. (See Hewlett Packard documentation supplied with the System). Program listings and flow charts may be found in Appendix A of this manual.

The transmissometer operating software for the HP 9825 calculator is a collection of subroutines divided into two overlays and activated through the use of the HP 9825 special function keys. Since the calculator memory is volitile (contents are lost when power is removed), the software is stored on a tape labeled "Software": File 0 of track 0 contains the initial overlay. The first overlay contains initialization, calibration and data review routines, the second overlay contains the data acquisition and data recording software. For convenience, some functions are in both overlays. Table 3-I contains a list of the transmissometer functions in each overlay. A discussion of each of these functions appears later in this section. If a function that is not in the resident overlay is requested, the operator is prompted to insert the "Software" tape if it is not already loaded, and press "Continue". The other overlay is then automatically loaded and the requested function executed.
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<td>0 INIT</td>
<td>System Initialization</td>
<td>0, Continued on 2</td>
</tr>
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<td>1 RUN</td>
<td>Collect and Record Data</td>
<td>2</td>
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<tr>
<td>2 STOD</td>
<td>Set Time of Day</td>
<td>0</td>
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<td>3 GTOD</td>
<td>Get Time of Day</td>
<td>0 and 2</td>
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<td>4 MARK</td>
<td>Mark (Format) Data Tape</td>
<td>0</td>
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<td>5 TAPE</td>
<td>Load and Position Data Tape</td>
<td>2</td>
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<tr>
<td>6 CAL</td>
<td>Input Calibration Constants</td>
<td>0</td>
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<td>7 INTERVAL</td>
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<td>11 DLIST</td>
<td>List Data Tape Headers</td>
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<td>SHIFT 0 REPLOT</td>
<td>Replot Data from Tape</td>
<td>0</td>
</tr>
<tr>
<td>SHIFT 6 PRT SCAN</td>
<td>Measure and Print Voltages on Each Channel</td>
<td>0 and 2</td>
</tr>
</tbody>
</table>
The software design consists of a series of relatively small subroutines. This modular approach should make the software relatively easy to modify should this become necessary.

The software is also designed so that an operator not familiar with the HP 9825 could operate the transmissometer with a minimum of training. Toward this end, all commands have been implemented through the special function keys, and the software tape has been configured so that the software is automatically loaded and the "INIT" function automatically executed whenever the calculator is turned on. (Assuming that the software tape has been loaded first See Chapter 5 on how to use the system).

The following are descriptions of the commands (or functions) summarized in Table 3-I.

**INIT - System Initialization**

This is the system initialization routine. It loads the special function keys from tape file 1, dimensions all arrays and defines all system constants. It calls subroutine MP TEST to test the multiprogrammer and then automatically sequences through functions STOD, CAL, INTERVAL, HEADER and TAPE. Upon completion of INIT, the system is ready for a RUN function to start data acquisition.

INIT may be started manually by using the calculator's RUN key (as opposed to the RUN special function), or, if the special functions have been initialized (by a previous INIT), by using the INIT special function key. Under normal conditions, it should not be necessary to re-execute INIT after the initial power on.
RUN - Start Data Acquisition and Recording

This is the "RUN" special function not to be confused with the calculator's RUN key. This program causes data from all optical and meteorological channels to be digitized, averaged if INTERVAL is greater than 1, and converted to physical quantities through the application of the calibration constants. The calibrated, averaged data is written on tape for permanent storage and printed/plotted on the printer if the print flag (see PRINT) is set.

Instead of recording transmittance values on tape, the transmitted and received signals, along with the calibration constants for the 3 laser channel pairs, are recorded. If the transmitted signal for any channel drops below 2.56 volts rms, it is assumed that there has been a laser malfunction. A message to that effect ("Channel I Below Threshold" - I 1 for HeNe, 2 for YAG, 3 for CO₂) is displayed in the LED display and the transmittance value printed for that channel is -1 (actual measured transmitted and received voltages are still recorded on tape).

If the transmittance on a channel exceeds 1.0, a warning message is displayed on the LED display ("Channel I needs calibration")

Output data to both the tape and the printer is buffered so that the periodic outputs do not interfere with data acquisition at regular intervals (every 2 seconds). There is enough buffer space in memory to allow time for loading a new tape when the current one is full or to replace paper in the printer if necessary, without stopping a RUN or losing data.
**STOD - Set Time of Day**

This routine prompts the operator to enter the time and date. This information is used to set the system clock (counters in the Multiprogrammer) and calendar (D array).

**GTOD - Get Time of Day**

This routine displays the time and date in the calculator's LED display. If a RUN command is active, the display will automatically be updated every 2 seconds. In addition to the time and date, a "timeout" number is displayed. This is the number of times a timing loop was executed after data collection while waiting for the next clock "tick". If this count ever gets to 200 the program is aborted on the assumption that the clock has malfunctioned. This number is meaningless if RUN is not active.

**MARK - Mark or Format Data Tape**

Before data can be recorded on tape, the tape must be marked or formatted into files. This routine will mark a tape into 290 files of 328 bytes on both tracks (580 files per tape). RUN will not record data on any tape not so marked and MARK will not mark a tape unless it is blank. RUN will also not record data in files already containing data. This is intended to prevent the inadvertent destruction of previously recorded data or software files. However, no system is fool proof: Do not attempt to MARK anything but a blank tape. Do not attempt to RUN with anything but a previously MARKed data tape.
TAPE - Position a Premarked Tape in Preparation to Run

The TAPE function verifies that the tape in the machine is a MARKed data tape and then searches for the end of the data - if any - which has already been recorded, assigns the next sequential volume number and leaves the tape in position for data recording.

If the MARKed data tape has had no data previously recorded on it, then TAPE will display "TAPE NO. + ?" in the calculator's LED display and wait for the operator to type in a tape number assignment. This number is recorded on the tape for identification purposes. The tape is positioned to Track 0, Volume 1 and a message to that effect is displayed.

CAL - Calibration Constants

The purpose of CAL is to establish values for the calibration constant array C. The first time CAL is executed this array is set up with default values written into the program. (This is bypassed on subsequent executions). The operator is then asked "Update CAL values (0-no, 1=yes)". If the answer is 0, all current values are retained. If it is 1, the current values are displayed one at a time. For each one, the operator may either type in a new value, or retain the current value by pressing CONTINUE without typing a new value.

INTERVAL - Input Number of Scans to Average

This function allows the operator to set the number of scans which will be averaged for a measurement. This average is actually an exponentially decaying running average analogous to a simple electrical low pass filter with a time constant of INTERVAL scans.
The average of each channel is computed individually according to the following

\[ \text{Average}_i = \text{Measurement}_i \times f + \text{Average}_{i-1} \times (1-f) \]

where \( f = \exp(-\text{INTERVAL}) \)

\[ \text{Measurement}_i = \text{the } i^{th} \text{ measurement (scan)} \]

\[ \text{Average}_i = \text{The average of a given channel after the } i^{th} \text{ scan} \]

**PRINT** - Compliment Print Flag

When **RUN** is executed, data is printed/plotted on the 9871 Printer as well as recorded on tape. The **PRINT** function compliments a print flag used by **RUN** to inhibit printing. (When **RUN** is started this flag is set on). During a **RUN**, if printing has been suppressed by a **PRINT** function, it can be re-enabled by a second **PRINT**.

**HEADER** - Input Header Text

One line-up to 80 characters - of user supplied text is included as part of the header information in both the printout and on tape. **HEADER** displays the current text and waits for operator input. The operator may type in a new text or retain the old one pressing "CONTINUE".

**TERM** - Terminate **RUN** or **REPLOT**

The primary function of **TERM** is to terminate a **RUN**. **TERM** sets a terminate flag monitored by **RUN**. When **RUN** sees this flag set, it stops collecting new data, finishes outputting the data it already has and then stops. **TERM** may also be used to abort **REPLOT**.
DLIST - List Data Tape Headers

The DLIST function will read and print the header information for each volume of a recorded data tape. This provides a summary printout - table of contents - for a data tape.

REPLOT - Replot a Volume of Data from Tape

REPLOT will produce a print/plot similar to the one produced by RUN. The only difference is that since the data is being read back from tape there are no real time constraints and all of the data from the selected volume is printed. (Printing a line of data takes about 3 seconds. Thus, not all data can be printed during a RUN if INTERVAL is 1).

REPLOT will terminate normally at the end of the selected volume, or it may be aborted with TERM.

Prt SCAN - Print Scan

The Prt SCAN function makes one SCAN i.e. digitized the voltage reading for each channel and prints the results on the calculator's thermal printer. For convenience, the ratio for each laser receiver pair is also printed. This ratio is the calibration factor required by CAL if the system is in proper alignment and the actual transmission between transmitter and receiver is unity.
4. ALIGNMENT AND CALIBRATION

The alignment of the instrumentation begins with the separate alignment of the receiver and transmitter. Once these components are mounted in their operational configuration, the alignment of the two parts to each other completes the alignment process.

Calibration of the system can be considered in terms of an initial calibration and a continuing self-calibration. In addition, transfer calibration standards can be used which supplement the basic calibration and allow rapid verification of system stability.

4.1 RECEIVER ALIGNMENT

Alignment of the receiver is relatively straightforward, and can be done without the transmitter. The receiver is placed so that a large brightly illuminated white screen fills the aperture with visible radiation. Using a small opaque white cardboard screen to observe the diffuse reflection, the focus at the prism diagonal mirror M2 is examined for uniformity of illumination. The diagonal M2 is adjusted so that the radiation reaching the transfer mirror M3 is uniform and centered, M3 is adjusted so that the radiation is centered on mirrors M4, M5, and M6 is adjusted so that the radiation is centered on the beamsplitter BS1, and BS1 is adjusted so that the radiation is centered on the filter screen F3. The large screen is removed, and the receiver is pointed at a remote scene with brightly illuminated patterns present. The image plane at lens K3 is examined for focus error in the primary telescope, and it is adjusted for the sharpest focus possible. The lens L4 is adjusted so that the reticle is superimposed on the scene.
(If the scene illumination is bright enough, it may be possible to see the focus at the lens L2 image plane.)

The two short wavelength detectors D2 and D3 can be aligned with a flashlight or other portable visible radiation source. By moving this source in and out of the receiver field at the telescope aperture, the alignment of beamsplitters BS2 and BS3 and detector modules D2 and D3 can be performed, since the detector corresponds to the primary mirror pupil. When the signal from the preamplifier shows an equal response when the source is moved in and out at any point around the periphery of the primary aperture, the detector is well aligned.

The same technique is used for the infrared detector, but a hot thermal source must be used instead of a visible source. A small flame or an exposed hot filament can be used. The detector module D1 is adjusted to provide uniform response as before.

4.2 TRANSMITTER ALIGNMENT

Transmitter alignment begins with the He-Ne laser S3. Since this radiation can be viewed directly, it is easy to view the beam using a small white screen or card, which can be inserted into the optical train. Preliminary adjustment of beamsplitters BS3, and BS1 and mirrors M1, M2, M3, M4, and M5 can be made using this screen. It should be noted that the alignment of laser S1 and S2 are independent of the above adjustments. It is sometimes useful to remove the beam expander EX1 to utilize the smaller beam size for alignment.
The alignment of the infrared lasers is accomplished by use of thermal sensitive paper, such as is used in the computer printer. This paper will show a spot "smearing" as moved through the beam, and use of this paper with the white screen allows the accurate adjustment of the infrared beams to the He-Ne beam. The \( \text{CO}_2 \) laser \( S_1 \) is adjusted by tilting the mirrors M8 and M9, and positional adjustments are made by shifting the laser slightly on its mount. Once the two beams are centered, the alignment of the \( \text{CO}_2 \) beam along the following optical elements must be checked. Some re-adjustment between the \( S_1 \) and \( S_3 \) beams may be necessary to achieve good alignment all through the system. Finally, the Nd-YAG laser \( S_2 \) is turned on, with the \( \text{CO}_2 \) laser off, and only BS2 and the \( S_2 \) laser are adjusted to attain alignment with the He-Ne beam, again using the thermally sensitive paper. Return both beam expanders EX1 and EX2 before final fine alignment is performed.

The transmitter monitor optical system is now aligned by the same process. Prism diagonal P1 and mirrors M6 and M7, and beamsplitter BS1 and BS2 are aligned in turn, following the somewhat weaker beam through the system. The output of the detector preamplifier is observed, and the detector module D3 is aligned to peak the signal. The He-Ne beam expander EX1 is replaced and the alignment is corrected by adjusting BS3, if necessary.

The other lasers \( S_1 \) and \( S_2 \) are aligned to the \( S_3 \) laser by focusing the telescope on the previously aligned receiver, which should be at a range of about 100 meters. (This alignment can be made at the 2.0 km range, provided that very stable atmospheric conditions are present.) The receiver is masked for each laser alignment according to Table 4-I. (Only one mask is provided with the instrument, with 0.1 and 1.0 cm apertures in it.)
<table>
<thead>
<tr>
<th></th>
<th>Aperture at Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser</td>
<td>100 m  1.0 km</td>
</tr>
<tr>
<td>S2, Nd-YAG</td>
<td>0.1 cm  1.0 cm</td>
</tr>
</tbody>
</table>

**TABLE 4-1**
ALIGNMENT MASKS
The laser L2 is adjusted to the He-Ne beam by adjusting beamsplitter BS2 until a signal maximum is obtained from the D2 detector in the receiver. Laser S1 is adjusted to the He-Ne beam by rotating the mirrors M8 and M9, using the fine adjustments provided, until a signal maximum is obtained from the D1 detector in the receiver.

The instrumental focus can be set tentatively by placing an optical flat in front of the telescope and adjusting this flat until the laser beam is seen exiting from BS3 at the same position as the entering beam. DO NOT VIEW THE LASER BEAM DIRECTLY!!! Using the white screen, adjust the focus of the primary until the exiting beam at BS3 is a minimum diameter. The telescope is now focused at infinity, and may be approximately set for the 2.0 km range by moving it back 1.1 mm. Slight adjustment of the alignment may be necessary.

4.3 SYSTEM ALIGNMENT

Once the transmitter and receiver have been aligned, calibrated, and positioned in the operational configuration, the final alignment of the system can be performed. The transmitter should, of course, be roughly aligned as well as possible in its installation using the boresight view through beamsplitter BS3. A large white screen can be used to help in the installation of both transmitter and receiver, using the He-Ne laser beam alone. Although the field irradiance of this beam is not injurious to the eye, the practice of not looking directly at the beam should be developed.

With the system roughly aligned, and during very stable atmospheric conditions, the transmitter primary M5 can be carefully adjusted to provide a minimum image size at the receiver aperture, and at the same time, to center that image on the aperture.
A small retroreflector is mounted on the center of the receiver aperture to facilitate the alignment. This can be seen through the transmitter boresight view, although the field-of-view is very restricted. A white screen is particularly useful for night work, and the dancing of the beam on the receiver aperture should be studied to optimize the alignment.

Alignment of the receiver can be accomplished very easily since the eyepiece reticle allows very precise adjustment. In the intended installation, it is advisable to mount the receiver using a high quality machinist's table, preferably with two-axis rotational adjustments.
5. ABSOLUTE TRANSMISSION CALIBRATION

The accurate calibration of transmission spectra is not a trivial problem, due to the presence of both instrumental error and atmospheric variation. The problem reduces to the difficulty of obtaining accurate measurements over the desired path with and without the atmosphere present. Since it is not reasonable to remove the atmosphere, it is necessary to correct the measurement for the loss or to obtain the transmission from several measurements at different atmospheric paths.

5.1 CORRECTION FOR ATMOSPHERIC LOSS

In many types of transmission measurement, the transmitted radiation beam spreads significantly, so that it is necessary to account for the geometrical configuration in determining the true transmission. Since the throughputs of the lasers used in this system are so low, it is possible to intercept the entire transmitted beam with the receiver so that the geometrical factors do not enter the correction. In this case, it is necessary to know the system's optical efficiency accurately and to monitor the transmitted beam in a precisely controlled way. The atmospheric transmission is then simply the received radiation divided by the transmitted radiation.
5.2 BEAM MONITORING

In actual practice, it is not possible to monitor the entire transmitted beam at the exit aperture, and one must either monitor a small part of the transmitted radiation at that point or monitor the entire beam at some internal location. Block provides monitoring at the exit aperture, because this provides the most accurate indication of the transmitter performance. As a result, a scale factor is present in the calibration to relate the monitor signal to the transmitted signal, in addition to the optical efficiency.

The monitored area of the transmitted beam is a small central region of the TEM\textsubscript{00} aperture distribution, and since the optical elements involved are fixed, the initial calibration of the monitor scale factor can be expected to hold for long periods of time. This calibration is accomplished by bringing the receiver very close to the transmitter, and equating the outputs of each monitor-receiver pair of detectors. If the laser radiates $W$ watts, the transmitter and receiver efficiencies are $\eta_t$ and $\eta_r$, and the receiver detector responsivity is $R_r$ volts/watt, the receiver output signal at zero range will be

$$E_{rc} = W \lambda \eta_t \eta_r R_r$$ \hspace{1cm} (4.2-1)

The monitor detector intercepts $K$ of the transmitted radiation, with optical efficiency of $\eta_m$ and responsivity of $R_m$, giving a monitor output signal of

$$E_m = K W \lambda \eta_t \eta_m R_m$$ \hspace{1cm} (4.2-2)
We can calculate the calibration factor $G$ which adjusts the monitor output to be equivalent to the transmitted signal by

$$G = \frac{E_{rc}}{E_m}$$

$$= \frac{\eta_r R_r}{K \eta_m R_m}$$

(4.2-3)

At any future time, the output $E_m$ can be adjusted to represent the transmitted signal output by multiplication by $G$. The transmission is consequently

$$T_\lambda = \frac{E_r}{G E_m}$$

(4.2-4)

and as long as the variations of $\eta_r R_r$ due to gradual deterioration are the same as those of $\eta_m R_m$, the factor $G$ will remain constant. It is clearly desirable that the same elements and coatings be used in the monitor optics as in the receiver optics.

5.3 MULTIPLE RANGE TECHNIQUE

A technique which is fairly well established for the absolute calibration of transmission spectra is the measurement at two distinct ranges with the same instrumentation. If these measurements can be performed in rapid sequence over the same transmission path, the correction can be accomplished on the assumption that a constant Beer's law extinction coefficient exists over the path. We perform signal measurements at two distances, intercepting the entire laser beam at each receiver position,

$$E_1 = W_\lambda \eta_1 \eta_1 R_1 \exp^{-\sigma x L}$$

(4.2-5)
\[ E_2 = \frac{W_n \eta_n \eta_2 R_2}{\lambda} \exp^{-\sigma x z_1} \quad (4.2-6) \]

and ratio them, giving

\[ \frac{E_1}{E_2} = \left[ \frac{\eta_1 R_1}{\eta_2 R_2} \right] \exp^{-\sigma x (z_1 - z_2)} \quad (4.2-7) \]

\[ = G' \exp^{-\sigma x (z_1 - z_2)} \]

The factor \( G' \) will be equal to 1.00 if every effort is made to make identical receivers, and it can be measured accurately by the comparison of both receivers at zero range. The coefficient \( \alpha_x \) can be computed knowing the ranges and signals. The measurements can, of course, be made with a single receiver, moving it from one position to the other. \( G' \) is identical to 1.00 in this case.

Unfortunately, the extinction coefficient can vary markedly over extended paths, but the above approach can be used for measurements over a rather limited range; and for controlled or very stable conditions. A similar analysis could be done for three distances, and a linear variation in coefficient with range could be evaluated. In the general case, we may treat the problem of \( N \) separate measurements along the same path, performing a statistical reduction of the error in the extinction coefficient.

5.4 COMPUTED CORRECTION

A technique which can be used in many cases for the approximate correction to zero air mass is the computation of an extinction
coefficient for relatively clear conditions, as measured by subsidiary instruments. This coefficient is simply applied to the measured transmission of the transmissometer at that wavelength, and the transmission correction is determined. Although this has an inherently large error for clear weather measurements, this error becomes much smaller as weather deteriorates, and corrections for larger extinction coefficients become increasingly good. The correction cannot be verified without returning to clear conditions, of course.

5.5 TRANSFER CALIBRATION STANDARDS

Block can supply a transfer calibration standard which can allow the accurate verification and correction of calibration by separate measurements at transmitter and receiver. Two separate standards are available, one effective in the visible and near infrared, and a second for the mid-infrared.

5.6 CALIBRATION

The initial calibration of this instrument is very important, and should be carried out after the separate component alignments have been performed. The transmitter and receiver are set up at essentially zero range, and aligned so that the signals from the receiver are maximum. The monitor and receiver detector outputs are recorded, and the ratio is obtained for each wavelength. As discussed in Section 5.3, the calibration factor G at each wavelength may be expected to remain stable for very long periods of time. The use of three independent measurements is advantageous since the degradation of any one channel can be easily noticed in repeated benign environmental conditions.
Since the instrument monitors the transmitted radiation in each channel, the ratioing of received-to-transmitted radiation is a form of self-calibration, since absolute radiation losses or fluctuations in the transmitter are canceled out in the ratio. Also, the use of identical optics in the monitor and receiver, as much as possible, results in the cancellation of common long term degradation and aging factors.

5.7 MOUNTING

It is essential that the transmitter and receiver be properly supported when mounted for measurements. The transmitter is a very precisely aligned instrument, and requires support over most of the bottom structure. Bending of the frame over the course of a measurement sequence will produce significant variations in the output through misalignments in the system. Therefore, the rigidity of the mounting is of great importance, but it should be noted that only differential motions after alignment will produce error. The mechanical precision of the support must be good to approximately 0.1 cm before alignment, but this must be maintained to better than 0.01 cm after alignment, despite environmental and station structural variation.

The receiver is somewhat less sensitive to mounting rigidity. The receiver is mounted at two points 226 cm apart, using mounting bolts which are provided. Since the receiver fields of view are 2 milliradians wide, the constraints on the mechanical precision of the support are 0.2 cm before alignment, and maintenance to 0.1 cm after alignment.

Both transmitter and receiver are made with aluminum structural members, and the mounting structure holding them should be made of the same material to avoid thermal strains. This structure can be installed on a steel machinists table if appropriate strain relief is designed into the mounting.
6. **HOW TO USE THE SYSTEM**

In this section a hypothetical use of the system to make a measurement will be discussed. It is assumed that the system has been previously installed, aligned and calibrated.

The following sequence should be used to power up the system from a complete shutdown.

1. Check to be sure no personnel are looking into or working around the transmitter aperture.

2. Turn on the main system power switch

3. Turn on the closed loop water cooler and wait 2 minutes.

4. Turn on the CO$_2$ POWER switch, be sure the interlock key is in the OFF position, the amber indicator lamp should illuminate.

5. Turn the interlock key on the CO power supply to the ON position, the interlock indicator lamp should illuminate.

6. Turn the power switch on the Transmissometer Controller to the ON position.

7. Turn the CLIMET signal conditioner power switch to ON

8. Turn the HP multiprogrammer power switch to ON

9. At this stage the complete system should be ON and operating.

10. Wait at least 30 minutes to allow the system to stabilize before starting a measurement sequence.

Before power is applied to the calculator, the "Software" tape should be inserted. (This tape should be a copy of the master "Software" tape supplied with the system. It should always be write locked with the slide switch at the base of the tape cartridge.)
When power is applied to the calculator, the software tape will automatically be loaded into the calculator and started. See Section 3 Software Description.

During the software initialization which follows, the functionality of the multiprogrammer is checked automatically. Likewise, most of the functions of the printer are automatically checked then it is turned on. Use of the self test button on the back of the printer-described in the printer manual completes the functional test of the printer.

If there are no previously MARKed blank data tapes available, the INIT sequence may be stopped after the HEADER text input when the LED display shows "Load Software Tape and CONTINUE". A blank tape may be MARKed at this time. After MARK is complete, press special function TAPE. You will be requested to "Load Software Tape and CONTINUE", the second overlay will be automatically loaded and you will be requested to "Load data tape and CONTINUE". After TAPE is complete (this is the last routine which would have been executed if the INIT sequence had run to completion) the system is ready to acquire data.

To acquire atmospheric transmission and meteorological data print/plot it on the printer and record the results on tape, simply press the RUN special function key. The system will now RUN without further operator intervention for the time shown in the display. This is the amount of record time left on the tape. The RUN will continue automatically until TERMINated with the TERM special function.
Having completed a measurement, the data tape is removed for safe storage.

For an orderly shutdown the following sequence is recommended.

1. Turn off the H.P. calculator and multiprogrammer
2. Turn off the CLIMET signal conditioner
3. Turn off the Transmissometer Controller
4. Turn off the high voltage power supply for the CO₂ laser.
5. Leave the water cooler on for 5 minutes, then turn it off.
6. Turn the interlock switch to the locked position.

6.1 MAKING A COPY OF THE SOFTWARE TAPE

It is good operating procedure and highly recommended that the software tape supplied with the system be used only for making copies of itself and be otherwise stored in a safe place. Only duplicate software tapes should be used for normal operation.

To produce a duplicate software tape, the following procedure is followed:

1. Insert a write enabled blank tape into the 9825
2. Position tape to the beginning of track Ø (rew; trk Ø EXECUTE)
3. Mark the three required files:
   (mrkl, 10000; mrkl, 500; mrkl, 10000 (EXECUTE))
4. Insert the master Software tape (write protected) into the 9825

5. Load files 0 and 1

   (ldf0 (EXECUTE))

   (idk1 (EXECUTE))

6. Re-insert tape marked in step 3

7. Record files 0 and 1 (rcf0; rckl (EXECUTE))

8. Insert master software tape and load file 2

   (idf2 (EXECUTE))

9. Re-insert tape from step 6 and record file 2

   (rcf2 (EXECUTE))

10. Remove the new duplicate software tape from the 9825 and write lock it.
CONTROLS, GENERAL

All necessary controls for normal operation are located at the control desk console. Each control function will be explained in the following sections.

7.1 LASER TRANSMISSOMETER SYSTEM POWER

All the necessary power for the system is routed through the switch labeled LASER TRANSMISSOMETER SYSTEM POWER. This switch besides controlling the system power also serves as the main circuit breaker for the entire system. The switch consists of a 25 ampere short time delay circuit breaker and is located on the front panel on the upper left side of the desk console.

7.2 CO₂ LASER POWER SUPPLY, MODEL 941

7.2.1 a.c. Power Switch

POWER toggle switch controls the a.c. power to the CO₂ laser power supply.

7.2.2 Amber Power Lamp

AMBER POWER LAMP should illuminate when the POWER switch has been turned to ON.
7.2.3 **Interlock Switch**

INTERLOCK SWITCH is key operated and provides an additional margin of safety against accidental turn on of the CO₂ laser. This key operated switch must be ON for the high voltage to be turned on in the power supply.

7.2.4 **Interlock Lamp**

INTERLOCK LAMP should illuminate (green) when all the system interlocks have been closed.

7.2.5 **High Voltage Lamp**

HIGH VOLTAGE LAMP should illuminate approximately 5 seconds after all interlocks have been closed.

7.2.6 **Current Adjust**

CURRENT ADJUST control can be used to optimize output power. Under normal usage it should not require adjustment. If the CURRENT ADJUST does require adjustment see the CO₂ LASER instruction manual for more details.

7.3 **CLOSED LOOP COOLER - MODEL 400**

7.3.1 **a.c. Power Switch**

The a.c. power switch for the closed loop cooler is located on the bottom left side of the desk console. This cooler supplies water to the CO₂ and YAG laser for cooling. For the lasers to operate the flow of water through the cooling system must be maintained. Each laser has a pressure switch as part of the cooling
system which provides an interlock which determines if the proper flow of water is present. For more details see the manual included for the water cooler and the manual for each laser.

7.4 LASER TRANSMISSOMETER CONTROLLER

7.4.1 Power Switch

This two position switch, OFF and ON, controls the application of d.c. power to the electronics in the Controller, all d.c. power to the Transmitter and the Receiver.

7.4.2 Gain Switch

The HIGH gain position provides an additional gain of 16 after the preamplifiers. In the LOW gain position the signal is coupled directly to the drivers from the preamplifiers with a gain of 1. With the switch in the AUTO position the computer will select which gain factor to use based on the amplitude of the signal. See the software section of this manual for the parameter which sets the level of the signal upon which a gain change is executed. This 3 position switch allows the operator to remotely control the gain of the three signal channels of the receiver.

7.4.3 Time Constant

This is a two position switch which selects either a 10 millisecond or 1 second time constant for the signals on the BNC connectors located on the front panel. The computer only samples the signal with the 1 second time constant therefore this switch does not affect the data as printed and recorded by the computer.
7.4.4 Signal b.n.c

There are six bnc connectors on the front panel. The connectors are labeled as follows TRANSMITTER: CH1, CH2 and CH3 which correspond to the transmitted He-Ne, YAG and CO$_2$ signals respectively and

RECEIVER: CH1, CH2, and CH3 which correspond to the received He-Ne, YAG and CO$_2$ signals respectively.
APPENDIX A
SOFTWARE KEY SHEETS
Program Name: FINIT

Description:
   a) Sets up all parameters and dimensions all arrays.
   b) Checks status and operation of the multiprogrammer.
   c) Check Status of the printer.
   d) Sequentially calls the various subroutines to get the necessary user supplied values.

Input: Software tape File 1 -- user supplied values.

Output: N, r8 +=14 inclusive, S$
All arrays and string variables dimensioned. Print buffer, 'BUF', allocated.

Dummy Variables: None

Subroutines Required: MP TEST FCAL
   onerc FINTERVAL
   nomp (on error) PHEADER
   FSTOD FTAPE

Calling Sequence: gsb 'FINIT'

Location: Part in File 0 and part in File 2.
Program Name: FTERMINATE

Purpose: This routine sets Flag 11, the terminate flag. If called during a data run ('FRUN'), the program exits gracefully, resetting the various flags, parameters, and system commands. In File 0, the terminate flag haults operation of FDLIST and FREPLOT.

Input: None

Output: Flag 11

Dummy Variables: None

Subroutines Required: None

Calling Sequence: Special function key fl0.

Location: File 0, File 2.
Program Name: FGTOD, GTOD

(Entry point GTOD is the display portion only.)

Purpose: If FLG 109 = 1; FGTOD complements FLG 9, thereby enabling/disabling the time display during SCAN if FLAG 109 = 0; FGTOD reads the counter cards, derives the time, and displays it.

Input: Multiprogrammer Counter Cards -- flg 10

Output: flg 9
DISPLAY
T[1], T[2], T[3], T[5]

Dummy Variables: A

Subroutines Required: READCOUNT
DRVTIME

Calling Sequence: gsb 'FGTOD' | gsb 'GTOD'
Special function key f3

Location:

A-3

Block Engineering, Inc.
Program Name: READCOUNT

Purpose: Reads the multiprogrammer counter cards.

Input: Multiprogrammer Counter Cards.

Output: A

Dummy Variables: B

Subroutines Required: None

Calling Sequence: gsb 'READCOUNT'

Location: File 0, File 2

Block Engineering, Inc.
Program Name: DRVTIME


Input: T[5]


Dummy Variables: A

Subroutines Required: None

Calling Sequence: gsb 'DRVTIME'

Location: File 9, 2.

A-5
Program Name: FSTOD

Purpose: Operator input of time and date. The counter cards of the multiprogrammer are set to the time in seconds.

Input: Time: T[1], hours; T[2], minutes; T[3], seconds.
        Date: D[1], Month; D[2], Day; D[3], Year

Output: To counter cards; D[1], D[2], D[3]

Dummy Variables: T[1], T[2], T[3], A

Subroutines Required: READCOUNT
                       DRVTIME
                       SET

Calling Sequence: gsb 'FSTOD'

Location: File Ø
Program Name: SET

Purpose: Sets the counter cards of the multiprogrammer.

Input: Function subroutine value:
cll 'set' ()

Output: Counter cards

Dummy Variables: p1, p2

Subroutines Required: None

Calling Sequence: cll 'set' ()

Location: File ø
Program Name: FPRINT

Purpose: During a data RUN FPRINT ENABLES/DISABLES the printer.

Input: Special function key f8.

Output: Flag 5

Dummy Variables: None

Subroutines Required: None

Calling Sequence: Special function key f8.

Location: File 0, File 2.
Program Name: PRINT

Purpose: a) Checks if the next output to Printer is a header text or a plot line.
If a header, the program is switched to Printheader.
If a data plot line, the transmission values are ordered by increasing value, a scaling is determined, and the program goes to Printline.

Input: P[ ], Q[ ], PRINTBUFFER STATUS, r0, r1, r3, r8, r9.

Output: r1, E, F, J, G[1, Q[ ], PRINTBUF 'PBF'

Dummy Variables: A, B, I, K

Subroutines Required: (gto) PRINTHEADER
(gto) PRINTLINE
(gsb) PRTSCALE

Calling Sequence: gsb 'PRINT'

Location: File 0, File 2

A-9
Program Name: PRINTLINE

Purpose: Prints a plot data line to the printer.

Input: I[], P[], E, F, J Formats #2,3

Output: r1, r3, PRINTBUFFER 'PBF', PRINTER

Dummy Variables: A, B, I

Subroutines Required: None

Calling Sequence: gto PRINTLINE called from Print.

Location: File 0, File 2

A-10
Program Name: PRINTHEADER

Purpose: Prints a header text to the Printbuffer and Printer.

Input: Flag 5, D[ ], H$ S$[ ], rl4, P, T, U, V,
       Formats 4, 5, 6, 7, 8

Output: PRINTBUFFER 'PBF', PRINTER

Dummy Variables: None

Subroutines Required: None

Calling Sequence: gto 'PRINTHEADER'

Location: File 9, File 2.

A-11
Program Name: FORMAT

Purpose: Sets up the formats for printout (HEADER and PLOTLINE).

Input: None

Output: Formats 2 through 9.
Note: FORMAT 0 is left a free field; FORMAT 1 is set before use.

Dummy Variables: None

Subroutines Required: None

Calling Sequence: gsb 'FORMAT'

Location: File 0, File 2.

A-12
Program Name: WRITE

Purpose: Writes header file or data file to tape.

Input: Status of tape, r4, r5, r7, r12, r13, N, P, R, T, U, V, D[ ], S$, W$, C[,], H$

Output: Tape, r9, r5, r7, R, T, U, V

Dummy Variables: I, J, O$

Subroutines Required: None

Calling Sequence: gsb 'WRITE'

Location: File 2
Program Name: FMARK

Purpose: Mark a blank tape with data file format.

Input: r10, r11

Output: Flag 8, TAPE

Dummy Variables: I

Subroutines Required: None

Calling Sequence: gsb 'FMARK'

Special function key f4

Location: File 0
Program Name: FTAPE

Purpose: Position tape cartridge to valid starting file.

Input: KEYBOARD, TAPE, rll, Flag 10

Output: Tape, Flag 8, R, T, U, V,

Dummy Variables: I, O$

Subroutines Required: None

Calling Sequence: gsb "FTAPE"

Location: File 2
Program Name: FDLIST

Purpose: Lists previously written header tape files to the printer.

Input: Tape, Operator input of TRACK

Output: Printer

Dummy Variables: I, R, flg 4, flg 5, flg 11

Subroutines Required: FORMAT
GETHEADER
DECODE
PRINTHEADER

Calling Sequence: gsb 'FDLIST'

Location: File Ø
Program Name: GETHEADER

Purpose: Checks successive tape files for a header file.

Input: TAPE, R, r10

Output: I, R

Dummy Variables: None

Subroutines Required: CHECKFILE

Calling Sequence: gsb 'GETHEADER'

Location: File 0

A-17
Program Name: CHECKFILE

Purpose: Checks a tape file to verify that it is the correct type and size of file.

Input: TAPE

Output: I, O$

Dummy Variables: J, K

Subroutines Required: None

Calling Sequence: gsb 'CHECKFILE'

Location: File Ø
Program Name: DECODE

Purpose: Derive from a header tape file loaded into O$, the original inputs.

Input: None

Output: N, P, T, V, C[,], D[,], S$, H$

Dummy Variables: A, I, J

Subroutines Required: None

Calling Sequence: gsb 'DECODE'

Location: File Ø
Program Name: SCAN

Purpose:

a) SCAN updated T[1], T[2], T[3] (hours, minutes, seconds) from T[5] (time in seconds at next SCAN).

b) SCAN then continually reads the counter cards until their value is equal to T[5],

c) And then sets the relays; starts and reads the analog to digital converter (Voltage Monitor Card); for each of the 13 channels. Note: If the number of channels increased, the parameter N must be changed and this routine must be modified.

Input: Current time (via Counter Cards)

T[5] C[1,I], C[2,I]
flg 9

Output: M[I] (I = 1, 13)

T[1] (I = 1, 3)

Dummy Variables: A, B, I, J, K, rl4, flg 9

Subroutines Required: DRVTIME

REACOUNT

Calling Sequence: gsb 'SCAN'

Location: File 2
Program Name: CALIM

Purpose: Check transmitter side of the laser channels.

Input: M[ ]

Output: E[ ]

Dummy Variables: I, J

Subroutines Required: None

Calling Sequence: gsb 'CALIM'

Location: File 0, File 2

A-21
Program Name: AVERAGE

Purpose: Averages values into the averaged array A[ ].

Input: A[], M[], N

Output: A[]

Dummy Variables: I

Subroutines Required: None

Calling Sequence: gsb 'AVERAGE'

Location: File 2
Program Name: STACK

Purpose: Stacks values in the Write Buffer array W$ and the Print Buffer array P[ ].

Input: C, P, V, T[ ], N, r2, r3, r4, r5, r6, r7, r12, r13, flg 5

Output: C, r4, r6, W$, P[ ]

Dummy Variables: p0, p1, p2, I

Subroutines Required: CALTRANS

Calling Sequence: call 'STACK'

Location: File 2
Program Name:  CALTRANS

Purpose:  Calculates transmission for Printout

Input:  A[ ], E[ ], T[ ], r$\theta$, r1, r2, r8, r9

Output:  P[ ], Q[ ], r2, r$\theta$

Dummy Variables:  p$\theta$

Subroutines Required:  None

Calling Sequence:  cll 'CALTRANS'

Location:  File $\theta$, File 2

A-24
Program Name: FCAL

Purpose: Operator input of the calibration constants for the N channels.

Input: KEYBOARD, S$[I], C[1,I], C[2,I]

Output: C[1,I], C[2,I], (I = 1 to N)

Dummy Variables: I

Subroutines Required: None

Calling Sequence: File Ø: gsb "FCAL"

Location: File Ø

A-25

Block Engineering, Inc.
Program Name: FHEADER

Purpose: Operator input of header text for printout and header tape file.

Input: Operator input of 80 characters.

Output: H$

Dummy Variables: G$, I, J

Subroutines Required: None

Calling Sequence: gsb 'FHEADER'

Location: File 0 and File 2
Program Name: MP TEST

Purpose: Tests the multiprogrammer
a) Counter Cards
b) Relays
c) Voltage Monitor (analog to digital converter).

Input: Multiprogrammer

Output: Stops on error in Relay or Counter.
Displays reading for A/D Converter for
Ø volts in
5.2 volts in
if not within least significant bit.

Dummy Variables: A, B, I, J, pØ

Subroutines Required: gsb 'READCOUNT'

Calling Sequence: cll 'MP TEST'

Location: File Ø
Program Name: READ A/D

Purpose: Sets the relays and cycles the voltage monitor card (analog/digital) converter. The reading is returned in B.

Input: I (Channel # 1-17), G

Output: B

Dummy Variables: A, J, K

Subroutines Required: None

Calling Sequence: 'READ A/D' →

Location: File 0, File 2

A-28
Simple Variables

| A   | Dummy Variable (Local use only)     |
| B   | Dummy Variable (Local use only)     |
| C   | Scan Count                           |
| D   |                                     |
| E   | Plot Scale Limit (Maximum)          |
| F   | Plot Scale Limit (Minimum)          |
| G   | Gain of Receiver Channels: ( =1 or =16) |
| H   | Dummy Index (local use only)        |
| I   | Dummy Index (local use only)        |
| J   | Dummy Index (local use only)        |
| K   |                                     |
| L   |                                     |
| M   |                                     |
| N   | Number of Channels                  |
| O   | Integration Interval                |
| P   |                                     |
| Q   | Current File # (Tape)               |
| R   | Count of Scans (For writing to Printer) |
| S   | Tape#                                |
| T   | Track#                               |
| V   | Volume#                              |
| W   |                                     |
| X   |                                     |
| Y   |                                     |
| Z   |                                     |

r0  Fill index into Q [ ]
r1  Take index into Q [ ]
r2  Fill index into P [ , ]
r3  Take index into P [ , ]
r4  Fill index into X [ ]
r5  Take index into X [ ]
r6  Fill index into W$[ , ]
r7  Take index into W$[ , ]
r8  # of rows of P[ , ]
r9  # of rows of Q[ ]
r10 Files per Track
r11 Bytes per File
r12 # of rows of W$[ , ]
r13 # of rows of X[ ]
r14 Single Scan time in seconds (One scan is N channels)
Array Variables

A[N]  Averaged values of M[ ]
B
C[2,N]  Calibration constants for each channel
E[3]  Channel Error
G[3]  Scale values for plot and update count for scale change
H
I[4]  Dummy array Local use only
J
K
L[3]  Last measured values of laser channel
M[N]  Measured values for each channel
N
O
P[r8,N-3] Print array
Q[r9]  Print request array
R
S
U
V
W
X[r13] Write Request array
Y
Z
**String Variables**

A$
B$
C$
D$
E$
P$
G$ Temporary header text
H$[132]$ Header text
I$[3]$ Characters + O X for Plotting
J$
K$
L$
M$
N$
O$ String variable for Tape I/O
P$
Q$
R$
S$[ ] Channel Names
T$
U$
V$
W$[ , ] Write Tape Array
X$
Y$
Z$
Flags

0
Print flag monitor
1
Print Flag enables printer
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Tape Ready flag
Display Time/Date flag
Run Flag
Terminate Run flag
Immediate Execute inhibit
Set if enter not satisfied
Not set; Stop on math error
Set on Math error
APPENDIX C
SOFTWARE FLOWCHARTS
**FILE I**

1. **Load File 1**
   - (of Software Tape)
   - FIX & (Set display)

2. **Set up A**
   - r8, r9, ..., r14

3. **Dimension all arrays**
   - Allocate the Printbuffer (BUF)

4. **Set up the Channel names S$**

5. **Set soons Time out and do error**

6. **ell MP TEST**

7. **Check that the error is the multiprogrammer**
   - If it is, display "Multiprogrammer Status incorrect"

8. **Display 'Load Software Tape and continue'**

   1. **If 2, 0, A**

**NOTE:**
- This loads File 2 of the Software Tape and begins execution at 1.0 C A.
; IN FRUN, WHILE FLAG9 = 1,
the 'I' parameter displayed at each scan, is the 'await scan time loop count'.

SET FORMAT 1 FOR TIME AND DATE AND I

DISPLAY TIME, DATE, AND I

Return
DRYTIME

Derive from T[5] (= Time in Seconds)
T[1] = hrs
T[2] = min
T[3] = seconds

Return
FSTD

READCOUNT

A → T[5]

DRVTIMIE

; Set up current time
T[1], T[2], T[3]

Successively display and wait
for operator input
Hours; T[1]
Minutes; T[2]
Seconds; T[3]

; Set the counter cards w/ the
Time in Seconds

Derive from T[2], the
time in Seconds

ell 'SET'

; Successively display
and await operator
input of
Month; D[1]
Day; D[2]
Year; D[3]

RNNNN
Set

Derive the input value into 12-bit binary slices.

Set the counter cards to these values.

Rewind
```plaintext
PRINT

STATUS OF PRINT BUFFER

- \( \Phi \) => BUFFER EMPTY
- \( -1 \) => TRANSFER 10

TRANSFERS

- \( \Phi \) => BUFFER HAS DATA BUT NO TRANSFER AVAILABLE

; \( r0 \) and \( ri \) are the fill and take indices into the
printrequest array \( GET \)

\((ri - r0 = \Phi) \Rightarrow \text{a print request}

\( G[3] = \Phi \)

\( G[3] = \text{New Scale} \)

\( G[2] = \text{New Scale} \)

\( G[1] = \text{Scale for the} \)

\( \text{plotted output:} \)

\( \text{Scale is done} \)

\( \text{to the nearest} \)

\( \text{Vi} \), close \( \text{minimum} \)

\( \text{maximum} \)

Determine a scale for the plotted output:

Scale is done to the nearest Vi, close to minimum

Do not want to change print scale each time.
```
Printline

Set Printer
Top of Form
Length = 0, 0

Determine Scale Factor

Output a '1'
To Print Buffer
Set I = 1

I > 3

No

PC [J, T[I]] 
> 0

Yes

Scale PC [ ]
Output to Buffer
And print the
Symbol T$[I[I]]

Output Value of Right Boundary;
Print '1'

Output to Buffer rest of
Line;

Transfer Buffer
To printer
q3 + 1 \rightarrow q3
q1 + 1 \rightarrow q1

---

2
Incrementing Take Indices
of Print and Print缓冲
array in order to clear them.
Initialize Header

If $\log_2 5$?

No

Format first line and print to buffer

Yes

Print to buffer lines 2, 3, 4

If $\log_2 5$?

No

Transfer print buffer to printer

Yes

Print remaining header (channel names and units)

; Line 1 is Transmitter Data Input Record

; Line 2 is Date: Month Day Year

; Line 3 is Header text

; Line 4 is 'TAPE' 'VOL', 'TRK', 'MIN/SEC', 'Message'

C-12
Format

Set up formats for printed output.

Formats are numbered
0 → 9
Format 0 is left at
free field.
Format 1 is set whenever
used.
Formats 2 to 9 are set
here and used by
the printheader and
printline routines.
WRITE

SET OCTAL MODE
READ STATUS OF TAPE

BIT(7, J) = 1?

DISPLAY PROTECTED TAPE
SET DECIMAL
RETURN

IF F + 5 = 0 => NO
X[I % 5] mod 13 + I
= 2 Header
= 1 File

WRITE REQUEST?

IDENTIFY FILE?
READ # BYTES WANTED

FILE EMPTY?

DISPLAY TAPE NOT EMPTY?

GO TO 'abt'

Clear string $0$
Assemble string from the various parameters:
Tape #, Volume, Time, Channel names
and current Calibration Constants etc.

TRK AND File Æ Ø

J = r7 mod r12 + 1
Points to read W$[J]
(String array)
Output this file
To TAPE
R + 7 = r7 + 1

R = R + 1

R Æ Ø

R Æ Ø

RETURN

TRK Æ 1

DISPLAY 'NEW TAPE'
SET TRK Æ 0

RETURN

Set Track = 1

F5 Æ F5 - 1

STOP $NEW TAPE$

$NEW TAPE$ error

Notes:
BIT(7, J) set when
PROTECTED TAPE
BIT(5, J) set when TAPE in motion
BIT(3, J) is cleared when cartridge out or unused

On change of TAPE, when
NEW TAPE IS
PUT IN, THE
TEST BIT 2 J
WILL DETECT IT.
('PROTECTED THIS')
is also set when
there is no
CARTRIDGE IN.)
NOTE USE OF 'ON ERROR'; THE IDF COMMAND IS AN ERROR FOR AN UNMARKED BLANK TAPE. (THE ROUTINE CHECKS FILE 0 ON BOTH TRACK 0 AND TRACK 1.)

; FIND FILE 0
; FIND I = # BYTES
; WRITTEN onto FILE

; FIND I = TRACK #
Folist

Display: 'LOAD DATA TAPE AND CONTINUE'
WAIT FOR
CONTINUE

Display 'TRACK (0 or 1)
Operator input of
TRACK; trk U

.gsb 'FORMAT'

.cfq 4; cfq 5;
.cfq 11; re w
Ø -> R

.gst GETHEADER
; GETHEADER returns I = -1 if
End of Tape or No File Found etc.

I = -1
NO

.gsb 'DECODE'

YES

1 + R -> R

 gst 'PAINTHEADER'

 gsb 'PAINTHEADER'

YES

STATUS
NO PAINTwriter
<= 0

RETURN

RETURN

C-18
GET HEADER

Find file R

gsb CHECKFILE

\( I \leq \emptyset ? \)

\( \Rightarrow +1(\emptyset - 1) \)

\( +R \rightarrow R \)

\(-I \rightarrow I\)
check file

idk, k, j
(identify file)

returns j current # bytes
k file type

j = Ø

no

j ≠ ll

no

k ≠ 3

no

display track ll
file r is empty

yes

display wrong file
size

yes

-1 → i

load file into
0

derive vol# → i

retreive

retreive
HEADER FILES AND DATA FILES ARE STRING CHARACTERS. THIS ROUTINE DERIVES THE ORIGINAL INPUT OF HEADER FILES.

; DECODE DATE

FOR I = 1 TO N
DERIVE Channel Names S$

FOR I = 1, G
Ø → c [I, I]
1 → c [1, I]

FOR I = 4 TO G
DERIVE c [I, I] FROM O$

DERIVE H$ FROM O$

;

; DECODE

DERIVE T, V, N,
FROM O$
Set Octal Mode
T = k

For I = 40000 to 60000 by 10000
S = A

If I = 60000 and G = 16; Set I to 66000 (keep gain relay on)
   For J = 1 to 6
      Set Relays TIME = 1
      Start A/D TIME = 1
      Read the A/D into an interface register
      Clear the relays TIME = 0
      Read interface and convert to decimal
      Binary shift on A, 2 places to left to set next mask
      Convert reading w/r to cal constants
      k+1 = k (pointer into internal channel)
      Next J

If not last card then next I
Set Decimal Mode, Return
CALIB

I = 1  J = \emptyset

\[ M[I] \geq \text{Threshold} \]

\[ I = I + 1 \]

\[ I = 3 \]

\[ J = J + 1 \]

\[ J = 3 \]

\[ \text{Display 'ALL Channels Out'} \] STOP

; ALL CHANNELS OUT?

; M[I] I = 1, 2, 3

IS TRANSMITTER SIDE LASER CHANNEIS
CALTRANS

J = r \times 2 \mod 8 + 1
point to row
P[J, J]

I = 1

E[I] ≥ 1

\text{no}

\text{yes}


\text{no}

\text{yes}

P[J, I] ≤ 1

\text{no}

\text{yes}

I = I + 1

I ≥ 3

DISPLAY CHANNEL
\text{I', NEEDS}
\text{COMMUNICATION}

ACTION
FOR I = 1 to G
1 \rightarrow C[1,I]
\varnothing \rightarrow C[2,I]

Display 'Default VALUES?'
\varnothing \rightarrow \text{No}, I = \text{YES}

\textbf{INPUT I} !

\textbf{FOR I = 4 \rightarrow G}
Display $S[I]$ and CURRENT $C(I,I)$
Operator inputs NEW VALUE

\textbf{RETURN}

\textbf{RETURN}

\textbf{RETURN}

\textbf{RETURN}

; CLEAR LASER CHANNELS
Note that $C[2,I]$ is
keep at 0.
Calibration VALUES ARE
LINEAR APPROXIMATION.
Of the form

$$ V = \alpha I + \beta $$

$\alpha = C[1,I]$
$\beta = C[2,I]$

+; \textbf{NOTE:} For I = 4 \rightarrow (G - 3)$
$C[1,I]$ is the
PARAMETER USED IN
the CALCULATION OF
TRANSMISSION.

**; \textbf{NOTE:} Pressing
CONTINUE keeps
the CURRENT VALUE
HEADER

DISPLAY 'CURRENT HEADER'
WAIT 1.5 SEC.

DISPLAY CURRENT HEADER G$

Operator input of NEW Header -> G$

Define # CHARACTERS IN G$
SET 132-# \to J

CLEAR H$ AND PUT G$ INTO H$ LEAVING J SPACES AT THE BEGINNING.
(G$ IS CENTERED IN H$)

RETURN
Gain

Find Maximum Value of $M_{[I]} \quad I=4,5,6$

Low $G=1$

Current Gain?

Low Threshold?

No

Maximum < Low Threshold?

Yes

Set $G = 16$

Reset Gain Relays

Yes

Set $G = 1$

Reset Gain Relays

High $G=16$

Low Threshold?

No

Maximum > High Threshold?

Yes

Return

Return

Laser

; Receiver Channels
Enter

Display "# of Scans to Average"
Operator input of D

Return
APPENDIX D
SOFTWARE LISTING
"Software file 0 MRU 6/14/78":
1: gto "FINIT"
2: gto "FMARK"
3: gto "FCAL"
4: gto "FREPLT"
5: gto "FDLIST"
6: "FINIT":
7: ldk l;fxd 0;trk 0
8: 13*N;3*r8;81=1+9;290+r10;320+r11;5+r12;122=1+r13;2+r14
9: dim A[N],C[2,N],D[3],E[3],F[2],G[3],I[3],M[N],L[3],P[r8,N]
10: dim Q[r9],T[5],X[r13];buf "PBF",800,0
11: dim G$[80],H$[132],I$[3],O$[r11],S$[N,8],W$[r12,r11];r11+8+r11
12: "HeNe Ref"*S$[1];"YAG Ref"-S$[2];"C02 Ref"*S$[3]
15: time 500
16: on err "nomp"
17: c11 'MP TEST'
18: gsb "onerc"
19: gsb "FSTOD"
20: gsb "ATEST"
21: gsb "FCAL"
22: gsb "FININTERVAL"
23: gsb "FHEADER"
24: gto "OTHERFILE"
25: ifrom=69;if ern=4;disp "Multiprogrammer not on.";stp
26: disp "Error ",char(ern),ern,"on line",erl;stp
27: onerc:on err "noer"
28: if flglO;cmf 9;ret
29: gsb "READCOUNT"
30: if not flglU;sfg 5;ret
31: cmf 5;ret
32: "CALQ":ent
33: if not flgl0;ret
34: for I=1 to 6;1+CI1,11;0+C[2,1];next I
35: +CI1,91;0.C[2,10]
36: 25.4[C,13];0*CI2,13]
60: if A=0;gto "caldone"
61: dsp "Input A,B (y=Ax+B) for each chan";wait 3000
62: dsp "To keep old value, CONTINUE"; wait 3000
63: for I=4 to 6
64: dsp SS[I], "A", C[I,1]; ent "", C[I,1]
65: next I
66: for I=7 to N
67: dsp SS[I], "A", C[I,1]; ent "", C[I,1]
68: dsp SS[I], "B", C[I,2]; ent "", C[I,2]
69: next I
70: "caldone": if A=0; dsp "CAL complete"; ret
71: O+A;ent "Repeat CAL ? (0=no, 1=yes)"; I; if A=1; gto "FCAL"
72: gto "caldone"
73: "FSTOD":
74: gsb "READCOUNT"
75: A+T[5]; gsb "DRVTIME"
76: gsb "GTOD"
77: dsp "Hours?", T[1]; ent "", T[1]; dsp "Minutes?", T[2]; ent "", T[2]
78: dsp "Seconds?", T[3]; ent "", T[3]
80: dsp "Month?", D[1]; ent "", D[1]; dsp "Day?", D[2]; ent "", D[2]
81: dsp "Year?", D[3]; ent "", D[3]; ret
82: "FINTERVAL";
83: dsp "No. of scans to average?"; ent "", P; if P<0; jmp 0
84: ret
85: "PHEADER";
86: dsp "Current HEADER:"; wait 1500; dsp G$
87: ent ",", G$
88: "GHEADER": len(G$)+I; int((132-I)/2)~J; "+H$[1,132]; G$[I,1]+H$(J,1+I)
89: "SET":
90: int(pl/4096)-p2; dto(pl-4096*p2)+p1; dtop2+p2
91: moc; wtb 9,170040,10000+p1,20000+p2; mdec; ret
92: "MP TEST":
93: gsb "READCOUNT"
94: A+I; wait 1500; gsb "READCOUNT"
95: A-I-A; if not (A=1 or A=2); dsp "Read Counter Error"; stp
96: for I=40000 to 60000 by 10000; 1+A; moc; for J=1 to 12
97: wtb 9,170160,1,1+A
98: wtb 9,170240; wti 0,11; wti 4, I; rdi 4-B
99: wtb 9,170160,1
100: if A-H#U; mdec; dsp "Relay Error at slot", I/10000, "relay bit", J; stp
101: shf(A,-1)~A; next J; next I; fxd 3
102: 17+I; READ A/D+p0; if prnd(p0, -1)#0; dsp "A/D offset", p0, "ABORT"; stp
103: 16+I; READ A/D+p0; if p0>5.4 or p0<5; dsp "A/D READS", p0, "ABORT"; stp
104: fxd 0; ret
105: "FMARK":
106: if r10=0; dsp "Must INIT before MARK"; stp
107: dsp "Load blank tape, CONTINUE"; stp
108: rew; trk 0; cfg 8; on err "fmarka"
109: "fmarkc": sdf 0; idf 1, I, I, I
110: if I#0; dsp "Not a blank tape... MARK aborted"; stp
111: idf I, I, I, I; if I#0; gto "fmarkb"
112: "fmarka": rew; trk 1; on err "fmarkc"; gto "fmarkc"
113: "fmarkb": on err "fmarkd"
114: rew; mrk r10, r11; ert r10; rew; trk 0; mrk r10, r11; ert r10; rew
115: gsb "onerc"
116: dsp "MARK complete"; stp
117: "fmarkd": if ern=42; if rom=0; dsp "TAPE WRITE LOCKED!"; stp
118: gto "fmarkb"
119: "PRINT":
120: rds("PBF")*A;if A>0;tfr "PBF",6;ret
121: if A<0;ret
122: if flg4=flg5;jmp 2
123: if flg4;cfg 4;wrt "PBF","Output to printer halted";wtb "PBF",10
124: if rU=r1=0;ret
125: if (fma1or5+1)=1;r1=r1+1;goto "PRINTTHEADER"
126: if not flg4;wrt "PBF","Continuation of printed output"
127: rsmour8+1;min(f(J,1),P[J,2],P[J,3])*B
128: for l=1 to 3;if a Unreal(J,1);next 1
129: if J,1=I+1;I=J,1+1+1;1=J,1+1
130: P[J,1]J=A;A=R;asg "Unable to Scale";0=P+F;1=A+B;goto "PRINTLINE"
131: if J,1<0;P[J,1,2]>B;it B<0;P[J,1,3]=B
132: A+jK;it K9(max(A,1),A+1)*A
133: B+jK;it K9(max(R,1),R+1)*R
134: if A=U=V=1
135: if E=F;A+E+B+F;goto "PRTSCALE"
136: if A=E and b=F;E+G[1];F+G[2];U+G[3];goto "PRINTLINE"
137: if A>B or max(A,1)+E+G[1];min(b,1)+F;B+A;goto "PRINTLINE"
140: if G[3]=6;goto "PRINTLINE"
143: "PNTSCALE":sig 4;fmt 1,f4.1,43,f5.1;wrt "PBF.1",F,E
144: "PRINTLINE":if not fl94;jmp -1
145: wtB "PBF",27,79,0,10,0,0
146: 472/(E-F)+B;wrt "PBF",27,84,27,70,0,0," "
147: for l=1 to 3;f P[J,1]<3;jmp 2
148: (P[J,1]-1)*B+A;wrt "PBF",27,65,472/64,472,0,0,0," "
149: next 1;wrt "PBF",27,65,472/64,472,0,0,0," "
150: fmt 1,3x,fx2.0,"":"fx2.0,0,4,0,4,x,z
151: wrt "PBF.1",P[J,4],P[J,5],P[J,6]
152: wrt "PBF.2",P[J,7],P[J,8],P[J,9],P[J,10],P[J,11],P[J,12],P[J,13]
153: tfr "PBF",0;P[1]=P[1]+1;P[1]+1;ret
154: "PRINTTHEADER":
155: if flg5;fmt 1,62x,"Transmissomter Data Input Record",/;wrt "PBF.1"
156: wrt "PBF.4",D[1],D[2],D[3]
157: wrt "PBF.5",x1,0,D[1],D[2],D[3]
158: wrt "PBF.6",x1,0,D[1],D[2],D[3]
159: wrt "PBF.7",x1,0,1,D[1],D[2],D[3]
160: if not flg5;tfr "PBF",6;ret
161: wrt "PBF.6"
162: wrt "PBF.7",x1,0,1,D[1],D[2],D[3]
163: wrt "PBF.8",tfr "PBF.9",tfr "PBF",6;ret
164: "FORMAT":
165: fmt 2,f5.2,4x,f5.2,4x,f5.2,2x,f5.1,3x,f6.1,7x,z
166: fmt 3,f4.1,7x,f4.0,4x,f7.2,5x,f6.2,6x,f5.2,z
167: fmt 4,75,x,fz2.0,",",fz2.0,",",fz2.0
168: fmt 5,49x,"Tape",f6.," Trk",f6.," Vol",f6.," Every",f6.," Seconds",/;
169: fmt 6,18x,"Transmission",24x,"Time",11x,"Transmission",7x,z
170: fmt 7,18x,"Transmission",24x,"Time",11x,"Transmission",7x,z
171: fmt 8,52x,"Trt:MN:Sc",2x,"Helen(+)",2x,"YAG(X)",2x,"CO2(O)",z
172: fmt 9,3x,"deg C",7x,"mb",10x,"",8x,"deg",8x,"kph",6x,"cm/hr",9x,"cm"
173: ret
174: "FREplot":
176: dsp "Load data tape and CONTINUE"; stp
177: gsb "Format"
178: stf 4; stf 5; stf 11; rew; 0+k; 0+u; gsb "GETHEADER"
179: if I=-1;ret
180: stf (O$[5,8])*T
181: fixa u; dsp "Tape", T, " Track (0 or 1)=?"; ent "", u
182: if u=0 or u=1; jmp 2
183: jmp -2
184: dsp "Vol. to Decode=?"; ent "", B; if B<1; jmp 0
185: if u<>0; trk u; gsb "GETHEADER"
186: "NOTYET": stf (O$[9,12])=v
187: l+r+r; if u=v; gto "REplot"
188: gsb "GETHEADER"
189: if I=-1;ret
190: gto "NOTYET"
191: "REplot": gsb "DECODE"
192: l*Q((r0+l*r)-1)modr9+1; gsb "PRINT"
193: for R=R to r10-1; gsb "CHECKFILE"
194: if I=0; fmt 1, ", "Unexpected termination"; gto "ENDPLOT"
195: stf (O$[5,8])*T[5]; 9+S; gsb "DRVTIME"
196: for C=1 to 6
197: 2*Q((r0+l*r)-1)modr9+1
198: for K=1 to N; stf (O$[S,S+S])=A[K]; S+S
199: if A[1]=-12345; fmt 1, "; gto "ENDPLOT"
200: next K
201: gsb "CALIN"
202: cl1 'CALTRANS'
203: if flag1; fmt 1, ", "Replot Terminated"; gto "ENDPLOT"
204: if rds("Pst")<0; jmp 0
205: gsb "PRINT""
206: T[5]+P*r14+T[5]; gsb "DRVTIME"
207: next C; next R; fmt 1, /
208: "ENDPLOT" if rds("Pst")<0; jmp 0
209: wrt 6, 1; wrt 6, "End Replot Trk", U, " Vol", V; ret
210: "GETHEADER":
211: for R=R to r10; fdf R
212: gsb "CHECKFILE"
213: if I=0; ret
214: next R; dsp "Tape Done"; -1+I; ret
215: "CHECKFILE":
216: idf K,K,J; if J=0; dsp "Track", U, "File", R, "is empty"; -1+I; ret
217: if J<>r11; dsp "Wrong file size"; -1+I; ret
218: if K<>3; dsp "Wrong file type"; -1+I; ret
219: idf R, O$; stf (O$[1,2])+1; ret
220: "DECODE":
221: stf (O$[5,8])*T; stf (O$[9,12])=V; stf (O$[13,16])=N; stf (O$[17,20])=A
222: A-(int(A/10000)+D[1])*10000+A; A-(int(A/100)+D[2])*100+D[3]
223: stf (O$[21,24])=r14+P; 25+J
224: for I=1 to N; O$[J+J+1]=S$[1]; J+8+J; next I
225: for I=1 to 6; 1=C[1,1]; 0=C[2,1]; next I
226: for I=4 to 6; stf (O$[J+J+3])=C[1,1]; J+4+J; next I
227: O$(J, len(O$)-1)+H$; ret
228:  "FDLIST":
229:  dsp "Load data tape and continue"; ent "", I
230:  gsb "FORMAT"
231:  cfg 11; cfg 5; rew; 0+R; 0+U
232:  "DLIST": gsb "GETHEADER"
233:  if I-1; ret
234:  gsb "DECODE"
235:  if rds("PB")<0; jmp 0
236:  if flg I; ret
237:  gsb "PRINTHEADER"
238:  1+R+R; gto "D LIST"
239:  "CALIM": 0+J
240:  for I-1 to 3; if M[I].> .56; jmp 2
241:  1+J+J; if E[I]-0; 1+R[I]; gsb "Channel", I,"Below Threshold"
242:  next I; if J-3; gsb "All channels below threshold"
243:  ret
244:  "CALTRANS":
245:  ((r2+1-r2)-1)mod 8+1+P
246:  for I-1 to 3; if E[I]-1; -1+P[p0; I]; jmp 2
247:  if (C[I+3]*A[I+3] /A[I]+P[p0; I])>1; gsb "Channel", I,"needs calibration"
248:  T[I]+P[p0; I+3]; next I
249:  for I=7 to N; A[I]+P[p0; I]; next I
250:  if r1-r0>=r9; gsb "Print Request array error"
251:  2=Q[((r0+i-r0)-1)mod 9+1]; ret
252:  "READ A/D":
253:  60000; J; if G=16; 66000+J
254:  mact; wtb 9, 170040, 40000, 50000, J; mdec
255:  if I<1 or I>17; gsb "Illegal Relay Channel"; stp
256:  if I=1 and I<6; 40000+A; I+B
257:  if I=7 and I<12; 50000+; I-6+B
258:  if I=13 and I<17; 60000+; I-12+B; if G=16; 66000+A
259:  3+K; mact; for J=2 to B; shd(K, -2)+K; next J
260:  wtb 9, 170160, A+K; wtb 9, 170260, 30000, 170240
261:  wti 0, 11; wti 4, 30000; rd 4-B
262:  wtb 9, 170040, A; odd B; if B>2047; B-4096+B
263:  .005*B+B
264:  mdec; ret B
265:  "ATEST": fxg 3; gsb "Channel Volts"
266:  for I=1 to N; "READ A/D'M[I"
267:  prt S[I], M[I]; next I
268:  spc; spc; spc; prt "Given trans=100%"
269:  prt "HeNe CAL=" M[I] /M[4]
272:  spc; spc; spc; ret
273:  "FRUN": 2+A; goto "OTHERFILE"
274:  "F'TAPE": 3+A; goto "OTHERFILE"
275:  "OTHERFILE": gsb "Load software tape and CONTINUE"; stp
276:  ldf 2, 0, A
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SOFTWARE FILE 1, SPECIAL FUNCTION KEY DEFINITIONS

f0: * run "FINIT"
f1: * cont "FRUN"
f2: * gsb "FSTOD"
f3: * gsb "FTOD"
f4: * gsb "FMARK"
f5: * gsb "FTAPE"
f6: * gsb "FCAL"
f7: * gsb "FIN_INTERVAL"
f8: * gsb "FPRINT"
f9: * gsb "FHEADER"
f10: * gsb "FRERMINATE"
f11: * gsb "FDLIST"
f12: * gsb "FREPLT"
f18: * gsb "ATEST"
0: "Software file 2 MRU 6/12/78":
1: "FINIT":gsb "nono";l+1;gto "OTHERFILE"
2: asp "Load data tape and CONTINUE";stp ;gto "FRUN"
3: dsp "Load data tape and CONTINUE";stp ;gto "FTAPE"
4: gto "FPRINT"
5: gto "ATEST"
6: "INITCON":dsp "Load data tape and CONTINUE";stp
7: cll "FTAPE"
8: stp
9: "DRVTIME":
10: \(T[5]\mod 60+T[3];(T[5]-T[3])/60\times A)\mod 60+T[2];(A-T[2])/60\mod 24+T[1]\);ret
11: "FTOD":
12: if flglO;cmf 9;ret
13: gsb "READCOUNT"
14: A\times T[5];gsb "DRVTIME"
15: "GTOD":
16: fmt 1,fz2.0,"","fz2.0","","fz2.0,6x,fz2.0","","fz2.0,6x,fz3.0
17: wrt \(1, T[1], T[2], T[3], D[1], D[2], D[3], 1\);ret
18: "FTERMINATE":
19: dsp "Terminate";sfg 11;ret
20: "FPRINT":
21: if not flg10;sfg 5;ret
22: cmf 5;ret
23: "READCOUNT":
24: mocc;wtb 9,170240;wti 0,11;wti 4,10000;rdi 4\times A;wti 4,20000;rdi 4\times B;mdec
25: otaA+4096*otdbA;ret
26: "PRINT":
27: rds("PBF")+A;if A>0;tfr "PBF",6;ret
28: if A<0;ret
29: if flg4=flg5;jmp 2
30: if flg4;cfg 4;wrt "PIF","Output to printer halted";wtb "PBF",10
31: if r0-r1=0;ret
32: if \(|r1\mod r9+1|=1\);if 1;ret
33: if not flg4;wrt "PBF","Continuation of Printed output"
34: r3modr6+1+3;min(P[J,1],P[J,2],P[J,3])-B
35: for I=1 to 3;if B=P[J,1];next I
37: P[J,1][3]A;I>0;asp "Unable to Scale";\(0+B+F+I+A+1\)gto "PRINTLINE"
38: if B<0;P[J,1][2]=B;I=I+1+I[2];B=B+I
39: A=K;I>\{prnu(1)\}=A+1=A
40: B=K;I<\{prnu(2)\}=B=B+I
41: if A>B=B,-1-B
42: if E=\'A+E;E=\'B+F;gtsto "PRTSCALE"
43: if A=E and B=F;E=G[I];F=G[2];0=G[3];gtsto "PRINTLINE"
44: if A>E or B<F;max(A,E)+E=G[I];min(B,F)+F=G[2];0=G[3];gtsto "PRTSCALE"
47: if G[3]=6;gsto "PRINTLINE"
50: "PRTSCALE":sfg 4;fmt 1,f4.1,43x,f5.1;wtb "PBF",1,F,E
51: "PRINTLINE":if not flg4;jmp -1
52: wtb "PBF",27,79,0,10,0,0
53: 472/(E-F)+B;wtb "PBF",27,84,27,70,0,0,"1"
54: for I=1 to 3;if P[J,1][1]=0;jmp 2
55: \(P[J,1][1]=F\)^B=A;wtb "PBF",27,65,int(A/64),int(A),0,0,1S[11],I[11]
56: next 1;wtb "PBF",27,65,int(472/64),472,0,0,"1"
57: fmt 1,3x,fz2.0,"","fz2.0","","fz2.0,3x,2
58: wtb "PBF",P[J,4],P[J,5],P[J,6]
59: wtb "PBF",P[J,1],P[J,2],P[J,3],P[J,4],P[J,5],P[J,6]

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60: wrt "PBF.3",P[J,9],P[J,10],P[J,11],P[J,12],P[J,13]
61: tfr "PBF",6;r+3+l+r+3;rl+r+1;r1;ret
62: "PRINTHEADER":
63: if flg5;fmt 1,62x,"Transmissometer Data Input Record",/;wrt "PBF.1"
64: wrt "PBF.4",D[1],D[2],D[3]
65: wrt "PBF.5","","HS";wrt "PBF"
66: wrt "PBF.6",T,U,V,P*r14
67: if not flg5;tfr "PBF",6;ret
68: wrt "PBF.7",SS[7],SS[8],SS[9],SS[10],SS[11],SS[12],SS[13]
69: wrt "PBF.8";wrt "PBF.9";tfr "PBF",6;ret
71: "PRTSCALE":
72: fmt 1,f3.1,44x,f3.1;wrt "P8F.1",F,E;ret
73: "FORMAT":
74: fmt 2,f5.2,3x,f5.2,4x,f5.2,4x,f5.2,4x,f5.2,6x,f5.2,7x,z
75: fmt 3,f4.1,7x,f4.0,4x,f7.2,5x,f6.2,6x,f5.2,2x,fz2.0,"/",fz2.0,"/",fz2.0
76: fmt 4,49x,"Tape","Trk","Vol","Every".,f6.","Seconds","/
78: fmt 6,18x,"Transmission",24x,"Time",11x,"Transmission",7x,z
79: fmt 7,c8,1x,c8,1x,c8,3x,c8,3x,c8,3x,c8,3x,c8
80: fmt 8,52x,"Hr:Mn:Sc",2x,"+","YAG(X)",3x,"CO2(O)",z
81: fmt 9,c8,1x,c8,1x,c8,3x,c8,3x,c8,3x,c8,3x,c8,3x,c8
82: ret
83: "WRITE":
84: mdec;rds(1)+J;if bit(7,J);mdec;dsp "PROTECTED TAPE";ret
85: if bit(5,J);mdec;rew;ret
86: if bit(2,J);mdec;rew;ret
87: mdec;if r4-r5=0;ret
88: "*OS";if X[r5m0r13+1]=2;WS[r7modr12+1]*OS;r7+1+r7;jmp 7
89: if R=0 and U=0;if I,1;I;if I=0;dsp "TAPE NOT EMPTY";gto "abt"
90: fti (0)&fti (V)&fts (T)&fts (V)&fts (N)&fts (D[1]*10000+D[2]*100+D[3])\0S
91: fts (r14*F)+OS[21,24];25+J
92: for I=1 to N;SS[I]+OS[J+3]+J;J+8+J;next I
93: for I=4 to 6;fts (C[I,1])+ OS[J,J+3]+J+4+J;next I
94: HS+OS[J,J+1+len(H$)]\3
95: rcf R,R;S[1]+R+5+R;1+R+5+R;if R=r10;dfd R;ret
96: l+x[(r5-1-r5)ma0r13+1]+Q[r0mod9+1];l+r0+R
97: if r0-r1>r9;dsp "Print request array error"
98: if U=1;disp "End of Tape";1+T+T
99: l+V;abs(U-1)+U;trk U+R;0,PR;U=0;rew;ret
100: if U=1;fod 0;ret
101: "SCAN":
102: 60000+I;if G=16;66000+I
103: moct;wtb 9,170040,400C0,50000,1;mdec
104: gsb "DRVTIME"
105: gsb "READCOUNT"
106: if A=T[5];dsp "Scan timing error";gto "abt"
107: for I=1 to 200;gdb "READCOUNT"
108: if A=T[5];next I;dsp "Timeout";gto "abt"
109: if flg9;call 'GTOD'
110: (A-T[4])+r14+r+T[5]+l+K;moct
111: for I=40000 to 60000 by 10000;3+A;if I=60000 and G=16;66000+I
112: for J=1 to 6;wtb 9,170160,1+A;wtb 9,170260,30000,170240
113: wti 0,11;wti 4,30000;rdi 4+B
114: wtb 9,170040,1;odt+B;if B>2047;B-3096+B
115: B*.005=M[K];shf (A,-2)+A;1+K+K
116: if I<60000;next J;next I
117: mdec;ret

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118: "GAIN":
119: max(2*M[4]-L[1],2*M[5]-L[2],2*M[6]-L[3])+A
120: for I=4 to 6;{(M[I]+L[I-3])/G*M[I]
121: if G=16;jmp 3
122: if A<.512;6+G+B;60000+I;goto "CGAIN"
123: ret
124: if A>9,.0625*B;14G;60000-I;goto "CGAIN"
125: ret
126: "CGAIN":mocnt;wtb 9,170160,I;modc;for I=1 to 3;L[I]*B*L[I];next I;ret
127: "CALIM":0+J
128: for I=1 to 3;if M[I]>0.56;jmp 2
129: if E[I]=0;1+I,E[I];disp "Channel",I,"Below Threshold"
130: next I;if J=3;disp "All channels below threshold"
131: ret
132: "AVERAGE":
133: 360/C[1,10]+J;M[10]modJ+M[10];if abs(M[10]-A[10])<=J/2;jmp 3
137: "STACK":
138: if CmodP#0;1+C-C;ret
139: if r6-r7>=r12;disp "Tape Buffer Error";goto "abt"
140: if Cmod(6*P)/P#00;jmp 2
141: fti (1)&fti (V)&fts (T[1]*3600+T[2]*60+T[3])+W$/A,1,8
142: 944*N*P+B
143: for I=1 to 6;fts (A[I])+W$/A,B+B;next I
144: for I=7 to N;C[I,1]*A[I]+C[2,1]*P;next I
145: for I=7 to N;fts (pI)+W$/A,B+B;next I
146: if Cmod(6*P)/P#5;)rnp 4
147: if r4-r5>=r13;disp "Channel",I,"needs calibration"
148: if E[I]=3;disp "Channel",I,"needs calibration"
149: if r3-r2>=r8;disp "Print array error, data line overwritten"
150: "CALTRANS":
151: if CmodP#0;1+C-C;ret
152: if r6-r7>=r12;disp "Tape Buffer Error";goto "abt"
153: if r3-r2>=r8;disp "Print array error, data line overwritten"
154: 2*|r4modr13+1|+r4+r4
155: if not (flg5 and (C-l)modS=0);ret
156: if r3-r2>=r8;disp "Print array error, data line overwritten"
157: "PRINT":
158: if S*r14<3;2S+S;jmp 0
159: if not flg8;disp "Tape not positioned";goto "abt"
160: buff "PBF";if rds(6)#291;disp "Printer Status incorrect";goto "abt"
161: "PRINT":
163: if P=0;gsb "FINTERVAL"
164: if P=0;jmp -1
165: 0+C;1-(exp(-P)*F[2])F[I];if not (G=16 or G=1);l+G
166: if P=S
167: if S*r14<3;2S+S;jmp 0
168: if not flg8;disp "Tape not positioned";goto "abt"
169: buff "PBF";if rds(6)#291;disp "Printer Status incorrect";goto "abt"
170: sfg 10;avd;on err "1rclear"
171: idf 1,1,1;if I=0;disp "Tape file not empty";goto "abt"
172: gsb "FORMAT"
173: wtb 16,13,1+Q[r4modr9+1];l+r0+r0;wtb 6,27,72,0,10;gsb "PRINT"
174: for I=1 to r12;""+W$/[1];next I
175: (r10-R+r10*abs(1-U))*6*P*r14+T[5];gsb "DRVTIME"
176: fmt 1;"Tape run time=";fzz2.0;" Hours",fzz2.0;" Minutes",fzz2.0;" Seconds"
179: gsb "READCOUNT"
180: \((A+T[4])+14+T[5]\); gsb "SCAN"
181: for \(I=1\) to \(3; M[I+3]=L[I]\); next \(I\)
182: for \(I=1\) to \(N; M[I]=A[I]\); next \(I\); \(A[10]\) mod \((360/C[1,10])\) + \(A[10]\)
183: gsb "CALIM"
184: gsb "GAIN"
185: "Main Loop":
186: gsb "PRINT"
187: gsb "WRITE"
188: gsb "SCAN"
189: gsb "GAIN"
190: gsb "CALIM"
191: gsb "AVERAGE"
192: coll 'STACK'
193: if not flg11; gto "Main Loop"
194: \(Cmod6P/P+A; r6modr12+1+B\)
195: \(9+4NA+A; fts (-12345)+WS[B, A, A+3]\)
196: \(2\times[r4modr13+1]1+r4+r4; l+r6+r6\)
197: if \(r0-r1>0\); gsb "PRINT"
198: if \(r4-r5>0\); gsb "WRITE"
199: if \(r0-r1>0\) or \(r4-r5>0\); jmp -2
200: fmt 1, "TERMINATED at ", f2.0, ",": f2.0, ",": f2.0
201: if \(rds("PB")<0\); jmp 0
202: wrt 6.1, T[1], T[2], T[3]; wtb 6, 10, 10, 10; wrt .1, T[1], T[2], T[3]
203: "abt": V+1;V; cfg 10; ave; mdec; on err "halt"
204: \(1/0+A\)
205: "halt": stp
206: "rclear": dsp "Error ", char(rom), er, "on line", er1; gto "abt"
207: "PTAPE":
208: if flg10; gto "nono"
209: if \(rds(1)>127\); dsp "TAPE WRITE LOCKED!"; ret
210: cfg 8; trk 0; fdf 0; idf T, U, I
211: if \(T\#r11\); jmp 3
212: if \(I=0; \); f1; R=U; l+V; ent "Tape No. = ", T; gto "FTdone"
213: if \(T\#r11\); jmp 2
214: dsp "Not a data tape... TAPE aborted"; ret
215: ldf 0, 0$; fx5 0
216: stf(0$[5,8]) + T
217: dsp "Tape ", T", OK? (0=no, l=yes); ent ",", R
218: if \(R=0;\) dsp "Tape ", T", rejected;"; ret
219: trk 1; fdf 0; idf I, I, I; if I=0; trk 0
220: for R=0 to \(r10-1\); fdf \(I; \); idf I, I, I, V, U
221: if \(I\#0;\) next R
222: if \(R=r10-2\) and \(U=1;\) dsp "Tape full... TAPE aborted"; ret
223: if \(R=r10-2\) and \(U=0;\) trk 1; jmp -3
224: if \(R=0; \); f1+V; gto "FTdone"
225: ldf R-1, 0$
226: itf(0$[3,4]) + V; V+1; V; fdf R
227: "FTdone": sfg 8; dsp "Tape", T, "Vol", V, "Track", U; ret
228: "FINTERVAL":
229: gsb "nono"
230: dsp "No. of scans to average ?"; ent ",", P; if P<0; jmp 0
231: ret
232: "FHEADER":
233: gsb "nono"
234: dsp "Current HEADER :"; wait 1500; dsp $G$
235: ent ",G$;len(G$)+I
236: int((132-I)/2)+J; "+H$[1,132];G$[1,I]+H$[J,J+1]; ret
237: "ATEST";fxd 3;gsb "READCOUNT"
238: (A+T[4])+2+T[5];prt "Channel Volts";gsb "SCAN"
239: for I=1 to N;prt S$[I,M[I]
240: next I;wrt 16;wrt 16;wrt 16;ret
241: "FMARK":gsb "nono";2+A;gto "OTHERFILE"
242: "FCAL":gsb "nono";3+A;gto "OTHERFILE"
243: "PREPLOT":gsb "nono";4+A;gto "OTHERFILE"
244: "FDLIST":gsb "nono";5+A;gto "OTHERFILE"
245: "PSTOD":gsb "nono";6+A;gto "OTHERFILE"
246: "nono":if flglO;dsp "Not while RUNing";stp
247: ret
248: "OTHERFILE":
249: dsp "Load software tape and CONTINUE";stp
250: ldf 0,0,A
250: +10545
APPENDIX E

ADDITIONAL MANUALS SUPPLIED WITH SYSTEM
HP 9825A Calculator:
- Operating and Programming 09825-90000
- Quick Reference Guide 09825-90011
- General I/O Programming 09825-90024
- String Variable Programming 09825-90020
- Advanced Programming 09825-90021
- Extended I/O Programming 09825-90025

HP Printer:
- 98032A Option 071 Interface Printer Operating Note 09825-90045

HP Multiprogrammer:
- 6940B Multiprogrammer Users Guide 59500-90005
- Multiprogrammer Model 6940B 06940-90005

HP Cards for Multiprogrammer:
- Relay Output/Read Back Model 69433A 69433-90001
- Voltage Regulator Card Model 69351B 69351-90002
- Voltage Monitor Card Model 69421A 69421-90001
- Frequency Reference Model 69601B 5950-1776
- Pulse Counter Card Model 69435A 69435-90001

Lasers:
- Instruction Manual CO₂ Laser Model 941, GTE Sylvania Co.
- Instruction Manual for Series TWO-1Ø YAG-TWO™ Lasers (Serial 162 and Above) General Photonics Inc.
Meteorology:
Instruction Manual for Climet Instruments CI-60
Climet Inst. Co.
Instruction Operation and Maintenance Rate of Rainfall
Transmitter Cat #6069A Book #15615B. BEDFORD INST. CO.
Tipping Bucket Raingauge Model 302 & 303 IM-78B 76 June
ISSUE Meteorology Research Inc.
APPENDIX F
TAPE FILE FORMATES FOR DATA ACCUMULATION
The cassette tape has two tracks, track 0 and track 1. Each track can be subdivided into files, numbered sequentially from 0, and having different capacities of bytes. The Transmissometer data accumulation program requires a specific number of bytes per file labeled prior to the data taking (See program 'FMARK': This makes r10(=290) files of r11(=320) bytes per track).

The data accumulation program writes two kinds of files; a header file, which stores various information about the test data and a data file, which stores the data.

The Header file has the following format:

- **File Type = 0**: 2 Bytes
- **Volumn #**: 2
- **Tape #**: 4
- **Volumn #**: 4
- **Number of channels (N)**: 4
- **Date MMDDYY**: 4
- **Reporting Period**: 4
- **Channel Names**
  - Channel 1: 8
  - Channel 2: 8
  - Channel 3: 8
  - Channel N: 8
- **LASER Channel Calibration Constants**
  - Channel 1: 4
  - Channel 2: 4
  - Channel 3: 4

**HEADER TEXT**

For N=13, less than 272 BYTES

F-1
The data file has the following format:

File Type = 1  2 BYTES
Volume #  2 "
Time of
Record 1
HHMMSS  4 "
Data
Record 1

\[
\begin{align*}
\text{Channel 1} & \quad 4 " \\
\vdots & \quad \vdots \\
\text{Channel N} & \quad 4 "
\end{align*}
\]

Record 6

\[
\begin{align*}
\text{Channel 1} & \quad 4 " \\
\vdots & \quad \vdots \\
\text{Channel N} & \quad 4 "
\end{align*}
\]

For N=13  32Ø BYTES

A volume consists of a header text and a set of data files. The first volume of a data tape on either track is always 1. A data collection that uses up all the files on track Ø, automatically rewinds, and writes a header file with Volume #1 track 1, file Ø and continues data collection. Upon completion of Track 1, the program requires a new tape. If the tape is provided, the program automatically writes a header text, with volume = 1, on track Ø file Ø and continues data collection. No data is lost in either case.

The volume # is incremented if the operator terminates the run with special function key program FTERMINATE or if a fatal error is discovered while running. A new data collection ('FRUN') will then start a new volume of data with the Header File.