Liutaio provides independent engineering expertise that helps industrial organizations understand plant behavior, reduce technical uncertainty, and make better engineering decisions

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1 The Operational Paradox

Many operating plants appear to perform correctly on paper.

Production targets may be achieved, instrumentation may be functioning, and process variables may remain within design limits. According to routine reports and steady-state models, the unit may therefore appear to be operating as expected.

Yet plant operators and engineers may experience a different reality. The plant remains stable and production continues, but operating close to its intended limits may become difficult or unstable. Operators may rely on repeated manual interventions to maintain stability. **The practical operating window can therefore become narrower than the design expectations**, causing the plant to be operated farther from its practical limits than originally intended.

These situations are rarely caused by a single equipment problem.

Instead, they typically emerge from subtle interactions between process dynamics, control architecture, constraint handling, and operating practice. Over time, these mechanisms can quietly limit production flexibility, energy efficiency, and recoverable economic margin.

Because these mechanisms are dynamic in nature, they are often invisible in steady-state analysis, design documentation, or routine performance reporting.

Understanding how plant behavior actually develops under real operating conditions is therefore the first step toward identifying where meaningful performance improvement may be possible.

2 Hidden Mechanisms in Operating Plants

When plants struggle to operate near their intended limits, the cause is rarely a single malfunction or design error. The limitation may instead emerge from the way several elements of the plant interact under real operating conditions.

Process dynamics, control architecture, constraint handling, and day-to-day operating practices continuously influence one another. Small variations in one part of the system can propagate through headers, recycles, energy balances, or interacting control loops, gradually shaping how the unit behaves in practice. Over time, the operating team may adapt to these behaviours through manual interventions, conservative setpoints, or protective operating practices. These adjustments are often reasonable responses to observed behaviour, but they can also mask the mechanisms that originally created the limitation.

As a result, the plant may settle into a stable but sub-optimal operating pattern. The absence of instability or equipment failure does not necessarily mean that the plant is operating at its full practical potential.

Because these mechanisms involve dynamic interactions rather than static design parameters, they are often difficult to identify using conventional performance reviews. Steady-state models, routine operating reports, or isolated loop analysis rarely reveal how these interactions evolve during real plant operation.

A clear understanding therefore requires examining how the plant behaves during normal operating disturbances, constraint approach, and interaction between units. This dynamic perspective helps reveal the mechanisms that limit performance while distinguishing them from the operating practices that have gradually evolved to keep the plant stable.

3 Different Engineering Situations

Different organizations may require different forms of engineering support depending on their current engineering situation. Similar operational symptoms do not necessarily indicate the same engineering problem or require the same engineering approach.

Some organizations first need to understand what is limiting their operation. Others already know the engineering problem they need to solve. Others have already developed their technical understanding or a proposed solution but require an independent technical perspective before committing to an important operational or investment decision.

The following sections describe three common engineering situations. Consider which one most closely matches your organization's current circumstances:

- Section 3.1 – Understanding Before Acting
- Section 3.2 – Solving a Known Engineering Problem
- Section 3.3 – Independent Technical Perspective

3.1 Understanding Before Acting

Many industrial organizations recognize that their plant is not performing as well as it should.

Production may be consistently below expectations. Energy consumption may appear higher than anticipated. Operators may rely on repeated manual intervention to maintain stable operation. Practical operating limits may be noticeably narrower than the plant was originally designed to achieve.

These observations indicate that improvement opportunities may exist.

They do not, however, necessarily explain **why** they exist.

In many situations, the underlying engineering mechanisms are not yet sufficiently understood to determine which corrective actions would produce meaningful improvement. Dynamic process interactions, control strategy limitations, operating practices, equipment behaviour, and process constraints often influence one another simultaneously. As a result, the visible symptoms may not be sufficient to define the engineering problem or determine which course of action is most appropriate.

Beginning implementation before establishing this understanding may result in considerable effort being directed toward symptoms rather than their underlying causes. Controller retuning, software modifications, equipment replacement, or operating procedure changes may each appear reasonable when considered individually, yet none may address the mechanism that is actually limiting plant performance.

For this reason, the appropriate first engineering objective is not immediate implementation.

The appropriate objective is to establish a technically defensible understanding of the plant's actual operating behaviour under normal production conditions.

Once that understanding has been developed, the appropriate engineering path usually becomes much clearer. In some situations, the findings justify a structured engineering assessment. In others they reveal that a specific implementation activity is appropriate. Occasionally they confirm that no further action is required.

Engineering understanding therefore reduces technical uncertainty before significant resources are committed.

The following example illustrates a typical situation in which an organization benefits from establishing an engineering understanding before selecting the most appropriate technical solution.

Illustrative Plant Operation Example

In one operating plant, utility consumption had gradually become higher than expected. Historical operating data showed that hydrogen production consistently exceeded the requirements of the downstream process units.

The plant design included a hydrogen header where pressure was regulated through production control, with excess hydrogen directed to flare when header pressure exceeded its operating target.

Over time, the operating team had adopted the practice of keeping the flare valve partially open in order to maintain stable header pressure and avoid pressure oscillations.

Although this operating practice maintained stable header pressure, it also resulted in a continuous loss of hydrogen to flare.

Because hydrogen is a high-value utility, this behavior represented a persistent economic loss that had gradually become embedded in routine operation.

The engineering effort therefore focused on understanding why the header pressure control structure required this operating practice to maintain stability.

Analysis of plant data and control configuration indicated that the existing pressure regulation strategy was overly sensitive to production variability, causing oscillatory behavior when the system attempted to operate closer to the intended pressure target.

Rather than immediately recommending modifications to piping or equipment, the engineering conclusion was that the existing pressure control strategy should first be reviewed and refined. This provided a lower-commitment engineering path for determining whether the control strategy was a significant contributor to the hydrogen losses before considering physical plant modifications.

By first establishing a clear understanding of the plant's dynamic behaviour, the organization could determine whether the identified control behaviour was contributing to the hydrogen losses before considering physical plant modifications.

Engineering Lesson

A persistent operating practice can sometimes be the visible response to an underlying engineering mechanism.

When the mechanism has not yet been established, changing equipment or operating procedures may address the symptom without addressing its cause.

In this case, establishing a clear understanding of the plant's dynamic behaviour provided a lower-commitment engineering path for reviewing the pressure-control strategy first, before considering physical modifications to piping or equipment.

3.2 Solving a Known Engineering Problem

In other situations, the engineering problem has already been identified.

The organization is no longer attempting to determine where operational improvement opportunities exist. Instead, attention is focused on resolving a specific engineering issue that is already affecting plant performance.

Examples include unstable control loops, commissioning difficulties, instrumentation problems, automation system modifications, process control deficiencies, advanced control applications that do not perform as intended, or other clearly identified operational problems.

Although the engineering problem is sufficiently understood to begin engineering work, the appropriate technical solution may still require engineering judgement. A clearly identified problem does not necessarily determine a single or predetermined solution.

Under these circumstances, the principal engineering challenge is no longer identifying the problem.

The challenge is applying the appropriate technical expertise to analyse the problem, determine the most effective corrective actions, implement those actions in a controlled manner, and verify that the desired operational improvements have been achieved.

As implementation progresses, additional engineering understanding frequently develops. New observations may refine priorities, reveal related technical issues, or identify further opportunities for improvement. This progressive understanding is a normal characteristic of complex industrial facilities and should not be interpreted as evidence that the initial problem definition was incorrect.

When the affected operating systems are already understood, organizations can benefit from engaging specialist expertise capable of solving the identified problem effectively while maintaining safe and reliable plant operation.

The following illustrative engineering example represents a typical situation in which the engineering problem is already known, and the primary objective is successful technical implementation.

Illustrative Plant Operation Example

In one MTBE plant, operators experienced persistent variability in reactor operation even though the individual flow-control loops appeared to perform satisfactorily. The process used C4's hydrocarbons, methanol, and reactor recycle as its principal feed streams. However, the required relationships among these streams were not being maintained in the way required for stable reactor operation.

A process engineer used DCS data from a historical database to review the MTBE plant's performance. The review of historical operating data identified several important observations:

1. C4's feed flow exhibited variations. Because this flow came from a surge drum, the variations were attributed to operator actions on the C4's flow controller to maintain the surge-drum level within its operating limits.
2. The Methanol and Recycle flows were maintained constants with flow controllers.
3. The required operating relationships among the C4's, methanol, and reactor-recycle flows were not being maintained dynamically according to the licensor requirements.
4. Frequent deficits and excesses of methanol flow were observed relative to the current C4's and reactor-recycle flows.

These observations showed that the individual flow controllers could appear to operate satisfactorily while the required relationships among the process flows were not being maintained. The engineering problem was therefore not simply the performance of an individual controller, but the way the controlled variables interacted during normal plant operation.

After reviewing the design data and licensor documentation, the relevant plant controls and reactor stoichiometric relationships were identified in terms of:

a. Isobutylene composition in C4’s flow.
b. Isobutylene to total reactor inlet ratio control.
c. Methanol to pure isobutylene mol ratio.

Review of the licensor documentation showed that the required control relationships had been defined, but the operating strategy was no longer maintaining those relationships dynamically during normal operation.

With the required relationships established, a control strategy was developed according to the licensor requirements.

One of the customer's main concerns was how to maintain stable MTBE plant operation if the C4’s feed flow had to be manually adjusted to maintain the surge-drum level within its operating limits.

To eliminate the manual disturbance, the surge-drum level controller was configured to automatically regulate the C4’s feed flow.

Following implementation and tuning of the new control strategy, the MTBE unit operated smoothly. The required feed-flow relationships were maintained automatically, the surge-drum level remained within its operating limits without the previous oscillatory behaviour, and manual adjustment of the C4’s flow for surge-drum level control was no longer required. The identified engineering problem was therefore successfully resolved through appropriate control-strategy implementation rather than by improving the performance of individual flow controllers in isolation.

Engineering Lesson

A known engineering problem may not be solved by improving individual control loops in isolation.

The individual control loops initially appeared to perform satisfactorily, yet the required relationships among the process feed flows were not being maintained dynamically. The effective solution came from understanding the required process relationships and implementing a control strategy that coordinated the relevant variables while respecting the actual operating constraint.

3.3 Independent Technical Perspective

In some situations, an organization already understands the engineering problem and has developed or selected a proposed technical solution.

However, before committing significant resources to implementation, management may wish to confirm that the proposed approach is technically justified and represents the most appropriate course of action.

These situations commonly arise before major automation upgrades, advanced process control projects, process modifications, equipment replacement, commissioning activities, or other investments involving substantial technical or financial consequences.

The objective is not to identify new operational improvement opportunities, nor to solve an already defined engineering problem.

Instead, the objective is to obtain an independent technical perspective capable of confirming engineering assumptions, identifying potential risks, evaluating alternative approaches, and increasing confidence before important decisions are made.

An independent engineering review can also help distinguish between issues that genuinely require corrective action and those that can be addressed through simpler operational or engineering improvements.

Because the review is performed independently of equipment suppliers, implementation contractors, or internal project teams, its conclusions remain focused on technical justification rather than on a particular implementation strategy.

This independent perspective enables organizations to make important engineering decisions with greater confidence, reduced technical risk, and a clearer understanding of the expected operational consequences.

The following example illustrates a typical situation in which an independent technical review identified a technical risk before a major implementation decision was taken.

Illustrative Plant Operation Example

An Oil and Gas project in the Middle East was developing new production wells in the Arabian Desert.

Each well required remote monitoring of field instrumentation together with local control of the wellhead control panel (WHCP, hydraulic power unit) and wellhead tree. An RTU is required to implement remote monitoring and local command.

From a functional perspective, several commercially available RTUs could satisfy these operational requirements. However, the project also required implementation of safety logic achieving at least SIL 1, with a proof test every year.

One supplier presented a convenient offer for an RTU rated SIL 1, with 2 different sets of failure rates if the RTU is working above or below 30.0 ºC.

The proposed RTU was supplied as a sealed enclosure, outdoor installation (no instrument shelter), with external cable connections only and no forced cooling system. Heat dissipation therefore depended entirely on natural convection through the enclosure surfaces.

Before proceeding to prepare the purchase order, the project manager requested an independent engineering review of the RTU SIL 1 device offered.

From public data, typical environment temperature at the Arabian desert is as follows:

- Summer: 25.0 to 55.0 ºC
- Winter: -5.0 to 25.0 ºC

Consequently, the RTU would be expected to operate above 30 °C during a significant portion of its service life.

Manufacturers commonly classify individual devices according to their SIL capability. However, the SIL rating of a complete Safety Instrumented Function (SIF) cannot be inferred solely from the individual ratings of its components. Compliance must be verified considering the integrated operation of all SIF components.

No details were provided about the safety logic design to implement in the RTU.

The independent engineering review proposed to perform a preliminary verification of a simple SIF without redundant components as follows:

- One pressure transmitter (initiator).
- The offered RTU SIL 1 (logic solver).
- The safety valve (final safety element: choke valve, surface or sub-surface safety valve).
- De-Energize to trip was selected as trip philosophy.
- Use verification procedure for low demand safety system.
- Do not consider “Common Cause Failure” (CCF).

If the offered RTU failed this preliminary verification, no further evaluation would be necessary. Only if the simple SIF satisfies the required SIL, then target additional engineering scenarios would be evaluated.

The SIF SIL rating will be verified with the offered RTU SIL 1 failure data. For the other SIF components:

- Public data was used for the **pressure transmitter**.
- Normally, the failure data **for safety valves** is confidential information. So, an average failure rate data was estimated from other projects.

For simplicity, no other components for SIF implementation or safety design refinements (SRS) were included in the preliminary verification, like:

- signal splitter,
- input/output barriers/isolators,
- SOV at the WHCP is not considered. Also named: Pilot valve, Dump valve or Directional control valve.
- type of RTU input and output cards,
- Only full proof test is considered (not partial proof test).

The independent engineering review consisted of two activities:

A) A failure data consistency check for each SIF component, with one year proof test.
B) A SIL verification for the simple SIF (all components together), with one year proof test.

From (A), it was found that each independent component satisfied the SIL 1 rating, working in environment temperatures below and above 30.0 ^{o}C.

From (B), it was found:

1. The simple SIF satisfied the required SIL 1 rating when environment temperatures were below 30.0 ^{o}C,
2. But, the simple SIF did not satisfy the required SIL 1 rating when environment temperatures were above 30.0 ^{o}C.

The independent engineering review demonstrated that evaluating only the SIL capability of an individual component would have led to an incorrect engineering decision. Although the proposed RTU satisfied its individual SIL 1 classification, the complete Safety Instrumented Function failed to achieve the required SIL 1 performance under the environmental conditions expected for normal plant operation. The review therefore identified a significant technical risk before equipment procurement, allowing the project team to reconsider an alternative RTU supplier before committing to final design and implementation. The independent review therefore provided the technical confidence required to support an informed engineering decision.

Engineering Lesson

A technically suitable component does not necessarily make the complete system suitable for the intended application. Independent review should therefore consider the complete technical function, including applicable system requirements, interfaces, and operating conditions, rather than relying solely on component-level certification or supplier documentation.

An individual component SIL rating does not establish the adequacy of the complete engineering function.

4 Engineering Philosophy

Industrial plants are complex dynamic systems in which process behaviour, control strategies, instrumentation, equipment, and operating practices continuously influence one another.

For this reason, engineering decisions should be based not only on design intent or historical operating experience, but also on objective evidence of how the plant actually behaves under normal operating conditions.

Liutaio's engineering philosophy is founded on a simple principle: engineering recommendations should follow technical evidence and engineering understanding rather than predetermined solutions.

Regardless of the engineering situation described in Section 3, underlying engineering principles remain the same.

Engineering conclusions should be technically justified, proportionate to the available evidence, and communicated with clarity.

Recommendations should focus on reducing technical uncertainty, supporting safe and reliable operation, and helping organizations make sound engineering decisions.

Independent engineering judgement also requires maintaining technical objectivity. Recommendations should remain independent of equipment suppliers, implementation contractors, software vendors, or other commercial interests, allowing engineering decisions to be based on technical evidence and engineering judgement rather than on predetermined commercial outcomes.

Ultimately, the objective is not simply to solve isolated engineering problems, but to improve the quality of engineering decisions by providing technically defensible conclusions that organizations can apply with confidence.

5 Starting the Technical Conversation

Every engineering situation is unique. Meaningful engineering discussions therefore begin by understanding the specific situation rather than by selecting a predefined service.

Some organizations wish to better understand the mechanisms limiting plant performance. Others seek specialist expertise to resolve a known engineering problem. Others require an independent technical perspective before committing to an important operational or investment decision.

Regardless of the situation, the initial technical conversation is intended to establish a common understanding of the engineering context before discussing possible technical approaches.

Depending on the situation, the discussion may consider questions such as:

- What engineering situation is the organization currently facing?
- What operational objectives are being pursued?
- What technical information is already available?
- What engineering uncertainties remain?
- What decisions must ultimately be supported?

Once these aspects are understood, the most appropriate engineering approach can be discussed with greater confidence and technical clarity.

Whether the outcome involves further engineering evaluation, specialist implementation, or an independent technical review depends entirely on the circumstances of the organization and the engineering objectives to be achieved.

Liutaio welcomes the opportunity to discuss these engineering situations and to establish a clearer understanding of the technical circumstances, objectives, and uncertainties involved, based on objective engineering judgement and practical industrial experience.

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Initial technical discussions may be conducted remotely to understand the engineering situation, discuss the technical objectives and uncertainties, and establish the appropriate basis for further technical discussion.