Engineering Consulting & Training Services

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Process Operating Stress Test (POST) = Pathway to Improved Unit Profitability

By George A. Swan III, Ph.D., P.E.

The first step toward maximizing process performance is to assess the overall "health" of the existing operation. Analogous to cardiac stress testing, methodology is available for systematically testing refinery or chemical process units, and extending their normal operating envelope. The Process Operating Stress Test (POST) protocol comprises a series of incremental changes in process variables (typically targeting higher severity operation) which results in corresponding responses of key process parameters, e.g., conversion, yields, etc. Statistical analysis of these responses facilitates diagnosis of probable process limitations and sets the stage for developing both optimization and unit debottlenecking strategies. An important outcome is also a blueprint for addressing identified process constraints.

A schematic overview of POST methodology is illustrated in the flow chart below. Current unit operation is the anchor point, and an elemental (hydrogen) mass balance ("Short Cut") tool provides input to drive calibration of the process model at base conditions. The Short Cut M.B. method relies upon process stream sampling and lab analysis instead of using flow meters in the plant to close the mass balance. The calibrated model is then employed to develop "delta" or stress cases, each of which generates a response for the target performance parameter. The model-predicted stress cases are subsequently implemented in the commercial plant. Manipulation of either a single variable or several process variables simultaneously is permitted for each stress case worked up via the Short Cut M.B. method. The aggregate of these cases constitutes an operating stress response matrix, and Excel-based statistical analysis techniques are employed to pinpoint the primary constraint or limiting process variable(s). The final step is building upon the initial diagnosis with a detailed engineering evaluation to identify the root cause of the constraint and plan corrective action.

POST is also complementary with Six Sigma applications and provides a codified framework for measuring and analyzing process unit capability. Key advantages for POST are (1) rapid assessment of potential for performance enhancement with no or low investment, (2) timely identification of potentially higher investment debottlenecking opportunities, and (3) cost-effective approach for identifying constraints with minimal process disruption – ultimately increasing unit profitability.

Upcoming Training Courses being held in Rockaway, NJ

- Course 607, *Design and Maintenance of Aboveground Atmospheric Storage Tanks*
  November 9-11, 2010
- Course 1613A, *Turnaround Best Practices*
  December 7-9, 2010
- Course 910, *Process Plant Piping System Design and Maintenance*
  December 15-17, 2010

For more information, see our website at www.carmagen.com

Work Highlights

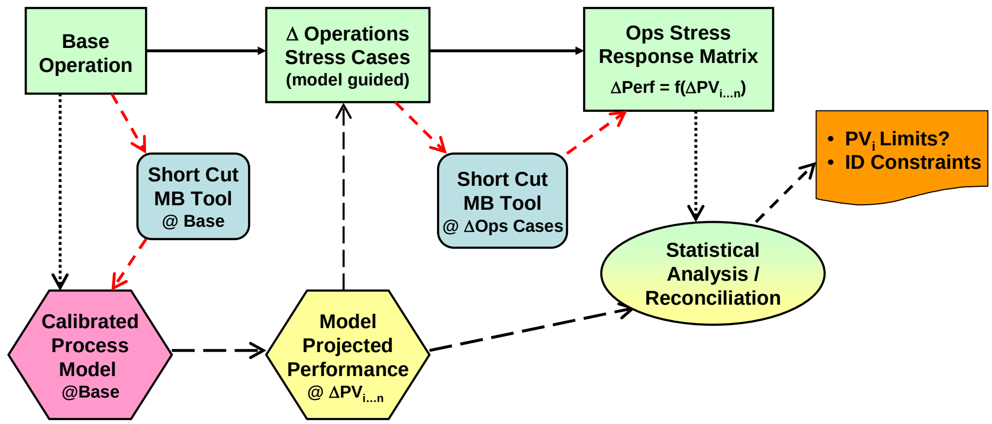
Process, Operations & Safety

Provided technical support regarding gas treating unit troubleshooting and consultation to assist in resolution of solution fouling, reclaiming and contamination issues.

Project Support

Four Carmagen engineers are integrated within a client's project team to provide technical support with respect to noise control, safety, fired equipment, heat exchangers, and project management. This is a mega-project involving a major "clean fuels" revamp at a refinery in the Middle East and our involvement is expected to be for 1-2 years.

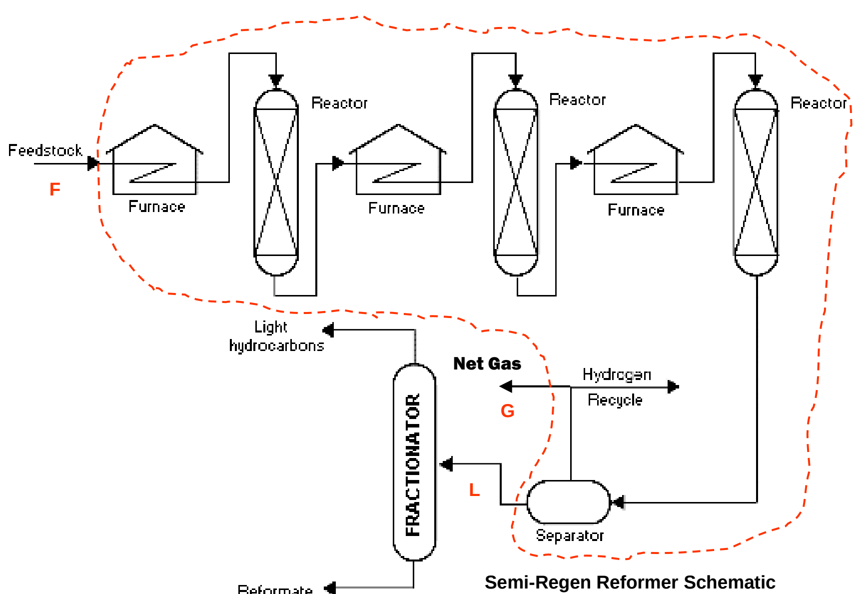
Process Operating Stress Test "Roadmap"



PV_i = process variable 1,2,..n and Δ PV_i = incremental change in PV_i

Following is an example of applying POST methodology to a catalytic naphtha reformer. Although a semi-regen unit is illustrated, a CCR unit may be tested in the same manner. First, a mass balance envelope is drawn around the reaction section as shown in the figure. The Short Cut M.B. method is utilized for base operation via sampling the feed (F), net gas (G), and separator drum liquid (L) and determining hydrogen content of these three streams. Generally it is preferable to analyze each stream sample and then calculate hydrogen content from composition. In this case the liquid feed may be analyzed by Leco or NMR; however, gas and separator drum (wild) reformate require GC analysis. Relative mass flow rates of these streams (with respective hydrogen fractions H_F, H_L, and H_G) are determined as follows:

$$G/F = (H_F - H_L) / (H_G - H_L) \text{ and } L/F = (H_G - H_F) / (H_G - H_L)$$



Semi-Regen Reformer Schematic
Courtesy: OSHA Technical Manual

Yield of any product (e.g., C_{5+} reformate) is then directly calculated from the mass flow rate and stream compositions. Several balances at base conditions may be conducted to provide an average dataset for calibration. The reformer process model is then adjusted to these average base operating conditions and applied to predict response of a key performance parameter such as hydrogen gas production to incremental changes in naphtha feed rate (e.g., +1-5%), reactor temperature (e.g., +5-10 $^{\circ}$F), hydrogen partial pressure (e.g., -5 to -10 psi), etc. When the test protocol is finalized, a risk assessment and operations review is conducted prior to its execution in the commercial unit to ensure that planned process perturbations will not result in unanticipated hazardous conditions such as piping vibration or otherwise negatively impact safety and reliability. The selected delta cases are conducted by adjusting the appropriate computer process control set points and allowing sufficient lineout time to reach steady state prior to sample collection. During these mass balance periods, it is recommended that normal online electronic data acquisition be continued and stored for reference. Short Cut M.B. delta case results are calculated for each test period as previously described for the base case, and the stress response matrix populated. Finally the stress responses are statistically analyzed and reconciled to identify the most probable process constraint. A significant advantage in applying POST methodology is that typically minor process variable changes can be used to implicate bottlenecks without major upsets in unit operation resulting in off-spec product.

POST analysis is the starting point for investigating constraint elimination opportunities. For this reformer example, if preheat temperature were determined to be limiting hydrogen production, a study of possible feed/effluent exchanger fouling and preheat furnace duty assessment would be appropriate. The analysis might also point to a restriction imposed by recycle gas compression as hydrogen purity of the gas marginally increases. In that event a survey of options to boost compressor efficiency would be appropriate. Changes in reformer feed composition as well as feed rate are accommodated as manipulated variables. For instance, stepwise addition of hydrocrackate to the base virgin naphtha feed (delta cases) could be used to probe capability for feed flexibility. Typically for the incremental process changes characteristic of POST, hydraulic limits are not encountered; rather, constraints are often the result of restrictions in heat transfer, gas compression, product separation, etc. A similar approach with the mass balance envelope confined to the reformate stabilizer could be pursued, if perhaps process data collected during the reaction section stress testing suggested incipient column flooding or degradation of separation efficiency. A column simulator could be used for guidance in lieu of the basic process model. In some cases the best and most cost-effective solution may be catalyst replacement, e.g., changing to a higher activity or improved selectivity catalyst system. In that situation POST is advantageous for re-optimizing unit operation following the catalyst change.

POST may be employed to assess capability of a range of refinery processes including FCCUs. A packaged toolset must be customized for every unit incorporating plant-specific requirements and laboratory analytical outputs. POST requires significant “manual” intervention, since by design it is non-routine methodology to be tailored for each application. To facilitate implementation, a comprehensive POST (PowerPoint) guide covering topics such as testing strategy, recommended stream sampling hardware and procedures, suggested laboratory support, expected outcomes, etc., may readily be prepared. In most cases a company proprietary process model will be available to guide formulation of the stress test program as discussed previously.

With some minimal upfront planning including preparation of sample points and sampling apparatus, a full range POST study including analysis of stress responses and preliminary recommendations from the test team can be completed in a relatively short time period. Given the large upside potential for enhanced unit profitability, the funding for POST is readily justified.

George Swan, III has over 40 years experience as a Process Development / Process Research chemical engineer specializing in innovative engineering solutions and profit opportunity identification, novel process conceptualization, technology development and deployment strategies, and intellectual property formulation and management.

Please contact Jerry Lacatena (jlacatena@carmagen.com) if you’d like more information on Carmagen’s expertise in this area.

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