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Barometric Pressure Variations

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BAROMETRIC PRESSURE VARIATIONS

ABSTRACT

This report presents Hanford Site barometric data that can be used to determine the breathing rate of Hanford Site tanks and details the derivation of the data. The barometric pressure data recorded at the Hanford Weather Station were used for this analysis. Data for 1988, 1989, 1990, and 1991 were used.

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BAROMETRIC PRESSURE VARIATIONS

1.0 BAROMETRIC PRESSURE VARIATIONS

The purpose of this report is to present Hanford Site barometric data that can be used to determine the breathing rate of Hanford Site tanks and to detail the derivation of the data.

1.1 ORIGIN

The Hanford Weather Station records several data on an hourly basis. Among them is barometric pressure which is given in inches of mercury to the nearest one-hundredth of an inch. The pressure is electronically recorded in fields 32-35 of an 80 field record. These data were used for this analysis.

The weather station is at an elevation of 733 feet, located between the two major tank farm areas. It is within 5 miles of all the tanks and within a 100-foot or less elevation of all the tanks.

1.2 RAW DATA

Data for 1988, 1989, 1990, and 1991 were used. A preliminary inspection showed that a few times (1-4 times) during the year the pressure was entered incorrectly. For data that should hover around 29.92, an entry such as 2.99 or 9.91 or 8 is obviously an error. These were corrected by substituting a value for the error of an average of the hour immediately preceding and the hour immediately after.

Further scanning revealed a few times (again, 1-4 times per year) when an entry error appears to have been made in the value. For example, a sequence might read 29.32, 29.33, 29.23, 29.33, and 29.34. After observing the usual slowness in barometric swings, probably the 29.23 should be 29.33. No attempt was made to correct at this level so the data would remain accurate enough to stand alone. As shown later (Section 1.2), the error is very small, about 0.4 inches per year, and tends to slightly overestimate the natural air flow in and out of the tanks.

1.3 RESULTS

The data were summed to provide the usual statistical parameters. Additionally, the change between an hour and the preceding hour was summed algebraically to give the following: (1) the total of pressure increases and (2) the total of pressure decreases. Of course, all of the no-changes summed to zero. The results are presented as Table 1.

The reported pressures are actual station pressure and are not corrected to sea level. Inspection of this material demonstrates several things. The variations from year to year are small and indicate that the answers would be the same for a 10- or 20-year database. The maximums and minimums show no

Table 1. Annual Data.

Value	Year				
	1988	1989	1990	1991	1950 -1980*
Average (inches of mercury)	29.25	29.26	29.22	29.23	29.21
Standard deviation (inches of mercury)	0.211	0.197	0.193	0.210	-
Number	8779	8756	8760	8758	-
Maximum (inches of mercury)	29.94	29.96	30.02	29.83	30.23
Minimum (inches of mercury)	28.52	28.79	28.50	28.33	28.10
Total increases (inches of mercury)	49.98	46.04	51.46	49.97	-
Total decrease (inches of mercury)	50.50	46.20	51.28	49.78	-

* Source: Stone et al. (1983)

gross outliers. Some years have more storms than others. Further computations would show that the coupling of extremes with the average and standard deviations indicate a well-behaved and normal distribution of values. Finally, 1988 was a leap year.

The total yearly breathing is 49.40 inches of mercury (0.005639 inches of mercury per hour) or about 1.69 atmospheres, which is somewhat lower than previous rates of about 2.2 atmospheres used in other studies (Klem 1991; Garfield 1975). Note that the present data gave breathing rates approaching 3 atmospheres before the few erroneous entries were corrected. Therefore, we believe the 1.69 atmospheres (0.005639 inches of mercury per hour) annual breathing rate to be valid and the best available.

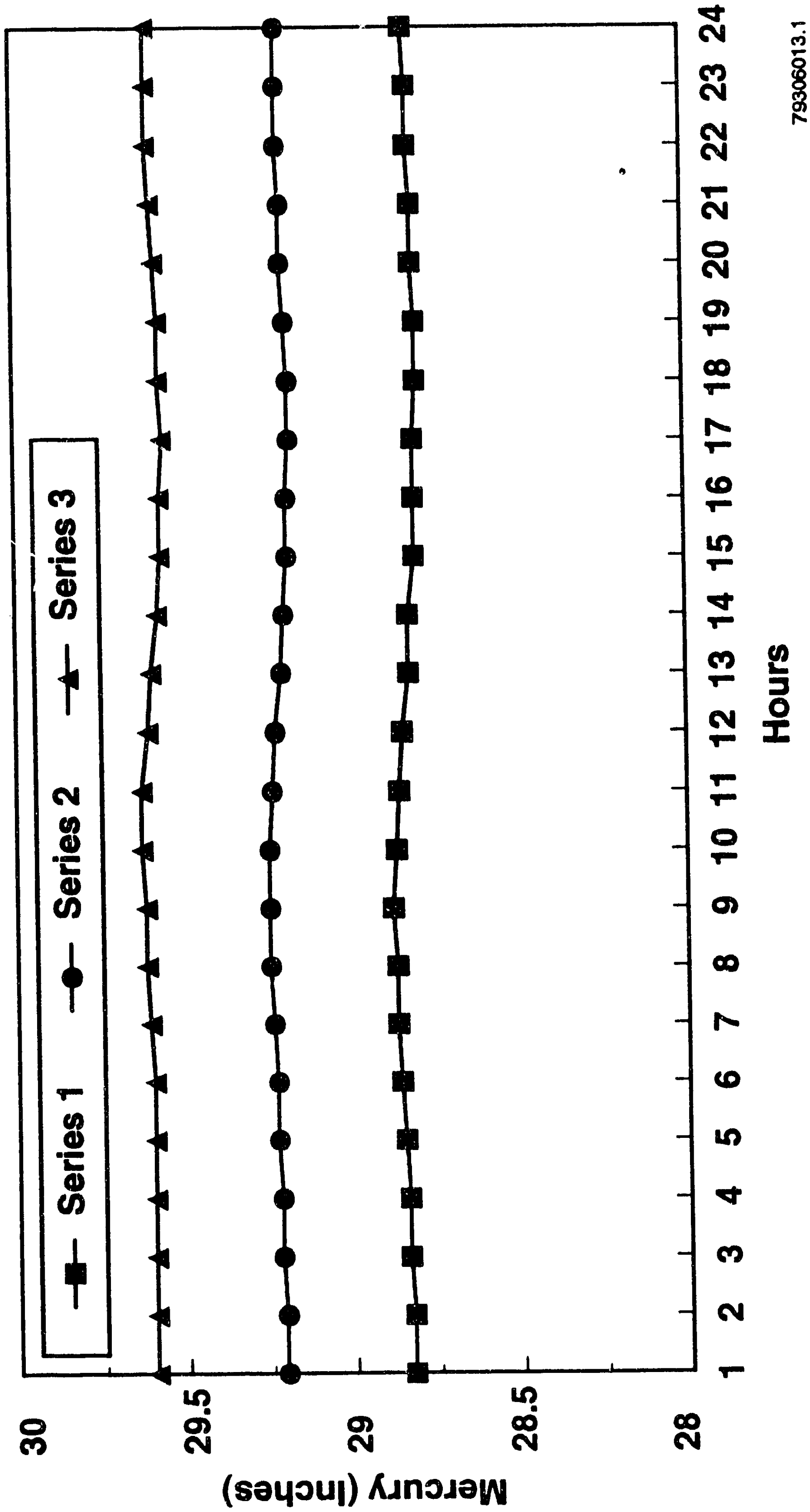
Note that the total hourly barometric movement (upward or downward changes being accumulated as separate accounts) are higher than would be determined from Stone et al. (1983). For example, Table 36 in Stone et al. (1983) gives the annual average station pressure for hours 1 through 24. From this, the average diurnal change from low to high is 0.04 inches of mercury, or about 30% of the movement determined by the present analysis from hourly changes. Although this is a natural rate, one needs to be aware that some tanks are actively being purged (through the Food Instrument Corporation level gauge or other instruments). These purges may be in excess of 0.71 m^3/h (25 ft^3/h), which is similar to the natural breathing rate.

The data were examined on a daily basis to see if variations could be seen that were similar to the sinusoidal temperatures seen during the day. Those results for 1990 are presented (other years are very similar) as Table 2. Figure 1 is a graphical representation of the same data. There really is no trend over the day; in this case, Figure 1 is more enlightening than Table 2. Therefore, it would be impossible to predict that tank pressure would be high or low for any given hour of the day at some time in the future.

Table 2. Average of All Hourly Pressures.

Time (hour of day)	Standard deviation	2.5 Percentile	Average	97.5 Percentile
	(Inches of mercury)			
1	0.1966	28.83	29.21	29.60
2	0.1958	28.32	29.22	29.60
3	0.1946	28.84	29.22	29.60
4	0.1930	28.84	29.22	29.60
5	0.1894	28.85	29.23	29.60
6	0.1894	28.86	29.23	29.60
7	0.1892	28.87	29.24	29.61
8	0.1915	28.87	29.25	29.62
9	0.1903	28.88	29.25	29.62
10	0.1941	28.87	29.25	29.63
11	0.1952	28.86	29.24	29.63
12	0.1948	28.85	29.23	29.61
13	0.1963	28.83	29.21	29.60
14	0.1917	28.83	29.20	29.58
15	0.1926	28.81	29.19	29.57
16	0.1932	28.81	29.19	29.57
17	0.1917	28.81	29.18	29.56
18	0.1966	28.80	29.18	29.57
19	0.1966	28.80	29.19	29.57
20	0.1972	28.81	29.20	29.58
21	0.1985	28.81	29.20	29.59
22	0.1989	28.82	29.21	29.60
23	0.1979	28.82	29.21	29.60
24	0.1968	28.83	29.21	29.60

Figure 1. Hourly Averages.



This may be somewhat misleading because there are actual diurnal changes. If the average changes from hour to hour are examined, the conclusion is somewhat different and the results are presented as Table 3.

Using Table 3, and observing the present hour and pressure, the likely pressure changes over the next several hours could be forecast. Because there are considerable variations in these numbers, the Hanford Weather Station probably should be consulted directly to obtain accurate information about storm movements over that time frame. Generally, if work was to be scheduled on a tank that required decreasing pressure to ensure the tank was exhaling, the probable starting time would be 10 a.m. with completion by 5 p.m. The opposite situation, requiring an increasing pressure to ensure tank inhalation, should start about 6 p.m. and work through the night to finish by 8 a.m. the next morning.

The data were further examined to determine the swings in pressure on an hourly basis. That is, the increase (or decrease) for every hour was determined and the population of those was summed. The results are presented in Table 4. Figure 2 is a graph for the 1990 data set.

Inspection of the data shows them to be as follows: (1) consistent from year to year, (2) evenly distributed around zero, and (3) a good normal distribution. Note that the previous caveat about data errors of 0.10 inches of mercury may explain a few of the ± 0.09, 0.10, and 0.11.

Another measure of interest is how long might a period of constant pressure last. For example, Table 4 shows that about one-third of the time the pressure is not changing; therefore, if several nonchanges occur in a row, a stable pressure situation might be maintained for some time. Table 5 displays the data.

The overall result is that the pressure is constantly changing. Nearly 70% of the time, the pressure will have changed in less than 1 hour; and 80% of the time, it will have changed in less than 2 hours. The probability that the pressure will stay constant for as long as an 8-hour shift is about once every 2 months.

Finally, the data were examined from another perspective as follows. Suppose one were interested in examining a tank phenomena over a short period of a few hours or a few days and coupling that with barometric swings. While the yearly average would give the average total pressure changes over the period in question, it would be prudent to be aware of the short-term maximums (or minimums) because they might be more important to the problem at hand.

To obtain the data for an 8-hour block, the hourly pressure increases and decreases were summed (all the increases together and all the decreases together) for hours 1-9, 2-10, ..., 243-251, ..., etc. For a 30-hour block, the calculations were done for hours 1-31, 2-32, ..., 5,421-5,451, ..., etc. This was done for all 4 years in a number of blocks ranging from 1 through 1,000 hours (a fast computer with compiled software is essential). Table 6 and Figure 3 (for short term) and Figure 4 (for longer term) present the data. The block hours describe the size of all continuous blocks of the indicated size during the year. The average is the average increase (or decrease) of

Table 3. Average of All Hourly Changes in Pressures.

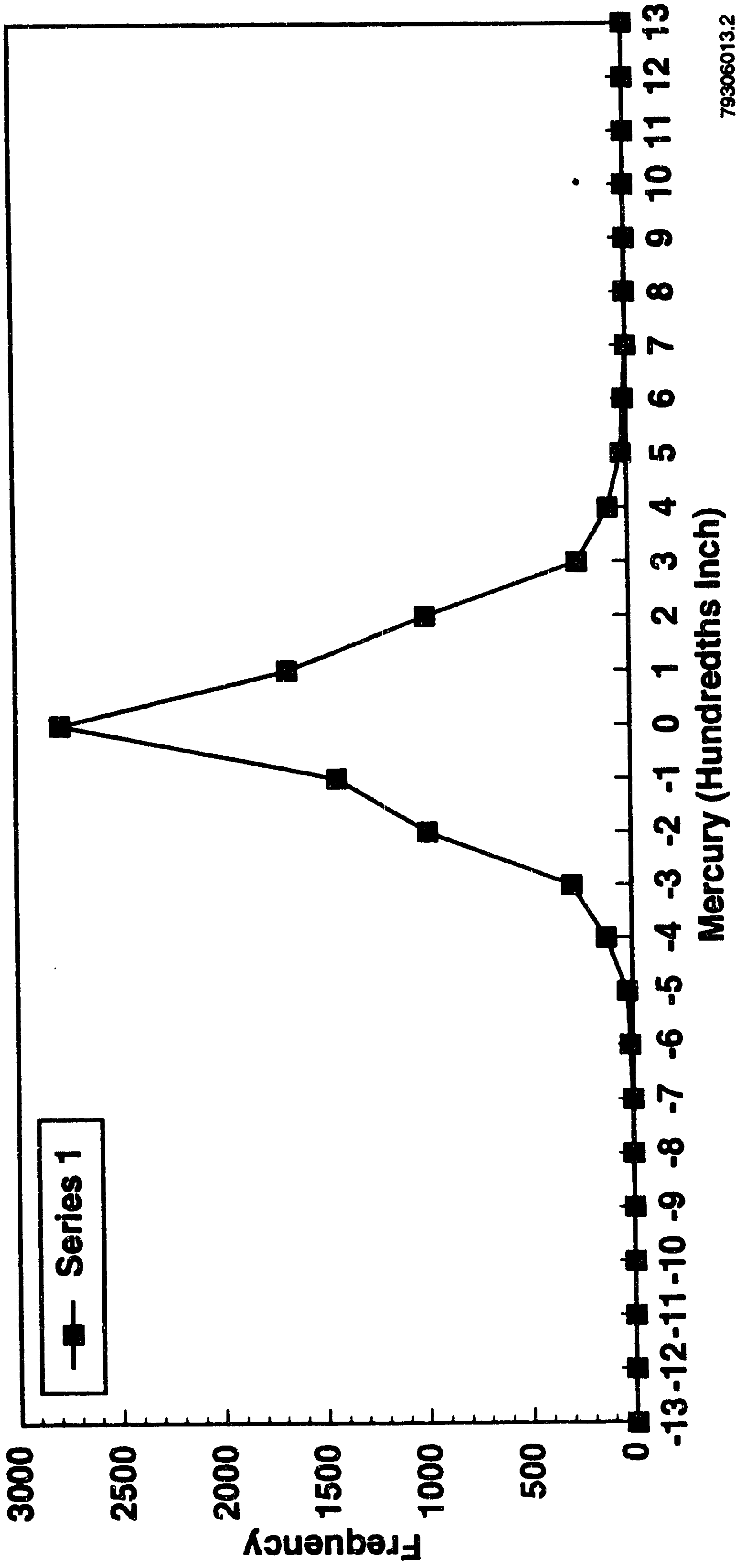
Start time (hour of day)	Year			
	1988	1989	1990	1991
	(Inches of mercury)			
1	0.0035	0.0030	0.0028	0.0026
2	0.0024	0.0014	0.0028	0.0019
3	0.0014	0.0008	0.0023	0.0021
4	0.0040	0.0042	0.0043	0.0036
5	0.0058	0.0065	0.0069	0.0057
6	0.0074	0.0076	0.0074	0.0074
7	0.0063	0.0055	0.0065	0.0061
8	0.0049	0.0045	0.0023	0.0035
9	-0.0012	-0.0013	0.0004	0.0003
10	-0.0042	-0.0055	-0.0058	-0.0061
11	-0.0112	-0.0108	-0.0133	-0.0135
12	-0.0142	-0.0141	-0.0159	-0.0146
13	-0.0133	-0.0134	-0.0129	-0.0133
14	-0.0106	-0.0098	-0.0102	-0.0086
15	-0.0079	-0.0056	-0.0047	-0.0052
16	-0.0063	-0.0035	-0.0037	-0.0040
17	-0.0020	-0.0007	-0.0001	-0.0002
18	0.0018	0.0045	0.0045	0.0059
19	0.0054	0.0073	0.0077	0.0081
20	0.0068	0.0070	0.0081	0.0081
21	0.0098	0.0053	0.0028	0.0041
22	0.0049	0.0031	0.0042	0.0030
23	0.0033	0.0018	0.0029	0.0021
24	0.0016	0.0016	0.0012	0.0013

Table 4. Population of Pressure Changes Every Hour.

Press swing (inches of mercury)	Year			
	1988	1989	1990	1991
-0.13 or lower	0	0	0	0
-0.12	0	0	1	0
-0.11	3	1	1	3
-0.10	0	2	1	0
-0.09	2	0	1	0
-0.08	3	3	3	3
-0.07	1	2	4	4
-0.06	10	5	15	7
-0.05	26	10	27	16
-0.04	130	86	128	110
-0.03	344	238	294	302
-0.02	890	915	990	976
-0.01	1,446	1,583	1,435	1,473
0	2,838	2,934	2,785	2,825
0.01	1,772	1,806	1,674	1,703
0.02	930	888	995	958
0.03	266	181	252	231
0.04	76	71	99	89
0.05	17	14	31	33
0.06	13	8	14	13
0.07	3	2	0	7
0.08	1	0	4	2
0.09	3	2	1	0
0.10	1	0	2	1
0.11	1	3	0	1
0.12	2	1	1	0
0.13 or higher	0	0	1*	0

*One reading was 0.18 but is ascribed to an error, see discussion in Section 1.2, "Raw Data."

Figure 2. Distribution of Hourly Swings.



summation of the swings of that block size for the 4 years. The maximum/minimum are the average of the yearly maximum (or minimum) increases (or decreases) for the 4 years for that particular block size.

Preliminary plots of these data indicated that, in the short term, decreases in pressure seemed to be more rapid than the increases. However, when examined statistically, this was found not to be true at the 95% confidence level. Therefore, the increases and decreases were combined as equivalent in this presentation. To clarify, if one were interested in the pressure decreases, the second column of the table would be the minimum that the pressure decreased and the fourth column would be the maximum that the pressure decreased. If increases were the question, the second column would be the minimum increase for the block and the fourth column would be the maximum increase for the block.

From this, one sees the following: (1) the pressure increase (or decrease) over any 4-day period is 0.541 inches of mercury (0.00564 inches of mercury per hour x 96 hours), (2) the minimum increase (or decrease) is 0.12 inches of mercury, and (3) the maximum increase (or decrease) is 1.37 inches of mercury. Similarly, for any 2-week period the following are seen: (1) average increase (or decrease) is 1.89 inches of mercury (0.00564 inches of mercury per hour x 336 hours), (2) the minimum increase (or decrease) is 1.17 inches of mercury, and (3) the maximum increase (or decrease) is 3.04 inches of mercury. As the time block is increased the values will converge on the annual average barometric movement of 49.40 inches of mercury as is illustrated by the last entry for a "banker's year" of 360 days.

Because the minimum change is zero for up to 48 hours, one might see a conflict with the data of Table 5, but the interpretations are different. While the likelihood of a constant pressure for longer than 8 hours is small, Table 6 shows that the average increase in pressure is 0.203 and the minimum could be zero because the pressure is some combination of constant or decreasing values over that 36-hour period.

One can also see that after about 40 days there would be little loss of accuracy in using the average yearly rate of 0.005639 inches of mercury per hour since the minimum/maximum are within 30% of the average.

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Table 5. Population of Constant Pressure Sequences.

Time not exceeded (hours)	Year			
	1988	1989	1990	1991
1	5,940	5,821	5,974	5,932
2	942	1,070	992	1,036
3	341	383	360	358
4	154	155	144	164
5	69	65	63	68
6	42	27	34	28
7	20	12	15	13
8	8	12	11	7
9	5	3	3	0
10	2	3	3	2
11	2	2	0	1
12	0	1	0	1
13 or more	1	0	0	0

Table 6. Short-Term Pressure Swings.

Block size (hours)	Minimum	Average	Maximum
	(Inches of mercury)		
1	0	0.00564	0.11
2	0	0.0113	0.15
3	0	0.0169	0.20
4	0	0.0226	0.23
6	0	0.0338	0.32
8	0	0.0451	0.38
10	0	0.0564	0.44
12	0	0.0677	0.47
16	0	0.0902	0.55
20	0	0.113	0.63
24	0	0.135	0.71
36	0	0.203	0.83
48	0.01	0.271	0.96
60	0.02	0.338	1.06
72	0.06	0.406	1.19
96	0.12	0.541	1.37
120	0.20	0.677	1.57
144	0.32	0.812	1.79
168	0.42	0.947	1.95
216	0.63	1.22	2.28
264	0.85	1.49	2.54
336	1.17	1.89	3.04
408	1.56	2.29	3.53
504	2.02	2.83	4.18
600	2.46	3.36	5.02
696	2.97	3.89	5.62
792	3.44	4.41	6.21
888	3.92	4.93	6.76
1,008	4.49	5.58	7.52
8,640	48.53	48.72	48.95

Figure 3. Short-Term Pressure Swings.

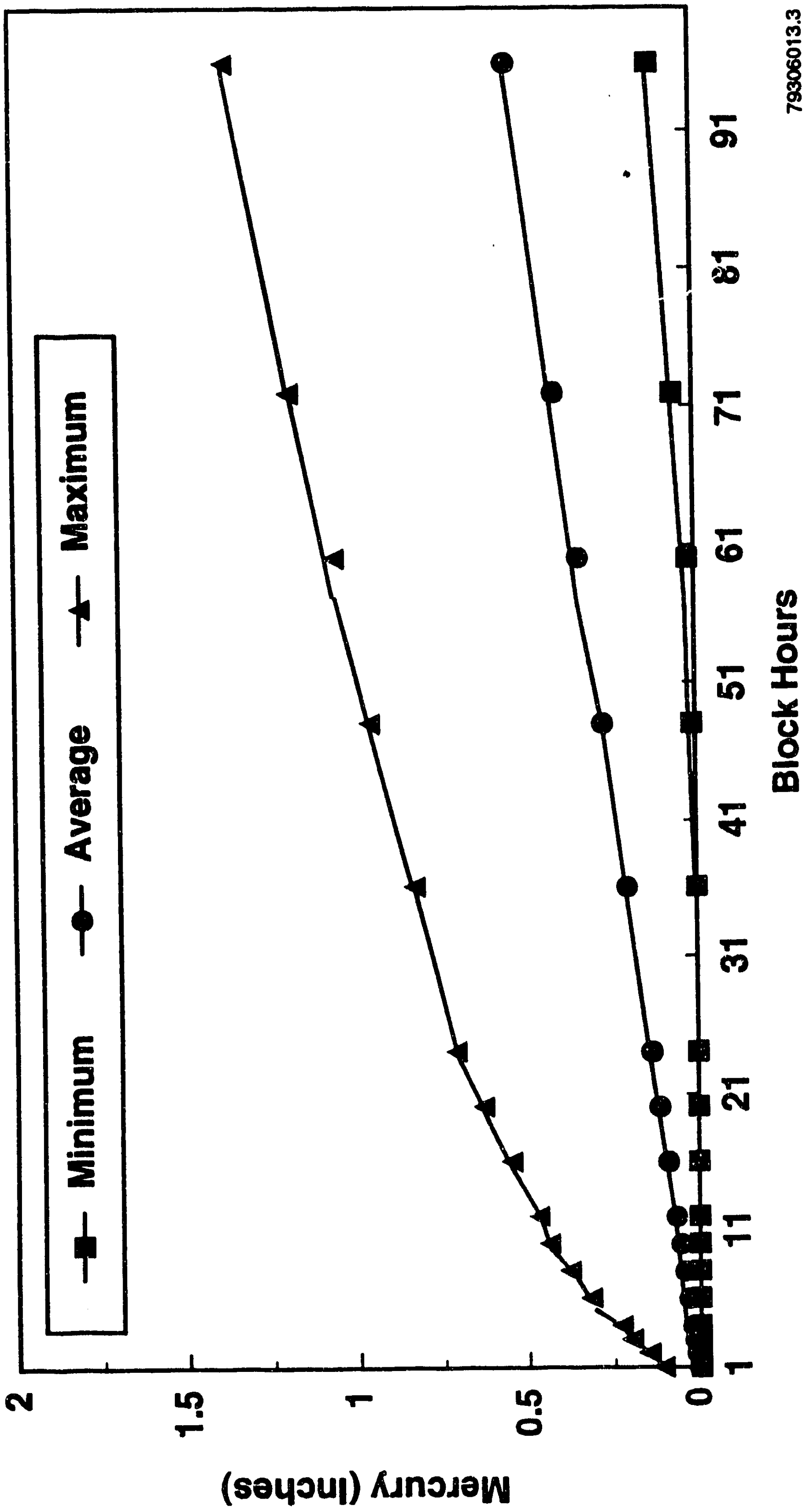
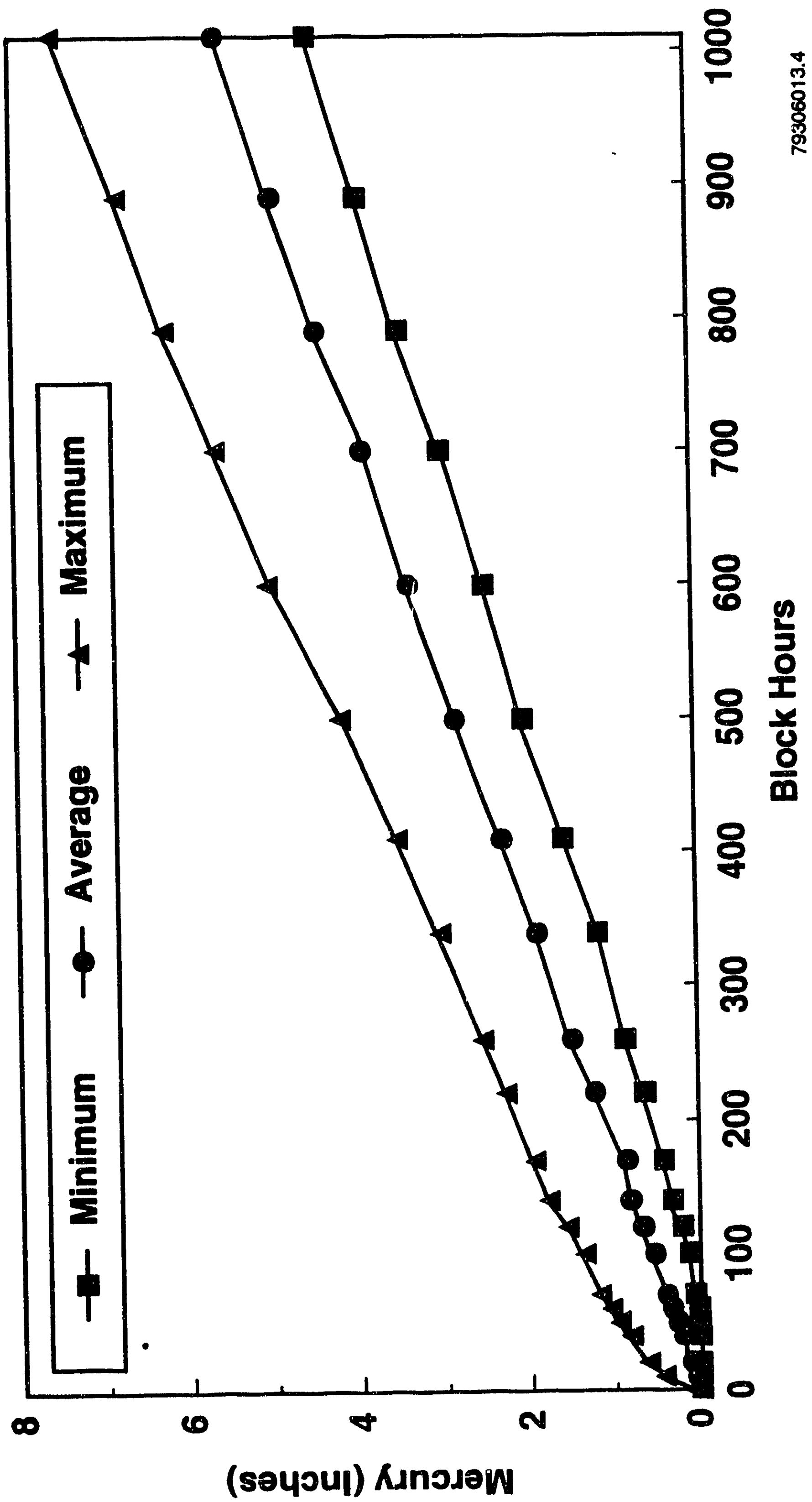


Figure 4. Long-Term Pressure Swings.



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