SYSTEM ENGINEERING LABORATORIES
SEL 810A
General Purpose Computer

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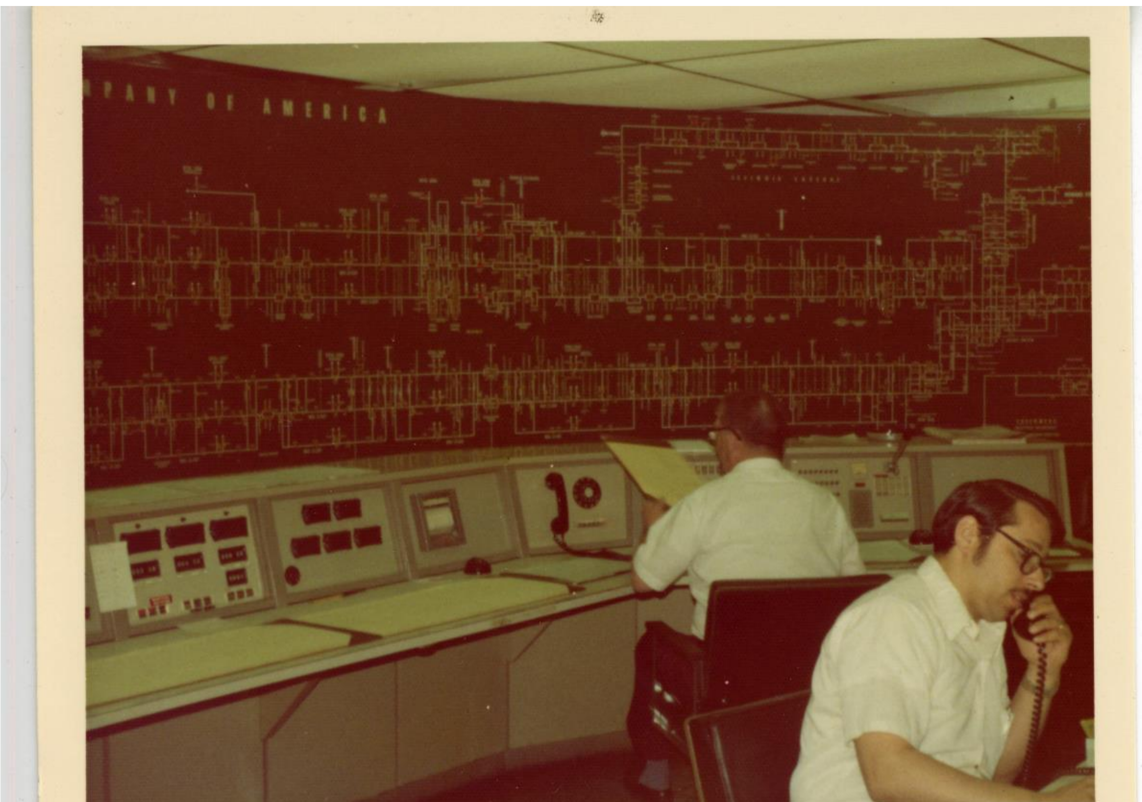
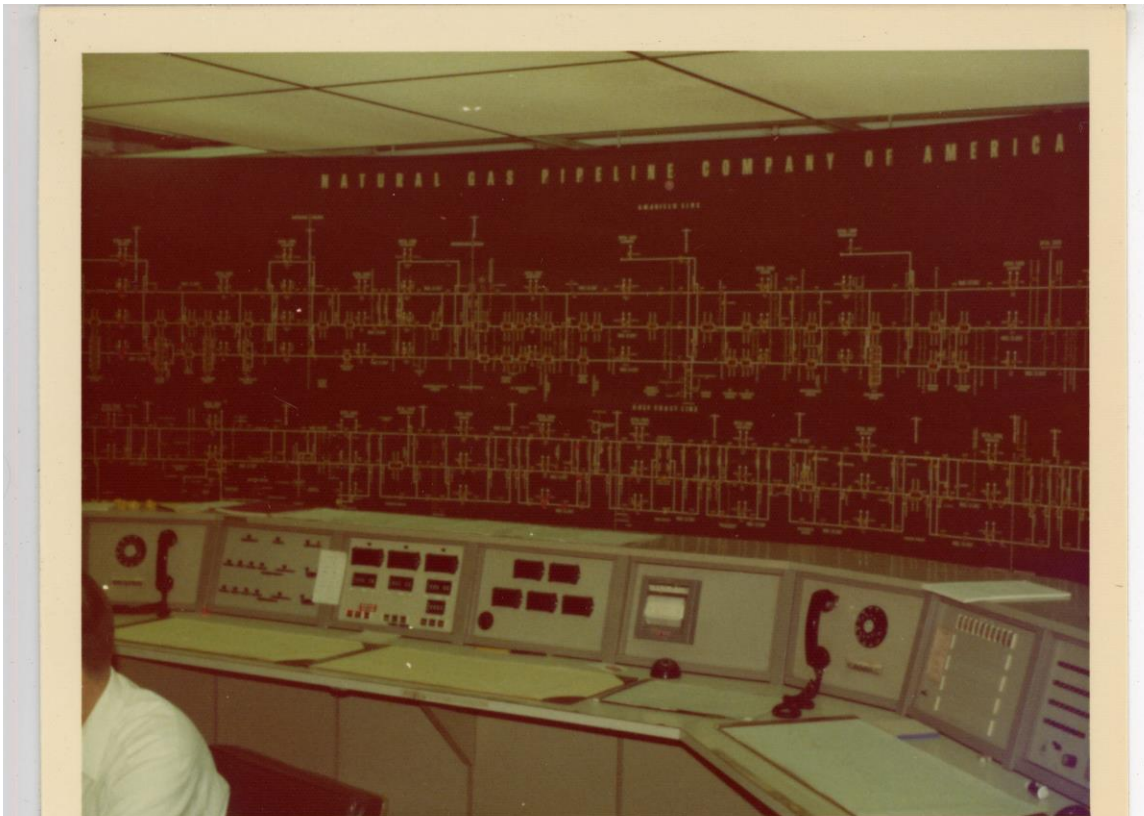
. When I started with Natural Gas Pipeline Company of America (NGPL) in June, 1974 the SEL 810A computers owned by NGPL were 5 years old. NGPL was using the SEL 810A computers in fifteen(15) supervisory control systems for natural gas compressor stations.

NGPL's daily pipeline operations were controlled by a department known as Gas Control.



Natural Gas Pipeline
122 S. Michigan Ave
Chicago, IL

Gas Control Center 1975



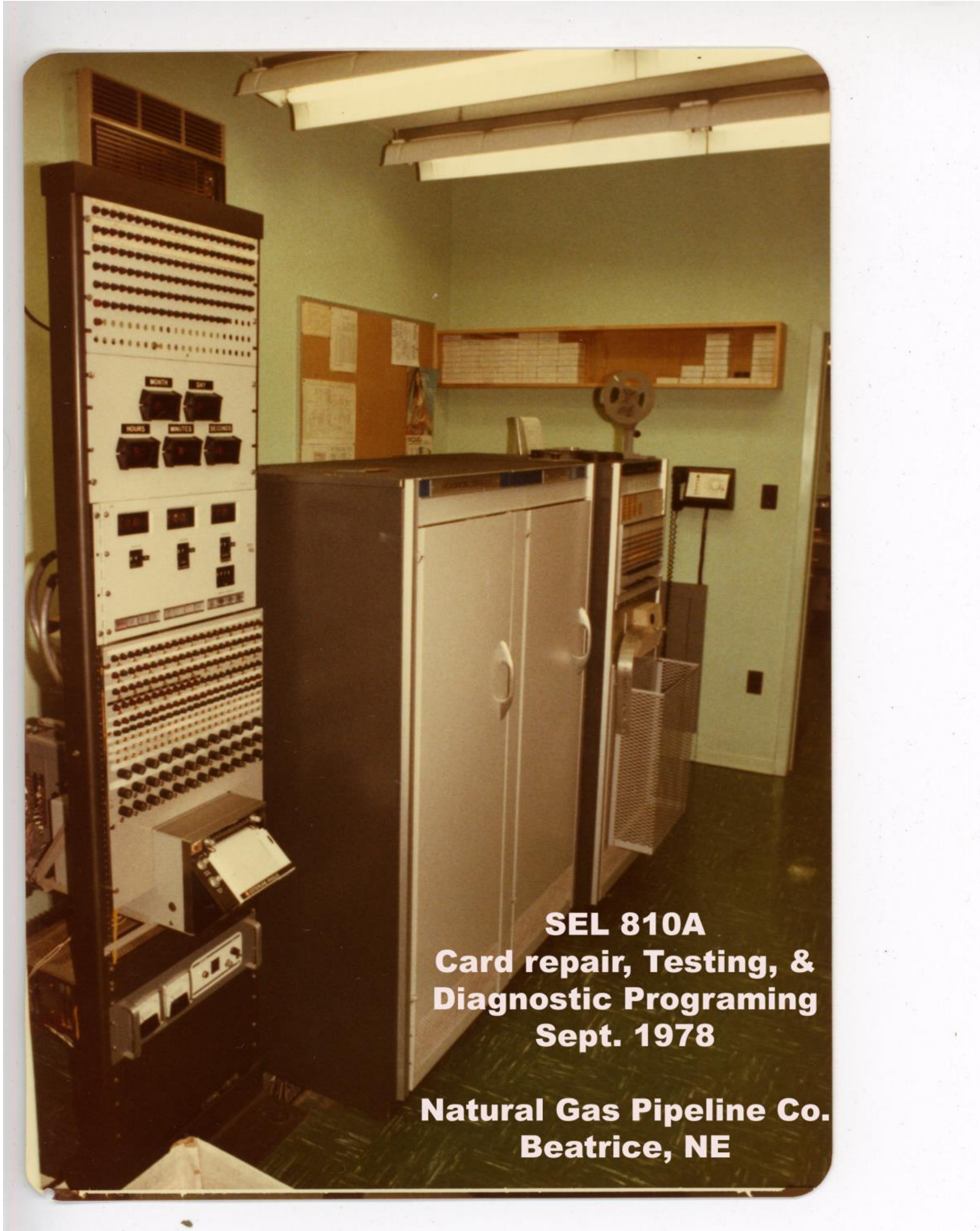
Natural Gas Pipeline Co
122 S. Michigan Ave
Chicago, IL

Gas Control
Operations Console
1975

Their responsibility was to monitor pipeline pressures and flow. They made decisions to run sufficient horsepower to have the required quantity of natural gas delivered to the market area when it was needed. The market area was primarily Chicago, Illinois. The gas moved through the pipeline at about 20 mph.

Natural Gas Pipeline's Amarillo System runs from Lovington, New Mexico to Joliet, Illinois. The SEL 810A computers were installed at natural gas compressor stations 167, 168, 169, 191, 192, 193, 194,195,196,197, 198, 199, and 113. Two additional SEL 810's were installed at compressor stations 342 and 343 on (NGPL's Gulf Coast pipeline system. This system ran from the Gulf area in Texas and Louisiana to Joliet, Illinois.)

In addition to the fifteen(15) SEL 810A computers listed above, three additional units were used for program development, maintenance and support for the field units. Program development and software changes were made by NGPL's Control Department that was located in NGPL's Chicago office. Hardware maintenance and card repair services was performed at Beatrice, Nebraska in by the Communications Department.

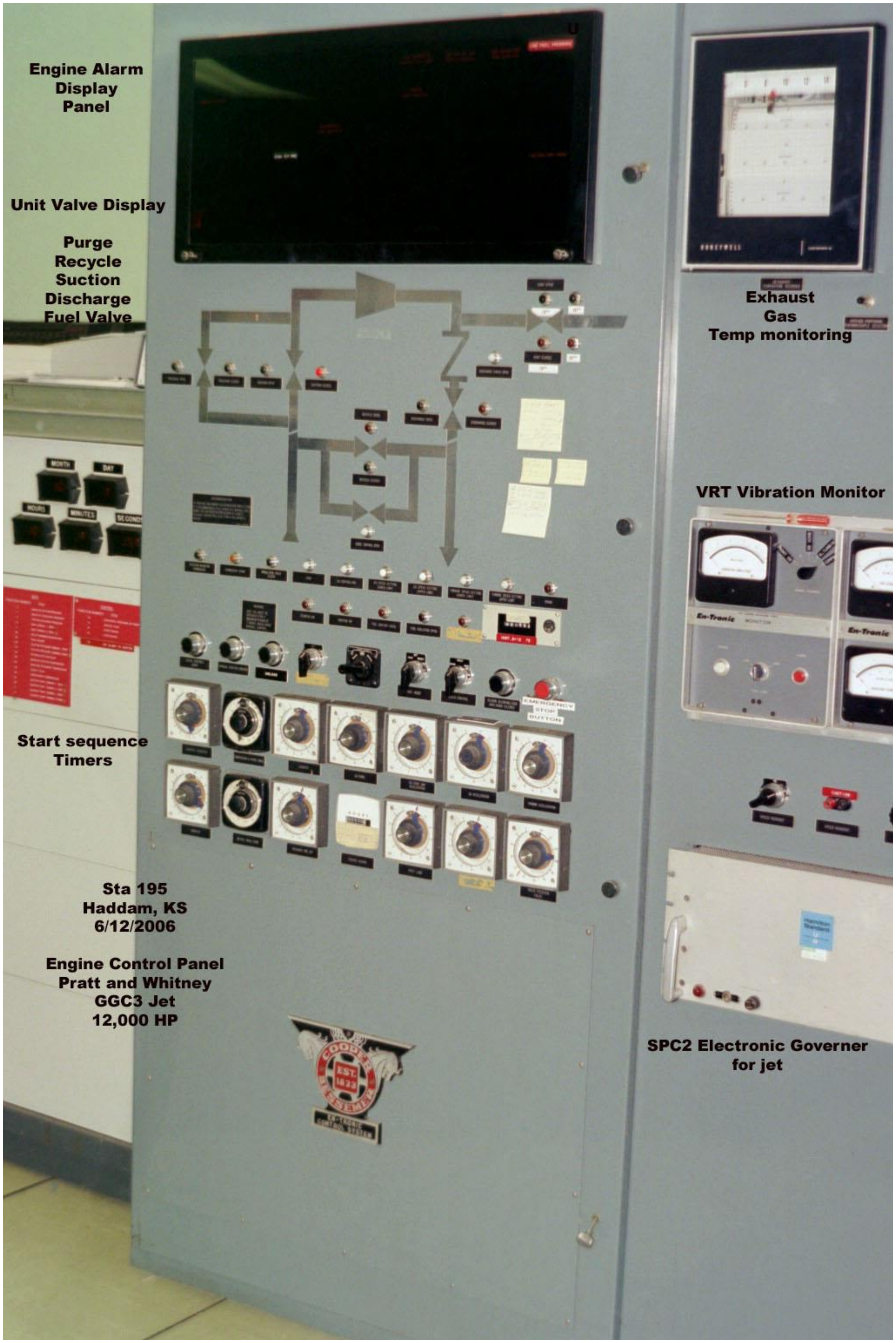


The last of the field SEL 810A computers was retired June 12, 2006. This computer was located at compressor Station 195 near Haddam, KS. This computer was in service for 37 years from 1969 until June, 2006.


Sta 195
Haddam, KS
Interface Cabinet
Computer
Clock &
Display
I/O
Sync.
Modem
Clock
Paper
Tape
Reader
Input
Relays
Latching
Relay
Display
Cables to
DCS cabinet
Output
Relays
DATA-CONTROL STATION
PARABAM

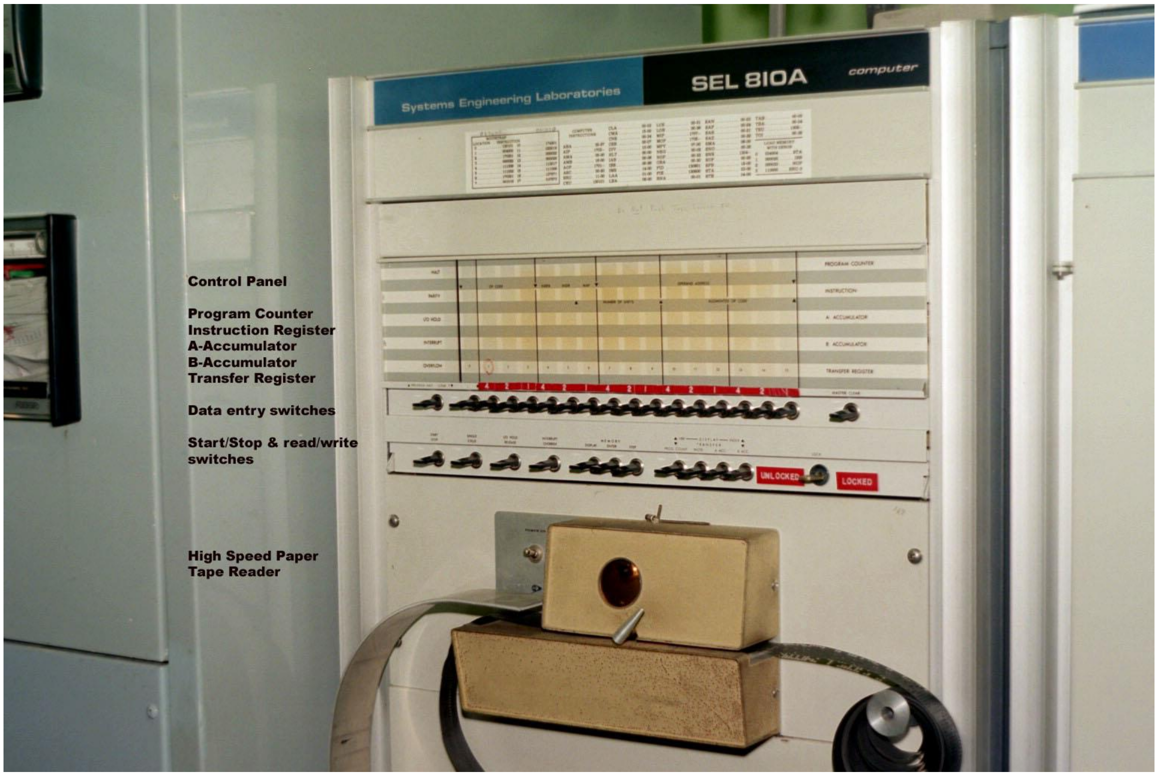
The SEL 810A computer at Sta. 195 with its various interfaces was used to remotely start and stop two natural gas fueled jet turbine engines, to monitor pipeline pressures, to report alarms, and to control station pipeline valves.

Each jet engine was capable of generating 12,000 horsepower. The compressor attached to the rear of each jet was driven by a reaction power turbine that used the jet exhaust to turn the compressor used to pump natural gas through the pipeline.


Engine Alarm Display Panel
Unit Valve Display
Purge
Recycle
Suction
Discharge
Fuel Valve
Exhaust Gas Temp monitoring
VRT Vibration Monitor
Start sequence Timers
Sta 195
Haddam, KS
6/12/2006
Engine Control Panel
Pratt and Whitney
GGC3 Jet
12,000 HP
SPC2 Electronic Governer for jet

The computer interfaces consisted of an input/output controller, a 12 bit analog/digital converter, a synchronous communications controller (remote data communications), and a terminal interface controller for a Teletype Model ASR 33 teletypewriter and high speed paper tape reader.

Software was loaded into the computer in a four(4) step process using the high speed paper tape reader on the front of the SEL 810A.. All software programs resided on punched paper tape.



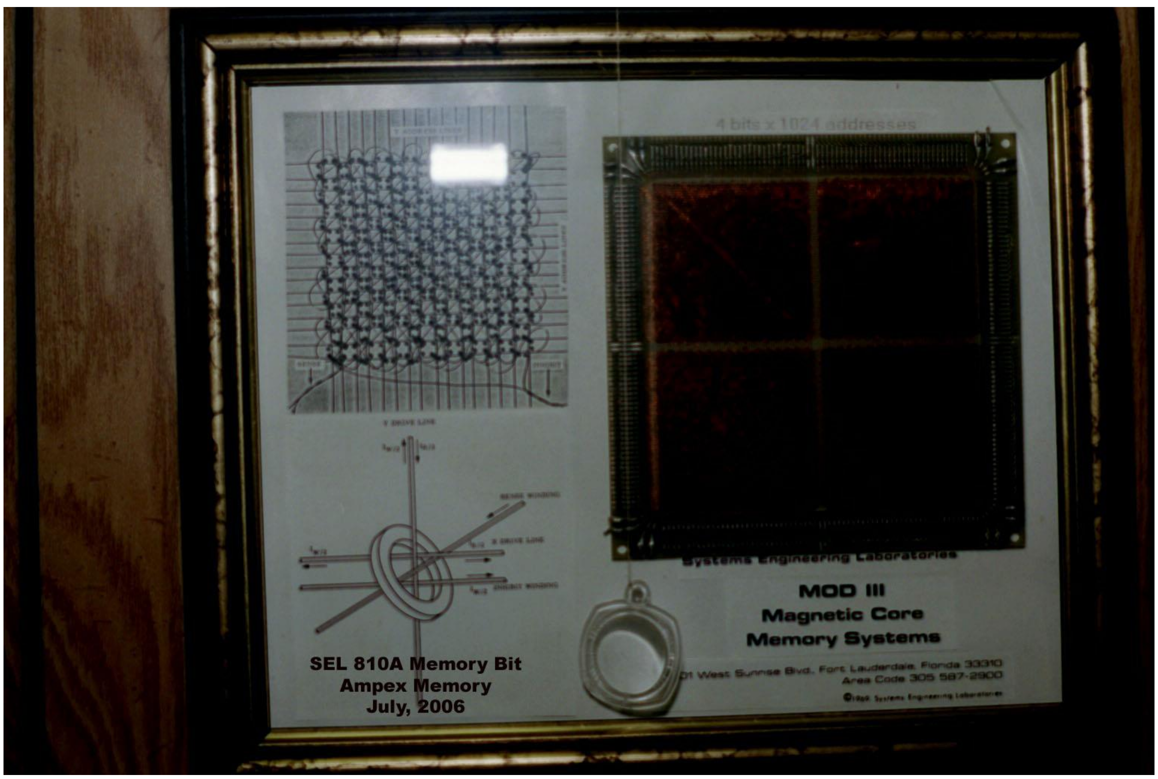
The steps are to load the software were:

1. Manually load a sixteen(16) instruction boot strap program into memory. (This is done by using the 16 toggle switches on the front of the computer control panel)
2. Mount the “Loader Program” in the paper tape reader and execute the bootstrap program entered in step 1 to load the loader program into memory. (The Loader Program was a paper tape program that contained a more complex program to load program tapes. This program would read 64 word blocks from the tape, calculate a checksum value for the block, and then compare checksum to the value punched on the tape. If the checksum did not compare the computer would print a “K” on the teletype and then HALT. You then examined the tape for tears or lint in the holes, rewound the tape and started again.)
3. Rewind the loader program and then mount the Station Program tape in the high speed paper tape reader. Start the loader program at address location 037673 to load the station program into memory.

4. Once the station program was loaded into memory the starting address (001020')of the station program was entered into the program counter by the front panel toggle switches and the START/STOP switch was pressed twice. It was just that easy.

This SEL 810A has 16,384 (16K)words of memory of a maximum amount of 32K. The memory is magnetic core memory and is divided into two 8,192 word modules. Typically the rear backplace contains the lower 8K of memory and the inside backplane contains the upper 8K of memory. The station program occupied about 12 K of the available 16K of memory.

Each word in memory had 18 bits. Sixteen(16) bits were data or program bits. One bit was for parity. One bit was reserved for an optional feature call program protect. (The program protect bit was used to prevent address locations from being erased.)



Each data bit was stored magnetically by polarizing the ferrite material of a circular core. To read the contents of a memory location, all data stored in the addressed cores was erased. The recovered data was temporarily stored in the memory data register. The data was then re-written back into the addressed cores. This was known as a destructive read. Each read operation was followed by a write operation to restore the data recovered from the read operation.

Four physical wires passed through each bit core. The wires were X, Y, Inhibit, and Sense windings. The X and Y wires used to address a particular core. The Inhibit winding was used to write 1's or 0's into a selected core from the memory data register. The sense winding was used in the read operation to sense the polarization of the magnetic field that was stored in the core in order to set bits in the memory data register.

To store a "1" in memory and magnetize a core, the X and Y wires each supplied 360 ma of current through the core to magnetize it. The was total of 720 ma. To store a

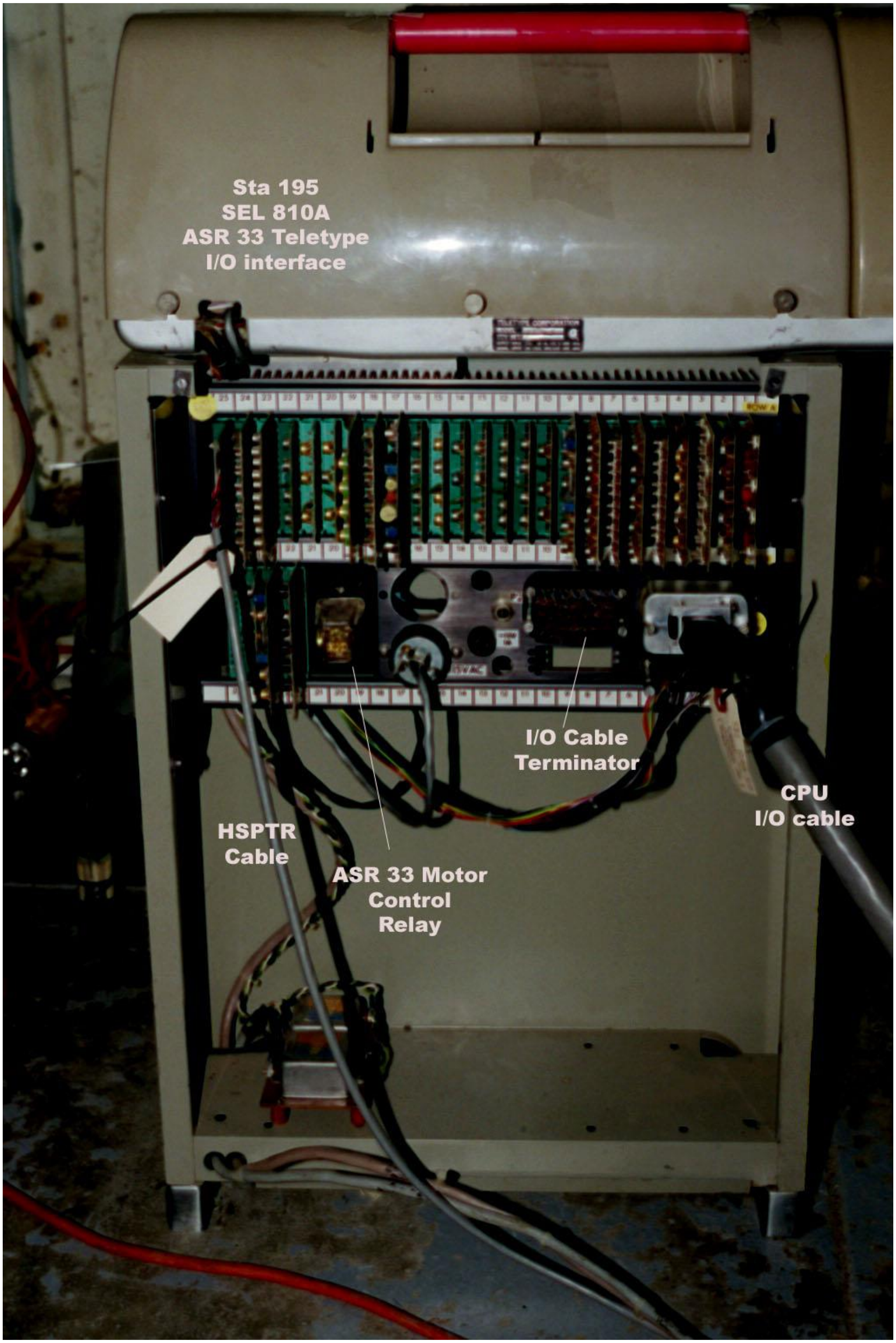
“0” the inhibit winding supplied an inhibit current that ran in the opposite direction of the X and Y currents. The effect was to cancel out the magnetic effect of X and Y currents and prevent the magnetization of the selected core.

A complete memory cycle to read one location and write the contents back into the cores required 1.75 microseconds. This was the basic instruction cycle time of the computer as it took this amount of time to fetch each instruction. Some instructions took as many as three memory cycles to complete.

The math functions were limited to addition, subtraction, multiplication and division. More advanced mathematical functions were performed by software subroutines. It had software subroutines for double precision and floating point math, and sine/cosine functions. It had a Fortran IV library of paper tapes for other program development. NGPL’s program was written in SEL’s macro assembly language.

Computer logic functions included AND, OR, SHIFT RIGHT, SHIFT LEFT and similar functions.

The computer communicated to the interface cabinets through an Input/Output cable(bus). I/O controllers on this bus were used to bring field inputs into the computer for processing. The I/O cable was terminated on each end with 104 pin connectors. The I/O cable diameter is about 1 inch. All the data in and out of the computer on the I/O cable was parallel data. The I/O cable was daisy chained from one controller to the next. Each controller had a unique unit identifier caused it to respond to commands issued to it. The teletype interface located in the base of the ASR 33 pedestal was unit 1.


Sta 195
SEL 810A
ASR 33 Teletype
I/O interface
I/O Cable
Terminator
CPU
I/O cable
HSPTR
Cable
ASR 33 Motor
Control
Relay

The discrete input and output controller was used to read valve positions, permissive start conditions from other panels, function switches on the operator display panel, and the digital clock. The computer would read in a 16 bit word from the controller. The software and wiring defined the function represented by each bit. The Station Operators manual contains the assignments of the input and output bit functions.

The output portion of this controller was used to operate relays that sent control signals to valve controllers to open or close valves, to start engines and to increase or to decrease the reaction turbine speed setpoint. The output portion of the controller was also used to display data on the operator nixie tube displays.

The analog to digital converter was connected to various transducers to monitor pipeline pressures, engine rpm, turbine rpm, gas temperature, atmospheric temperature and other parmeters. Typically there was a total of 24 analog input channels. Three channels were used as a hardware check for the A/D. The voltage on these channels were fixed. The voltages were 0, +2.5 and +5 volts. The station program monitored these voltages. If any reading varied by more than 7 counts (about 10 millivolts) the program alarmed indicating the A/D as being out of calibration. The control system was then placed in STANDBY mode and was disabled from control functions. A/D readings were read by the program every second. It was possible to hear the selector relays in the A/D operate as each channel was selected and read.

All scaling of the A/D data was performed by the station program. A one(1) – five(5) volt signal from analog pressure transducer was scaled to read 400-800 PSI on the nixie tube displays.

Data points were transmitted to Gas Control in response to polling from the Chicago office computer systems. Each synchronous interface contained a card with a hardwired sync word address unique for the station. The polling channel was on a party line circuit via NGPL's private microwave communications system. The protocol used for the communications was unique to NGPL.

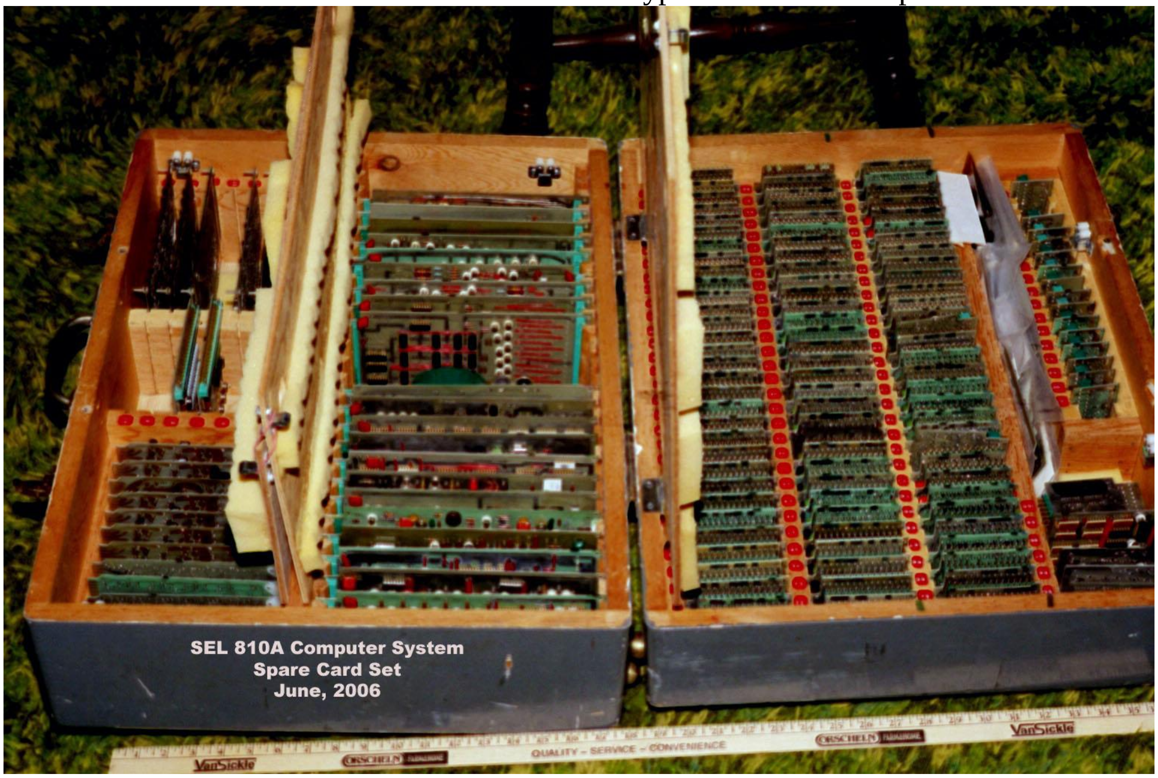
Maintenance on the computers was performed monthly. Generally one communications technician had one SEL 810A computer to tend in addition to other responsibilities. Maintenance involved checking power supply voltages, cleaning cooling fan filters, and checking and oiling the fans were running. The computer system contained 10 separate fans for cooling the electronics.

Power supply dc voltages and ac ripple on all power supplies were recorded and adjusted if necessary. (This established benchmark readings for future troubleshooting.)

Every six(6) months the ASR 33 Teletype was lubricated. The teletype motor that powers the mechanics of the unit had a motor control circuit that allowed the computer to turn the motor off when it was idle. This prevented a lot of mechanic wear on the ASR 33. When data was to be printed, the computer program turned the motor on and then output the characters to be printed.

Annually the technicians ran diagnostic programs on the SEL 810A and interface hardware. Special diagnostic cables were constructed at Beatrice, Ne . These were used with diagnostic programs that allowed all the interface points to be tested. Each A/D channel was connected via a test connector to a 2.5 reference voltage. A program was ran that tested the accuracy and consistency of each A/D channel input. Output relays were looped to input relays to check the operation of the discrete I/O. Other diagnostics that checked the nixies displays, function switches, and modem were ran.

Each SEL location had spare parts kits containing integrated circuits and transistors necessary to do component level repair on any of the logic or power supplies. In addition to components, there were two or three spare card sets that were placed at strategic locations along the pipeline. The spare card sets contained roughly 200 printed circuit cards. This was at least one card for each type used in the computer.



Troubling shooting started with checking power supplies followed by determining what instructions were failing. From that point, you used the schematic drawings of the logic and an oscilloscope to determine what component failed. The SEL 810A computer technical reference manual contained flow charts of timing and gating for each instruction.

The school I attended on the SEL 810A was in February 1976. It was taught by William Delinger who was a instructor from System Engineering Laboratories. The school was four(4) weeks long at NGPL's Beatrice location. The first week was learning the instruction set and some simple programming. The remainder of the time was following signals in the logic drawings to see how the logic worked and troubleshooting problems introduced by the instructor.

Some training sessions were taught by Carl Thompson, an NGPL service engineer. Carl did a lot of work with the SEL 810A systems. He wrote a number of diagnostic programs for maintaining the interface controllers and hardware. The programs he developed were written in the SEL 810A's assembly language. Each instruction was typed on a separate punch card. The cards were then placed in a card reader where the computer read the assembly language and then compiled the program into a binary object program tape.

Carl L. Thompson
Temple V. Guyse
Joel G. Hoegemeier
Robert E. Praeuner
Myron B. Roker
Jerry J. Sneddeker
Tracy C. Losh

It was possible to make copies of paper tapes with the paper tape reproducer/verifier program. This program is loaded into memory. The tape to be copied is loaded into the reader. It was read through in its entirely the first time to generate and store checksum values. The source tape is then rewound and reloaded in the reader. The program then reads the source tape and punches a new one on the teletype paper tape punch. When the operation was complete, the new tape was then loaded into reader for a verification pass. If it failed to verify, the tape was discarded and you tried again. You wanted a good, well oiled teletype to do this. It would take about 20 minutes to punch a new station program tape(12K) if all worked well. The teletype baud rate was 110 baud or 10 (8 bit bytes) charaters per second or five(5) 16 bit memory words per second. (Note: The tape to be copied required a stop code on the end. I think is was three colons.)

One of the more memorable problems I recall was at a compressor location in Texas. You have seen on television and in movies where a computer fails and spews sparks out the front. I bet you thought that was all for show and never to be seen in reality. This computer in Texas did this.

One of the 4 inch muffin fans on a front power supply was replaced. One of the power supply wires came in contact with the rotating fan blade. Each time a fan blade rotated, it hit the wire and arced. Apparently it was throwing sparks out the front at a rapid rate. Sort of a sparkler affect.

One hardware problem I worked on was with the parabam clock. Some unexplained control problems cause us to examine the interface logic between the Parabam clock and discrete I/0 interface. We found that the computer was allowed to read the clock time when the digits were in transition. This problem caused the time the computer read to be incorrect at random times. Carl Thompson wrote a program to verify that his was occurring. We corrected the problem by using some unused logic gates and inhibiting the computer from reading the time when the clock digits were changing. Once we had a solution, the change was added to the interface on all the SEL 810A computers on the pipeline.

When think that the first lunar landing occurred about the time this computer was constructed, it gives you a little idea what computing was like at this time. In searching the internet for SEL 810A, I found a couple of other interesting applications for this machine.

Two SEL 810A's were used as part of a camera aiming system for an Optical Missile Tracking System in the Marshall Islands. They were used as part of a project to track ICBM missles.

A college thesis on Argonne National Laboratories from 1946 to 1992 indicated that in 1968 the Accelerator Division had an SEL 810A.

The on-line library catalog for Los Alamos National Laboratories did a report (LA-3640) in 1967 entitled "Simulation of the SEL 810A computer on MANIAC II (SELMA).

A medical journal "The Journal of Clinical Investigation" Volume 50 1971, page 143 had an article entitled " STUDIES ON HYPERKALEMIC PERIODIAC PARALYSIS. EVIDENCE OF CHANGES IN PLASMA NA AND CL AND INTRODUCTION OF PARALYSIS BY ADRENAL GLUOCORTICOIDS". The article states that "Statistical computations were made by standard methods (19) using an SEL 810A computer." This article was from the Department of Medicine at State University of New York Upstate Medical Center, Syracuse, New York.

The above references indicate that the SEL 810A may have been widely used in a number applications besides controlling of natural gas pumping stations.