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A Methodology for the Systematic Modernization of Gas Condensate Treatment Facilities: From the Diagnostics of Process Constraints to the Replication of Engineering Solutions

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Abstract

The methodology examines the systematic modernization of gas condensate treatment facilities that operate with elevated carbon dioxide content and a heavy hydrocarbon composition, where field conditions diverge from the design assumptions. The relevance of the work follows from a recurring industrial situation in which stable emulsions, incomplete phase separation, and local hydraulic resistances degrade product quality and increase hydrocarbon losses, while the prevailing engineering response addresses each fault in isolation. The novelty consists of an integrated decision algorithm that unites multi-criteria equipment prioritization, dual-hypothesis verification through laboratory testing on actual media and mathematical modeling, classification of engineering solutions by type of action, quantitative acceptance over a defined observation period, and a formalized replication procedure. Field application confirms the approach, as two modernized buffer vessels discharged 109 cubic meters of water-methanol solution over 120 days, and replacing a control valve with a spool reduced the pressure drop from 0.26 to 0.02 megapascals. The methodology benefits process engineers responsible for treating gas and gas condensate.

Keywords: *Gas Condensate Treatment, Process Modernization, Phase Separation, Corrosion Inhibitor, Mathematical Modeling, Three-Phase Separation, Hydraulic Optimization, Acceptance Criteria, Solution Replication.*

INTRODUCTION

Gas and gas condensate treatment facilities at fields with high carbon dioxide and heavy hydrocarbon content encounter operational complications that the design solutions did not anticipate (Tengku Hassan et al., 2022). The most consequential among them are the formation of stable emulsions during CO_2 corrosion-inhibitor injection, the insufficient efficiency of phase separation, liquid carryover under variable operating regimes, and hydraulic constraints in the condensate transport system (Behnam Motlagh et al., 2026; Iakhin, 2026a; Zubkov, 2026a). These complications interact with one another, so an emulsion that forms upstream propagates into vessels intended for cleaner feed, and a hydraulic limitation that was invisible at design throughput becomes binding as production grows. Existing approaches to the modernization of such facilities remain local in character, since each problem receives an isolated remedy without systematic diagnostics and without a formalized decision procedure, and the transition from a pilot installation to wider deployment usually proceeds without clear quantitative criteria.

The aim of the methodology is to provide process engineers with a reproducible algorithm for identifying process constraints and selecting optimal engineering solutions during the modernization of gas condensate treatment facilities. The aim addresses a concrete operational need: engineers who face a stable deviation require a structured path from symptom to confirmed remedy.

The methodology pursues several tasks. It systematizes approaches to the diagnostics of process deviations, formalizes procedures for hypothesis verification, defines criteria for the selection of solution type, and establishes quantitative acceptance criteria along with the conditions for replication. Each task corresponds to a stage of the algorithm, so the tasks together describe a continuous workflow.

The scientific novelty consists of the first proposal of an integrated modernization algorithm that unites five

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components. Figure 1 presents the five-stage algorithm that forms the backbone of the methodology, where each stage feeds the next and the final stage returns its conclusions to the design of new objects.

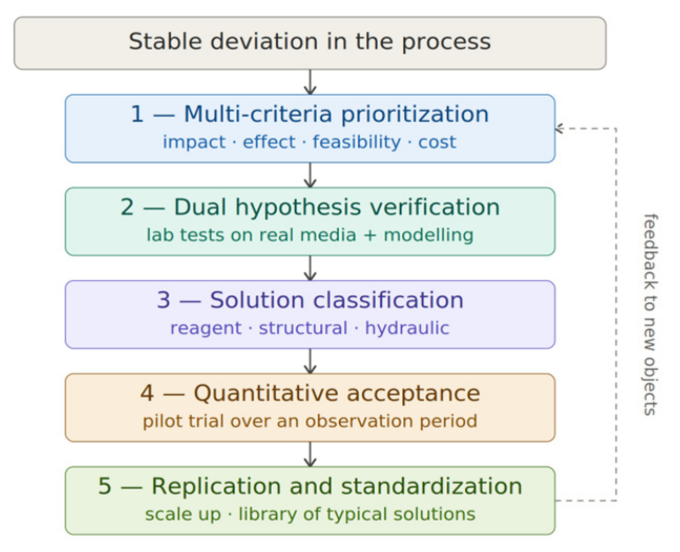

Figure 1. Five-stage algorithm of the systematic modernization methodology

The first component is the multi-criteria prioritization of equipment, which weighs a unit's influence on the system, the scale of the achievable effect, the feasibility of the work, and the economic value. The second component is dual verification of hypotheses, combining laboratory testing on actual media with mathematical modeling and computational-experimental confirmation where the deviation depends on the operating envelope of separation equipment (Iakhin, 2025). The third component is the classification of engineering solutions by type of action, comprising reagent, structural, and hydraulic solutions, along with the criteria governing the choice between them. The fourth component is the set of quantitative acceptance criteria assessed over a defined observation period. The fifth component is the formalized replication procedure that moves from a pilot through accumulated statistics toward wider deployment. The combination matters more than any single element, since the value of the methodology arises from how the stages constrain and inform one another.

CHAPTER 1. DIAGNOSTICS OF PROCESS CONSTRAINTS AND PRIORITIZATION OF EQUIPMENT FOR MODERNIZATION

This chapter lays the foundation for the methodology, because without systematic diagnostics, it is impossible to determine which equipment to modernize first and which type of solution to apply. The treatment scheme that frames the discussion is shown in Figure 2, which depicts the path of the reservoir fluid through separation, the liquid divider, the weathering vessel, and the buffer-vessel block toward the condensate pipeline, along with the aqueous-phase off-take introduced by the modernization.

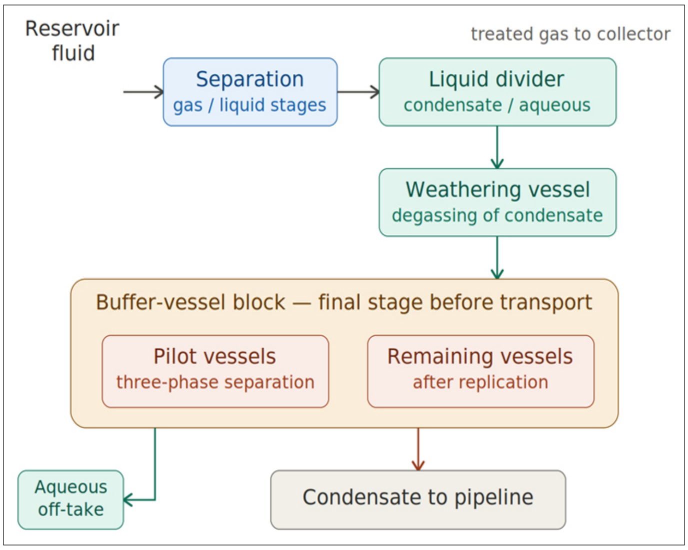

Figure 2. Generalized low-temperature separation scheme with the buffer-vessel block

Identification of Stable Process Deviations

The identification of a deviation begins with its classification, since the nature of a fault directs the subsequent search for its cause. The first class covers the unstable operation of equipment, which manifests as the actuation of protective systems, the failure of level gauges when the calculated and actual phase densities diverge, and the shutdown of pumps due to cavitation protection. The second class covers deterioration in product quality, which manifests as water content in the condensate exceeding the permissible value or as liquid carryover from gas-separation equipment under fluctuating flow rates, pressures, and fluid compositions (Iakhin, 2026a). The third class covers the growth of hydrocarbon losses, which manifests as gas discharge to the flare.

The fixation of a deviation relies on several methods that complement one another. Analysis of data from the supervisory control and data acquisition system reveals trends over long intervals (Wang et al., 2025); laboratory control of the stream composition establishes the chemical state of the media; and monitoring operational parameters captures the dynamic behavior of the equipment. The criterion of stability separates a single random excursion from a systemic problem, because only a deviation that recurs across many regimes justifies the effort of modernization.

A practical example clarifies the distinction. During operation, a facility recorded repeated actuations of the pump cavitation protection system, along with intermittent level-gauge failures, and supervisory data showed that these events coincided with periods when the actual phase density deviated from the calculated value. A single such event would have warranted only a routine check, yet the recurrence across multiple operating regimes identified the behavior as a stable deviation that demanded a root-cause investigation.

The numeric record of the same case supports the classification. The supervisory archive showed that the density of the aqueous phase drifted between 0.98 and 0.99 tonnes per cubic meter, while the mineralization varied from about 550 to 1450 milligrams per cubic decimetre over a single month. The level gauges that the project tuned to a fixed density misread the interface and triggered the protections. The water content in the condensate reached values above 1.2 percent during the same intervals, exceeding the permissible threshold and confirming the second class of deviation. The free gas that accumulated at 7.5 to 10 thousand cubic meters per hour and the flare discharge of nearly 22 cubic meters per hour completed the picture of the third class. The convergence of three independent records across the month established the deviation as systemic and justified the transition to a root-cause search, since a single reading could never carry that weight.

Establishment of the Root Cause

The identification of the root cause proceeds through the analysis of the composition of the process streams, since the introduction of reagents and changes in the reservoir fluid properties alter the behavior of the phases. The analysis examines the influence of methanol and the corrosion inhibitor, both of which can modify the interfacial properties that govern separation (Xin et al., 2025; Zubkov, 2026a). Where the composition explains the deviation, the search narrows toward a reagent interaction, especially when the corrosion inhibitor stabilizes a water-methanol and hydrocarbon emulsion rather than merely protecting equipment from CO_2 corrosion.

Comparing process parameters across different points in the scheme reveals connections between deviations that appear unrelated when viewed in isolation. A rising level in one vessel, a falling discharge in another, and a fluctuating density in a third can together indicate the formation of a stable water-condensate emulsion and of a gas-water-condensate foam zone. The comparison, therefore, converts a set of separate symptoms into a single mechanistic hypothesis.

A calculation check completes the investigation, because a hydraulic constraint or a mismatch between the design and the actual throughput can reproduce the observed symptoms without any chemical cause. When the calculated capacity of a node falls below the actual flow, the deviation traces to hydraulics and excludes a reagent interaction, and the diagnosis directs the engineer toward a different class of solution.

A practical example shows the method in operation. A facility observed degraded separation, along with a foam zone, in the liquid divider, and analysis of the stream composition linked the behavior to the corrosion inhibitor dissolved in the reservoir water. Comparing levels and discharges across the divider, the weathering vessel, and the buffer vessels confirmed that the aqueous phase carried over with the condensate, while a parallel hydraulic calculation ruled out throughput as the cause. The investigation isolated a reagent-driven emulsion as the root cause.

The quantitative trace of the same investigation reinforces the conclusion. The residual content of the corrosion inhibitor in the aqueous phase ranged from about 250 to 3300 milligrams per cubic decimetre across the sampling period, and the methanol mass fraction varied from about 4 to 23 percent, so the divider received a feed whose interfacial chemistry shifted from day to day. The volumetric content of condensate carried into the aqueous phase reached values above 1% on the days of the highest inhibitor residual, tying the carry-over directly to the reagent load and clearing the mechanical equipment of blame. The correlation between the inhibitor residual and the carry-over, observed across many days, provided the hypothesis with a numerical foundation that a single sample could not.

Multi-Criteria Prioritization of Equipment

The prioritization of equipment is based on four criteria that, together, convert engineering judgment into a transparent ranking (da Silva et al., 2021). The first criterion is the influence of a node on the system as a whole, which depends on its position in the process chain and on the total volume of its apparatus. A node that occupies the final stage before transport and that offers a large working volume carries a high weight, because a change there propagates to the product and to every downstream object.

The second criterion is the scale of the potential effect, which the methodology measures through reductions in losses, elimination of causes of shutdowns, and assurance of product quality. The third criterion is feasibility, which considers the possibility of staged implementation without a facility shutdown, the availability of materials, and minimal intervention in the apparatus construction. The fourth criterion is economic justification, which compares the cost of the work to its expected effect.

Table 1 presents the prioritization matrix recommended by the methodology, in which each candidate node receives a score for the four criteria, and the total score guides selection. The matrix does not replace engineering judgment, yet it records the reasoning in a form that others can examine and reproduce.

Table 1. Multi-criteria prioritization matrix for equipment selection

Criterion	System influence	Effect scale	Feasibility	Economic value
Buffer-vessel block	high	high	high	high
Liquid divider	high	medium	medium	medium
Pressure header	medium	medium	high	high
Weathering vessel	low	low	medium	medium

A practical example demonstrates the matrix's application. On the facility under discussion, the buffer-vessel block scored highest against every criterion, because the vessels formed the last stage before condensate transport, because their combined volume exceeded the volume of the upstream separators by a factor of about two and a half, and because their internal space offered an opportunity for the additional capture of the aqueous phase. The high feasibility stemmed from the option to take individual parallel vessels out of service without stopping the facility, and from the option to fabricate the internal elements using the repair service's resources. The matrix, therefore, directed the modernization to the buffer-vessel block as the first priority.

CHAPTER 2. METHODS OF VERIFICATION OF PROCESS HYPOTHESES

This chapter describes the instruments used to test the hypotheses derived from diagnostics, and the dual verification through laboratory work and modeling reduces the risk of implementing an ineffective solution. The two instruments answer different questions: the laboratory establishes the chemical and interfacial behavior of the media, while the model establishes the hydraulic and thermal behavior of the system. A solution that passes both tests rests on a firm foundation.

Laboratory Testing on Actual Process Media

The methodology rejects the standard bottle test on model media as the primary evidence, because a test on a kerosene-sodium chloride system does not reproduce the actual operating conditions and can therefore mislead the engineer. The standard test retains a role as a preliminary screening, yet the decisive evidence must come from media that approximate the real streams, namely gas condensate, reservoir water with methanol, and the corrosion inhibitor under study. This requirement is especially important for CO_2-corrosion inhibitor systems, where reagent concentration can produce a nonlinear deterioration of separation quality and where the demulsifier must be assessed as part of the same multifunctional reagent formulation (Zubkov, 2026a).

The procedure runs the tests in series on a control sample without the inhibitor and on samples with the inhibitor at several concentrations, and it varies the ratio of the studied media. For each sample, the procedure records the time of onset of separation, the time of complete separation, the presence of a stable emulsion, the presence of foam, the character of the interface, and the presence of a residual aqueous phase in the hydrocarbon phase. The breadth of the recorded parameters allows the engineer to distinguish a partial improvement from a genuine resolution.

Table 2 reports the results of such a series for a corrosion inhibitor in the system of condensate, reservoir water, and methanol, across inhibitor concentrations from 5% to 60%. The data show that a stable emulsion formed across all regimes, indicating the negative effect of the inhibitor on phase separation efficiency and justifying the search for a reagent solution.

Table 2. Laboratory phase-separation results across inhibitor concentrations

Inhibitor concentration, %	Onset of separation, min	Stable emulsion	Interface character
0 (control)	clear	absent	sharp
5	delayed	present	diffuse
20	delayed	present	diffuse
60	strongly delayed	present	foamed

A practical example links the table to a decision. The series confirmed that the inhibitor produced a stable emulsion at every concentration the facility might use, so the engineer could exclude a simple change in dosage as a remedy and direct the design toward a reagent solution that modified the inhibitor composition (Behnam Motlagh et al., 2026). The laboratory result thereby selected the solution class before any equipment was touched.

Mathematical Modeling of Process Operations

The modeling of the trunk and connecting pipework proceeds in an established process simulation environment, and the calculation employs the standard correlations of the Beggs and Brill method for the two-phase flow (Beggs & Brill, 1973). The model represents the geometry of the pressure header, the parallel branches, and the local resistances, so it can reproduce the distribution of pressure and velocity along the path of the working medium (Ahmed et al., 2024). Where the deviation is linked to separation efficiency rather than pipe hydraulics, the same logic is extended to the operating envelope of separation internals, because gas-dynamic separation under variable flow regimes depends on swirl generation, radial pressure gradients, residence time, droplet capture, and liquid carryover (Iakhin, 2026b). The fidelity of the model depends on integrating the actual operating data, including the pressures, temperatures, flow rates, and densities the facility records.

Figure 3 shows the hydraulic model of the pressure header before and after the retrofit, where the local resistance of a control valve produces a high velocity and a large pressure drop in the original arrangement, and replacing the valve with a spool removes the resistance and restores a moderate velocity. The model, therefore, predicts the effect of the intervention before any work occurs on the facility.

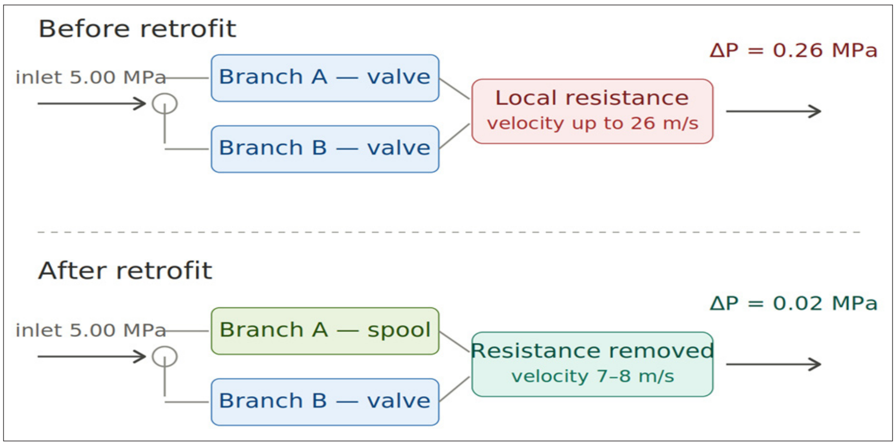

Figure 3. Hydraulic model of the pressure header before and after the retrofit

Table 3 reports the calculated parameters in the header for the two arrangements, and the figures confirm that replacing the valve with a spool reduces the velocity at the constriction and lowers the pressure drop from 0.26 to 0.02 megapascals at increased throughput.

Table 3. Calculated header parameters before and after the retrofit

Parameter	Unit	Before	After
Condensate flow rate	t/h	252.5	350.0
Velocity at the constriction	m/s	up to 26	7 to 8
Pressure drop across the node	MPa	0.26	0.02
Nominal node capacity	m3/h	285	restored

A practical example shows the modeling in use. The original arrangement carried two control valves whose summed nominal capacity reached 285 cubic meters per hour, while the actual flow approached 375 cubic meters per hour, so the valves imposed a velocity near 26 meters per second at the constriction and a pressure drop of 0.26 megapascals. The model with one valve replaced by a spool predicted a velocity of 7-8 meters per second and a pressure drop of 0.02 megapascals at a throughput of 350 tonnes per hour, which justified the replacement before the planned shutdown.

The predictive run also converts the retrofit into a measurable forecast that the field can later check. The model reported that the spool would maintain a velocity of 7-8 meters per second, even at the raised throughput of 350 tonnes per hour, so the pressure drop fell by an order of magnitude from 0.26 to 0.02 megapascals. The agreement between this forecast and the later field record, where the required discharge pressure dropped by about 0.28 megapascals and the energy consumption of the pumping group fell from about 924 to 693 kilowatt-hours, closed the loop between calculation and measurement. The model thereby served not only as a design tool but as the standard against which the field result was judged.

Integration of the Laboratory and Calculation Results

The integration of the two streams of evidence yields the decision about the transition to design. The methodology treats the laboratory and calculation data as sufficient when they converge on a single mechanism and when the predicted effect exceeds the measurement uncertainty. For separation equipment operating outside its original design envelope, the calculation may be supplemented by computational-experimental confirmation of the effective operating zone, because maintaining the operating point within the optimal velocity range is a prerequisite for limiting carryover and avoiding unnecessary replacement of the apparatus (Iakhin, 2025). Where the laboratory establishes a chemical cause, and the model confirms that hydraulics play no role, the engineer can proceed to design with confidence.

Some cases require additional field testing to confirm the laboratory results, because bench tests cannot reproduce the residence time, turbulence, and scale of an industrial vessel. When the laboratory result depends on a parameter that the bench cannot reproduce, a limited field trial precedes the wider design. The methodology admits a third source of evidence when the first two leave a residual doubt.

The documentation of the verification results supports subsequent coordination with the design institute and the equipment manufacturer, as a clear record of evidence enables external parties to assess the proposal. A practical example illustrates the integration, because on the facility under discussion, the laboratory established the emulsion and the model excluded a hydraulic cause for the carry-over of the aqueous phase, so the two results together directed the work toward a structural solution inside the buffer vessels and supported the coordination of that solution with the process developer.

CHAPTER 3. DESIGN, IMPLEMENTATION, AND ASSESSMENT OF THE EFFECTIVENESS OF ENGINEERING SOLUTIONS

This chapter forms the center of the methodology and unites the three types of solution into a single classification, using the criteria of choice, the principles of implementation, and the quantitative assessment of the result. The classification provides the engineer with a vocabulary for decision-making, as a clear correspondence between a root cause and a type of solution shortens the path from diagnosis to design.

Classification of Engineering Solutions and the Criteria of Choice

The first type is the reagent solution, which modifies the composition of the applied reagents by adding a demulsifier to the corrosion inhibitor (Yu et al., 2025; Zubkov, 2026a). The engineer selects this type when the root cause lies in the chemical interaction between the reagents and the process media, because changing the equipment alone cannot remove a chemical incompatibility. In CO_2-corrosion inhibitor systems, the reagent solution is justified when the base inhibitor stabilizes the emulsion, while the demulsifying additive restores phase separation without abandoning anticorrosion protection (Zubkov, 2026a). The reagent solution acts on the cause and leaves the equipment untouched.

The second type is the structural solution, which installs additional internal elements within the existing apparatus, including calming baffles, plate packing, off-take troughs, and a changed point of withdrawal (Shoghl et al., 2021; Zubkov, 2026b). The engineer selects this type when the design construction does not provide the required process efficiency, since the vessel has volume but lacks the internal organization that separation demands. Figure 4 shows the internal devices of a modernized horizontal three-phase vessel, in which the flow equalizer distributes the feed, the plate packing enlarges the separation surface, the light-phase collector and the weir organize the withdrawal, and the separate off-takes deliver the condensate and the aqueous phase to their respective destinations (Shin et al., 2025).

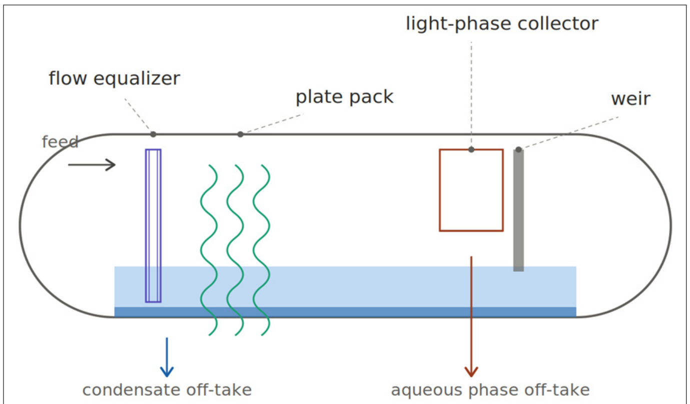

Figure 4. Internal devices of the modernized horizontal three-phase vessel

The third type is the hydraulic or gas-dynamic solution, which removes local hydraulic resistance by replacing the control armature with spools or changing the pipework, and, for separation internals, restores the correspondence between the actual flow regime and the effective operating zone of the apparatus (Iakhin, 2025; Iakhin, 2026b). The engineer selects this type when the design estimate of throughput did not account for the actual operating conditions, because the constraint resides in the geometry of the flow path. A practical example draws the three types together, since the facility under discussion applied a reagent solution to the emulsion, a structural solution inside the buffer vessels, and a hydraulic solution on the pressure header, and the correspondence between each root cause and each type of action confirmed the value of the classification.

The three types differ in the depth at which they act, and the classification orders them by that depth. The reagent solution acts at the level of molecular interaction, the structural solution acts at the level of the internal geometry of one apparatus, and the hydraulic solution acts at the level of the flow path between apparatuses. An engineer who matches the depth of the remedy to the depth of the cause avoids the two symmetric failures of the discipline, namely a heavy structural retrofit applied to a chemical fault and a reagent adjustment applied to a geometric bottleneck. The classification functions as a diagnostic mirror, since the type of solution that fits a problem reveals the level at which the problem truly lives.

Principles of Staged Implementation

The implementation begins with a pilot on a limited number of vessels, achieved by withdrawing individual parallel units without shutting down the facility. The pilot confines the risk to a small part of the system, so an unexpected result affects neither the product nor the continuity of production. The parallel arrangement of the buffer vessels enables such a withdrawal.

The implementation adheres to the principle of minimal intervention into the construction, meaning the installation of internal elements without welding or cutting the shell and supporting the elements on the existing structural members. The principle preserves the integrity of the pressure vessel and reduces the approval required for a shell modification. Fabricating the elements with the repair service's resources reduces both the cost and the duration of the work, as the facility avoids the procurement cycle of an external supplier.

A practical example shows the principles in operation. The facility modernized two buffer vessels first and installed the internal elements without welding the shell, supporting them on the existing internal members, while the repair service fabricated the elements from available materials. The staged approach allowed the facility to observe the behavior of the two vessels before any commitment to the remaining units.

Quantitative Acceptance Criteria and the Observation Period

The acceptance criteria define success in measurable terms and comprise the stable off-take of the target phase, the absence of deterioration in product quality, and the stable operation of the apparatus in its normal regime (Zubkov, 2026b). For gas-separation equipment, the same logic requires confirmation that liquid carryover remains within the permissible range under the actual variability of flow rate, pressure, and fluid composition (Iakhin, 2026a). The criteria exclude a judgment based on a single favorable discharge, because the methodology accepts a solution only on the basis of a series of observations. The criteria protect the organization against a premature conclusion.

The determination of a sufficient observation period rests on the need for a representative statistic, since a period that spans several operating regimes captures the variability that a short period would miss. The methodology sets the minimum duration by the requirement that the data represent the range of conditions under which the equipment operates. Table 4 sets out the acceptance criteria, along with the results of the pilot operation, and the figures confirm that the two modernized vessels met all criteria throughout the observation period.

Table 4. Acceptance criteria and results of the pilot operation

Acceptance criterion	Target	Result
Stable off-take of the aqueous phase	present	confirmed
Aqueous phase in the condensate	absent	absent
Observation period	representative	120 days
Total aqueous phase discharged	recorded	109 m3
Average daily off-take	recorded	about 0.9 m3/day

A practical example completes the section. The two modernized buffer vessels operated for 120 days of pilot service, and across that period they discharged a total of 109 cubic meters of water-methanol solution at an average of about 0.9 cubic meters per day, while the condensate showed no aqueous phase and the vessels held their normal regime. The series of observations across the full period, taken together, established the effectiveness of the solution and justified the recommendation for wider deployment.

The length of the observation period follows from the variability of the feed under a principle that a fixed calendar rule would ignore. Because the inhibitor residual and the methanol fraction in the feed fluctuated widely from day to day, a short window could have captured only a favorable spell and reported a success that the next regime would overturn. A span of 120 days covered the seasonal and operational regimes the facility passes through, so the average off-take of 0.9 cubic meters per day was based on a sample broad enough to capture the daily scatter. The methodology ties the minimum duration to the timescale over which the governing variable changes, thereby supplanting any arbitrary count of days.

CHAPTER4. REPLICATION AND STANDARDIZATION OF SOLUTIONS

This chapter closes the methodology's cycle, carrying the work from a single successful installation toward systematic scaling and the formation of a library of typical solutions. The library should record not only the implemented design but also the applicability boundary: reagent composition and emulsion behavior for reagent solutions, vessel geometry and phase-withdrawal arrangement for structural solutions, and the effective operating zone for hydraulic or gas-dynamic solutions (Iakhin, 2025; Zubkov, 2026a; Zubkov, 2026b). Replication converts a local success into an organizational asset because a documented, repeatable solution serves every facility with the same configuration.

Conditions and Procedure of Scaling

The decision to replicate rests on mandatory conditions, among them a confirmed effect across the established period, the existence of a statistic, and the absence of any negative influence on the adjacent processes. The structural modernization of buffer vessels satisfies these conditions only when the pilot confirms stable withdrawal of the water-methanol phase and absence of aqueous carryover into the condensate, while gas-dynamic modernization of separator internals requires confirmation that the operating point remains within the effective velocity zone after retuning (Iakhin, 2025; Zubkov, 2026b). The conditions guard against the propagation of an unproven solution, because the organization commits to many units only after the pilot has demonstrated a stable result. The technological reproducibility of the construction on similar apparatus completes the conditions, since a solution that depends on a unique feature of one vessel does not scale.

A practical example shows the procedure. The facility extended the structural solution to the remaining four buffer vessels only after the two pilot vessels confirmed stable off-take of the aqueous phase, the absence of carryover into the condensate, and the preservation of the normal regime. The accumulated statistics from the pilot, together with the identical construction of the remaining vessels, satisfied every condition and supported the decision to scale.

Adaptation of Solutions for New Objects

Adapting a solution to a new object begins with considering modernization experience during the design of new installations, which allows the designer to exclude identified bottlenecks at the design stage. A constraint revealed by the methodology at an operating facility becomes a design rule for the next facility, so the organization avoids repeating a known fault. The early exclusion of a bottleneck costs far less than correcting it later.

The application of the developed technical solutions in projects to develop new sections further extends the benefits, as a proven internal arrangement or proven pipework geometry is adopted as a standard element in the new project. A practical example follows from the facility under discussion, since the experience of the buffer-vessel modernization informed the design of the treatment scheme for new sections, which incorporated the organized off-take of the aqueous phase from the outset and thereby removed the need for a later retrofit.

Formation of a Library of Typical Solutions and Documentation of Experience

The structure of a typical solution card underlies the formation of a library, which records the problem description, the method of verification, the technical solution, the result, and the conditions of applicability. The card compresses a complete case into a form that another engineer can locate and apply, because the five fields answer the questions that arise when a similar problem appears elsewhere. The conditions of applicability matter most, since they prevent the transfer of a solution to a situation that does not match its origin.

The organization of the transfer of experience between departments and design organizations completes the standardization, because a library serves its purpose only when the people who need it can reach it. A practical example illustrates the card, since the buffer-vessel solution yields a card that states the problem of aqueous-phase carry-over, the verification through laboratory testing and modeling, the structural solution of internal devices, the result of 109 cubic meters discharged across 120 days, and the condition of an identical horizontal vessel with a parallel arrangement.

CONCLUSION

The methodology systematizes the results into a single algorithm that runs from diagnostics to replication, providing the process engineer with a reproducible path through the five stages. The algorithm unites the multi-criteria prioritization of equipment, the dual verification of hypotheses, the classification of solutions by the type of action, the quantitative acceptance over a defined period, and the formalized scaling, so that each stage constrains and informs the next.

The practical significance follows from the possibility of applying the methodology to similar gas condensate treatment facilities, with confirmed effectiveness, since the field application discharged 109 cubic meters of the aqueous phase over 120 days and reduced the header pressure drop from 0.26 to 0.02 megapascals. These results demonstrate that the algorithm produces measurable improvements when an engineer follows its stages in order. The prospects for development include integrating the methodology with predictive monitoring methods based on supervisory control and data acquisition system data, as well as extending the classification of solution types. A predictive layer would allow the engineer to detect a stable deviation earlier, and a broader classification would accommodate the solutions that future facilities require.

The field results give the chain a concrete measure of its worth across the three types of action. The reagent and structural work captured 109 cubic meters of the aqueous phase across 120 days and held the condensate free of water. The hydraulic work reduced the header pressure drop from 0.26 to 0.02 megapascals and lowered the pumping energy from about 924 to 693 kilowatt-hours, and the gas-equalization work recovered about 1100 thousand cubic meters of gas per year at an effectiveness near 89 percent. A method that demonstrates its effect in such terms transfers to any facility that meets the recorded conditions of applicability.

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