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Inferential control model input selection

It is not a secret that I prefer to base inferential models on engineering principles, rather than on regression. Having said that, the use of regression is widespread, and being a consultant in the field, I am often asked about how inferential model performance can be improved. Indeed it can be much improved, if one only took the trouble to consider chemical engineering principles.

Example. A classic example of bad input selection is a set of input variables that contain intensive variables, such as pressures and temperatures, together with extensive variables such as flows. The fluid catalytic cracking (FCC) fractionator (Fig. 1) will serve to illustrate this point. To infer the naphtha 90% point regression practitioners habitually take these regression model inputs:

1. Column top temperature
2. Column top pressure
3. Naphtha product flow.

Why naphtha product flow? How can such a blatant violation of process engineering facilitate a successful inference? Answer: There is a correlation of flow against 90% point because at a fixed throughput and severity, increasing the naphtha yield increases the naphtha cutpoint. That following a throughput change the inference would be erroneous is just one example of inferences that correlate but do not predict. Such inferences fail during a transient operation, when they are needed the most. Can this problem be solved by inputting naphtha yield instead of naphtha flow? It is definitely an improvement but still vulnerable to reactor severity or feed quality change.

Why is there a need for naphtha flow or yield input to begin with? Process engineering dictates that the naphtha 90% point is a function of column top partial pressure and temperature, with some internal reflux influence on the heavy distillation tail. It takes some engineering calculations to create a partial pressure input, and regression practitioners have become "purists" in the sense that they would not consider any engineering procedure—only straight measurements. Because total pressure is an imprecise input, the use of naphtha yield or flow "improves the fit." I do not recall seeing a calculated partial pressure anywhere as a regression inferential input.

FCC reactors have several significant steam injections, all of which end up in the fractionator. Reactor steam injections are determined by reactor considerations and are not necessarily proportional to the feed. Inputting total pressure in lieu of partial pressure is not a very good idea. Further, the FCC reaction creates a large amount of LPG and gas. At fractionator top conditions, those light components are not miscible and, in terms of their effect on partial pressure, they behave like steam. I would assert that no reasonable inference can be created without partial pressure being one of the inferential inputs.

Things go downhill from here. What would you suggest as inputs for inferring light cycle oil (LCO) 90% point? The regression practitioner would typically use:

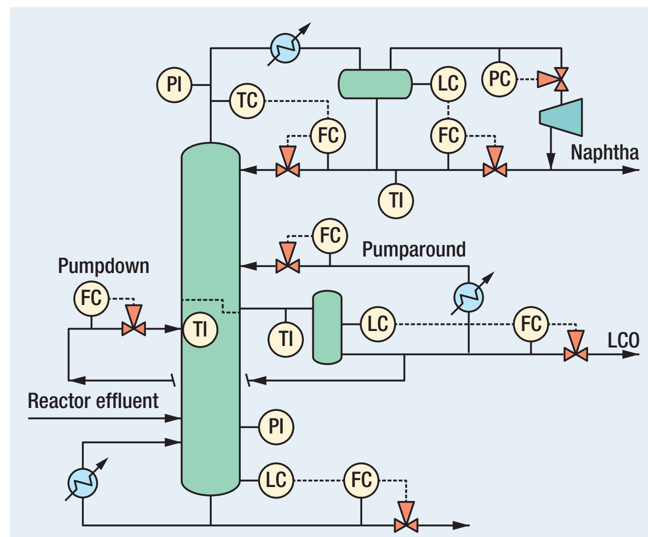

FIG. 1 Classic example of bad input selection—FCC fractionator with total draw trays.

1. LCO draw temperature
2. Column top pressure
3. LCO product flow.

Why LCO flow? Again, for the same reason, at steady operation, increasing LCO yield affects the LCO cutpoint. Of course, such an inference is again weak. It can handle neither throughput nor severity changes. And for the side draw, there is another element of uncertainty. LCO yield can be changed in different ways. For example, at steady operation, if naphtha yield changes up and LCO yield down, then the LCO 90% point would actually not move at all. The LCO inference is vulnerable not only to transient throughput and severity but also to normal manipulation of the fractionator top section.

Internal reflux in the LCO section affects both the partial pressure and heavy distillation tail. Is it possible to take that into account? The fraction (Fig. 1) has a total draw LCO tray where internal reflux is measured as pump down, so even the purist statistician should accept that.

Process engineers spend years studying chemical engineering, then more years performing process calculations on the real plant. Where is all that accumulated knowledge? Please, show the world that a process control engineer is not a statistician. **HP**

The author is a principal consultant in advanced process control and online optimization with Petrocontrol. He specializes in the use of first-principles models for inferential process control and has developed a number of distillation and reactor models. Dr. Friedman's experience spans over 30 years in the hydrocarbon industry, working with Exxon Research and Engineering, KBC Advanced Technology and, since 1992 with Petrocontrol. He holds a BS degree from the Israel Institute of Technology (Technion) and a PhD from Purdue University.

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