Field Experience in the Use of High-Pressure Automatic Samplers

Rafael Alves Rodrigues, Petrobras
Thierry Rampinelli Bravo, Petrobras

1 INTRODUCTION

The use of automatic samplers for oil sample collection constitutes a legal requirement established by the technical measurement regulations issued by the regulatory authorities in Brazil, specifically the ANP – National Agency of Petroleum, Natural Gas, and Biofuels and INMETRO – National Institute of Metrology, Quality, and Technology.

According to the ANP/INMETRO Joint Resolution (2013) [1], item 7.17:
"*Oil measured by the fiscal metering system must be stabilized and contain no more than 1% water and sediment, as determined by automatic sampling proportional to the flow, carried out according to Chapter 8 of this Regulation*."

Sample collection must comply with the recommendations of the automatic sampling standards: ISO 3171 [2], API MPMS 8.2 [3], and API MPMS 8.3 [4]. These standards establish requirements and guidelines for the design, installation, and operational performance of automatic samplers.

ISO 3171 provides recommendations for obtaining representative samples of crude oil and liquid petroleum products transported by pipelines through automatic means. The standard covers all aspects from the selection of the sampling point and probe design to the installation, operation, maintenance, and monitoring of automatic samplers. API MPMS 8.2 defines the standard practice for automatic sampling of petroleum and its derivatives, encompassing the selection of the sampling location, system design, installation, testing, operation, and performance monitoring. API MPMS 8.3, on the other hand, establishes practices for the mixing and handling of liquid petroleum and petroleum product samples.

Manufacturers and operators of automatic sampling systems must fully comply with these standards. However, even when all normative requirements are met, operational failures frequently occur, especially in units high pressure applications. In these conditions, accelerated wear of components, continuous oil leaks, and even interruptions in sample collection are frequently observed. Given this scenario, it is necessary to adopt additional solutions to ensure the proper performance of automatic samplers under high-pressure conditions. This work is structured as follows:

- Section 2: Main operational challenges observed in automatic sampling systems under high pressure;
- Sections 3 and 4: General description of the operation of automatic samplers, highlighting limitations under high-pressure conditions;
- Section 5: Presentation of a solution based on a special probe head designed for high-pressure operation;
- Section 6: Final considerations

2 HIGH-PRESSURE SAMPLING CHALLENGES

Major manufacturers of automatic samplers provide systems designed to operate under high-pressure conditions. This scenario is commonly encountered in fiscal metering systems or offloading operations on platforms where the metering systems are located downstream of oil export pumps, as is the case in SS (Semi-Submersible) platforms. In these situations, the automatic samplers installed in the metering system are subjected to pumping pressures typically ranging from 70 bar to 100 bar.

In addition to high pressure, the oil flowing in some platforms also exhibits elevated temperatures, around 60 ºC. The combination of high pressure and high temperature significantly accelerates wear on the components of sampling systems, even when these systems are designed for such operational conditions. In some cases, sampling systems operates for only a few days after maintenance before failures occur.

These observations are based on operational experience accumulated over the years on Petrobras platforms operating under high-pressure conditions. It is evident that samplers installed under low-pressure conditions — such as on FPSO (Floating Production Storage and Offloading) platforms, which transfer oil to storage tanks — remain operational for much longer periods compared to samplers installed on SS platforms. The main difference between these scenarios lies in the pressure and temperature of the fluid flow.

The main operational challenges identified in high-pressure automatic sampling systems are:

1. Accelerated wear of internal sealing rings and components of the relief valve in the sample probe.
2. Leaks caused by small gaps or debris (e.g., sand), which would be negligible under low-pressure conditions.
3. Accelerated wear of internal check valves.
4. Overloading of the external relieft valve, responsible for reducing process pressure to atmospheric pressure, resulting in increased wear due to both its critical function and high operational frequency.
5. Continuous leakage of sampled oil.
6. Untimely interruptions in sample collection.
7. Leaks in the external tubing connections of the probe, caused by high pressure, especially when obstructions occur along the path to the collection container.

3 GENERAL OPERATING PRINCIPLE

The complete architecture of automatic sampling systems varies depending on the manufacturer. In Petrobras installations, the main suppliers are Autocontrol, Doedjns, Jiskoot, Welker, and Metroval. Figure 1 illustrates a typical automatic sampling system, which consists of a sampling control system (flow computer), a probe actuation valve (5/3-way), a collection container selector valve (3-way), the sampling probe itself, storage containers, and weighing scales.

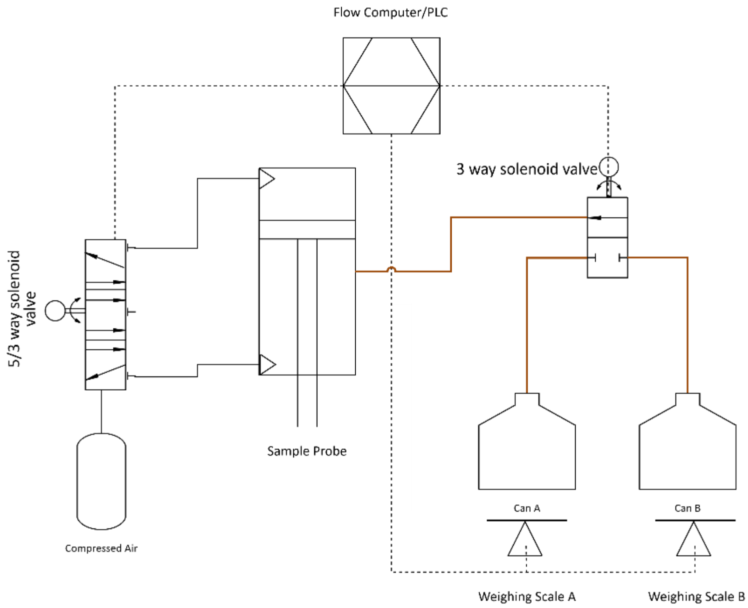

Fig. 1 – A typical automatic sampling system.

This configuration is typically found in Doedjns and Jiskoot systems. Systems from Welker and Metroval, on the other hand, control the filling of collection containers using level switches instead of weighing scales. In general, systems from different manufacturers present similar configurations, differing mainly in the technology employed in the sampling probe, particularly in the probe head.

Based on the control signal received from the flow computer and a source of compressed air, the 5/3-way valve actuates the sampling probe, which collects an oil sample. The sample then passes through the 3-way valve, which directs it to the appropriate container. If the container is full — as identified by the level switch or by weight — the sample is redirected to a secondary container or the sampling process is temporarily halted. This describes the typical operation of an automatic sampling system.

4 SAMPLE PROBE

The sampling probe is the main component of an automatic sampling system, responsible for collecting oil samples from within the pipeline and delivering them externally to the collection containers. The probe is typically actuated by a pneumatic system, which enables mechanical movement of the internal components to grab the samples. Figure 2 illustrates a drawing of a typical automatic sampling probe. The main components of the probe are:

- Relief valve: responsible for retaining the oil flow until the probe is actuated;

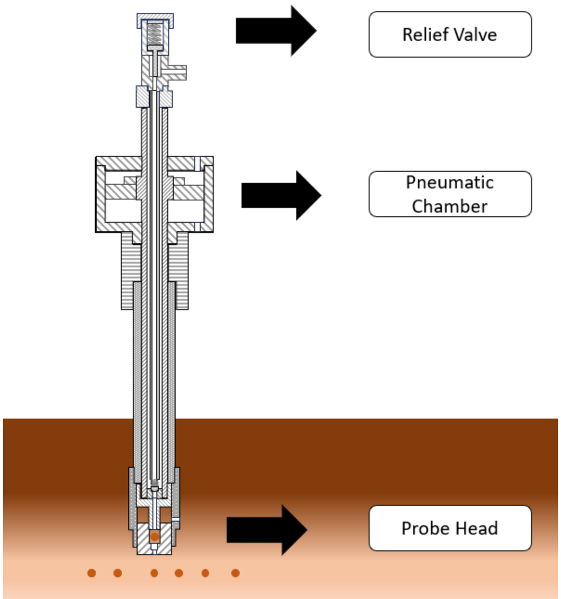

Fig. 2 – A sample probe example.

- Pneumatic chamber: part of the probe designed to move the probe using compressed air applied to the upper or lower part of the chamber;

- Collector head: part of the probe responsible for grabbing a sample from the pipeline.

4.1 OIL SAMPLING PROCESS

The oil sampling process can be visualized through the pressure changes within the sample, as illustrated in Figure 3. Oil flowing in the pipeline at a process pressure $P_{process}$ passes through the probe head (1) and is captured when the probe is actuated. Upon actuation, the sample pressure becomes P_{internal} , and the sample travels through the internal tubes of the probe to the relief valve (2), which opens as the internal probe pressure increases due to pneumatic actuation.

After passing through the relief valve, the sample pressure becomes $P_{external}$, and the oil flows to the 3-way valve (3), which directs the collected volume to the collection container (4). The relief valve separates the external pressure from the internal probe pressure, retaining the oil flow. The valve is set to open at P_{set} configured at a differential pressure ΔP above the process pressure $P_{process}$, according to the manufacturer's recommendation. Typically, ΔP is set between 5 bar and 10 bar.

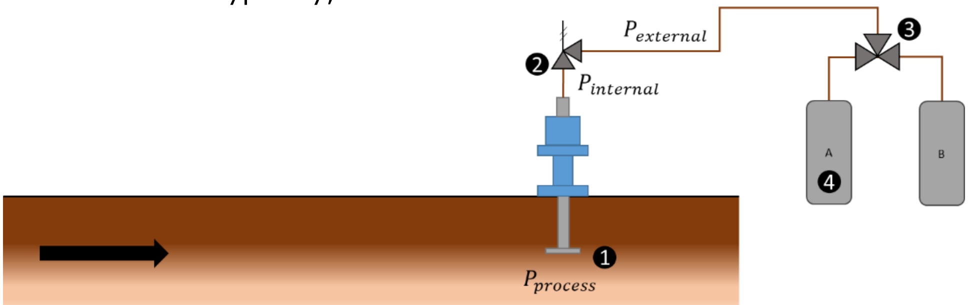

Fig. 3 – Oil sampling using automatic sampler.

Thus, along the flow path from the pipeline to the collection container, the sample experiences pressure variations, as illustrated in the pressure profile in Figure 4, which shows both the internal probe pressure and the sample pressure. During the downward movement of the probe during sampling, the internal pressure increases until it reaches a maximum value $P_{internal}^{max}$ equal to the relief valve set pressure:

$$P_{internal}^{max} = P_{set} = P_{process} + \Delta P\ (5 - 10)\ bar$$

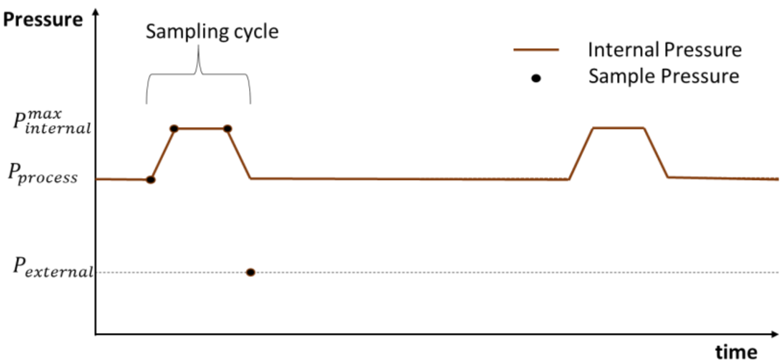

Fig. 4 – Internal and sample pressure variation.

While the probe is inactive, the sample remains at the process pressure $P_{process}$. Once the sampling process begins, the sample pressure rises to $P_{internal}^{max}$, at which point the check valve opens, allowing oil to flow out of the probe. This pressure is maintained until the end of the sample collection, which coincides with the completion of the downward probe movement. The oil sample is then delivered externally, assuming $P_{external}$. Meanwhile, the internal probe pressure returns to $P_{process}$ until the next sampling cycle.

4.2 OPERATIONAL LIMITATIOINS

A critical issue arises when there is high variability in process pressure ($P_{process}$), which can prevent sample collection in case of a pressure drop, or worse, cause continuous leakage if the pressure exceeds the relieft valve set point P_{set}. This scenario is common in high-pressure systems, where process changes can lead to continuous leaks or interruptions in sample collection.

Although increasing the relieft valve set pressure can mitigate leaks temporarily, this solution is only short-term: any further increase in process pressure will require readjustment, or if the process pressure drops significantly below the set point, sampling may be interrupted. This constitutes a significant operational challenge, as it requires frequent manual adjustment on the relief valve.

5 SPECIAL PROBE HEAD FOR HIGH-PRESSURE APPLICATIONS

To address the challenges of high-pressure applications, a market solution was sought that could overcome the operational issues previously described. To provide a more suitable solution for high-pressure applications, a Brazilian company (Metroval) [5] developed a probe head that does not require an external relief valve and, according to the manufacturer, is made of materials with higher resistance to wear, increasing its service life.

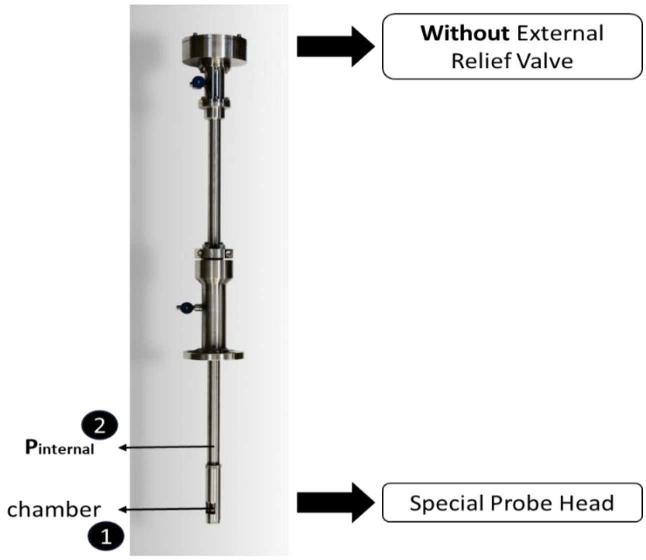

Fig. 6 – Sample Probe with Special Head [5].

The main advantage of this technology lies in the elimination of the external relief valve, effectively addressing the issues described in the previous sections. Figure 6 illustrates a schematic diagram of Metroval's sampling probe. The probe head includes an opening that allows oil to flow while the probe remains at rest. When actuated, the pneumatic piston moves downward, displacing the upper section of the probe head and capturing a sample within chamber (1). As the downward movement continues, the collected sample is directed toward the upper section of the probe head (2) and subsequently discharged from the probe.

The probe head features a special design that enables internal pressure balancing, which keeps the internal check valve closed independently of the process pressure. Variations in process pressure do not affect the resting position of the internal valve, since the forces exerted by the process pressure and by the pressure within chamber (1) remain in equilibrium. The maximum sample pressure during collection corresponds to the maximum pressure within the capture chamber (1), calculated as follows:

$$P_{chamber}^{max} = P_{check\ valve} + P_{process}$$

The pressure in the chamber increases until it equals the force acting on the check valve, which is formed by the check valve pressure ($P_{check\ valve}$) and the process pressure. At this point, the valve opens, allowing the sample to flow out of the probe. Thus, resultant force in the check valve only rely on the check valve pressure.

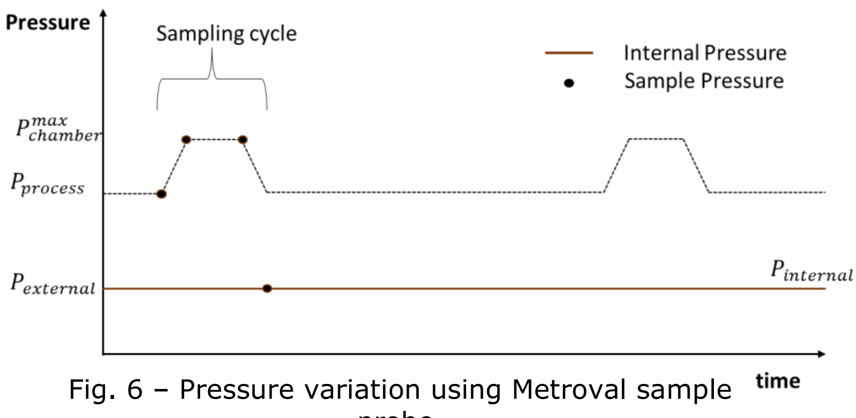

Fig. 6 – Pressure variation using Metroval sample probe.

The pressure behavior inside this probe differs from conventional probes: the sample pressure changes only within the capture chamber, while the internal probe pressure remains constant and equal to the external pressure. This feature is critical as it reduces system-wide pressure, maintaining high pressure only within the probe head, thereby reducing wear and minimizing the risk of leaks.

In summary, this collector head moves the relief valve from the external part of the probe into the probe head itself. The pressure balance makes its operation independent of process pressure. Additionally, internal components and seals are constructed from more resistents materials to extend the service life of the collector head. It is noteworthy that, for pressures exceeding 120 bar, the manufacturer recommends installing an external relief valve to reduce pressure in stages, thereby further increasing the service life of the internal components and preventing premature wear.

6 CONCLUSION

This work presented and discussed the main issues related to the operation of automatic sampling systems under high-pressure conditions, with particular emphasis on the effects of pressure variability, which often result in continuous leakage in conventional systems. As analyzed, traditional samplers are not fully effective under such conditions, since they rely on external check valves, which become critical points of wear and failure.

As an alternative, a solution developed by a brazilian company was presented, consisting of a sampling probe equipped with a special probe head. This technology eliminates the need for an external relief valve by incorporating it into the probe head itself and employing the principle of pressure balance. In this way, the opening of the internal check valve becomes independent of process pressure, thereby increasing operational reliability. Furthermore, the use of more resistant materials in seals and internal components contributes to an extended service life of the equipment.

Practical results have shown that this sampling probe improves the operational continuity of high-pressure systems, although the severe regime of pressure and temperature still imposes additional wear challenges compared to low-pressure applications. Thus, the need for specific design and maintenance practices for these systems is reinforced.

Based on the analyses and observations carried out, the following general principles are recommended for the application of automatic samplers under high-pressure conditions:

- Suitability to operational conditions: The probe and its components must be designed to withstand high pressure and temperature, also considering the presence of solids (such as sand), which may accelerate wear.

- Probe head selection: Models specifically designed for severe conditions should be adopted, employing materials with higher mechanical and thermal resistance.

- Structured preventive maintenance: Implement a maintenance plan tailored to high-pressure conditions, including:

  - Periodic replacement of the probe head, at intervals of one year or less;
  - Availability of spare equipment on site for both preventive and corrective maintenance.

- Avoidance of external relief valves: Whenever possible, choose probes that eliminate this component, since their use in high-pressure conditions with process variability significantly increases the risk of failures and leaks.

In summary, the adoption of solutions that eliminate reliance on external relief valves, combined with a proper preventive maintenance plan, represents a safer and more efficient approach for sampling systems operating under high-pressure conditions

7 REFERENCES

[1] ANP/INMETRO (2013). Resolução conjunta ANP/INMETRO N º1. Relatório Técnico- DOU 12.6.2013 – RETIFICADA DOU 17.6.2013, AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS - ANP.
[2] ISO 3171-1:1988. Petroleum Liquids-Automatic Pipeline Sampling. Standard, International Organization for Standardization, Geneva, CH
[3] API MPMS CHAPTER 8.2 (2022). Standard Practice for Automatic Sampling of Petroleum and Petroleum Products. Standard, American Petroleum Institute, Washington, DC
[4] API MPMS CHAPTER 8.3 (2019). Standard Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products. Standard, American Petroleum Institute, Washington, DC
[5] Metroval Automatic Samples Probe. Site: https://metroval.com.br/wp-content/uploads/2023/02/Automatic-Sampling-Probes-EN.pdf