Flow Regulation of Cryogenic Fluids: Design of a High-Rangeability Control Valve

Introduction

The function of a control valve is to regulate a flow by varying the geometry of the throttling area. By reducing the cross section, through which the medium flows, the resistance is increased and the flow thus reduced.

This geometric variation is parametrized in the Kv value, defined as:

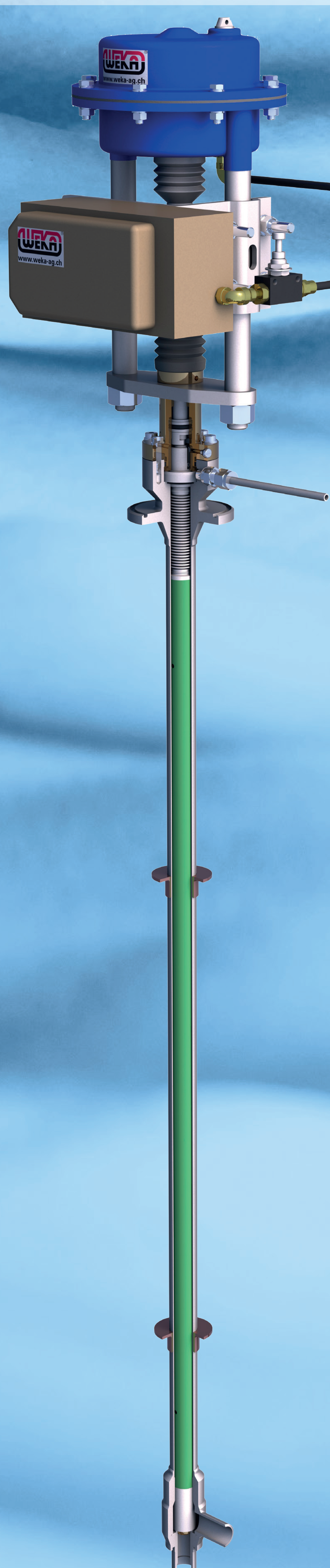
$$Kv = Q \cdot \sqrt{\frac{\rho/\rho_{Water}}{\Delta p}}$$

Q is the mass flow, Δp the pressure difference between inlet and outlet and ρ is the density of the given medium at the operating temperature and pressure.

The Kv value is defined for each position of the valve and can be plotted in function of the valve stroke into a so-called regulation curve.

Typical regulation curves for cryogenic globe valves are equal percentage. In such a curve, each linear step of the stroke produces the same percentage variation of the Kv value. The literature speaks about rangeability as the ratio between the highest realized Kv and the lowest controllable value. A valve with high rangeability can be thus used over a wide range of possible Kv values.

In cryogenic applications, in particular, the same valve shall be able to control small flows during cold operation, as well as to give the possibility of large flows during cooldown or warmup. Moreover cryogenic valves also fulfill the function of on/off valves and should be tight in the closed position.



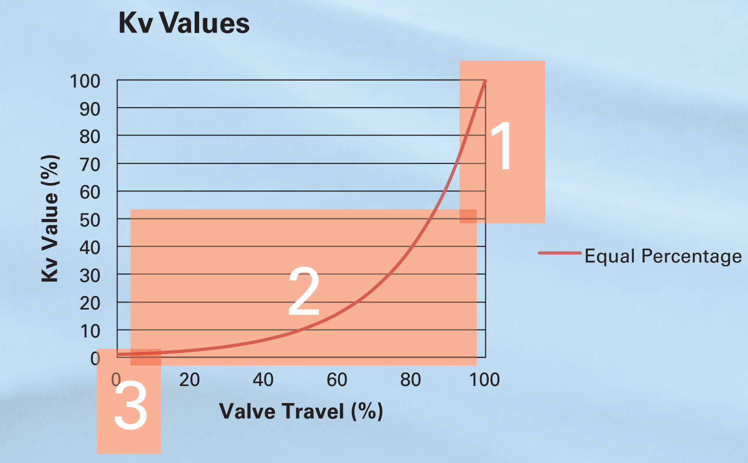
Actuator · Valve Stroke

The choice of the actuator of the valve is not only determined by the force needed to operate the valve, but also by the stroke that is required. The choice of the stroke of the valve has a very important influence on the precision of control and on the on the rangeability. A valve with a longer stroke can have a much better resolution, allowing the positioner to find the exact position without corrections and oscillations.

Positioner

The positioner is the device converting an electric signal provided by the control unit into an input to the actuator. It has an internal loop which allows controlling the travel of the valve with a precision of about 0.1 to 0.3 %. Depending on the position of the working point on the valve regulation curve, this precision leads to a higher or lower Kv deviation.

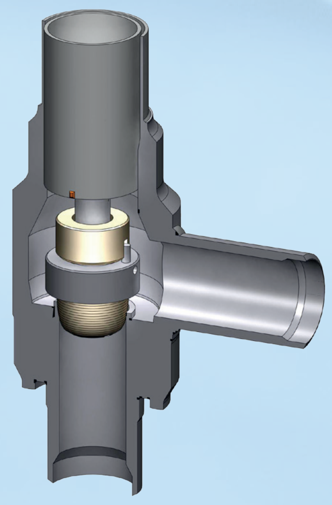
1. In the low region, the definition and precision of the Kv value is given by the tolerances of the bore and of the plug. There is thus a minimum value of Kv that can be stably regulated.
2. In this region, the working point should be located during normal operation. Here the regulation is stable and allows to set and keep a working point very precisely.
3. In the fully open position the valve is capable to let a large flow through with a low pressure drop.



Flow Plug

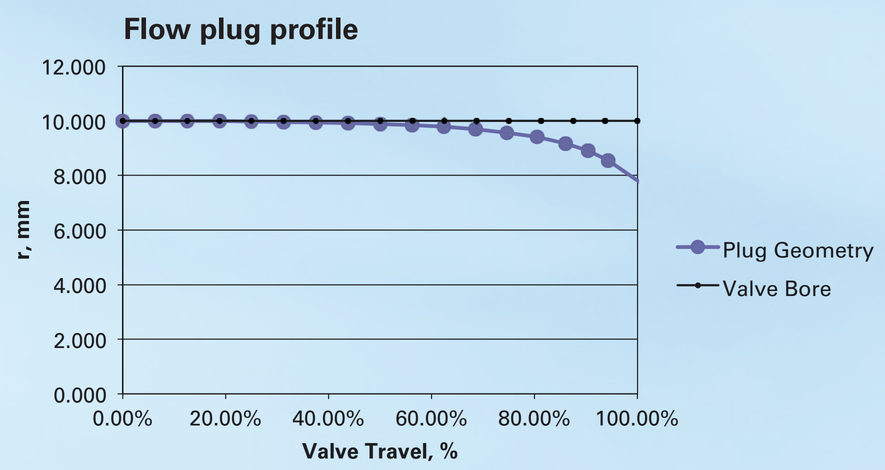
The flow plug is the part that essentially needs to be shaped in order to realize the regulation profile. Between the seat bore and the outer surface of the plug an annular cross section with a thickness of less than 0.01 mm is being created and should be kept in place by a precise realization of the parts. The algorithm used for sizing a flow plug considers the resistances produced by a restriction of the cross section for the fluid and has been experimentally improved and validated.

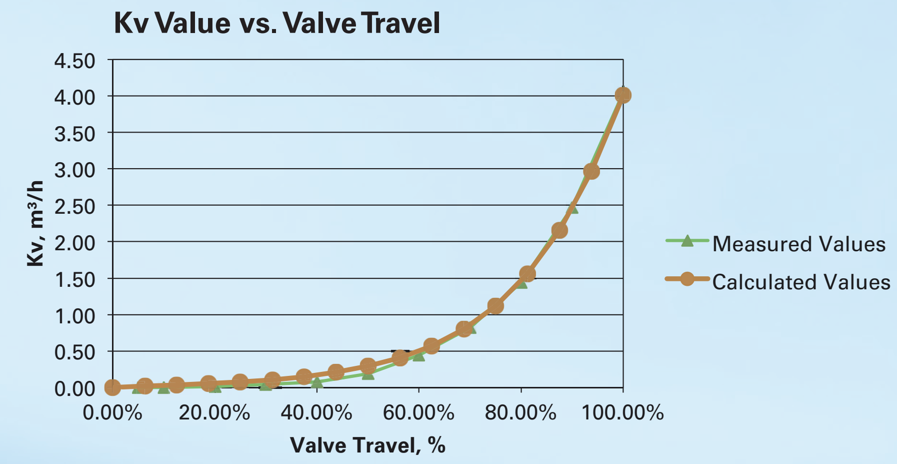
Test campaigns have demonstrated the validity of the calculation model on a wide range of sizes, as the pictures show.



Conclusions

- As the graphic demonstrates, the comparison between the measurement and the calculation confirms the validity of the calculation model.
- The deviation from the calculated profile is reduced all over the range of values.
- High rangeability and complex profiles can be reflected on the design of the flow plug by using the calculation model





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