Conf-820524--9 6081

INSTITUTE OF GAS TECHNOLOGY

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CONF-820524--9

DE83 000720

DATA-COLLECTION INSTRUMENTATION AND INTERPRETATION FOR GEOPRESSURED AQUIFER WELL TESTS

by

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AC08-78ET27098

Paper Presented at

**SPE/DOE UNCONVENTIONAL GAS RECOVERY SYMPOSIUM
OF THE SOCIETY OF PETROLEUM ENGINEERS**

Pittsburgh, Pennsylvania

May 16-18, 1982

3424 SOUTH STATE STREET

IIT CENTER

CHICAGO, ILLINOIS 60616

AFFILIATED WITH ILLINOIS INSTITUTE OF TECHNOLOGY

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ABSTRACT

The Wells of Opportunity program funded by the Department of Energy, sought to determine the amount of natural gas and thermal energy entrained in geopressured, geothermal aquifers of the Texas and Louisiana Gulf Coast fairways. This determination was made by bringing representative wells onto production for periods long enough to ascertain such characteristics as temperature, gas/brine ratio, reservoir boundaries and permeabilities. During testing, amounts of produced gas and brine were carefully monitored through a computer controlled instrumentation station, which provided reliable and precise indications of the amounts of recoverable gas being produced from the reservoir.

A data collection system was designed to be integrated into the surface test equipment to provide real-time control and data compilation during the well tests. Pressure transmitters continuously monitored the wellhead tubing and annulus, separator, and disposal wellhead pressures. Differential pressure transmitters (DPTs) provided continuous readings across the flare line orifice plate and downstream brine filters. Temperature transmitters relayed wellhead brine, flare line gas, and disposal brine temperatures. Turbine meters upstream of the choke and after the separator measured the brine flow. Signals from an acoustic sand detector located after the choke and upstream of the separator were monitored to provide data on solids production.

All sensors sent outputs to an analog to digital converter that was monitored by a microcomputer, which converted the outputs to standard units. The computer scanned each channel every five seconds and appropriately averaged the measurements over an interval selected by the operator. Data was recorded on

magnetic cassette tapes by date and time. In addition, a separate thermal printer displayed a list of the recorded values. The microcomputer's internal printer displayed calculated flow rates for the two-phase flow at the wellhead and for the brine after the separator.

Strip chart records provided real-time control information during the test. All pressures, both differential pressures, brine and gas temperatures, and sand detector signals were displayed, and the physical records were maintained for interpretation of well performance.

The data collection system coupled with the interpretation software permitted gas/brine ratio to be determined with accuracy of five percent for values as low as 0.02 MCF/STB. In addition, graphical representation of well performance, brine flow rates, gas production, pressure histories, etc., could be made as the test progressed.

Data system reliability was very high. Downtime was minimal even under relatively harsh environmental conditions for electronic equipment. A backup power supply functioned properly during power failures without interrupting data collection. This data collection system, while designed initially for geopressured aquifers, is adaptable to the automated collection of scientific and engineering information for the interpretation of well tests of other petroleum resources.

INTRODUCTION

IGT's instrumentation unit, housed in a 38-foot trailer along with field analytical chemistry facilities, is capable of continuous automatic measurement of produced natural gas and brine from a well in user-designated time intervals as short as 15 minutes. In addition, the produced fluids were chemically analyzed and their results were used in conjunction with

References and illustrations at end of paper.

the automated data collection system for an interpretation of the gas/brine ratios (GBRs). These measurements are a reliable basis for predicting well performance and economic feasibility.

To date, two Louisiana Gulf coast and three South Texas wells have been monitored for extended periods with the aid of the instrumentation network. This paper describes both the component network and operational functions of the system.

INSTRUMENTATION

Figure 1 shows the instrumentation system used to measure the parameters required for determining flow rates, production, and GBR as a function of time, and those utilized to detect production problems. The data gathering and reduction network consisted of the following five basic subgroups:

- o Digital Data Recording group (DDR). The primary function of this group is to provide computerized control of data input/output and processing functions. The DDR consists of a Hewlett-Packard HP-85 desktop computer with an internal thermal printer and magnetic tape drive, a Hewlett-Packard 6940B multiprogrammer and associated interface unit, an external impact or thermal printer assembly, and all connectors, interfaces, and software required for the acquisition of data. The microcomputer acts as the system controller and uses stored calibration data to provide outputs in desired units.
- o Surface Equipment group (SE). All parameter sensing, monitoring, and conversion to computer readable signals is performed by the SE hardware. This group consists primarily of two turbine meter units, three resistance temperature detector (RTD) type temperature devices, four pressure transmitters, two differential pressure transmitters, a complete array of backup devices and the wiring umbilical which passes uninterruptible power to the transmitters and data from the transmitters and sonic sand detector to the DDR and AR.
- o Analog Recording group (AR). This is the real-time control and backup system. The AR protects critical data channels from computer-generated interruptions while providing visual displays of parameters. The group consists of four dual trace Hewlett-Packard strip chart recorders with heat-writing option, and one Hewlett-Packard dual trace recorder with an ink-writing option.
- o Electrical System (ES). This subsystem provides one of three types of system power, uninterruptible 110 V ac, unregulated 110 V ac and uninterruptible 24 V dc to each electrical component of the

data collection network. Components of the ES include a 24 V dc power supply and a Topaz 110 V uninterruptible source with battery storage capable of maintaining a full load for 4 to 6 hours of continuous operation through a 60 cycle inverter.

- o Analysis/Interpretation group (A/I). This group combines raw data with the results of chemical analyses, reduces the data, and generates data plots, tables, and reports. The group consists of a Hewlett-Packard HP-85 controlling computer selected for its interchangeability with the DDR controller, a four-pen plotter capable of generating color-coded graphs of all monitored production parameters, and a modem which can transmit well data through telephone lines to a similarly equipped computer at IGT's Chicago facility.

As illustrated in Figure 1, each of the five basic subgroups was an integral part of the entire data collection and interpretation system. Permanent records were maintained on magnetic tape and on strip charts with the latter providing visual real-time information for control of the well test. The capability of continuous operation, even during power interruptions which occasionally do happen in the field, is an important system design feature. Compatible desk-top computers for data collection and interpretation facilitated the reservoir performance analysis and provided for a backup system controller should the data collection (DDR) computer malfunction.

A separate analytical chemistry section housed in the trailer along with the automated data collection system provided information on gas and brine composition. While the chemistry section of the trailer complemented the data collection effort, detailed discussions of the analytical chemistry equipment and procedures are omitted from this paper.

DATA ACQUISITION

Typically, data acquisition from any particular channel proceeded in the following manner: A signal transmitter, which received its power (110 V ac or 24 V dc) from an uninterruptible supply inside the trailer, converted a sensed parameter (pressure, temperature, differential pressure, or noise) into a 4-20 mA current output. This current was converted to a 1 to 5 V dc signal which was applied to both the DDR and the AR. Inside the DDR, this signal was sampled every five seconds by a computer and averaged over an interval chosen by the operator for output to a printer and stored on a magnetic tape, where it was subsequently retrieved for interpretation.

In the analog section permanent records were provided by strip chart recorders which were used to provide visual records of greater time resolution than that inherent in computerized printouts. These records also provide data for real-time control. The data

collection process began before the well was opened and continued until after the shut-in well stabilized.

As the data were made available to the A/I section from the DDR, they were combined with the results of the field chemical analysis and assimilated into a comprehensive overview of well performance and characteristics. In the A/I, processed information was produced in the form of computer-generated daily reports, plots and printouts. In addition, the A/I hardware is fully interchangeable with that in the DDR, thus providing flexibility and redundancy should the need arise.

Pressure data were generated by sensors installed on production wellhead tubing and annulus ports, the separator, and the injection wellhead. Diffused silicon type sensors were used in which a 4 to 20 mA current proportional to pressure was generated by a strain-gauge circuit diffused onto a hysteresis-free silicon crystal. The wellhead pressure transmitters were calibrated from 0 to 10,000 psig and the separator and disposal well sensors from 0 to 1,000 psig.

RTDs measured temperature at the production wellhead, on the gas leg of the separator, and at the disposal wellhead. These sensors operate by returning a 4 to 20 mA dc current proportional to resistance change, which is a linear function of temperature from 0 to 400° F.

Strain-gauge-type DP cells recorded differential pressures across the separator orifice plate and across the filter assembly, which conditions brine for disposal well injection. The 4 to 20 mA output of these cells was proportional to differential pressure. The DPT on the gas leg of the separator was calibrated to read 0 to 400 inches of water, while the filter DPT ranged from 0 to 100 psid.

Turbine meters at the production wellhead and on the metering skid after the separator brine leg transmitted pulses to an amplifier/counting unit located inside the trailer. The turbine meter at the wellhead measured two-phase flow rates. A turbine meter mounted on a skid accurately measured the produced brine leaving the separator.

IGT's instrumentation system also monitored outputs from a sand detector unit maintained by surface equipment contractors. The sand detector was used to detect solids production from the reservoir and provided a basis for calculating the volume of produced sand.

Signals from all sensors were transmitted to a junction box inside the IGT field test trailer through a wiring umbilical. The wiring harness also transmitted uninterruptible system power to the sensors.

Continuous unprocessed data at the junction box was routed to a computer multiprogrammer

where it was sampled every five seconds and averaged over operator-selected intervals. The outputs were stored on magnetic tape and displayed by the printer. A continuous record was also made on strip chart recorders at the same time. Supplemental strip charting of signals fulfills three important functions: 1) Providing timely display for operational control decisions. 2) Providing visual records with greater real-time resolution than that inherent in the computerized printouts, and 3) providing an effective backup system in the event of computer-related malfunction, in which case the traces could be manually digitized at a later date for output to analytical software without down time or loss of accuracy.

Each midnight from start of test until final shut-in the magnetic tape containing data for the previous 24-hour period was duplicated and input to the analytical software, where records of the day's production details such as flow rate, cumulative production, and GBR were generated for inclusion in the daily report. The magnetic tape for the next day's data was inserted into the computer where it was assigned the next sequential number. The data file was automatically coded for time and date.

At the completion of each test, a more comprehensive printout was produced that detailed the history of the entire test in half hour increments with analysis of gas and brine production rates, GBRs, and cumulative production of brine, as well as hydrocarbon and thermal energies.

SOFTWARE

Several computer programs were developed to drive hardware that collected, analyzed, reduced, plotted, duplicated and printed data records collected in conjunction with the field tests.

The logic flow for the program which collected and averaged unprocessed data, printed and stored it on magnetic tape is shown in the flow diagram, Figure 2. After the execution of each subroutine the program determined the status of the interrupt flag. An interrupt flag was set by the operator anytime it became necessary to read computer memory stored values at other than default times, to change these default times, exchange data tapes, reset the cumulative brine barrel counter, change orifice diameter, or output a remark to the printer.

Anytime the interrupt flag had not been triggered the program continually read it's own internal quartz crystal clock and determined if five seconds had lapsed since data channels were scanned. If not, the clock reading was continued. When five seconds had elapsed, all data channel values were read by the multiprogrammer and, with the exception of two channels, stored into computer memory. The exceptions were the values for separator orifice differential pressure (h_w) and

separator static pressure (P_f) which were raised to the $1/2$ power prior to computer memory storage. Taking the square root of these parameters at that time and subsequent averaging permitted accurate gas flow rate (Q_b) calculations in spite of wide fluctuations in both h_w and p_f .

After storing data values into the computer memory, the program determined if the operator-selected time interval had elapsed since data values were last averaged, printed and stored on magnetic tape. If this determination proved true, all data values were recalled from computer memory and averaged, total cumulative brine flow was calculated over this interval, brine flow and gas flow rates were deduced, and all values were stored on magnetic tape and printed in tabular form on the external printer. If not, the program returned to the mode of five second checks.

Other programs developed for the Wells of Opportunity fall into two basic categories -- those which handle basic plotting and printing routines and those which handle reduction of large data bases into manageable formats¹. Figure 3, a representative sample of the former, is a graphical representation of GBR vs. time during the final seven days of production of the second Well of Opportunity. Output of data base reduction software which calculates the correction for brine volume from production temperatures to stock tank barrels is depicted in Figure 4. Final results tabulated in Figure 5, include values for both wet and dry flare gas rates and disposal well gas. Wet gas values in this table reflect no correction for steam content in gases through the orifice meter. Dry gas rates are fully corrected. The column labeled disposal gas reflects calculations of post separator gas/brine ratios, as a function of separator pressure, discussed in the Appendix.

CONCLUSIONS

The automated data collection and analysis system, augmented with the field analytical chemistry results, provided an accurate account and interpretation of the fluids produced during well tests. In particular, gas and brine production volumes and rates, thermal energy, and well performance were monitored and analyzed to determine the gas/brine ratio and the capacity of the reservoir to produce fluids. Overall accuracy of better than 5% is believed to have been achieved in the GBR determination².

The equipment reliability was very high with limited downtime, despite some severe environmental conditions encountered and heavy usage, especially for the electronic components. Use of an uninterruptible power supply was essential to provide continuous electrical power due to failures of field generators and outside power sources.

Continuous monitoring of critical

pressures, temperatures, and differential pressures provided improved accuracy and more data on which to base scientific analyses and engineering assessments than traditional hand-logging of information permits. Use of data stored on magnetic tapes simplified analysis procedures. Automated electronic data collection allowed the field staff more time to concentrate on interpreting and understanding the test progress.

This data collection system was primarily designed for use on geopressured geothermal formations. However, with minor modifications to sensors and software, the equipment and procedures discussed above can be applied to testing other petroleum resources.

NOMENCLATURE

- Q_b = Flow rate at base conditions, (ft³/hr)
- C' = Orifice flow constant, (dimensionless)
- h_w = Differential pressure, (in of H₂O @ 60°F)
- F_b = Basic orifice factor
- F_r = Reynolds number factor
- Y = Expansion factor
- F_{pb} = Pressure base factor
- F_{tb} = Temperature base factor
- F_{tf} = Flowing temperature factor
- F_g = Specific gravity factor
- F_{pv} = Supercompressibility factor
- F_m = Manometer factor

REFERENCES

1. Rose, R.E.: "Field Operations Manual -- Unconventional Natural Gas Research Well Test Trailer, Volume II, Software", Institute of Gas Technology, Chicago, 1982
2. Randolph, P.L.: "Gas/Brine Ratio From Tests of Five Wells of Opportunity", Fifth Geopressured-Geothermal Energy Conference, Baton Rouge, Louisiana October 1981
3. American Gas Association: "Orifice Metering of Natural Gas", Gas Measurement Committee Report No.3, New York, April 1955.
4. Culberson, O. L. , and McKetta, J. J. Jr.: "Phase Equilibria in Hydrocarbon-Water Systems III- The Solubility of Methane in Water at Pressures to 10,000 psia", Petroleum Transactions, AIME Vol. 192, 1951.
5. "Standard Method of Calculating Calorific Value and Specific Gravity of Gaseous Fuels", edition approved June 24, 1977,

ANSI/ASTM d 3588-77, ASTM Committee D-3 on Gaseous Fuels, American National Standards Institute, New York.

APPENDIX

METHODOLOGY FOR GAS BRINE RATIO DETERMINATION

The gas/brine ratios were determined by the following procedure:

- o Gas production rates to the flare line are calculated for specific time intervals on the basis of procedural specifications of the American Gas Association (A.G.A.) Gas Committee Report³. This calculated gas production is then reduced for steam content by subtracting the ratio of partial pressure of water to separator absolute pressure.
- o Brine production rates over identical time intervals are calculated by subtracting successive readings of cumulative production values and correcting these to stock tank barrels from separator conditions.
- o Gas production rates are divided by brine production rates to obtain flared gas/brine ratios.
- o The GBR of post-separator fluids is estimated with the algorithm developed by System Science and Software to fit data of Culberson and McKetta⁴ for methane solubility in distilled water. This value is added to flared GBR to obtain total GBR.

The general equation relating gas flow rate and measurable parameters from the A.G.A. handbook previously cited is -

$$Q_b = C' (h_w \cdot p_f)^{1/2} \dots \dots \dots (1)$$

The orifice flow constant C' is defined as

the flow rate in ft^3/hr at base conditions when $(h_w \cdot p_f)^{1/2}$ is equal to unity, and is given by the following equation:

$$C' = F_b \cdot F_r \cdot Y \cdot F_{pb} \cdot F_{tb} \cdot F_{tf} \cdot F_g \cdot F_{pr} \cdot F_m \dots \dots \dots (2)$$

The component factors of C' are themselves functions of various interrelated parameters such as meter run I.D., orifice diameter, absolute flowing temperature, specific gas gravity, gas heating value, absolute viscosity, and mole fractions of both carbon dioxide and nitrogen:

Fortunately, A.G.A. methodology provides empirical relationships between many of these difficult-to-asertain parameters and the chemical compositions of the gas, which greatly facilitates computational efforts and reduces task complexity.

In practice, with a temperature base of 520°R (60°F), a pressure base of 14.73 psia and a meter run I.D. of 1.939 inches, which remained constant from well to well, C' was uniquely determined with a knowledge of gas temperature and chemistry for C_1 to C_6 hydrocarbon fractions and content of both carbon dioxide and nitrogen, which were determined by personnel in the chemistry laboratory on site.

Algorithms based on ANSI/ASTM D3588-77⁵ methodology, developed by IGT for this project, allowed automatic computation of heating value and specific gas gravities based on hydrocarbon fractions. Supercompressibility values based on gas composition, pressure and temperature were determined using algorithms developed by IGT for another research program.

With C' determined, gas flow rate Q_b required only a knowledge of separator static pressure and the differential pressure of the gas across the orifice meter, both directly measurable from separator sensing apparatus.

Figure 1. INSTRUMENTATION UNIT SCHEMATIC DIAGRAM

Figure 2. FLOW DIAGRAM FOR RAW DATA COLLECTION, AVERAGING, PRINTING AND STORING

Figure 3. REPRESENTATIVE COMPUTER PLOT: GBR vs. TIME

113

IGT WELL TEST ANALYSIS

MARTIN - CROWN ZELLERBACH
WELL NO. 2

DATE: 6/17/81

GAS COMPOSITION:
NITROGEN..... 0045
CARBON DIOXIDE..... 2409
METHANE..... 7047
ETHANE..... 0389
PROPANE..... 0069
N-BUTANE..... 0008
I-BUTANE..... 0007
PENTANES..... 0002
C6+..... 0024

CALCULATED GAS PROPERTIES:
DRY GAS HTG VAL..... = 818.84
DRY GAS GRAVITY..... = .8241

PRES BASE=14.73; TEMP BASE=60F
THERMAL ENERGY BASE TEMP =120F

PRODUCTION SUMMARY:
-----GAS----- THERMAL
(MCF) (MMBTU) (MMBTU)
DAILY 56.8 46.5 48.6
CUM. 75.8 61.4 59.5

PRODUCTION DETAILS:
TIME BRINE GAS
DEGF STBPD MCF/D SCF/STB
0030 190 2867 91.3 31.85
0100 191 2846 91.9 32.29
0130 193 2837 90.6 31.94
0200 194 2838 89.2 31.42
0230 195 2781 89.4 32.16
0300 195 2768 89.7 32.41
0330 196 2744 88.2 32.15
0400 197 2729 87.9 32.22
0430 197 2716 87.7 32.30
0500 198 2695 86.8 32.20
0530 198 2677 86.9 32.47
0600 198 2667 85.9 32.21
0630 199 2662 85.1 31.96
0700 199 2646 85.8 32.14
0730 199 2627 84.6 32.21
0800 200 2605 84.2 32.31
0830 200 2601 82.8 31.85
0900 200 2589 82.7 31.97
0930 200 2572 82.2 31.97
1000 200 2566 82.3 32.06
1030 200 2547 82.1 32.23
1100 200 2548 80.6 31.64
1130 201 2538 81.8 32.02
1200 201 2528 79.7 31.51
1230 201 2518 79.9 31.84
1300 201 2516 79.8 31.70
1330 201 2497 80.6 32.28
1400 201 2494 79.6 31.90
1430 201 2496 79.9 32.00
1500 201 2480 78.8 31.79
1530 201 2474 79.1 31.98
1600 201 2465 78.9 32.02
1630 190 1091 33.7 30.85
1700 178 0 0.0 0.00
1730 164 0 0.0 0.00
1800 153 0 0.0 0.00
1830 - 0 0.0 0.00
1900 - 0 0.0 0.00
1930 - 0 0.0 0.00
2000 - 0 0.0 0.00
2030 - 0 0.0 0.00
2100 - 0 0.0 0.00
2130 - 0 0.0 0.00
2200 - 0 0.0 0.00
2230 - 0 0.0 0.00
2300 - 0 0.0 0.00
2330 - 0 0.0 0.00
2400 - 0 0.0 0.00

Figure 4. SAMPLE OF DAILY SUMMARY OF PRODUCTION DETAILS

***** IGT WELL TEST ANALYSIS: MARTIN - CROWN ZELLERBACH WELL #2 *****

PRESSURE BASE = 14.73 PSIA

TEMPERATURE BASE = 60 DEGREES F

THERMAL ENERGY BASE TEMPERATURE = 120 DEGREES F

--DRY GAS PROPERTIES--					---FLARE GAS RATE---			---BRINE RATE---		GAS TO BRINE RATIO			----CUMULATIVE PRODUCTION----			
DATE	TIME	HHV	GRAV-	Fpv AT	WET	DRY	HYDRO-	AT SEP.	CORRECTED	FLARE	DISP.	TOTAL	DRY	BRINE	GAS	THERMAL
		(BTU/MCF)	ITY	ORIF P&T	(MCF/D)	(MCF/D)	CARBONS	(BPD)								
6/17/81	00:30	818.8	0.8241	1.0211	88.3	85.8	64.8	2956.8	2866.8	29.9	1.9	31.9	20	664	16	12
6/17/81	01:00	818.8	0.8241	1.0211	88.8	86.4	65.2	2936.9	2846.0	30.3	1.9	32.3	22	724	18	14
6/17/81	01:30	818.8	0.8241	1.0211	87.5	85.1	64.2	2928.7	2836.8	30.0	1.9	31.9	24	783	20	15
6/17/81	02:00	818.8	0.8241	1.0211	86.1	83.7	63.1	2930.9	2837.8	29.5	1.9	31.4	26	842	21	17
6/17/81	02:30	818.8	0.8241	1.0211	86.5	84.1	63.4	2873.0	2781.0	30.2	1.9	32.2	28	900	23	18
6/17/81	03:00	818.8	0.8241	1.0211	86.9	84.4	63.7	2860.8	2768.4	30.5	1.9	32.4	29	958	24	20
6/17/81	03:30	818.8	0.8241	1.0211	85.4	82.9	62.6	2836.1	2744.0	30.2	1.9	32.1	31	1015	26	21
6/17/81	04:00	818.8	0.8241	1.0211	85.1	82.7	62.4	2821.2	2728.9	30.3	1.9	32.2	33	1072	27	23
6/17/81	04:30	818.8	0.8241	1.0211	85.0	82.5	62.3	2808.6	2716.2	30.4	1.9	32.3	35	1128	29	24
6/17/81	05:00	818.8	0.8241	1.0211	84.0	81.6	61.6	2787.1	2695.0	30.3	1.9	32.2	37	1184	30	26
6/17/81	05:30	818.8	0.8241	1.0211	84.2	81.8	61.7	2769.0	2677.1	30.5	1.9	32.5	39	1240	32	28
6/17/81	06:00	818.8	0.8241	1.0211	83.2	80.8	61.0	2759.2	2667.2	30.3	1.9	32.2	40	1296	33	29
6/17/81	06:30	818.8	0.8241	1.0211	82.4	80.0	60.3	2754.0	2661.9	30.0	1.9	32.0	42	1351	35	31
6/17/81	07:00	818.8	0.8241	1.0211	82.3	79.9	60.3	2737.5	2645.7	30.2	1.9	32.1	44	1406	36	32
6/17/81	07:30	818.8	0.8241	1.0211	81.9	79.5	60.0	2718.1	2626.7	30.3	1.9	32.2	46	1461	37	34
6/17/81	08:00	818.8	0.8241	1.0211	81.5	79.1	59.7	2696.2	2605.5	30.4	1.9	32.3	47	1515	39	35
6/17/81	08:30	818.8	0.8241	1.0211	80.1	77.8	58.7	2691.7	2600.8	29.9	1.9	31.8	49	1569	40	37
6/17/81	09:00	818.8	0.8241	1.0211	80.1	77.7	58.6	2679.0	2588.5	30.0	2.0	32.0	51	1623	42	38
6/17/81	09:30	818.8	0.8241	1.0211	79.6	77.2	58.2	2662.0	2571.9	30.0	2.0	32.0	53	1677	43	40
6/17/81	10:00	818.8	0.8241	1.0211	79.6	77.2	58.3	2655.8	2565.9	30.1	2.0	32.1	54	1730	44	41
6/17/81	10:30	818.8	0.8241	1.0211	79.4	77.1	58.2	2636.0	2546.6	30.3	2.0	32.2	56	1783	46	43
6/17/81	11:00	818.8	0.8241	1.0211	77.9	75.6	57.1	2637.9	2548.3	29.7	2.0	31.6	58	1837	47	44
6/17/81	11:30	818.8	0.8241	1.0211	78.4	76.0	57.4	2619.4	2530.4	30.0	2.0	32.0	59	1889	49	46
6/17/81	12:00	818.8	0.8241	1.0211	77.0	74.6	56.3	2616.7	2527.7	29.5	2.0	31.5	61	1942	50	47
6/17/81	12:30	818.8	0.8241	1.0211	77.3	74.9	56.6	2598.8	2510.4	29.9	2.0	31.8	63	1994	51	49
6/17/81	13:00	818.8	0.8241	1.0211	77.1	74.8	56.4	2605.0	2516.3	29.7	2.0	31.7	64	2047	53	50
6/17/81	13:30	818.8	0.8241	1.0211	78.1	75.7	57.1	2584.8	2496.8	30.3	2.0	32.3	66	2099	54	52
6/17/81	14:00	818.8	0.8241	1.0211	77.0	74.6	56.3	2582.0	2494.1	29.9	2.0	31.9	68	2151	55	53
6/17/81	14:30	818.8	0.8241	1.0211	77.4	74.9	56.6	2583.6	2495.6	30.0	2.0	32.0	69	2203	57	55
6/17/81	15:00	818.8	0.8241	1.0211	76.4	74.0	55.8	2567.5	2480.0	29.8	2.0	31.8	71	2254	58	56
6/17/81	15:30	818.8	0.8241	1.0211	76.7	74.3	56.0	2561.4	2474.1	30.0	2.0	32.0	73	2306	60	57
6/17/81	16:00	818.8	0.8241	1.0211	76.5	74.1	55.9	2552.5	2465.5	30.1	2.0	32.0	74	2357	61	59
6/17/81	16:30	818.8	0.8241	1.0211	34.7	32.5	24.5	1129.5	1091.5	29.8	1.1	30.8	75	2380	61	60
6/17/81	17:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	17:30	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	18:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	18:30	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	19:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	19:30	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	20:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	20:30	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	21:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	21:30	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	22:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	22:30	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	23:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	23:30	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60
6/17/81	00:00	0.0	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75	2380	61	60

Figure 5. REPRESENTATIVE COMPUTER PRINTOUT OF PRODUCTION HISTORY