WHITE PAPER

Five Best Practices for Refineries:

Maximizing Profit Margins Through Process Engineering

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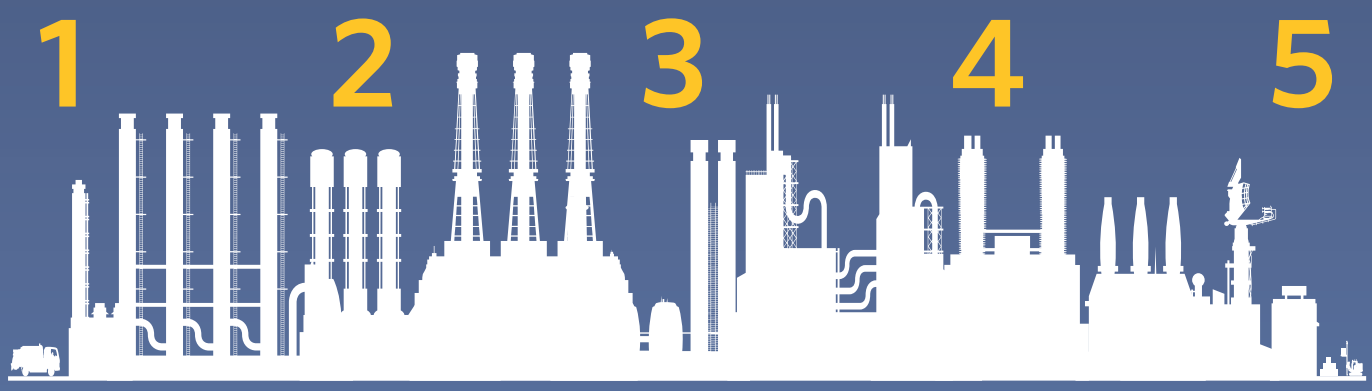

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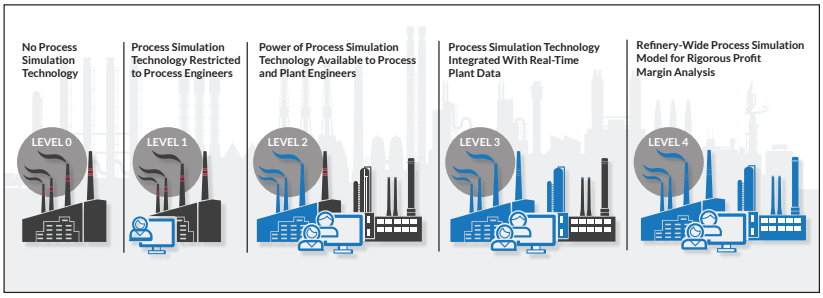
Today, the complexity of the refining business is growing everyday with new markets, new feedstocks, and new regulations in place. In addition, refineries worldwide are facing declining profit margins. In order to sustain their profitability, refineries must focus on leveraging process simulation technology and capabilities to achieve best-in-class operational excellence. Process simulation technologies have advanced substantially to help refineries optimize a broad range of processes spanning operational troubleshooting, crude selection, refinery planning, profit margin analysis, turnaround planning and more.

While the world of crude oil refining has witnessed significant developments in process simulation, many refiners are still leaving money on the table by not taking full advantage of the growing range and sophistication of process optimization technology. To understand how your refinery and its process engineers can better use process simulation to improve profit margins, it is important to consider your company's level of maturity in leveraging process optimization technology. AspenTech has a point of view on this maturity spectrum, and believes every refinery can be broadly classified to fall in one of the following five maturity levels.



Maturity Level Zero: These refineries do not yet have a culture of using process simulation technology to support their operations.

Maturity Level One: These refineries have rigorous process models developed for specific units that the process engineers use on an ad-hoc basis for operational troubleshooting.

Maturity Level Two: Process engineers in refineries at this level of maturity have process simulation models set up so they can be leveraged by plant engineers through familiar interfaces such as Microsoft Excel for operational troubleshooting or root-cause analysis. The process simulation models are calibrated to match the actual refinery operations data from a point in its recent past.

Maturity Level Three: These are refineries who are higher up the technological maturity ladder, with process simulation models hooked up to real-time operations data. This allows them to monitor Key Performance Indicators (KPIs) for their processes and equipment on an ongoing basis, and enables engineers to make informed operational decisions. These refineries also have capabilities in place to regularly update the models used by their planning tools, using rigorous process simulation models, so that the refineries consistently produce the most optimal plans.

Maturity Level Four: At the pinnacle of technological maturity are these refineries who employ refinery-wide process simulation models in a single flowsheet. Process engineers in these refineries bring valuable insights into the planning and strategy divisions by bringing a more accurate assessment of profit margins for operational improvements, strategic capital project evaluations, and more.

An inevitable element of a refinery's journey to higher levels of technological maturity is its partnership with technology providers who can equip them with state-of-the-art technology and

industry best practices. Process engineers at these refineries should have access to technology that can accomplish a wide variety of simulation and estimation capabilities. More importantly they should have access to best practices and training materials that can help them become more sophisticated in how they use and leverage the technology.

This paper will discuss five technological applications that are critical for refineries who intend to grow their technological maturity in order to achieve best-in-class operational efficiency.

1. Heat exchanger maintenance & monitoring
2. Column operations troubleshooting
3. Integrated refining & gas plant analysis
4. Planning model update
5. Refinery-wide process analysis

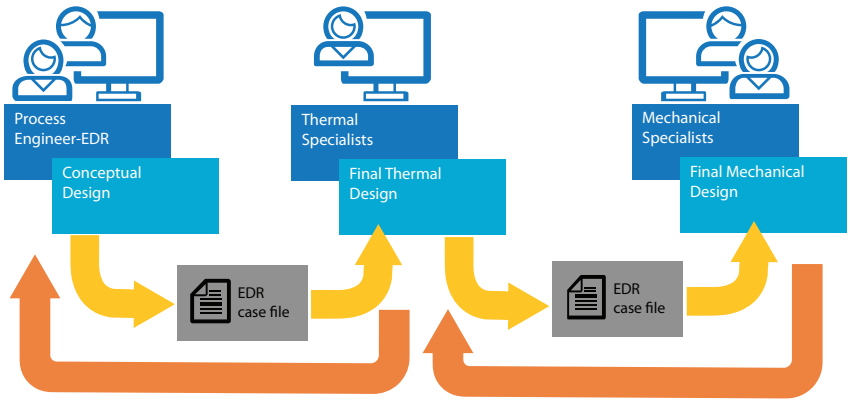
1. Heat Exchanger Maintenance & Monitoring

Since refineries run continuous process operations at low profit margins, any operational inefficiencies or outages have a huge impact on their bottom line. Heat exchangers are a critical part of the refining process and play a crucial role in determining energy efficiency. Refineries employ a number of heat exchangers of varied types, and the heat exchanger network layout can impact fuel consumption quite considerably. The nature of process streams in a refinery causes frequent fouling of heat exchangers, reducing their effectiveness. This also reduces energy utilization and increases fuel consumption. To avoid this, heat exchangers must undergo routine cleaning and maintenance. The challenge for refineries is in determining the right time to take out each of the heat exchangers for maintenance so profits are not affected. The economic benefit from cleaning is different for each heat exchanger unit. So in order to prioritize them, a rigorous simulation of heat exchanger operation is essential.

Rigorous simulation of heat exchanger unit operations within the broader process model allow refineries to determine the fouling level in each of the units and the economic impact they have on the overall process. This helps refineries set up a prioritized maintenance schedule for the heat exchanger network, designed to sustain refinery profits. Engineers are challenged by inefficiencies that stem from the disparate tools used for process simulation and heat exchanger design. Most often, the links between these tools (because they are supplied by different companies) are nonexistent or weak, requiring users to manually enter data back and forth. This makes the workflow followed to get a useful simulation of the heat exchanger network operation inefficient and time consuming, and as a result, too tedious for refineries to pursue.

To overcome this challenge, refiners should look for solutions with seamless integration between process simulator and heat exchanger design and rating tools. This enables rigorous simulation of heat exchanger operations within the broader process simulation model. The heat exchanger design tool, needless to say, must be able to simulate all major heat exchanger types used in the refining industry. Furthermore, process engineers can easily develop and integrate rigorous simulation for their heat exchanger units as part of the refinery flowsheet without leaving their familiar simulation environment. Also critical to success is a platform that enables operations data to be easily brought into the simulation environment for improved operational decision-making.

AspenTech offers such a solution with its comprehensive integration of Aspen HYSYS® (our process simulation software) with Aspen Exchanger Design & Rating (also known as EDR, our heat exchanger design and rating software). Aspen EDR is based on technology developed from over 40 years of heat exchanger research and can model all major heat exchanger types used in the refining industry. Process engineers can easily develop and integrate rigorous simulation of their heat exchanger units as a part of the refinery flowsheet without leaving their familiar Aspen HYSYS environment. Process engineers can easily model rigorous simulation of heat exchanger units in their process flowsheet by simply entering data from the specification sheet of the heat exchanger unit, when it is available, or by letting the interactive design capability in the software develop the model. Seamless integration of the simulation software with Microsoft Excel, through Aspen Simulation Workbook™, offers a well-integrated platform that brings together operations data and simulation tools together to determine the fouling levels and the fouling trend for each of the heat exchanger units, in addition to the economic impact each would have on the overall process profitability. Hindustan Petroleum's refinery in Mumbai, India saved over $250,000 (USD) on an annual basis, in addition to a great deal of their plant engineers time, from an improvement in their heat exchanger maintenance schedule using AspenTech software.



Similarly, while considering process changes or improvements, refineries can easily model different alternative heat exchanger networks with rigorous models for each of the units. The solution set offers process engineers, who might not have expertise in costing or equipment design, the ability to conduct a preliminary cost (both capital and operating) evaluation for alternative network designs. They can also use the software to predict the potential for mechanical equipment issues such as vibration, material erosions, etc. The Tupras refinery in Turkey estimated a 20% reduction in their fuel consumption from an improved heat exchanger network layout the refinery engineers developed using Aspen Technology software.

Refineries who are at either maturity level zero, with no heat exchanger simulation model set up, or at maturity level one, where it is set up for only process engineers to use heat exchanger simulation models, stand to gain from considerable improvements in their profit margins by moving into maturity level two and three where the simulation tools and plant data can be brought together and made available to plant engineers via a more familiar Microsoft Excel interface. This way plant engineers can make well informed maintenance schedules and set in place a more proactive maintenance culture.

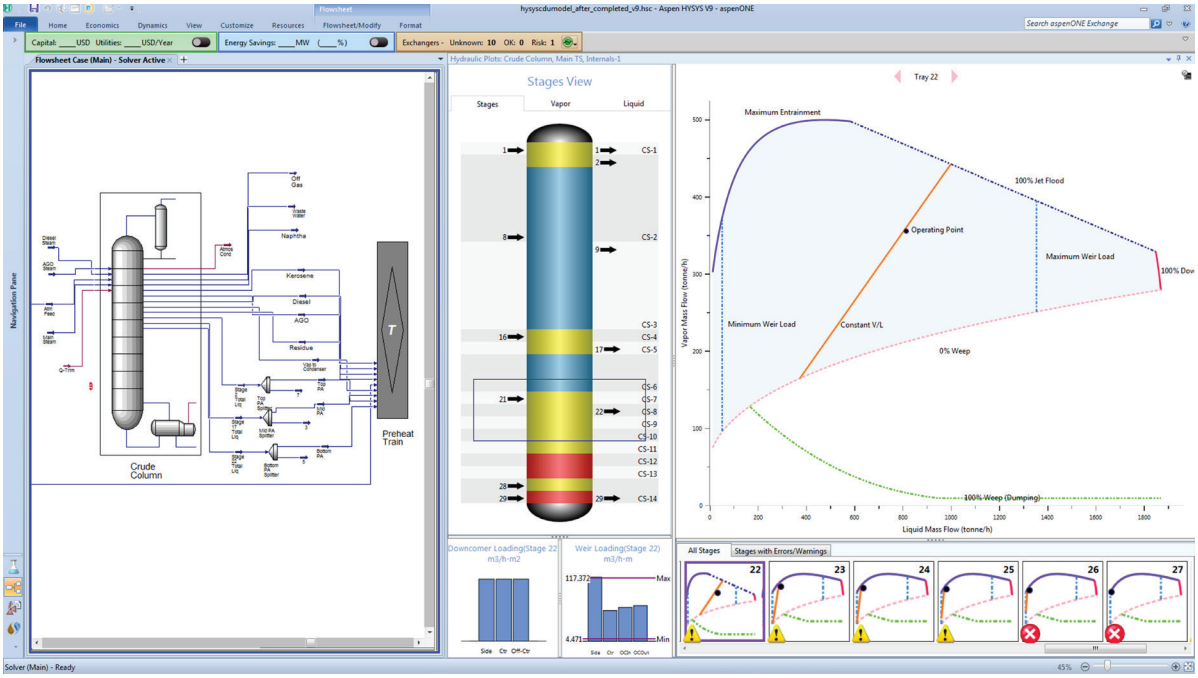
2. Column Operations Troubleshooting

When refinery operators observe issues with their column operations such as column weeping and flooding, they usually have to resort to their past experiences to temporarily relieve the situation. This is because, as mentioned before, the nature of the refining business does not allow for frequent shutdowns for inspection or troubleshooting. However, these ad-hoc methods are available to only those operators who have had years of experience with the unit. Furthermore, these operational tweaks may only provide temporary relief and could lead to non-optimal functioning of the broader process unit. Another issue is that this lack of insight into the internal operations of the column forces refineries to operate columns very conservatively to meet product specifications. This causes additional energy to be consumed in reboilers and reflux condensers, increasing costs.

The ideal solution is one which can shed light on the root cause of operational issues without requiring a unit shutdown or expensive physical inspections. It would be ideal if the solution can offer visualization into the operating point of the unit. Visual presentations can be very effective when process engineers want to communicate their analysis to operators and plant engineers. In addition to visualization capabilities, engineers can use the same solution to predict the impact of alternative courses of actions and select the most optimal. In other words, this approach brings intelligent insights to operators, helping them maintain optimal operation while considering thermodynamic and hydraulic limitations. This solution calls for an integrated process simulator that can accurately simulate the hydraulics of the column unit. The challenge with many types of process simulation software is that they do not have the necessary rigor to provide enough information on column operations. This rigor is needed to give the process engineers the confidence to make effective operating decisions. Without this, engineers have to conduct their analysis through the tedious workflow of switching back and forth between separate software tools for process simulation and column analysis.

The process simulation software from AspenTech, Aspen HYSYS, enables users to accurately simulate thermo-hydraulic functioning of columns based on their construction and operating conditions. As a result, users can better understand the behavior of their columns and avoid operational mishaps. Simulating the operation of the column unit in the broader setting of the overall process enables users to identify root causes of the problems and figure out the optimal point of operation for the overall process unit. Moreover, the visualization tools can provide insight into the operating point of the column and impending breach of operational limits causing issues such as jet flooding, weeping, down-comer backup and others. This capability provides refiners with the confidence needed to optimize column capacity and operate columns closer to the limits.

This capability allows refineries who are in maturity level zero to move into higher maturity levels and thereby build up a work culture of continual process optimization and preventive maintenance by taking advantage of advanced process simulation technology.



3. Integrated Refining & Gas Plant Analysis

Petroleum refineries utilize many integrated complex processes that can make it difficult to maximize margins while meeting production targets, product specifications and regulatory requirements. In recent years, refinery crude slates have diversified significantly, as refiners try to increase margins by lowering feed costs. As crude oils and unconventional feedstocks continue to get heavier and more sour, increasing demand is being placed on processes in the downstream gas plant, such as acid gas treating and sulfur recovery. Refiners must continue to meet the same emissions standards with these challenging feeds. To do this, refiners need an accurate assessment of their downstream sour gas cleaning capacities to determine the extent to which they can take advantage of sour crude.

A solution that rigorously simulates the entire gas plant, including acid gas treatment units, sulfur recovery, tail gas units and flare systems, together with the mainstream refining process units, such as distillation units and reactor units, would be ideal for refineries who are looking for ways to maximize their profit margins by accommodating more sour crude. This would give the refiners enough confidence to push the levels of sour crudes closer to the limit the refinery can process while meeting all the regulations.

AspenTech offers the capability to accurately simulate the gas plant processes in conjunction with refining processes using Aspen HYSYS. The combination of rigorous rate-based distillation modeling capability for acid gas treatment, the industry standard sulfur recovery unit modeling technology (Sulsim™ Technology), flare system analyzer and the mainstream refining process unit simulation capabilities enables engineers to have an accurate simulation of the refining and gas plant operations in one simulation environment. This allows refinery operators to assess whether or not they can

accommodate increased levels of sour crudes in their refinery, and pre-emptively adjust operations in the gas plant accordingly. Feed flexibility, capacity creep, and OPEX optimization enabled via integrated refining and gas plant modeling can save refiners millions of dollars each year in operating margins, while ensuring maximum reliability and plant on-stream time. In addition, the rigorous simulation of the gas plant operation offers refineries visibility and ability to better document their emission levels.

This capability is valuable to refineries in any of the maturity levels to progress in technological maturity in order to boost their profit margins.

As many companies have continuous and batch processes, it's critical to have data management, visualization and analysis capabilities that cover the unique requirements of both. Look at manufacturing master data management to simplify the integration of information across business domains and workflows.

4. Planning Model Update

Refineries use planning tools to make decisions on how to run their operations. Decisions on what crude oil to process, what product slate to produce and how to operate the refinery so as to maximize profits, are made by considering the continually fluctuating global market and the capacity constraints of the refinery. Traditionally linear programming (LP) models[1] are employed by these planning tools to analyze hundreds of alternative options in order to find the most optimal plan. These LP models are relatively fast in analyzing the numerous scenarios that the planners are required to process on a daily basis. One limitation of the LP models employed by these planning tools is that they are accurate only within a specific operating range of the refinery. Over time the refineries move away from that operating range, for example due to catalyst deactivation or other operational changes. As a result, LP models get outdated. The outdated model reduces the effectiveness of the planning tools in helping with the most optimal operational decisions, which could potentially cost millions in lost profits. Many refineries are dependent on expensive external consultants and experts to update their planning models, which costs more time and money. In addition, any delay in updating the planning model can cost huge amounts in lost profit.

The ideal solution to this challenge is a technology that offers a streamlined workflow to update the planning models, enabling frequent updates and when the models are observed to be out of sync with the operating range of the refinery. The workflow needs to be one that can be followed by the refiners themselves, rather than having to stay dependent on expensive outside consultants. Process simulation software is a key part of this solution as they have the predictive capability that comes with rigorous process analysis based on reaction kinetics and heat and mass balance.

[1] *Modern planning tools based on non-linear models, such as Aspen PIMS-AO™ from Aspen Technology, has been making significant improvements to refinery plans recently.*

Aspen HYSYS helps refineries in ensuring that their planning models are always pertinent. The integration between Aspen PIMS™, the world's leading refinery planning software, and Aspen HYSYS enables a streamlined workflow to update planning models. Several points of integration between the software, such as shared assay management tools, shared crude distillation models, and others, combined with their seamless integration into Microsoft Excel, offer an easier way to update of planning models. This enables refineries to maintain their planning models and sustain higher profits. Japan's Taiyo Oil Company increased their profit margin by 12.7% using Aspen HYSYS to improve the linear programing (LP) models used in their planning and scheduling tools.

This application helps all refineries who are in maturity levels three or below to grow to maturity level four, where there is a culture of true partnership between planners and process engineers in maintaining planning and scheduling tools to maximize and sustain refinery profits.

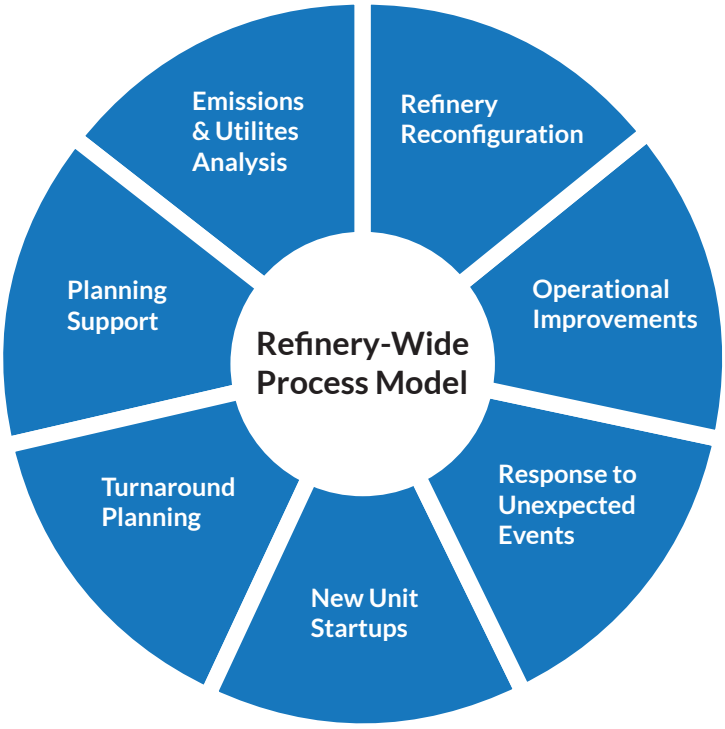
5. Refinery-Wide Process Analysis: The Pinnacle of Technological Maturity

The scale and complexity of refining processes poses a big challenge to refineries in their effort to conduct a holistic analysis of their operation. LP models offer a feasible approach to such an analysis. However, as discussed previously, their accuracy is limited to a specific operating range of the refinery and they lack the necessary rigor for many applications outside planning. For instance, when refiners need to make an accurate prediction of the effect of an unusual crude feedstock or a new reactor catalyst on the overall process, make changes to the processes to meet new regulatory requirements, or decide how to operate the refinery in face of an unexpected unit breakdown, the linear programing tools might not be sufficient. The alternative option of a rigorous refinery-wide process simulation model is often too cumbersome and expensive for any practical use.

In short, what refineries need is a manageable way to analyze the refining operation, in its entirety, with sufficient rigor and flexibility. In other words, they need a solution that will provide the rigor of a process simulator, but without the complexity and expenses entailed with a rigorous refinery-wide process simulation model. The solution should be one that can be maintained in-house without having to stay dependent on expensive consultants.

AspenTech offers a unique way of developing a refinery-wide process simulation model that is both manageable and accurate. The integration between Aspen PIMS and Aspen HYSYS enables refineries to develop a refinery-wide process model out of their refinery-wide planning model in a relatively short period of time. The accuracy of the simulation model can be enhanced by selectively incorporating rigorous models of reactor units to the refinery-wide flowsheet. In this methodology users have full control over the level of rigor and flexibility of the model. The model can be used for rigorous profit-margin analysis, when evaluating strategic reconfiguration options or operational improvements to the refinery. This will also be a handy tool in evaluating responses to unexpected operational events, and in determining turnaround and start-up plans.

Refinery-wide process analysis is for every refinery who would like to reach the pinnacle of technological maturity. Refineries using this refinery-wide model are at level four. They use the model to accurately assess the economic impact of possible strategic reconfiguration projects. They also use the same model to support planners for special cases when they need a more accurate assessment than what is projected by their LP tools.



A crucial element for refineries to grow their technological maturity level is to have employees skilled in the latest technology and abreast of industry best practices. With more than 35 years of experience in the field of process simulation and the widest user base across the world, AspenTech brings in a wealth of best practices and innovative technologies to users. Ambitious process engineers can continually develop their skill sets and process knowledge to become world-class engineers. AspenTech is the singular technology partner who can present refineries with a comprehensive end-to-end solution platform that they can use to improve their technological maturity in order to achieve world-class operational efficiency.

Solutions from AspenTech are set up to support any refinery irrespective of their maturity level. The user-friendly interfaces in the software, coupled with training tools such as video viewlets, jump start guides, and large collections of example models, are all available from within the product and enable engineers in refineries who do not have experience using simulation software to quickly get up-to-speed using them.

AspenTech will be taking our users on a journey where they will learn more about the applications discussed here and train on how to leverage these best practices to boost refinery efficiency and profits. If you would like to be part of this journey, please **register for our upcoming webinar** on how to update your refinery planning models.

AspenTech is a leading supplier of software that optimizes process manufacturing — for energy, chemicals, engineering and construction, and other industries that manufacture and produce products from a chemical process. With integrated aspenONE® solutions, process manufacturers can implement best practices for optimizing their engineering, manufacturing, and supply chain operations. As a result, AspenTech customers are better able to increase capacity, improve margins, reduce costs, and become more energy efficient. To see how the world's leading process manufacturers rely on AspenTech to achieve their operational excellence goals, visit **www.aspentech.com**.

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