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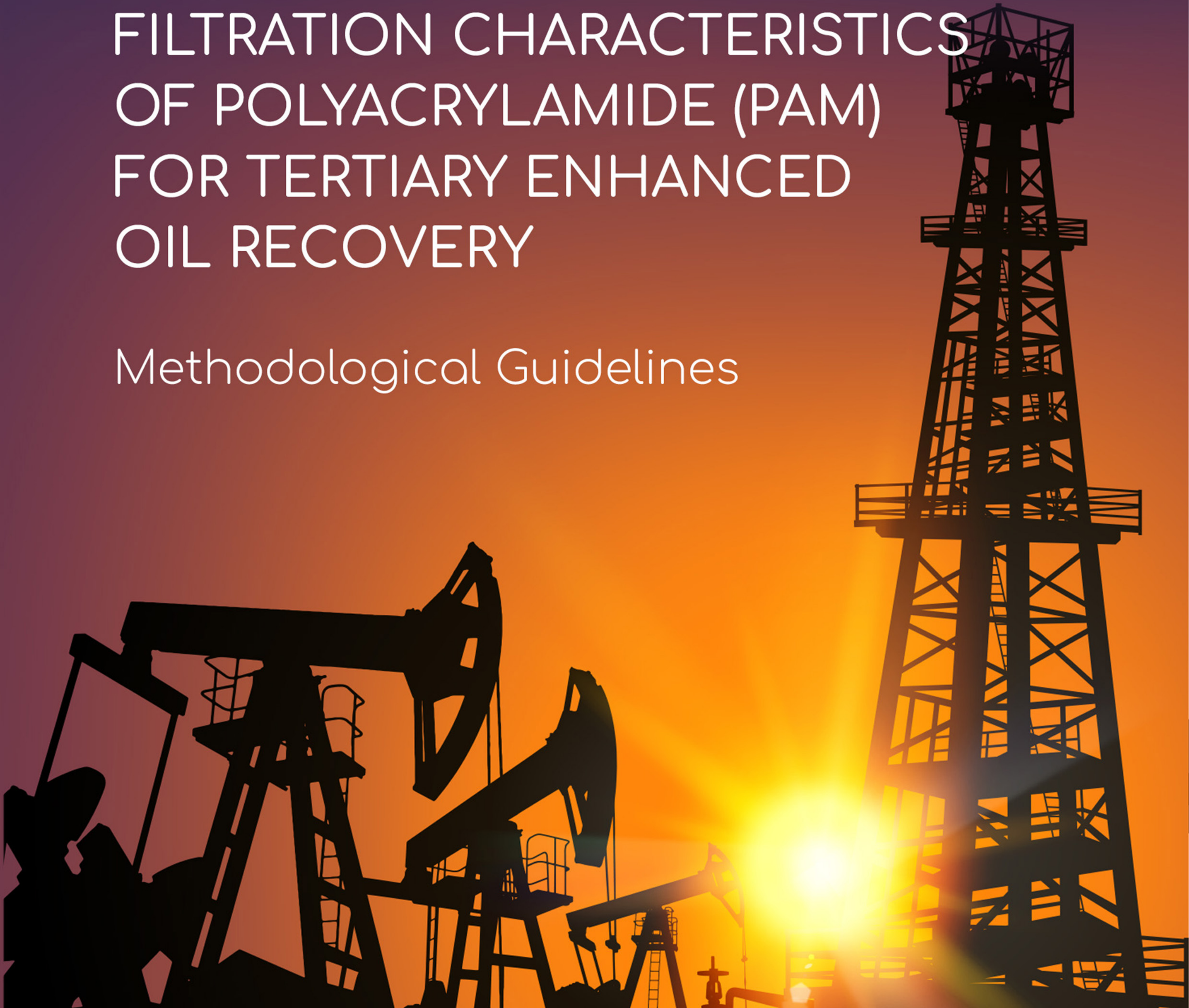
# AN INTEGRATED LABORATORY VERIFICATION METHODOLOGY FOR THE RHEOLOGICAL AND FILTRATION CHARACTERISTICS OF POLYACRYLAMIDE (PAM) FOR TERTIARY ENHANCED OIL RECOVERY

Methodological Guidelines



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## Methodological Guidelines

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The methodology considers a set of laboratory procedures for verifying the rheological and filtration characteristics of polyacrylamide used in tertiary enhanced oil recovery at fields with hard-to-recover reserves. The purpose of this work is to develop a scientifically grounded incoming quality-control protocol that integrates physicochemical identification of the reagent, standardized preparation of model formation waters, and rheological analysis at reservoir-relevant shear rates. The novelty of the methodology lies in tightening the filtration criterion (1.2 μm membranes, FR $\leq 1.2$), strict regulation of the brine ionic composition, and coupling filtration tests with rheological parameters. It is demonstrated that the proposed approach establishes a reliable barrier against off-spec PAM batches, reduces the risks of near-wellbore plugging and injection pressure escalation, and enhances the technological and economic performance of polymer flooding. The methodology will be constructive for laboratories of oil and gas companies, service companies, engineering centers, and specialists involved in the design and monitoring of chemical EOR projects.

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# Introduction

Within the contemporary paradigm of oil and gas field development, an irreversible shift is observed toward an increasing share of hard-to-recover reserves (HTRR) and the exploitation of assets at a late stage of development (Semenova & Sokolov, 2025). Under these conditions, conventional reservoir-pressure maintenance methods, based on the injection of unmodified water, demonstrate declining effectiveness, as evidenced by increasing water cuts in produced fluids and the presence of substantial volumes of residual oil in the reservoir. Tertiary enhanced oil recovery (EOR), particularly physicochemical methods, is gaining the status of critically important technologies for extending the life cycle of fields (Ghorbanpour & Khodapanah, 2025). Among these, polymer flooding occupies a dominant position, based on the addition of high-molecular-weight synthetic polymers, predominantly partially hydrolyzed polyacrylamides (HPAM), to the injected water (Seright & Wang, 2023).

The fundamental mechanism of polymer flooding consists in modifying the rheological properties of the displacing agent. Increasing the viscosity of the aqueous phase reduces its mobility (mobility ratio control), which promotes front stabilization, suppresses viscous fingering, and mobilizes low-permeability layers previously bypassed by water (Seright & Wang, 2023). However, the successful implementation of this technology is inextricably linked to the quality of the chemical reagent used. The use of a polymer that does not meet stringent criteria for filterability and rheological stability poses a high risk of technogenic reservoir damage (Xue et al., 2025). Plugging of the near-wellbore zone (NWZ) by undissolved polymer aggregates, commonly referred to as microgels or fish eyes, results in a catastrophic reduction in injectivity, necessitates costly stimulation operations, and ultimately leads to adverse project economics (Wang et al., 2025).

Historically, laboratory testing practices for polymers have primarily relied on standards developed in the 1980s–1990s, particularly the American Petroleum Institute API RP 63 Recommended Practices for Evaluation of Polymers Used in Enhanced Oil Recovery Operations. Despite their foundational nature, these standards have, in several respects, ceased to meet modern challenges, mainly when operating in low-permeability reservoirs and under stringent requirements for preserving reservoir flow and storage properties. In particular, the API RP 63 filterability test, which uses membranes with a 5 µm pore size, is often insufficiently sensitive for detecting small gel particles capable of blocking pore channels in real core material that may exhibit submicron dimensions (Mai et al., 2023).

The objective of the present work is to formulate an advanced, scientifically grounded laboratory methodology for verifying polyacrylamide that integrates contemporary advances in polymer physicochemistry and reservoir physics. The methodology was developed through the synthesis of requirements and supplemented with current data from global studies over the past five years. A key feature of the proposed approach is the tightening of filtration-test criteria (transition to 1.2 µm membranes), strict regulation of the ionic composition of model media, and accounting for the non-Newtonian behavior of solutions at shear rates characteristic of reservoir conditions. The document is structured according to an academic format and is intended to serve as a normative basis for the incoming quality control of reagents for critical EOR projects.

# Chapter 1. Physicochemical Identification of the Reagent

The first stage in the hierarchy of verification procedures involves confirming the physicochemical identity of the reagent and evaluating its commercial characteristics. At this stage, the foundation is established for understanding polymer behavior in solution, since macroscopic properties of the powder (particle size, density, and moisture) directly correlate with dissolution kinetics and rheological activity. Failing to address this stage or conducting it informally may result in subsequent testing being performed on an inherently off-spec product that has been degraded during manufacturing or logistics.

## 1.1. Requirements for Commercial Form and Visual Inspection

Polyacrylamide for enhanced oil recovery is a product of radical polymerization of acrylamide, often with the addition of acrylate groups (copolymerization or post-hydrolysis) to impart polyelectrolyte properties (Al-Kindi et al., 2022). The commercial form of the reagent is a dry granular powder. Visual evaluation, despite its apparent simplicity, is a powerful tool for primary diagnostics.

A high-quality reagent shall be a white, free-flowing powder free of foreign inclusions. Color uniformity is an indicator of stable temperature conditions during the drying stage in manufacturing. The appearance of yellowish or brownish shades indicates thermal degradation of polymer chains, commonly referred to as scorching, which inevitably leads to a reduction in molecular weight and loss of viscoelastic properties (Gu & Feng, 2024). The presence of dark inclusions may indicate contamination of the product with mechanical impurities or burnt polymer from dryer paddles.

A critically important parameter is the homogeneity of the particle-size distribution. The presence of a significant amount of dust-like particles (smaller than 100 μm) creates high risks during solution preparation. According to polymer dissolution theory, upon contact with water, small particles hydrate instantaneously at the surface, forming a viscous water-impermeable gel shell. If particles are in close contact (as in a dust lump), they adhere into large agglomerates, within which dry powder remains (Chelu & Musuc, 2023). Such formations, known as fish eyes, are complicated to dissolve even with prolonged mixing, and they become the primary agents of reservoir plugging (Wang et al., 2025). Conversely, excessively large granules require unreasonably long hydration times, reducing the efficiency of field preparation processes. Thus, visual control of homogeneity and flowability constitutes the first barrier against low-quality reagents. The algorithm for the incoming visual inspection of commercial polyacrylamide for EOR is shown in Figure 1.

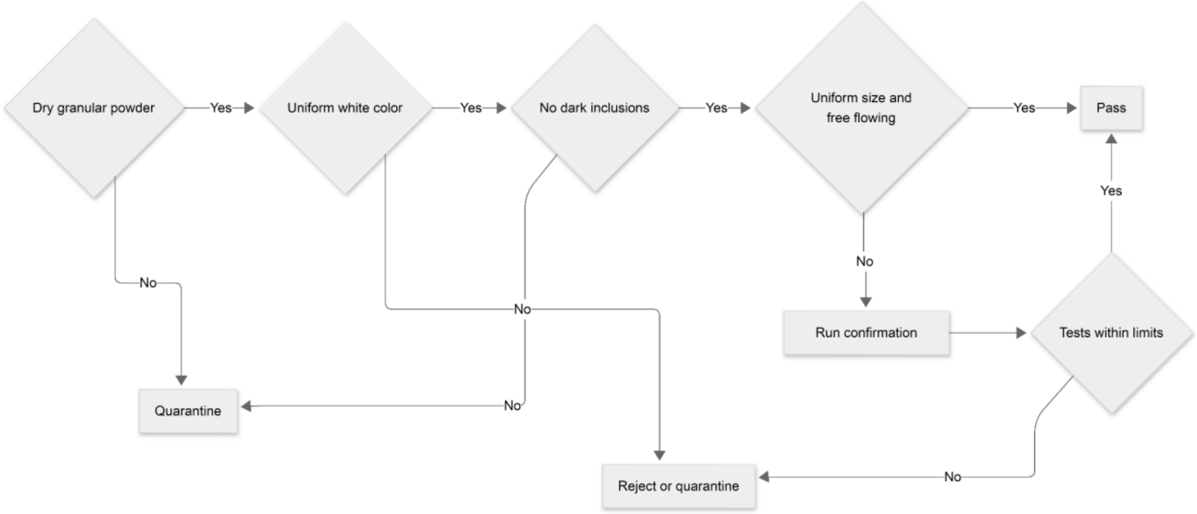

Fig. 1. Algorithm for incoming visual inspection of the commercial form of polyacrylamide for EOR

## 1.2. Determination of Bulk Density

Bulk density is a fundamental characteristic that reflects granule porosity, particle shape, and packing density. For high-molecular-weight polyacrylamides used in EOR, the target range of bulk density is established at 0.6–0.8 g/cm³. This range is not arbitrary and reflects an optimal balance between processability and product activity.

Density values below 0.6 g/cm³ are typical of products with high porosity or high content of fine fraction (fluffy powders). Such products are prone to dusting, creating industrial safety issues, and exhibit poor wettability due to air entrapped within particle aggregates, leading to the formation of floating lumps on the water surface. Values above 0.8 g/cm³ may indicate low granule porosity (vitrification), which slows diffusion of water molecules into the particle and increases dissolution time, or elevated moisture content that compacts the material.

The bulk density determination procedure requires strict standardization because polymer powders are compressible media. The measurement is performed using a clean, dry 100 mL graduated cylinder. The method comprises two steps: weighing the empty cylinder and taring the balance, and carefully filling the cylinder with polymer to the 100 mL mark.

A fundamental point distinguishing this methodology from construction standards is the requirement of no tapping or compaction. The polymer shall freely pour into the cylinder under gravity. To ensure uniform filling, the discharge point (scoop spout or funnel) should be smoothly moved over the cylinder cross-section, avoiding formation of a cone (heap) at a single point with subsequent avalanching. According to the above, the polymer mass m is first recorded with an accuracy of 0.01 g, after which the density is calculated. The measurement is performed at least twice, with the results averaged.

Compliance with this methodology is crucial for calibrating metering equipment (screw feeders) at field polymer dissolution units, where dosing is often performed volumetrically, while reporting is maintained in mass units. The bulk density determination algorithm is shown in Figure 2.

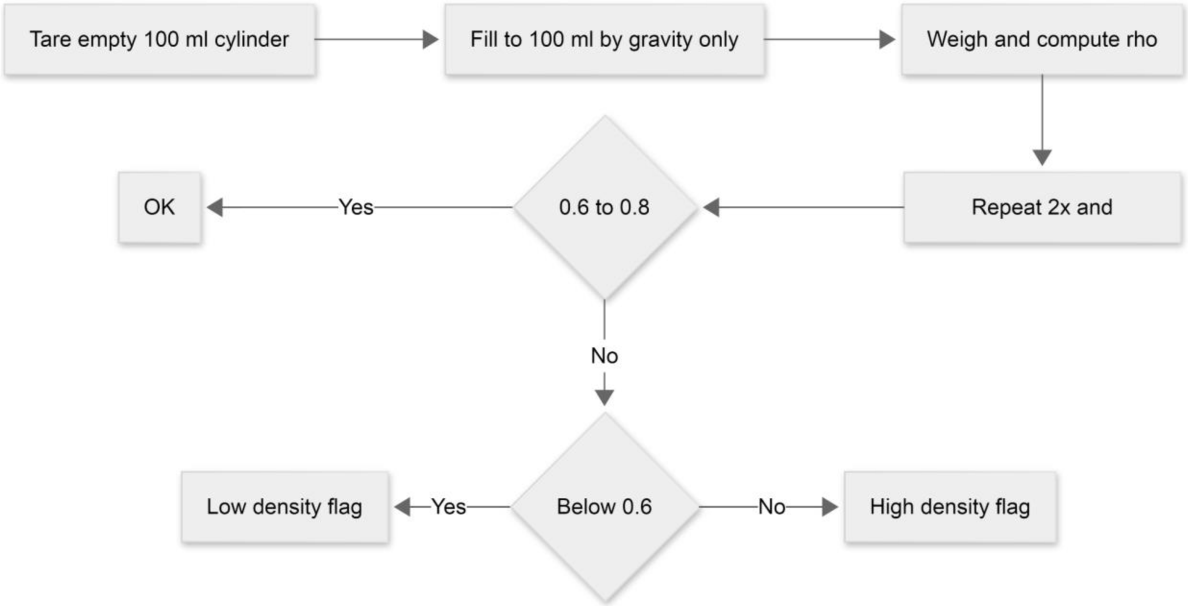

Fig. 2. Bulk density determination algorithm

### 1.3. Determination of Active Substance Content

Commercial polyacrylamide is never a 100% pure substance. It contains equilibrium moisture, residual monomers, hydrolysis products, and processing additives (e.g., anti-caking agents). The key quality indicator determining project economics (i.e., the buyer should pay for the active substance, not water) is the polymer mass fraction.

According to the developed regulation, the target value of active substance content (activity) shall be equal to 88% or greater. This implies that the total content of volatile components (predominantly water) shall not exceed 12%. Exceeding the 12% moisture threshold is critical not only commercially but also in terms of chemical stability. Excess moisture in the powder creates a favorable environment for spontaneous hydrolysis of amide groups, leading to uncontrolled changes in the degree of hydrolysis (anionicity) during storage. This, in turn, alters the reagent sensitivity to formation-water salinity and its adsorption characteristics. Additionally, moist polymers tend to cake and form monolithic blocks in packaging, making them unsuitable for automated feeding systems (Kleba-Ehrhardt et al., 2025).

The method is based on gravimetric analysis of the mass loss that occurs upon drying. Unlike standard procedures using 105°C, the present methodology prescribes a temperature of 120 ± 2°C with a holding time of 2 hours. At 120 °C, it is ensured that all water bound to the hydrophilic polymer matrix through hydrogen bonds has evaporated. At 105 °C, some firmly bound water may still be trapped in the sample. A bias in the analysis results may be accompanied by an artificially high active ingredient content in the matrix. However, exceeding 2 hours at 120°C is unacceptable due to the risk of initiating thermo-oxidative degradation of the polymer chain (C–C bond scission) and imidization, which would lead to false overestimation of mass loss.

The analysis procedure includes:

1. Preparation of weighing dishes (drying, cooling in a desiccator, weighing, and determining the dish mass in g, W1).
2. Weighing a polymer sample of 1.0000 ± 0.0002 g (mass of dish with polymer before drying, g, W2).

3. Drying in an oven at 120°C for 2 hours.

4. Cooling in a desiccator and weighing the dry residue (mass of dish with polymer after drying, g, W3).

The formula calculates the mass fraction of the active substance:

$$S = \frac{W_3 - W_1}{W_2 - W_1} \times 100.$$

The algorithm for determining active substance content is shown in Figure 3.

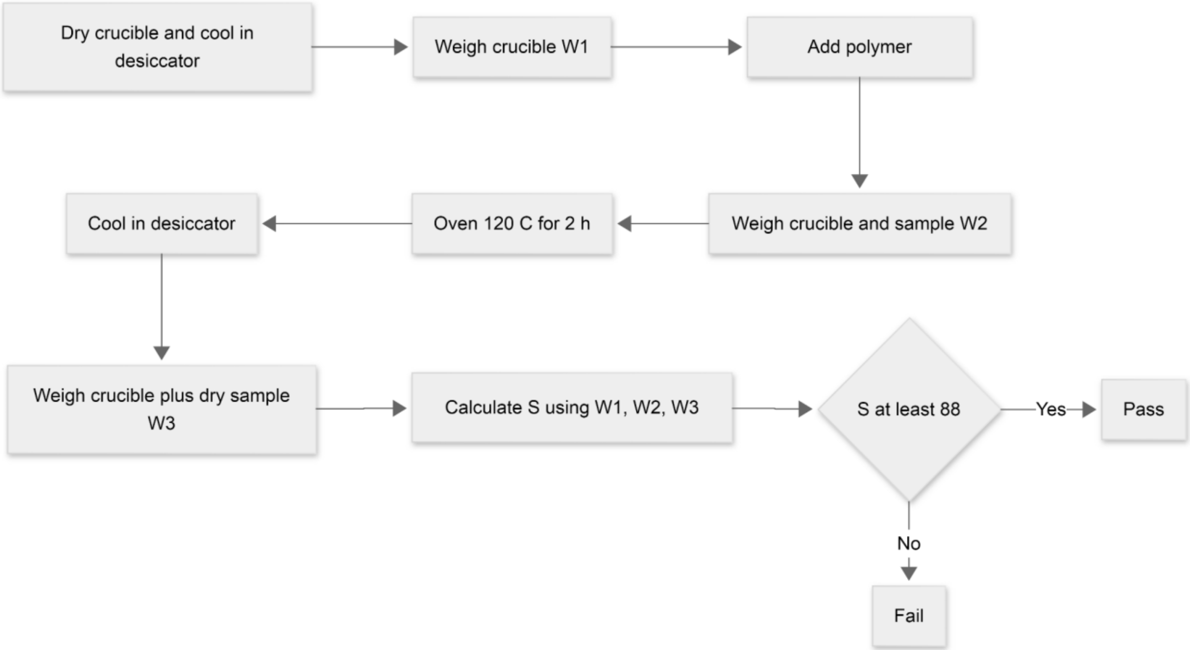

Fig. 3. Determination of active substance content

The obtained data are baseline inputs for calculating accurate polymer charges when preparing solutions of specified concentration in subsequent testing stages.

# Chapter 2. Preparation of Model Media and Solubility Assessment

Correct preparation of the polymer solution is the cornerstone of the entire verification procedure. The behavior of polyelectrolytes, including partially hydrolyzed polyacrylamide, critically depends on the ionic composition of the solvent. The ionic strength of the solution and the presence of multivalent cations determine the conformational state of the macromolecule (coil size) and, consequently, the viscoelastic properties of the solution (Bind et al., 2025). Therefore, the use of a unified model formation water (MFW) is a mandatory condition for the reproducibility of results.

## 2.1. Model Formation Water Recipe

Within this methodology, the standard is MFW with total dissolved solids (TDS) of 17.38 g/L. This composition is selected as representative of a broad class of reservoirs and contains a balanced set of ions, enabling the evaluation of polymer resistance to saline stress.

The theoretical rationale for the composition is based on the influence of ions on the electrostatic repulsion of polymer chain segments. In distilled water, like-charged carboxylate groups along the polymer chain repel each other, causing the molecule to expand maximally and thereby providing high viscosity. With the addition of salts, charges are screened by counterions (Debye–Hückel double-layer effect) (Li et al., 2023).

Monovalent ions form an ionic atmosphere, reducing the range of electrostatic forces, which leads to polymer coil compression and a decrease in viscosity. This is the polyelectrolyte effect (Lopez et al., 2023).

Divalent ions, due to their higher charge and specific affinity for carboxyl groups, can form intra- and intermolecular bridges, binding two carboxylate groups (Abdelkrim et al., 2024). This can result in coil collapse (coiling) and even phase separation (precipitation) at high temperatures or degrees of hydrolysis.

The table below presents the MFW recipe, which shall be followed with precision.

Table 1. Component composition of model formation water (TDS 17.38 g/L)

| **MFW composition (TDS 17.38 g/L)** | **Content** | **Function in the model** |
|---|---|---|
| $NaHCO_3$, g/L | 1.239 | Creation of a buffer capacity |
| NaCl, g/L | 14.118 | Baseline ionic strength; salinity simulation |
| KCl, g/L | 0.592 | Clay stabilization |
| $MgCl_2 \cdot 6H_2O$, g/L | 1.268 | Hardness simulation; stability test with $Mg2^+$ |
| $CaCl_2$, g/L | 0.833 | Hardness simulation; critical ion for crosslinking $Ca2^+$ |
| Water, g | 981.95 | Solvent |

The preparation procedure requires sequential dissolution of salts in the specified order (from monovalent to divalent) under continuous stirring to avoid localized supersaturation zones where calcium or magnesium carbonates may precipitate. After dissolving all salts, the water shall be filtered through a 0.45 µm membrane to remove insoluble impurities that may distort polymer filtration-test results.

## 2.2. Dissolution Kinetics and Stock-Solution Preparation

Dissolution of a high-molecular-weight polymer is kinetically complex and proceeds through swelling (diffusion of solvent into the polymer) and chain disentanglement (reptation of macromolecules into the solvent) (Alexandridis, 2025). Process deviations at this stage result in the formation of microgels that cannot be subsequently eliminated without degrading the polymer itself.

The methodology prescribes preparation of a stock solution at 5000 ppm (0.5%). This concentration is selected to create a high-viscosity concentrate that is subsequently diluted to working concentrations, thereby minimizing polymer weighing errors and aligning with the field practice of preparing a mother solution. The dissolution algorithm is as follows:

1. Place 398.00 g of MFW into a 500 mL or 1000 mL beaker.
2. Use an overhead paddle mixer. The impeller design shall ensure adequate mixing of the entire liquid volume, without any stagnant zones.

3. Set the rotational velocity to 500 ± 20 rpm (this is a test optimum value, sufficient to produce a deep vortex and uncover the bottom of the beaker only briefly, so that each powder particle can be quickly trapped and wet).

4. Add the polymer (2.00 g) to the shoulder of the vortex (the region of maximum flow velocity) and not directly into the vortex over a period of 30 seconds to prevent particle agglomeration. Avoid contact of the powder with the mixer shaft or beaker wall to prevent the formation of insoluble crusts.

5. After adding the full amount of powder, continue stirring. Once viscosity increases, and the vortex disappears (typically after 10–15 minutes), the mixer speed may be reduced to a level that maintains the movement of the entire liquid mass while minimizing shear degradation (approximately 200–300 rpm). The total mixing time is regulated to 2 hours.

After 2 hours, perform visual control. The solution shall be transparent or slightly opalescent, homogeneous, without visible clots (fish eyes) or undissolved particles. The presence of fish eyes indicates that the water diffusion rate into particles was lower than the rate of gel-shell formation at their surface. If heterogeneities are visually observed, this constitutes grounds for a preliminary conclusion that the dissolution kinetics are unsatisfactory; however, the final decision is made based on the filtration test results. The dissolution and stock-solution preparation algorithm is shown in Figure 4.

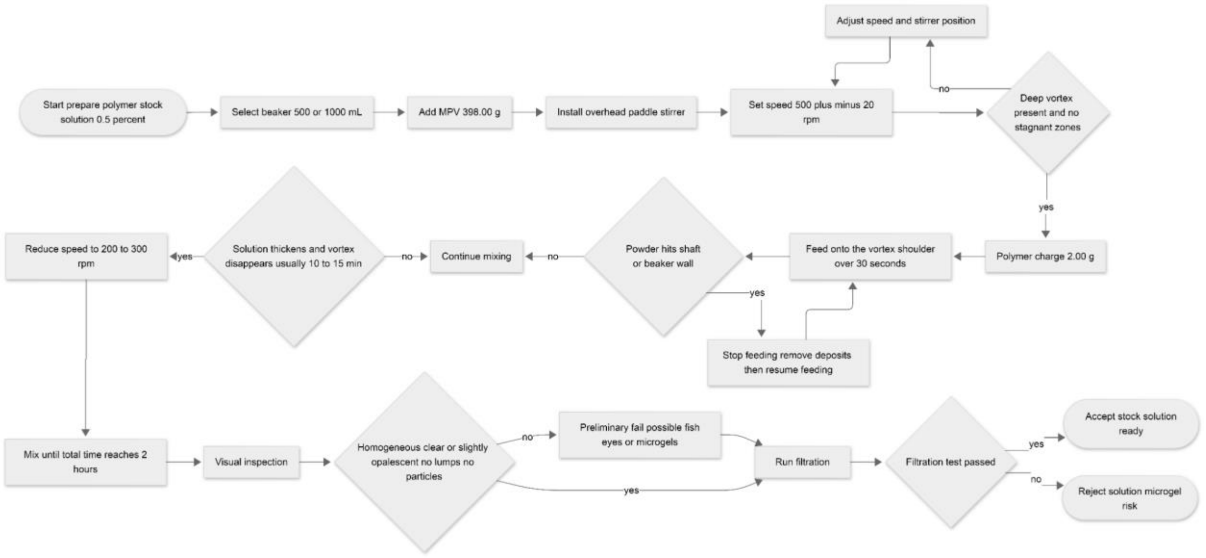

Fig. 4. Dissolution and stock-solution preparation algorithm

### 2.3. Rheological Control (Viscosity)

Rheological measurements confirm the polymer’s ability to thicken water under high salinity conditions. For this purpose, the stock solution (5000 ppm) is diluted with MFW to working concentrations close to actual injection conditions. The methodology establishes two control points: 870 ppm and 950 ppm. Primary emphasis is placed on 950 ppm, which is also used for the filtration test.

The dilution procedure is as follows. To obtain 950 ppm, add 81.0 g of MFW to 19.00 g of stock solution (5000 ppm). To obtain 870 ppm, add 82.60 g of MFW to 17.4 g of stock solution. Homogenization of diluted solutions is performed on a magnetic stirrer at 400 ± 20 rpm for 20 minutes. Use of a magnetic stirrer at this stage is permissible because solution viscosities are low (typically 10–50 cP), and the risk of mechanical degradation is minimal compared to the powder dissolution stage.

Viscosity measurements are performed using a rotational Brookfield-type viscometer (DV-II, DV-III, or equivalent) with the UL (Ultra Low) adapter. The UL adapter is a coaxial-cylinder system, providing a uniform shear rate field in the gap and enabling the correct measurement of low-viscosity liquids.

Measurement parameters are strictly regulated: temperature, 40°C (thermostating accuracy ±0.1°C), which is the standard comparative temperature; however, reservoir temperature may be used for specific projects. Rotational speed is 13 rpm. The selection of 13 rpm is due to the need to reach the target shear rate. For UL geometry, the shear rate constant is 1.223. Thus, the shear rate is 15.9 $s^{-1}$. The value of 15.9 $s^{-1}$ is not arbitrary. Flow analysis in porous media indicates that the average shear rates experienced by the polymer during reservoir flow (away from the near-wellbore zone) lie within the range of 1–20 s-1 (Rosado-Vázquez et al., 2022). Measuring viscosity at this shear rate provides the most representative information on the polymer’s capacity to control water mobility (Mobility Control) in the interwell region. HPAM solutions are pseudoplastic (shear-thinning); viscosity decreases with increasing shear rate (Kleba-Ehrhardt et al., 2025). Therefore, stating viscosity without referencing shear rate lacks physical meaning. The methodology requires recording viscosity after the instrument readings have stabilized (typically after 5–10 minutes of spindle rotation).

# Chapter 3. Filtration Ratio Test as an Applicability Criterion

While rheological tests determine the potential effectiveness of oil displacement, the filtration ratio test serves as a critical safety barrier, determining the feasibility of injecting the reagent into the reservoir. The injection of a polymer with unsatisfactory filtration characteristics will inevitably lead to near-wellbore plugging, increased injection pressure above the fracture pressure, and loss of control over the development process (Khlaifat et al., 2024).

## 3.1. Filterability Theory and Selection of Test Parameters

For decades, the industry has relied on API RP 63 standards, which recommend filters with a pore size of 5 μm or larger. However, accumulated experience and recent studies convincingly demonstrate that a 5 μm test lacks sensitivity under modern development conditions. Many reservoirs targeted for polymer flooding have permeability of 100–500 mD and average pore-throat radii of less than 10 μm. Microgels and aggregates of 2–3 μm, which readily pass a 5 μm filter, can accumulate in constrictions of real core pore channels, causing progressive plugging via the bridging mechanism (Zhou et al., 2023).

Accordingly, this methodology introduces a stricter standard: the use of track-etched polycarbonate membranes with calibrated pores of 1.2 μm. Such membranes have strictly cylindrical pores and a narrow pore-size distribution, unlike fibrous depth filters (such as glass fiber and paper), which ensure high reproducibility and test rigidity. The 1.2 μm size is selected as a critical threshold: if the polymer coil (whose hydrodynamic radius in solution may reach 0.5–1 μm) can deform and pass through a 1.2 μm pore without being irreversibly trapped, it is guaranteed to propagate in most oil-bearing reservoirs.

## 3.2. Methodology for Determining FR (Filtration Ratio)

Sample preparation is performed first. A 950 ppm solution is used, prepared, and homogenized in accordance with Chapter 2. The sample volume shall be at least 400 mL.

Apparatus configuration is then implemented. A stainless-steel filtration cell capable of withstanding pressure is used. A fundamentally essential requirement is the use of a 90 mm diameter membrane (as opposed to 47 mm laboratory membranes). The increased filtration area improves filter performance in terms of reduced edge effects, larger volumes of produced filtrate before the filter becomes blocked, and improved statistical confidence in the data. The cell is supplied with compressed gas (either nitrogen or purified air) through a precision pressure regulator that maintains a constant pressure.

For the test, the membrane has a pore size of 1.2 μm, a diameter of 90 mm, and is made of polycarbonate. The polymer solution has a constant pressure of 0.14 MPa that deforms the microgels as it is compressible, which can lead to the soft microgels flowing through the pores with a small pressure difference.

Test procedure:

1. Pour the solution into the cell reservoir.
2. Seal the cell and apply 20 PSI.
3. Degassing/flush stage. Immediately open the outlet valve to discharge the first 20–30 mL of solution into a separate container. This is necessary to remove air bubbles that may accumulate under the membrane or in the drainage system of the filter holder. Entry of an air bubble into a membrane pore blocks it and will be falsely interpreted as polymer plugging.
4. After air removal, direct the flow into a receiving vessel placed on an electronic balance.
5. Start the stopwatch. Record cumulative filtration time upon reaching specified mass marks of filtered liquid. Key points are: 100 g ($t_{100}$), 200 g ($t_{200}$), 300 g ($t_{300}$). Time is recorded with an accuracy of 0.1 s.

The FR determination algorithm is shown in Figure 5.

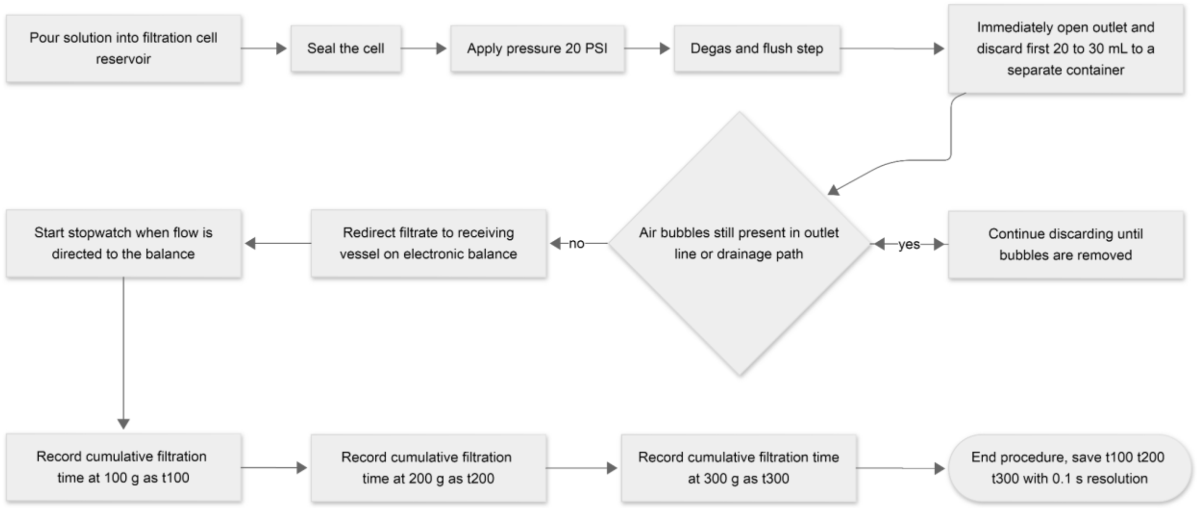

Fig. 5. FR determination algorithm

### 3.3. Calculation and Interpretation of Results

The filtration ratio is a dimensionless quantity reflecting the dynamics of filter permeability change during solution flow. It is calculated as the ratio of the time required to pass a fixed volume of fluid at the end of the test to the time needed to pass the same volume at the beginning of the test. The calculation formula is:

$$F_R = \frac{t_3 - t_1}{t_2 - t_1},$$

where $t_3 - t_1$ is the time interval required to filter 100 g of solution from 200 g to 300 g (late stage), and $t_2 - t_1$ is the time interval needed to filter 100 g of solution from 100 g to 200 g (early stage).

The physical meaning and acceptance criteria are as follows. In the ideal case for a Newtonian fluid without particles, the filtration rate is constant and FR = 1.0. For pseudoplastic polymer solutions, a slight deviation is permissible.

If FR is less than or equal to 1.2, this indicates that the polymer solution passes through 1.2 µm pores without significant sediment accumulation or pore blockage. Such a solution is considered of acceptable quality, and the risks of injectivity loss are minimal.

An FR value above 1.2 indicates progressive membrane pore plugging. This may be caused by undissolved microgels, aggregates formed due to interactions with hardness ions (crosslinking), or a high concentration of ultra-high-molecular-weight fractions that cannot pass through pores due to steric constraints. The use of such a polymer in practice will lead to rapid growth of the skin factor and a decrease in injectability.

If FR > 1.2 is obtained, the polymer batch is classified as off-spec. For research purposes, it is possible to increase the mixing time or modify the preparation regime to determine whether poor filterability is due to product properties (synthesis defect) or insufficient hydration. However, for incoming field quality control, the result is final.

Considering the above, aggregated requirements for indicators are shown in Table 2.

Table 2. Requirements for indicators

| **Indicator** | **Requirement** |
|---|---|
| Appearance | White granular powder |
| Bulk density (g/cm³) | 0.6–0.8 |
| Polyacrylamide content (120°C, 2 h) | ≥ 88% |
| Viscosity (Brookfield viscometer, 40°C, 15.9 $s^{-1}$) | , |
| Filtration ratio (FR) (at 950 ppm; through a membrane filter with 1.2 µm pores, 90 mm diameter) | ≤ 1.2 |
| Dissolution time | ≤ 2 h |

The table defines the material quality specification: appearance, white granular powder, bulk density 0.6–0.8 g/cm³, polyacrylamide content ≥ 88% (120°C, 2 hours), FR ≤ 1.2 at 950 ppm through a 1.2 µm membrane filter (Ø90 mm), dissolution time ≤ 2 hours. The viscosity indicator is specified as not applicable/not defined. Therefore, this specification does not impose any viscosity requirements.

Thus, the calculation and interpretation of the FR index make it possible to quantitatively assess the propensity of a polymer solution to accumulate precipitate and induce pore plugging during filtration through a 1.2 µm membrane: an FR value ≤ 1.2 corroborates stable permeability and batch compliance with incoming quality-control requirements, whereas FR > 1.2 unambiguously indicates progressive fouling (microgels, aggregates, hardness-ion effects, or ultrahigh-molecular-weight fractions) and, consequently, an elevated risk of increased skin factor and reduced injectivity; taken together with specifications for appearance, bulk density, polyacrylamide content, and dissolution time, these criteria constitute an integrated material-quality specification, while viscosity within this specification is not subject to normative limits.

# Conclusion

The presented Comprehensive Methodology for the Laboratory Verification of the Rheological and Filtration Characteristics of Polyacrylamide (PAM) for Tertiary Enhanced Oil Recovery Methods establishes an integrated, scientifically substantiated framework for reagent incoming quality control, wherein individual tests are not treated as isolated procedures but are methodologically coupled through a unified logic of risk-oriented assessment of polymer applicability in polymer flooding projects. Under conditions of an increasing share of hard-to-recover reserves and development of late-stage fields, emphasis predictably shifts from the declarative criterion of meeting specification toward the verification of those PAM properties that directly determine the technological viability of the intervention: the ability to ensure the required rheological behavior in a saline medium and, critically, filtration safety during injection.

The scientific novelty and practical value of the methodology are evident in the purposive tightening of acceptance criteria and the disciplined standardization of test conditions. In contrast to historically predominant approaches relying on filterability through 5 µm media, the methodology relocates the filtration test into a more stringent sensitivity regime by employing track-etched polycarbonate membranes of 1.2 µm (Ø90 mm) and by setting the acceptance index FR at no more than 1.2 at a concentration of 950 ppm and a constant pressure of 0.14 MPa (20 psi). Therefore, the filtration module ceases to be a formal attribute of compliance with a standard and instead becomes a functional barrier against PAM batches that potentially contain microgels and aggregates capable of initiating progressive near-wellbore plugging and escalating injection pressure.

Equally significant is the placement of filtration testing within a framework of strictly reproducible preparation of the model medium. Regulation of the ionic composition of model formation water (TDS 17.38 g/L) and the sequence of salt dissolution followed by filtration through 0.45 µm reduces variability attributable to the polyelectrolyte nature of partially hydrolyzed PAM and its sensitivity to ionic strength and hardness cations. As a result, the observed effects, viscosity reduction under charge screening and the risk of bridging binding in the presence of divalent cations, are interpreted not as noise of the laboratory procedure but as a reproducible characteristic of a specific reagent batch under a defined salt load.

The integration of physicochemical identification of the commercial form (visual evaluation of homogeneity and signs of thermal degradation), determination of bulk density (0.6–0.8 g/cm$^3$), and control of the mass fraction of active substance (not less than 88% after drying at 120 ± 2°C for 2 hours) with regulated dissolution kinetics (stock solution 5000 ppm, total preparation time up to 2 hours, verification of the absence of fish eyes) forms a closed exclusion system for substandard supplies before transition to field manifestations that are costly in terms of consequences. In parallel, the rheological module, conducted at 40°C and a shear rate of 15.9 s$^{-1}$ (as representative for a reservoir range of 1–20 s$^{-1}$), methodologically anchors the requirement for the physical meaningfulness of measurements (viscosity as a function of shear rate for pseudoplastic systems), although in the final specification of the methodology viscosity is not directly normalized and is treated as an indicator without an established requirement.

Collectively, the proposed protocol defines a normatively structured, technologically relevant scheme for laboratory verification of PAM that reduces the probability of introducing into a project batches with unsatisfactory filterability, minimizes risks of formation damage in the near-wellbore zone and the associated loss of injectivity, and increases the predictability and stability of polymer flooding as a key physicochemical EOR method. The methodology has a constructive character for laboratories of oil and gas companies, service organizations, and engineering centers. It may be considered as a basis for a corporate standard of incoming reagent quality control for critical chemical EOR projects.

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## Content

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**Nikita Popov**

# AN INTEGRATED LABORATORY VERIFICATION METHODOLOGY FOR THE RHEOLOGICAL AND FILTRATION CHARACTERISTICS OF POLYACRYLAMIDE (PAM) FOR TERTIARY ENHANCED OIL RECOVERY

Methodological Guidelines

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