



Application Note AN-PAN-1011

Online analysis of permanganate absorption number (PAN)

Caprolactam, a vital precursor to Nylon 6, is widely used in the production of various industrial fibers, textiles, and plastics. Maintaining consistent caprolactam purity is essential for ensuring the quality of these finished products. The permanganate absorption number (PAN) analysis serves as a key indicator of caprolactam purity within the

production process, adhering to ISO 8660 standards.

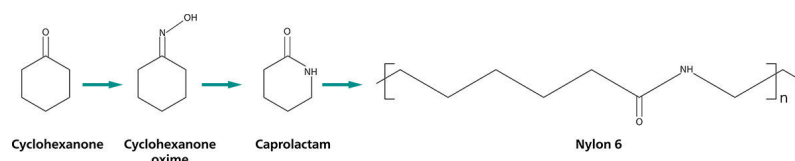
This Process Application Note describes the straightforward 24/7 monitoring of the permanganate absorption number (PAN) as a measure of the caprolactam purity in the corresponding process.

INTRODUCTION

In 2023, global caprolactam production capacity was approximately 9 million tons [1], the majority of which went on to produce Nylon 6. Nylon 6 is mainly used to manufacture fibers for clothing, carpets, and industrial purposes. About 30% of produced Nylon 6 is used for resin production [1].

Caprolactam is primarily manufactured from cyclohexanone, cyclohexane, or toluene. The dominant industrial process involves converting cyclohexanone to cyclohexanone oxime, followed by Beckmann rearrangement to yield caprolactam with nearly 98% efficiency [2]. The industry standard Beckmann rearrangement

process employs sulfuric acid (or oleum) as a catalyst to transform cyclohexanone oxime into caprolactam (**Reaction 1**). However, this method generates ammonium sulfate as a byproduct.



Reaction 1. Reaction mechanism from cyclohexanone to form Nylon 6.

Maintaining caprolactam quality is crucial for its downstream applications like Nylon 6 production. This can be achieved by employing a specific test – permanganate absorption number (PAN) analysis.

This standardized procedure, detailed in international references like ISO 8660, measures the presence of oxidizable impurities within the caprolactam sample.

Essentially, PAN analysis measures the stability of caprolactam by evaluating its reaction with potassium permanganate. Lower PAN values indicate a purer caprolactam sample, leading to the production of better-quality Nylon 6.

Traditional laboratory analysis employing manual sampling is a viable option, but it

While valuable for fertilizer production, its environmental impact has led to restrictions in certain regions.

presents certain drawbacks. The time-consuming nature of this approach misses real-time process variations. Analyzing multiple process streams concurrently becomes labor-intensive, and the use of sulfuric acid introduces safety concerns within the laboratory environment.

In light of these limitations, online process analyzers such as the 2060 TI Process Analyzer (**Figure 2**) have emerged as the preferred solution. This process analyzer exhibits cutting-edge technology and offers continuous, high-precision analysis of caprolactam impurities, ensuring the consistent production of top-quality Nylon 6.

APPLICATION

Oxidizable impurities are monitored in caprolactam according to ISO 8660 for online purposes, with precise time- and temperature-controlled colorimetric measurements. Metrohm Process Analytics offers a multiparameter process analyzer solution for precisely measuring PAN online according to ISO 8660: the 2060 TI Process Analyzer (**Figure 2**).



Figure 2. The 2060 TI Process Analyzer is suitable for monitoring PAN during caprolactam production.

Table 1. Typical range found for the permanganate absorption number in the caprolactam production process.

Parameter	Range
PAN	0–35

REMARKS

Since caprolactam absorbs moisture, employing a reliable technique for water content determination is also crucial. The 2060 *The* NIR Analyzer from Metrohm Process Analytics stands out as an excellent solution in this regard. It delivers accurate water content measurements within seconds, eliminates the need for sample

preparation, and generates no chemical waste. Other online applications are possible depending on the production process, including NH_4OH , NH_4NO_2 , SO_3^{2-} , alkalinity, moisture, iron, high/low acidity in cyclohexanone (Anolon), $(\text{NH}_4)_2\text{SO}_3$, H_3PO_4 , and other related components.

Continuous online monitoring of PAN in caprolactam is essential for optimizing downstream Nylon 6 production. The Metrohm Process Analyzer 2060 TI Process Analyzer delivers precise, real-time PAN analysis. This

enhances efficiency, reduces costs, and improves product quality. Its versatility enables simultaneous monitoring of multiple process parameters for comprehensive process control.

REFERENCES

1. *Caprolactam Market Size, Share Analysis and Industry Forecast*. Prisma Consulting. <https://prismaneconsulting.com/report/market-reports/global-caprolactam-market-study-report-2016-2032/23> accessed 2025-12-03).
2. Ritz, J.; Fuchs, H.; Kieczka, H.; et al. Caprolactam. In *Ullmann's Encyclopedia of Industrial Chemistry*, Wiley-VCH, Ed.; Wiley, 2011. DOI:10.1002/14356007.a05_031.pub2

RELATED APPLICATION NOTES

AN-PAN-1041 Inline monitoring of free isocyanate (%NCO) content in polyurethane

AN-NIR-077 Moisture analysis in caprolactam

BENEFITS FOR ONLINE PROCESS ANALYSIS

- **Fully automated diagnostics** – automatic alarms for when samples are out of specification parameters.
- **Guarantee compliance** with global standards.
- **Avoid unnecessary costs** by measuring multiple parameters simultaneously in the process stream.
- **Enhanced control** over the caprolactam production process, enabling fine-tuning for **optimal purity and efficiency**.
- **Safer working environment** for employees (no handling of H_2SO_4).



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CONFIGURATION



2060 Process Analyzer

2060 Process Analyzerは、無数のアプリケーションに対応するオンライン湿式化学アナライザーです。このプロセスアナライザーは、「ベーシックキャビネット」と呼ばれる中核プラットフォームによって構成される新たなモジュラー式コンセプトを提供するものです。

ベーシックキャビネットは、2つの部分から構成されます。上部はタッチスクリーンと産業用PCを含みます。下部には、実際の分析のためのハードウェアが格納されるフレキシブルな湿式部が含まれます。基本湿式部の容量が分析課題を解決するのに充分でない場合、最も困難なアプリケーションでも解決できる十分なスペースを確保するため、ベーシックキャビネットを4つまでの追加湿式部キャビネットに拡張することが可能です。追加キャビネットは、各湿式部キャビネットを、アナライザーの稼働時間を増加させる内蔵式(非接触式)レベル検出を有する試薬キャビネットと組み合わせるという方法によってコンフィグレーションすることができます。

2060 Process Analyzerは様々な湿式化学技術を提供します: カール フィッシャー滴定、光度測定、直接測定、および標準追加メソッドです。

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