Results of an Extended Pump Test of Wells 1 and 9

Prepared for

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EXHIBIT I-4

PETITIONER'S EXHIBIT NO. 4

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Introduction

This report presents the results of an extended pump test of Wells 1 and 9 which are located in Lanai's Palawai Basin. Both of these wells draw water from high level, brackish groundwater compartments. It is the intention of the Lanai Water Company to deliver water from these wells for golf course and other landscape irrigation at Manele Resort. Because the intended use rate is greater than levels of historic use, the response of the wells to extended pumping is of significant interest.

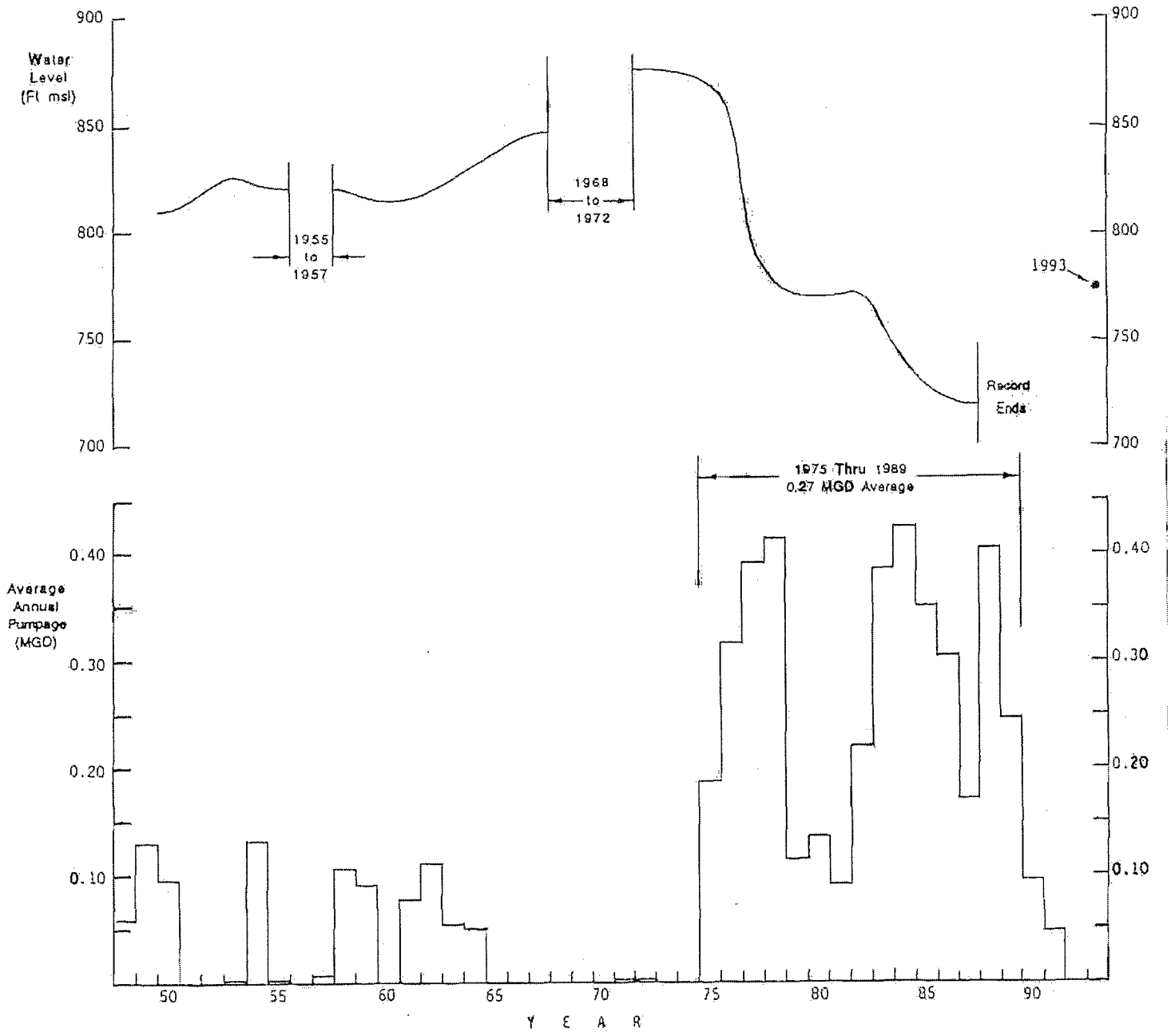
In June 1993, Lanai Company completed construction of a 15-million gallon (MG) open reservoir on the outer edge of Palawai Basin. The storage it provides is in integral part of the Manele Resort's irrigation system. The necessity to fill the reservoir while also supplying the golf course's ongoing irrigation and dust control requirements provided an opportunity to conduct an extended pump test of both wells. This report provides a compilation of the data and results of this test.

Background Information

Well 1 was developed in 1948 for pineapple irrigation. The well is 1266 feet deep, terminating three feet below sea level. Its original water level was reportedly 818 feet above sea level. The original chloride concentration may have been in the range of 750 milligrams per liter (MGL), but this value cannot be confirmed and it is not known if it was a pumped or grab sample. The plantation's use of the well in the years since 1948 was modest and sporadic. Peak use occurred in the 1975 through 1989 period when the 15-year average was 0.27 MGD. During the peak year, 1984, the average was 0.43 MGD. Figure 1 depicts the well's pumpage since 1948 and available water level data since 1950. Chloride data is not available for most of this period. However, since 1991, chlorides have consistently been in the range of 320 to 350 MGL.

The pilot hole of Well 9 was drilled in 1990 to a depth 1450 feet, ending nine feet below sea level. The water level stood approximately 840 feet above sea level. A temperature profile in the pilot hole by DOWALD personnel showed a steady increase from 80° F. at the top of the water to 101° F near the bottom. The well was reamed and cased to a depth of 775 feet (about 665 feet above sea level), with cuttings from the reaming process filling the pilot hole below 775 feet. Pump tests at 340 GPM showed a drawdown of 105 feet and a chloride level of approximately 550 MGL. Just prior to installation of a permanent pump in May 1993, the well was deepened by 200 feet. The well's performance with its new depth of 975 feet is substantially better. Drawdown is just 25 feet at 360 GPM. The water produced is also less saline; the chloride concentration is about 400 MGL.

The proximity of Wells 1 and 9 to several potable wells which are located further upslope and tap into higher groundwater compartments is shown on Figure 2. Figure 3 is a geologic cross section which illustrates relative water levels, chloride concentrations, and temperatures in all of these wells. Based on water levels and responses to pumping, each of these wells tap into physically distinct compartments. Chlorides and temperature increase and water levels decrease in these compartments with distance away from the mountain's crest. Wells 9 and 10 in Palawai Basin have substantially greater chlorides and higher temperatures than any of the potable wells. Well 10, which is located at the outer edge of Palawai Basin, has an even greater salinity and temperature than Wells 1 and 9. The



Based on Reports by
Keith E. Anderson
and company records

Figure 1

Historic Pumpage and Resulting
Water Levels in Well 1

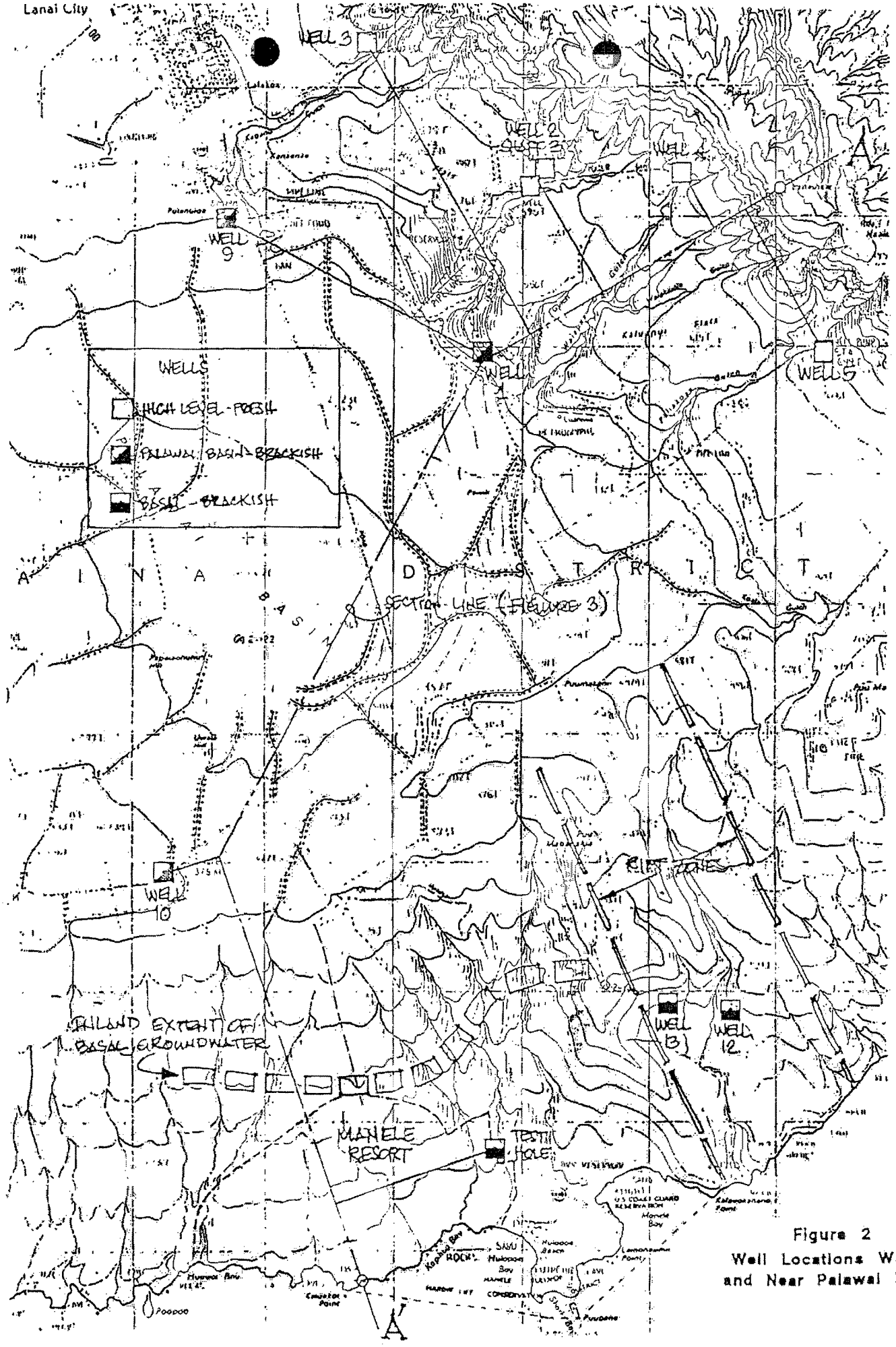


Figure 2
Well Locations Within
and Near Palawai Basin

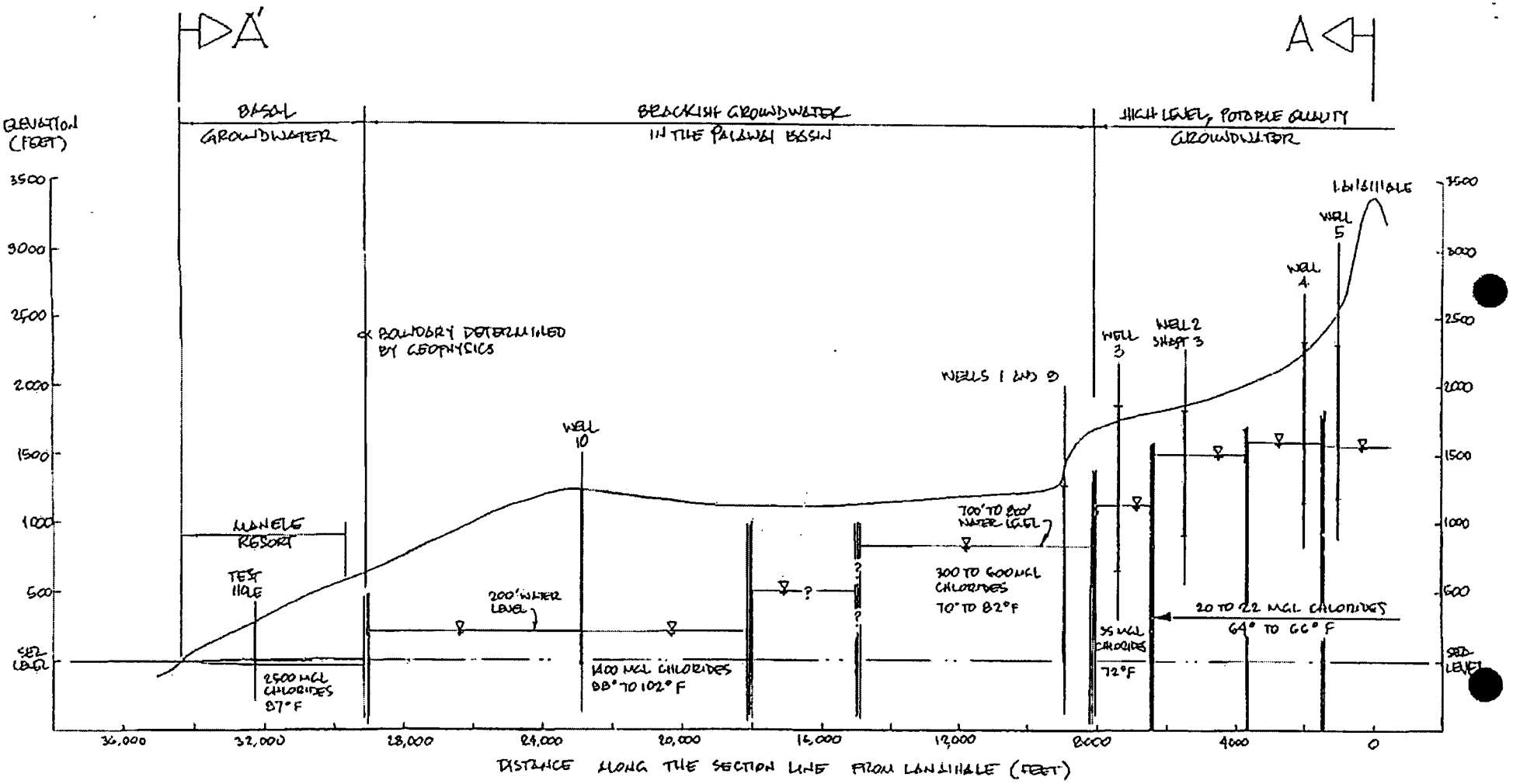


Figure 3
Hydro-Geologic Section From Manele to Lanaihale

most probable explanation for the brackish water quality of the three wells in Palawai Basin is that geothermal-driven convection currents have moved salt upward.

Description of the Pump Test

The primary objectives of the pump test were to determine water level and water quality responses in Wells 1 and 9 during their extended, simultaneous pumping. Secondary objectives were to determine if any response in the upslope, potable wells due to this pumping could be detected. Measurements taken to meet the primary objectives were as follows: (1) flowmeters on the discharge lines of Wells 1 and 9 were read a minimum of once a day; (2) water level responses were continuously recorded in each of the pumping wells using airlines, bubblers and chart recorders; and (3) the water pumped by the wells was sampled at the start and end of the test.

To determine possible water level response in the upslope, potable wells, water levels were continuously recorded using the airline and bubbler system at each well. Lanai Water Company turned off as many of these wells as possible during the pump test. However, to meet its ongoing supply obligations in Lanai City and Manele Resort, it was necessary to continuously run Well 3. It was intended that all the other upslope wells -- Well 2/Shaft 3, Well 4, and Well 5 -- would be kept off for the duration of the test. However, it was necessary to run Well 5 for several periods of relatively short duration during the pump test period.

Pump Test Data

In the days before the start of the pump test on Saturday, June 19, Well 1 was being operated on a daily basis to meet ongoing construction requirements for the Manele Golf Course. Daily pumpage was in the range of 300,000 to 400,000 gallons and limited to daylight hours. The well is outfitted with an engine-driven unit and is started and stopped manually. The first two days of the pump test, June 19 and 20, occurred on a weekend. Manpower scheduling required that Well 1 continue to be operated on a daylight-hour only basis for these two days. However, starting at 0620 on Monday morning, June 21, the well was operated continuously until the end of the test on July 7.

Well 9 is outfitted with a submersible pump and its power is presently supplied by a diesel generator unit. The pump was turned on at 0545 on the morning of June 19 and ran continuously through July 7 except for a 4-hour outage of the generator on June 22nd. Table 1 summarizes the daily pumpage amounts as logged by Lanai Water Company personnel (Appendix A contains copies of these logs). Total and average pumpage amounts are summarized below. Average pumpage, including outages, amounted to 1.15 MGD over an 18-day period.

	Well 1	Well 9	Both Wells
Total Pumpage, June 19 to July 7 (MG)	11.594	9.460	21.054
Average Pumpage Rates, Excluding Outages (GPM)	466	362	828
Average Pumpage Rates Including Outages (MGD)	0.633	0.517	1.150

Table 1

Pumpage of Wells 1 and 9 From June 19 to July 7, 1993

Day	Well 1				Well 9			
	Time of Reading	Meter Reading (MG)	Pumpage From Last Reading (MG)	Average Flowrate Between Readings (GPM)	Time of Reading	Meter Reading (MG)	Pumpage From Last Reading (MG)	Average Flowrate Between Readings (GPM)
June 19	0545-1745	209.520 to 209.850	0.330	458	0545	0.052	--	--
20	0615-1745	209.850 to 210.153	0.303	439	0745	0.623	0.571	366
21	0620	210.153	--	--	0545	1.111	0.488	370
22	1400	211.068	0.915	482	0545	1.636	0.525	365
23	1400	211.675	0.607	422	0545	2.064	0.428	355
24	1400	212.380	0.705	490	----- No Reading -----			
25	1400	213.029	0.649	451	1030	3.213	1.149	363
26	1400	213.690	0.661	459	0720	3.655	0.442	354
27	1400	214.336	0.646	450	0750	4.188	0.533	363
28	1400	215.015	0.679	472	1423	4.853	0.665	363
29	1400	215.592	0.577	401	1435	5.380	0.527	363
30	1410	216.239	0.647	446	1400	5.888	0.508	362
July 1	1430	216.921	0.692	474	0730	6.272	0.384	366
2	1410	217.592	0.671	473	0715	6.786	0.514	361
3	1406	218.264	0.672	468	0711	7.305	0.519	361
4	1420	218.987	0.723	497	0728	7.830	0.525	360
5	1405	219.688	0.701	492	0745	8.356	0.526	361
6	----- No Reading -----				0715	8.865	0.509	361
7	1305	221.114	1.426	506	1315	9.512	0.647	359

Notes:

1. Well 9 ran continuously from 0545 on June 19 through July 7 at 1305 except for 4 hours on June 22 when the generator went out. Average pumpage shown for June 22 above is corrected for the 4-hour outage.

2. Well 1 is an engine-driven pump. It was operated during working hours on June 19 and 20 and then was run continuously from 0620 on June 21 to July 7 at 1305.

Figure 4 is a graphic depiction of pumping rates and resulting water level responses in the two Palawai Basin wells and three of the upslope potable wells, Well 2/Shaft 3, Well 3, and Well 5. Breaks in the airline recordings did occur and are noted on the figure. There are also several discontinuities in the water level record which were the result of the weekly chart changes. Only one of these discontinuities is significant. It occurred during the recovery of water level in Well 1 on July 10. Based on semi-log plots of Well 1's recovery presented subsequently, the 10-foot difference on the chart has been ignored.

Copies of all of the water level charts can be found in Appendix B. The water level in Well 4 was not recorded because its airline was not functional and the size of the pump's column pipe and power cable prevented installation of a pressure transducer and data logger.

Water samples were obtained from Wells 1 and 9 on June 18th, one day before the start of pump testing and on July 7th, minutes before the pumps were shut off. Chloride concentrations and salinity of these samples are tabulated below. Chloride concentrations were determined by mercuric nitrate titration and salinity was determined using an Ocean Sensors Model OS-200 CTD.

	Well 1		Well 9	
	Chlorides (MGL)	Salinity (PPT)	Chlorides (MGL)	Salinity (PPT)
Prior to Start of Test: June 18 at 1300	330	0.753	404	0.920
End of Test: July 7 at 1300	326	0.740	395	0.905

Discussion of the Pump Test Results

Water Levels Generally. Several basic observations about water levels and responses to pumping are important to note: (1) the static water in Well 9 is about 50 feet higher than in Well 1 and this difference prevailed during and following the pump test; (2) pumping in either Well 1 or Well 9 over the 18-day period had no observable effect on the water level in the other well, demonstrating that the draft of these wells is from physically distinct compartments; (3) pumping of Wells 1 and 9 had no detectable effect on the water level of any of the higher elevation, potable wells; and (4) pumping of any of the higher elevation, potable wells had no observable water level response in any other groundwater compartment. Although these results do not entirely rule out hydraulic interconnections among the compartments, they do demonstrate that if water does move between them, it occurs at moderate to negligible rates. Also, this conclusion based on the pump test results is consistent with long-term pumpage and water level records.

Water Quality of Wells 1 and 9. Chloride and salinity declined in Wells 1 and 9 by two percent or less over the 18 days of pumping. Although the magnitude of the change was very small, the consistency of the results suggest that the change is due to pumping. Monitoring of this effect as the wells are put into continuous service is warranted. Lanai Company's 28-day monitoring periods are adequate to track this possible effect.

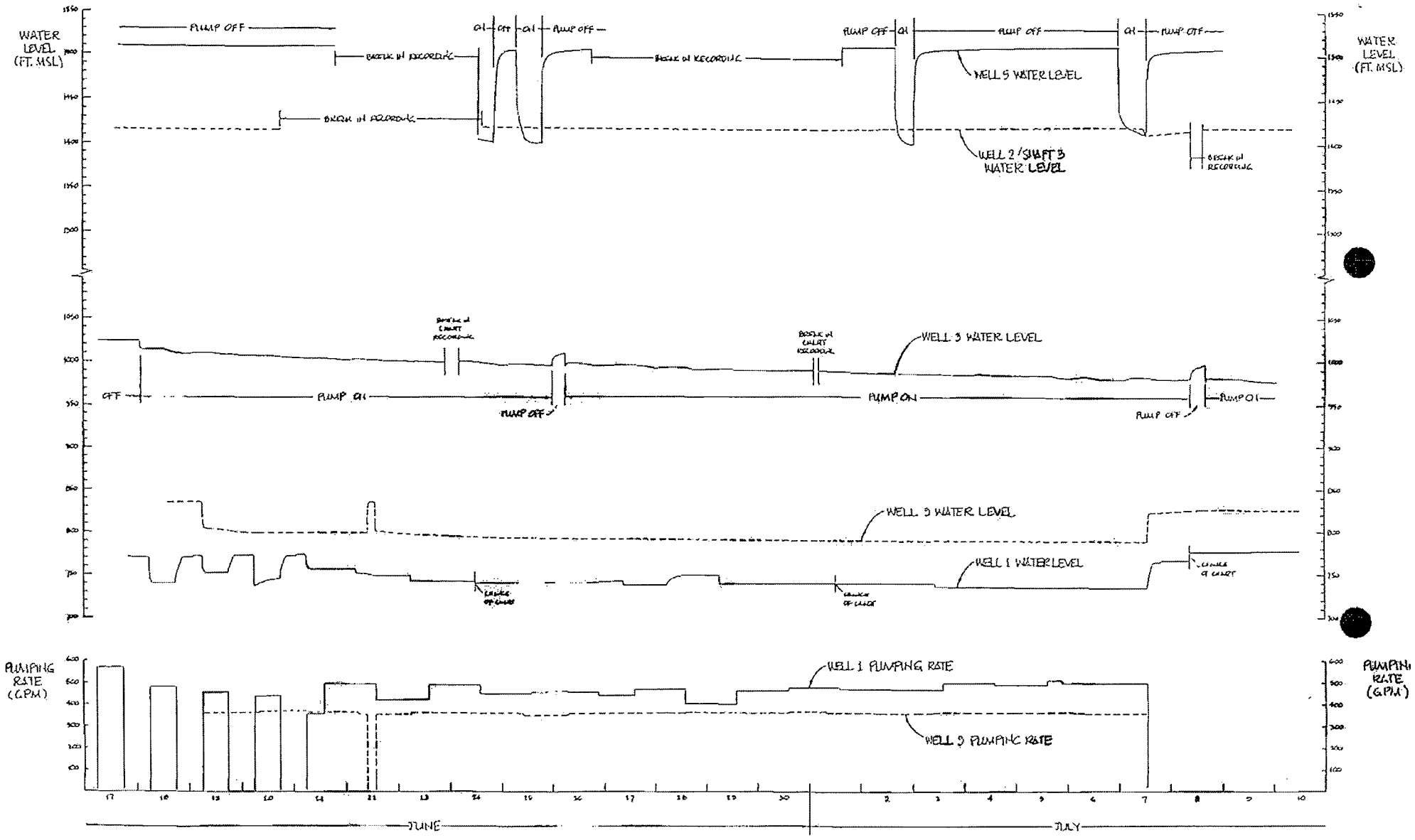


Figure 4

Pumpage and Water Level Response, June 19 to July 7, 1993

Specifics of the Water Level Response in Well 1. Figure 5 is semi-log plot of the drawdown in Well 1. The plot covers continuous pumping from 0620 on June 21 to 1305 on July 7, a total of 23,445 minutes. Day-to-day changes in the pumping rate, although relatively modest, produced the irregularities in the drawdown curve, occurring first after 1300 minutes and several other times thereafter. Despite these irregularities, boundary effects are evident in the drawdown. Also, an equilibrium was not reached by the end of pumping and the well had not fully recovered in the three days following the pump test. The rate of drawdown indicates that the transmissivity of the formation is on the order of 28,000 GPD/ft (3740 ft^2/day). For purposes of illustration, if it is assumed that the aquifer's thickness extends to sea level, then the equivalent permeability would be 4.8 feet per day. Although these computed values of transmissivity and permeability are relatively low compared to most Hawaiian basalt aquifers, they are consistent with values calculated previously for other wells on Lanai.

Specifics of the Water Level Response in Well 9. There was a four-hour outage of Well 9 on June 22nd, during which time there was a virtually complete recovery of its static water level. Figure 6 is a semi-log plot of drawdown and recovery for this initial period. Figure 7 is a semi-log plot which begins at the restart of the pump after the outage and continues for the remainder of the test. As with Well 1, an equilibrium had not been reached at the end of pumping and the well had not fully recovered in the three days following. Unlike Well 1, boundary effects are not obvious. A transmissivity in the range of 20,000 to 25,000 GPD/ft (2670 to 3340 ft^2/day) provides the best fit of the observed drawdown and recovery. Again assuming the aquifer thickness is equivalent to its head above sea level, the permeability is on the order of 3.2 to 4.0 feet per day.

Conclusions

Eighteen days of pumping Wells 1 and 9 at a combined rate of 1.15 MGD produced no observable effects in the higher elevation potable wells, no interference effects between Wells 1 and 9, and a very small decrease in salinity of the water pumped by Wells 1 and 9. Because equilibrium levels had not been reached in either well, continued monitoring of water levels and water quality of Wells 1 and 9 is appropriate. Lanai Company's ongoing monitoring program will provide the necessary data. However, the pump test results are generally quite promising, particularly when compared to initial pump tests of other Lanai wells, such as Well 3, which has subsequently proven itself during decades of continuous use.

For the remainder of 1993, the County has imposed a limit on the combined draft of Wells 1 and 9 of 0.75 MGD, just 65 percent of the 18-day test pumping rate. The pump test results indicate that Palawai Basin will be able to supply more than 0.75 MGD of brackish water, particularly if Lanai Company is given the flexibility to develop a third Palawai Basin well in another, physically distinct compartment. Data collected for Wells 1 and 9 through December 1993 should be evaluated from this perspective.

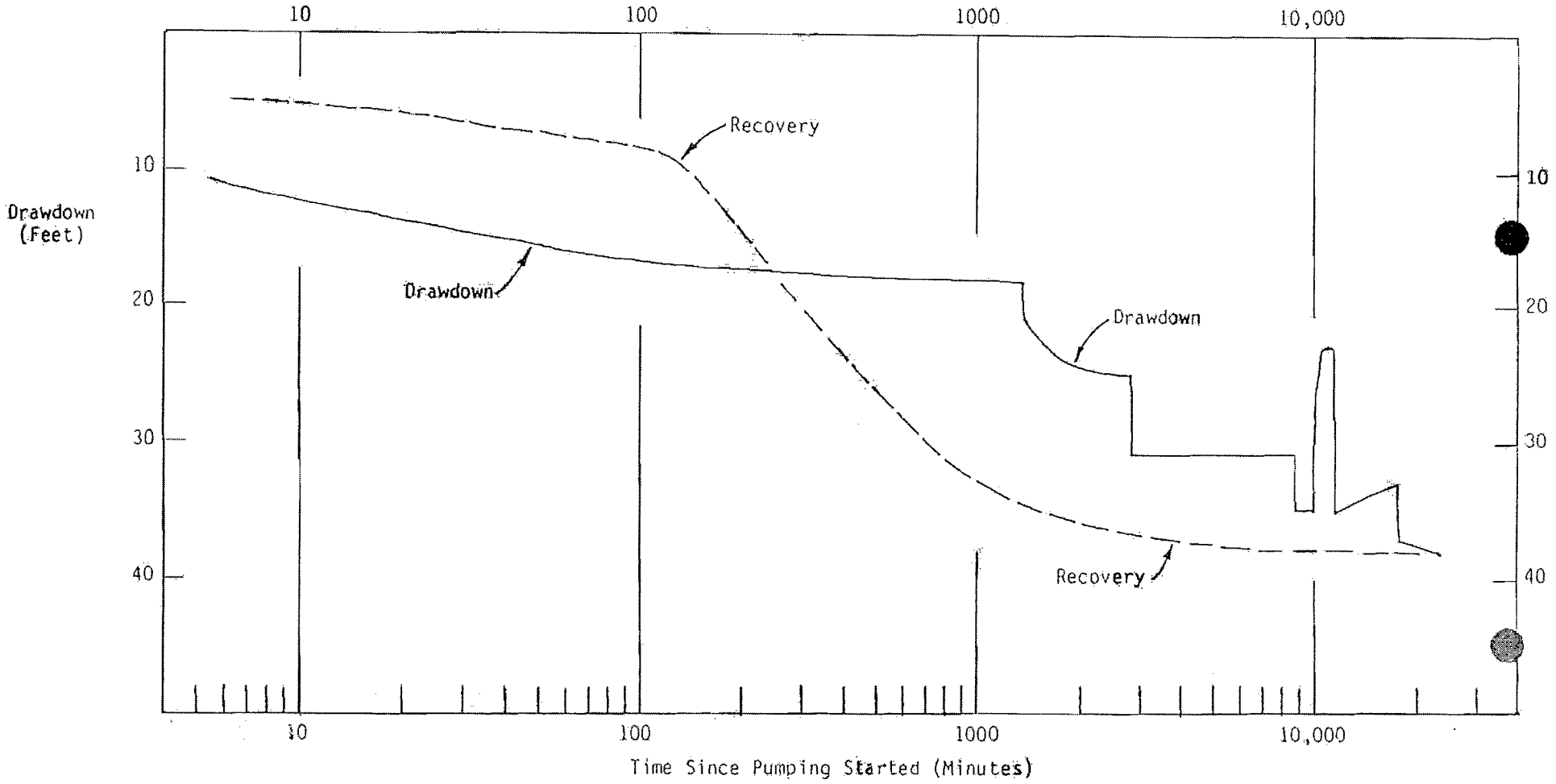


Figure 5

Drawdown and Recovery in Well 1,
June 21 to July 10, 1993

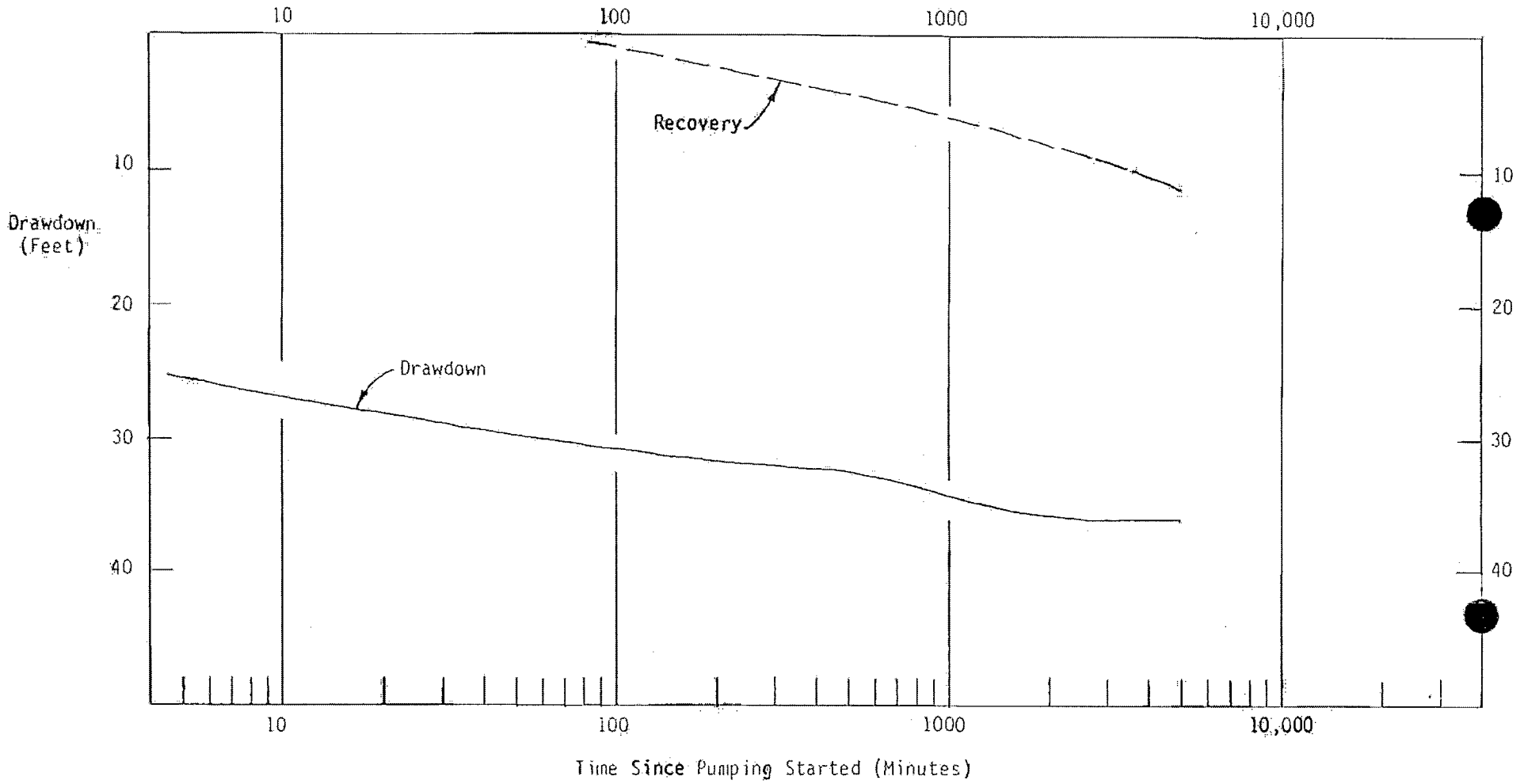


Figure 6

Drawdown and Recovery in Well 9,
June 19 to 21, 1993

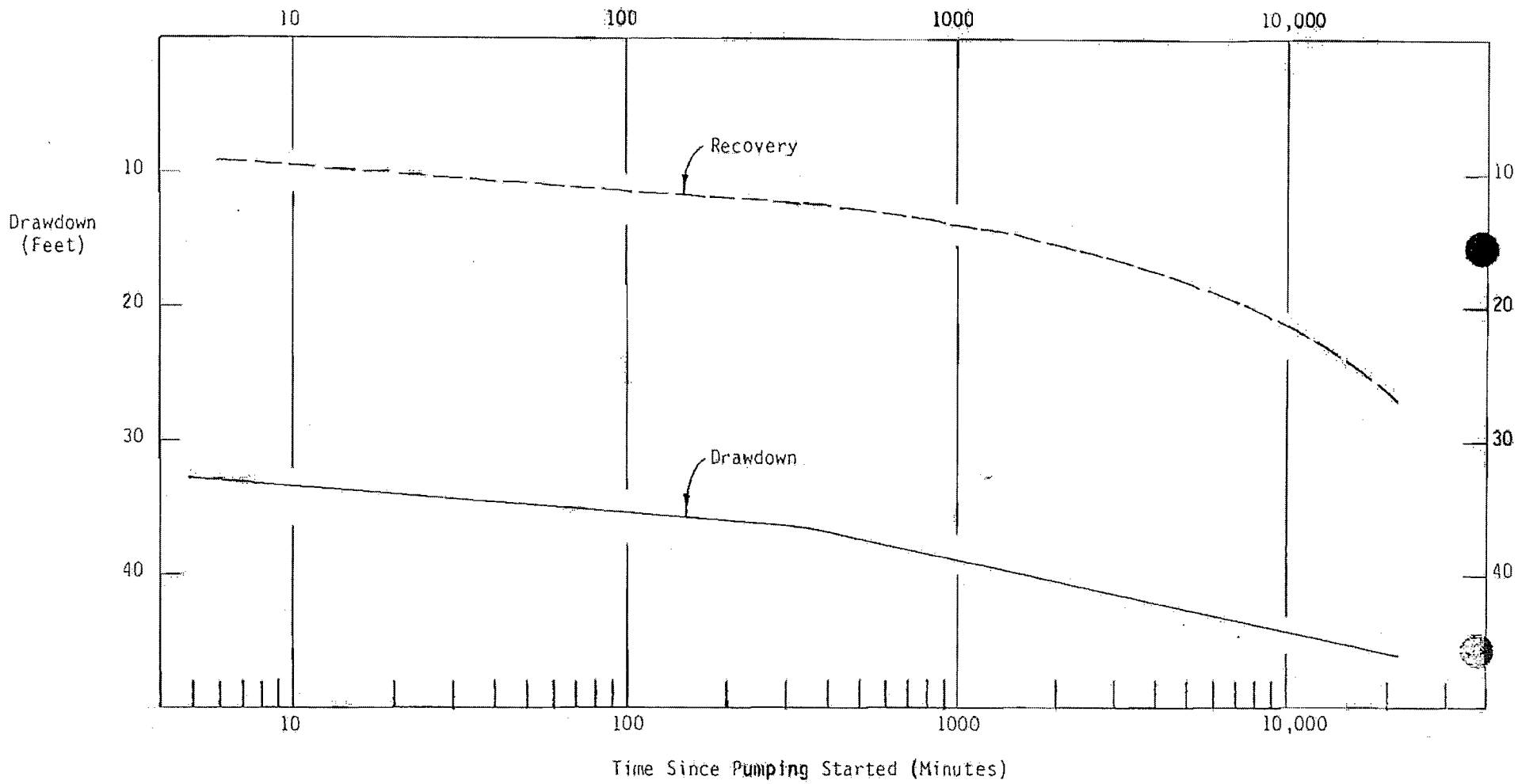


Figure 7

Drawdown and Recovery In Well 9
After the Generator Outage on June 22, 1993

Appendix A

Operating Logs of Wells 1 and 9

WELL 1

04-Aug-93

DATE	TIME START	TIME PAU	METER READING	PREVIOUS READING	GALLONS PUMPED	PUMPING TO
17-Jun-93	6:05	5:45	209,131,000	208,791,000	340,000	Manele Golf
18-Jun-93	6:15	5:50	209,520,000	209,131,000	389,000	Reservoir
19-Jun-93	5:20	5:45	209,850,000	209,520,000	330,000	"
20-Jun-93	6:15	5:45	210,153,000	209,850,000	303,000	"
21-Jun-93	6:20	2:20	210,326,000	210,153,000	173,000	"
22-Jun-93		2:00	211,068,000	210,326,000	742,000	"
23-Jun-93		2:00	211,675,000	211,068,000	607,000	"
24-Jun-93		2:00	212,380,000	211,675,000	705,000	"
25-Jun-93		2:00	213,029,000	212,380,000	649,000	"
25-Jun-93	9:10	9:20	213,230,000	213,029,000	201,000	"
26-Jun-93	7:10		213,502,000	213,230,000	272,000	"
26-Jun-93		2:00	213,690,000	213,502,000	188,000	"
26-Jun-93	9:20	5:45	213,892,000	213,690,000	202,000	"
27-Jun-93	2:00	2:00	214,336,000	213,892,000	444,000	"
28-Jun-93		2:00	215,015,000	214,336,000	679,000	"
29-Jun-93		2:00	215,592,000	215,015,000	577,000	"
30-Jun-93		5:45	216,239,000	215,592,000	647,000	"
01-Jul-93		5:45	216,921,000	216,239,000	682,000	"
02-Jul-93	7:40		217,408,000	216,921,000	487,000	"
02-Jul-93	2:10		217,592,000	217,408,000	184,000	"
03-Jul-93	2:06		218,264,000	217,592,000	672,000	"
04-Jul-93	2:20		218,987,000	218,264,000	723,000	"
05-Jul-93	2:05		219,688,000	218,987,000	701,000	"
05-Jul-93	9:15		219,907,000	219,688,000	219,000	"
06-Jul-93	2:30		220,430,000	219,907,000	523,000	"
06-Jul-93	9:15		220,639,000	220,430,000	209,000	"
07-Jul-93	7:20		220,944,000	220,639,000	305,000	"
				TOTAL GALS.	12,153,000	

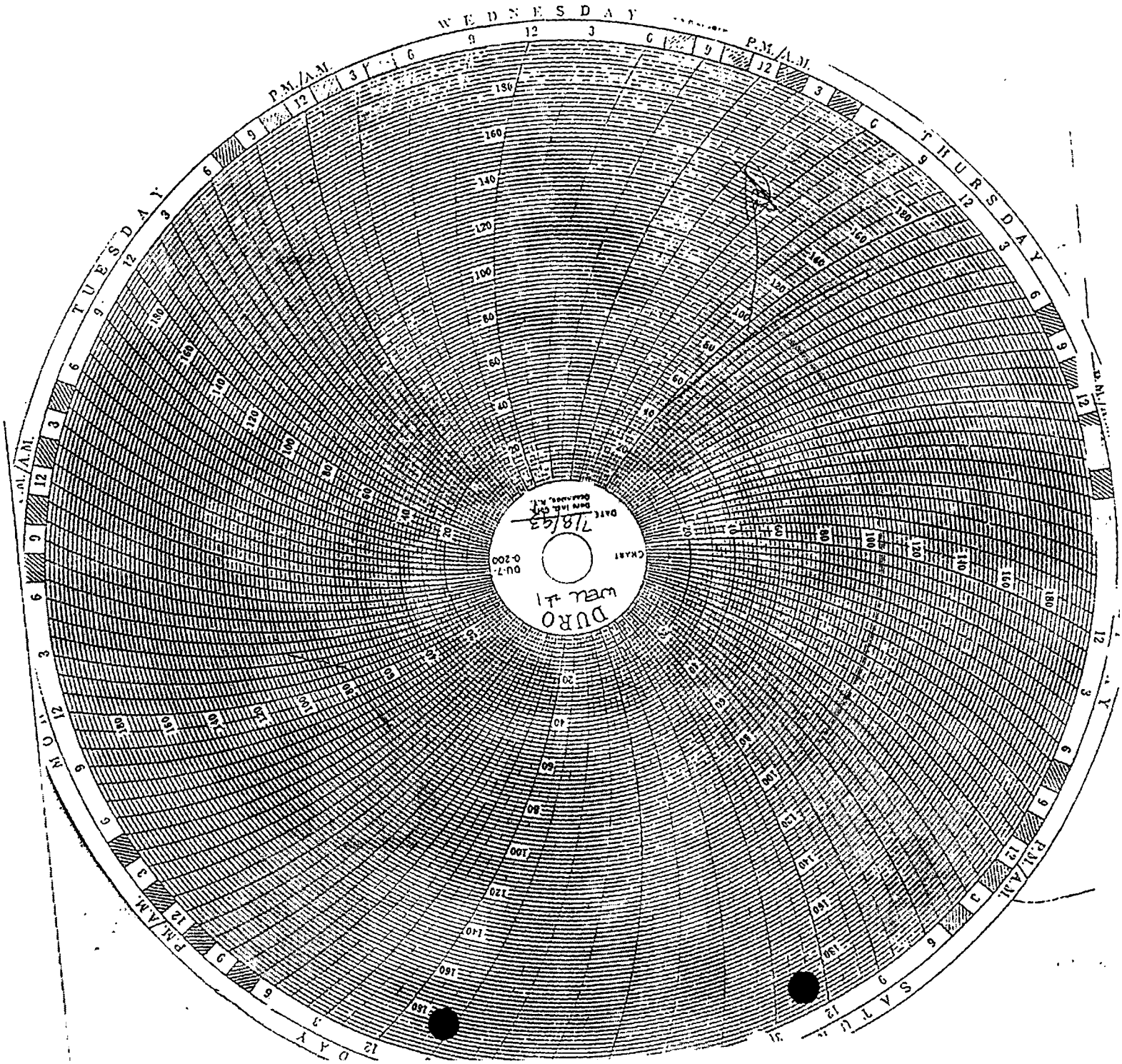
WELL 9

04-Aug-93

DATE	TIME	METER READING	PREVIOUS READING	GALLONS PUMPED	PUMPING TO	
19-Jun-93	5:45	260,000	52,430	207,570	Manele Golf	start
19-Jun-93	15:45	411,000	260,000	151,000	Reservoir	check
19-Jun-93	22:12	623,000	411,000	212,000	"	check
20-Jun-93	7:45	887,000	623,000	264,000	"	check
20-Jun-93	19:40	1,111,000	887,000	224,000	"	check
21-Jun-93	5:45	1,329,000	1,111,000	218,000	"	check
21-Jun-93	15:40	1,422,000	1,329,000	93,000	"	check
21-Jun-93	19:54	1,636,000	1,422,000	214,000	"	check
22-Jun-93	5:45	1,723,000	1,636,000	87,000	"	check
22-Jun-93	14:10	1,870,000	1,723,000	147,000	"	check/restart
22-Jun-93	20:53	2,064,000	1,870,000	194,000	"	check
23-Jun-93	5:45	3,213,000	2,064,000	1,149,000	"	check
25-Jun-93	10:30	3,431,000	3,213,000	218,000	"	check
25-Jun-93	21:35	3,655,000	3,431,000	224,000	"	check
26-Jun-93	7:20	3,668,000	3,655,000	13,000	"	check
26-Jun-93	8:00	3,860,000	3,668,000	192,000	"	check
26-Jun-93	4:40	3,952,000	3,860,000	92,000	"	check
26-Jun-93	9:03 pm	4,188,000	3,952,000	236,000	"	check
26-Jun-93	7:50	4,326,000	4,188,000	138,000	"	check
27-Jun-93	2:10	4,430,000	4,326,000	104,000	"	check
27-Jun-93	19:00	4,853,000	4,430,000	423,000	"	check
28-Jun-93	2:23	5,380,000	4,853,000	527,000	"	check
29-Jun-93	2:35	5,888,000	5,380,000	508,000	"	check
30-Jun-93	2:00	6,272,000	5,888,000	384,000	"	check
01-Jul-93	7:30	6,422,000	6,272,000	150,000	"	check
01-Jul-93	2:30 pm	6,786,000	6,422,000	364,000	"	check
02-Jul-93	7:15 am	6,943,000	6,786,000	157,000	"	check
02-Jul-93	2:30 pm	7,305,000	6,943,000	362,000	"	check
03-Jul-93	7:11 am	7,451,000	7,305,000	146,000	"	check
03-Jul-93	2:00	7,830,000	7,451,000	379,000	"	check
04-Jul-93	7:28 am	7,977,000	7,830,000	147,000	"	check
04-Jul-93	2:10	8,131,000	7,977,000	154,000	"	check
04-Jul-93	9:05	8,356,000	8,131,000	225,000	"	check
05-Jul-93	7:45	8,490,000	8,356,000	134,000	"	check
05-Jul-93	1:55 pm	8,646,000	8,490,000	156,000	"	check
05-Jul-93	9:05	8,865,000	8,646,000	219,000	"	check
06-Jul-93	7:15	9,017,000	8,865,000	152,000	"	check
06-Jul-93	14:20	9,162,000	9,017,000	145,000	"	check
06-Jul-93	7:05	9,388,000	9,162,000	226,000	"	check
07-Jul-93	7:30 am	9,512,000	9,388,000	124,000	"	check
08-Jul-93	7:15	10,031,000	9,512,000	519,000	"	start
10-Jul-93	7:00	10,188,000	10,031,000	157,000	"	check
			TOTAL GALS.	10,135,570		

Appendix B

Water Level Recordings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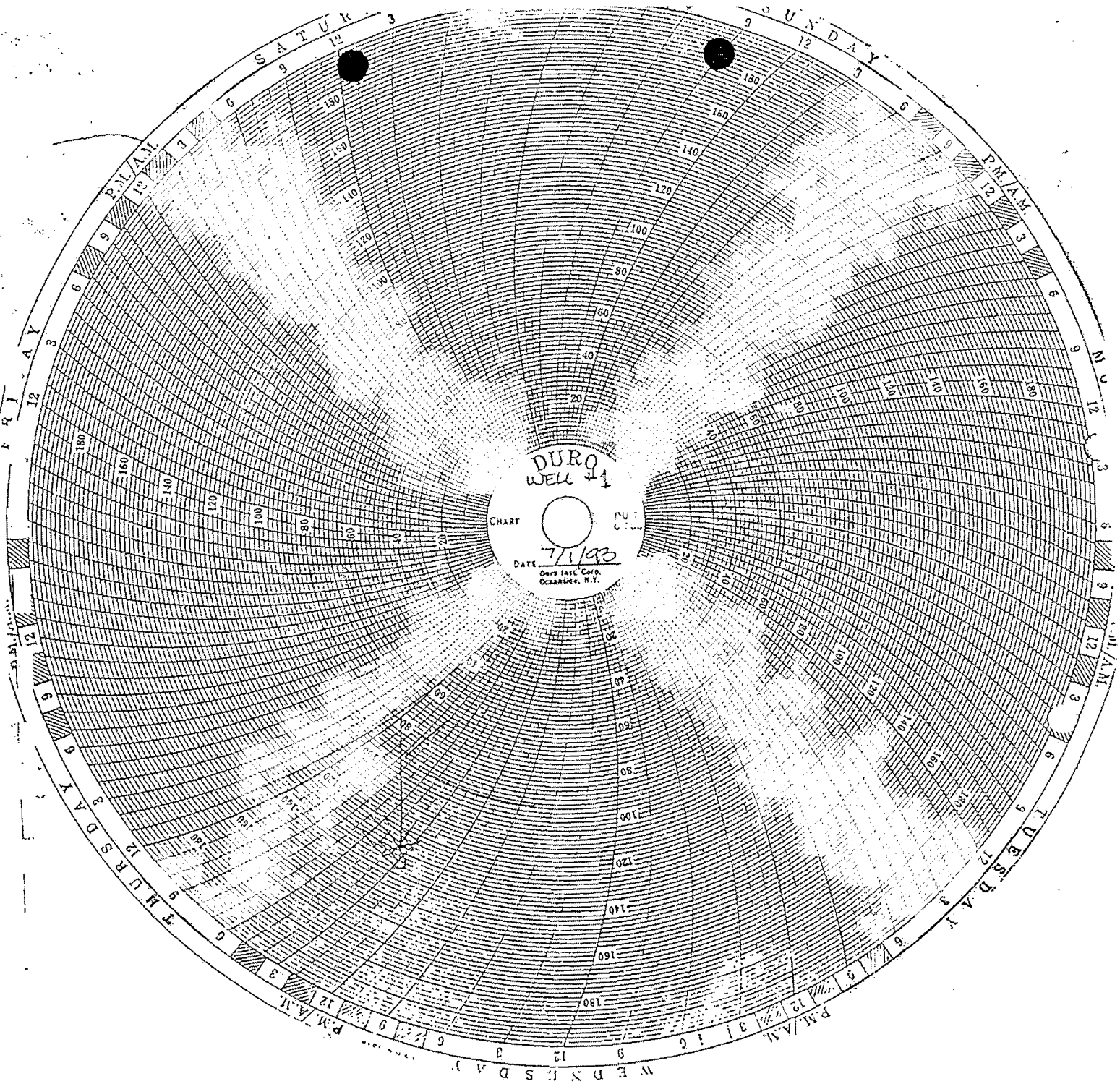
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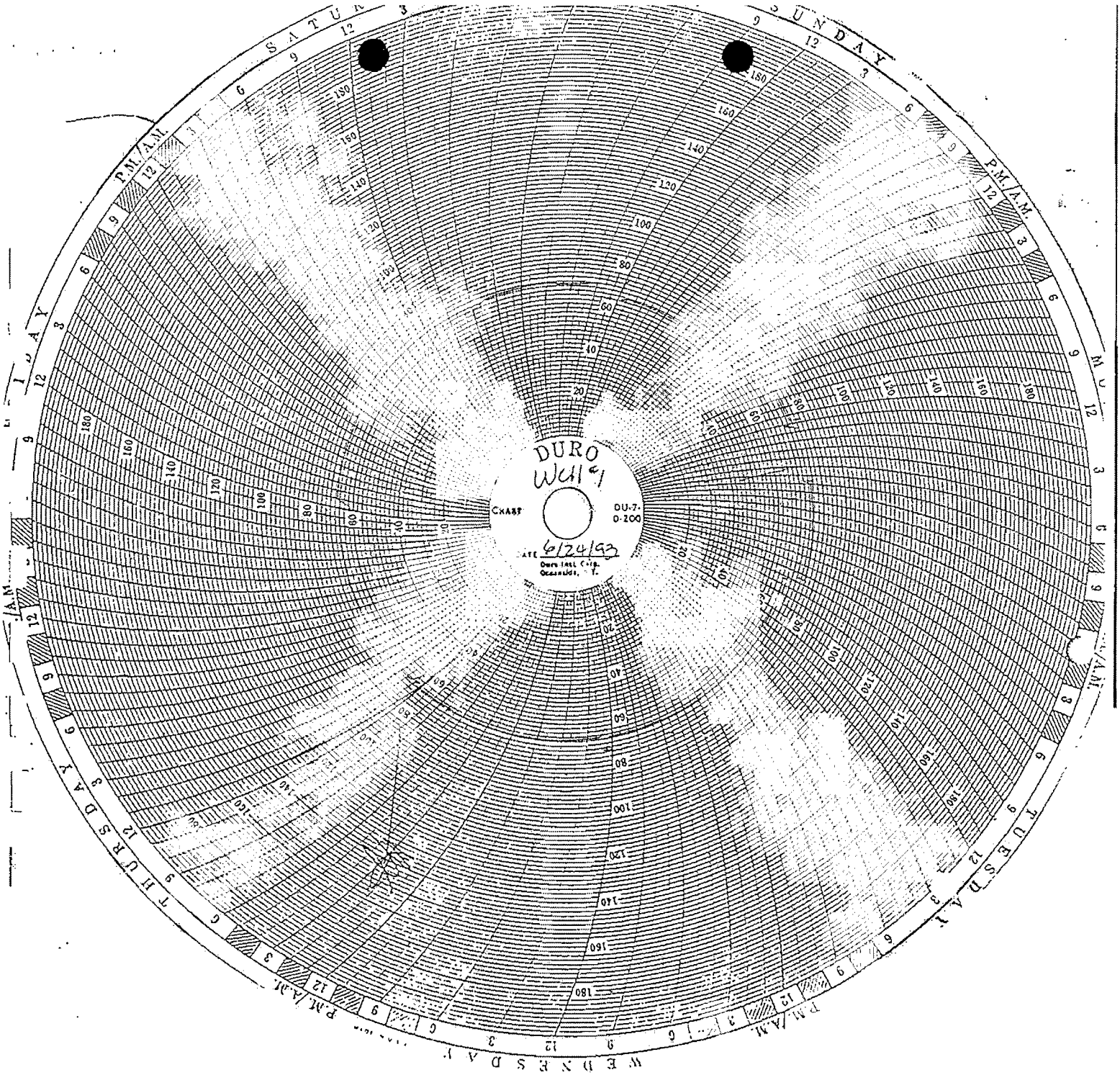
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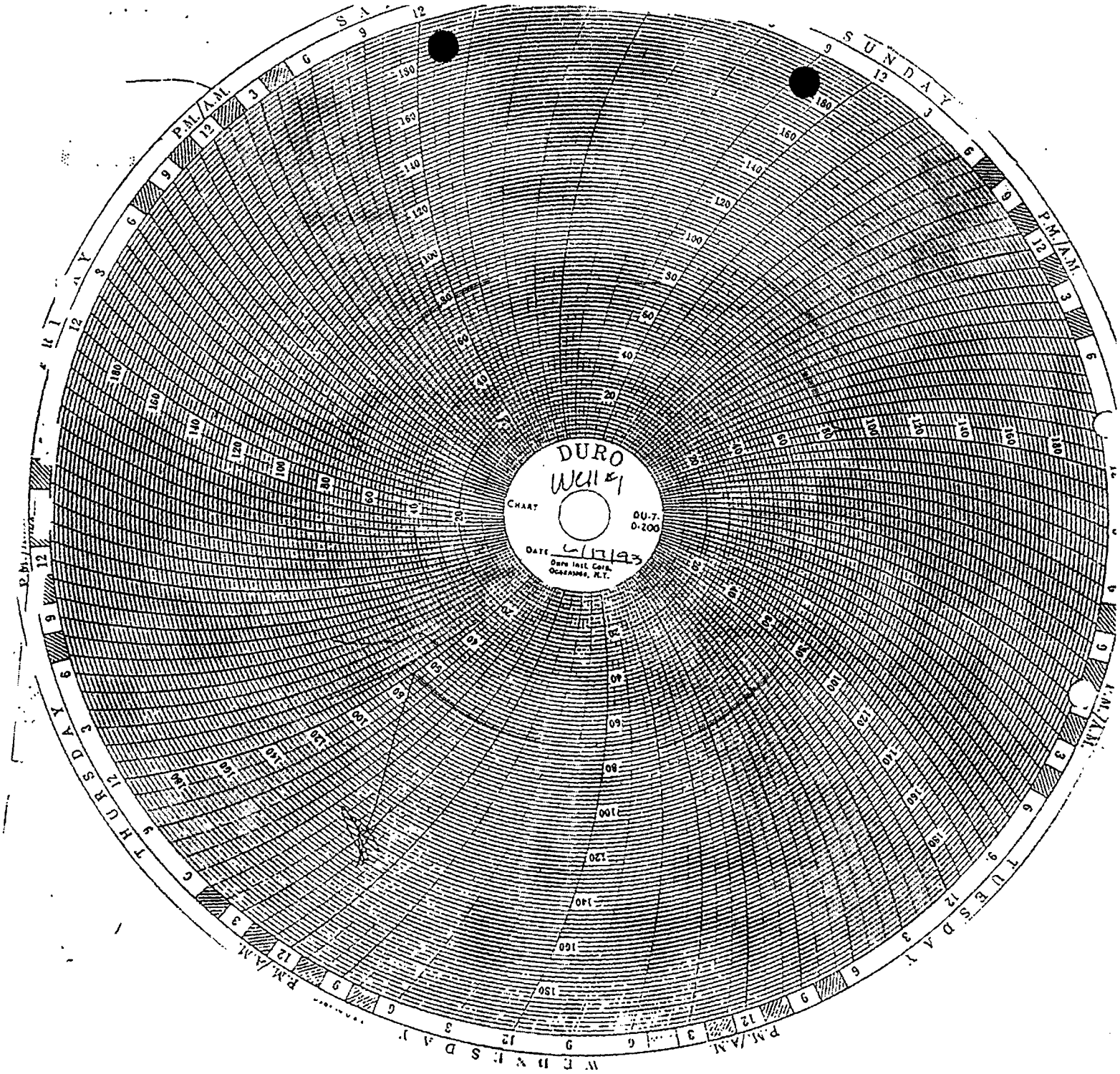
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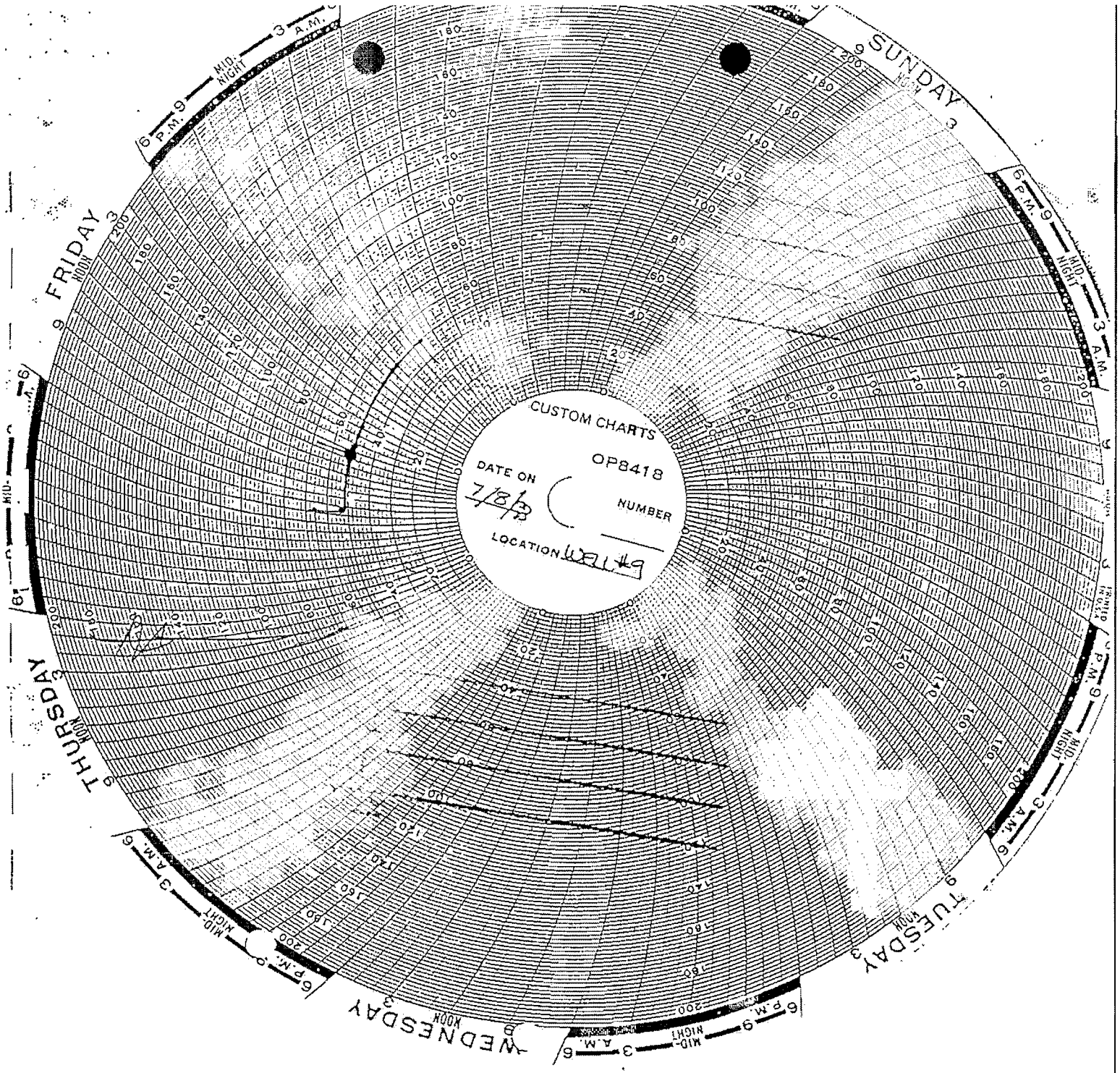
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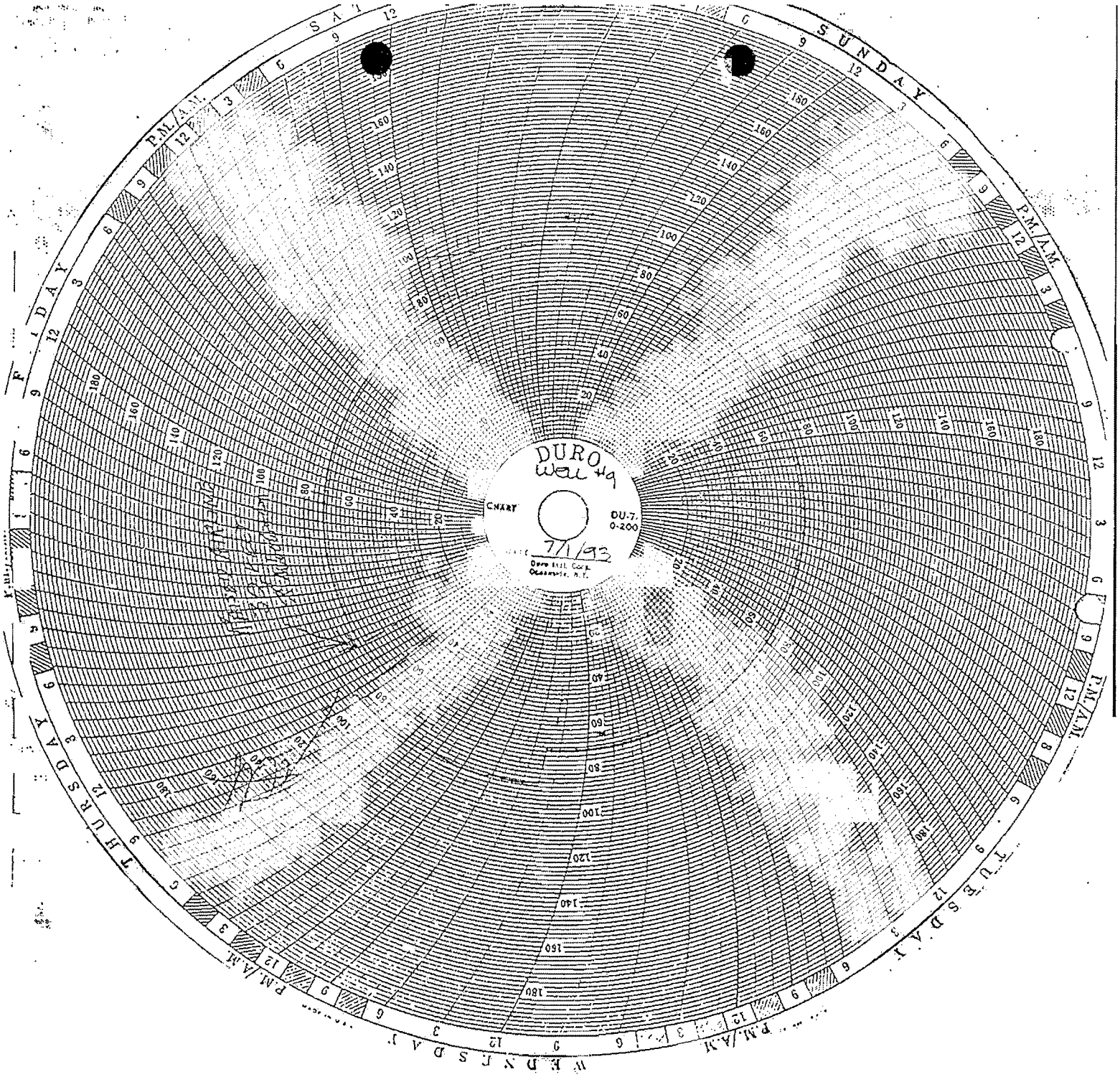
DURO
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CHART
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7/1/93
Dwyer Instr. Corp.
Chesterton, Ind.
SUNDAY
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WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
A.M.
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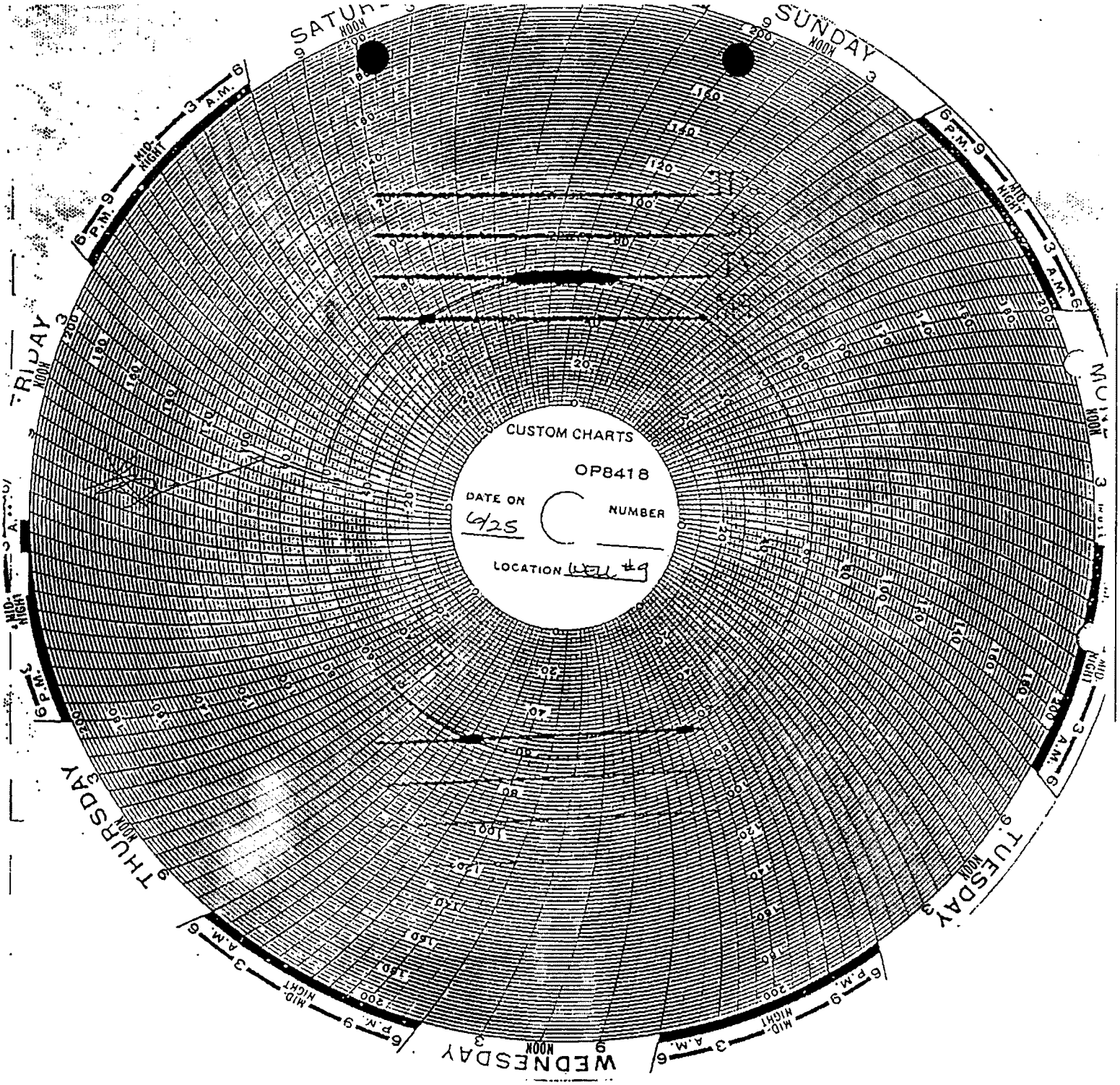
SUNDAY
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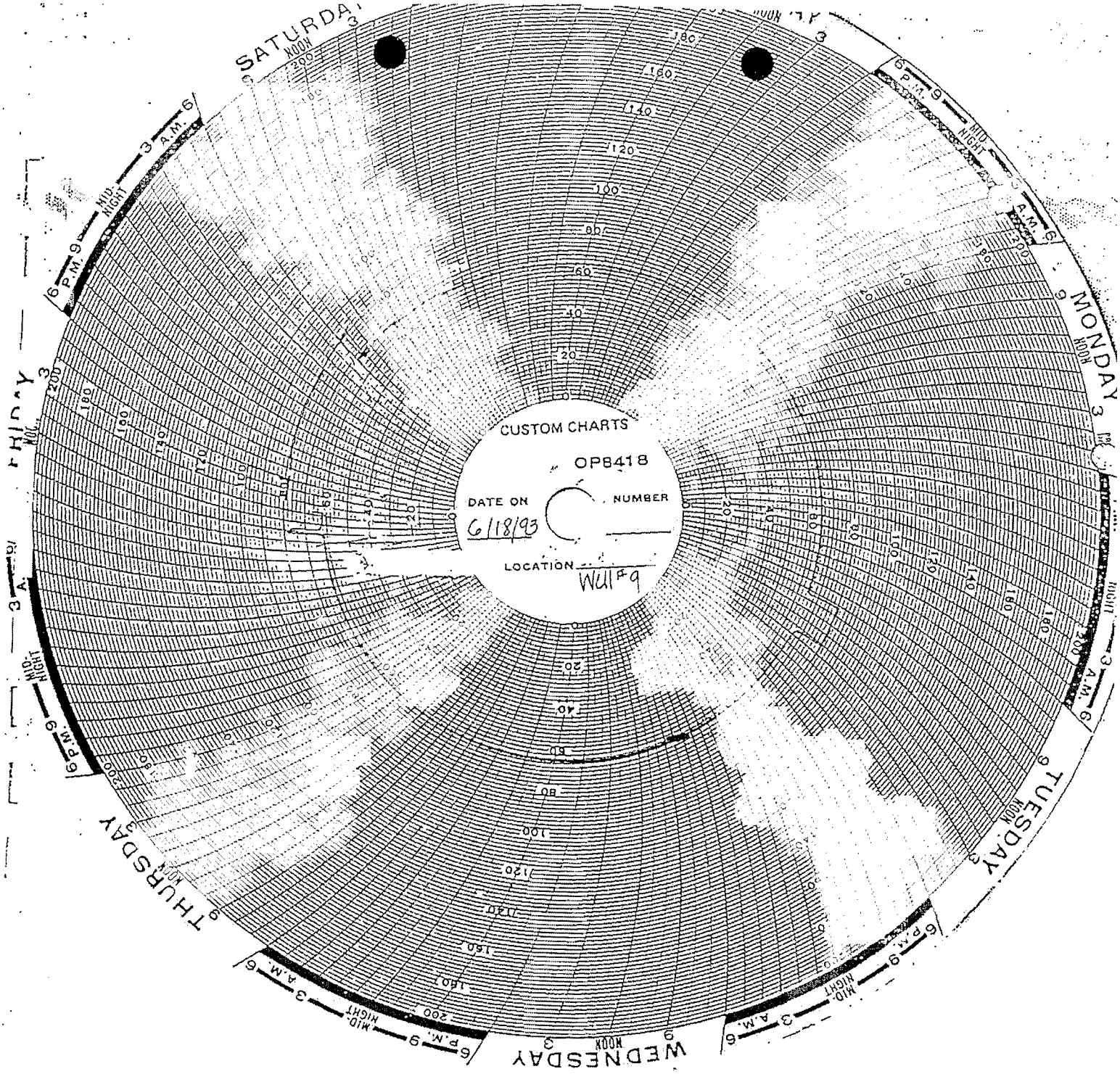
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
NOON
MIDNIGHT
6 P.M.
6 A.M.
3 P.M.
9 P.M.
3 A.M.
9 A.M.
CUSTOM CHARTS
OP8418
DATE ON
6/25
NUMBER
C
LOCATION Well #9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OP8418
DATE ON
6/18/93
NUMBER
LOCATION
Wulfg
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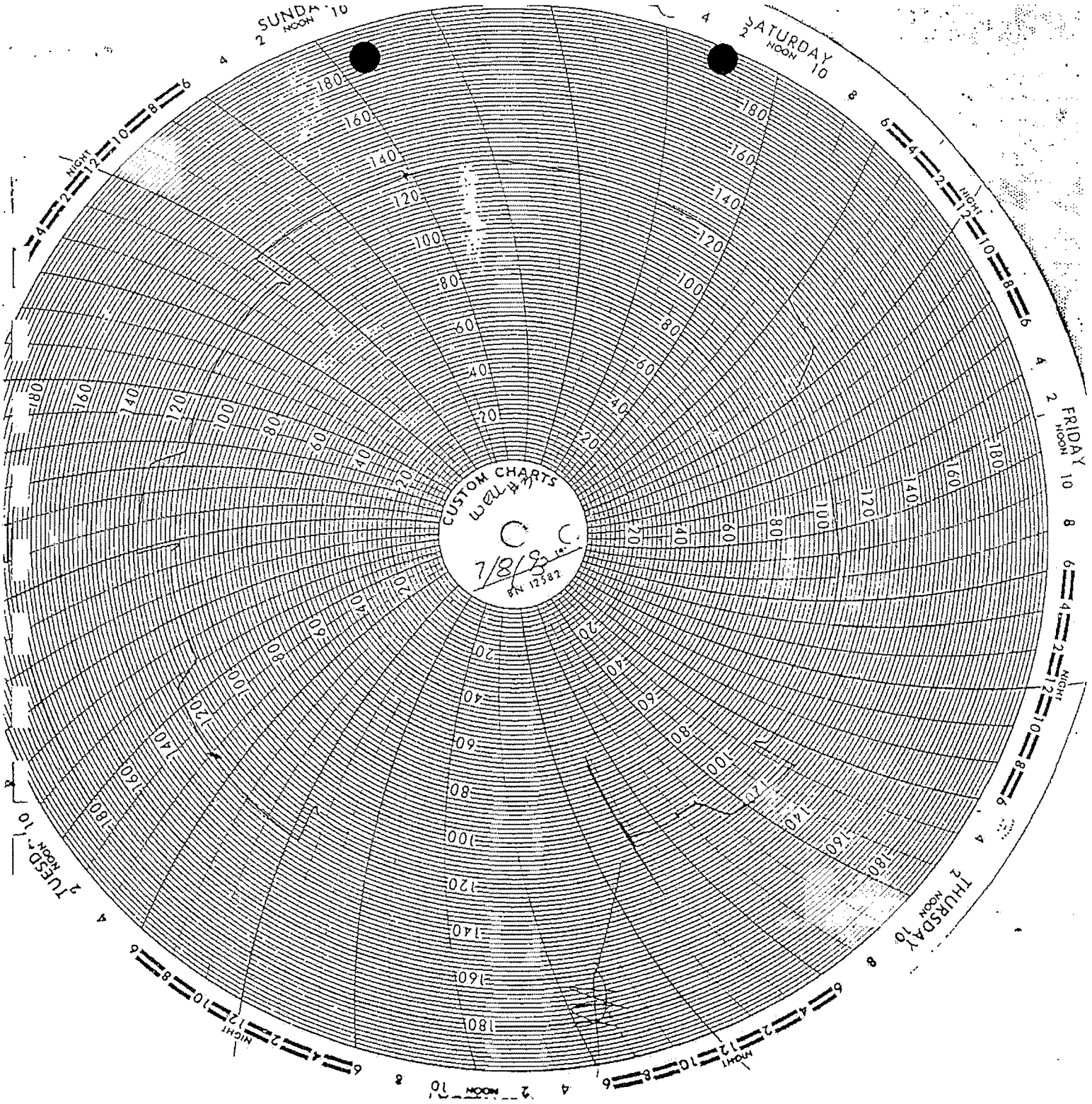
THURSDAY
FRIDAY
NOON
MIDNIGHT
A.M.
P.M.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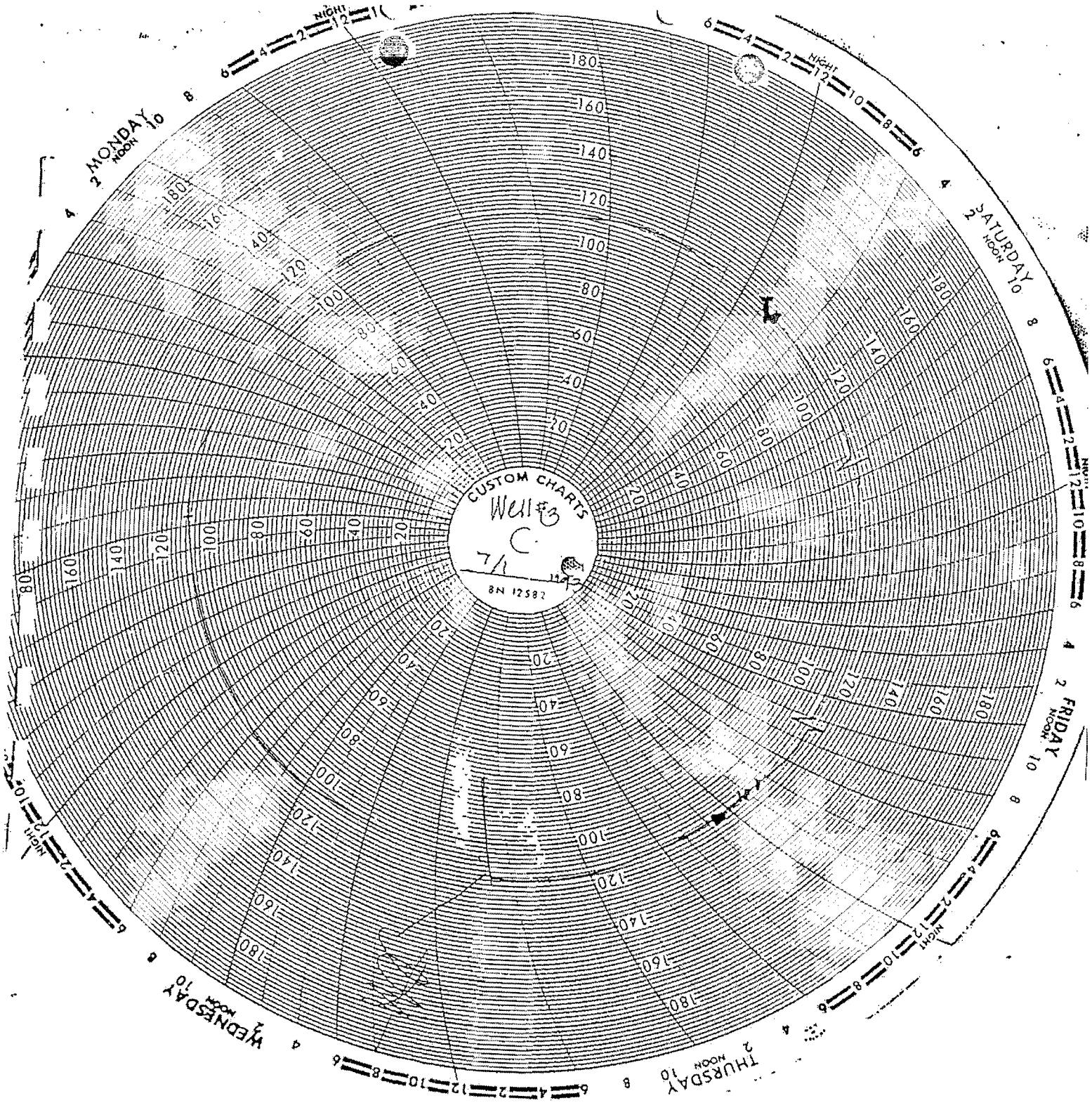
TUESDAY
NOON
NIGHT
CUSTOM CHARTS
7/8/8
PN 12582


CUSTOM CHARTS
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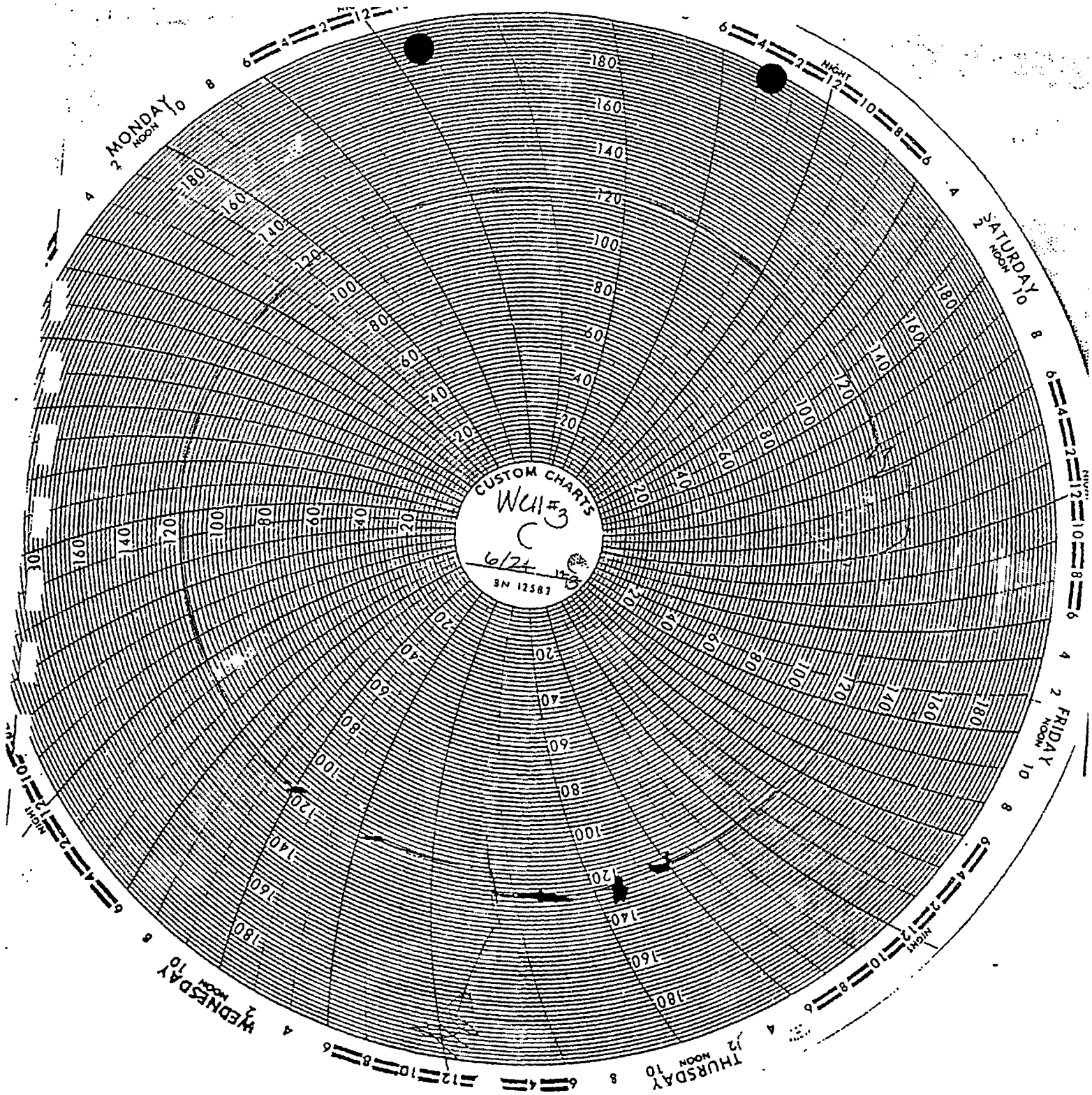
NOON
NIGHT


CUSTOM CHARTS
WU#3
C
6/24
SN 12587 NE
MONDAY
TUESDAY
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FRIDAY
SATURDAY
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40
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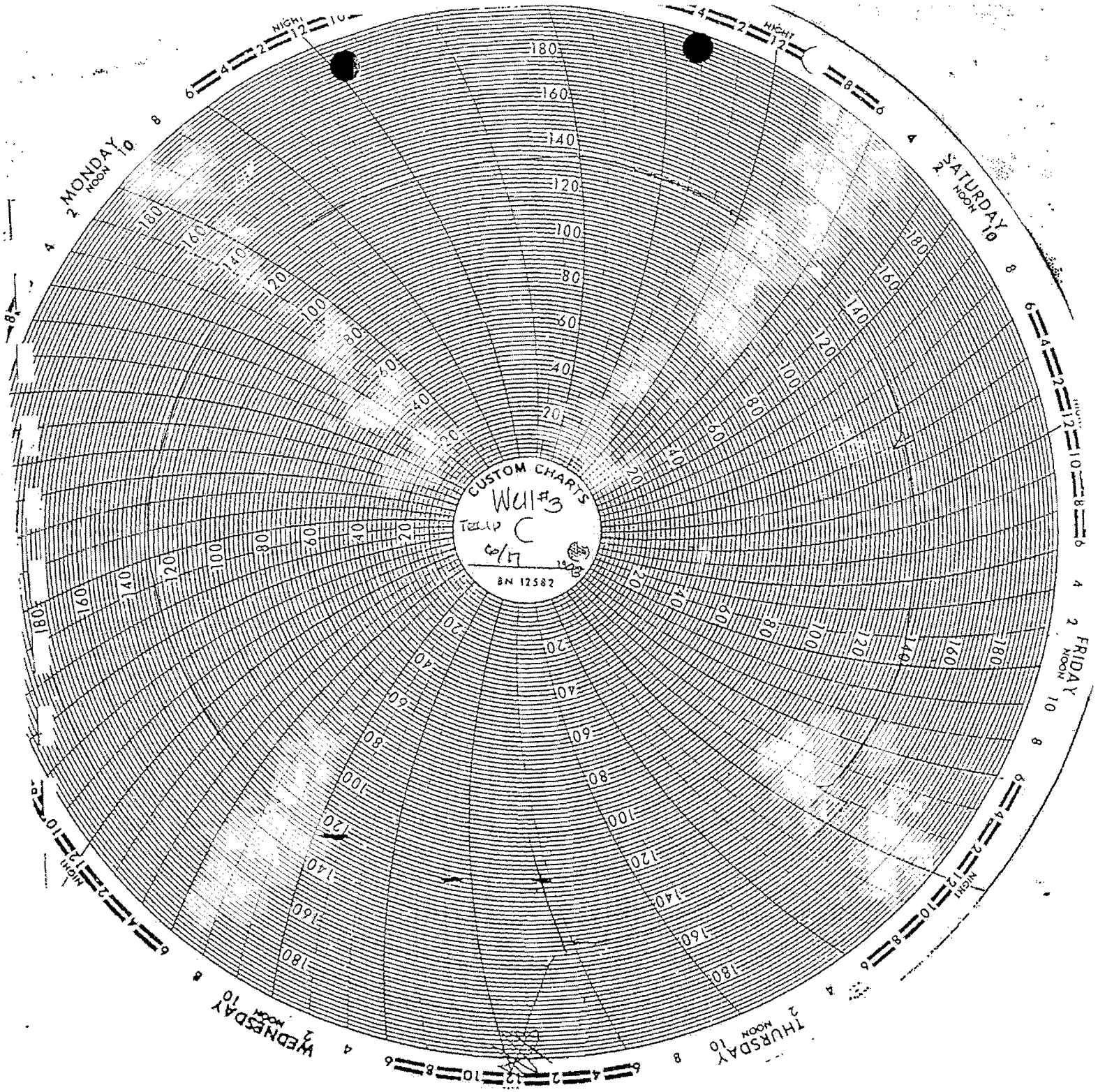
180


CUSTOM CHARTS
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BN 12582
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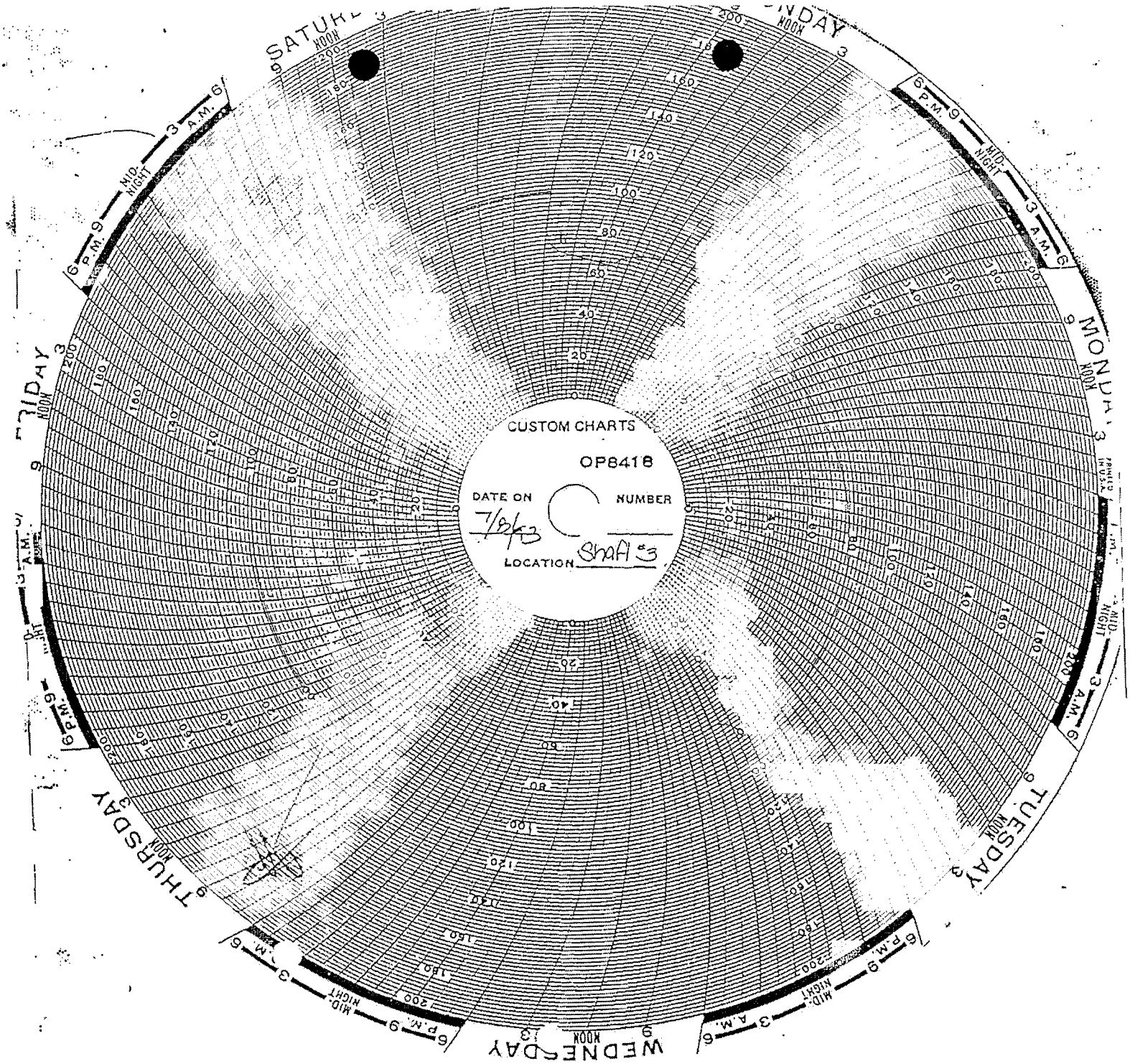
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
NOON
NIGHT


CUSTOM CHARTS
OP8416
DATE ON
NUMBER
7/8/53
LOCATION Shaft 3
SATURDAY
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
NOON
MID-NIGHT
3 A.M.
6 A.M.
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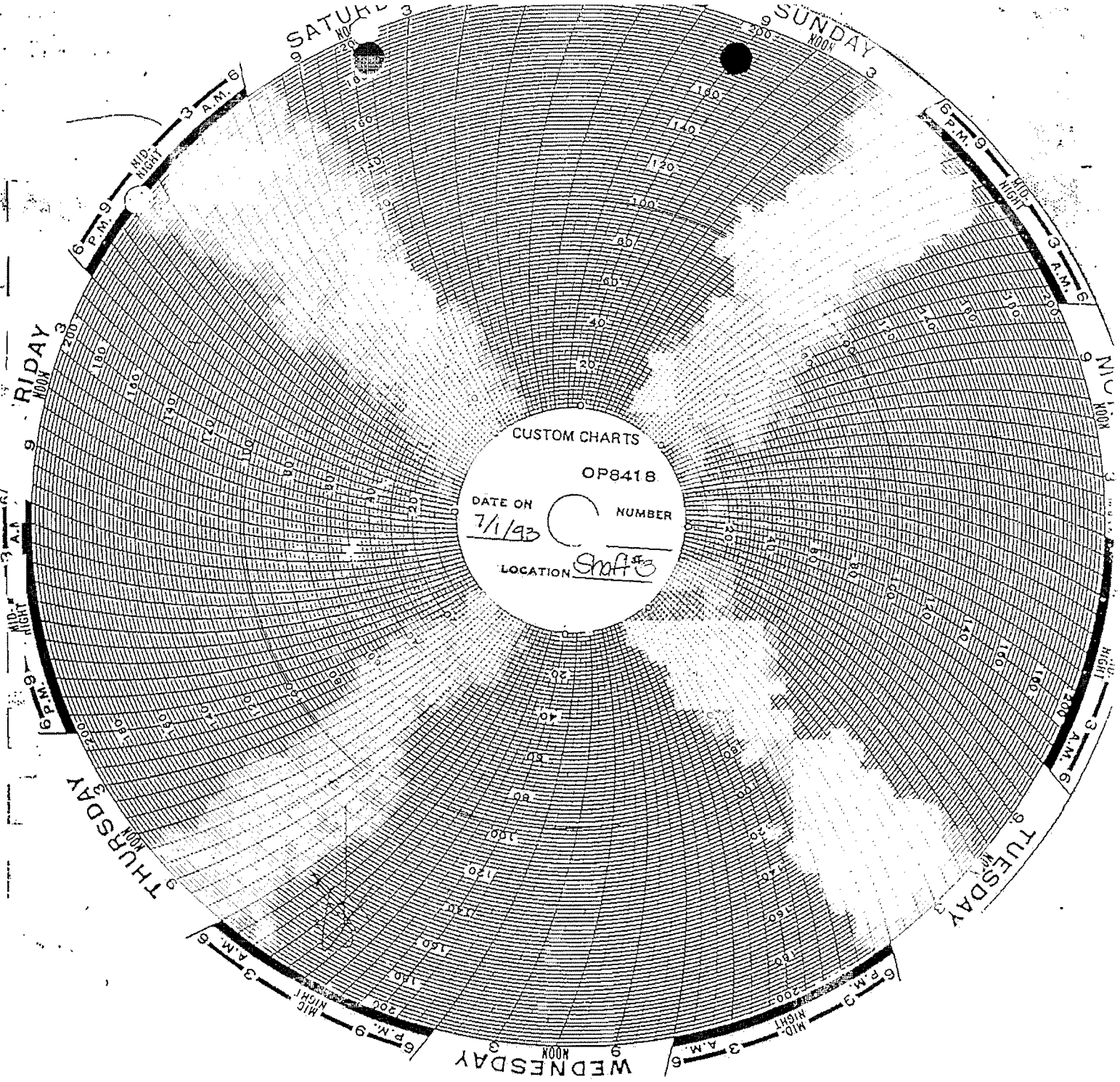
SATURDAY
SUNDAY
MONDAY
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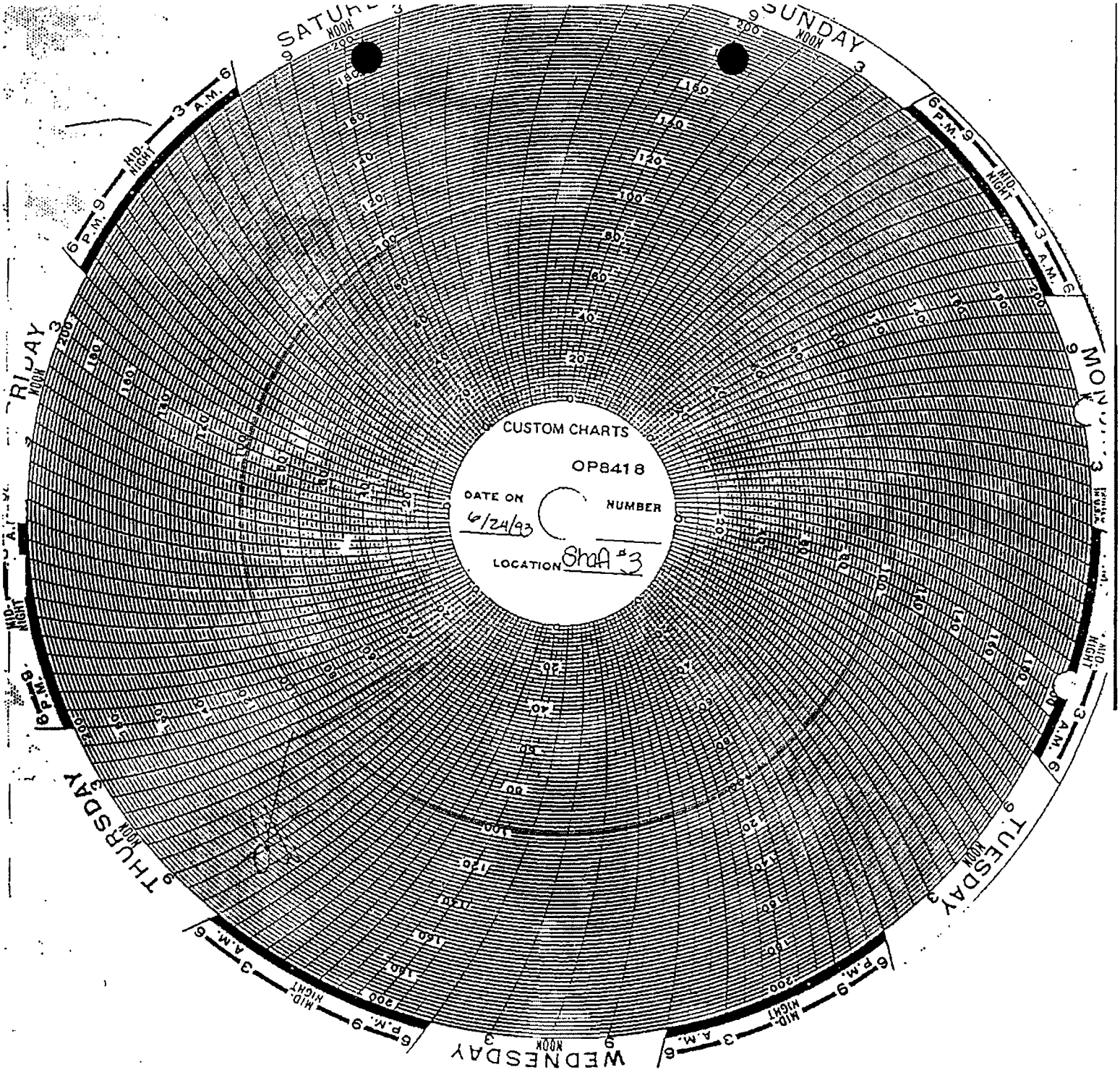
THURSDAY
FRIDAY
NOON
MIDNIGHT
3 A.M.
6 P.M.
9
CUSTOM CHARTS
OP8418
DATE ON
7/1/93
NUMBER
LOCATION
Staff


CUSTOM CHARTS
OP8418
DATE ON
6/24/93
NUMBER
LOCATION Shaft #3
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
NOON
MID-NIGHT
3 A.M.
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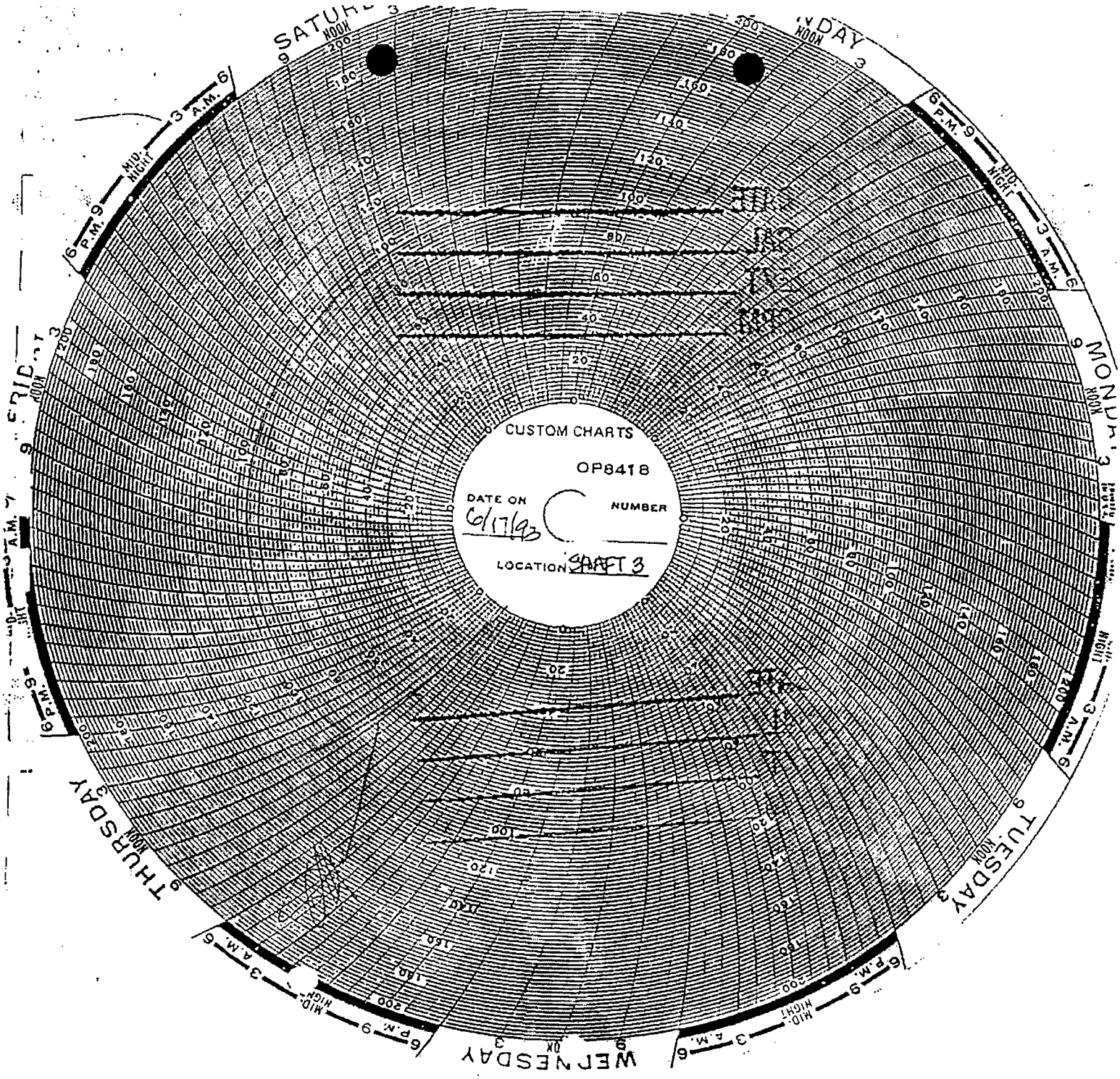
9 P.M.


CUSTOM CHARTS
OP8418
DATE ON
6/17/93
NUMBER
LOCATION
SHAFT 3
SATURDAY
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
NOON
MIDNIGHT
A.M.
P.M.