CO_2 INJECTION USING MEMBRANE TECHNOLOGY

by

Joseph Mackey

Plant Manager, Pepsi-Cola Bottling Company of Charleston, WV

and

John Mojonnier

Technical Marketing Manager, Meyer-Mojonnier

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INTRODUCTION

For the past 18 months, we have used a new, highly efficient membrane technology for beverage carbonation.

Coupled with mass flow measurement and PLC control, we achieve straightline carbonation performance under typical filler start-stop conditions. (slide #1) Accuracy is typically 0.25% of CO_2 setpoint as measured at the outlet of the system. This is equivalent to +/- .01 CO_2 volumes for a 4.0 volume beverage.

This performance level is a significant improvement over other carbonation technologies which report accuracies ranging from 1.0% to 2.5% of CO_2 setpoint.

To fully describe this development (slide #2), I will briefly summarize our background requirements, discuss processing system design, explain the new membrane technology, and conclude with performance data.

BACKGROUND REQUIREMENTS

Our background needs required supply of an automated mix processor capable of deaerating, carbonating, and blending to satisfy (slide #3) a filler speed of 1,250 x 12 oz cans per minute (7,032 GPH) on a 72-valve can filler with capability to cool from 85° to 38°F in order to produce the highest quality product possible. (Slide #4) The system was to be PLC-controlled, and fully integrated with the syrup room, filler, and depalletizer operation to enable (slide #5) automatic rapid changeover and maximum materials yield. This required minimum syrup and product loss through no-dump start-ups and changeovers for numerous products, and minimum empty can and packaging loss at end of run. To achieve these goals (slide #6), PLC stations in the syrup room, processor, filler, and depalletizer were linked and integrated via data highway.

PROCESSING SYSTEM DESIGN

In order to automate processor operation, achieve straightline brix and CO_2 control, and continuously acquire and report performance and yield data, (slide #7) mass flowmeters were used on the processor to measure, control, report, and trend water, syrup, and CO_2 flowrates.

Because mass flow systems are more easily adapted to in-line, real-time, single-point measurement and control, conventional processing system design was reviewed and modified.

In the case of deaeration (slide #8), a vacuum system was selected instead of a CO_2 gas stripping system because carbonation was to be measured and controlled at one point. While gas stripping systems are generally simpler and more efficient than vacuum systems, single point CO_2 addition would not be possible if deaerated water carried some unmeasured CO_2 residual.

To obtain total integration with minimum changeover time, syrup and product contact surfaces were minimized. (slide #9) This meant elimination of the large carbonator-cooler tank traditionally used for mix carbonation. This was replaced by a small glycol Plate Heat Exchanger for water chilling connected to a small and efficient membrane carbonator designed for water carbonation only. The membrane carbonator, equipped with mass flowmeter and control valve, added all of the CO2 required for final product carbonation in a bubbleless and non-dispersive process. Thus, the functions of deaeration, chilling, and carbonation occurred in non-syrup and non-product contact areas.

Accurate blending (slide #10) was obtained using mass flowmeters in the water and syrup streams to control variable-speed sanitary Positive Displacement (PD) pumps. PD pumps provided precise flow control for each stream, and permitted the system pressure to be adjusted to assure stable carbonation.

The carbonated, blended beverage was then cooled to 36°-38°F in another small glycol Plate Heat Exchanger, and transferred to the Product Tank.

The Product Tank (slide #11) provided a buffer capacity for filler start-stop operation, allowed cooling, carbonation, and blending to continue as long as possible to minimize short-cycling, and served as a product run-out reservoir at end-of-run. This last function also reduced CIP and flavor changeover time by allowing syrup and product sections to be cleaned while the last quantity of product was being filled.

NEW MEMBRANE TECHNOLOGY

Total system automation, integration, straightline carbonation control, and product stability enhancement would not have been possible without the use of a high-efficiency carbonation system (slide #12). Microporous hollowfiber membrane technology found early applications in blood oxygenation where gas transfer had to be non-dispersive or "bubbleless", and extremely efficient.

In this carbonation application, CO2 is instantaneously transported into solution by absorption at a molecular level through proprietary microporous hydrophobic (water-repelling) hollow-fiber membranes.

By contrast (slide #13), conventional dispersive in-line injection carbonation systems must first disperse small bubbles into a flowing liquid and then cause those bubbles to be absorbed into the liquid by using pressure, temperature, surface exposure, and time.

In this illustration (slide #14) we see a typical membrane. In construction, it resembles a shell and tube chiller. Water and CO2 flow in counter-current directions with CO2 on the tube-side and water on the shell-side. The many thousands of tubes (slide #15) are very small, microporous hollow filaments which are made of a hydrophobic polymer.

CO2 is held at a lower pressure in the tube than the water in the shell. Because the polymer is hydrophobic and repels water, water does not enter the micropores but is held by surface tension across them, thereby allowing carbonation to occur quickly by absorption.

With recipe-driven mass flow control, the amount of CO_2 added is synchronized with forward product flowrate and dispensed into the membrane carbonator for absorption into water.

(slide #16) The efficiency of the membrane system very nearly approaches 100% saturation for any given pressure-temperature combination as noted typically in a Heath or other carbonation chart. This efficiency permits the lowest possible system pressures to be used, which will be helpful when warm filling. Non-dispersive carbonation also improves product stability by eliminating the problem of foam-generating undissolved CO_2 micro-bubbles which may occur with dispersive injection or carbonation tank systems.

Another stability-enhancing aspect of membrane technology was additional oxygen removal from water during the carbonation process. Nearly all CO_2 dispensed into the system is absorbed. However, a very small amount of CO_2 is exhausted from the system to flush condensed moisture from the interior surface of the tubes. This small exhaust stream further removes 0.2 to 0.4 ppm dissolved oxygen from vacuum deaerated water to deliver extremely low D.O. water for blending.

(Slide # 17) Membrane carbonation also provided process flexibility during automated start-up and changeover. These processes typically required that processing system settings be changed between what we refer to as the "blend-sweeten" and "blend-run" modes.

In the "blend-sweeten" mode, carbonation levels are reduced to compensate for slight CO_2 pick-up as the product tank is initially filled. When the system is fully charged with product, carbonation levels are raised and the "blend-run" mode is initiated. This change is easily accomplished with the membrane carbonator via PLC program by proportionally decreasing then increasing the target recipe amount of CO2 directed to the system. This permits the first can off the filler-seamer to be on target.

(slide #18) As the membrane carbonator handles water only, the CIP regimen differs from syrup and product contact areas. Whereas syrup and product contact areas receive daily chemical and weekly hot sanitizing, water contact areas are flooded overnight and micro-counts are monitored on a daily basis. To date, micro-counts in and around the membrane system have been nil, and overall system counts have been extremely low. We attribute nil counts on the membrane system to complete absence of nutrients, high carbonic acid levels, and extremely low dissolved oxygen levels.

PERFORMANCE DATA

The next nine (9) slides illustrate three different typical performance profiles during the afternoon shift on January 26, 1995:

A. 30-Minute Continuous Run (Slides 19, 20, & 21)

B. 15-Minute Filler Break (Slides 22, 23, & 24)

C. Flavor Changeover - Sugar-to-Diet (Slides 25, 26, & 27)

We used WinTrend (PLC-to-PC) data acquisition software to gather and trend this information, and formatted it in both chart and graph form using Microsoft Excel.

Product Brix and CO_2 readings were supplied from a GAC Lan IIdz brix/CO_2 Monitor. All other readings were supplied from PLC units in the Syrup Room, Processor, and Filler.

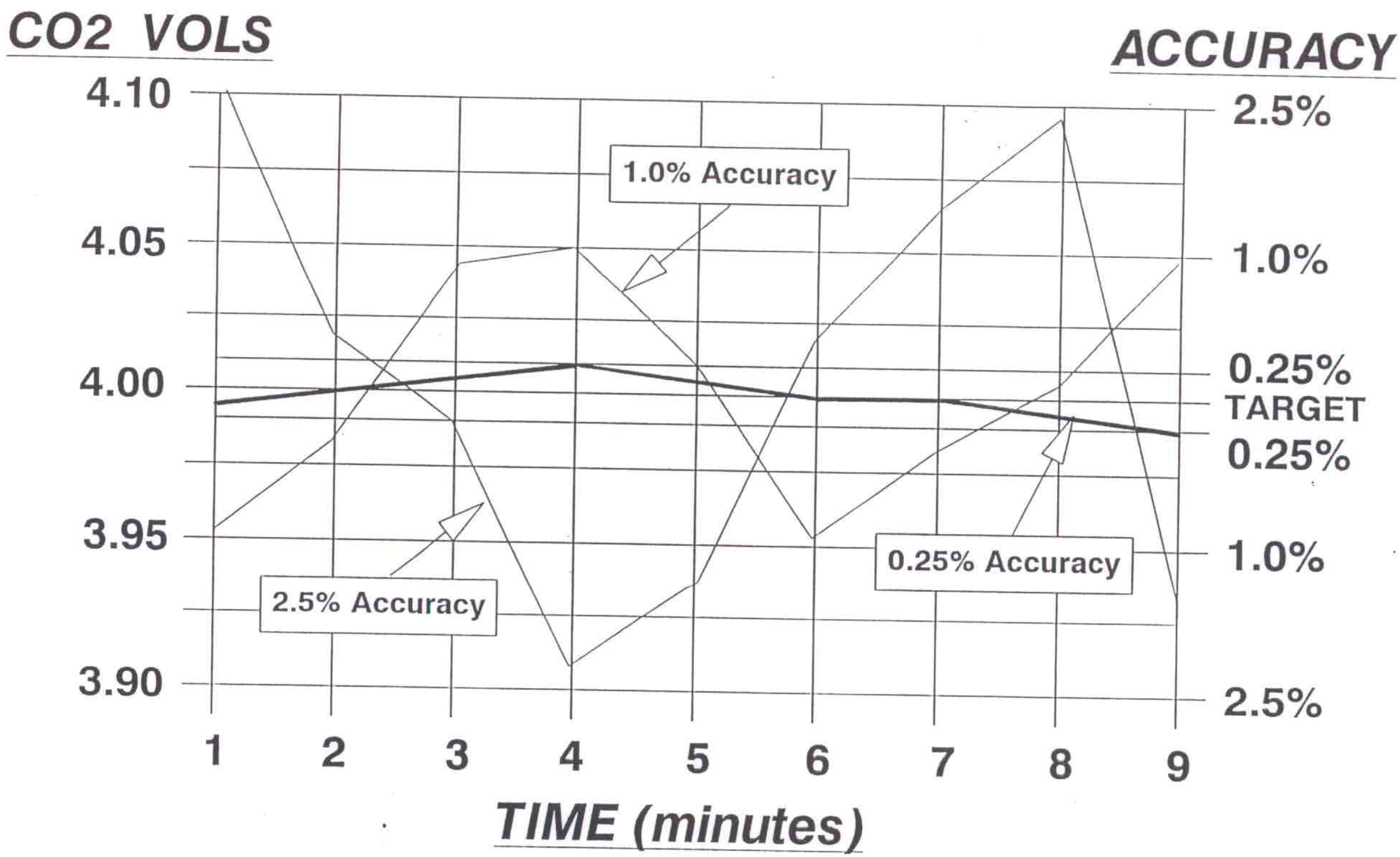
Throughout the first 2 profiles, Brix and CO_2 are very stable.

In the third profile, "Flavor Changeover - Sugar-to-Diet", the four (4) phases of the flavor changeover routine are charted. Throughout this entire automatic routine, Brix and CO_2 are under tight control.

CONCLUSION

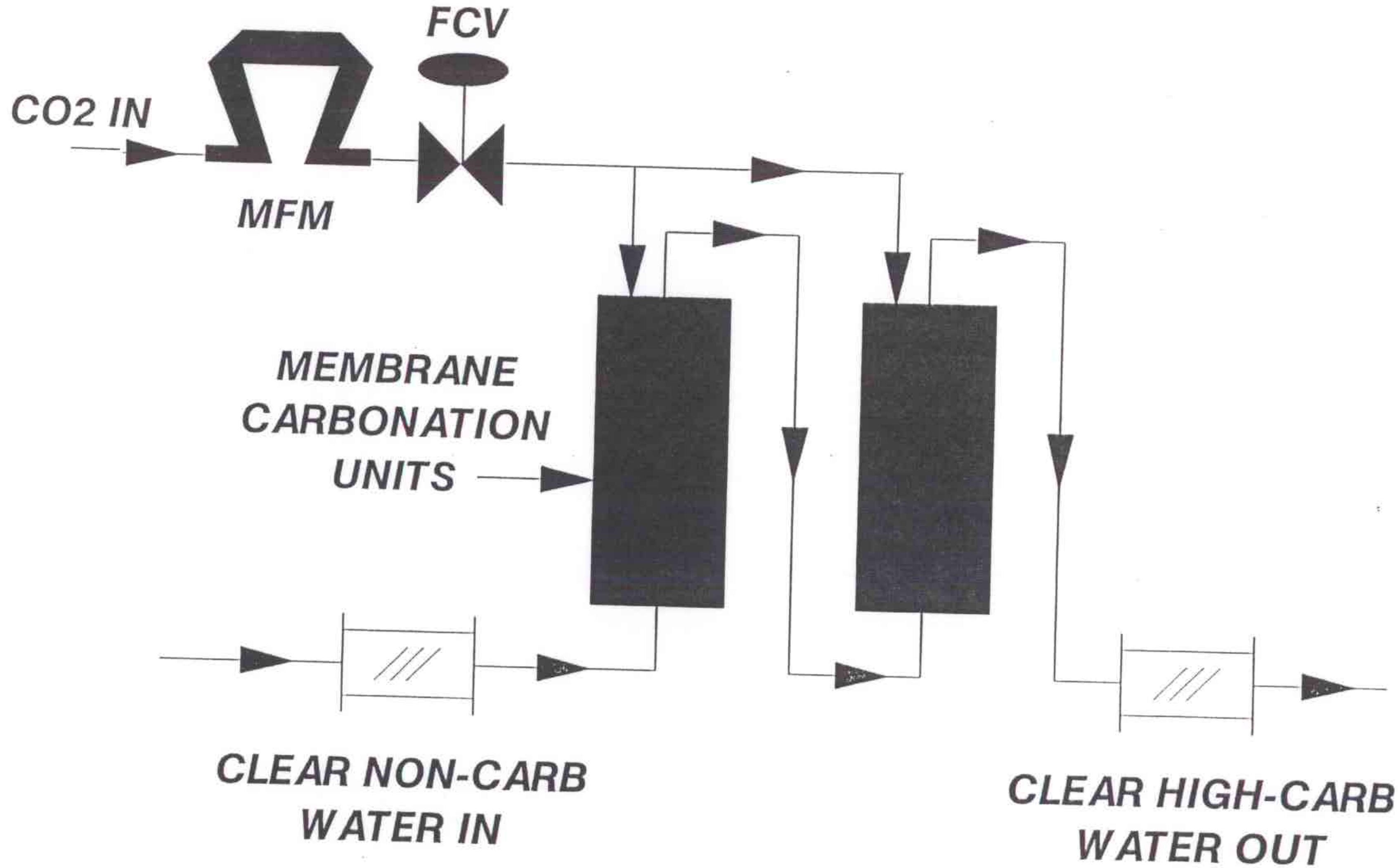
We have been extremely satisfied with the performance characteristics of membrane carbonation technology. Coupled with mass flow and PLC control, we are achieving consistent straightline carbonation levels with an accuracy of 0.25% of CO_2 setpoint at system outlet. It has worked well within our concept of total integration of syrup room-processor-filler-depalletizer for minimum changeover time, maximum materials yield, and highest product quality.

I wish to thank my colleagues at Pepsi Corporate Engineering, system engineers and technicians at Meyer-Mojonnier, and membrane specialists at Hoechst Celanese Corporation for their assistance in developing this new advanced technology for the soft drink industry.

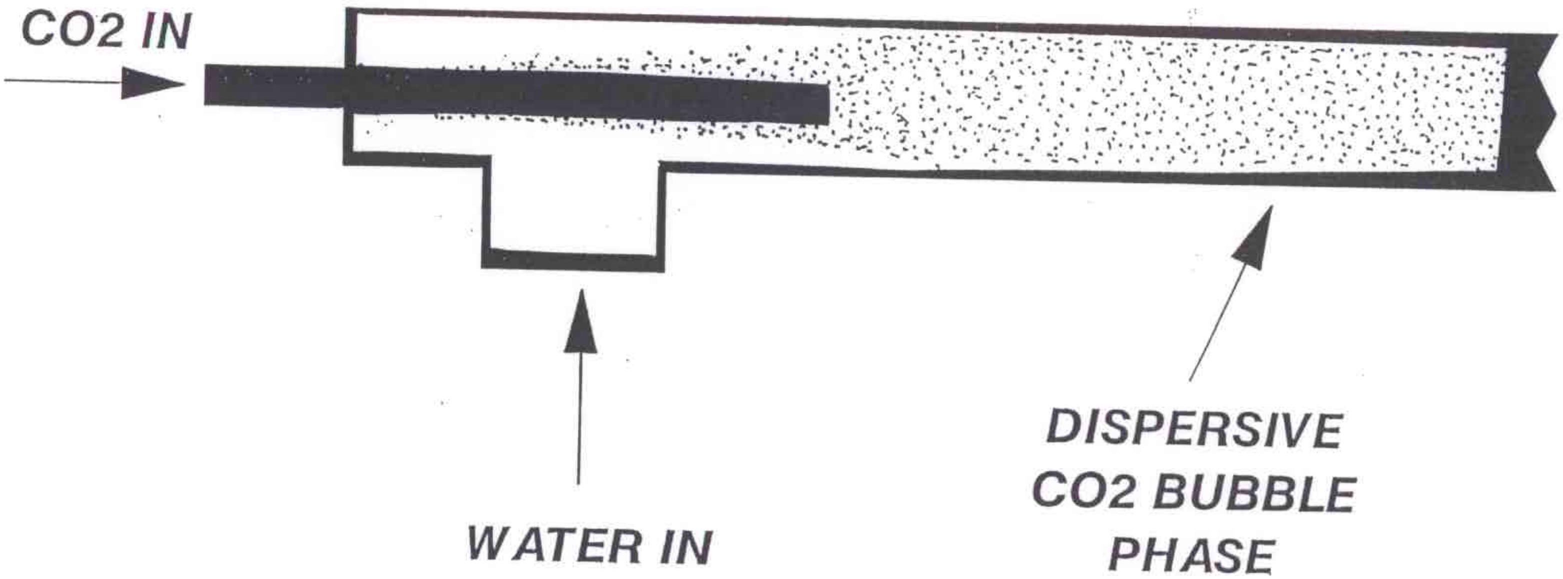


Carbonation Accuracy vs. Time

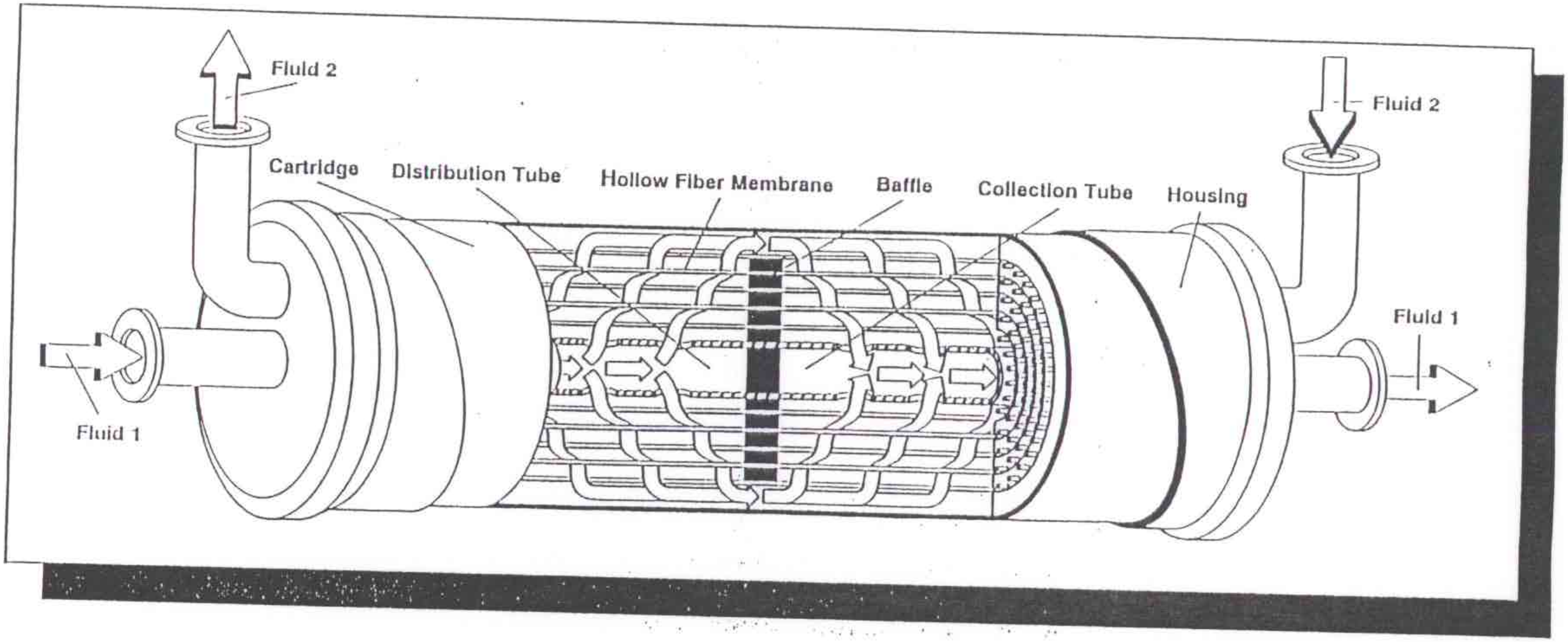
#1



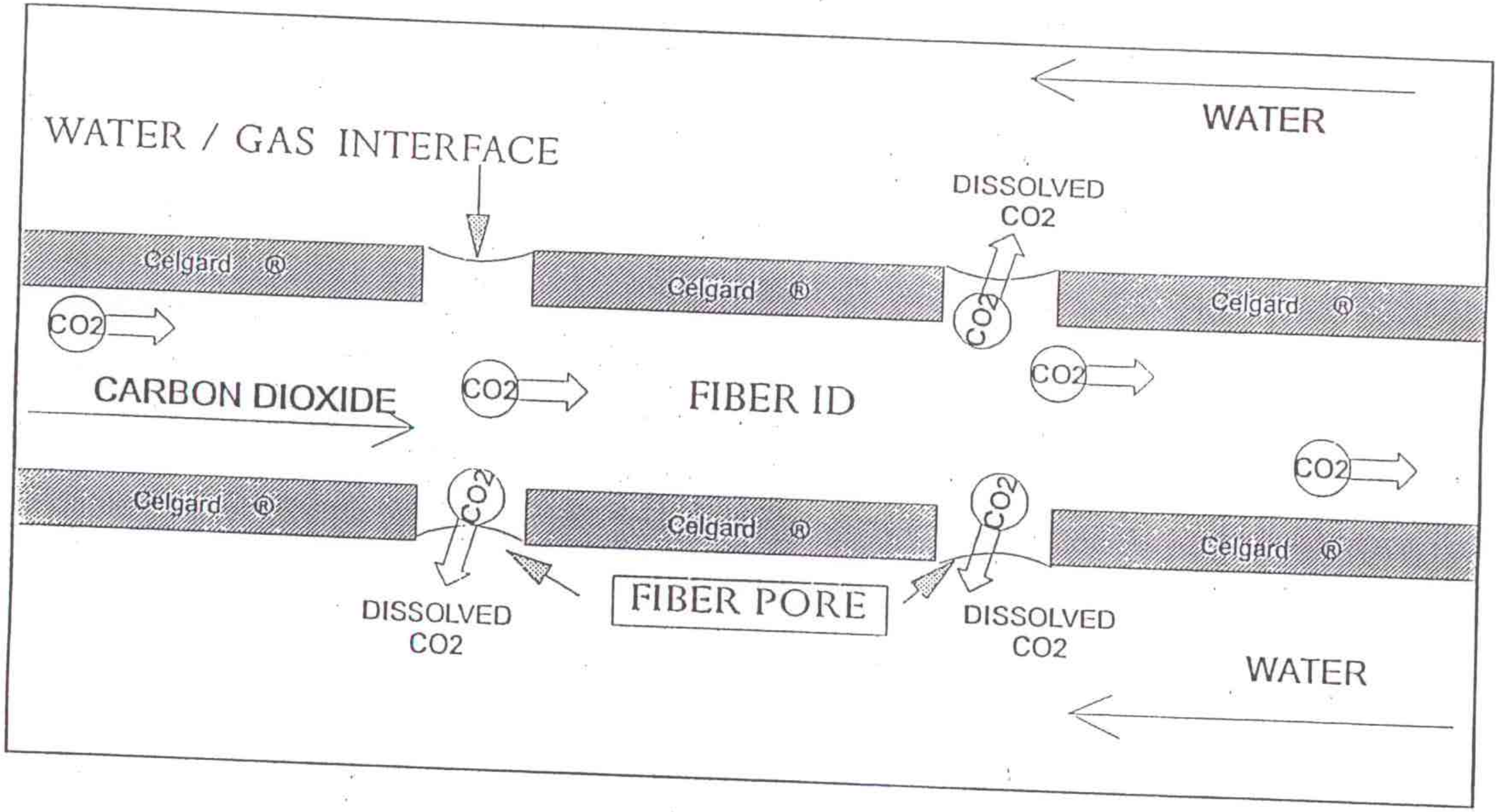
NON-DISPERSIVE CARBONATION



DISPERSIVE CARBONATION



MEMBRANE CARBONATOR



CO2 / WATER INTERFACE

Nitro, WV

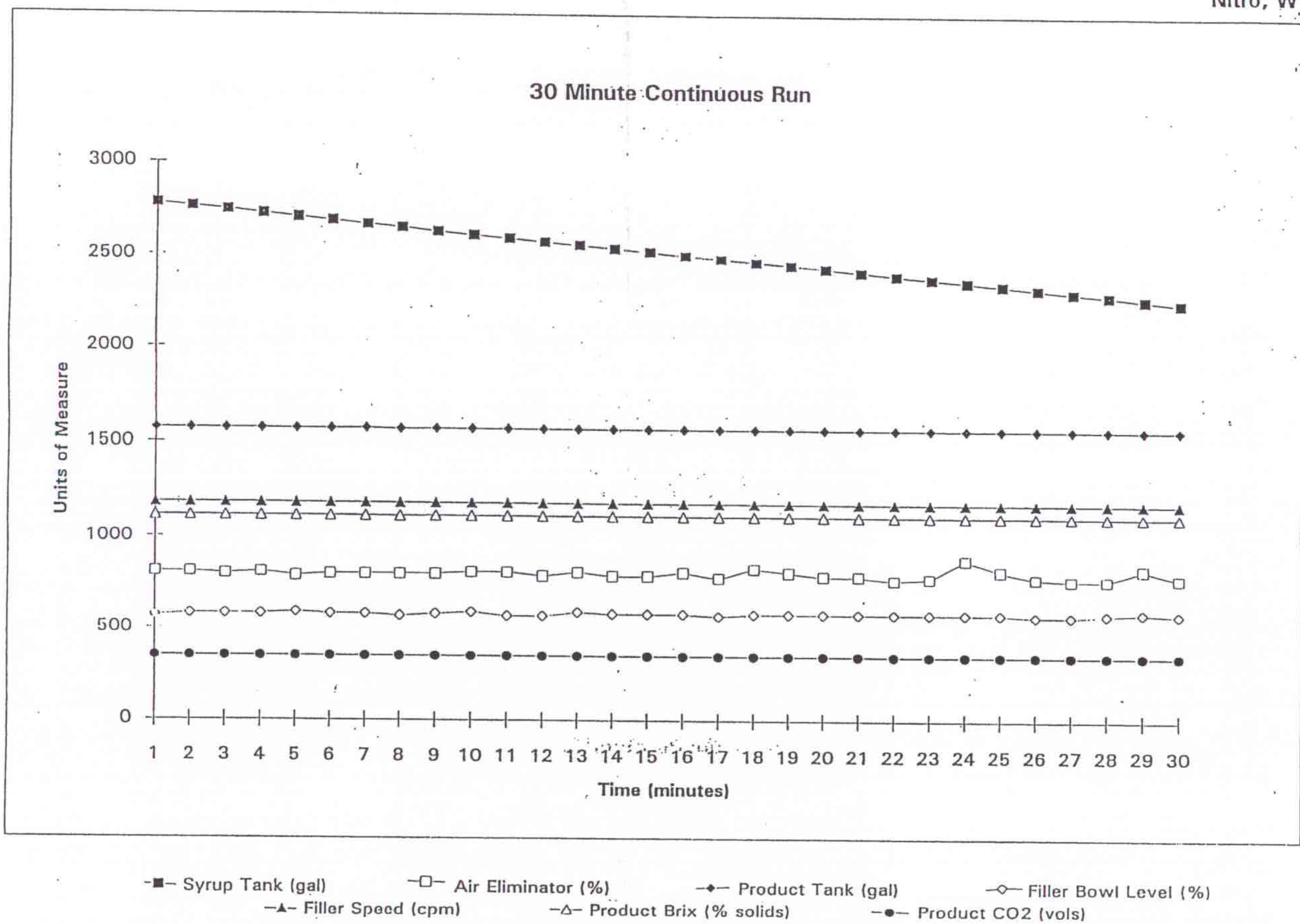
30 Minute Continuous Run

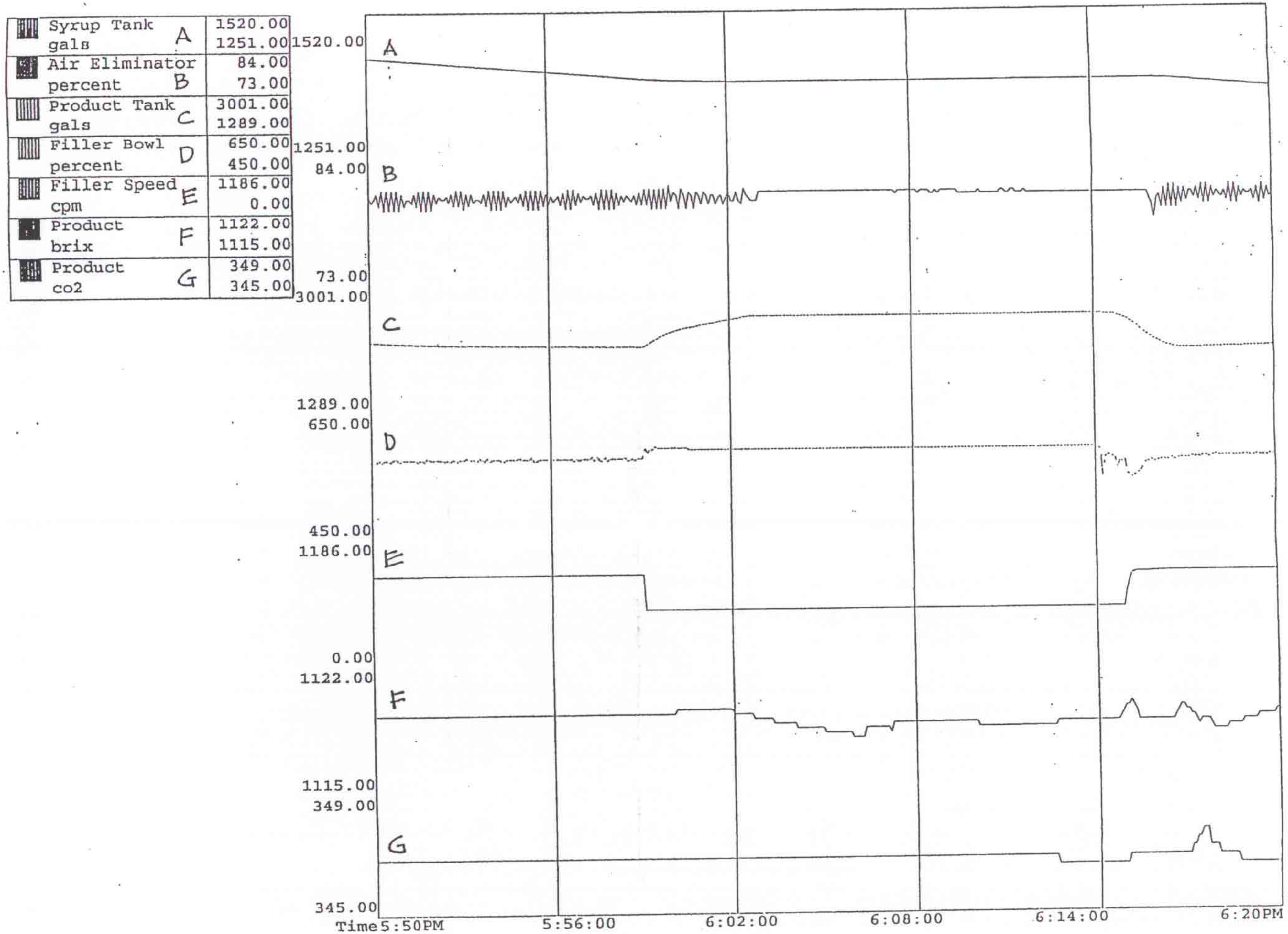
January 26, 1995

LOG POINT	TIME 16:40	16:41	16:42	16:43	16:44	16:45	16:46	16:47	16:48	16:49	16:50	16:51	16:52	16:53	16:54
Syrup Tank (gal)	2779	2762	2745	2726	2708	2691	2671	2654	2632	2614	2597	2577	2561	2543	2525
Air Eliminator (%)	81	81	80	81	79	80	80	80	80	81	81	79	81	79	79
Product Tank (gal)	157.5	157.6	157.6	157.5	157.5	157.5	157.8	157.4	157.5	157.5	157.5	157.5	157.6	157.6	157.5
Filler Bowl Level (%)	57	58	58	58	59	58	58	57	58	59	57	57	59	58	58
Filler Speed (cpm)	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187
Product Brix (% solids)	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.17	11.18	11.18	11.18	11.18	11.18	11.18	11.18
Product CO2 (vols)	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46

LOG POINT	TIME 16:55	16:56	16:57	16:58	16:59	17:00	17:01	17:02	17:03	17:04	17:05	17:06	17:07	17:08	17:09
Syrup Tank (gal)	2504	2486	2467	2450	2432	2412	2392	2375	2358	2340	2321	2301	2284	2265	2247
Air Eliminator (%)	81	78	83	81	79	79	77	78	80	82	78	77	77	83	78
Product Tank (gal)	157.5	157.6	157.5	157.5	157.5	157.6	157.5	157.6	157.5	157.6	157.5	157.5	157.5	157.5	157.6
Filler Bowl Level (%)	58	57	58	58	58	58	58	58	58	58	57	57	58	59	58
Filler Speed (cpm)	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187
Product Brix (% solids)	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18
Product CO2 (vols)	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46

Pepsi-Cola
Nitro, WV



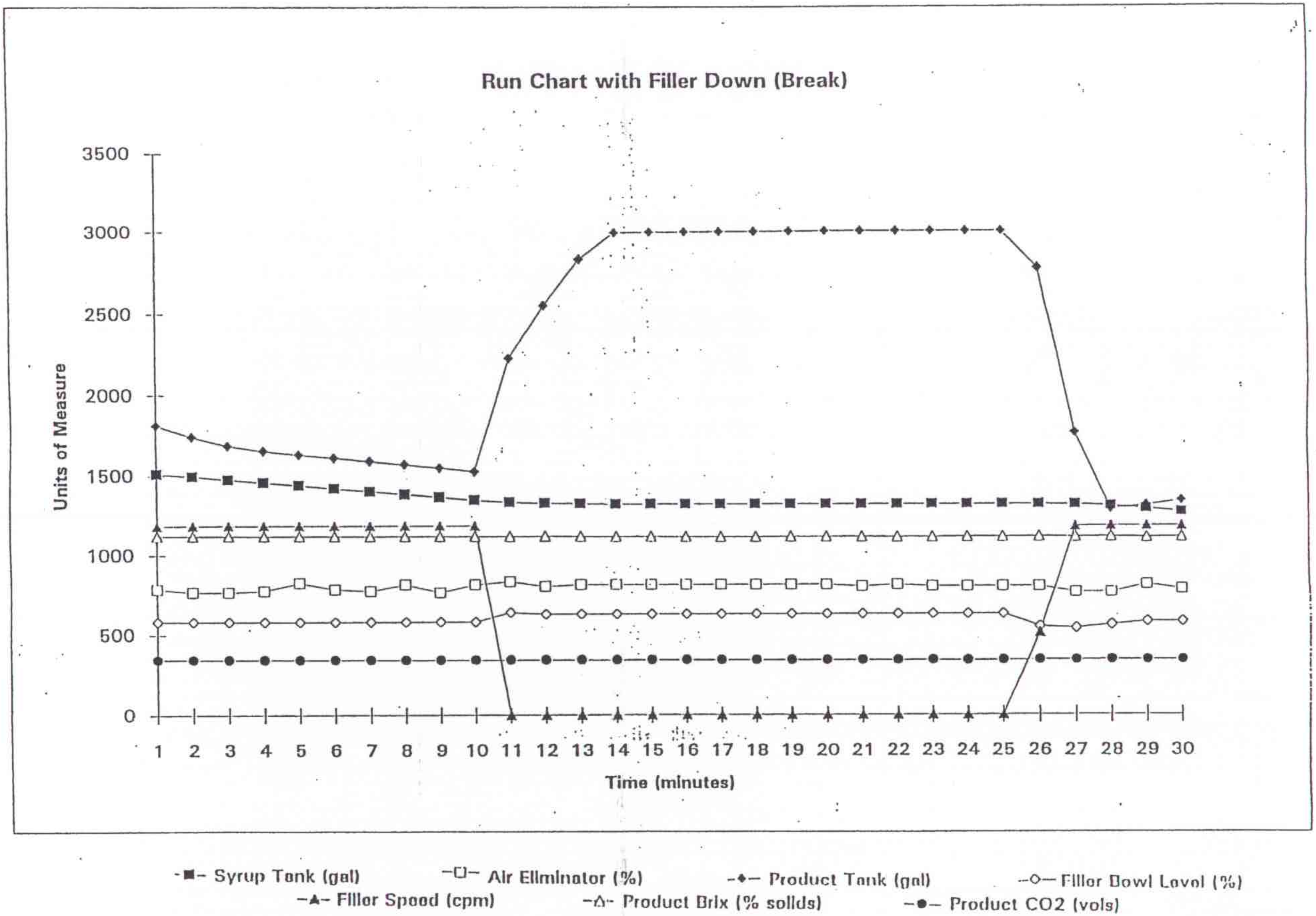

Syrup Tank gals A 1520.00 1251.00
Air Eliminator percent B 84.00 73.00
Product Tank gals C 3001.00 1289.00
Filler Bowl percent D 650.00 450.00
Filler Speed cpm E 1186.00 0.00
Product brix F 1122.00 1115.00
Product co2 G 349.00 345.00
1520.00
A
1251.00
84.00
B
73.00
3001.00
C
1289.00
650.00
D
450.00
1186.00
E
0.00
1122.00
F
1115.00
349.00
G
345.00
Time 5:50PM
5:56:00
6:02:00
6:08:00
6:14:00
6:20PM

Run Chart with Filler Down 15 Minutes (Break)

January 26, 1995

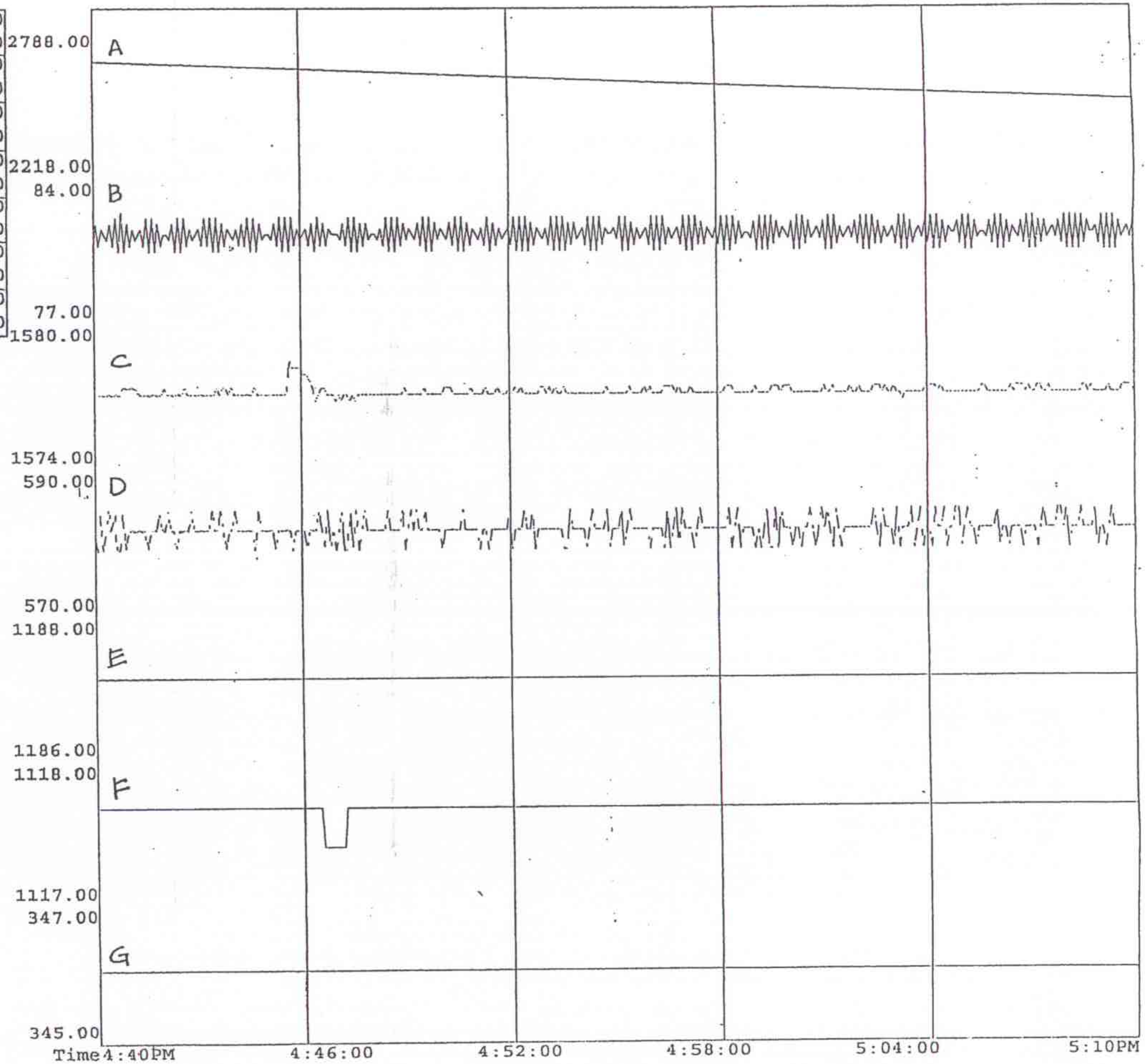
LOG POINT	TIME														
	17:50	17:51	17:52	17:53	17:54	17:55	17:56	17:57	17:58	17:59	18:00	18:01	18:02	18:03	18:04
Syrup Tank (gal)	1512	1496	1477	1461	1443	1424	1406	1388	1370	1352	1338	1332	1328	1326	1326
Air Eliminator (%)	79	77	77	78	83	79	78	82	77	82	84	81	82	82	82
Product Tank (gal)	181.5	174.4	168.7	165.5	163.2	161.3	159.2	157.1	155.1	152.9	222.5	255.4	282.8	299.3	299.5
Filler Bowl Level (%)	58	58	58	58	58	58	58	58	58	58	64	63	63	63	63
Filler Speed (cpm)	1184	1185	1186	1186	1186	1186	1186	1186	1186	1186	0	0	0	0	0
Product Brix (% solids)	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.21	11.20	11.19	11.18
Product CO2 (vols)	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46

LOG POINT	TIME														
	18:05	18:06	18:07	18:08	18:09	18:10	18:11	18:12	18:13	18:14	18:15	18:16	18:17	18:18	18:19
Syrup Tank (gal)	1326	1326	1326	1326	1326	1326	1326	1326	1326	1326	1326	1325	1315	1296	1277
Air Eliminator (%)	82	82	82	82	82	81	82	81	81	81	81	77	77	82	79
Product Tank (gal)	299.7	299.8	299.8	299.9	300	300	300	300	300.1	300.1	277.6	177.2	129.5	131.9	134.8
Filler Bowl Level (%)	63	63	63	63	63	63	63	63	63	63	55	54	56	58	58
Filler Speed (cpm)	0	0	0	0	0	0	0	0	0	0	515	1184	1186	1186	1186
Product Brix (% solids)	11.17	11.17	11.17	11.18	11.18	11.18	11.17	11.17	11.18	11.18	11.20	11.18	11.20	11.16	11.18
Product CO2 (vols)	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.45	3.45	3.46	3.46	3.48	3.46	3.46



Run Chart with Filler Down (Break)
Units of Measure
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Time (minutes)
Syrup Tank (gal)
Air Eliminator (%)
Product Tank (gal)
Filler Bowl Level (%)
Filler Speed (cpm)
Product Brix (% solids)
Product CO2 (vols)

Syrup Tank gals	A	2788.00	2218.00
Air Eliminator percent	B	84.00	77.00
Product Tank gals	C	1580.00	1574.00
Filler Bowl percent	D	590.00	570.00
Filler Speed cpm	E	1188.00	1186.00
Product brix	F	1118.00	1117.00
Product co2	G	347.00	345.00



WinTrend - DAILYRUN

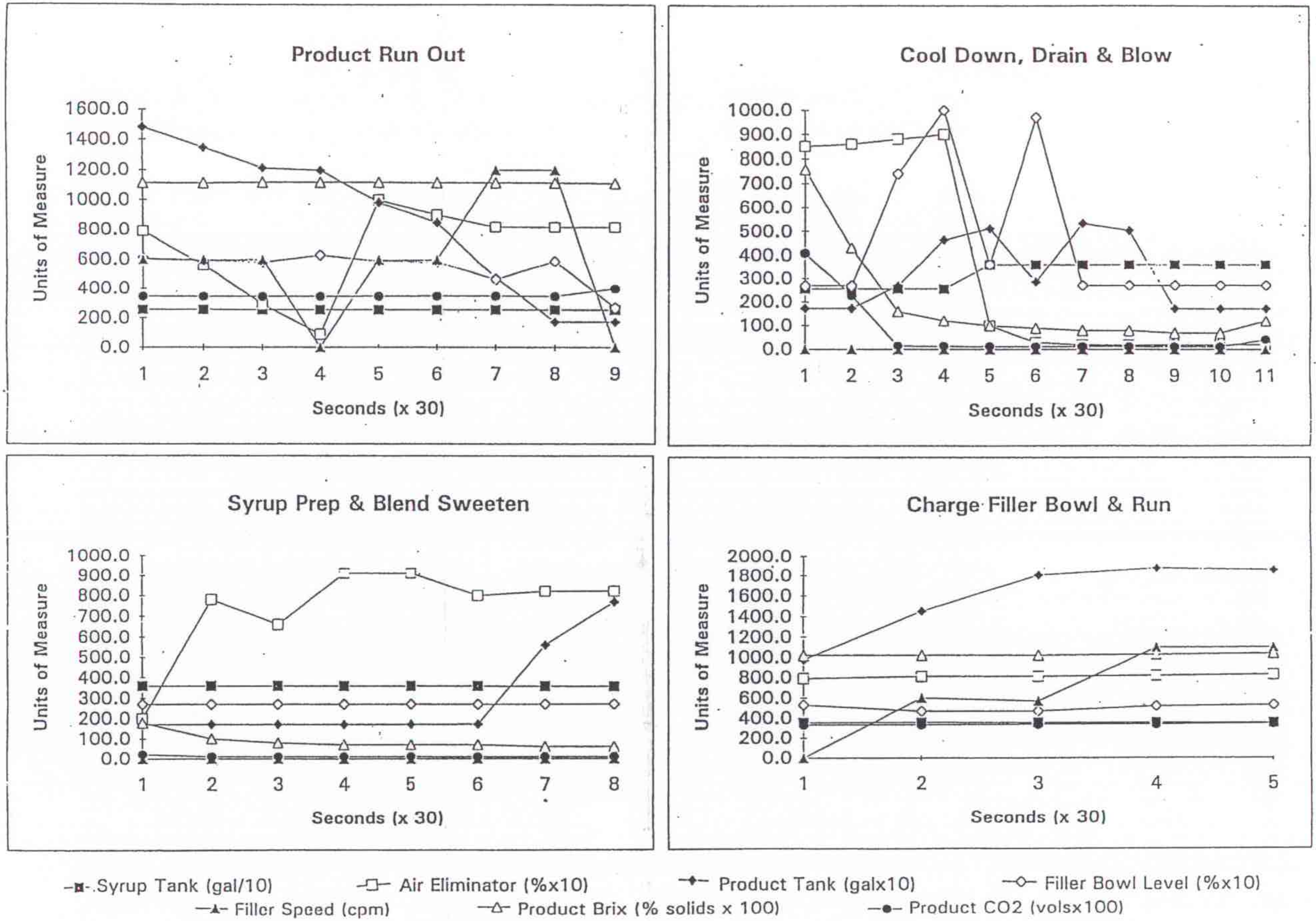
Run Chart for Flavor Changeover (Sugar to Diet)
January 26, 1995

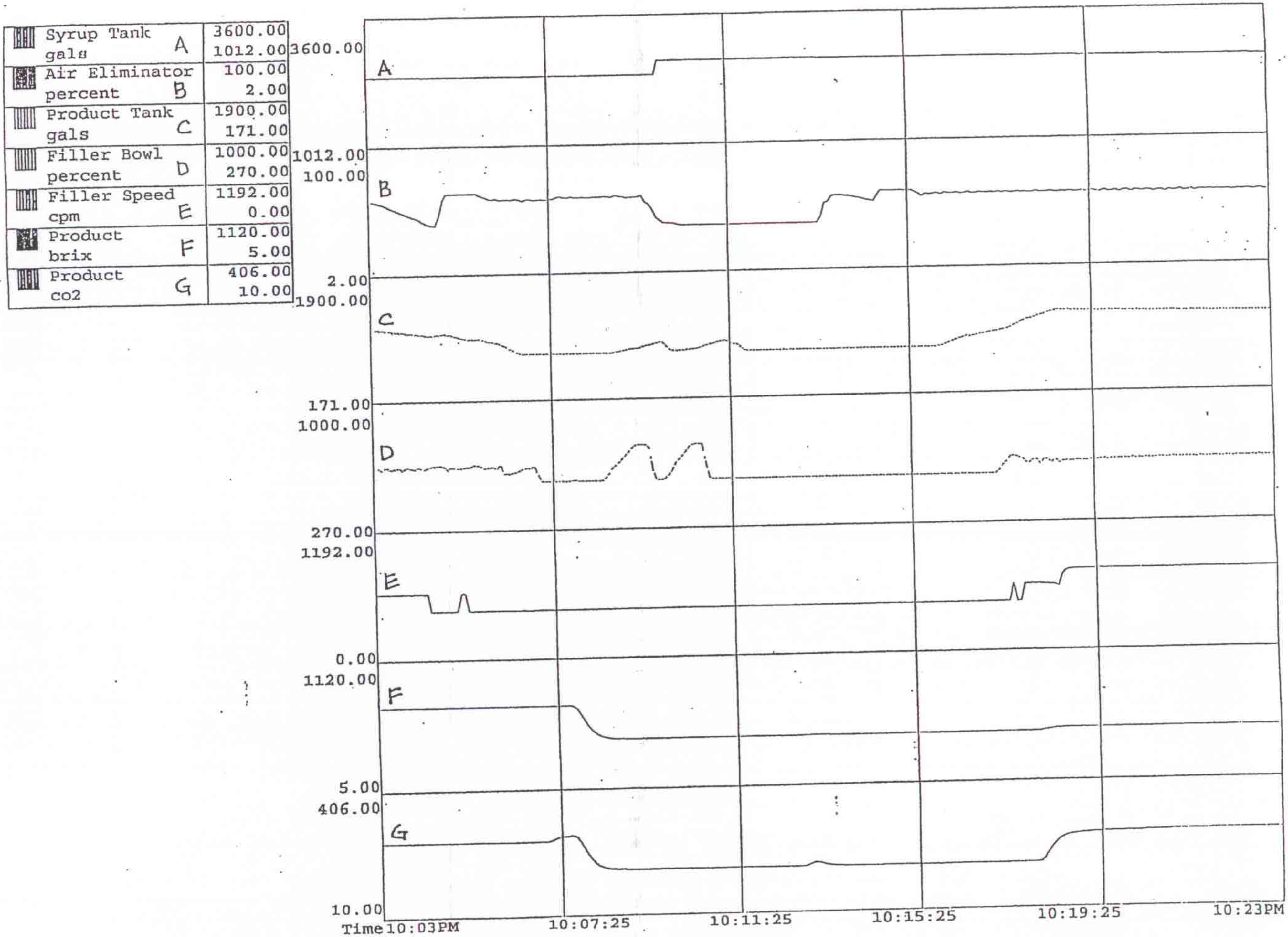
Pepsi-Cola
Nitro, WV

LOG POINT	TIME										
	22:03:30	22:04:00	22:04:30	22:05:00	22:05:30	22:06:00	22:06:30	22:07:00	22:07:30	22:08:00	22:08:30
Syrup Tank (gal)	2558	2555	2553	2551	2549	2549	2549	2549	2549	2549	2549
Air Eliminator (%)	79	56	29	9	100	90	82	82	82	85	86
Product Tank (gal)	148.3	134.7	121.4	119.7	98.3	85	47.2	17.3	17.3	17.3	17.3
Filler Bowl Level (%)	61	59	58	63	59	58	46	59	27	27	27
Filler Speed (cpm)	599	599	599	0	599	599	1199	1199	0	0	0
Product Brix (% solids)	11.15	11.14	11.18	11.19	11.18	11.17	11.17	11.17	11.13	7.58	4.32
Product CO2 (vols)	3.46	3.45	3.45	3.45	3.46	3.47	3.46	3.46	3.99	4.1	2.28

LOG POINT	TIME										
	22:09:00	22:09:30	22:10:00	22:10:30	22:11:00	22:11:30	22:12:00	22:12:30	22:13:00	22:13:30	22:14:00
Syrup Tank (gal)	2549	2549	3600	3600	3600	3600	3600	3600	3600	3599	3599
Air Eliminator (%)	88	90	10	3	2	2	2	2	2	20	78
Product Tank (gal)	26.9	46.6	51.2	28.6	53.6	50.5	17.2	17.2	17.2	17.2	17.2
Filler Bowl Level (%)	74	100	36	97	27	27	27	27	27	27	27
Filler Speed (cpm)	0	0	0	0	0	0	0	0	0	0	0
Product Brix (% solids)	1.60	1.20	1.00	0.90	0.80	0.80	0.70	0.70	1.20	1.80	1.00
Product CO2 (vols)	0.14	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.41	0.22	0.11

LOG POINT	TIME										
	22:14:30	22:15:00	22:15:30	22:16:00	22:16:30	22:17:00	22:17:30	22:18:00	22:18:30	22:19:00	22:19:30
Syrup Tank (gal)	3598	3597	3597	3593	3586	3578	3570	3561	3551	3542	3534
Air Eliminator (%)	66	91	91	80	82	82	79	81	81	82	83
Product Tank (gal)	17.2	17.2	17.2	17.3	56.1	76.9	97.8	145	180.2	187.6	185.5
Filler Bowl Level (%)	27	27	27	27	27	27	53	47	47	52	53
Filler Speed (cpm)	0	0	0	0	0	0	0	599	569	1100	1102
Product Brix (% solids)	0.80	0.70	0.70	0.70	0.60	0.60	10.20	10.20	10.20	10.30	10.40
Product CO2 (vols)	0.11	0.11	0.11	0.1	0.1	0.1	3.33	3.33	3.36	3.38	3.45


Product Run Out
Units of Measure
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1 2 3 4 5 6 7 8 9
Seconds (x 30)
Cool Down, Drain & Blow
Units of Measure
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1 2 3 4 5 6 7 8 9 10 11
Seconds (x 30)
Syrup Prep & Blend Sweeten
Units of Measure
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1 2 3 4 5 6 7 8
Seconds (x 30)
Charge Filler Bowl & Run
Units of Measure
2000.0
1800.0
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1 2 3 4 5
Seconds (x 30)
Syrup Tank (gal/10)
Air Eliminator (%x10)
Product Tank (galx10)
Filler Bowl Level (%x10)
Filler Speed (cpm)
Product Brix (% solids x 100)
Product CO2 (volsx100)



Syrup Tank gals A 3600.00 1012.00
Air Eliminator percent B 100.00 2.00
Product Tank gals C 1900.00 171.00
Filler Bowl percent D 1000.00 270.00
Filler Speed cpm E 1192.00 0.00
Product brix F 1120.00 5.00
Product co2 G 406.00 10.00
3600.00
A
1012.00
100.00
B
2.00
1900.00
C
171.00
1000.00
D
270.00
1192.00
E
0.00
1120.00
F
5.00
406.00
G
10.00
Time 10:03PM
10:07:25
10:11:25
10:15:25
10:19:25
10:23PM