APPENDIX A

EQUIPMENT DETAILS

The objective of this appendix is to give more details on various system components.

Reactor Components

The reactor is constructed from four glass sections 5' in length and 6" in diameter. The glass sections are connected through flanges to five metal spool pieces. A schematic diagram of the reactor is shown in Figure A-1.

The spool pieces have entries for sample taps, pressure taps, and thermo-wells to monitor the system. A drawing of a spool piece is shown in Figure A-2. As shown in this figure, the system is designed to insert two pressure taps through each spool piece. Thus, a total of eight DP measurements is feasible with this design. The lines are maintained clear by bleeding a low gas rate through each tap. Use of this arrangement resulted in significant vibrations in the lines and the pressure drop measurements. For this reason, four new pressure taps were rigidly connected to the spool pieces. Although this resulted in reliable measurements, pressure drop measurements are possible only every five feet.

A sample probe can also be inserted into the rector through each spool piece. A drawing of the sample probe asembly is shown in Figure A-3. The probe is inserted into the reactor through a full-bore ball valve. Samples of the slurry are used to monitor the coal fines in slurry concentration along the reactor.

The reactor inlet distributor is based on aproprietary design supplied by Hydrocarbon Research, Incorporated (HRI). The distributor was modeled after the one used by HRI on the PDU. Establishing the proper distance between the bubble cup and the reactor bottom is the key for eliminating plugging problems.

The recycle cup design is also a proprietary design supplied by HRI. It is also similar to the one used by HRI in the PDU. The recycle cup is connected to the downcomer with a section of flexible pipe. The recycle cup is spaced inside the glass with Taflon tabs to keep the cup from scratching the reactor. The cup is supported from the top spool piece with four thin steel pipes.

Gamma-Ray Equipment

An elevator is designed so that a gamma-ray source and detector can travel vertically along the reactor to monitor the fluid dynamics of the system. The source and detector are supported on a Unistrut frame. The frame runs in Unistrut guides with Unistrut trolley wheels. The framework is adjustable so two detector/source combinations can be mounted up to 36" apart.

The gamma-ray system attached to the elevator used for scanning the reactor was obtained from Harshaw and K-Ray. The scintillator detection system was manufactured by Harshaw. A NaI scintillation crystal closely coupled to the photomultiplier tube (PMT) and preamplifier is mounted on the elevator. Other components used are: a stabilized amplifier/ single-channel analyzer, a high-voltage source for the PMT, and a rate meter. The scan output is monitored using a Texas Instruments recorder on the panel board. Ten millicuries of Cs-137 from K-Ray is used as the gamma-ray source. Using the elevator system, the reactor can be scanned continuously from the bottom spool piece to the recycle cup.

An Ortec scintillation detection system and a Cs-137 source are used to scan the internal liquid recycle line at the bottom of the reactor. The components used in this system are the same as in the Harshaw system, except that the amplifier/single-channel analyzer does not have the stabilizer option. A vertical length of pipe is scanned. The system is used to monitor the quantity of entrained gas in the recycle liquid. The output is recorded on a Leeds and Northrup recorder.

Compressor and Pumps

A Corken reciprocating compressor, Model D-290K9, with a 5-HP motor was chosen for recycling gas. This compressor has a water-cooled aftercooler and a continuous pressure unloader. It is designed to pump 102 liters per minute at 1 atm inlet and 4 atm outlet pressures. The compressor discharges into a capacity tank to damp out flow rate fluctuations.

March magnetic drive pumps, Model TE-7S-MD, were originally chosen for the feed, slurry recycle, and transfer pumps. These centrifugal pumps are magnetically coupled to the motor so there are no problems with liquids or gas leaking through a dynamic seal. Because of the magnetic coupling design of this pump, it will not uncouple from the motor, so pump stoppage is not a problem. At a head of 1.4 atm, the pump will deliver about two gallons per minute. The centrifugal pump performed well provided that the amount of gas entrained in the recycle line was not excessive. It was found that under certain conditions the centrifugal pump became vapor-locked. For this reason, a Tuthill rotary positive displacement pump was ordered to replace the recycle pump. The pump was piped in parallel to both the existing feed and recycle pumps so that it could be used to replace either pump. The pumping capacity was controlled with a Reeves motor drive. Control valves were initially used to vary the liquid flow rates, but they were prone to plugging when the fines were slurried with kerosene.

Other mechanical design details are reported in Reference 34.

Control Components

A Honeywell TDC-2000 microprocessor-based system is used for controlling slurry feed and slurry recycle flows, gas flows, gas/liquid separator level, and reactor pressure. Dual-pen analog recording is provided for hard copy of these process variables. Digital displays of variables, set points, and valve positions are also provided.

Flow Measurement

A Nusonics Model 8000 meter was chosen to monitor slurry feed flow rate. The difference in frequency of sonic beams propagated axially to the flow is correlated with flow rate. A MicroMotion flow meter is used to measure slurry recycle flow rate. The deflection of this U-shaped flow tube due to the Coriolis-type acceleration of the flowing liquid is correlated with the mass flow rate. This flow meter was selected because tests show that entrained gases which are well dispersed do not affect flow measurement and entrained gases are expected in the recycle line. A Nusonics Model 6180 concentration analyzer was chosen for continuous monitoring of the coal concentration in the slurry feed. The gas flow is monitored with a Honeywell Model 41105 differential pressure transmitter with an integral orifice assembly. The pressure drop across the orifice is dependent upon the gas velocity.

Pressure

Pressure drop measurements along reactor sections are made to determine the average ebullated bed three-phase volume fraction. Bournes Model 5020 differential pressure transmitters with high speed of response were chosen for this function. Analog recorders used are: a three-pen Gould/Brush Model 2600 with 100 mm scales for the critical high-speed measurements; and two three-pen Texas Instruments Servo/Riters with overlapping pens on a 25 cm grid. All three recorders feature multiple chart speeds for maximum flexibility.

A small, continuous bleed of feed gas through each 3.2 mm ID pressure tap impulse line is used to keep the lines free of catalyst or slurry. Should the lines become plugged, however, a high-pressure gas surge can be initiated manually via three-way solenoid valves in the purge lines.

As discussed earlier, eight pressure drop measurements were made with the taps spaced about 61 cm apart. However, the first series of pilot plant tests exhibited excessive data fluctuations due to the vibration of the pressure measurement impulse lines within the reactor. A liquid-filled impulse line without purge flow was tried, but was unsuccessful because of catalyst and slurry plugging.

Thermowell taps in each spool piece are now utilized for the differential pressure measurements. This eliminated the impulse line vibration problem, but reduced the number of differential pressure measurements to four. The pressure drop across each five-foot reactor section is now being monitored.

Temperature

Process and coolant temperatures are displayed digitally via a 1° resolution Doric indicator and recorded on a Honeywell Model 112 24-point recorder.

Computer Hardware Configuration

The general hardware configuration for the computerization of the unit is shown in Figure A-4. Selected equipment items are described below.

ModComp II Computer.--The computer is a general-purpose 16-bit processor with 128K bytes of memory. It employs a dual moving head disc with 5196K bytes of storage capacity. This computer is equipped with asynchronous ports for serial devices such as CRT's and teletypes and with digital I/O for interfacing with the parallel data bus.

Tektronix 4662 Plotter.--This device is used to generate user plots offline for numerous applications. It is driven by the Tektronix Plot 10 software package, which contains the following features: automatic coordinate transformations (linear, logarithmic, and polar); virtual plotting; relative plotting, segmented line drawing; character generation allowing unlimited control of character size and slant; scaling and rotating of relative virtual vectors. Besides being used for graphic representation of test results, the plotter is also used for generating graphic displays similar to those produced by the Intelligence Systems Corporation (ISC) color graphic CRT, thus allowing hard copy of CRT displays. Examples of this feature are reported in Reference 34.

ISC 8001G Color Graphic CRT.--This peripheral is employed for real-time display of unit data. The CRT has eight colors, which may be used as foreground or background colors, with which graphic displays are generated of the pilot plant. When these displays are output to the CRT, real-time data--which are scanned every minute--are inserted at appropriate locations on the screen. An additional useful feature is a software refresh of data in real time. In this way the data are kept current and trends are easy to spot. Also, this refresh feature can be used effectively when lining out the unit.

Computer Software Configuration

The ModComp II computer used for monitoring this unit is running under MAX II/III, which is a vendor-supplied executive system. In addition to this ModComp-supplied operating system, several tasks have been added to the system environment which implement some very useful features.

All of the "system" programs provide a base for application programs specific to this unit. A generalized flow chart of the applications software configuration is shown in Figure A-5. All of the programs are written primarily in Fortran with subroutine calls to Assembly language subroutines. An exception to this is Program TSC, which operates the traveling scintillation counter. This program is written with a mixture of Fortran and Assembly language. A brief description of each major applications program is given in Reference 34.

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Figure A-1

Reactor design

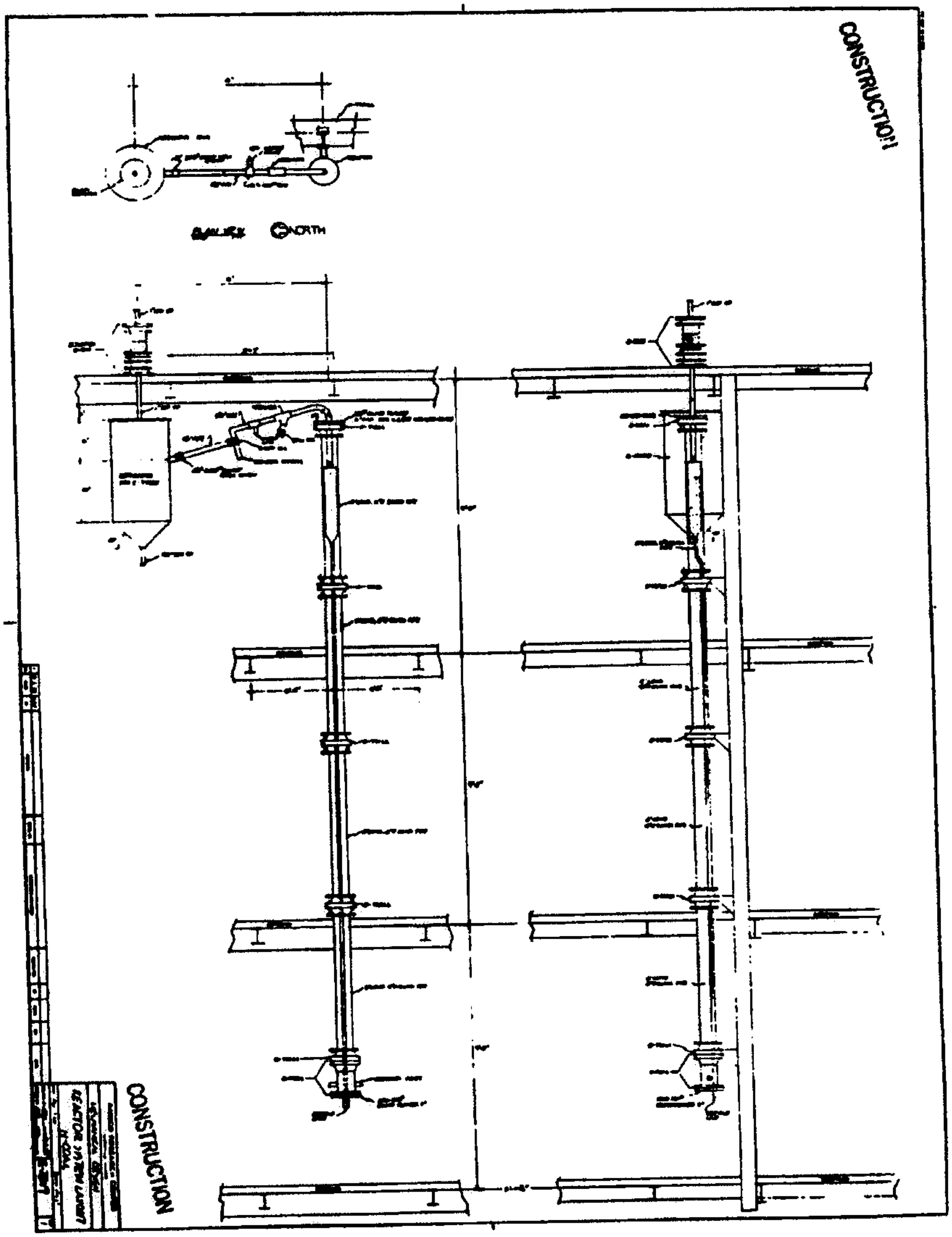

Figure A-2

Spool piece design

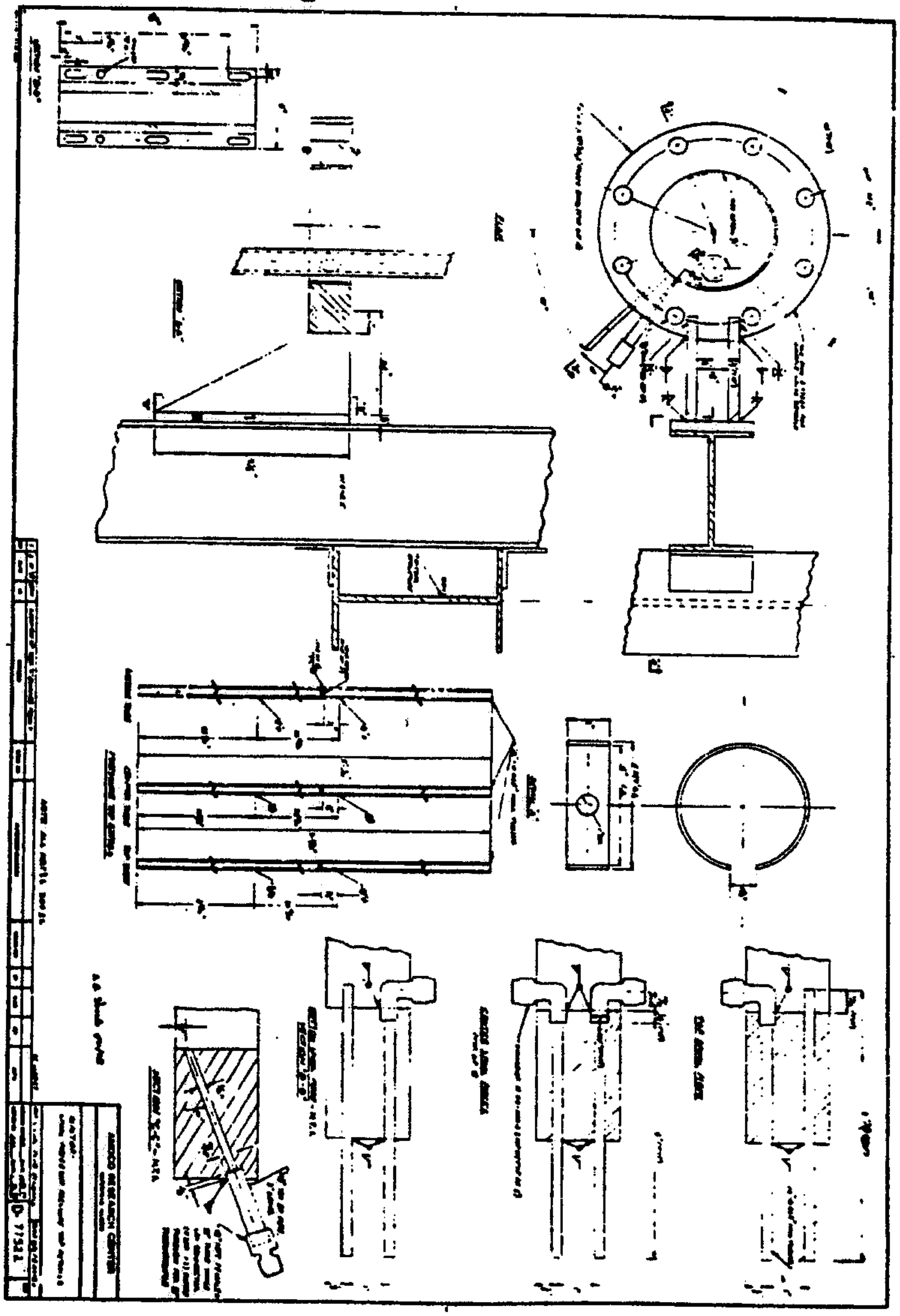

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Figure A-3 M80-21

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Sampling probe design

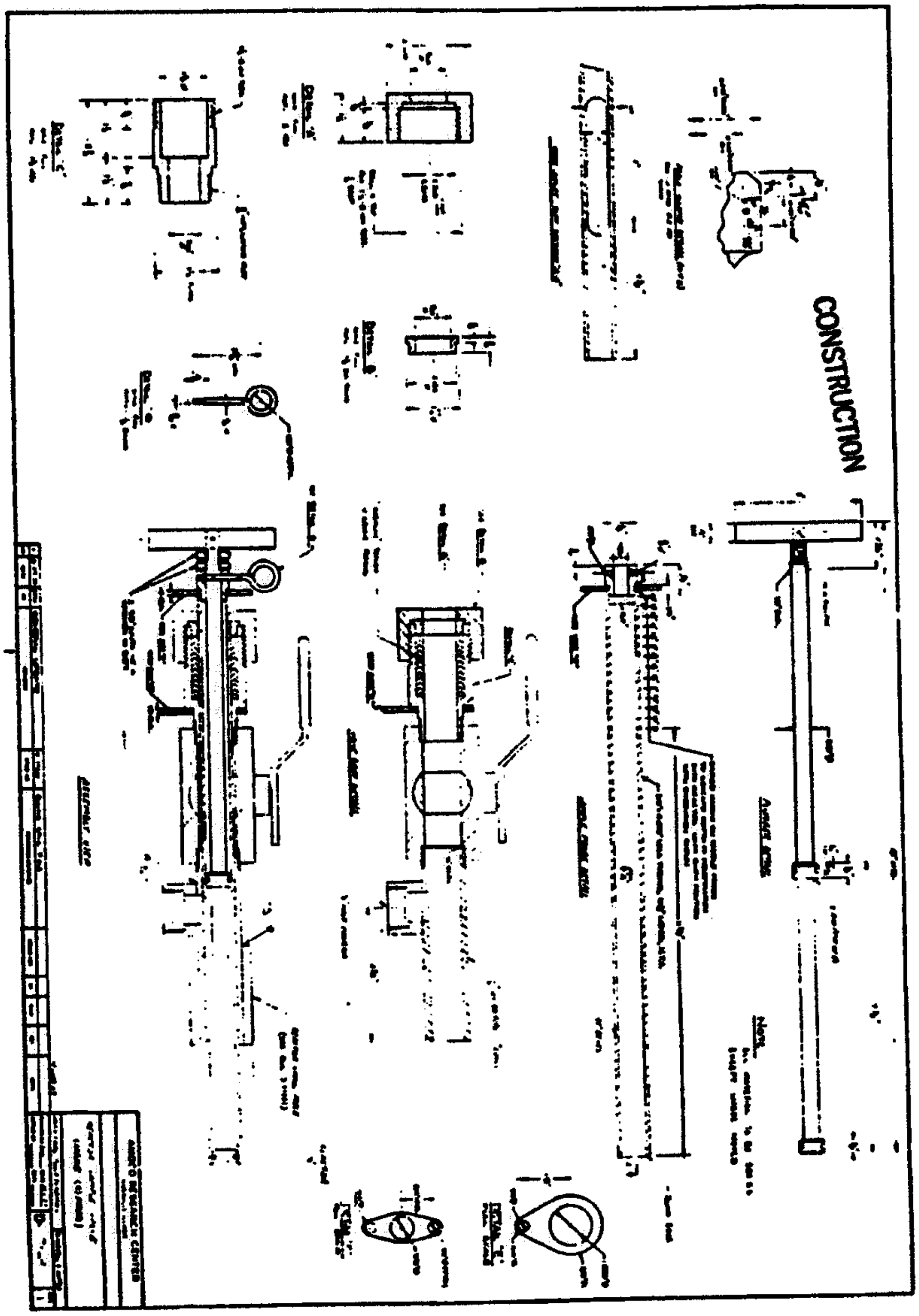

Figure A-4

Computer configuration

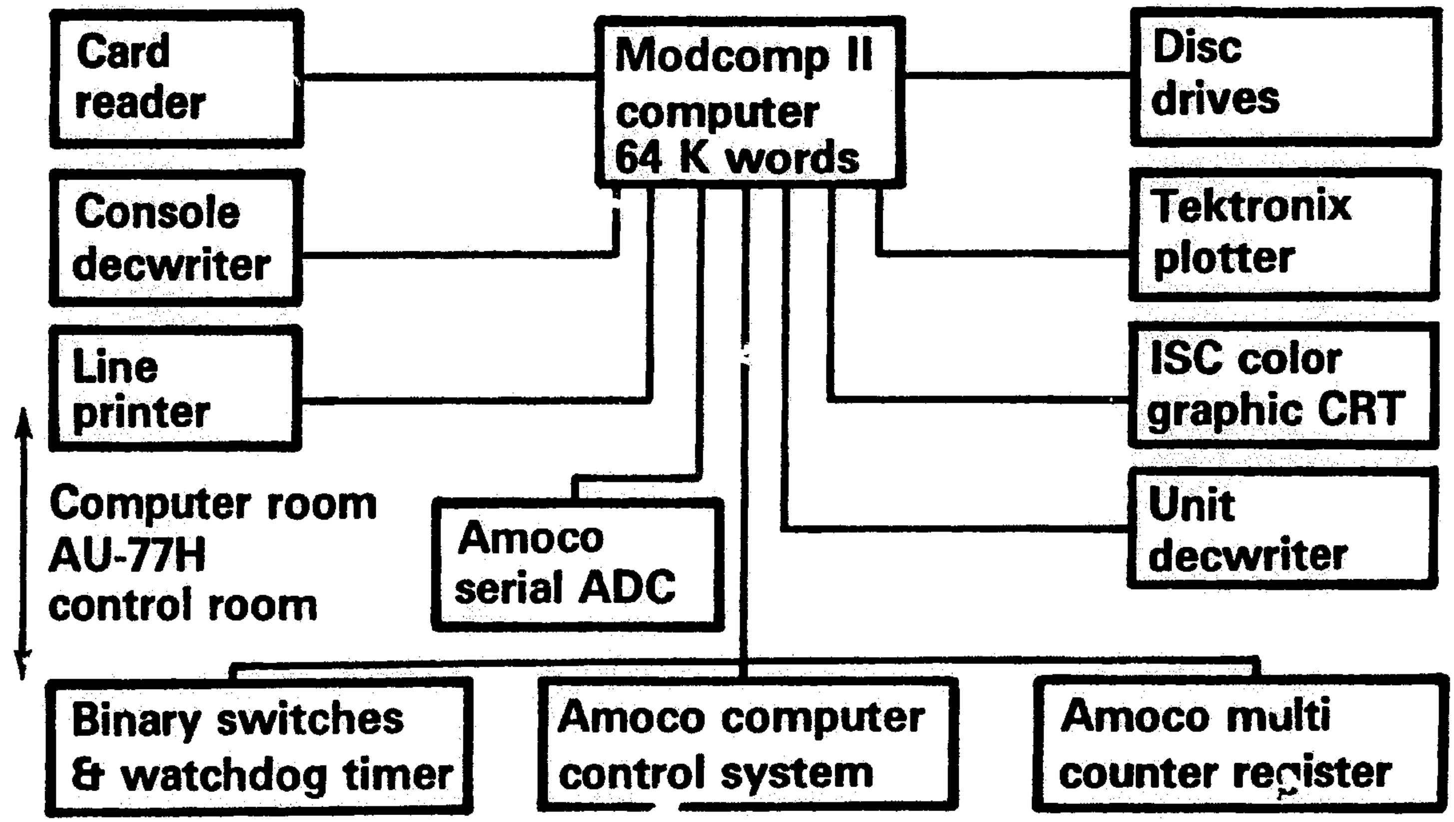

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Figure A-5

Appications software configuration