

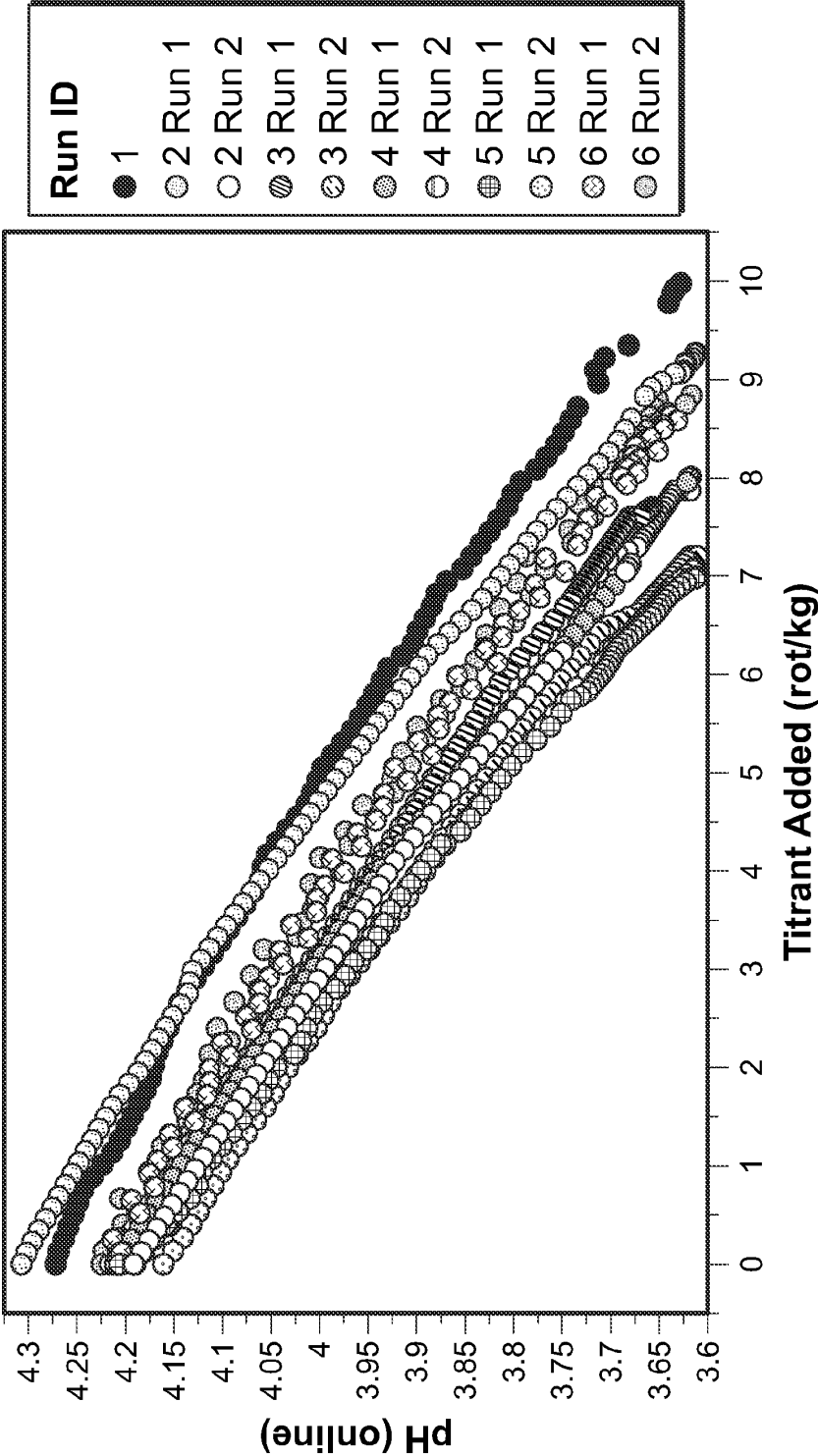


FIG. 1

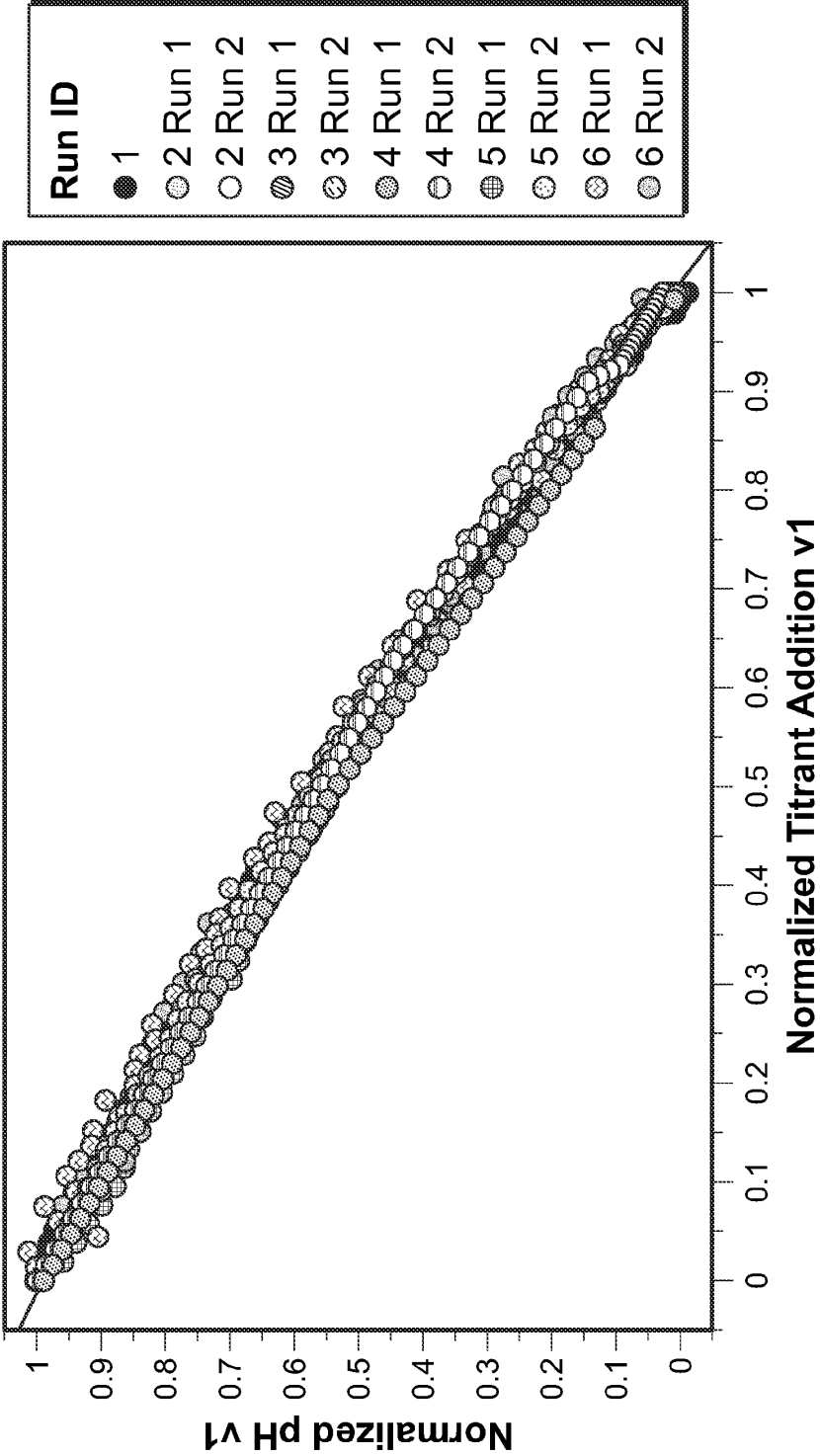


FIG. 2

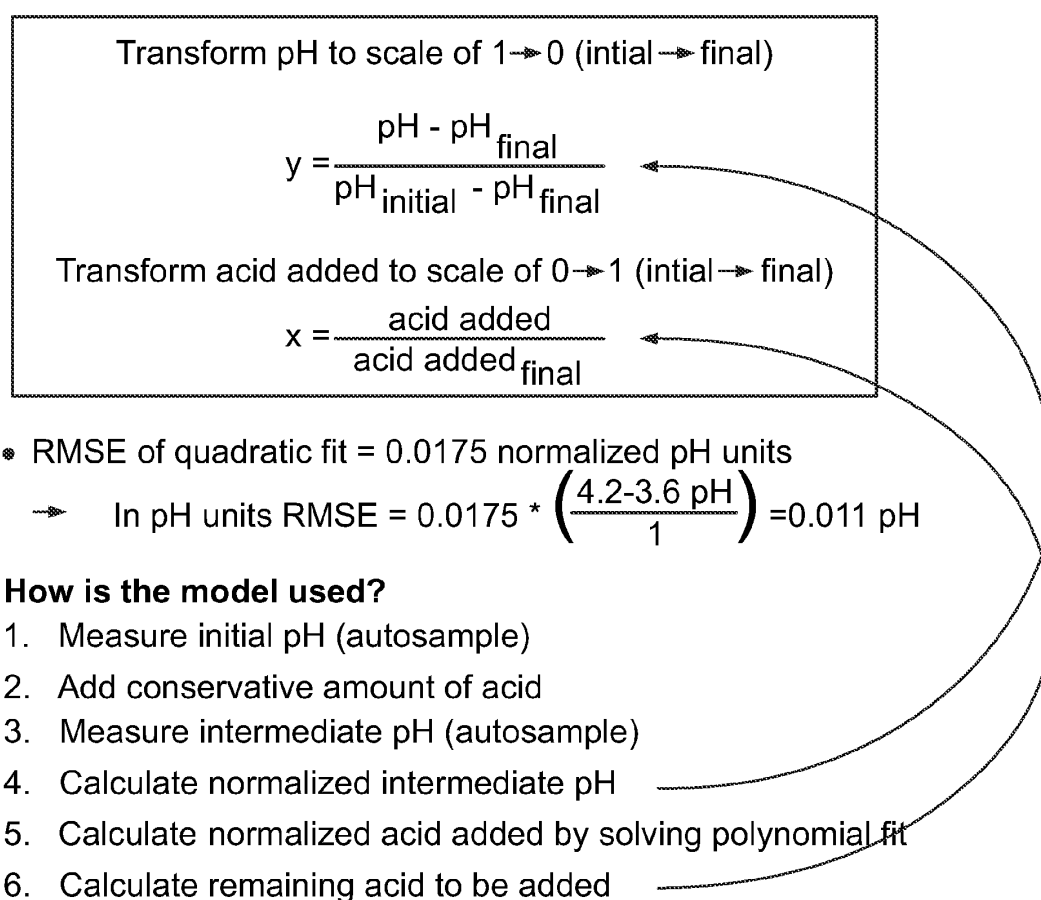


FIG. 3

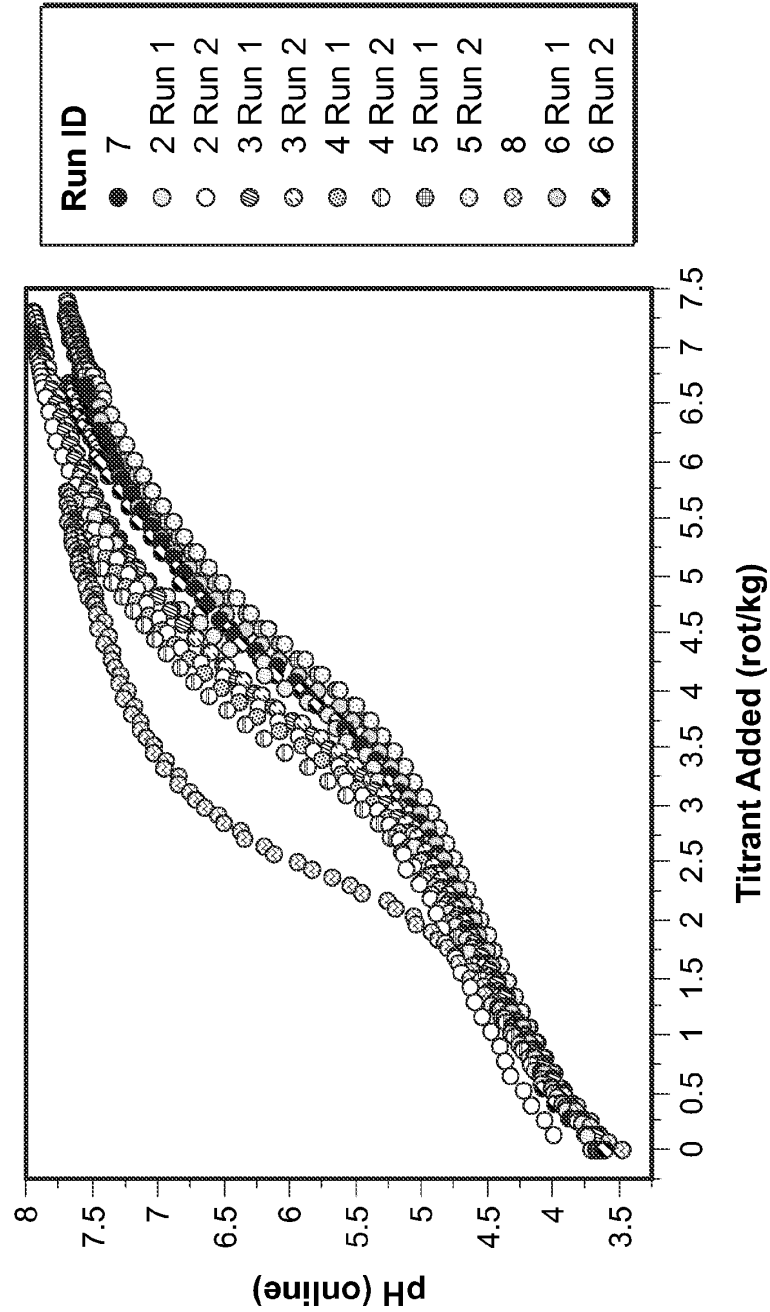


FIG. 4

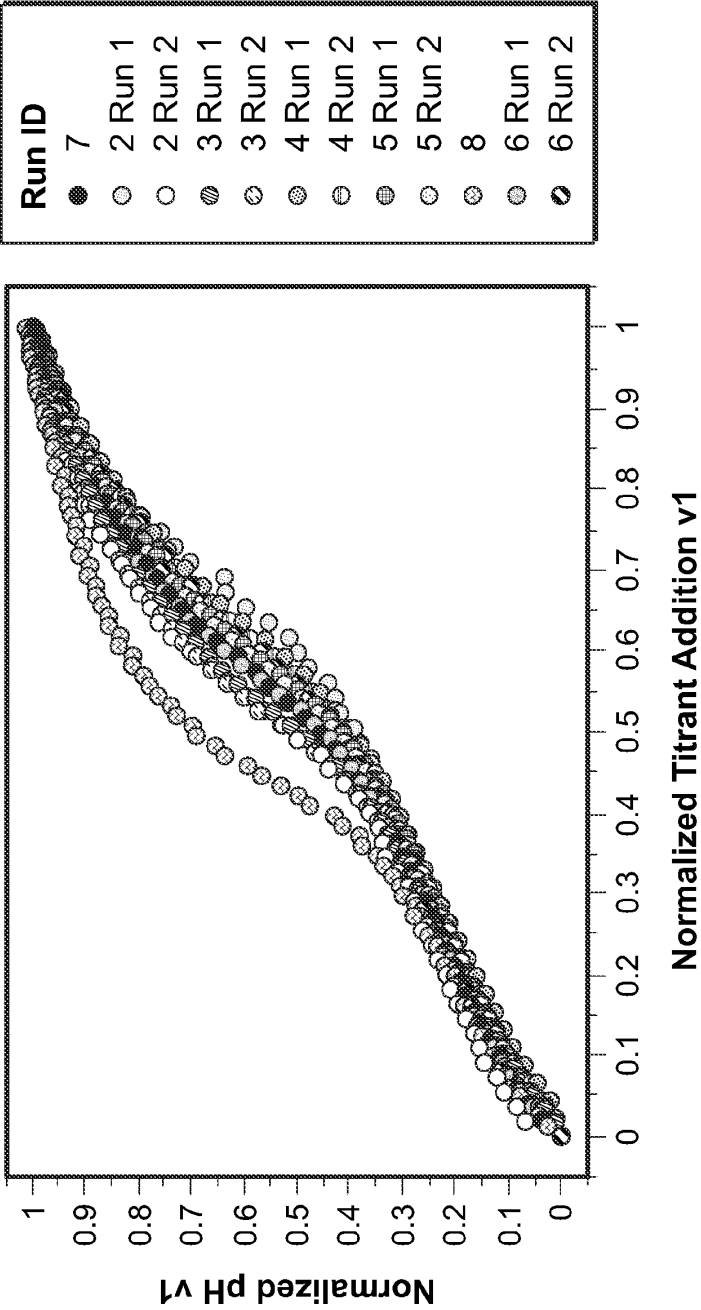


FIG. 5

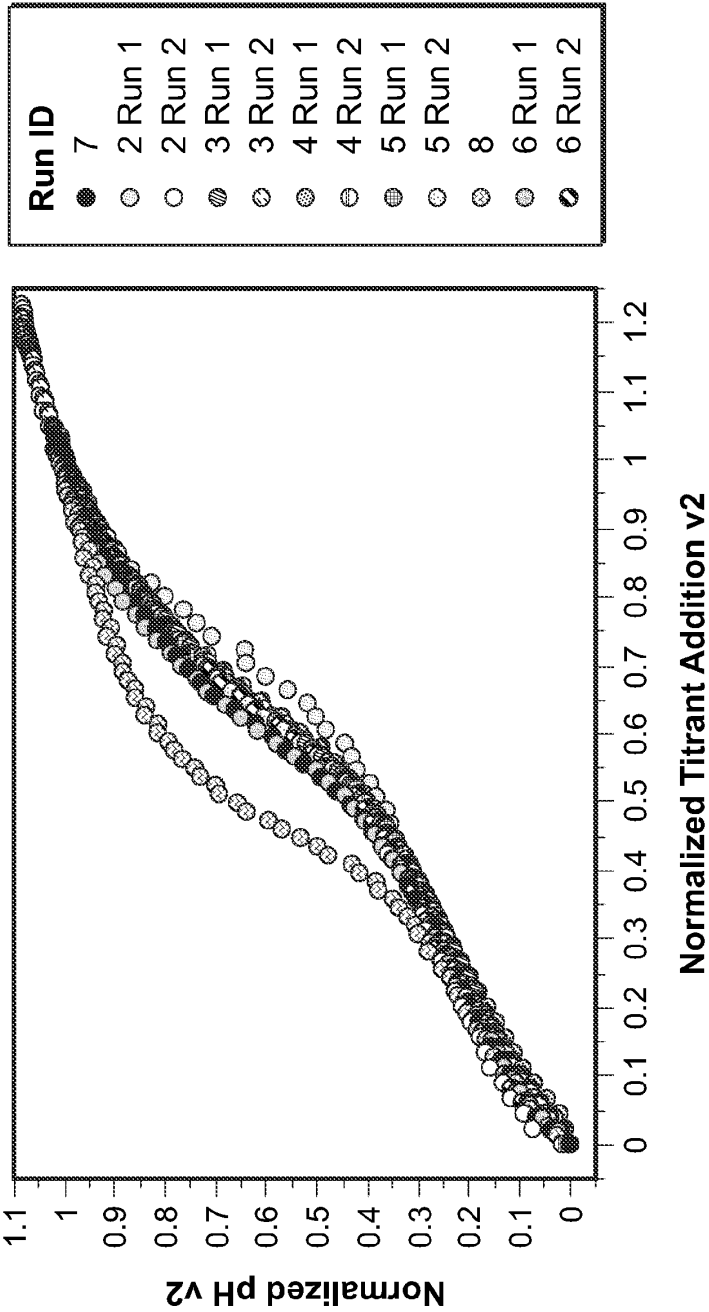


FIG. 6

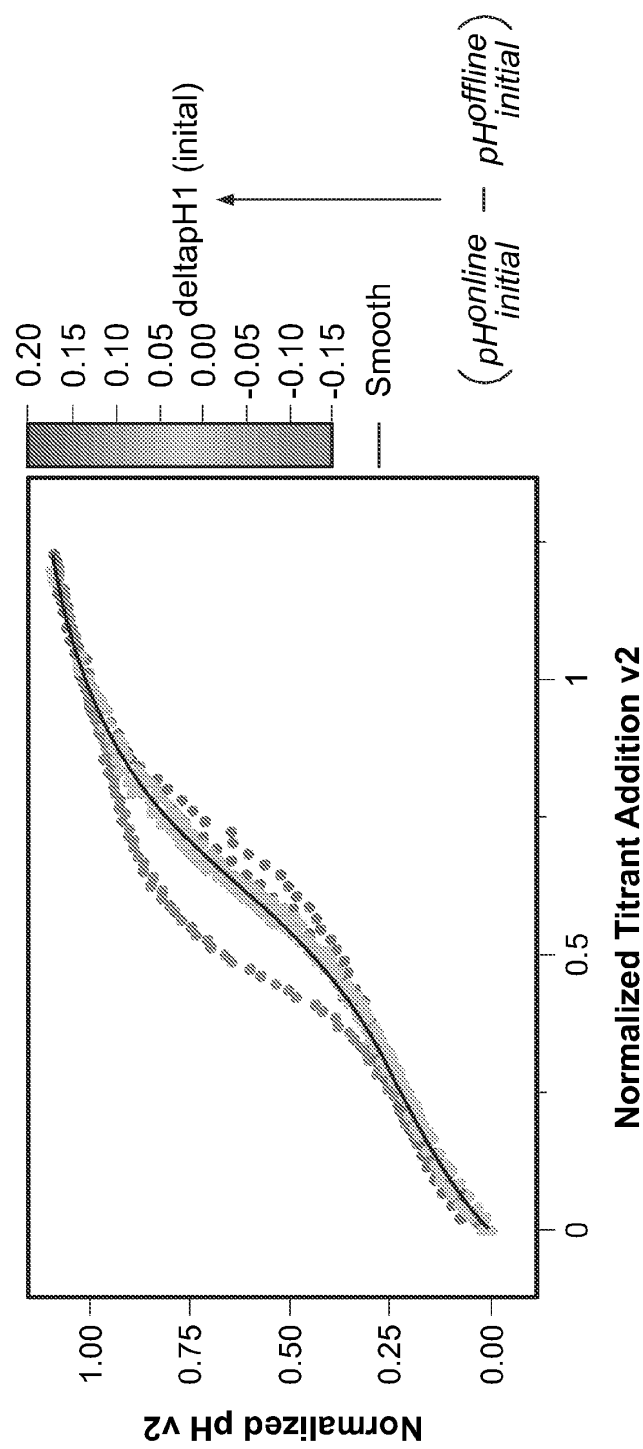


FIG. 7

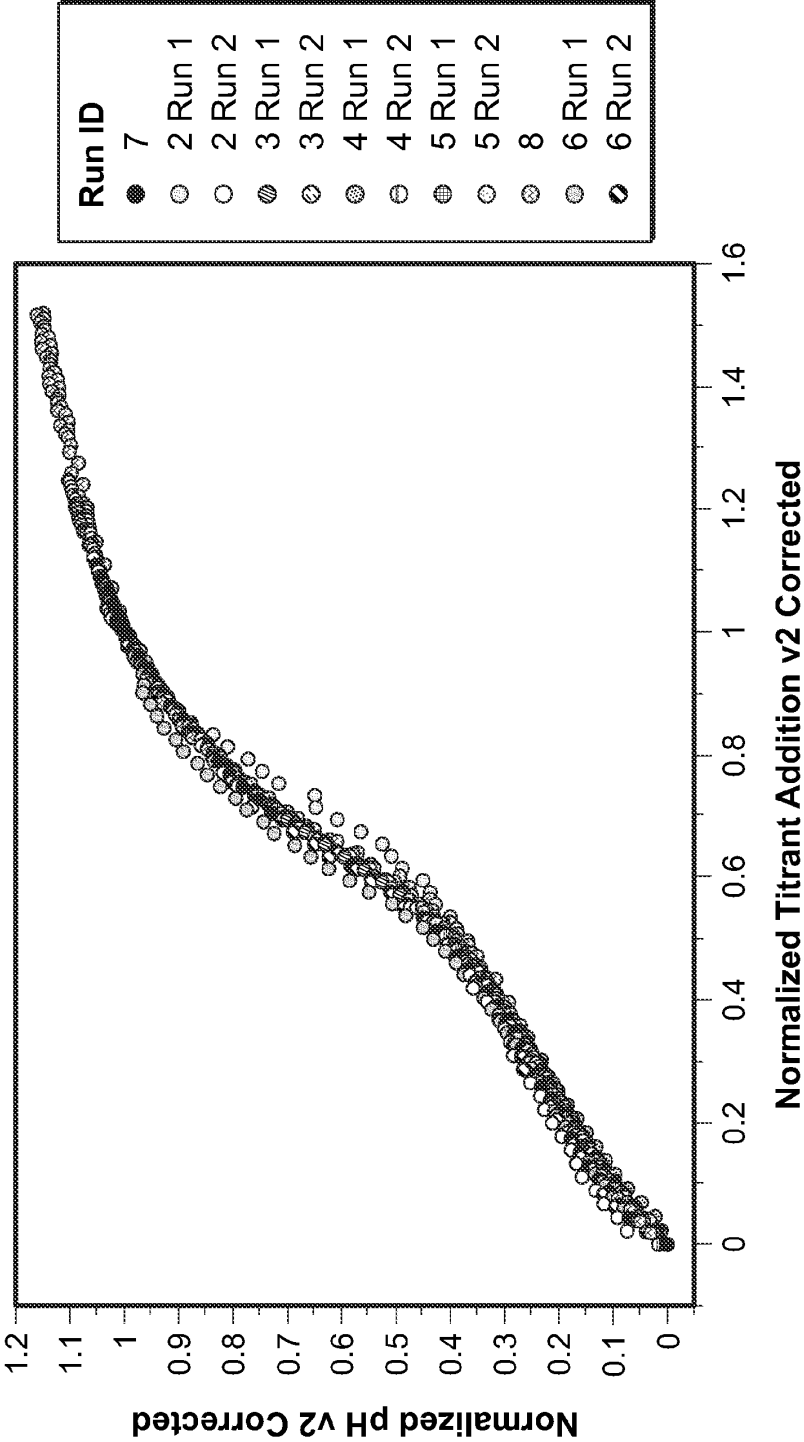


FIG. 8

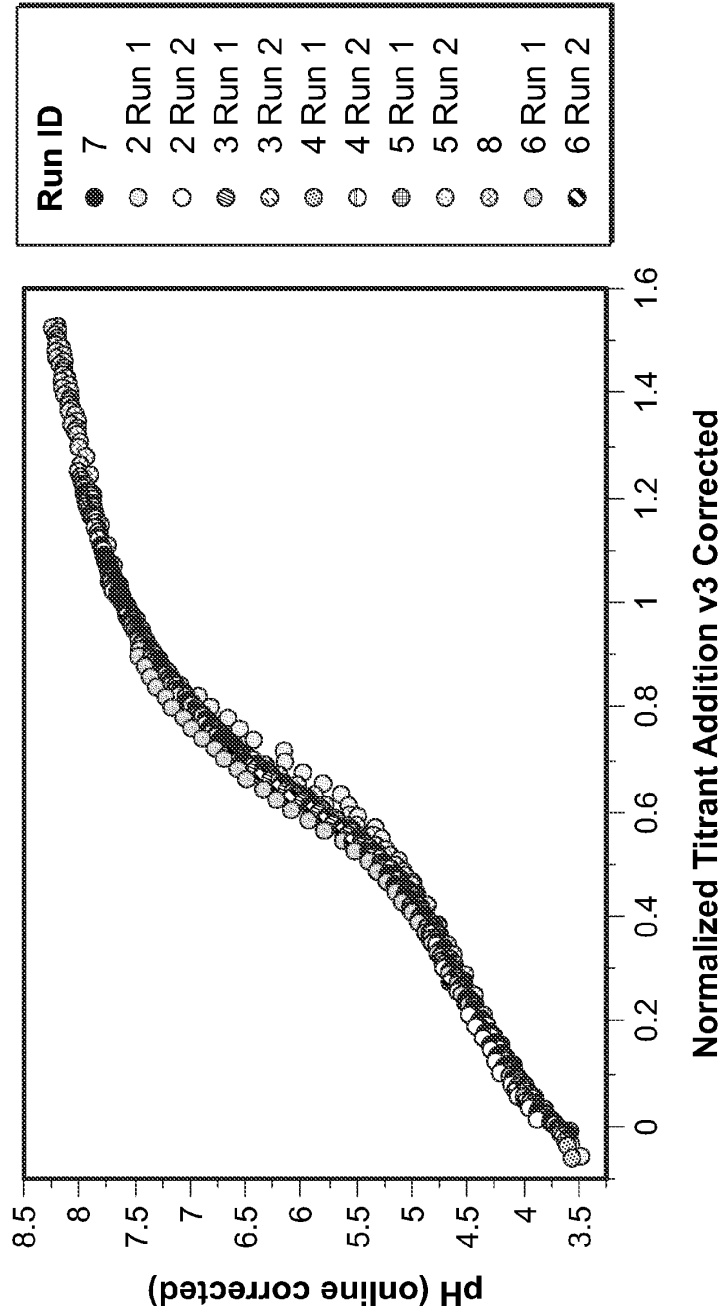


FIG. 9

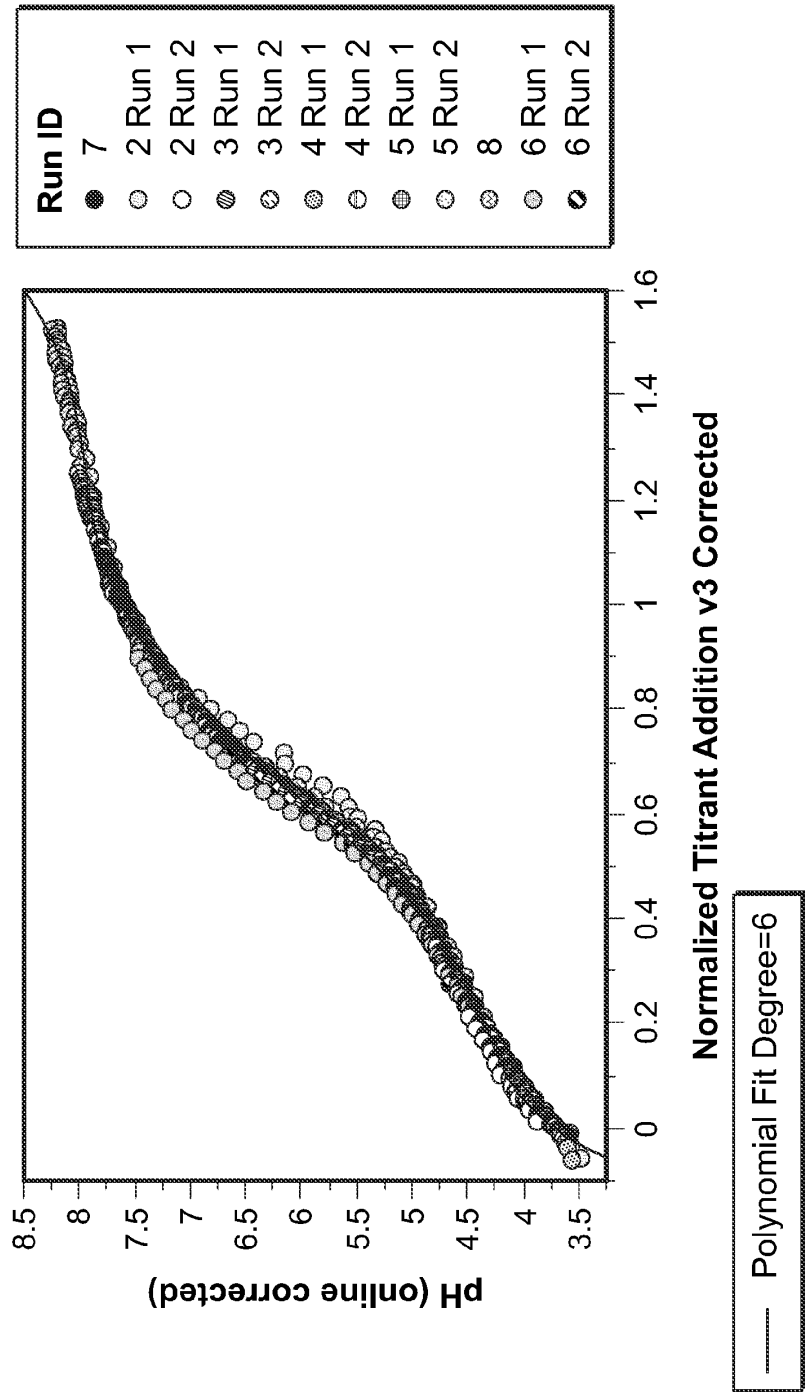


FIG. 10

Components	Signals
2 x Watson Marlow 530 pumps	Speed Setpoint (AO) Speed Feedback (AI) On/Off (DO)
1 x Watson Marlow 120 pump	Speed Setpoint (AO) Speed Feedback (AI) On/Off (DO)
2 x Sonotec CO.55 ultrasonic flow meters	Autozero (DO) Volume Pulse (DI)
1 x Mettler M400 pH transmitter	pH (AI) Temperature (AI) mV (AI)
1 x Mettler pH flow cell	N/A
1 x imPULSE mixer control cable	Speed Setpoint (AO) On/Off (DO)
3 x Ethernet I/O modules	N/A

FIG. 11

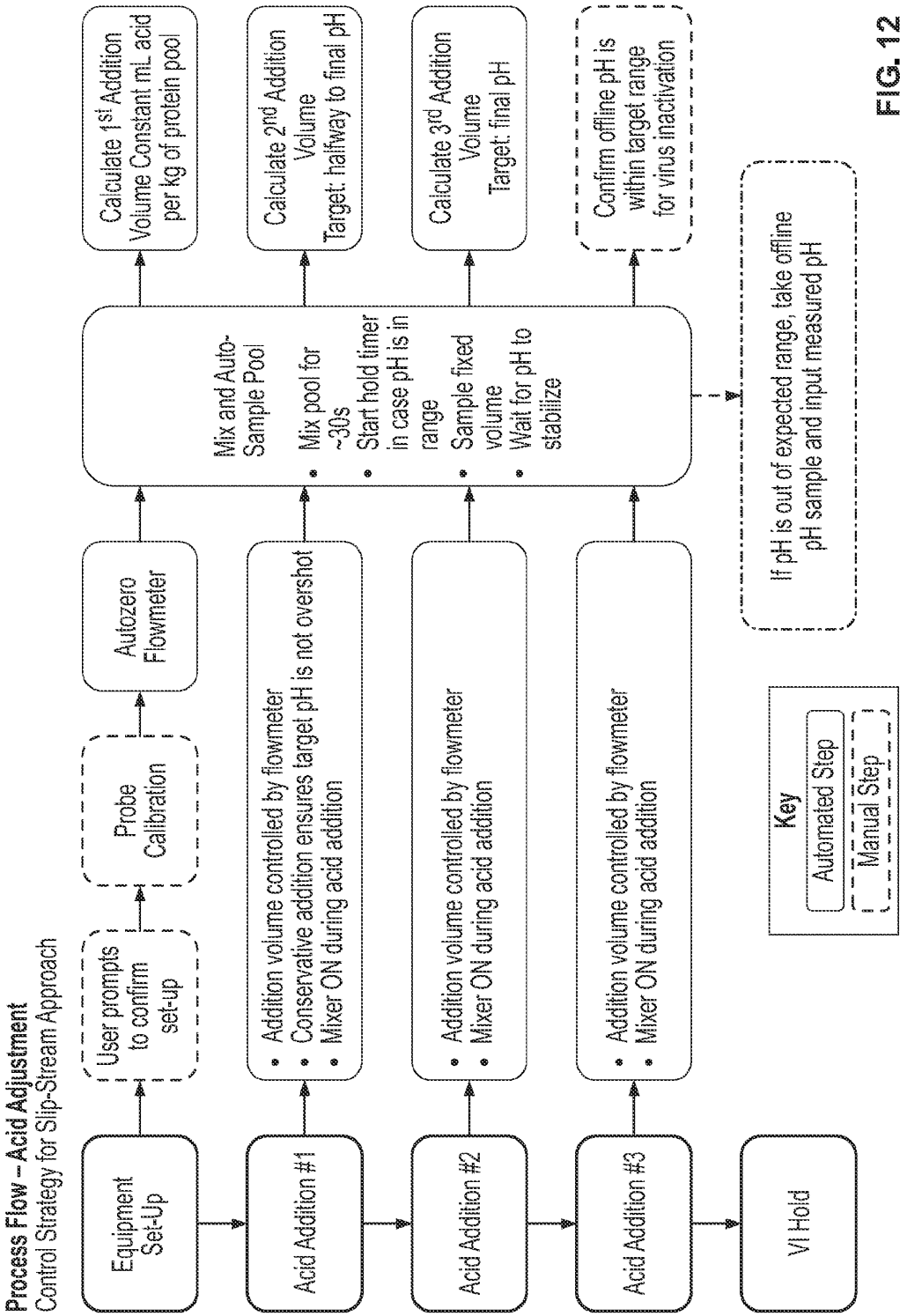


FIG. 12

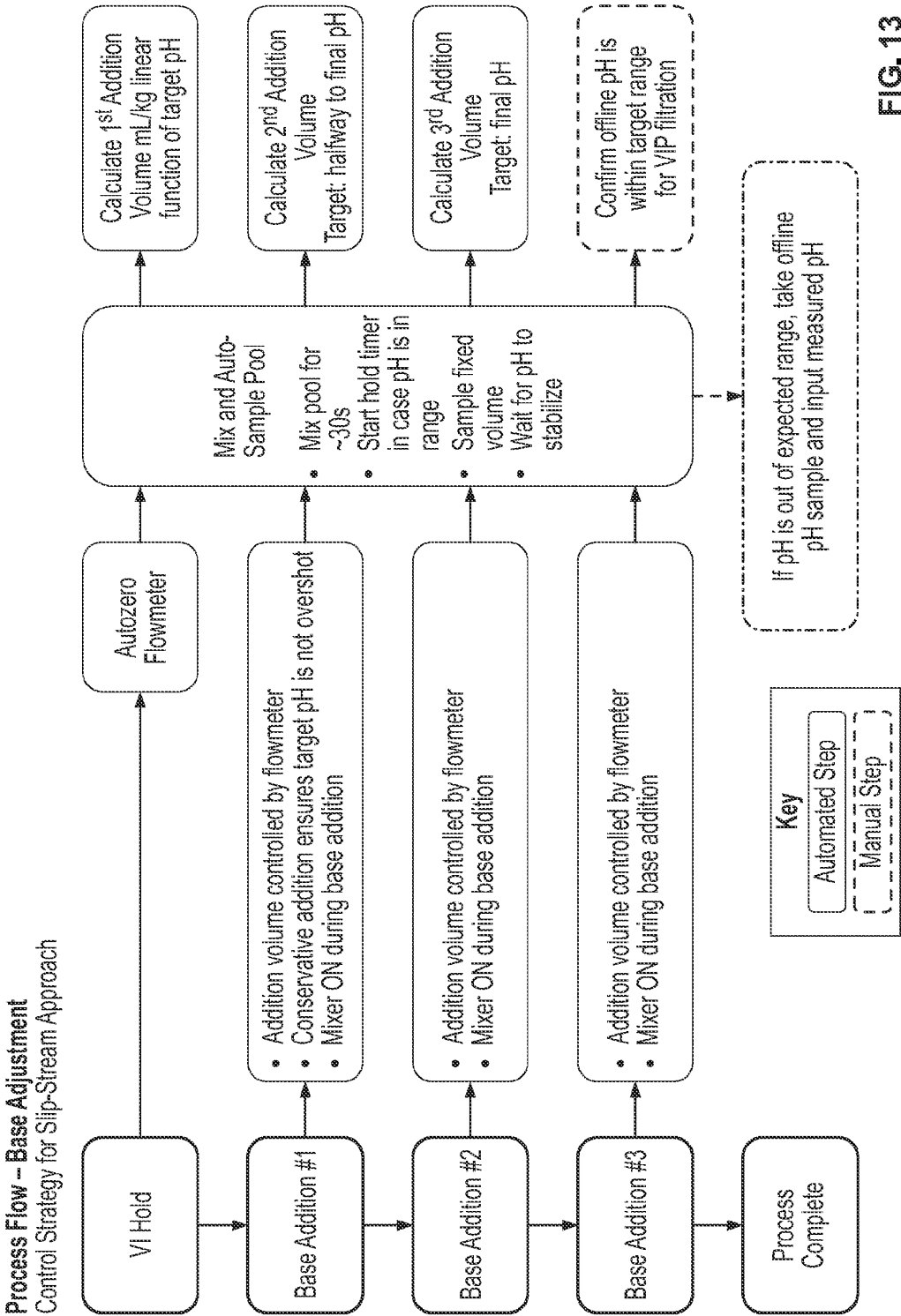


FIG. 13

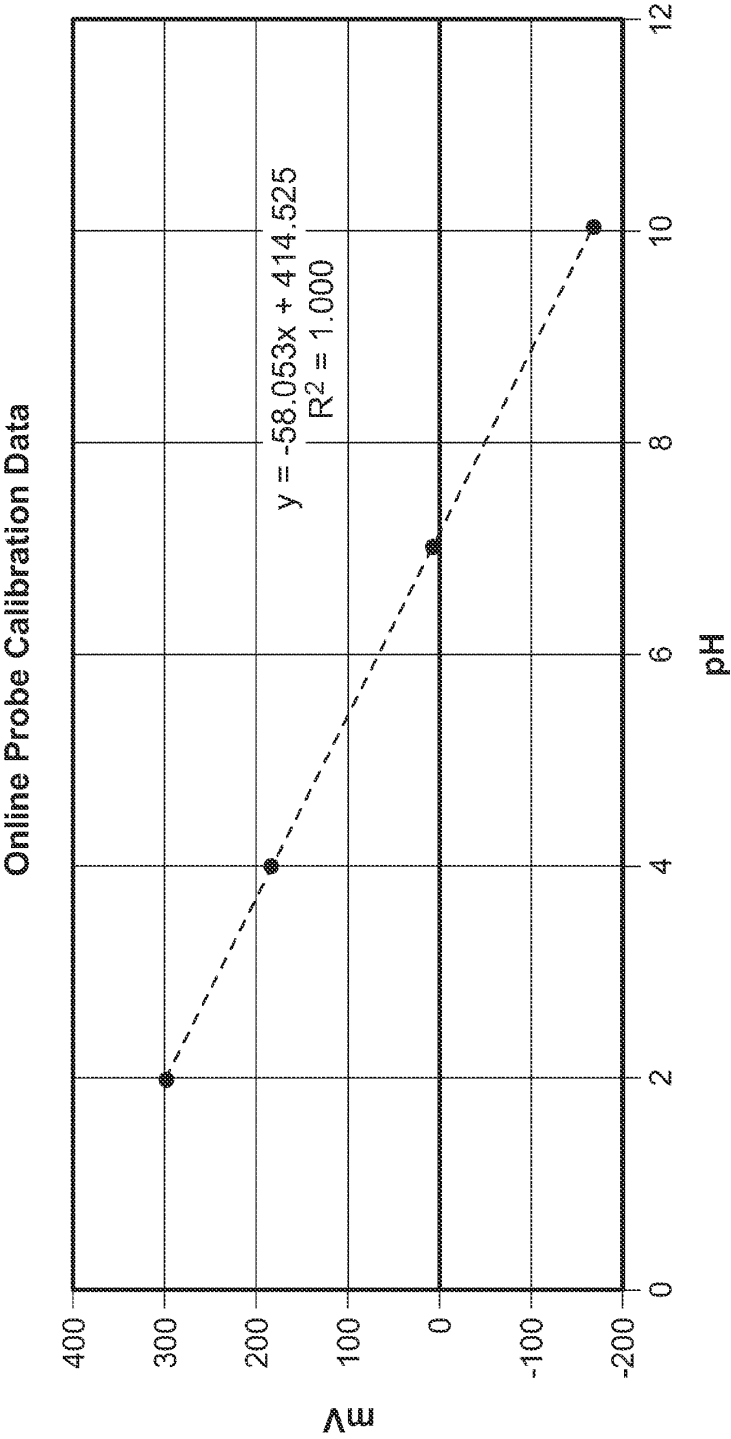


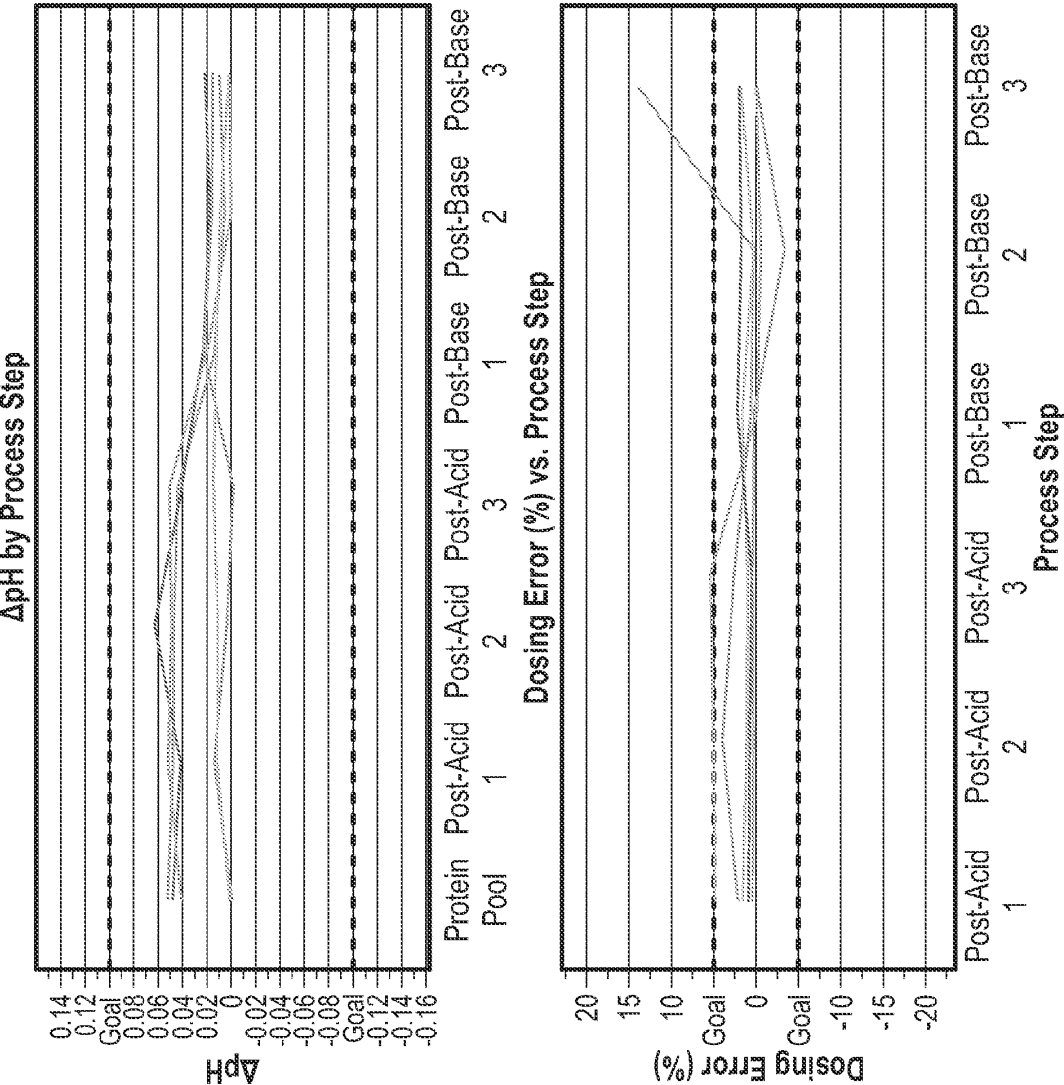
FIG. 14

Process Step	Test Run #1		Test Run #2		Test Run #3		Test Run #4		Test Run #5	
	Δ pH	Dosing Error (%)	Δ pH	Dosing Error (%)	Δ pH	Dosing Error (%)	Δ pH	Dosing Error (%)	Δ pH	Dosing Error (%)
Protein Pool	0.05	N/A	0.05	N/A	0.00	N/A	0.00	N/A	0.04	N/A
Acid Add #1	0.05	2.2	0.04	0.9	0.01	1.6	0.01	0.4	0.05	4.9
Acid Add #2	0.05	4.0	0.06	0.9	0.01	1.1	0.00	0.3	0.05	5.0
Acid Add #3	0.04	2.6	0.04	0.5	0.01	1.0	0.00	0.4	0.05	5.5
Base Add #1	0.01	0.6	0.02	2.2	0.01	1.7	0.02	0.2	0.02	-0.1
Base Add #2	0.00	0.3	0.02	1.8	0.01	0.4	0.02	-3.4	0.00	-0.6
Base Add #3	0.01	13.9	0.02	1.9	0.00	1.7	0.01	-0.1	0.00	0.0

Δ pH = Slipstream pH - Offline pH

$$\text{Dosing Error} = \frac{(\text{Volume Dosed} - \text{Target Volume})}{\text{Target Volume}} * 100\%$$

FIG. 15



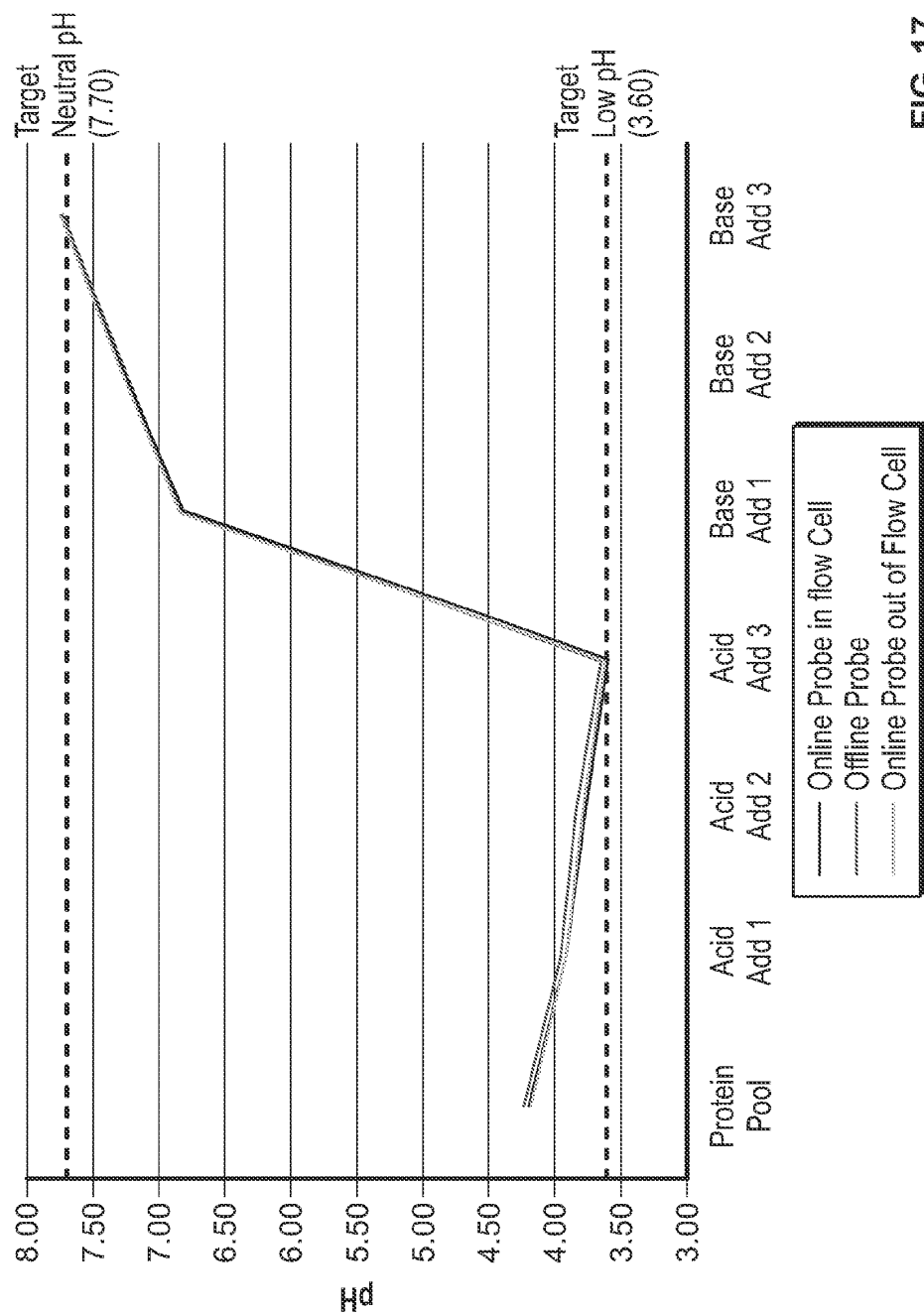


FIG. 17

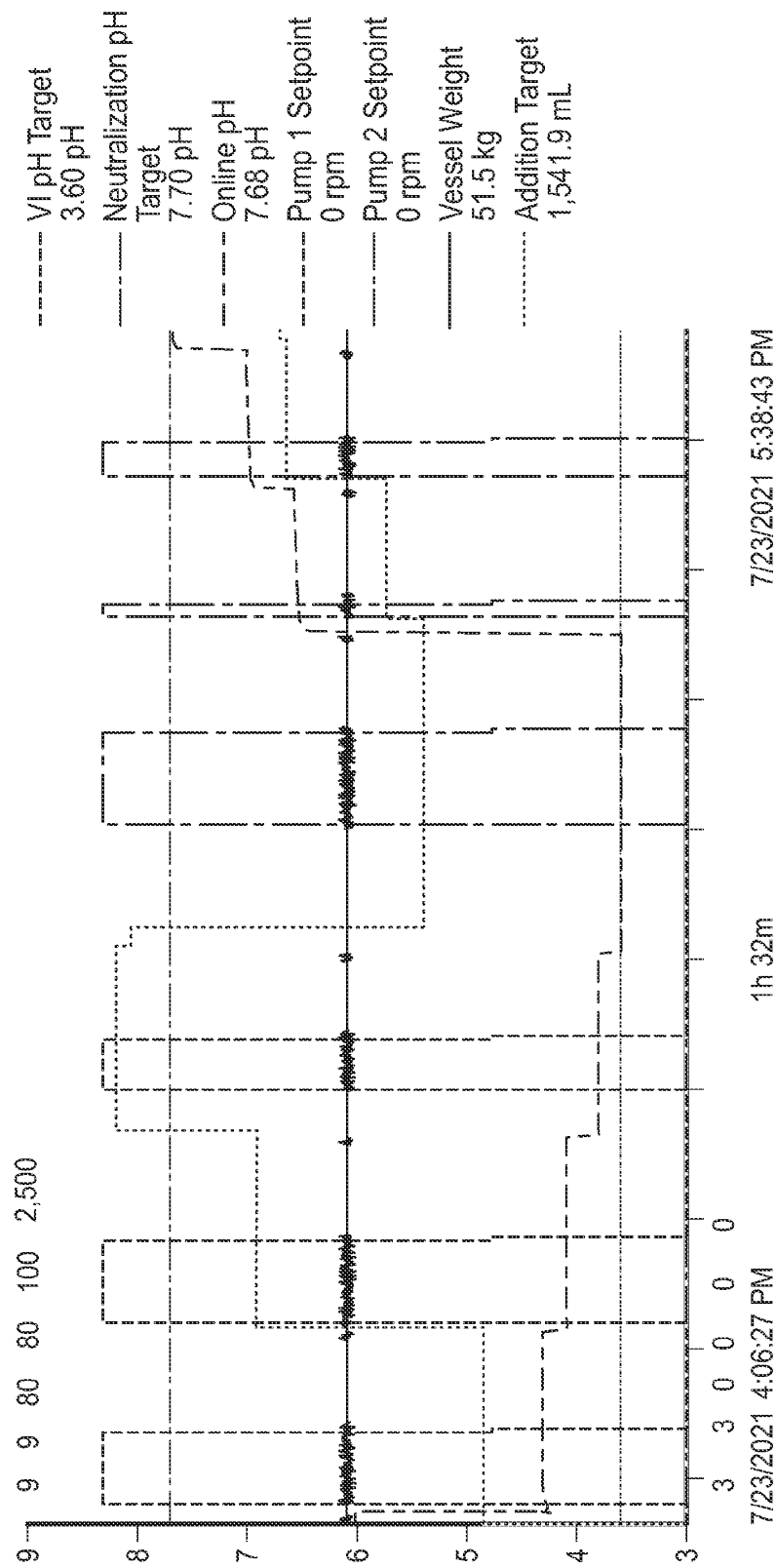


FIG. 18

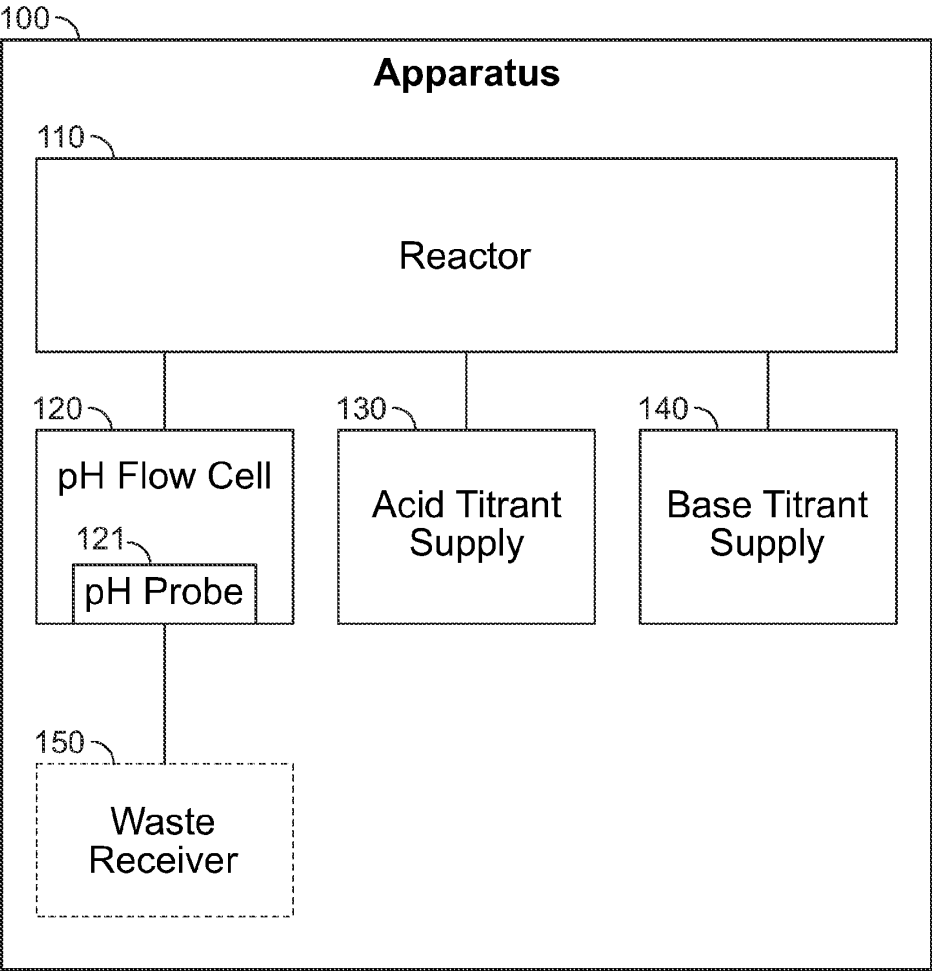


FIG. 19

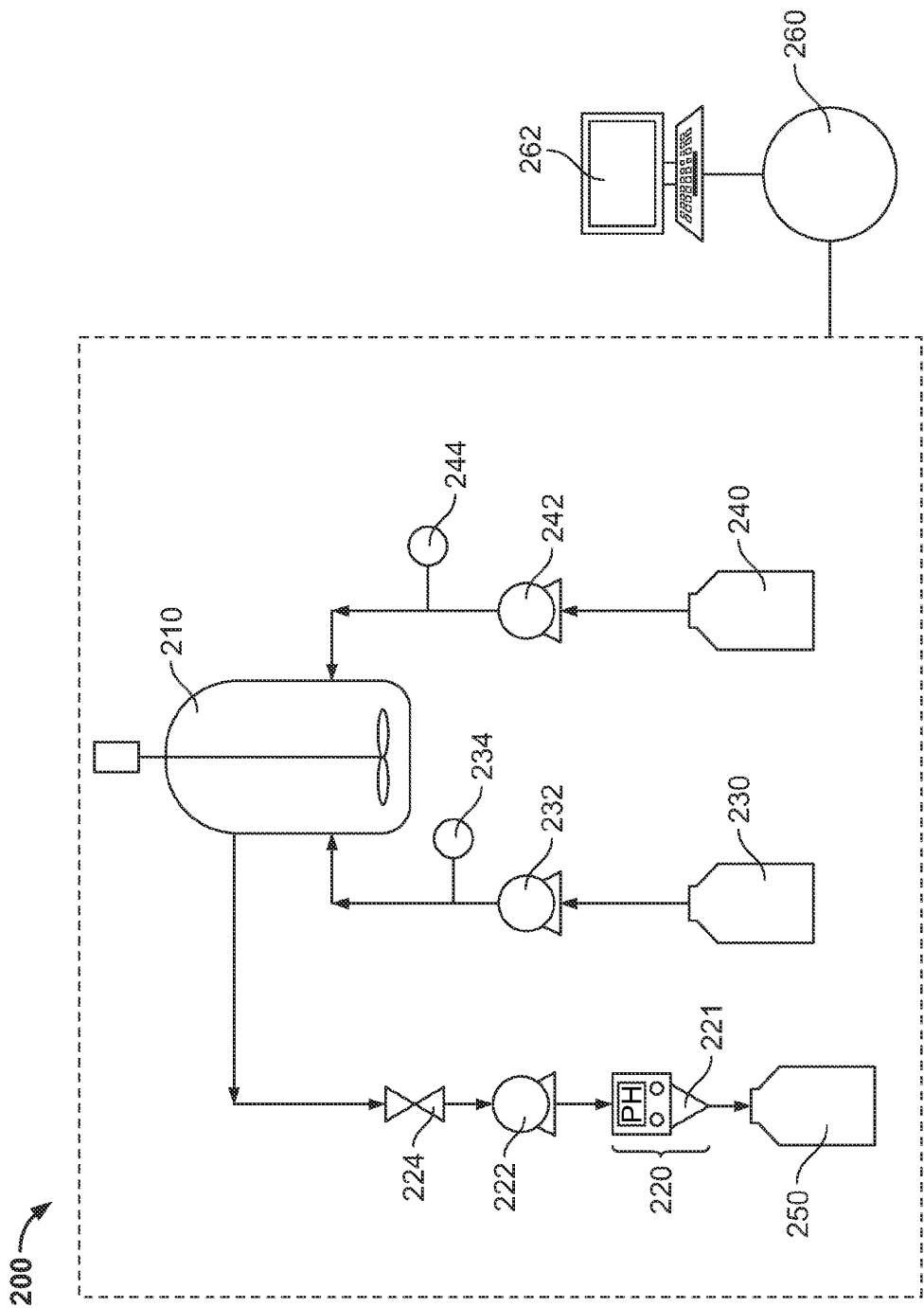


FIG. 20

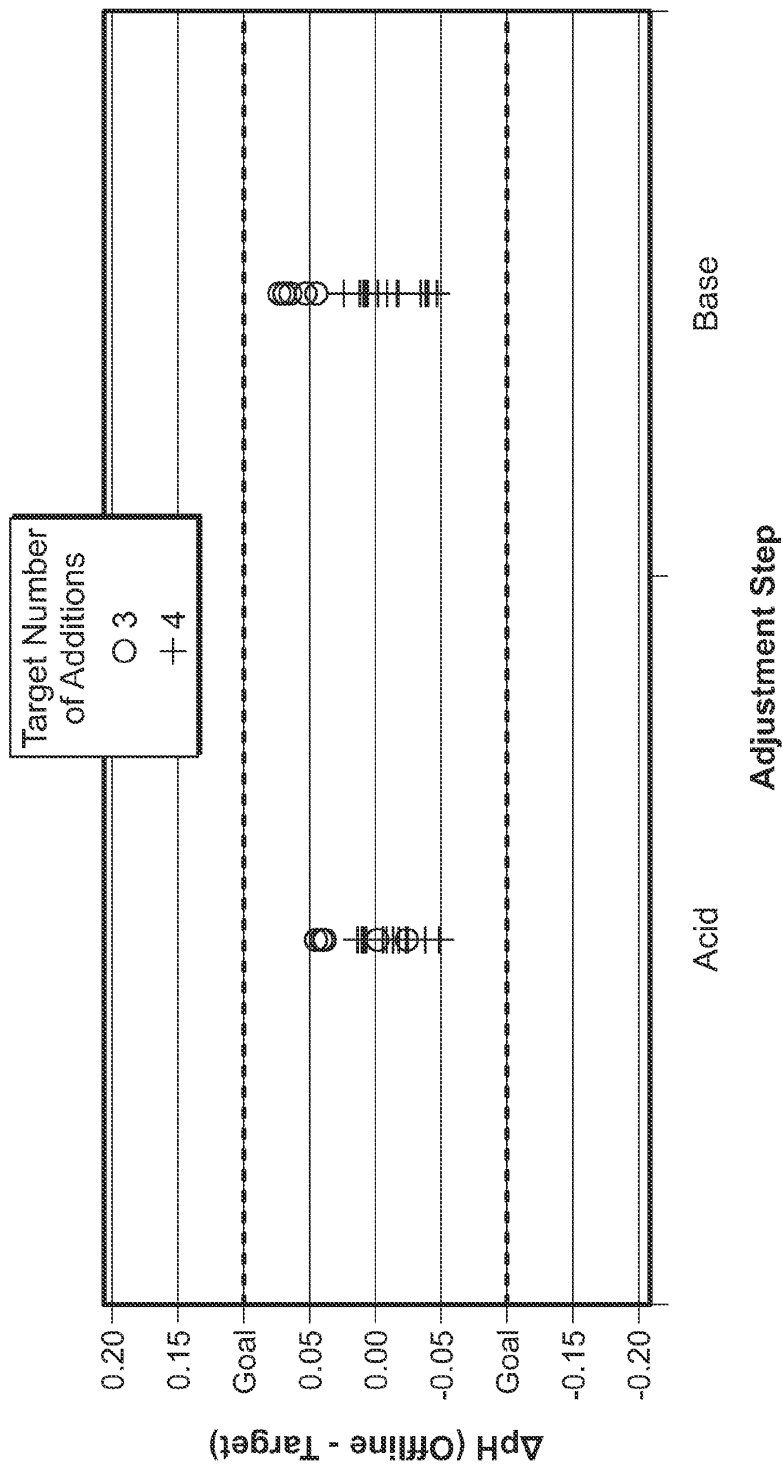


FIG. 21

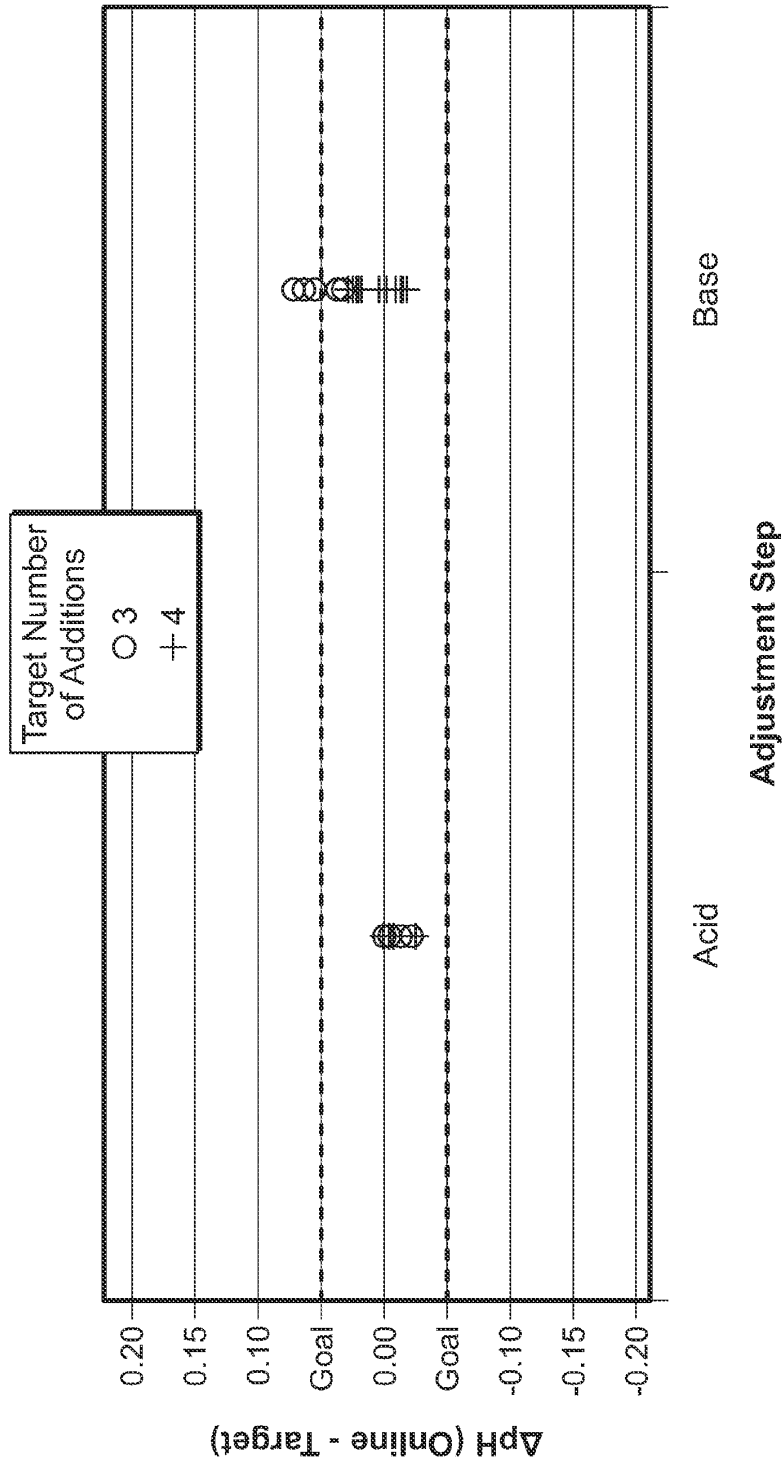


FIG. 22

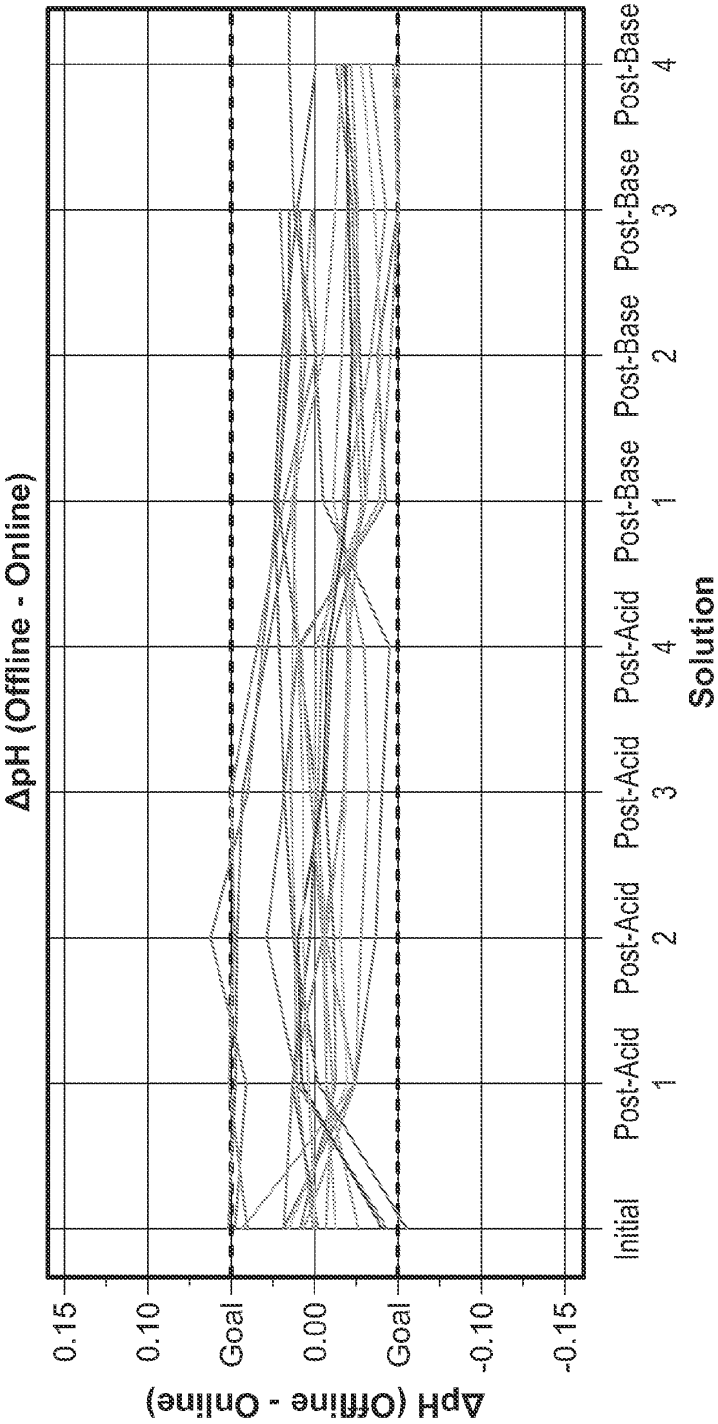


FIG. 23

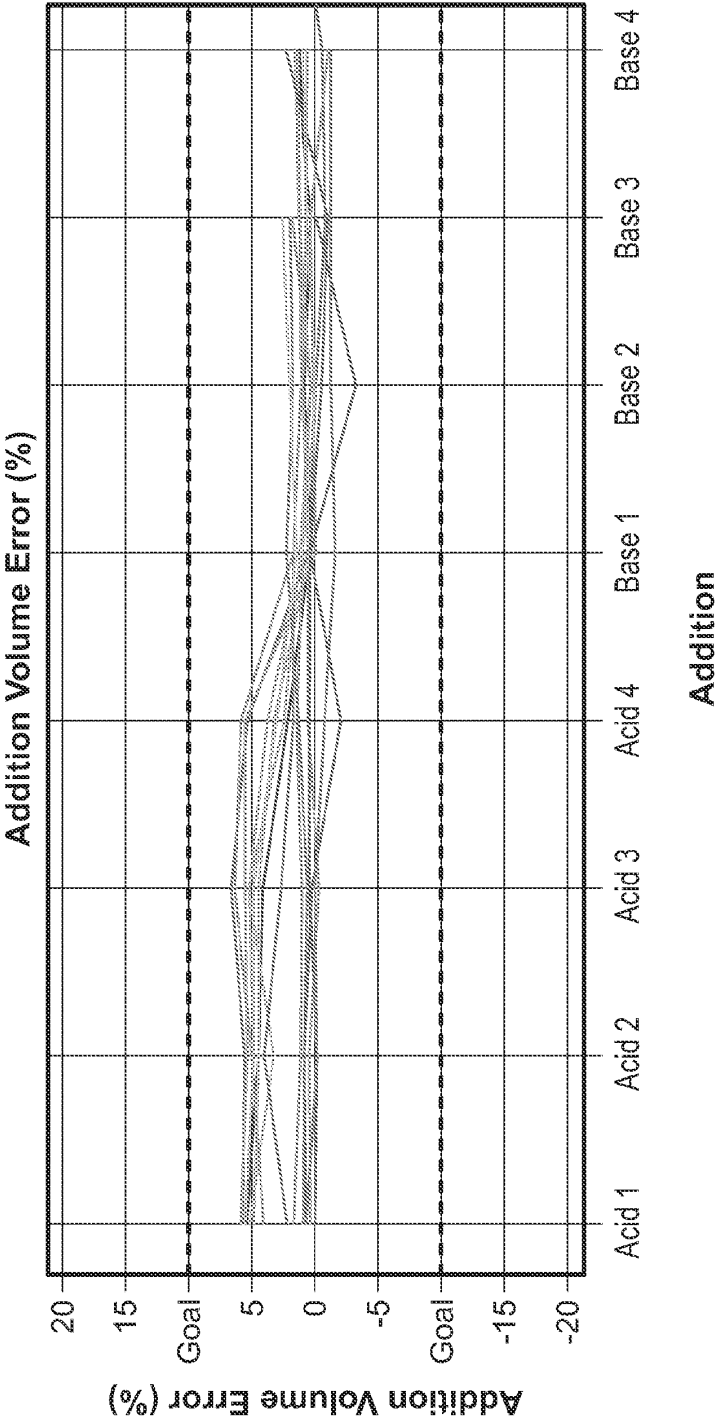


FIG. 24