COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

APPLICATION OF SOUTHERN MADISON WATER DISTRICT FOR CERTIFICATE OF CONVENIENCE AND NECESSITY TO COMPLETE CONSTRUCTION OF STORAGE FACILITIES	))))	CASE NO. 92-161

O R D E R

On April 6, 1992, Southern Madison Water District ("Southern Madison") filed an application for a Certificate of Public Convenience and Necessity to construct a $26,000 waterworks improvement project. Commission Staff, having performed an investigation of the hydraulic capability of Southern Madison, has prepared the attached Staff Engineering Report containing Staff's findings and recommendations regarding Southern Madison's proposed construction. All parties should review the report carefully and provide any written comments or requests for a hearing or informal conference no later than 15 days from the date of this Order.

IT IS THEREFORE ORDERED that all parties shall have 15 days from the date of this Order to provide written comments regarding the attached Staff Engineering Report or requests for a hearing or informal conference. If no request for a hearing or informal conference is received, then this case will be submitted to the Commission for a decision.

Done at Frankfort, Kentucky this 24th day of February, 1993.

PUBLIC SERVICE COMMISSION

For the Commission

ATTEST:

Executive Director

Commonwealth of Kentucky
Public Service Commission

INVESTIGATION OF THE HYDRAULIC CAPABILITY OF THE
SOUTHERN MADISON WATER DISTRICT
CASE NO. 92-161

January 29, 1993

BRIEF

The purpose of this report is to present engineering data and hydraulic calculations concerning the proposal of the Southern Madison Water District to place its water storage tank on Dogwood Drive into service. On April 6, 1992, the Public Service Commission received an application from Southern Madison Water District for approval to construct a $26,000 waterworks improvement project. The proposed project would construct a pump station to fill the recently constructed 90,000-gallon water storage tank on Dogwood Drive. Southern Madison stated in its application that it had discovered that the tank cannot be filled by the existing pump station located near I-75. In an attempt to determine if the proposed construction would indeed make the Dogwood Drive tank "used and useful in rendering service to the public" additional engineering data was requested from the District by Order dated April 30, 1992. Southern Madison asked for and received several extensions of time before filing its response on September 11, 1992. On October 14, 1992, an informal conference with representatives of Southern Madison was held at the Commission's offices in Frankfort to facilitate the Commission's engineering staff's review of the proposed construction project. A general

discussion of computer generated hydraulic analyses and calibration methods was followed by a statement of Commission Staff's concerns about the computer hydraulic analyses filed in this case. Southern Madison's consultants were asked about the measurements and methods used to calibrate the analyses filed in this case. At the conference the Commission's engineering staff stated that it would be making its own additional field measurements on Southern Madison's distribution system. This report presents the results of the Commission's engineering staff's data collection efforts.

BACKGROUND

The present case has its roots in Case No. 9377 filed June 28, 1985 by Southern Madison. In Case No. 9377 Southern Madison sought, inter alia, approval for construction of a 100,000-gallon standpipe, a 150-gallon per minute duplex booster pump station and approximately 22.5 miles of water mains. The Commission entered an Order April 7, 1986, to dismiss Case No. 9377 without prejudice after Southern Madison requested that it be dismissed. The Commission stated in the Order that Southern Madison had not submitted sufficient documentation to support its case within the statutory 10-month time frame. On May 28, 1986, Southern Madison filed its motion to reopen Case No. 9377. By Order entered June 6, 1986, the Commission established Case No. 9596 and incorporated therein the entire record of Case No. 9377 by reference. Appendixed to the June 6, 1986 Order was a staff report outlining the engineering staff's concerns with the proposed construction

project as presented. Foremost among those concerns was the location selected for the proposed storage tank and two service areas where low system operating pressures were expected to occur. The Commission's Order for Case No. 9596 entered August 14, 1986 granted Southern Madison a certificate for the proposed construction on the condition that two hydropneumatic stations be installed to serve the low pressure areas identified by the Commission's engineering staff.

The Commission received a letter January 4, 1988, from Southern Madison requesting a deviation from regulations requiring a water utility to have storage facilities for one day's supply of water. This request was established as Case No. 10122 and an Order granting a deviation until July 1, 1991 was entered by the Commission on April 20, 1988. That Order also directed Southern Madison to retain a professional engineer to conduct a comprehensive study of its water storage tanks and distribution system. Southern Madison was instructed to file a copy of the report of the study with the Public Service Commission no later than July 1, 1989.

In January and June of 1988 the Commission received a customer complaint of low water pressure in the Braggs Lane area of Madison County served by Southern Madison. Staff engineers from the Commission met with Southern Madison's manager and engineering consultant in Berea on June 3, 1988 to discuss the complaint. Southern Madison's representatives stated that the newly

constructed booster pump station near I-75 was not working due to problems with the operating control system. The installation of the hydropneumatic pump station to serve the Braggs Lane area was discussed and Southern Madison's representatives expressed their opposition to such construction. Commission's Staff instructed Southern Madison's representatives to activate the new booster pump station and to perform an engineering review of the situation at Braggs Lane.

The report that Southern Madison was directed to file by July 1, 1989, per the Order in Case No. 10122 was not submitted to the Commission. In its answer to the Commission's reminder, Southern Madison replied on August 30, 1989, that the required study had not been conducted. After an informal conference with Commission Staff on September 28, 1989, Southern Madison offered to furnish the report by December 15, 1989. The Commission granted Southern Madison additional time and an engineering report was submitted to the Commission on December 14, 1989.

In July 1990 Southern Madison informed the Commission of its intent to construct a new water storage tank by the end of 1990. On August 23, 1990, the Commission received from the Natural Resources and Environmental Protection Cabinet ("NREPC") a copy of its letter approving Southern Madison's proposed construction of a water storage tank. Southern Madison subsequently filed on October 5, 1990, its application for a Certificate of Public Convenience and Necessity for the construction of a water storage tank in the

Dogwood Drive area of its distribution system. The Commission assigned Case No. 90-305 to this application. This application was for approval of construction of a 90,000-gallon water storage tank, 1,525 feet of 4-inch connecting water line and related appurtenances. Various information was requested by the Commission's deficiency letter of October 16, 1990. Southern Madison's response was received October 26, 1990. After reviewing the application the Commission found that additional engineering information was needed to determine if the proposed construction would be "used and useful". An Order requesting additional information was entered November 21, 1991. The requested information, which included hydraulic analyses, field measurements, etc. was directed to be filed by December 5, 1990. On December 3, 1990, Southern Madison filed a motion for an extension of time to comply with the request. By Order entered December 6, 1990, the Commission granted Southern Madison an extension until January 19, 1991. Additional information was filed by Southern Madison on January 18, 1991. Even with the additional information Southern Madison's application did not offer a clear picture of how the existing water distribution system operated or how the proposed tank was going to improve system operation. In an attempt to address the Staff's concerns directly, an informal conference was scheduled with Southern Madison's representatives. After several schedule changes, the informal conference was held on February 27, 1991, at the Commission's offices in Frankfort. At the conference,

Southern Madison's representatives stated that more field measurements would be made and additional hydraulic information would be filed by June 1, 1991. After the conference the Commission's engineering staff concluded that its review could be expedited by making its own field measurements on Southern Madison's water distribution system. On April 30, 1991, staff engineers from the Commission went to Southern Madison to set pressure recorders and to conduct flow tests. During the April 30, 1991 visit the Commission's Staff discovered that the facilities proposed in Case No. 90-305 had already been constructed. This fact was reported to the Commission by staff memorandum on May 10, 1991. The Commission responded on June 19, 1991 by establishing Case No. 91-188 which initiated show cause proceedings against Southern Madison for possible assessment of penalties for violation of KRS 278.020.

On June 25, 1991, the Commission received an application from Southern Madison requesting a deviation from regulations requiring a water utility to have storage facilities for one day's supply of water. Case No. 91-212 was established and an Order dismissing Southern Madison's request was entered July 15, 1991. In that Order the Commission found that, considering the water storage available from its supplier, Southern Madison was in compliance with the Commission's water storage regulations and no deviation was required.

An informal conference in Case No. 91-188 was held July 31, 1991 at the Commission's offices in Frankfort. At that conference representatives of Southern Madison and the Commission's Staff discussed the penalty proceedings pending before the Commission. The possibility of submitting a settlement agreement to the Commission for its consideration was discussed. In addition the Commission's engineering staff presented copies of pressure recording charts made on Southern Madison's distribution system to its engineering consultant. The engineering staff presented at length its observations and opinions on the operational deficiencies of that part of Southern Madison's distribution system served by the I-75 booster pump station. The staff engineers expressed their opinion that the Dogwood Drive tank had been constructed at an inappropriate location and could not be filled by the existing I-75 pump station. Staff engineers further stated that preliminary calculations indicated that if the I-75 booster pump station were modified to fill the Dogwood Drive tank, substantial portions of Southern Madison's distribution system would be subjected to unacceptably high operating pressures. In fact, some parts of the distribution system would have to operate above the rated capability of the pipelines themselves. On September 10, 1991, Southern Madison filed its proposed settlement agreement for the Commission's consideration. The Commission entered its Order September 24, 1991 in Case No. 91-188, accepting the offered

settlement and assessing individual fines against the officers of the Southern Madison Water District for violation of KRS 278.020.

On August 20, 1991, Southern Madison filed its motion to hold in abeyance that portion of the Commission's August 14, 1986 Order in Case No. 9596 requiring the installation of two hydropneumatic stations. The Commission subsequently entered its Order on November 1, 1991 granting Southern Madison an abeyance period of one year on the installation of hydropneumatic stations. That Order in Case No. 9596 also directed Southern Madison to file a comprehensive hydraulic analysis of its distribution system by December 1, 1992.

As previously mentioned, Southern Madison filed its application in Case No. 92-161 with the Commission on April 6, 1992. The following information deals with the Commission's engineering staff's review of Case No. 92-161.

FIELD OBSERVATION AND DATA COLLECTION

After review of the information submitted by Southern Madison Water District in Case No. 92-161, Staff found it to be insufficient to allow an adequate engineering evaluation of the proposed waterworks improvements. In order to gather additional data on the water system's operational characteristics, Eddie Smith, Bob Arnett, and Ghasem Pour-Ghasemi of the Commission's engineering staff made a field visit on Thursday, October 15, 1992. During this visit the water distribution system was discussed with Ray Curry, manager and Charles Black, consulting engineer.

The primary purpose of the field visit was to set recording pressure gauges at various points on Southern Madison's distribution system in order to monitor its operational characteristics. To this end, recorders were placed at the locations listed in the following table.

TABLE I. RECORDER LOCATIONS

Position Number	Location Description	Recorder Number	Approximate Elevation Above Sea Level (ASL)
1)	on the suction line of the I-75 pump station	801361	972 feet ASL
2)	on the discharge line of the I-75 pump station	74A-25695	972 feet ASL
3)	at the meter to Cummins Barn	74A-25691	1,076 feet ASL
4)	at the hydrant on Braggs Lane	707080	1,131 feet ASL
5)	at the hydrant on old Walnut Road near PRV	74A-25692	984 feet ASL
6)	at the meter to Taylor Residence	74A-25694	975 feet ASL
7)	at the hydrant at base of the Indian Hills Tank	801360	1,090 feet ASL
8)	at the hydrant on Guynn Road	801358	1,005 feet ASL
9)	at the meter pit at EKP Substation	74A-25693	898 feet ASL

The sea level elevations of the various recorder locations were determined from a USGS topographic map of the area and from information furnished by Southern Madison for the pump station and tank sites. The pressure recorders were checked for calibration by Denis Hildenbrand at the PSC meter laboratory in Lexington prior to the trip to the Southern Madison Water District.

Eddie Smith, Bob Arnett, and Ghasem Pour-Ghasemi returned on Friday, October 16, 1992 to check operation of the pressure recorders and to conduct flow tests on the I-75 pump station. In addition a flow test was conducted on a 2.5-inch hose nozzle at the hydrant located on Guynn Road and Estridge Road. During the hydrant flow test the distribution system's pressure at the EKP Substation was also monitored. The following data was obtained from the hydrant flow test.

TABLE II. GUYNN ROAD HYDRANT FLOW TEST

Date:	October 16, 1992
Time:	11:40 a.m. EDT
Location:	Guynn Road & Estridge Road
Elevation:	1,005 feet ASL
Static pressure @ hydrant:	65-70 PSI
Residual pressure @ hydrant:	1.5 PSI approximately
Estimated hydrant flow:	200 GPM approximately
Static pressure @ Substation:	114 PSI
Residual @ Substation:	100-105 PSI

During the October 16, 1992, visit the operation of the District's I-75 pump station was observed, and pumping rates were measured. The I-75 pump station contains two vertical turbine centrifugal pumps each rated at a nominal 150 gallons-per-minute.

Southern Madison's manager, Ray Curry, explained that both pumps were basically the same except that Pump No. 1 contained two pump stages while Pump No. 2 contained three pump stages. The I-75 pump station was isolated from the distribution system and both pumps were operated at various flow rates while measurements were taken. Pressure readings were taken on the suction and discharge side of the pumps during operation and flow readings were taken directly from the I-75 master meter. The information obtained during these tests is summarized in the following table.

TABLE IV. PUMP FLOW TEST DATA

Pump:	No. 1	No. 1	No. 1
Date:	10/16/92	10/16/92	10/16/92
Time:	2:20 p.m.	2:24 p.m.	2:28 p.m.
Discharge:	91 PSI	132 PSI	165 PSI
Suction:	80 PSI	81 PSI	80 PSI
Flow Rate:	225 GPM	152 GPM	15 GPM
Pump:	No. 2	No. 2	No. 2
Date:	10/16/92	10/16/92	10/16/92
Time:	2:34 p.m.	2:38 p.m.	2:42 p.m.
Discharge:	117 PSI	139 PSI	152 PSI
Suction:	80 PSI	81 PSI	81 PSI
Flow Rate:	206 GPM	173 GPM	159 GPM

On October 21, 1992, Eddie Smith, Ghasem Pour-Ghasemi, and Larry Updike of the Commission's engineering staff visited Southern Madison to monitor the activity of the I-75 master meter. Southern Madison's I-75 master meter was monitored by the Commission's engineering staff for the entire 24-hour period of Wednesday, October 21, 1992. The master meter readings were read and recorded on approximately 15-minute intervals from 6:00 a.m. to midnight for

that day. The list of observed master meter readings is attached to this report.

Eddie Smith and Ghasem Pour-Ghasemi returned on October 22, 1992, to retrieve the recording gauges and their charts (copies attached). In addition a flow test was conducted on a 2.5-inch hose nozzle at the hydrant located on Braggs Lane. During the hydrant flow test the distribution system's pressure was monitored at the meter to Cummins Barn on Dogwood Drive. The following data was obtained for the hydrant flow test.

TABLE V. BRAGGS LANE HYDRANT FLOW TEST

Date:	October 22, 1992
Time:	9:21 a.m. EDT
Location:	Braggs Lane
Elevation:	1,131 feet ASL
Static pressure @ hydrant:	59-60 PSI
Residual pressure @ hydrant:	less than 1 PSI
Estimated hydrant flow:	100 GPM approximately
Static pressure @ Cummins:	89 PSI
Residual @ Cummins Barn:	55-57 PSI

During the visit copies of daily readings made on Southern Madison's master meter for the previous week were obtained from Ray Curry. In addition a copy of the previous month's electric bill for the I-75 pump station was supplied by Southern Madison's office staff.

CALCULATIONS AND DATA REDUCTION

The I-75 master meter readings indicate that Southern Madison purchased 69,370 gallons of water from Berea College in the 24-hour period midnight to midnight Wednesday, October 21, 1992. This

reduces to an average rate of 48 gallons-per-minute. However, the master meter readings show a range of 0 to 100 gallons-per-minute with a typical daytime flow rate of approximately 70 to 80 gallons-per-minute. In order to maintain adequate operating pressure on the water distribution system in the Dogwood Drive area Southern Madison operates the I-75 pump station's No. 1 pump continuously. Southern Madison maintains a fairly uniform pump station discharge pressure by partially opening the pump station bypass pipeline and allowing a portion of the pumped water to flow in a circle around the pump station. This has the very useful effect of keeping the discharge pressure of the pump from getting too high. Southern Madison's operating personnel manually adjust the bypass valve twice each day in order to set the system's operating pressure at a slightly lower level at night. In addition Southern Madison further controls the distribution system's operating pressure in the Possum Kingdom Road and Indian Hills areas by the use of a pressure regulating valve located at the junction of Dogwood Drive and Old Walnut Road. The pressure regulating valve reduces the pump discharge pressure to prevent overflowing the water storage tank at Indian Hills.

During the Commission's engineering staff's review of Southern Madison's construction proposal in Case No. 90-305 a copy of the manufacturer's pump curve was obtained from the pump station manufacturer (copy attached). The pump operation data contained in Table IV was reduced to pump flow VS head per stage for each of the

observed points and plotted on a pump capacity graph. A computer program was written to calculate and draw a pump characteristic curve to fit the plotted points using the pump formula used in Dr. Wood's KYPIPE program. The curve as constructed is subject to some error, of course, due to the limited range of operation points and the lack of precise measurements. Nevertheless, the curve is a useful indication of the capability of the District's I-75 pump station. In addition to the constructed curve the three characteristic curves "A", "B", and "C" from Layne & Bowler Curve No. 36-026 were also computer drawn on the head VS capacity graph for comparison. This graph is shown on following page as Figure No. 1.

An understanding of Southern Madison Water District's hydraulic capabilities can be gleaned from reviewing the recorded pressure charts in detail. Because of mechanical limitations associated with the operation of the pressure recorder clock devices, it is not always possible to compare exactly the pressure recorded at a particular time on one chart with the pressure recorded on another at the same time. However, the charts can be coordinated through the use of pressure events created throughout the system by the operation of the pump station. One such obvious event occurs twice each day when Southern Madison personnel change the valve on the pump station bypass pipeline. Review of the charts will show that the pressure recorder at the Taylor residence malfunctioned a short time after being placed in service. Also it

PUMP CURVE
Calculated
by KYPIPE

HEAD	GPM
93.0	0
59.0	152
12.5	225

FIELD DATA

Pump No. 1

HEAD	GPM
92.5	15
59.0	152
12.5	225

Pump No. 2

HEAD	GPM
54.7	159
44.6	173
28.3	206

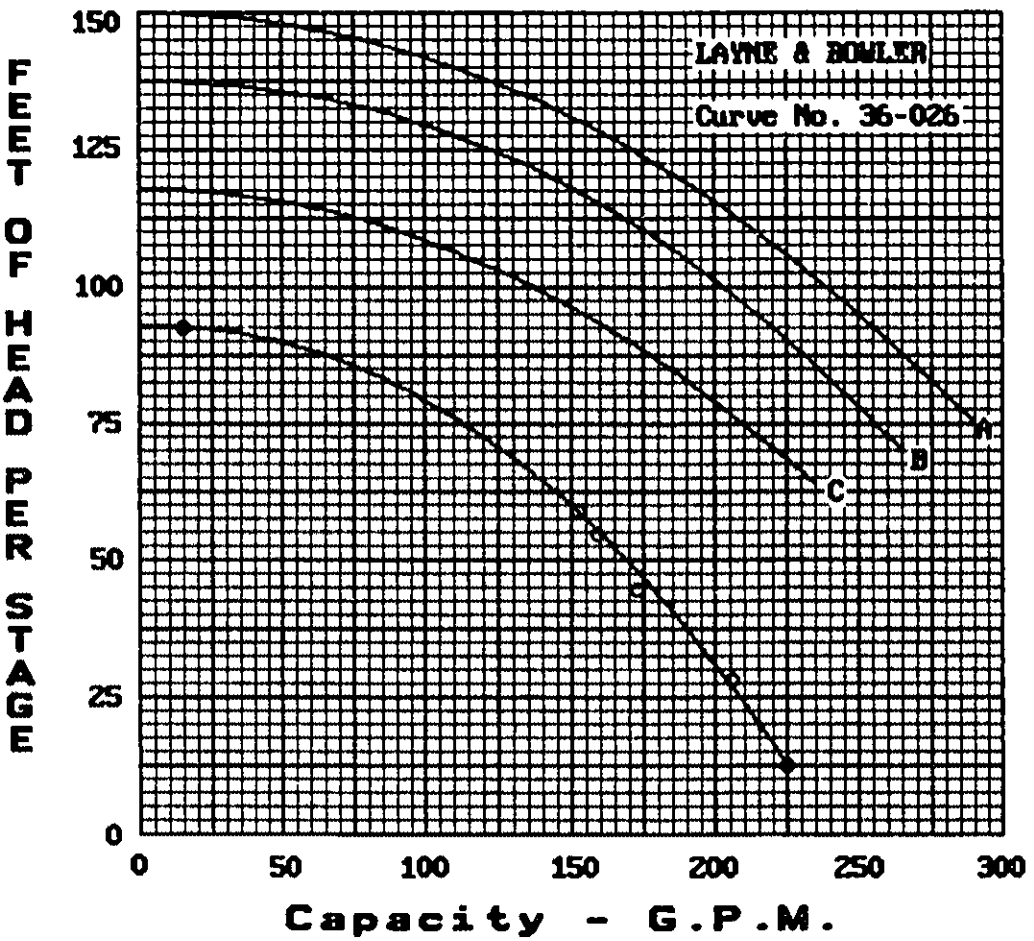

Figure No. 1

will be noted that the clock mechanisms on the recorders placed on the suction and discharge lines of the I-75 pump station quit early Tuesday, October 20, 1992. Southern Madison's daily operation sequence in the south-western part of its system is apparent in the charts for the period recorded.

CALIBRATION OF COMPUTER MODEL

Modeling is a computerized method of simulating actual events. Modeling a water distribution system is a process of using a computer program that, when given network input data, will perform mathematical calculations to solve for values of unknown elements in the system. Cesario and Davis[1] describe the modeling process as composed of four stages: (1) data collection, (2) network solution, (3) model calibration, and (4) network analysis.

Data collection consists of compiling data describing the physical characteristics of the water system in terms of pipes and junctions where pipes are connected and parameters for tanks, pumps, and pressure-regulating valves. Input information requirements for pipes include length, diameter, and roughness coefficient, whereas junction requirements include elevation and demand or water taken out of the system.

The network solution program, using the network data, solves for pressures at junctions and flows in pipes throughout the

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[1] This discussion of calibration is taken from: Cesario, A. Lee, and J. O. Davis, "Calibrating Water System Models." Journal AWWA, July 1984, pp. 66-69.

network. The use of a data file describing the water system and a network solution program results in a computer model.

The process of calibration fine-tunes a model until it accurately simulates field conditions for a specified time period to a specific degree of accuracy. The purposes of calibration are: (1) to establish model credibility, (2) to establish a benchmark for reference, and (3) to gain knowledge and understanding of system operations. Thomas M. Walski[2] states that "If an engineer is to have any confidence in the results of a water distribution system model, the model must be calibrated using good quality data."

Cesario and Davis further explain that calibrating a water system model is simply a process of adjusting the data input to the computer until the output values reasonably match actual field measurements for a given time. Some of the adjustments to input data made during the calibration process include:

- Adjusting pump characteristics to match actual discharge pressures;
- Adjusting pipe diameters or minor loss coefficients to simulate partially closed valves;
- Adjusting pressure-regulating valves to match actual downstream pressures;

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[2] Walski, Thomas M. "The Importance of Accurate Field Data for Model Calibration." AWWA Seminar Proceedings, June 10, 1984, p. 5.

- Adjusting junction elevations to match actual pressures measured during low or no flow conditions;
- Adjusting pipe roughness coefficients to obtain measured pressures and flow rates; and
- Distributing demands at the junctions to achieve the actual measured pressures at key points in the system.

Due to the many variables that must be brought into harmony, calibration is an iterative process that requires several executions of the model in order to achieve the desired close accuracy. It is generally understood that the degree of model accuracy obtained is essentially a function of the accuracy of the input data and the engineer's persistence. However, Cesario and Davis hold that the degree of accuracy sought should be related to the purpose of the study.

To evaluate Southern Madison's proposal to place the tank it constructed on Dogwood Drive in service it was first necessary to verify Southern Madison's computer model of the distribution system. Due to the size of Southern Madison's water distribution system and the limited amount of field data available to the Commission's engineering staff it was decided to truncate the hydraulic model to that portion of the system served by the I-75 pump station south of the EKP Substation on Walnut Meadow Road. The section of Southern Madison's schematic map showing this part of its distribution system is included as Figure No. 2. The time period selected for the calibration effort was the 24-hour period

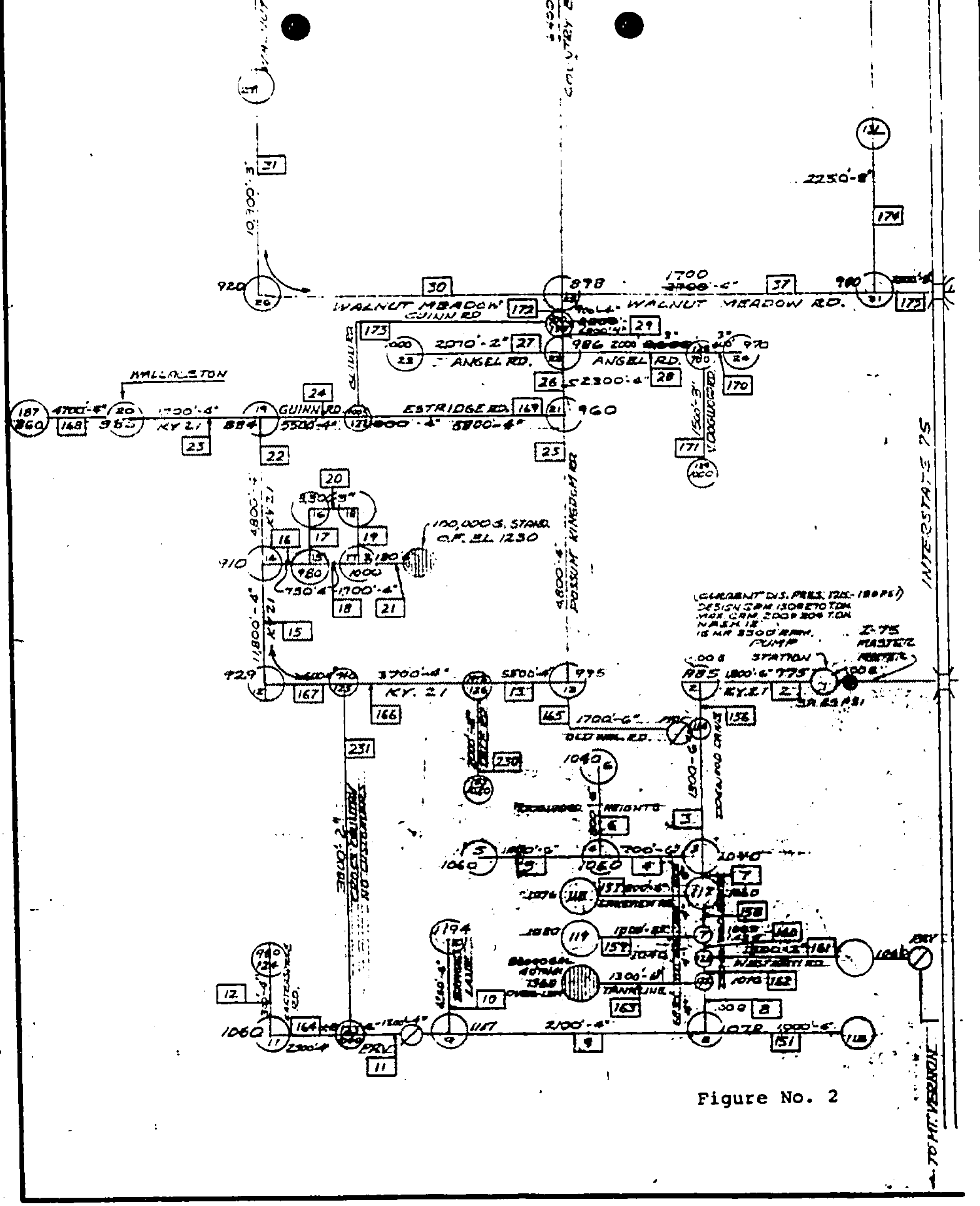


Figure No. 2

that occurred on Wednesday, October 21, 1992. The objective was to obtain a computer generated model of Southern Madison's water distribution system that agreed within 5 psi of the recorded pressure data throughout the 24-hour period. The purpose of the calibration effort was to obtain a hydraulic model of this portion of the water distribution system for use as a benchmark to determine the expected effect of changes made to the system itself. In addition, the Commission's engineering staff expected to acquire knowledge and understanding of the system's operational characteristics.

The computer modeling effort itself consisted of inputting the water system data for analysis into the KYPIPE2 computer program developed by Dr. Don Wood at the University of Kentucky. Initial changes made to the system data as submitted by Southern Madison included closing the pipeline shown on the schematic layout as pipe 169 on Estridge Road, and closing the pipeline labeled as pipe 17 shown in the Indian Hills subdivision. The PRV's shown on the schematic on pipe 11 and pipe 161 do not exist and are not included in the model. In addition pipe 163 is 1,525 feet of 4-inch main instead of 1,300 feet of 6-inch shown on the schematic. These changes were based on discussions with Ray Curry about the system's layout and configuration. In addition the majority of the roughness coefficients for the pipeline were changed to a C-factor of 140 instead of the 145 C-factor used in Southern Madison's submittal. Southern Madison's September 11, 1992 response to the

Commission's information request in this case contained data on the field determination of its C-factor value by Don Chase and Bill Gilbert. Preliminary calculations from the Commission's engineering staff's flow tests indicated that the C-factor for the system's pipeline was approximately 130. In deference to the more precise C-factor test conducted by Don Chase and Bill Gilbert a C-factor of 140 was considered appropriate. No significant difference was noticed in the results calculated by the computer for either C-factor.

The pump curve calculated from the field test data and shown in Figure No. 1 was substituted for the two pumps at Southern Madison's I-75 pump station. Pump No. 1 was entered as a two-stage pump and Pump No. 2 was entered as a three-stage pump. The constrained pipe feature of KYPIPE2 was utilized to calculate a minor loss component for the partially closed valve in the pump station by-pass pipeline. This feature was used to match the three different valve settings used on October 21, 1992.

Intensive review of the pressure charts determined that the pressure-regulating valve on Dogwood Drive at Old Walnut Road was in fact a type known as a "Differential Control Valve." A differential control valve is an automatic valve designed to maintain a constant pressure differential between two pressure points in a water system. Review of the recorded pressure charts indicates that the differential control valve was set to reduce the system pressure by approximately 25 psi from Dogwood Drive to Old

Walnut Road. This type of pressure-regulating valve is not generally used on water distribution systems. After discussing this particular valve operation with Bill Gilbert at the University of Kentucky's Department of Civil Engineering, he suggested that the differential control valve could be modeled in KYPIPE2 as a pump with a flattened head curve equal to the pressure drop in negative feet of head. The PRV shown on Southern Madison's schematic at pipe 165 was therefore replaced in the model by a pump with a head of negative 57.7 feet.

Initial runs of the computer model immediately indicated that the pipeline along Possum Kingdom Road contained either a closed or partially closed valve somewhere along its length from Highway 21 to Walnut Meadow Road. Further review of the computations suggested that a partially opened valve was located somewhere in the vicinity of either Guynn or Possum Kingdom Roads. This situation was discussed with Ray Curry, manager of Southern Madison, and he commented that he had noticed restricted flow conditions during past maintenance on Possum Kingdom Road. It was decided to use KYPIPE2's constrained pipe feature to calculate a minor loss component for the section of pipeline labeled pipe 29 on Southern Madison's schematic.

The customer demands on the distribution system were disaggregated and distributed throughout that portion of the system under study. The demands were placed into four different demand groups to facilitate use of the global demand change feature of

KYPIPE2. The customer demands were modified each hour and each identifiable operation condition throughout the 24-hour period to match the observed and recorded data. The results of the computer calibration efforts are shown on the computer generated graphs attached to this report. Comparison of the computer generated graphs with the recorded field data obtained on Wednesday, October 21, 1992, shows rather close agreement. Review of the calibrated computer model shows a bimodal diurnal customer demand pattern. High customer usage occurs twice during the day, first at 6-8 a.m. in the morning and again at 6-8 p.m. in the evening. Very little water was required by customers from 11:00 p.m. to 6:00 a.m.

The "Recommended Standards for Water Works" published by the Great Lakes Upper Mississippi River Board of State Public Health and Environmental Managers states that "the normal working pressure in the distribution system should be approximately 60 psi." Review of both the recorded pressure charts and the calibrated computer model show a substantial portion of the system served by the I-75 pump station to routinely operate above 60 psi. The Recommended Standards further state that when static pressures exceed 100 psi, pressure reducing devices should be provided on mains in the distribution system. Public Service Commission regulations require that static pressure not exceed 150 psi at the customer's point of service. Only one area, Braggs Lane, was shown to experience system pressures below the Recommended Standards' 35 psi minimum or the Commission's regulatory 30 psi minimum. This only occurred

during the peak demand period in the morning before the pump discharge pressure was manually increased by Southern Madison.

Once the computer model was calibrated to match the Wednesday, October 21, 1992 data, the input data was modified to compute the effect of the construction and operational changes proposed by Southern Madison in this case. The pump station proposed for the Dogwood Drive Tank was added to the model, as well as the proposed pressure regulating valves to reduce the pressure leaving the Dogwood Drive Tank. Pressure switches were included in the model data to operate both the existing and proposed pump stations in tandem to fill the Dogwood Drive Tank. The bypass line at the existing pump station was closed. The computer program KYPIPE2 was then utilized to model the proposed system's operation for the same diurnal demand pattern used for the October 21, 1992 calibration effort. Under these conditions the model predicts that the pump stations will be able to fill the Dogwood Drive Tank on a daily basis. The Indian Hills Tank will not be able to routinely fill by gravity without some modification to the system. However, it does not appear that a completely full Indian Hills Tank is necessary for adequate service. The results of the model of the proposed system operation are shown on the computer generated graphs attached to this report. Comparison of the computer generated graphs of the proposed system with those of the existing system show slightly higher pressures in the Dogwood Drive area and approximately the same pressure levels in the rest of the system.

CONCLUSIONS AND RECOMMENDATIONS

Based on the investigation, data review, and hydraulic computations conducted, the following conclusions are presented:

1. Appropriate operation of Southern Madison Water District's I-75 pump station requires eliminating the use of the bypass valve to control the pump discharge pressure.

2. Efficient operation of the I-75 pump station requires the installation of an automatic control mechanism to operate the pumps.

3. The Indian Hills Tank is not hydraulically capable of serving adequate pressure to the two customers at the higher elevations on Braggs Lane during high demand periods.

4. A substantial portion of the water distribution system served by the I-75 pump station routinely experiences operating pressures above that generally recommended by standard engineering references.

5. Use of the Dogwood Drive Tank will increase operating pressures in the majority of the distribution system served by the I-75 pump station.

6. The Dogwood Drive water storage tank is not properly sized to serve those customers located in the higher elevations of the Dogwood Drive area of Southern Madison's system.

7. The Dogwood Drive water storage tank is not appropriately located to serve the overwhelming majority of Southern Madison's customers.

8. The operation and pump control sequence proposed by Southern Madison is inefficient and unnecessarily complex.

9. There is no demonstrable need for the Dogwood Drive water storage tank.

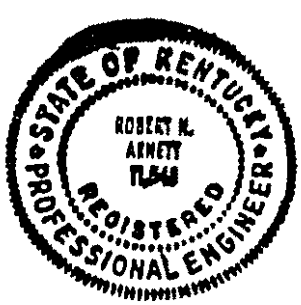
This report makes the following recommendations:

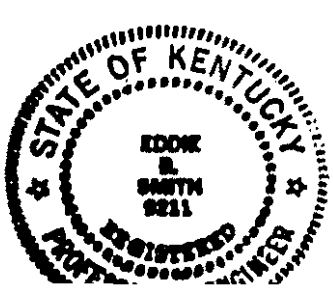
1. Southern Madison Water District's application for a Certificate of Public Convenience and Necessity should be denied.

2. Southern Madison Water District should be instructed that the Dogwood Drive Tank does not need to be placed in service.

3. Southern Madison Water District should be instructed to construct two hydropneumatic pump stations to directly serve those few customers located at the previously identified higher elevations of its water distribution system.

4. Southern Madison Water District should be instructed to modify its pump operation procedures and to install an automatic control system for the efficient operation of the I-75 pump station.





Submitted by:

Robert N. Arnett

Robert N. Arnett, P.E.

Eddie B. Smith

Eddie B. Smith, P.E.

SOUTHERN MADISON WATER DISTRICT - I-75 MASTER METER

585

DATE: 10 / 21 / 92

TIME	METER READING	MIN. DIFF.	READING DIFF.	AVG. GPM	NOTES:
10:35	64,830				
10:20	63,580	15	1,250	74	
10:10	62,830	10	750	75	
9:55	61,680	15	1,150	76.7	
9:40	60,570	15	1,110	74	
9:25	59,390	15	1,180	78.7	
9:10	58,190	15	1,200	80	
9:00	57,400	10	790	79	
8:45	56,170	15	1,230	82	
8:35	55,400	10	770	77	
8:25	54,525	10	875	87.5	
8:15	53,700	10	825	82.5	
8:00	52,380	15	1,320	88	
7:52	51,680	8	700	87.5	
7:39	50,400	13	1,280	98.5	SMWD adjusted value
7:30	50,200	9	200	22.2	
7:16	49,700	14	500	35.7	
7:00	48,910	16	790	49.4	
6:50	48,500	10	410	41	
6:40	48,230	10	270	27	
6:30	47,940	10	290	29	
6:15	47,570	15	370	24.7	
6:00	47,500	15	70	4.7	
5:54	47,425	6	75	12.5	
12:00	43,424,733,330	354	95	0.27	

* NOTE: Start readings at bottom row of the sheet and continue up the page!

SOUTHERN MADISON WATER DISTRICT - I-75 MASTER METER

DATE: 10 / 21 / 92

	TIME	METER READING	MIN. DIFF.	READING DIFF.	AVG. GPM	NOTES:
*	3:45	869800	15	1150	76.7	
	3:31	859700	14	1010	72.1	
	3:30	859110	1	60	60	
	3:15	848500	15	1060	70.7	
	3:00	839000	15	950	63.3	
	2:45	828700	15	1030	68.7	
	2:30	818500	15	1020	68	
	2:15	808100	15	1040	69.3	
	2:00	796600	15	1150	76.7	
	1:45	786500	15	1010	67.3	
	1:30	775800	15	1070	71.3	
	1:15	764900	15	1090	72.7	
	1:00	753700	15	1120	74.7	
	12:46	742900	14	1080	77.1	
	12:45	742000	1	90	90	
	12:31	731100	14	1090	77.9	
	12:30	730300	1	80	80	
	12:15	719500	15	1080	72	
NOON	12:00	708500	15	1100	73.3	
	11:45	698000	15	1050	70	
	11:30	687100	15	1090	72.7	
	11:20	680000	10	710	71	
	11:10	672500	10	750	75	
	10:35	434264690	35	2560	73.1	

* NOTE: Start readings at bottom row of the sheet and continue up the page!

SOUTHERN MADISON WATER DISTRICT - I-75 MASTER METER

DATE: 10 / 21 / 92

	TIME	METER READING	MIN. DIFF.	READING DIFF.	AVG. GPM	NOTES:
*	8:45	11570	15	1270	84.7	
	8:30	10270	15	1300	86.7	
	8:15	08920	15	1350	90	
	8:00	07700	15	1220	81.3	
	7:45	06460	15	1240	82.7	
	7:30	05210	15	1250	83.3	
	7:15	04010	15	1200	80	
	7:00	02830	15	1180	78.7	
	6:55	02400	5	430	86	
	6:50	01980	5	420	84	
	6:45	01590	5	390	78	
	6:30	43430023 0	15	1360	90.7	
	6:15	98980	15	1250	83.3	
	6:00	97810	15	1170	78	
	5:45	96650	15	1160	77.3	
	5:40	96150	5	500	100	
	5:35	95720	5	430	86	
	5:30	95260	5	460	92	
	5:15	93900	15	1360	90.7	
	5:00	92760	15	1140	76	
	4:45	91600	15	1160	77.3	
	4:30	90440	15	1160	77.3	
	4:15	89300	15	1140	76	
	4:00	43428813 0	15	1170	78	

* NOTE: Start readings at bottom row of the sheet and continue up the page!

TRS

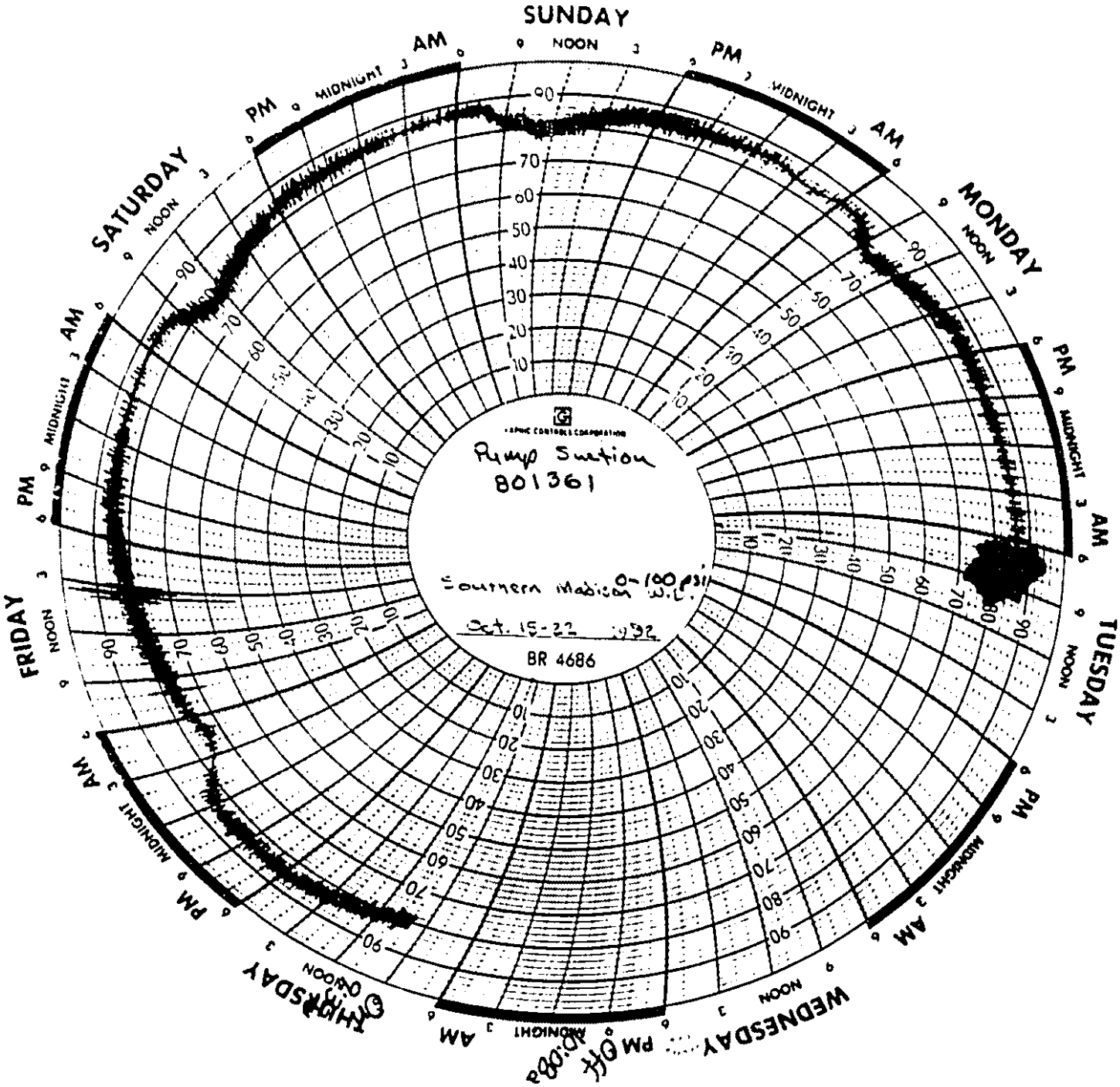
SOUTHERN MADISON WATER DISTRICT - I-75 MASTER METER

DATE: 10/21/92

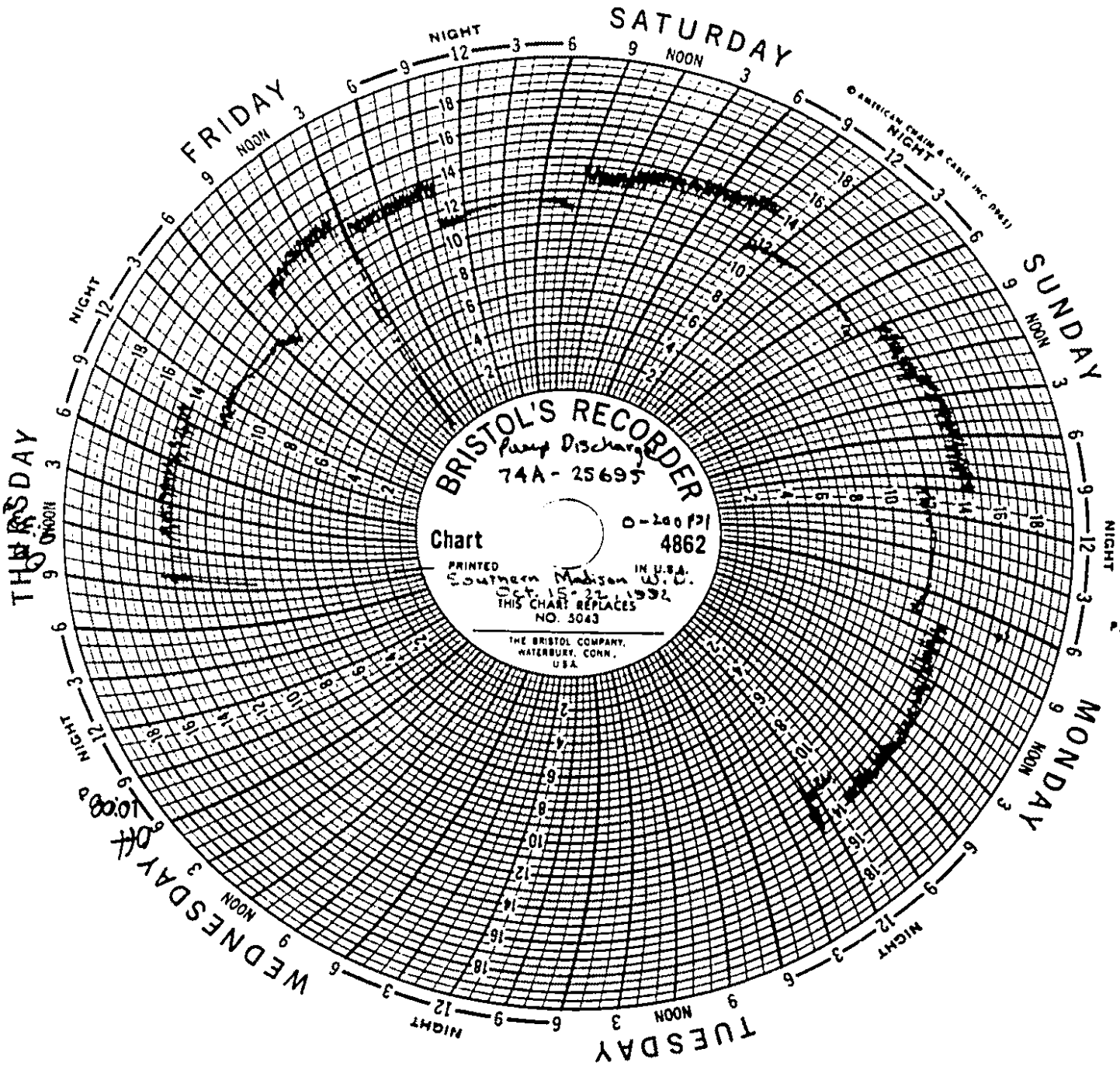
	TIME	METER READING	MIN. DIFF.	READING DIFF.	AVG. GPM	NOTES:
*						
			1440	69370	48.2	AVG. /24 HRS
Midnight	12:00	4343167000				
	11:45	16700	15	0	0	
	11:30	16680	15	20	1	.3
	11:15	16670	15	10	0	.7
	11:00	16660	15	10	0	.7
	10:45	16640	15	20	1	.3
	10:30	16580	15	60	4	
	10:15	16570	15	10	0	.7
	10:00	16160	15	410	27	.3
	9:45	15900	15	260	17	.3
	9:30	15120	15	780	52	9:40 SMWD adjusted value
	9:15	14030	15	1090	72	.7
	9:00	4343128400	15	1190	79	.3

* NOTE: Start readings at bottom row of the sheet and continue up the page!

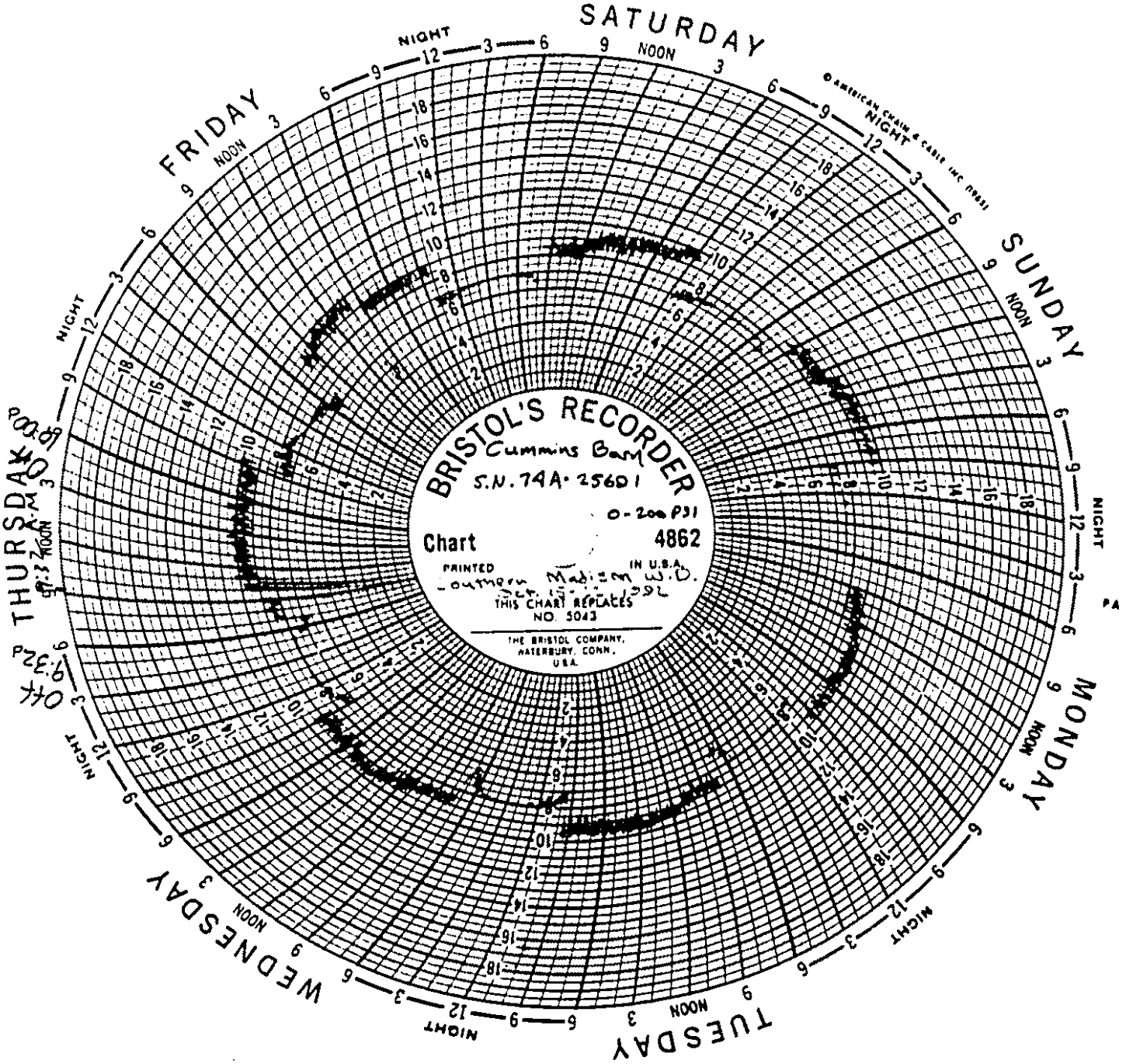
SOUTHERN MADISON WATER DISTRICT



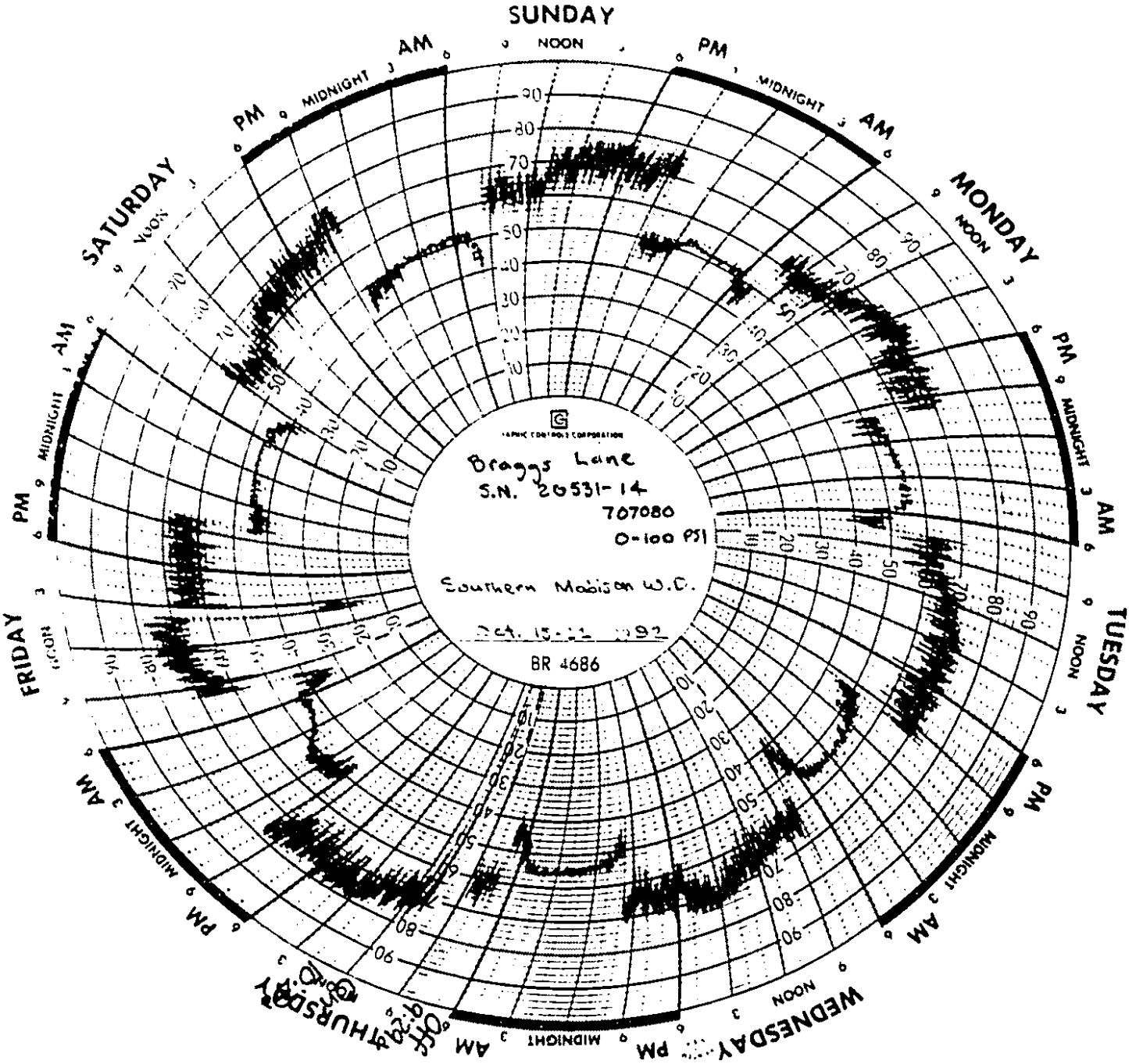
SOUTHERN MADISON WATER DISTRICT



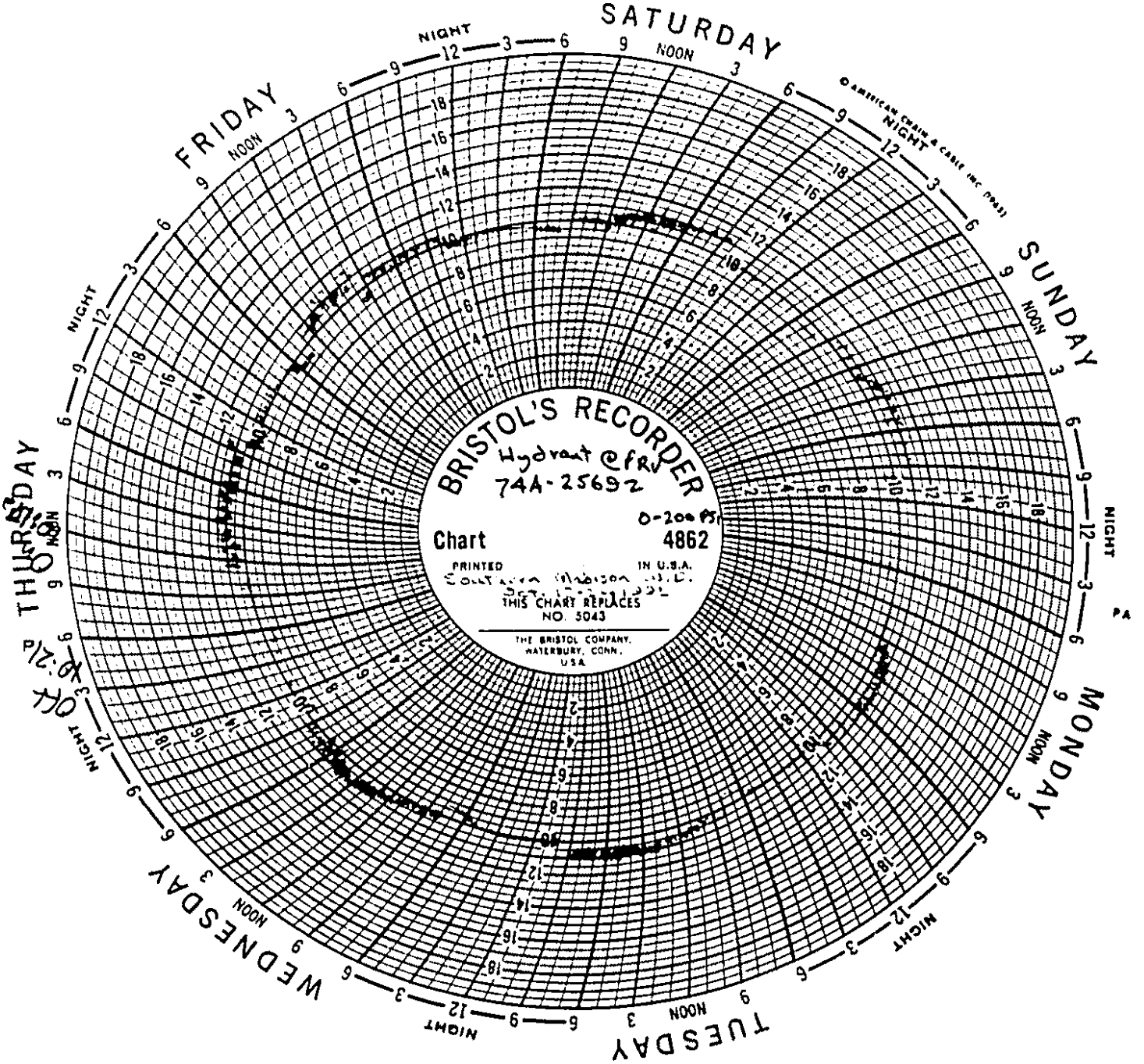
SOUTHERN MADISON WATER DISTRICT



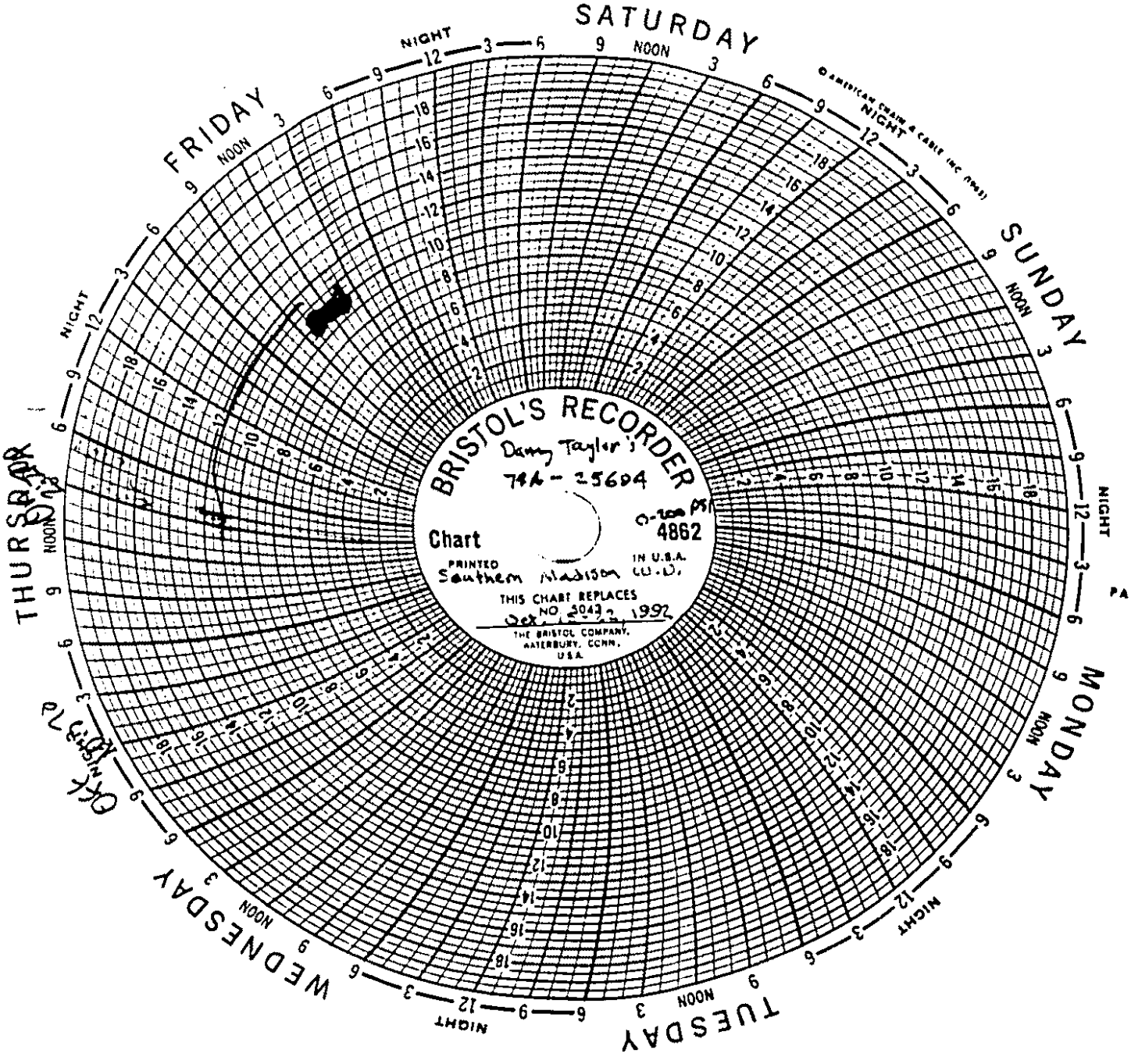
SOUTHERN MADISON WATER DISTRICT



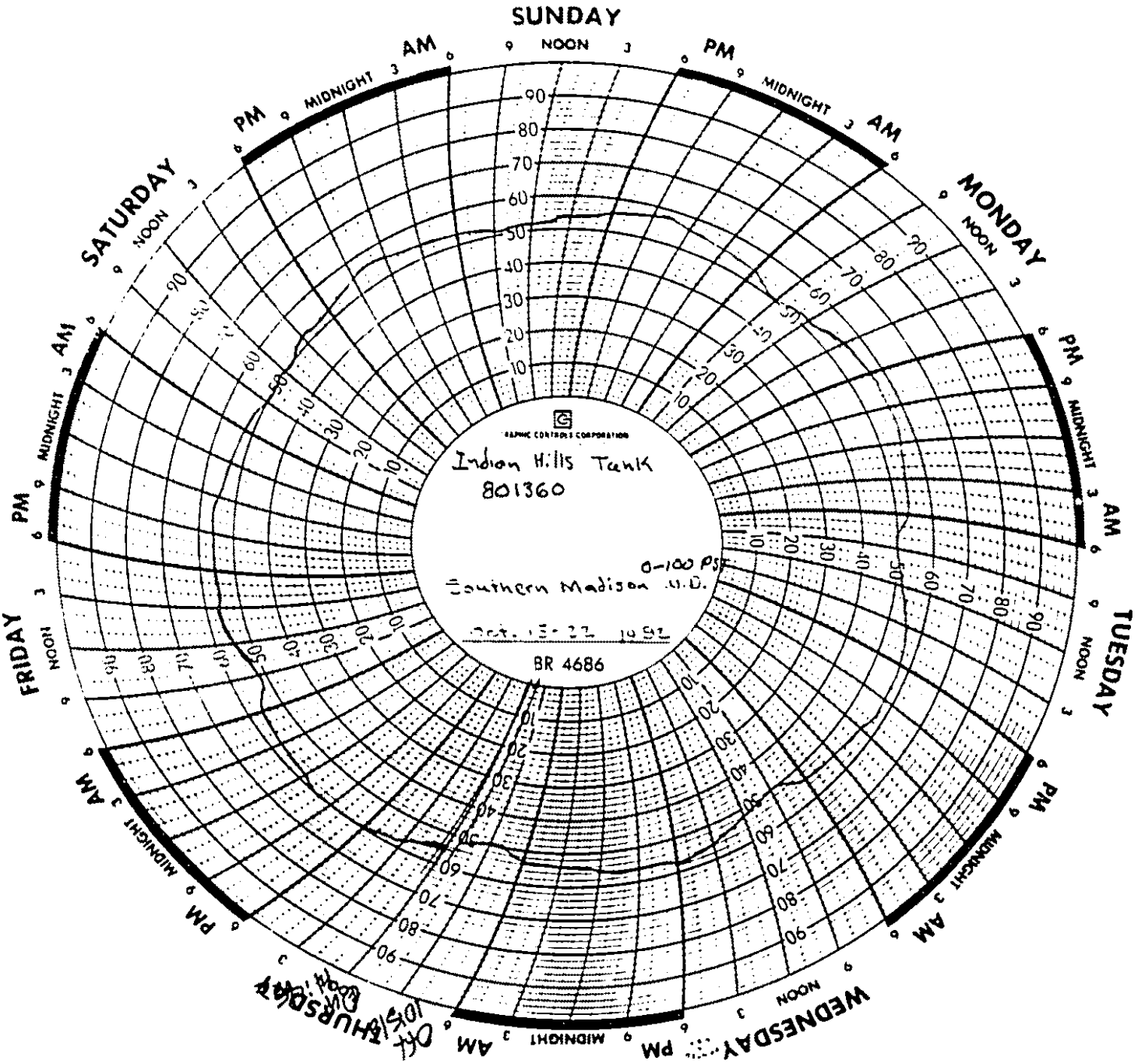
SOUTHERN MADISON WATER DISTRICT



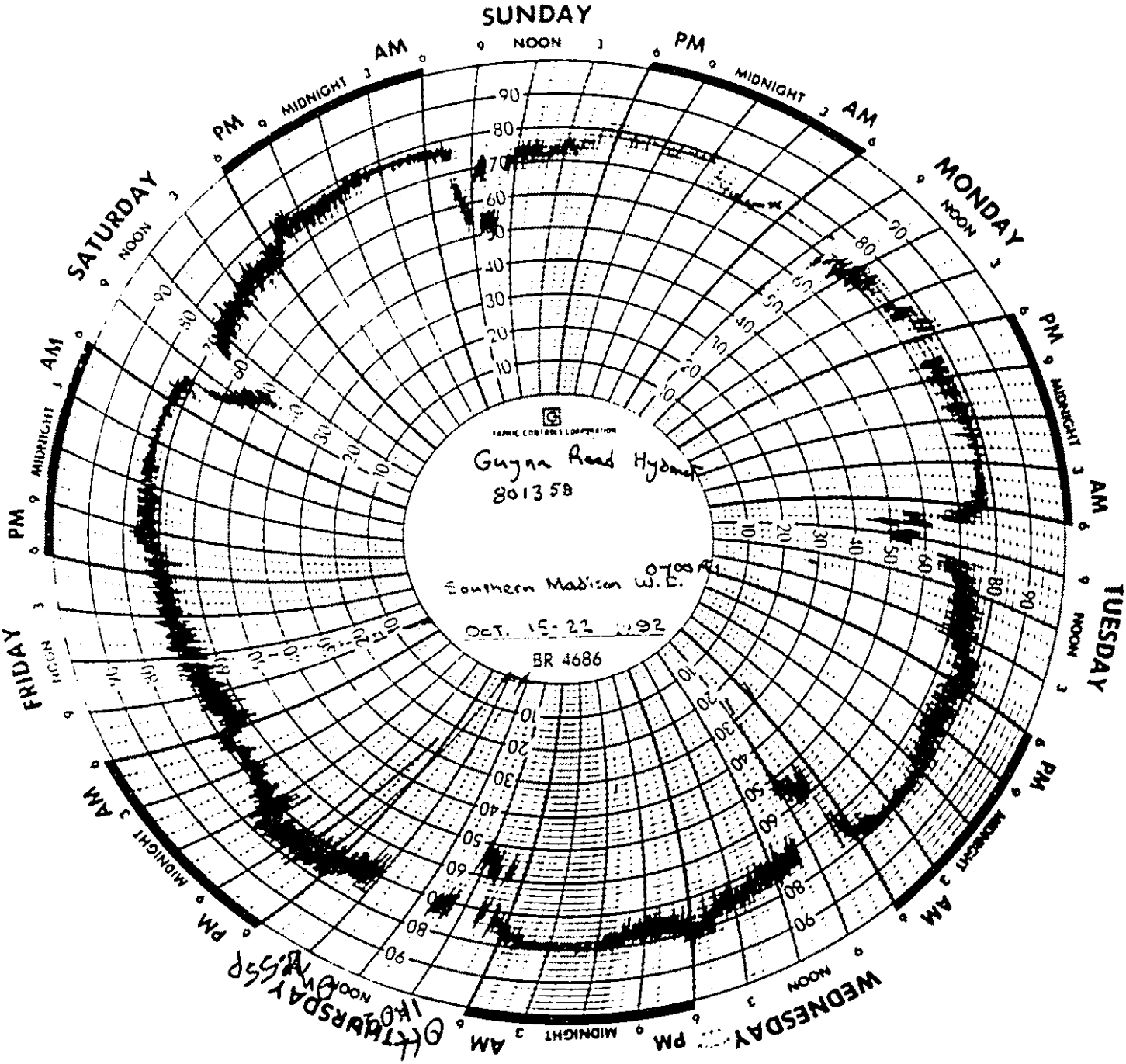
SOUTHERN MADISON WATER DISTRICT



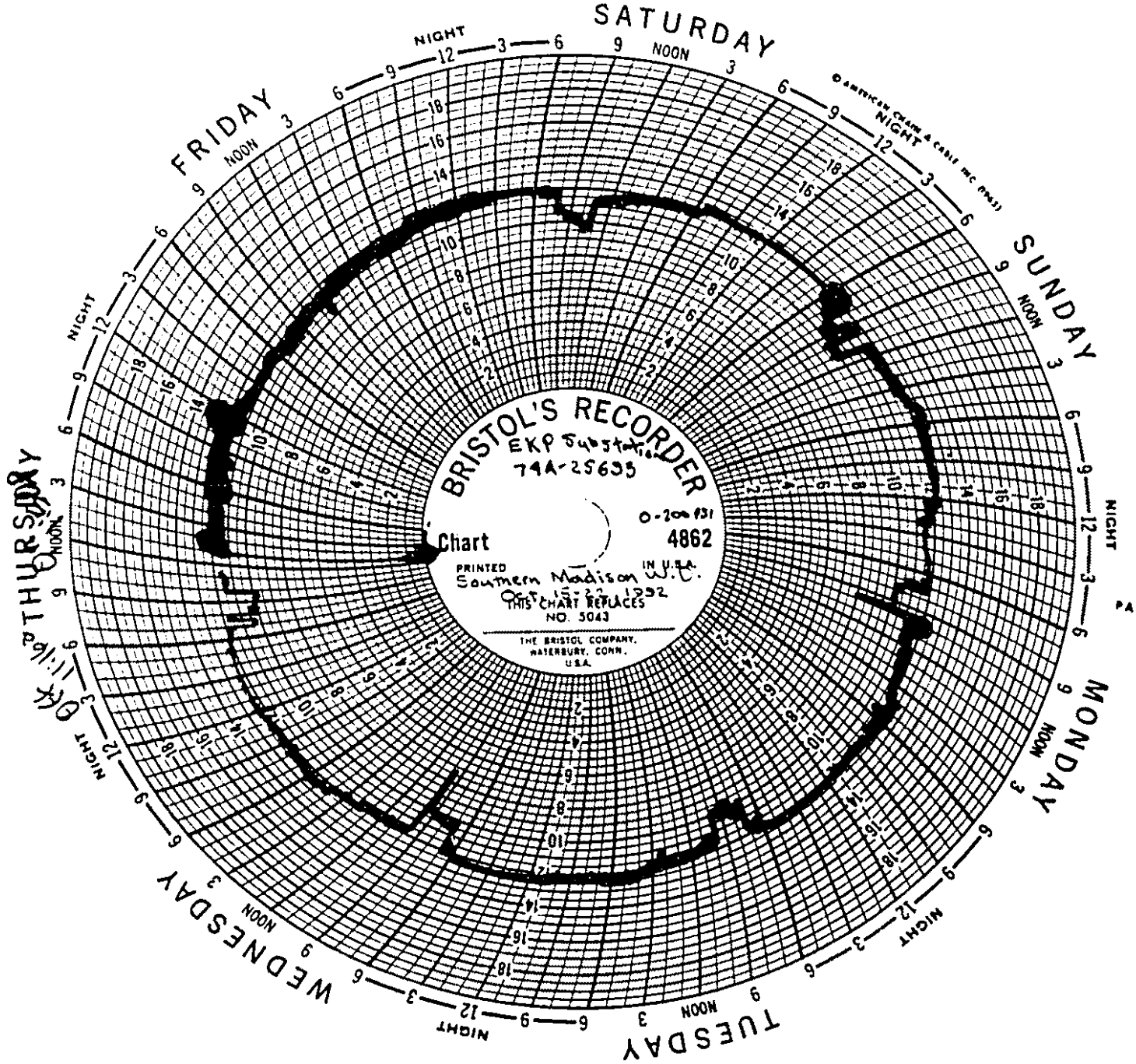
SOUTHERN MADISON WATER DISTRICT



SOUTHERN MADISON WATER DISTRICT



SOUTHERN MADISON WATER DISTRICT



LAYNE & BOWLER, INC.
MEMPHIS, TENN. 38108

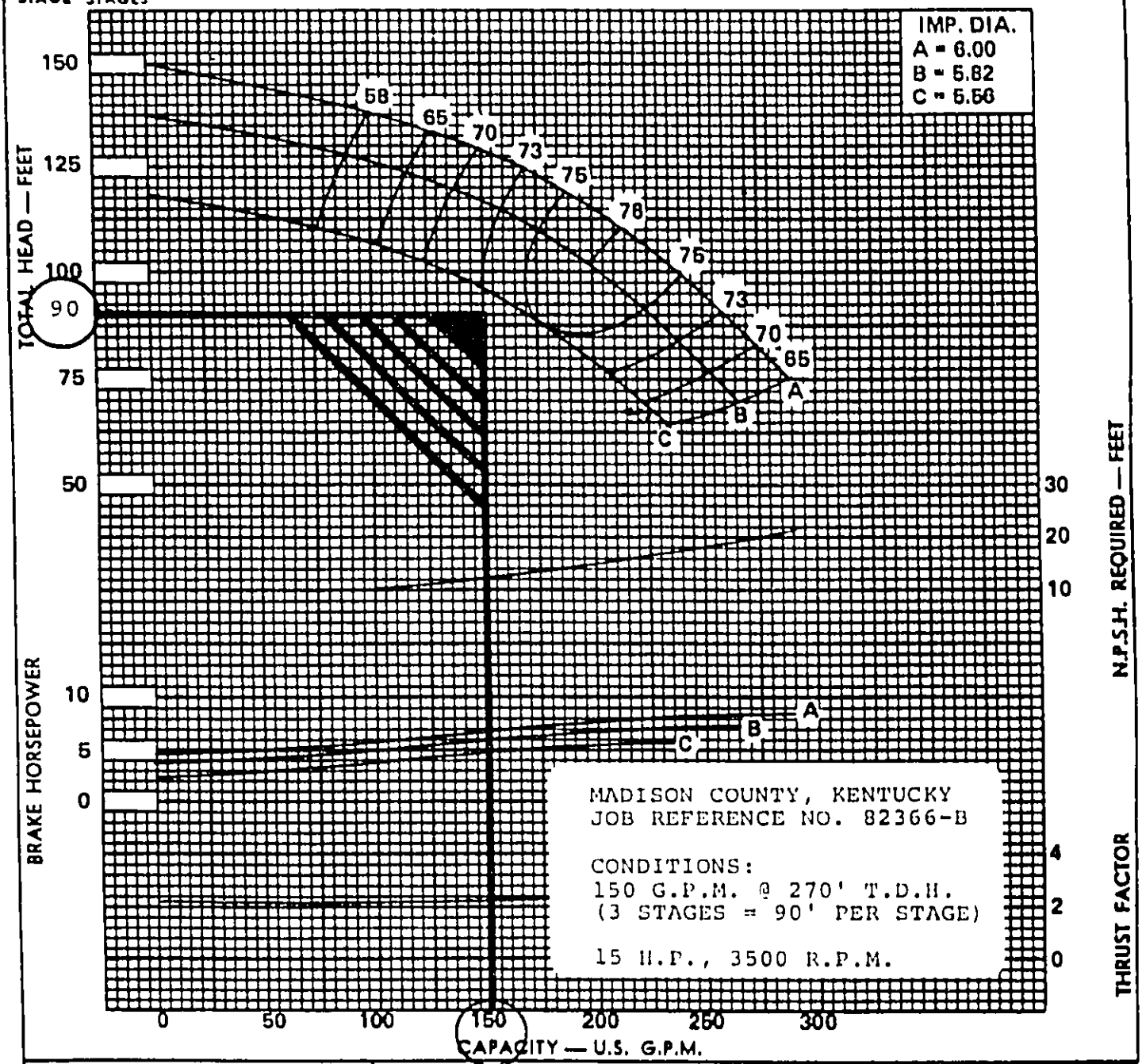
No. Stages	Eff. Change
1	-2
2	-1
3	0
4	

MATERIAL	Eff. Change
IMP.—C.I.	-1
IMP.—NI-RI	-1
BOWL—BRZ.	-1
BOWL—NI-R.	-1

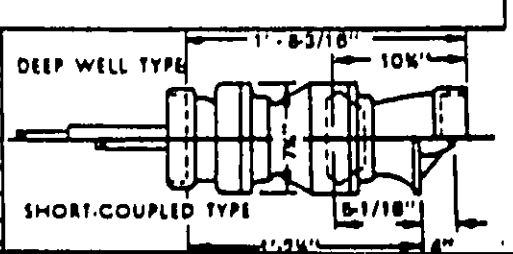
8URHC 3500 R.P.M.

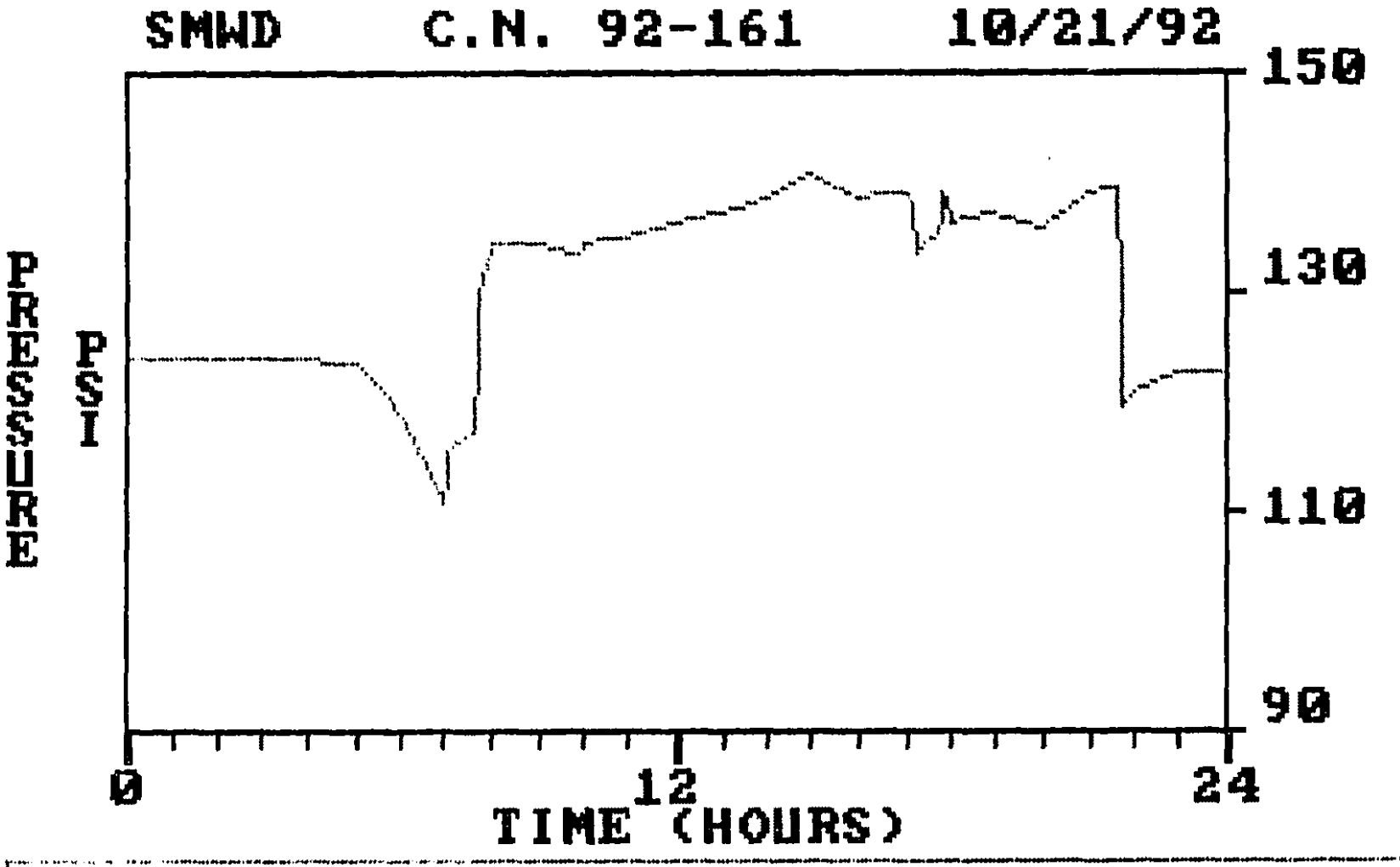
SINGLE STAGE LAB PERFORMANCE WITH STANDARD MATERIALS. EFFICIENCY SHOWN FOR 3 OR MORE STAGES. HORSE POWER SHOWN FOR ONE STAGE BASED ON 3 STAGE EFFICIENCY. CORRECTIONS SHOULD BE MADE FOR STAGES AND MATERIAL.

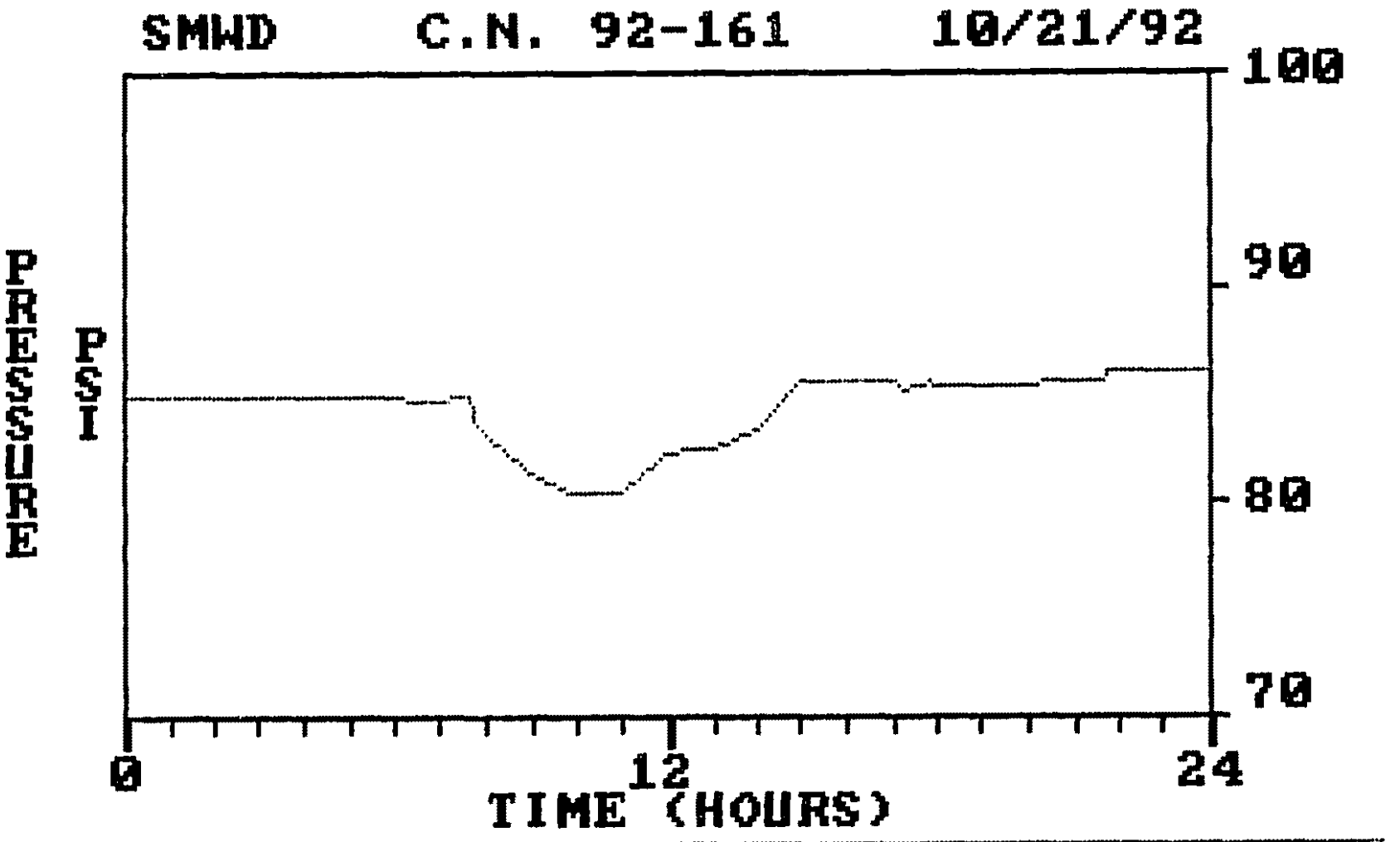
ONE STAGE (3) STAGES

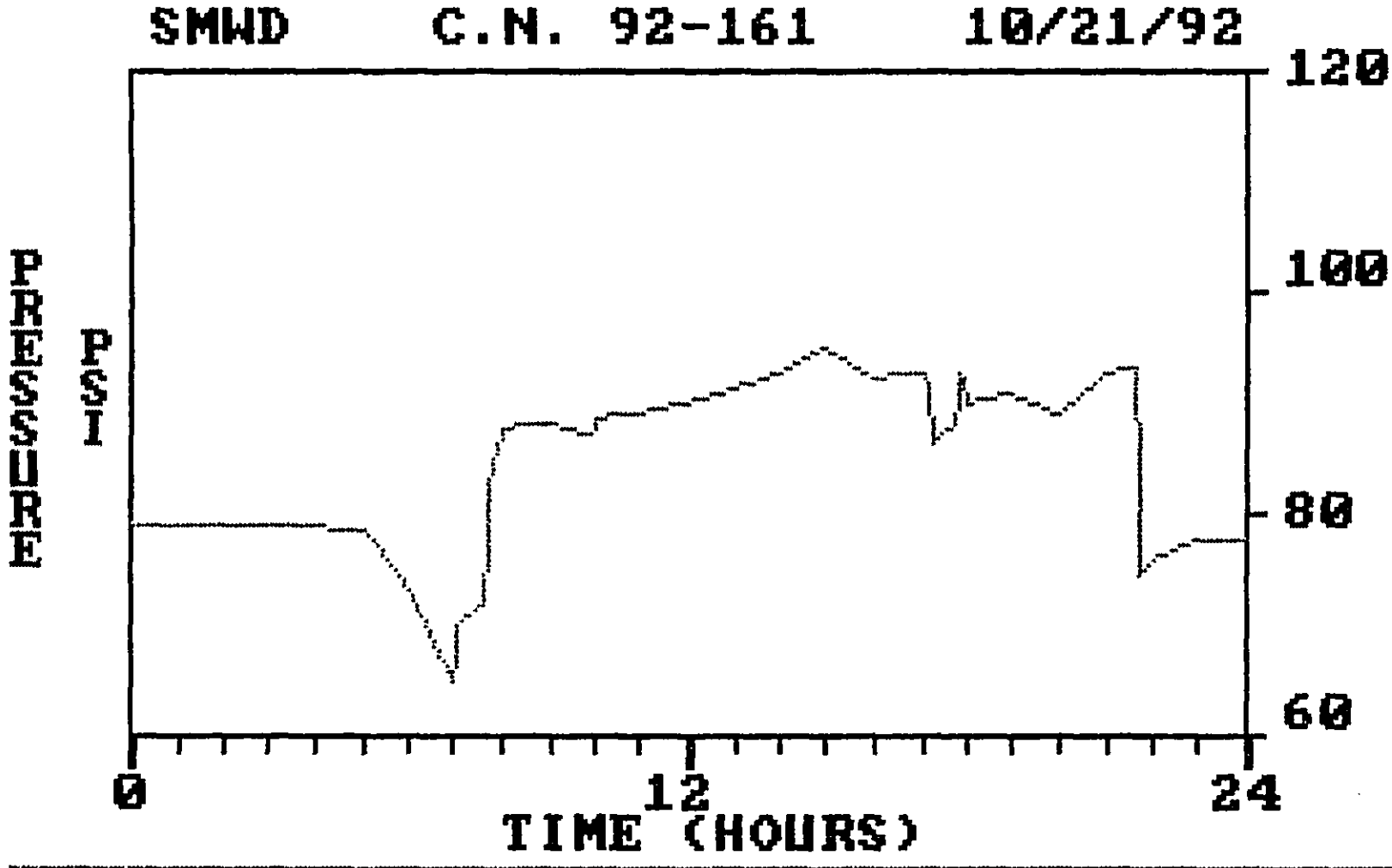


EYE AREA — SQ. IN.	=	4.11		IMPELLER WT.-LBS.	= 5.8
WR² PER IMPELLER	=	0.13	LB.-FT.²	ONE STAGE WT.-LBS.	= 107
MAX. SPHERE SIZE	=	0.41	In.	ADD'L STAGE WT.-LBS.	= 37
MAX. NO. STD. STAGES	=	12		IMPELLER NUMBER	= 4UB17
MAX. OPERATING P.S.I.	=	800		DISCH. SIZES	= 4.6.8
STD. LATERAL	=	0.44	In.	SUCTION SIZES	= 4
STD. SHAFT DIA.	=	1.187	In.	MAX. LATERAL	= 0.66 In.
MAX. SHAFT DIA.	=	1.50	In.	BOWL CONN.	THREADED-COLLET

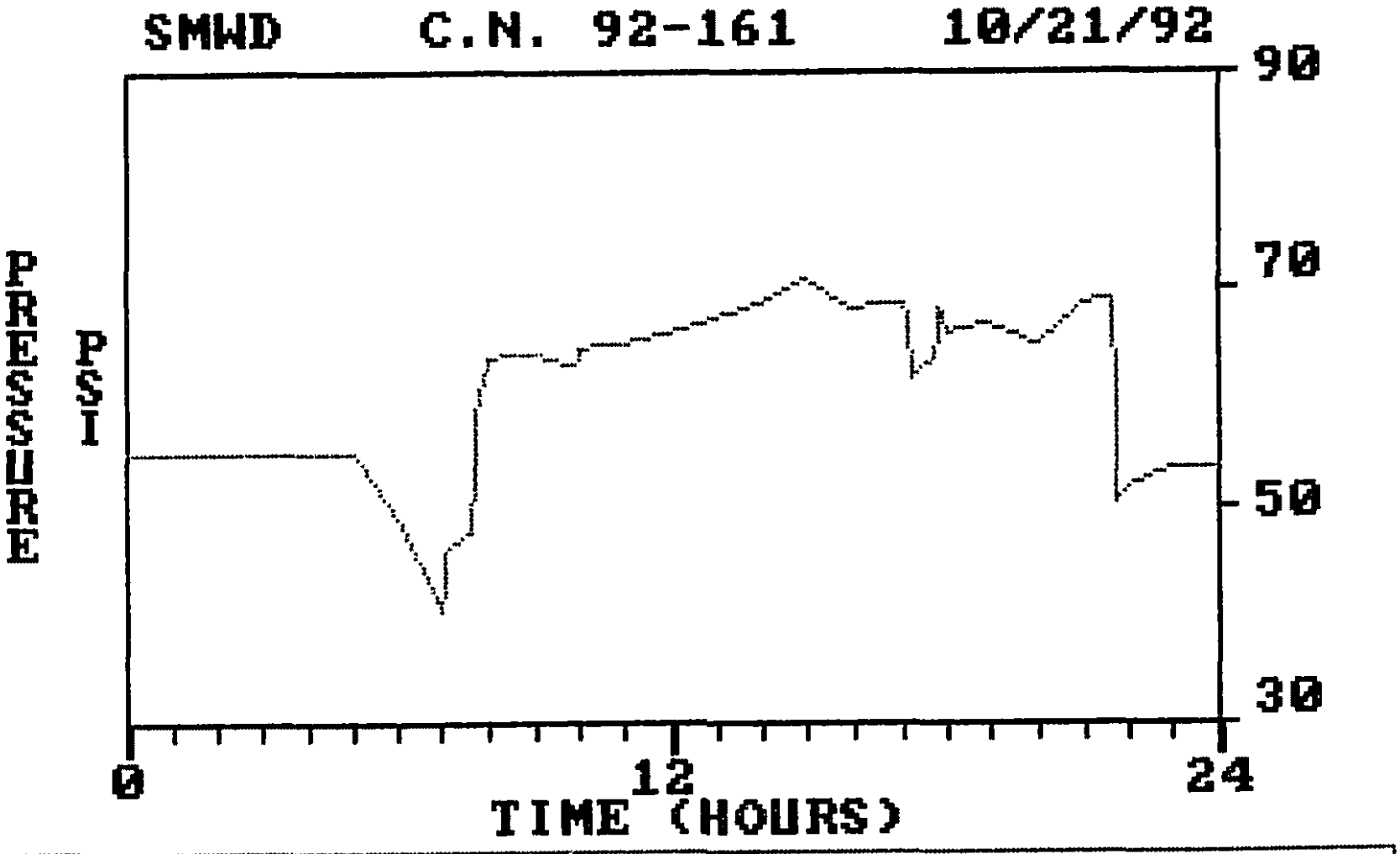


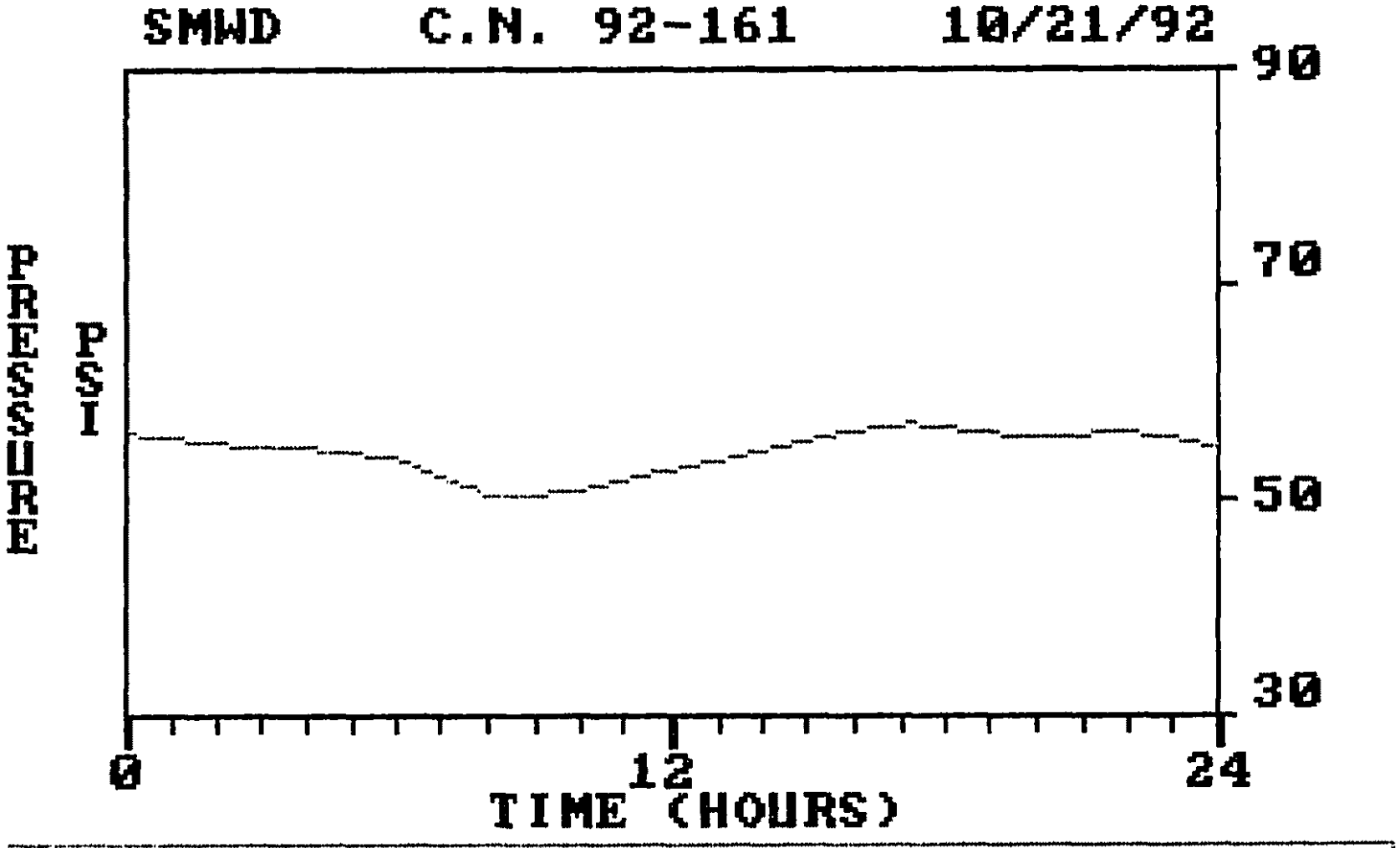

SMWD C.N. 92-161 10/21/92
PRESSURE
PSI
150
130
110
90
0
12
24
TIME (HOURS)
KEY: Pump Discharge

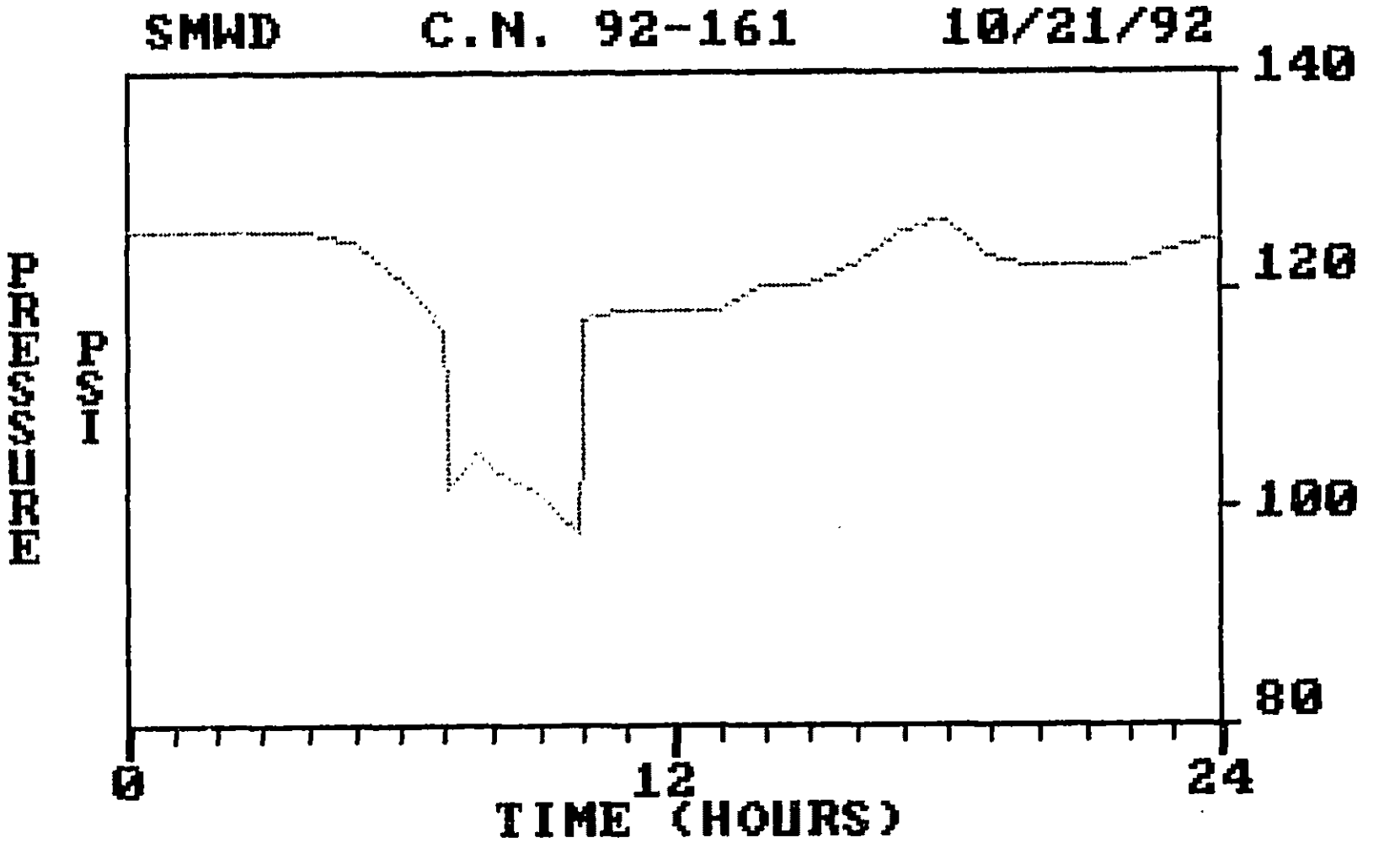

SMWD C.N. 92-161 10/21/92
100
90
80
70
PRESSURE
PSI
0
12
24
TIME (HOURS)
KEY: = Pump Suction

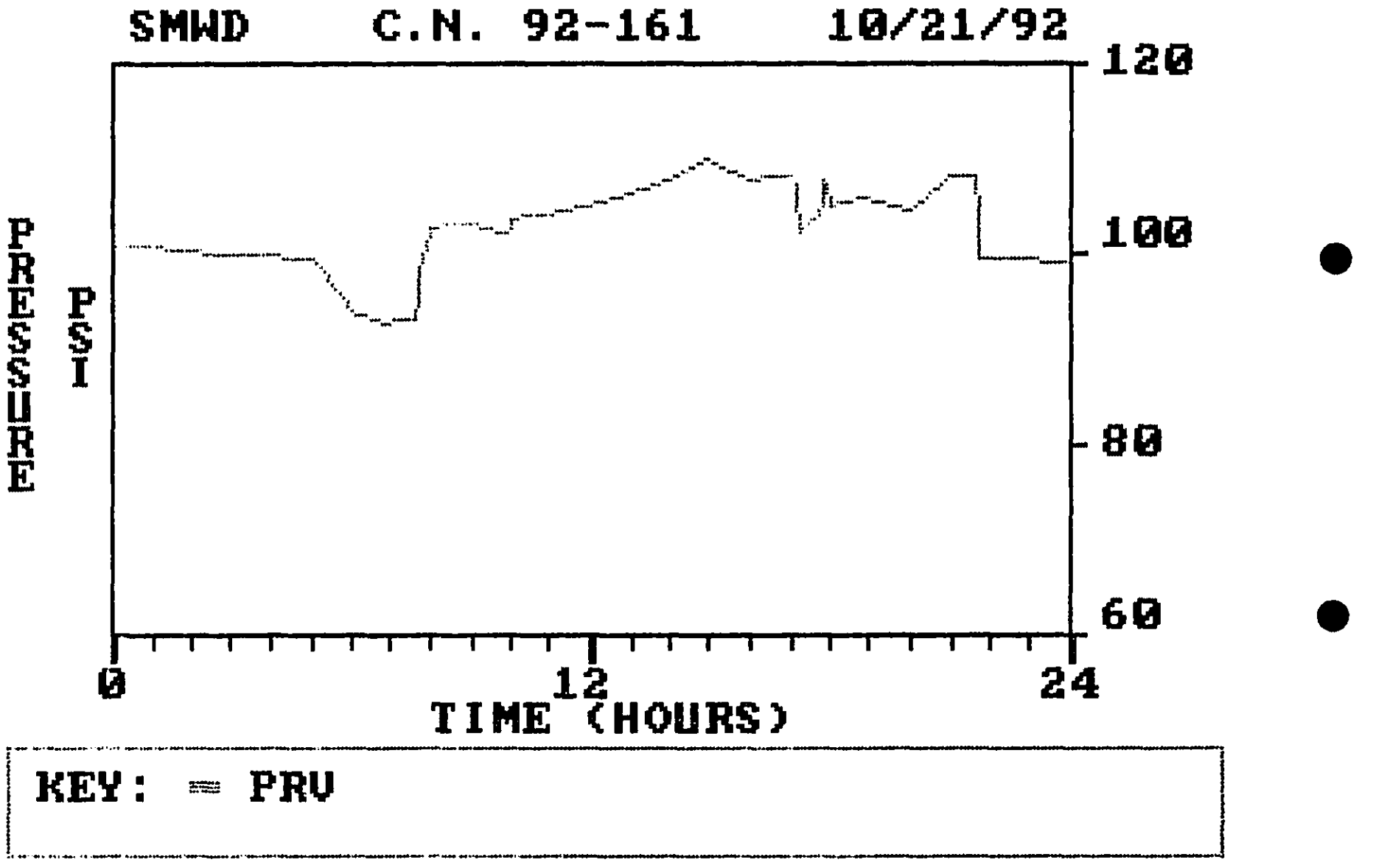


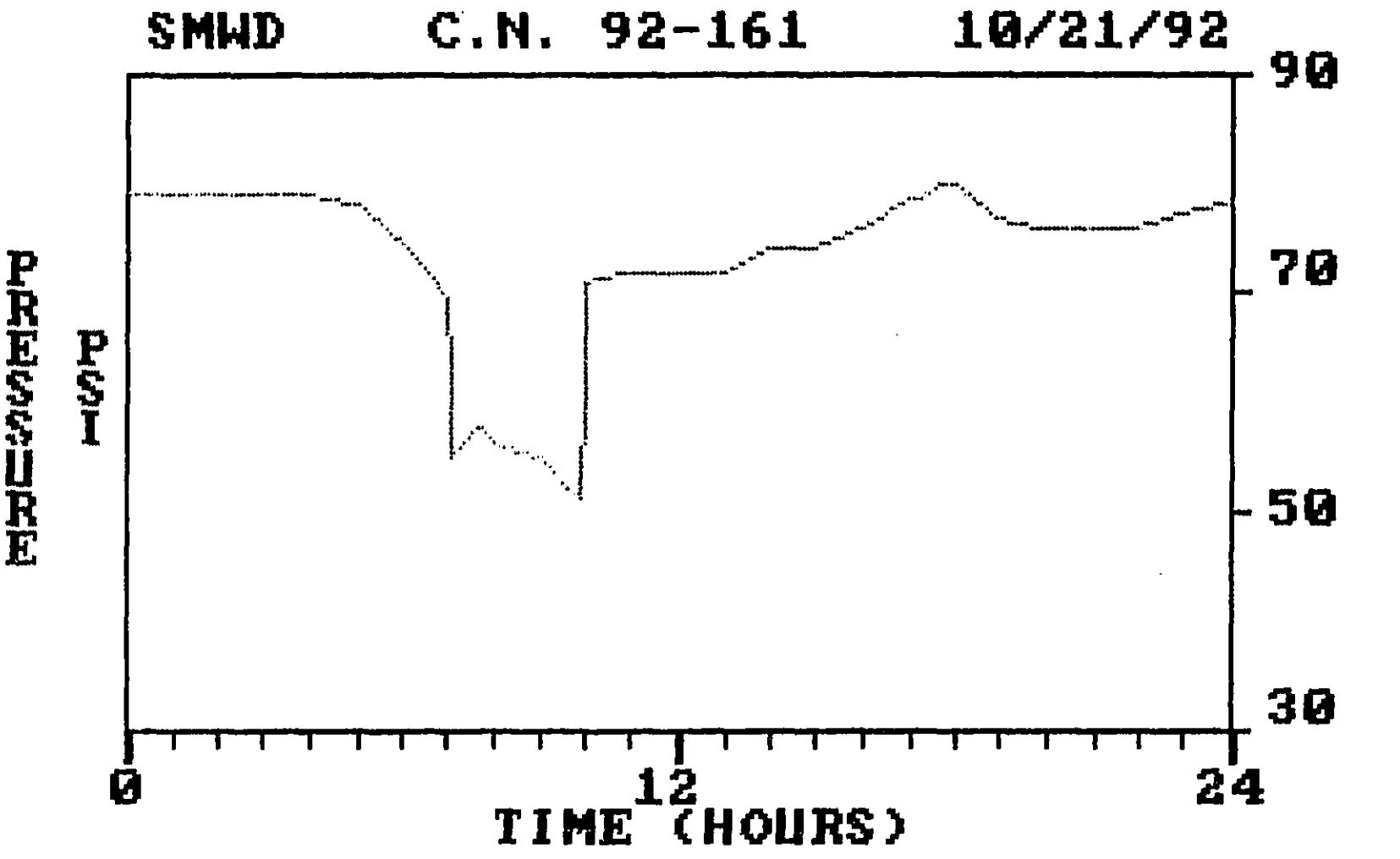
KEY: = Cummins Barn


SMWD C.N. 92-161 10/21/92
PRESSURE PSI
90
70
50
30
0
12
24
TIME (HOURS)
KEY: = Braggs Lane

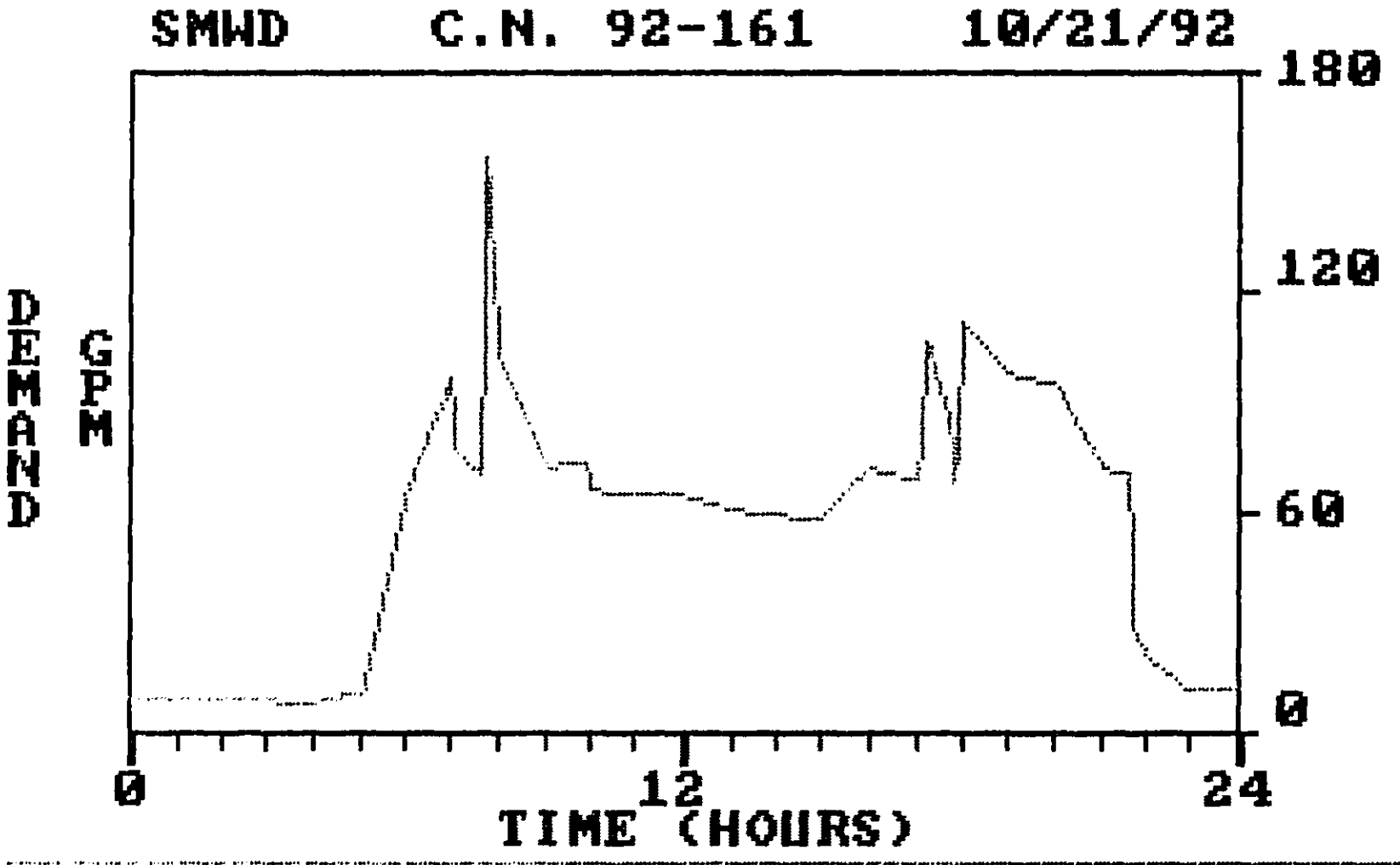

SMWD C.N. 92-161 10/21/92
PRESSURE
PSI
90
70
50
30
0
12
24
TIME (HOURS)
KEY: = Indian Hills Tank

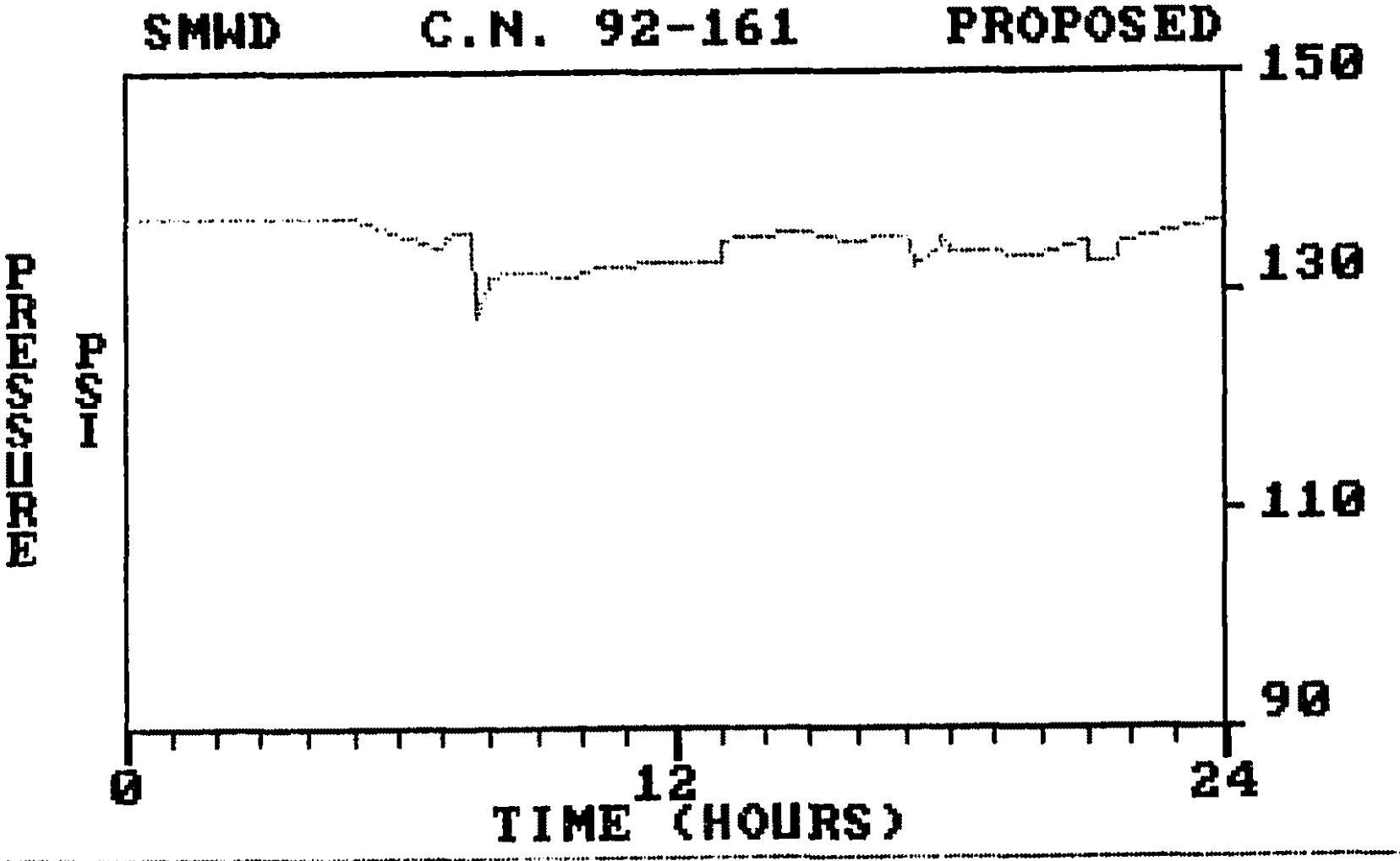

SMWD C.N. 92-161 10/21/92
PRESSURE
PSI
140
120
100
80
0
12
24
TIME (HOURS)
KEY: = EKP Substation

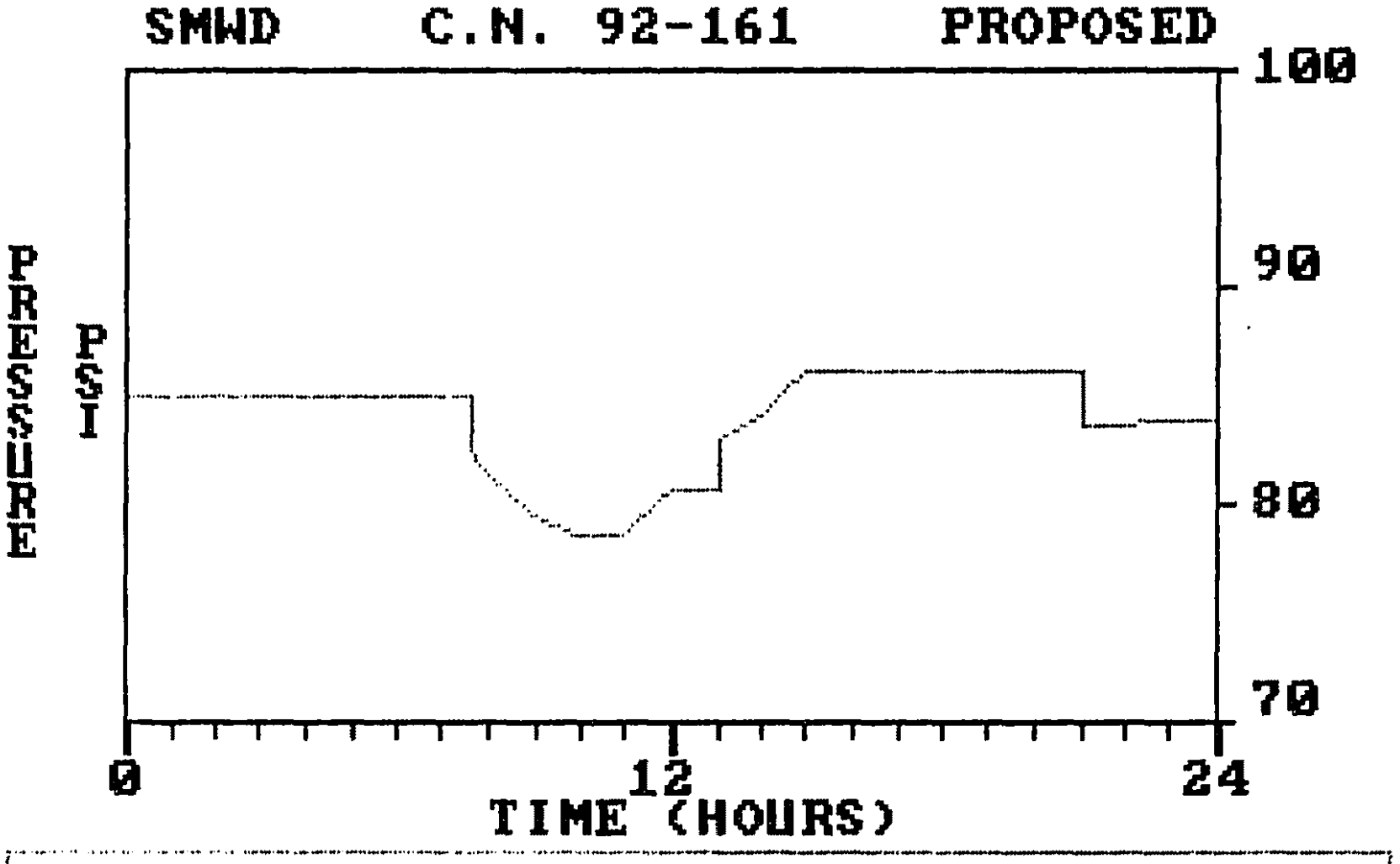

SMWD C.N. 92-161 10/21/92
PRESSURE
PSI
120
100
80
60
0
12
24
TIME (HOURS)
KEY: = PRU

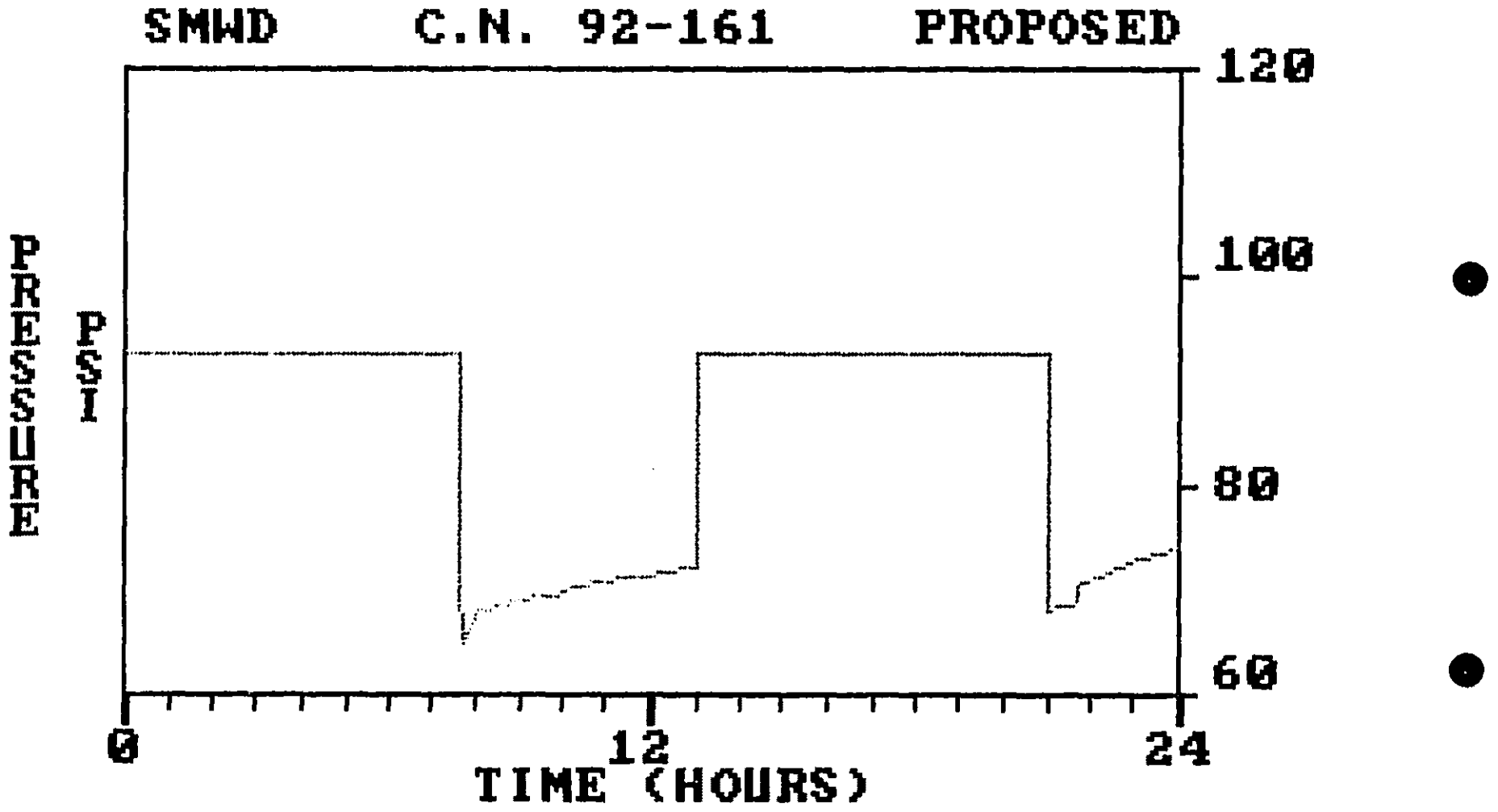


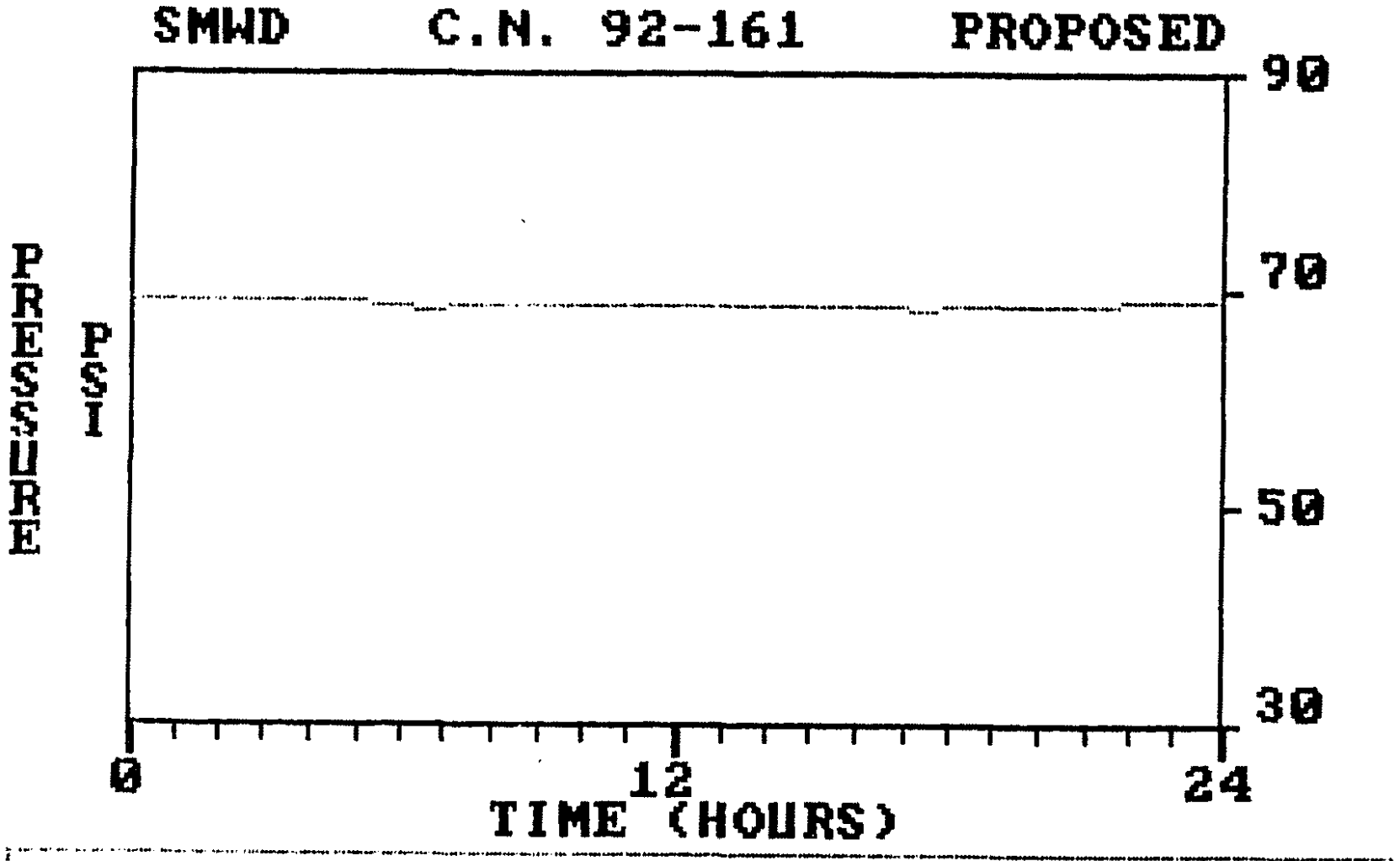
KEY: = Guynn Road

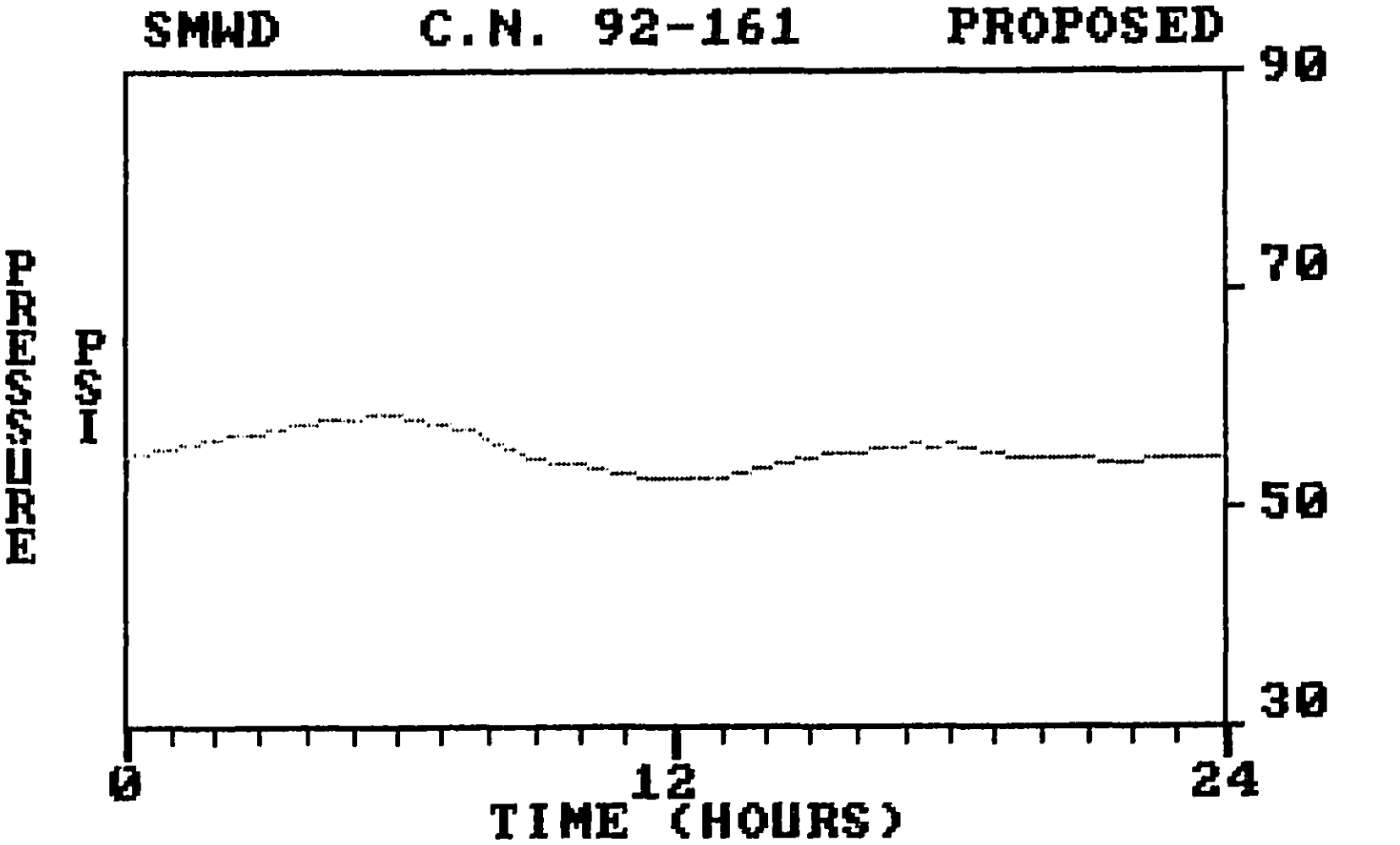

SMWD C.N. 92-161 10/21/92
DEMAND GPM
180
120
60
0
0
12
24
TIME (HOURS)
KEY: Customer Demand

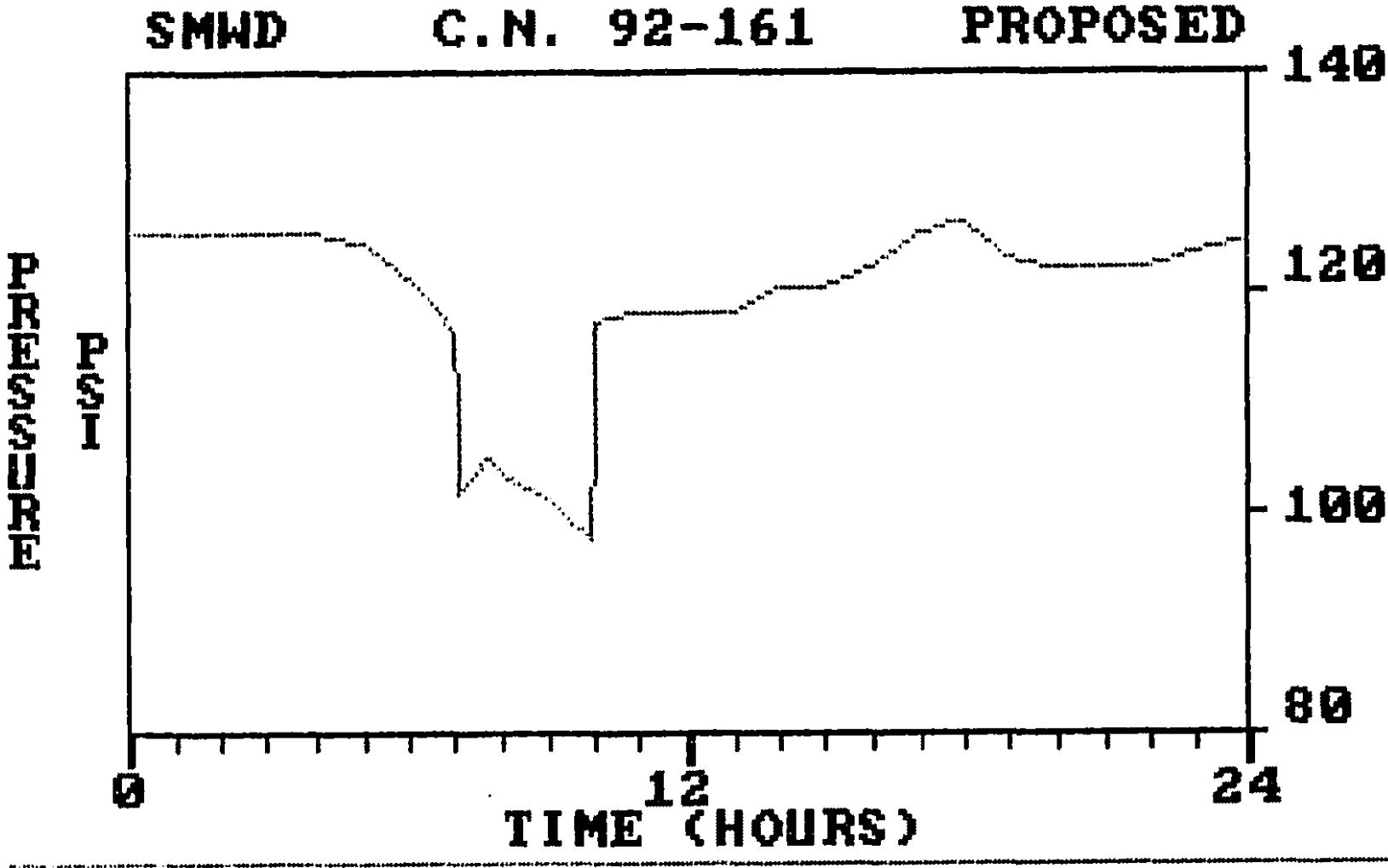

SMWD C.N. 92-161 PROPOSED
150
130
110
90
PRESSURE
PSI
0
12
24
TIME (HOURS)
KEY: = Pump Discharge


SMWD C.N. 92-161 PROPOSED
PRESSURE
PSI
100
90
80
70
0
12
24
TIME (HOURS)
KEY: Pump Suction

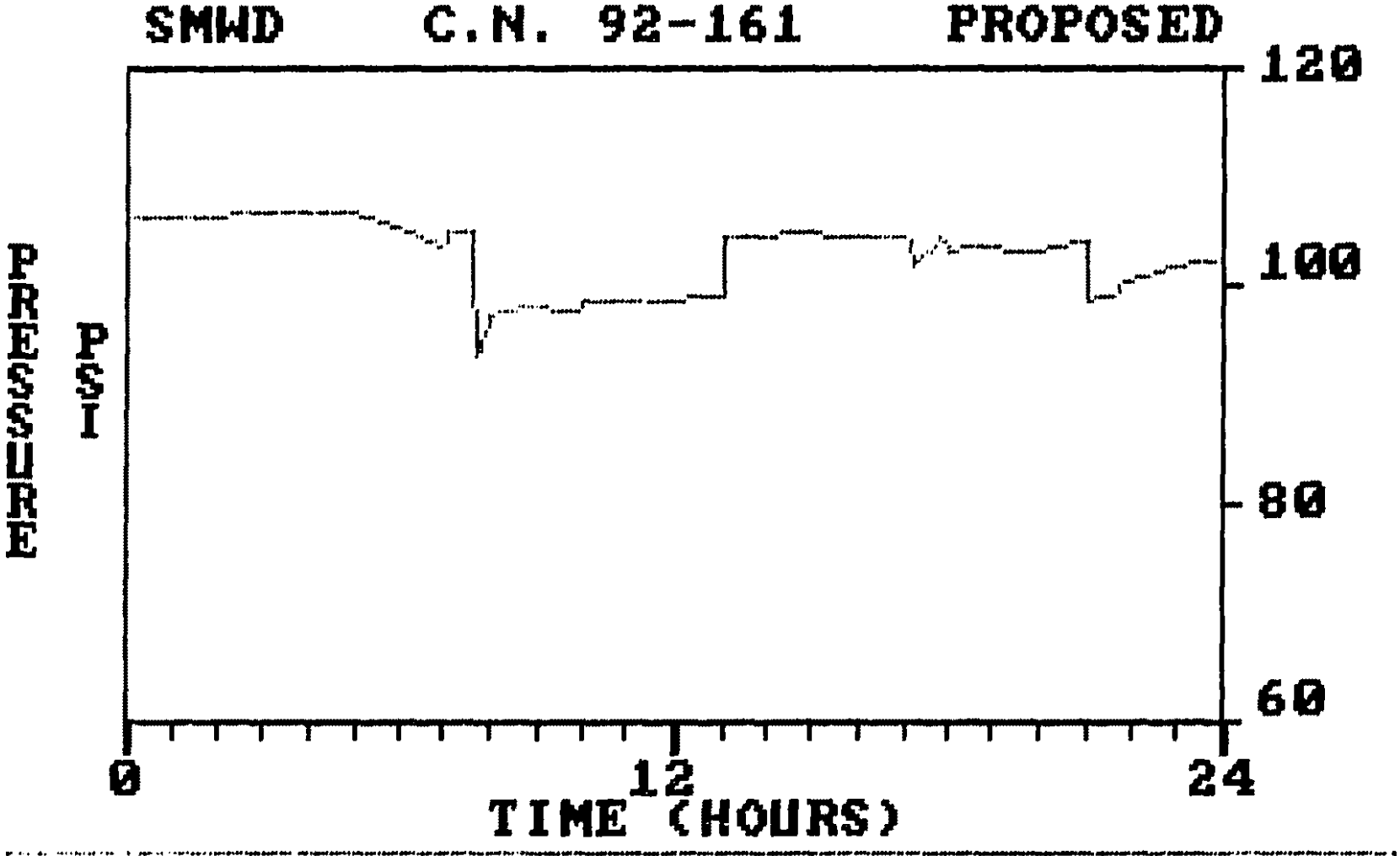

SMWD C.N. 92-161 PROPOSED
PRESSURE
PSI
120
100
80
60
0
12
24
TIME (HOURS)
KEY: = Cummins Barn

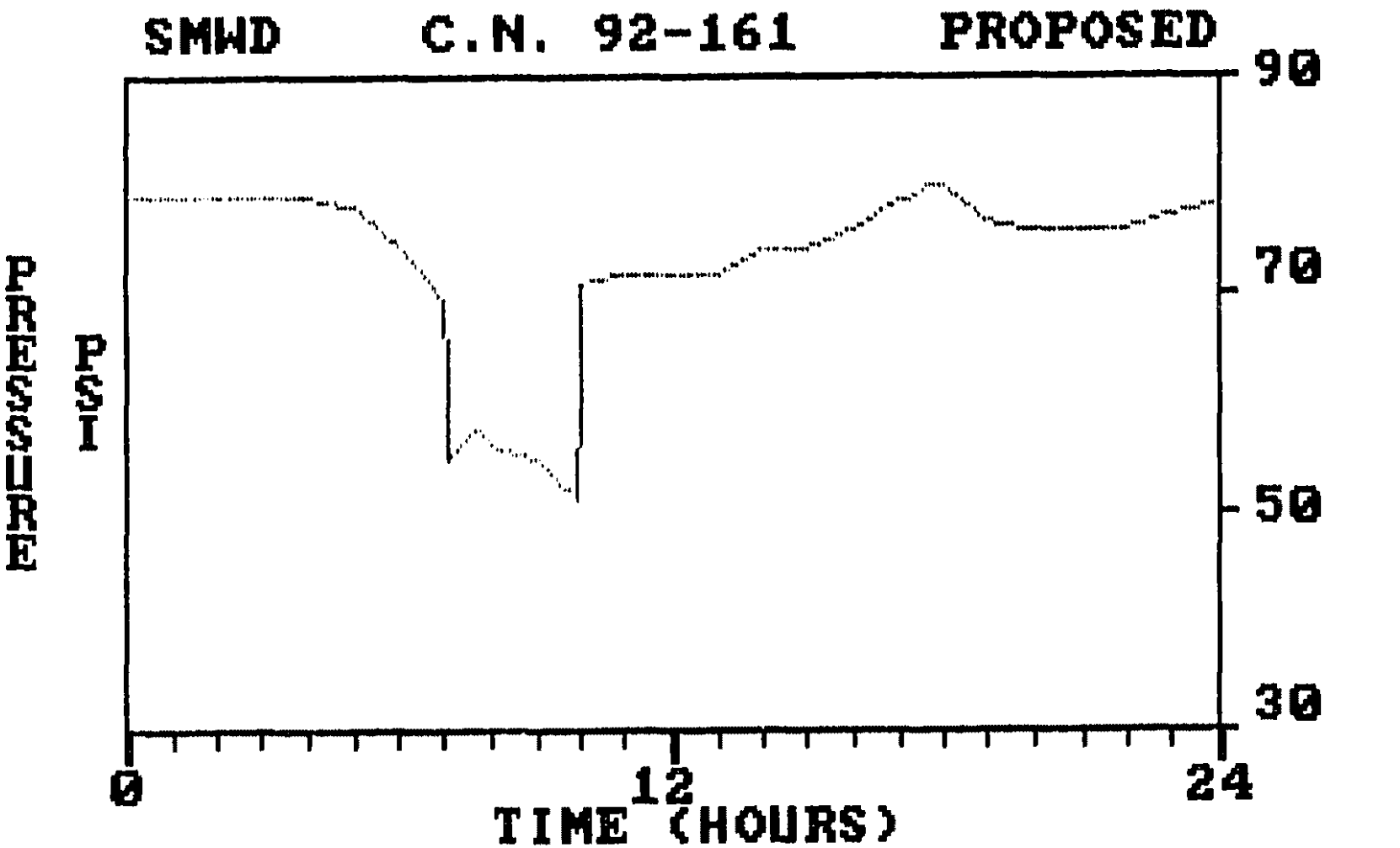

SMWD C.N. 92-161 PROPOSED
PRESSURE
PSI
90
70
50
30
0
12
24
TIME (HOURS)
KEY: = Braggs Lane

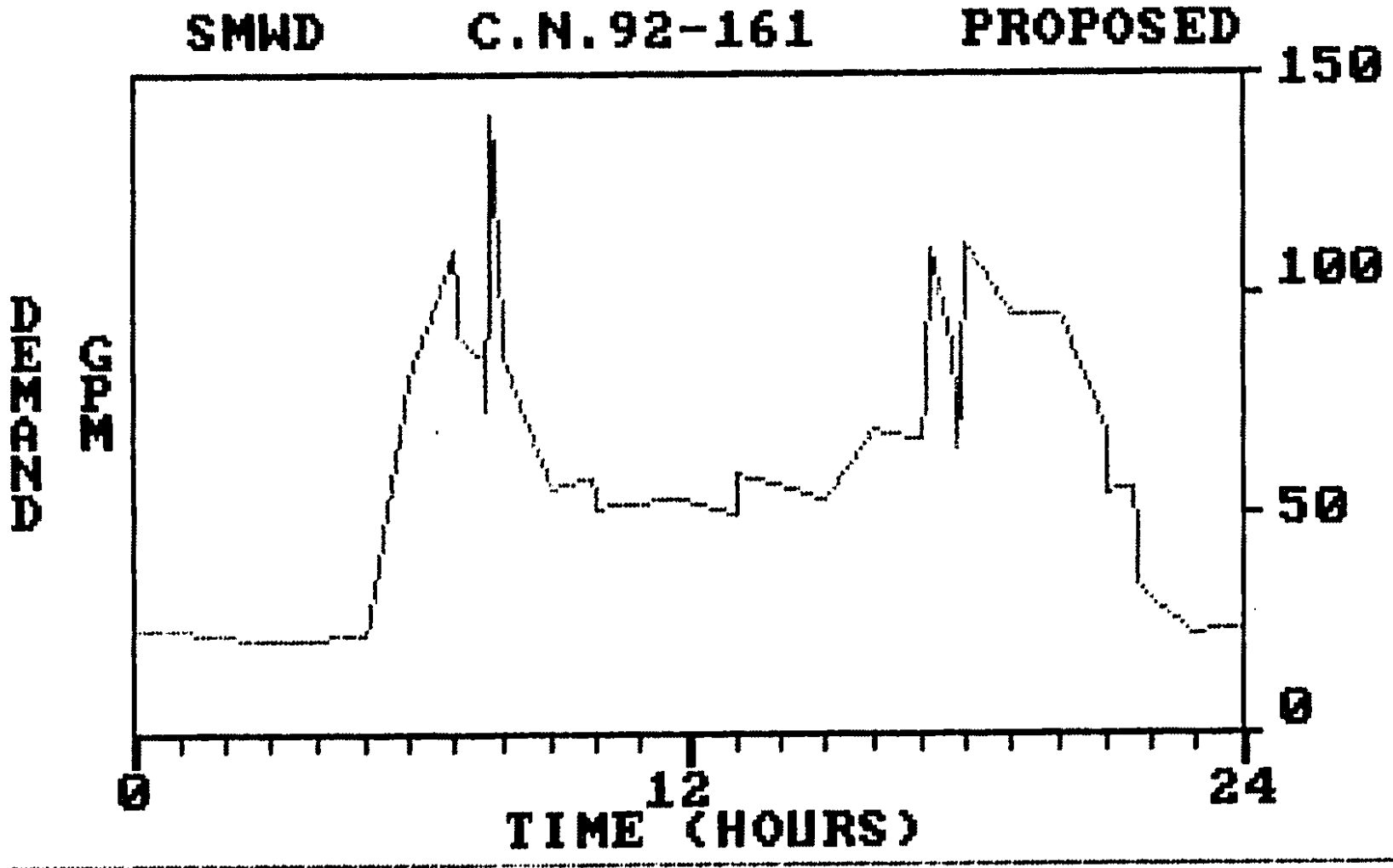

SMWD C.N. 92-161 PROPOSED
PRESSURE PSI
90
70
50
30
0
12
24
TIME (HOURS)
KEY: = Indian Hills Tank



KEY: = EKP Substation


SMWD C.N. 92-161 PROPOSED
PRESSURE
PSI
120
100
80
60
0
12
24
TIME (HOURS)
KEY: PRV


SMWD C.N. 92-161 PROPOSED
PRESSURE
PSI
90
70
50
30
0
12
24
TIME (HOURS)
KEY: Guynn Road


SMWD C.N.92-161 PROPOSED
DEMAND GPM
150
100
50
0
0
12
24
TIME (HOURS)
KEY: = Customer Demand