Convenient Idealizations We Accept

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Often, common engineering idealizations are fully adequate representations of nature, and they are useful for design or analysis. But recognize that they are human conveniences, which are chosen to balance simplicity with performance. Desirably, the error caused by simplification is smaller than the error related to the "givens" or uncertainties in the context, making the idealizations fully adequate. But it is not always so. Be aware of the impact of idealizations when you are using models and data. Here are some common idealizations in process modeling and control.

The Bernoulli velocity exponent in ideal flow is 2, which is used in friction losses in pipes and fittings, and which leads to the square root functionality in orifice equations and in the control valve flow response to ΔP. Somewhat better coefficients for matching measurements are the 1.8 and 0.52 exponents [1]. However, considering the effects of turbulence noise on measurements, installation artifacts, and uncertainty on friction factors, the ideal 2 and 0.5 exponents are often fully adequate.

There are many other approximations: The ideal gas law models P, V, T relationships. Activity coefficients are often assumed to be unity. Antoine's Equation and Raoult's law relate vapor and liquid composition. Homogeneous reaction kinetic laws, and the Arrhenius model for temperature dependence are common. These are all asymptotic limits for low pressure, low dilution, or very high flow rate conditions. But of course, the error they introduce may be tolerable for the application.

A valve may be marketed as having an equal-% relation between valve flow rate and stem position. If the characteristic is true, the valve can never close. Real equal-% valves have a modified characteristic at near closed conditions.

Constant density is often presumed, despite of the effects of temperature, pressure, composition, entrained gases, dimerization, etc.

Are liquids and gases are pure? The reality is that there are dissolved non-condensable gases in liquids, and entrained mist or particulates in gases. Cavitation and choked flow might be due to gas effervesce rather than the classic liquid vapor-pressure explanation.

Can a process be first-order-plus-deadtime (FOPDT)? This model may have utility for tuning controllers and dynamic compensators, but I've never seen it to be true to reality. I think SOPDT models are much truer to real process behavior, but their complication in designing control algorithms does not seem to have sufficient benefit to compensate for the effort.

Common assumptions about material properties include: The molecular weight of water is 18 (not 18.015). The composition of air is 80/20 N_2/O_2 (for dry air the ratio is closer to 78% N_2 21% O_2, and 1% CO_2. But air also contains a varying amount of water vapor). And the pH of water is 7 (temperature, dissolved salts or CO_2 have no effect).

Plugging Value is a measure of particulate content in a fluid. It is the volume pumped through a filter to get a target pressure drop. One incorrect practice I experienced was volume-weighted averaging of Plugging Values when batches are blended. The blended value should be a reciprocal of volume-weighted reciprocals [2]. But local tradition would not change the method, because it had been working for years, it was easier to understand, and the error caused by the simple averaging did not seem impactful relative to measurement uncertainty.

Device calibrations are perfect (because our techs are the best anywhere). So, you can be assured that a 50% controller output means 12 mA to the i/p device, means 9 psi to the actuator, means a 50% stem position.

Calibrations are linear. This is defended by the perfect knowledge that responses are linear.

Measurements are true.

Future economic predictions can be based on today's prices and costs.

The volume of liquid in a tank is height times cross sectional area. Indentions, ribs, exit drain lines, bottom curvature, can be ignored.

Adiabatic, Isothermal, and Isentropic are all achievable.

Plug flow happens in packed columns and pipes.

When you are using such conveniences, be sure you understand the implicit presumptions, and can validate that the error caused by the idealization is negligible relative to the uncertainties that you cannot control (such as the basis for the design, or givens in the situation, or proximity to a constraint). The use of an idealization cannot be defended because 1) it makes analysis simple, or 2) it is commonly used, or 3) it is what the modeling software experts provided, or 4) we've always done it that way. A simplification needs to be defended by utility – the improvement of convenience is large relative to the impact on error.

On the other hand, don't claim that a more rigorous approach should be used when the convenient method is adequate. Balance perfection with sufficiency.

References

[1] Rhinehart, R. R, S. Gebreyohannes, U. Manimegalai-Sridhar, A. Patrachari, and Md S. Rahaman, “A Power-Law Approach to Orifice Flow Rate Calibration”, ISA Transactions: The Journal of Automation, Vol. 50, No. 2, pp 329-341, 2011

[2] Do a simple particle balance in mixing batches.

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Russ Rhinehart started his career in the process industry. After 13 years and rising to engineering supervision, he transferred to a 31-year academic career. Now “retired”, he enjoys coaching professionals through books, articles, short courses, and postings on his web site www.r3eda.com. One of his favorite rules was learned in school, “i before e, except after c.” He comments, “It is a weird rule, but science is not. Neither is the number eight. Delightfully, engineering is efficient.”