CLAIMS

1. A method for estimating a volume of liquid output from an electric pump during an operation period of the electric pump, the method comprising:

determining a current delay of the pump, wherein the current delay is a period between a first time corresponding to a first current drawn by the pump, and a second time corresponding to a second current drawn by the pump; and

generating, based on the current delay, an estimate of the volume of liquid output from the electric pump during the operation period,

wherein the first current substantially corresponds to a zero-crossing of an alternating supply voltage supplied to the pump.

2. The method of claim 1, further comprising:

determining an average of an alternating supply voltage supplied to the electric pump, wherein generating the estimate of the volume is further based on the average of the alternating supply voltage.

3. The method of any preceding claim, wherein determining the current delay of the pump comprises:

determining the first time based on measurements of an alternating supply voltage supplied to the pump during the operation period;

determining the second time based on measurements of a current drawn by the pump during the operation period; and

calculating a difference between the first time and the second time as the current delay of the pump.

4. The method of any preceding claim, wherein the second time corresponds to a time proximal to the end of or within a time period over which a current drawn by the pump has substantially constant rate of change.

5. The method of any preceding claim, wherein:

generating the estimate of the volume of liquid output from the pump is further based on a technique selected from a plurality of techniques, the selection based on an indication of whether a power of the pump during the operation period of the pump is above a predefined power threshold; and/or

generating the estimate of the volume of liquid output from the pump is further based on a technique selected from a plurality of techniques, the selection based on an indication of whether a temperature of the liquid is greater than a predefined temperature threshold or whether a heating operation is to be applied to the liquid; and/or

generating the estimate of the volume of liquid output from the pump is further based on a technique selected from a plurality of techniques, the selection based on an indication of whether a duration of the operation period of the pump is greater than a predefined duration threshold.

6. The method of claim 5, wherein the operation period of the pump is a first operation period, the current delay is a first current delay, and the estimate of volume is a first estimate of volume, the method further comprising:

responsive to determining that a second operation period of the electric pump has elapsed, determining a second current delay of the electric pump and generating, based on the second current delay, a second estimate of the volume of liquid output from the pump during the second operation period; and

calculating a total volume of liquid output from the pump during the first operation period and the second operation period by summing the first estimate of the volume and the second estimate of the volume.

7. The method of claim 6, wherein the technique is a first technique, and wherein the second estimate of the volume is generated based on a second technique selected from the plurality of techniques, the selection based on at least one of: an indication of whether a power of the pump during the second operation period of the pump is above the predefined power threshold, an indication of whether a temperature of the liquid is greater than the predefined temperature threshold

or whether a heating operation is to be applied to the liquid, and an indication of whether a duration of the first operation period and the second operation period of the pump is greater than the predefined duration threshold, and optionally wherein the first technique and second technique are the same or different.

8. The method of claim 5, wherein the operation period of the pump is a first operation period, the method further comprising:

responsive to determining that a second operation period of the pump has elapsed and determining that a difference between an average of an alternating supply voltage in the first operation period and an average of an alternating supply voltage in the second operation period is greater than a predefined difference value:

determining a second current delay of the electric pump;

generating, based on the average of the alternating supply voltage in the second operation period and a second technique, an estimate of the second current delay of the electric pump;

subtracting the estimate of the second current delay from the second current delay to calculate an adjusted current delay; and

generating, based on the adjusted current delay and a third technique, an estimate of the volume of liquid output from the pump during the second operation period.

9. The method of claims 5 to 8, wherein the technique, the first technique, the second technique and/or the third technique are a trained regression model trained based on performing regression analysis on training data comprising values of current delays of a test apparatus and volumes of liquid output by the test apparatus during operation of the test apparatus, wherein the test apparatus corresponds to the electric pump.

10. The method of claim 9, wherein the trained regression model comprises one or more predetermined model parameters, and wherein generating the estimate of the volume comprises:

inputting the current delay and an average of an alternating supply voltage supplied to the pump to the trained regression model; and

performing one or more mathematical operations using the one or more predetermined model parameters, the current delay, and the average of the alternating supply voltage.

11. A liquid dispensing machine comprising an electric pump and processing circuitry configured to perform the method of claims 1 to 10.

12. The liquid dispensing machine of claim 11, wherein the liquid dispensing machine is configured to cease dispensing liquid in response to determining that the estimate of the volume of liquid output from the pump is equal to a predetermined threshold volume.

13. A computer-readable medium comprising instructions which, when executed by a programmable liquid dispensing machine, cause the programmable liquid dispensing machine to carry out the method of claims 1 to 10.

14. A method for training a regression model to estimate a volume of liquid output from an electric pump during an operation period of the electric pump, the model comprising:

obtaining training data comprising values of current delays of a test apparatus and volumes of liquid output by the test apparatus during operation of the test apparatus, wherein:

the test apparatus corresponds to the electric pump; and

the current delays are periods between a first time corresponding to a first current drawn by the test apparatus, and a second time corresponding to a second current drawn by the test apparatus; and

performing regression analysis on the training data to provide one or more parameters usable to estimate the volume of liquid output from the electric pump from a measurement of a current delay of the electric pump.