ABB INDUSTRY SPECIFIC DRIVES

# Sensorless flow calculation ACQ580/ACH580

This guide assists with the set up and use of the sensorless flow calculation function in the ACQ580 or ACH580.

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# Introduction

Flow sensors can be expensive and complicated to use. In many applications, an estimation of the actual flow will satisfy the data output required for the application; therefore, a flow sensor is not required. A sensorless flow calculation function uses pump data to calculate the actual flow in the system based on measurements of pressure or power and performance data of the pump. A sensorless flow calculation function is more cost effective than a flow sensor; however, there are some limitations using the function. Applications should be chosen carefully and only used where an estimation is acceptable.

There are two different ways of calculating flow using the ACQ580 and ACH580:

- Based on HQ (head-flow) information of the pump (requires the use of a differential pressure sensor or two independent pressure sensors)
- Based on PQ (power-flow) information of the pump

The tolerance on the calculated flow depends on a series of parameters. The higher the data quality is, the better the result. An estimation of flow is better in systems with few and slow flow changes, compared to systems with fast changing demands.

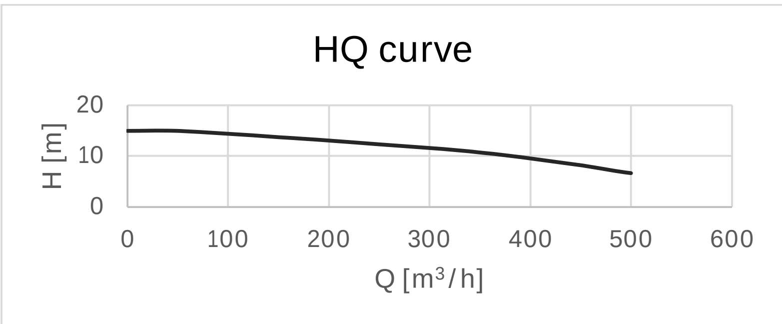
Note! Sensorless flow calculation function provides an estimate of the flow and cannot be used for invoicing purposes.
Note! Pump performance curves in this document are called HQ and PQ. Curves can also be called QH and QP depending on the source.
Note! The use of manufacturer supplied pump system specific performance data, including the media to be pumped, will increase the accuracy of the senseless flow calculation.

# Sensorless flow estimation

## Data quality – Estimation - Uncertainty

The calculation uses mathematics to predict what is occurring within the system. Better data (high precision/quality) will result in a better estimate. The high data quality not only comes from the pump, but also from the performance of the motor turning the pump. It is easier to predict a steady state situation compared to highly dynamic one. Although the accuracy of the sensorless flow estimation is highly dependent on the precision of the data being entered for the calculation, an accuracy generalization of within 10% for the HQ method and within 15% of the PQ method can be assumed when high quality data is used.

A pump performance curve is given by the relationship between Flow (Q) and Head (m); flow is volume, head is the lift the pump can give to the pumped media. At a no flow condition, Q= 0, head is typically at maximum, and at maximum flow, the head drops off. A typical performance curve can be seen below:



Note! Pump performance data is based on pumping 20 deg C (68 Deg F) water, if no other data is supplied to the pump manufacturer.
The pump curve and pump data sheet supplied from the pump manufacturer represent how the pump is expected to perform. This information includes production tolerances, measurement tolerances, etc.
An actual pump curve will likely differ from what is shown in the data sheet. Tolerance of +/-9% of flow and +/- 7% of head, is common; however, lower tolerances can be expected for higher grade pumps. Tolerances on the head and flow will lead to an uncertainty on the actual power needed. Note that these values are only for the pump, when a motor is added, additional tolerances from the motor will need to be added to the system.

Entering precise data into the ACQ580 or ACH580 parameters allows for better performance of the sensorless calculation function. A reduction of the tolerances can be obtained by measuring the performance of the actual pump and using this data for the calculation. This is more complex than using data from a datasheet and typically only possible for larger pumps. The performance data sheet/certificate can usually be purchased from the pump manufacturer to improve the estimate. One thing to consider in this case is how the pump will wear over time; it is typical to lose some efficiency. How much efficiency is lost over time depends on the actual load profile and the pumped media.

Pumping liquids other than water will have impact on the pump curve. Most pump manufactures can provide pump curves for liquids other than water at 20 °C (68 Deg F) or give guidance on the behavior when pumping other liquids or pumping water at a different temperature.

## Factors influencing the estimation

Other factors that will influence the estimate are:

- Motor control mode:
    - Scalar control. Scalar control sets a specific V/Hz according to the data given on the motor nameplate. The actual slip of a motor (Async. motor) will be dependent on the pump load compared to the motor capabilities.

    - Vector control. Vector control uses a model of the motor, based on the motor data given, and uses a series of measurement of motor current/voltage to get the right relationship for obtaining the speed required. The uncertainty of the actual shaft speed is reduced by using vector control and it helps to get a better estimate of the actual flow.

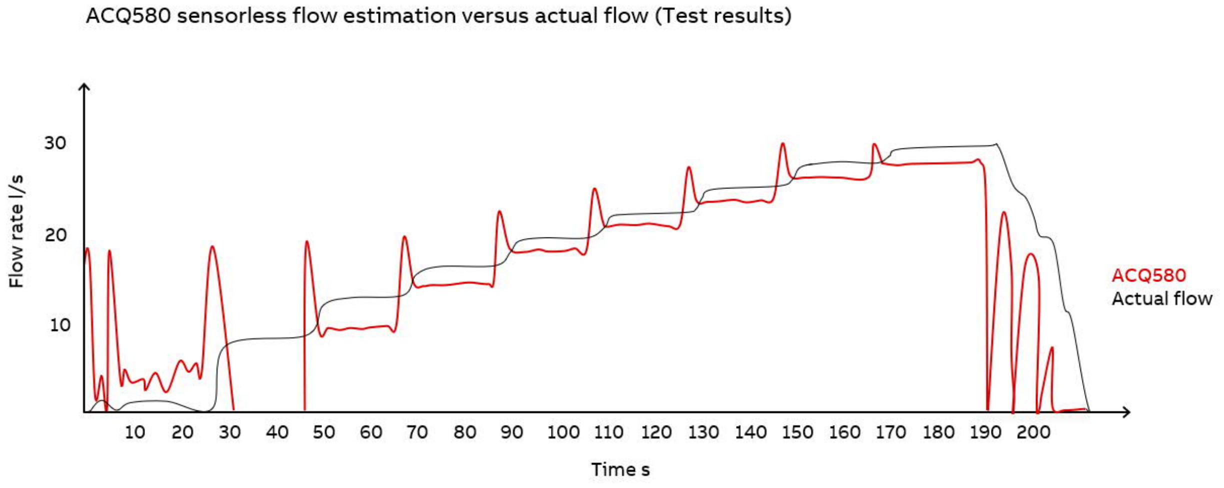
- Motor selected:
    - Pumps are designed for a specific load point Q and H and for a specific speed. The actual max load of the pump might not fit a standard motor size, or an oversized motor might be selected to compensate for high ambient temperature. Let’s have a look at some examples:

        - The pump is designed to fit with the speed of a specific IE3 motor, but the motor is changed to an IE4. The IE4 motor will have a lower slip, it will turn a little bit faster, and the pump will load the motor a little bit more; therefore, the HQ curve will move to a higher position when using scalar control. Using vector control will give the same shaft speed with both motors, due to the more advanced control, and the flow estimation will be more precise.

- The pump max load is below the motor load capability. Some pumps will load the motor only partially, even at full speed. This will result in a reduced slip if scalar control is used. This can add the uncertainty of the flow estimation.

- The selected motor is oversized to account for ambient conditions; It is rather common practice. This oversizing will have the same effect as partial load mentioned above if scalar control is used.

The estimate of the flow calculation function is best in constant flow systems or systems where the flow changes slowly over time. These kinds of systems will have long periods of steady state operation, where the speed is relatively fixed and where all input parameters for the flow calculation is rather constant, giving the best opportunity for a precise calculation.




The flow calculation function can be used with limited uncertainty in the speed range down to approximately 50% of nominal speed. By using the affinity laws, it can be calculated that a speed reduction to 50% corresponds to 50% flow and 25 % Head. The uncertainty on the estimate can be seen by an increasing difference between the estimate and the actual flow on the drawing above.

Estimation at low flow is a challenge and typically the uncertainty increases at lower flow. Also, the tolerance increases with lower flow (larger deviation from the actual flow). Therefore, it is not recommended to use flow calculation for systems running at low flow.

Additionally, the flow calculation function is not reliable in systems with a high number of transients. This is due to the mathematical models used and the fluctuations in the parameters used for the calculation.

As previously stated, the flow calculation function is best suited for slow changing systems, like HVACR/filter/irrigation applications, but is not recommended for pressure boosting applications where transient behavior is the norm for the system.
In traditional W&WW applications the flow calculation function can be used when pumping water from one part of the plant to the other, or as a back-up for flowmeters, in case of a failure. A larger deviation between estimation and actual measurement could indicate the need for service to the application.

Note!
The sensorless flow calculation is an estimation only and cannot be used for invoicing purposes.
The sensorless flow calculation function cannot be used outside the normal operating range of the pump.

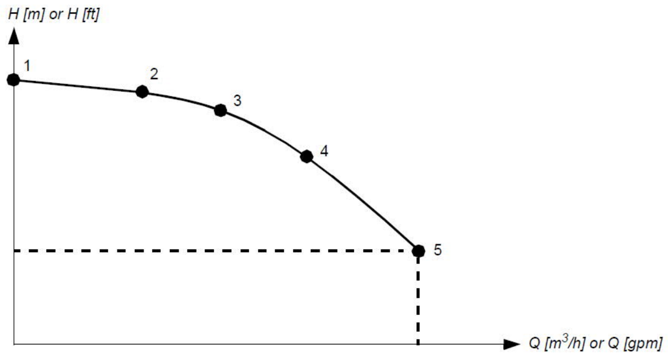
# Pump curves and power curves

The sensorless flow calculation has some requirements for the pump curves and power curves.

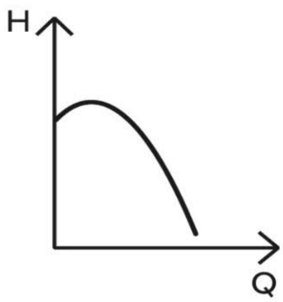
## HQ based sensorless flow calculation

The following is required for the calculation based on the HQ function: Head points in the HQ curve are expected to be in descending order (H1 > H2 > H3 > H4 > H5).

A HQ curve shows the pump performance measured in the pressure (Head) it can generate as a function of the flow. With a limitation on power it is either possible to create a high head for a low volume or create a lower head for a higher volume. The typical shape of a HQ curve is shown below.

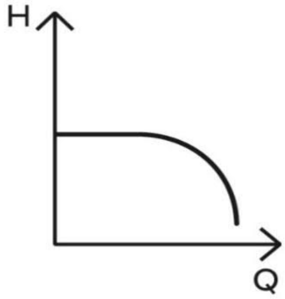



Most pumps will have this type of curve, but there are other types of curves. Some pumps will have what is known as a labile pump curve:




The first point (H1) should be the peak point of the curve and the rest should be towards higher flow. The flow calculation should not be active to the left of the peak point.

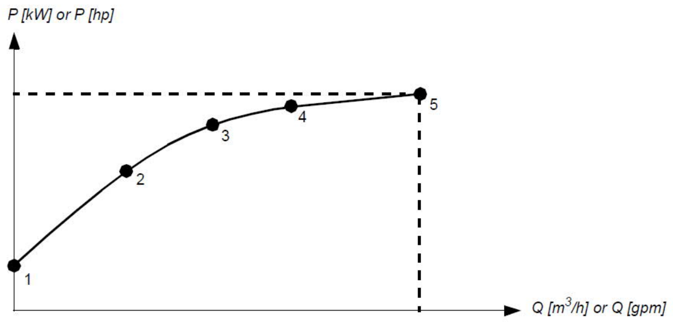
Another curve type is the flat curve:



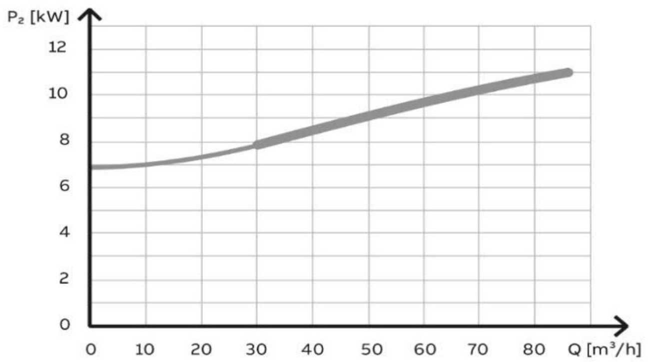

The flat curve is a problem, it will never be completely flat, but the curve shape will have an influence on flow calculation since H (Pressure) is almost constant over a large flow area. For pumps with this kind of curve it is best to use flow calculation based on the PQ curve as an alternative solution.

## PQ based sensorless flow calculation

The following is required for the calculation based on the PQ function: Power points in the PQ curve are expected to be in ascending order (P1 < P2 < P3 < P4 < P5).




It is very typical to have this kind of curve; however, flatter curves can be found as well as curves that drop off at high flow. An example on a flatter curve can be seen below.

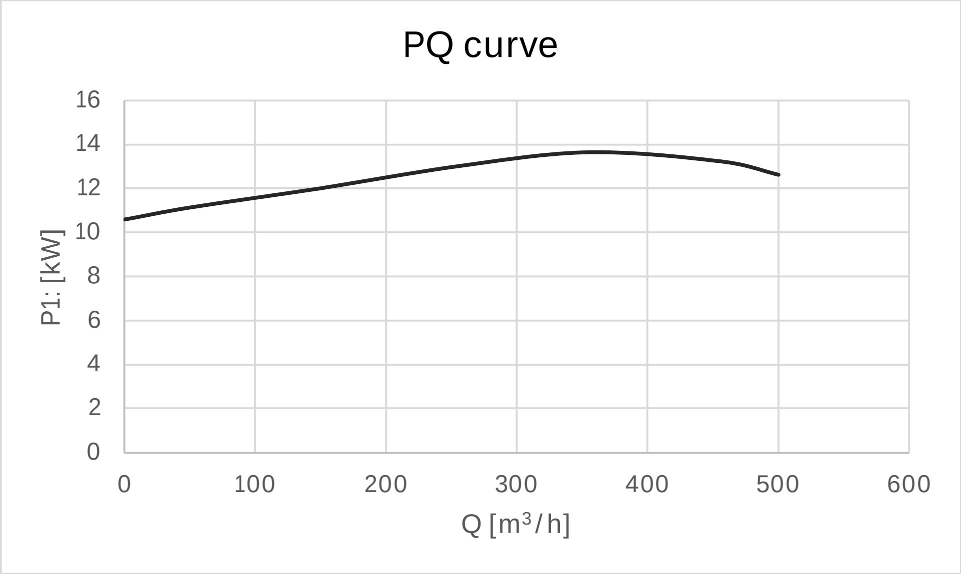



The selected points should be on the part of the curve where the power is increasing, and the use of the pump should be limited within these boundaries.
In the picture above, the thicker part of the curve is the pump's normal operation range, where the pump is allowed to operate. The pump should not be operated continuously in the narrow part of the curve.

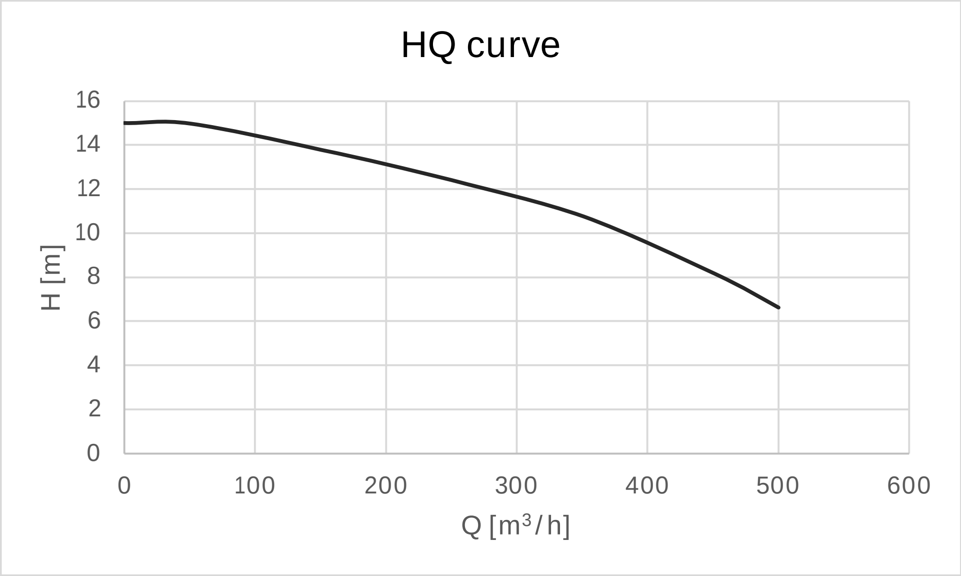
Note! The flow estimate is not accurate with flow rates below the first selected point, if it is not at zero flow.

Note! Be aware that different power curves can be given from the pump manufacturer. It is very typical to give two power curves; one representing the mechanical power required at the shaft of the pump and one representing the electrical power input to the motor. For programming of the PQ based sensorless flow calculation, the curve based on pump's mechanical shaft power should be used.

Note! Some pumps cannot be used for the PQ based flow calculation; an example is shown below. The power curve is almost flat and is decreasing at high flow.




However, since the HQ curve for the same pump is nicely dropping across the full flow range, HQ flow estimation could be used instead.



### Calculation correction multiplier

It is possible to make a simple correction to the flow estimate by using a correction factor. If the actual flow can be verified with a flow sensor or other method and the flow proportional error can be seen in the calculated result, a correction factor can be used. The multiplier (k) is used as a correction factor with the flow calculation. The correction factor can be above or below 1.0 or even negative. The flow value calculated with 80.13 Flow feedback function is multiplied by this value.

The correction factor can be entered to parameter 80.14 Flow feedback multiplier

### Inlet and outlet diameter and sensor height difference compensation

When using the head-flow (HQ) calculation, the inlet and outlet diameter of a pump has an influence on the estimate. It is essential to program the inlet and outlet diameters if they are not the same; the diameter information is not needed when the inlet and outlet diameters of the pump are the same. In addition, the height difference between the inlet side pressure sensor and outlet side pressure sensor must be entered.

The compensation parameters:

- 80.22 Pump inlet diameter
- 80.23 Pump outlet diameter
- 81.12 Sensors height difference

## Pump protection functions

The pump inlet and outlet protection function monitors pump inlet and outlet pressure and flow and uses the user defined actions when the pressure or flow is outside the normal range. Protections can be programmed to first generate a warning and then fault in different setpoints.

Pressure protection

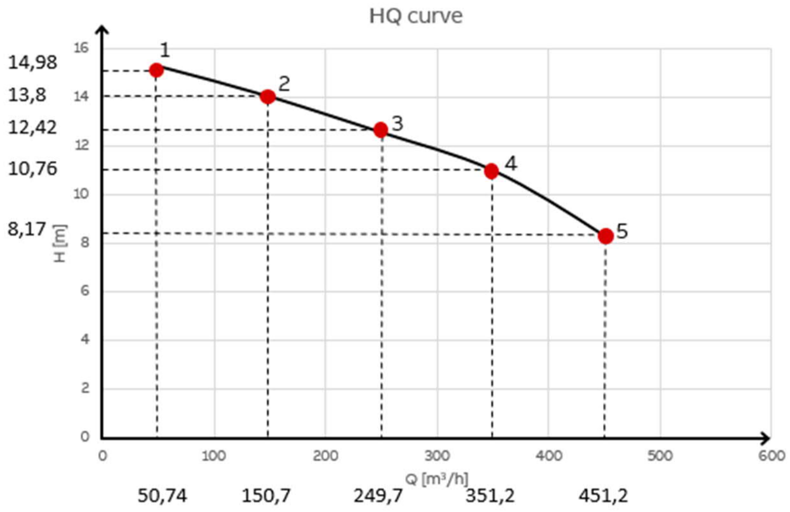
*Minimum outlet pressure protection* can help to detect pipe rupture in a pressure-controlled system.
*Maximum outlet pressure protections* can help to detect blockage in the pipeline or a closed valve.
*Minimum inlet pressure protection* can help to prevent cavitation in a pump when the inlet pressure is prevented from dropping below the vaporization pressure of the liquid.

Flow protection

*Maximum flow protections* can help to detect pipe rupture and leakage in a flow-controlled system.
*Minimum flow protection* can help to detect closed valve or blockage. If the pipe is blocked, the pump can keep running without exceeding the pressure limits, but the water is circulated in the pump chamber and eventually starts boiling.

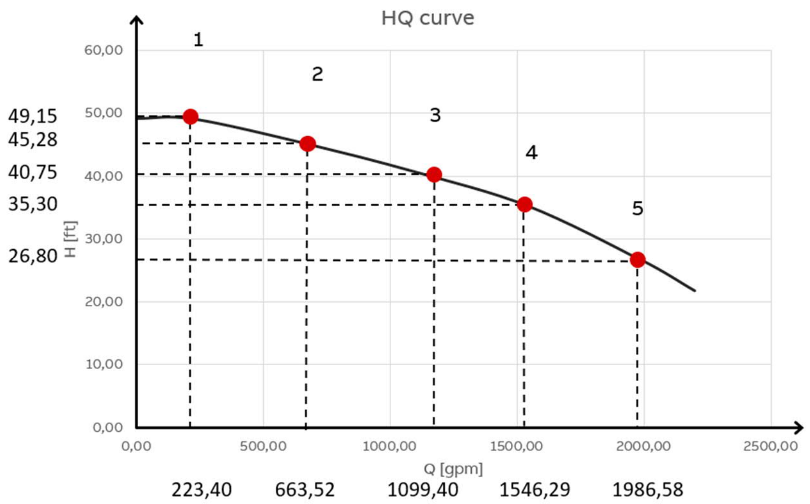
The pump protection parameters can be found in Menu → Primary settings → Pump features and in parameter group 82.

# Example: Load points for HQ flow estimation




| Load point | H | Q |
|---|---|---|
| | [m] | [$m^3$/h] |
| 1 | 14,98 | 50,74 |
| 2 | 13,8 | 150,7 |
| 3 | 12,42 | 249,7 |
| 4 | 10,76 | 351,2 |
| 5 | 8,17 | 451,2 |

*Pump curve according IEC standard.*

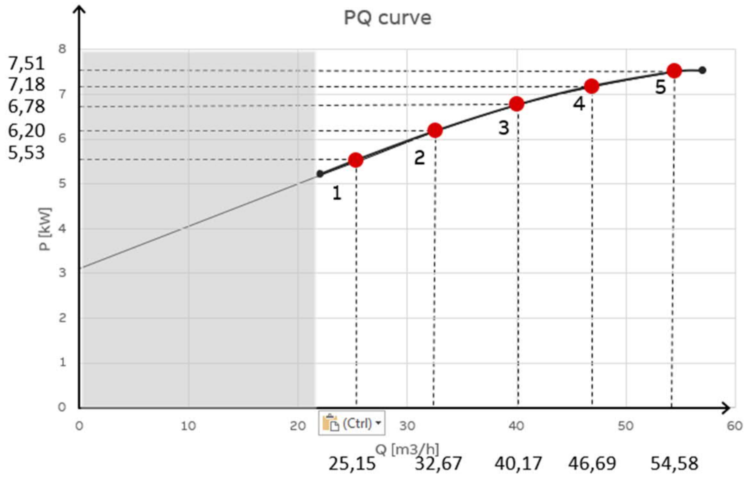



| Load point | H | Q |
|---|---|---|
| | [ft] | [gpm] |
| 1 | 49,15 | 223,40 |
| 2 | 45,28 | 663,52 |
| 3 | 40,75 | 1099,40 |
| 4 | 35,30 | 1546,29 |
| 5 | 26,80 | 1986,58 |

*Pump curve according imperial standard.*

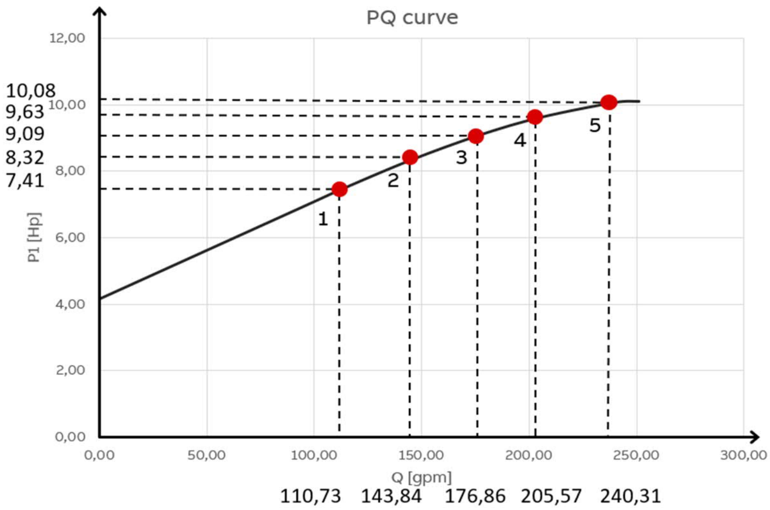
Note! The PQ curve is not needed for HQ based estimate
Note! The flow estimation is not accurate with the flow rates below the first selected point, if it is not at zero flow.

# Example: Load points for PQ flow estimation




| Load point | P | Q |
|---|---|---|
| | [kW] | [m³/h] |
| 1 | 5,525 | 25,15 |
| 2 | 6,201 | 32,67 |
| 3 | 6,782 | 40,17 |
| 4 | 7,184 | 46,69 |
| 5 | 7,519 | 54,58 |

*Pump curve according IEC standard.*




| Load point | P | Q |
|---|---|---|
| | [hp] | [gpm] |
| 1 | 7,41 | 110,73 |
| 2 | 8,32 | 143,84 |
| 3 | 9,09 | 176,86 |
| 4 | 9,63 | 205,57 |
| 5 | 10,08 | 240,31 |

*Pump curve according imperial standard.*

Note! The grey zone in the PQ curve table indicates the area where it is NOT allowed to operate the pump continuously
Note! The flow estimate is not accurate with the flow rates below the first selected point, if it is not at zero flow.

# Commissioning the drive

## Prerequisites for the pump curves and system:

1. The pump's HQ curve must be known and available
2. The pump's HQ curve must not be too flat, it must be a clearly descending curve (see *Figure 1* below)
3. There must be either a differential pressure sensor or two independent pressure sensors (one on the inlet and one on the outlet) installed on the pump
4. The height difference between the sensors must be known
5. The inlet and outlet diameter of the pipeline must me known at both sensors' locations

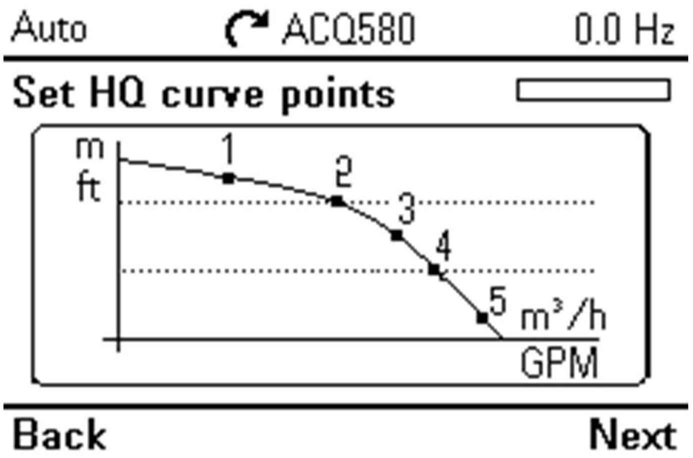
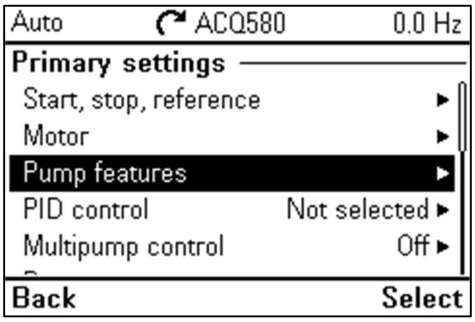



*Figure 1. HQ pump curve of the pump should be clearly descending curve for best accuracy*

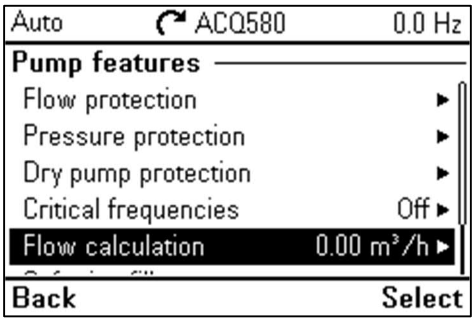
# Getting started programming the HQ curve-based flow calculation

To set up the HQ curve-based flow calculation on the ACQ580 drive follow these steps.

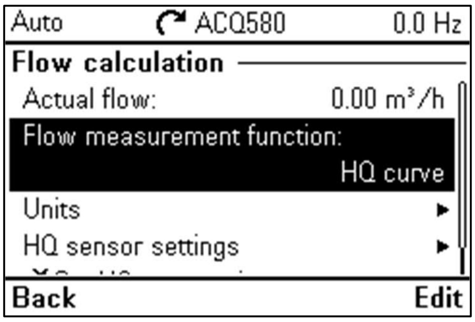
*Menu → Primary settings → Pump features*



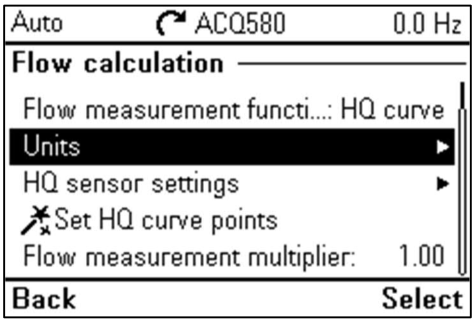

→ *Flow calculation*

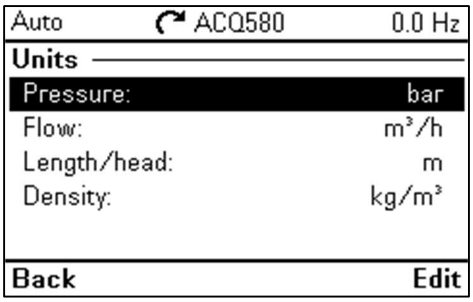



Change *Flow measurement function*: HQ curve



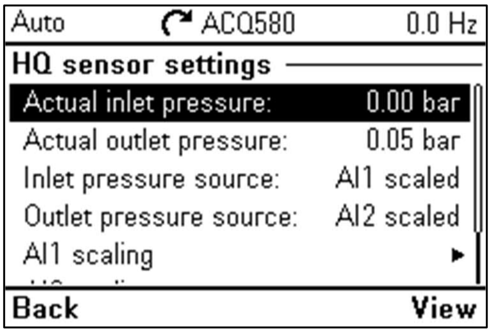

Change *Units* if required

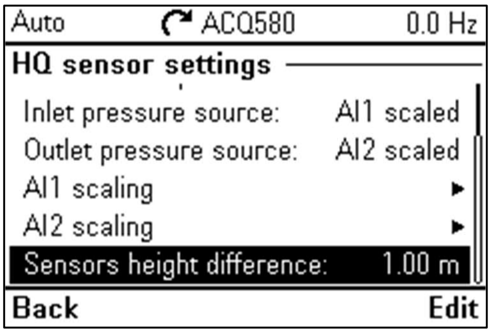


Go to *HQ sensor settings*

- Set *Inlet pressure source:* (e.g. AI1 scaled)
- Set *Outlet pressure source:* (e.g. AI2 scaled)
- Set *AI1 scaling* according to the sensor's datasheet, e.g. 4 to 20 mA corresponds to 0 to 6 bars
- Set *AI2 scaling* as well
- Set *Sensors height difference*

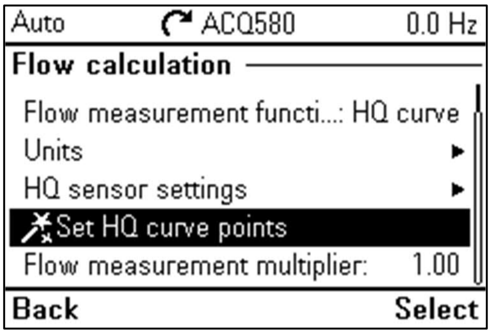


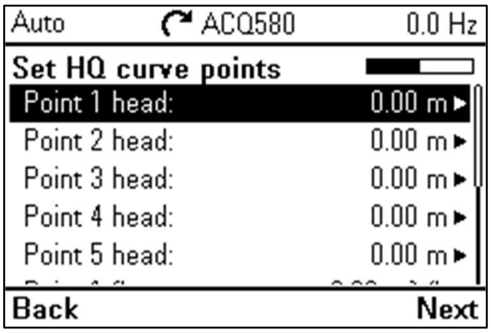



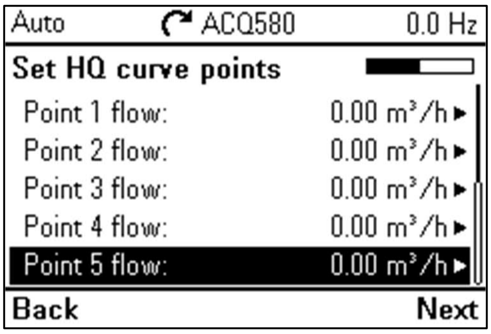

Note! If a differential pressure sensor only is used, *Inlet pressure source* can be set to *Not selected* and *Outlet pressure source* can be set per the instructions above.

Run *Set HQ curve points* assistant

- Set 5 points of head. Select the points from the HQ curve in a way that there are more points in the area where the curve is less linear and less points in the area where the curve is more linear.
- Set 5 points of flow which match the head points set above
- Press *Next* after setting the last point

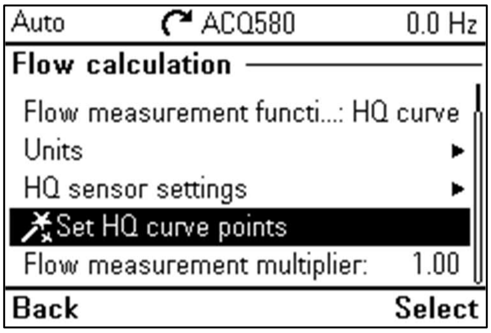


You may enter a correction factor to the flow measurement multiplier if there is a possibility to check the actual flow.

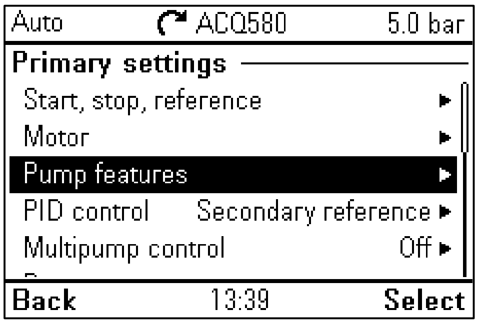
Enter a correction factor to *Flow measurement multiplier.*



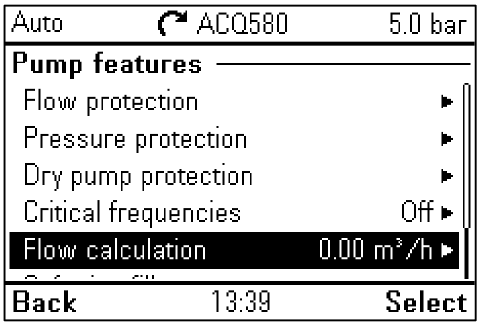
# Getting started programming the PQ curve-based flow calculation

To set up the HQ curve-based flow calculation on the ACQ580 drive follow these steps.

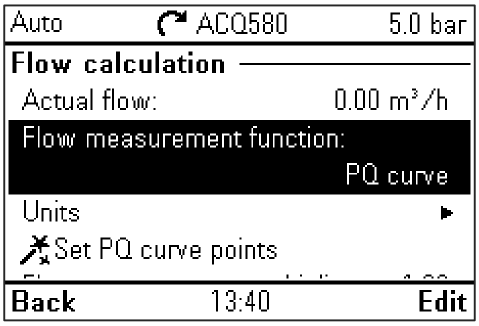
*Menu → Primary settings → Pump features*



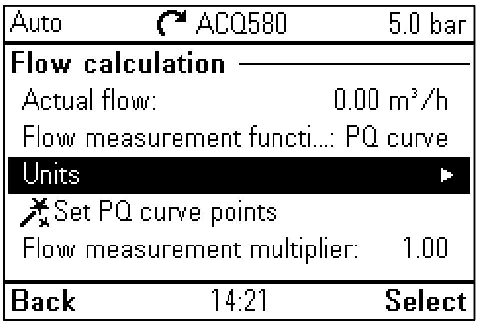

Select *Flow calculation*

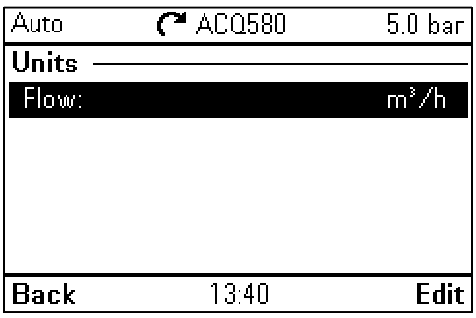



Change *Flow measurement function*: PQ curve



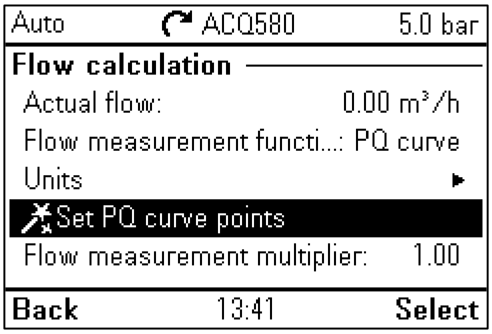

Change *Units* if required

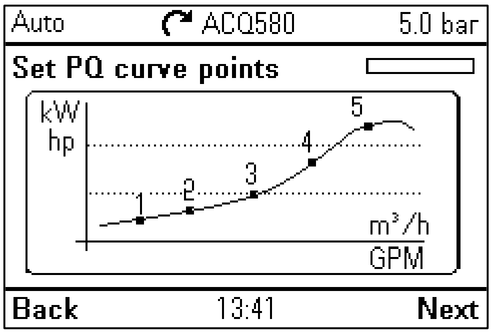


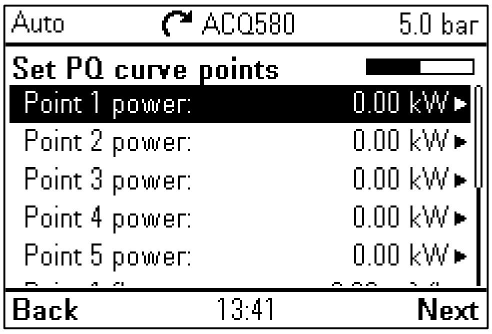



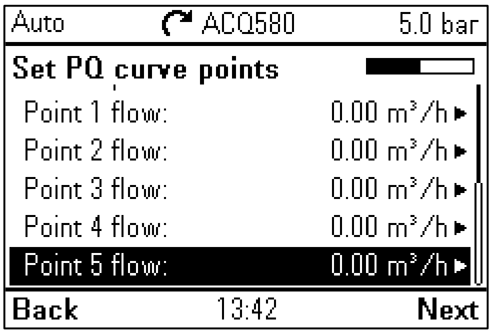
Run *Set PQ curve points* assistant

- Set 5 points of Power. Select the points from the PQ curve in a way that there are more points in the area where the curve is less linear and less points in the area where the curve is more linear. (Power should be increasing)
- Set 5 points of flow which match the power points set above
- Press *Next* after setting the last point



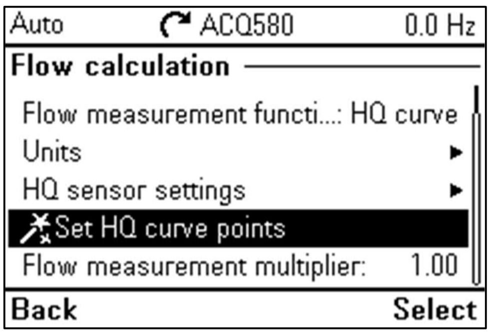




You may enter a correction factor to the flow measurement multiplier if there is a possibility to check the actual flow.

Enter a correction factor to *Flow measurement multiplier.*




You will be able to see the actual flow at Flow calculation menu and in parameter 80.01 Actual flow if the pipe diameters of the incoming and outgoing pipelines are the same. If the diameters are different, you must enter the diameters before you can see the estimation.

In addition, if the density of the fluid pumped is not 1000 kg/m3, you may edit the density via the *Menu → Parameters → Complete list* as well:

| PAR | Description | Default |
|---|---|---|
| 80.22 | Pump inlet diameter | 0.1 m |
| 80.23 | Pump outlet diameter | 0.1 m |
| 80.28 | Density | 1000 kg/m3 |

Once all settings are made, there is a lot of useful information available in group 80:

| PAR | Description | Default unit |
|---|---|---|
| 80.01 | Actual flow | m3/h |
| 80.02 | Actual flow, % of the max flow set in PAR80.15 | % |
| 80.03 | Total accumulated flow, can be reset via PAR80.29 | m3 |
| 80.04 | Specific energy of the pump | m3/kWh |
| 80.05 | Estimated pump head | m |

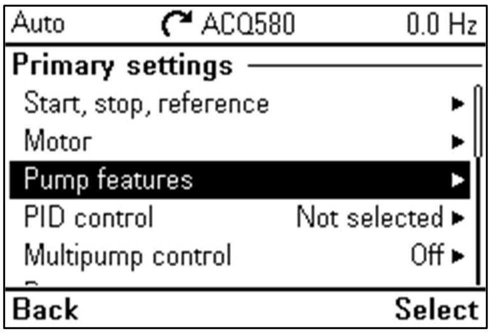
As the HQ-curve based flow calculation is not very accurate with low speeds, there is a minimum speed limit under which the flow calculation is stopped.

| PAR | Description | Default |
|---|---|---|
| 80.26 | Calculation minimum speed | 5 Hz |

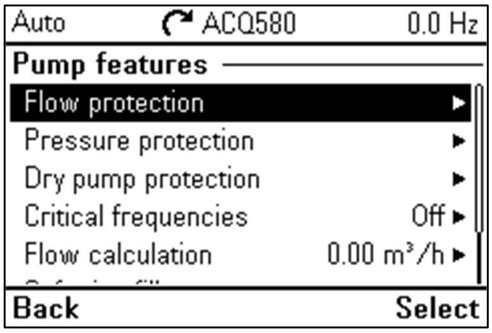
Note! Consider setting the calculation minimum speed limit to about 50% of motor nominal speed to get low deviations and reliable estimation.

Flow information can also be used to trigger minimum or maximum flow faults or warnings or preset safe speed can be activated. Safe speed can be used in case e.g. excess flow has been detected in case of pipe rupture and the utility company wants to limit the leakage but doesn't want to stop pumping totally.

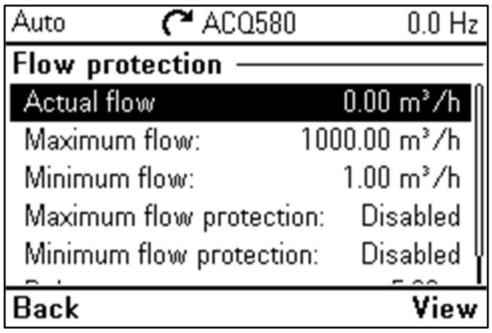
*Menu → Primary settings → Pump features*



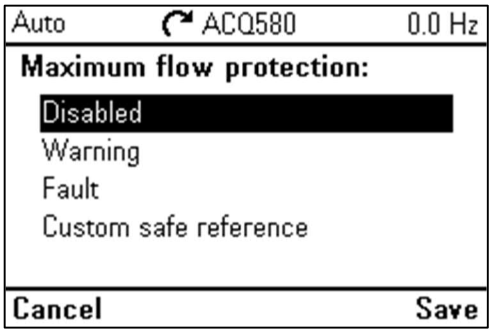
→ *Flow protection*



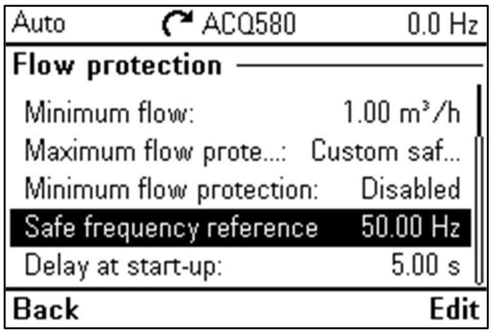

Set *Minimum flow* and/or *Maximum flow* boundaries



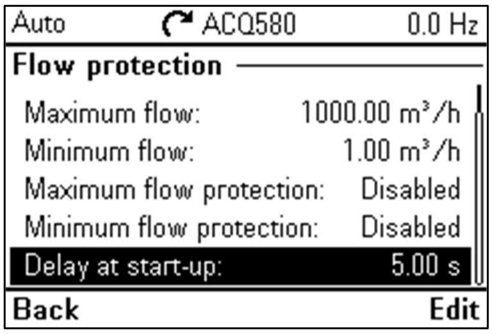

Choose the action when exceeding *Maximum flow* or dropping below *Minimum flow* by selecting *Minimum/Maximum flow protection* action




In case *Custom safe reference* is chosen you may edit the *Safe frequency reference / Safe speed reference*




Set the *Delay at start-up* to avoid unnecessary fault trips or warnings at start-up




This guide is designed to help assist with using the sensorless flow calculation function that is available in the ACQ580 and ACH580 VFD. Please consult your local ABB for additional assistance.