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Countermeasures against Elevated C_3 Content in Feedstock during High-Purity Isobutane Production

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Abstract: Aiming at the practical problem of increased C_3+ content in the feedstock for industrial isobutane production at the Butane Plant of Zhongyuan Oilfield Natural Gas Treatment Plant, this paper investigates the effects of C_3+ content fluctuation on key process parameters, and further optimizes the regulation methods for production parameters. When light components in the process materials for industrial isobutane production rise significantly, key control parameters including the overhead temperature of the isobutane column, the overhead temperature of the purification column and the C_3+ content in No.1 reflux drum are kept within the standard ranges. This prevents the accumulation of C_3+ components and unplanned shutdown reflux of the unit, improves the adaptability of the industrial isobutane production process to variations in feedstock composition, and ensures continuous and stable production of qualified industrial isobutane products.

Keywords: Industrial isobutane; high-purity isobutane; parameter regulation; increase of light components.

1. Introduction

The Butane Plant of Zhongyuan Oilfield Natural Gas Treatment Plant is mainly engaged in deep processing of light hydrocarbons. Using mixed butane as feedstock, it adopts distillation columns and purification columns to produce industrial isobutane with a mass fraction of over 99.99% and commercial butane liquefied petroleum gas with a mass fraction of over 98%.

The overall production process for industrial isobutane was developed on the premise that the mass fraction of C_2+C_3 in feedstock is no more than 1.5% (M/M). However, since the raw material supplier adjusted its production scheme, the C_3+ content of the incoming feedstock has increased to generally above 2% (M/M). The unstable feedstock composition has brought a series of adverse impacts on the entire production process.

Specifically, the rising C_3+ content in the feedstock directly increases the concentration of light components inside the columns and raises the load of the stripping section below the feed tray.

In actual production of the butane plant, n-butane and isobutane are separated in the n-butane column and isobutane column. Afterwards, isobutane together with C_3+ and other light components flows from the No.1 reflux drum into the purification column, where isobutane is further purified by removing C_3+. Compared with normal feed composition, the elevated C_3+ content reduces the purity of isobutane in the No.1 reflux drum, posing great challenges to the subsequent purification process[1].

In addition, excessive C_3+ light components lead to a drop in the overhead temperature of the purification column, accompanied by a pressure rise in the connected No.2 reflux drum. The liquid level becomes difficult to stabilize, and the C_3+ content inside the drum increases accordingly[2], which ultimately deteriorates the purity of the finished industrial isobutane.

This paper explores the impacts of fluctuating C_3+ content in feedstock on the production process of industrial isobutane, mainly focusing on the parameters of facilities associated with the purification column and the composition of materials in the No.1 reflux drum. Corresponding measures are adopted to comprehensively regulate the process parameters, so as to ensure the continuous and normal production of industrial isobutane.

2. Current Situation Analysis

The feedstock of the unit mainly consists of three components: propane, isobutane and n-butane. The schematic flow diagram of the process unit is shown in Figure 1. The n-butane column (T1-X) and isobutane column (T1-S) are connected in series to separate n-butane from isobutane. Liquefied petroleum gas of commercial butane with a purity of over 98% is obtained at the bottom of T1-X. The overhead stream of T1-S, which is high-concentration isobutane, is fed into Column T2 for further purification. Industrial isobutane product with a purity higher than 99.99% is finally collected at the bottom of T2.

Analyze the variations of feedstock composition and corresponding process parameters during normal operation. Through continuous production monitoring, feedstock assay compositions and key production parameters were collected at four fixed time points (08:00, 12:00, 16:00 and 20:00) every day from December 18 to December 22, 2025. The statistical reports and line charts are presented as follows:

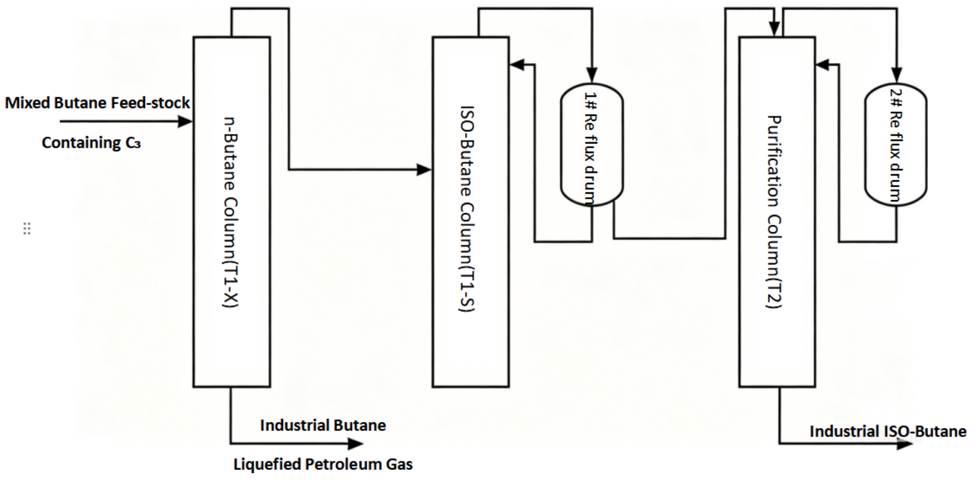


Figure 1. Process Flow Schematic

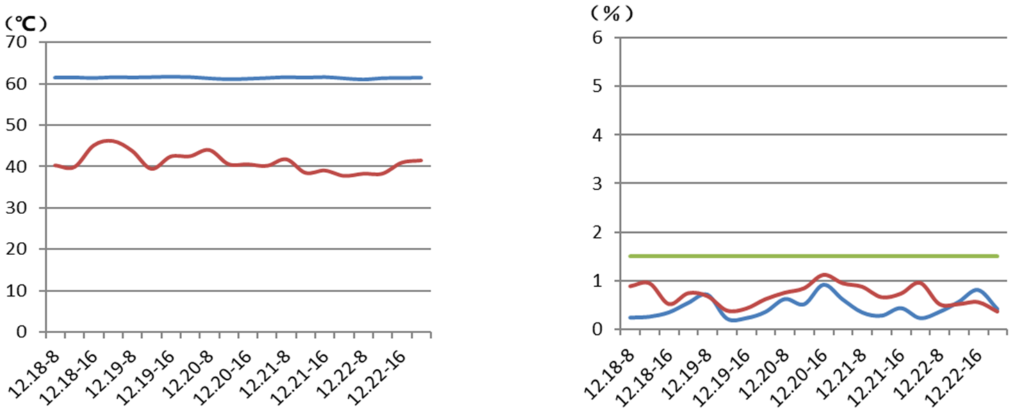
Table 1. Monitoring Table of Key Production Parameters During Normal Operation from December 18 to 22, 2025

Time	T1-S overhead temperature (℃)	T2 overhead temperature (℃)	Mass fraction of C_3+ in feedstock (%)	Mass fraction of C_3+ in No.1 reflux drum (%)
12.18-8	61.53	40.32	0.23	0.88
12.18-12	61.58	39.92	0.25	0.94
12.18-16	61.43	45.1	0.34	0.52
12.18-20	61.64	46.17	0.54	0.74
12.19-8	61.56	43.8	0.71	0.68
12.19-12	61.64	39.48	0.21	0.39
12.19-16	61.74	42.44	0.22	0.43
12.19-20	61.66	42.51	0.35	0.62
12.20-8	61.35	44.02	0.62	0.75
12.20-12	61.14	40.63	0.51	0.84
12.20-16	61.25	40.59	0.92	1.11
12.20-20	61.43	40.20	0.61	0.94
12.21-8	61.64	41.79	0.34	0.87
12.21-12	61.53	38.53	0.27	0.66
12.21-16	61.65	39.09	0.43	0.73
12.21-20	61.35	37.8	0.22	0.95
12.22-8	61.09	38.32	0.35	0.52
12.22-12	61.40	38.35	0.56	0.52
12.22-16	61.43	40.98	0.81	0.56
12.22-20	61.51	41.5	0.41	0.37

Notes:

1.Data are sourced from the daily production statistics and assay reports of the Butane Plant.

2.T1-S refers to the isobutane column, and T2 refers to the purification column.

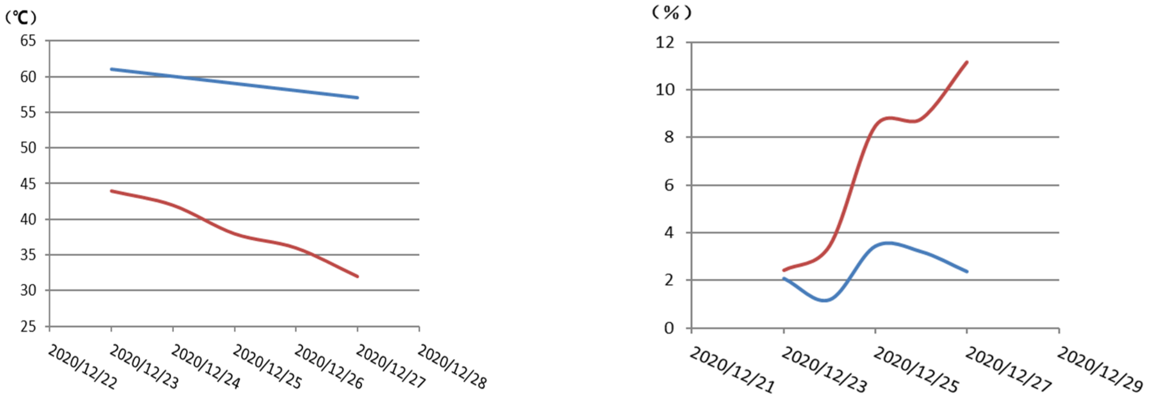


(a) Overhead Temperature Variation of T1-S and T2 (b) Variation of C_3+ Content in Feedstock and No.1 Reflux Drum

Figure 2. Trend Chart of Key Parameters and C_3+ Content During Normal Production

The statistical monitoring data in Table 1 show that during normal production from December 18 to 22, 2025, the C_3+ content of the received feedstock was no more than 1.5%. The overhead temperature of the isobutane column remained between 60°C and 68°C, the C_3+ content in the No.1 reflux drum was ≤ 2%, and the overhead temperature of the purification column was kept within 38°C to 45°C. All key technical parameters complied with the specifications, ensuring the stable production of industrial isobutane.

The line charts below present the feedstock composition assay data collected from December 23 to 27, 2025, when the raw material supplier intermittently adjusted its production plan. During this period, operators in the central control room adopted a localized parameter adjustment method based on routine operational experience. Without considering the downstream process, they only adjusted parameters for the individual unit once its operating parameters deviated from the standard range. Relevant monitoring data for industrial isobutane production are illustrated in the following line charts.



(c) Overhead Temperature Variation of T1-S and T2 (d) Variation of C_3+ Content in Feedstock and No.1 Reflux Drum

Figure 3. Trend Chart of Key Parameters and C_3+ Content During Feedstock Fluctuation

Combined with the line trends in Figure 3, during December 23 to 27, 2020, the raw material supplier intermittently manufactured high-purity propane, leading to changes in feedstock composition. The conventional parameter adjustment strategy proved ineffective in stabilizing the overhead temperatures of the isobutane column and purification column. As a result, C_3+ continuously accumulated in the No.1 reflux drum with its content climbing steadily, which greatly undermined the separation of isobutane and C_3+. The product from the bottom of the isobutane column consequently failed to reach the required quality standards. To enhance the separation performance, the entire unit was forced to halt feed and product discharge and run under continuous total reflux.

This indicates that the original control strategy lacks holistic thinking and sufficient adaptability to feedstock variations. Its passive operating mode is no longer applicable to production scenarios where the C_3+ fraction in feed rises due to the supplier's intermittent process adjustments. Accordingly, it is urgent to establish an integrated process control method with a global perspective, stronger adaptability to feedstock changes and higher initiative.

3. Literature References

Generally, an increase in the concentration of light components in the feed will raise the load of the stripping section. For a column with a fixed number of trays in the stripping section, light components cannot be fully vaporized, resulting in greater loss of light components in the bottom liquid. Meanwhile, variations in feed composition will disrupt the overall material balance and process conditions of the column[3]. Lighter feedstock leads to a higher distillate flow at the column top and a lower discharge rate of bottom liquid, accompanied by a drop in column temperature and a rise in column pressure. In view of the above problems, the improvement measures are proposed as follows:

a. Appropriately increase the heat duty

Raise the heat duty by 0.5% to 1% on the original basis. The elevated C_3+ content in the feed increases light components in the ascending vapor inside the column. Given the relatively low boiling point of light components, the temperature across the column, especially at the top, decreases accordingly. The temperature drop reduces vaporization efficiency and leads to insufficient gas-liquid contact, which hinders the separation of light and heavy components and deteriorates product quality. A moderate increase in heat duty helps maintain stable temperatures inside the column, particularly at the top.

b. Increase the discharge flow of the No.1 reflux drum

Boost the discharge rate by 200 L/H to 400 L/H compared with the normal operating level. The No.1 reflux drum is connected to the isobutane column. The ascending vapor from the column top is cooled into liquid by the air cooler and then flows into the No.1 reflux drum. Since the isobutane column is mainly filled with isobutane and C_3+, all C_3+ fractions in the feed will enter the reflux drum along with the vapor phase and tend to accumulate there. Increasing the drum discharge can effectively prevent volatilization of accumulated C_3+ and overpressure of the drum, and stop the continuous build-up of C_3+.

c. Open the vent of the No.2 reflux drum

Cooperate with operators at the gas holder station to open the vent valve of the No.2 reflux drum connected to the purification column, so as to discharge gaseous C_3+ into the gas holder. The purification column primarily contains isobutane and C_3+. C_3+ rises with the vapor flow[4], is condensed into liquid by the air cooler and enters the No.2 reflux drum. Due to the high volatility of light components, C_3+ will re-vaporize inside the drum and cause pressure buildup. This impedes the inflow of cold liquid and results in a continuous drop of liquid level. Venting can effectively remove vaporized C_3+ from the drum and discharge such fractions out of the purification system[5], stabilizing the liquid level of the reflux drum. This measure will not affect the purity of isobutane product at the bottom of the purification column and avoids unit shutdown and total reflux caused by excessive C_3+ content.

d. Drain liquid from the No.2 reflux drum

After the vent is opened, continuously monitor the overhead temperature of the purification column. A temperature rebound indicates that venting is sufficient to remove C_3+ from the system[6]. If the overhead temperature keeps decreasing, arrange sampling and analysis by the measurement and testing center. When the C_3+ content in the sample exceeds 60%, open the drain valve of the No.2 reflux drum and reduce the liquid level to 200 mm before closing the valve. The purification unit will then operate under total reflux to restore the normal liquid level of the No.2 reflux drum.

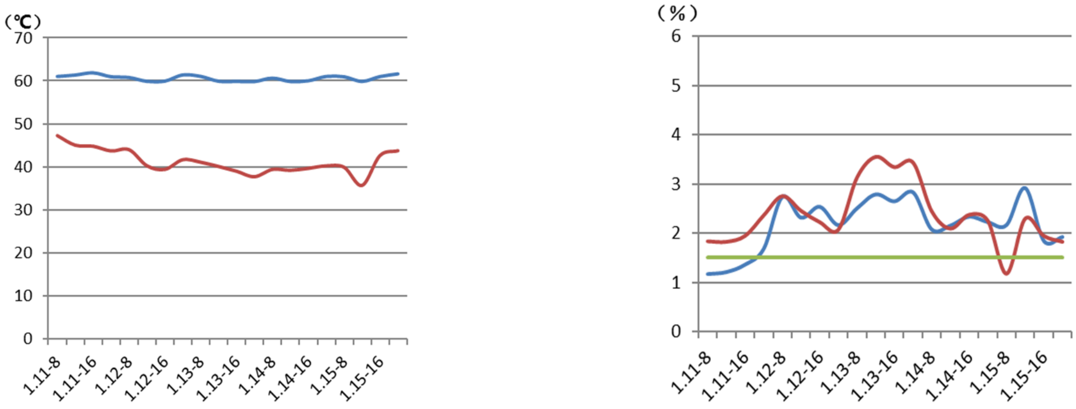
The combined application of the above control measures enables proactive and effective responses to the increased light components in the system. It improves the adaptability of the isobutane production process to feedstock variations, eliminates the adverse impact of accumulated C_3+ in the No.1 reflux drum on the product composition at the bottom of the purification column, and prevents unplanned product cutoff and total reflux operation of the unit.

4. Practical Verification

The proposed improved parameter control scheme was put into practical verification. From January 11 to 15, 2026, the scheme was implemented when the raw material supplier adjusted its production process again. Feedstock composition data from laboratory analysis and key production parameters were recorded at four time points (08:00, 12:00, 16:00 and 20:00) every day. The corresponding statistical table and line charts are presented below:

Table 2. Monitoring Table of Key Production Parameters During Normal Operation from January 11 to 15, 2026

Time	T1-S overhead temperature (℃)	T2 overhead temperature (℃)	Mass fraction of C_3+ in feedstock (%)	Mass fraction of C_3+ in No.1 reflux drum (%)
1.11-8	61.01	47.32	1.18	1.83
1.11-12	61.31	45.07	1.22	1.82
1.11-16	61.79	44.82	1.37	1.94
1.11-20	60.95	43.71	1.69	2.36
1.12-8	60.79	44.01	2.74	2.75
1.12-12	59.96	40.22	2.32	2.45
1.12-16	60.01	39.37	2.54	2.22
1.12-20	61.34	41.66	2.17	2.07
1.13-8	61.02	41.06	2.51	3.13
1.13-12	59.98	40.05	2.79	3.55
1.13-16	59.95	38.93	2.65	3.34
1.13-20	59.92	37.65	2.83	3.43
1.14-8	60.65	39.37	2.08	2.44
1.14-12	59.93	39.15	2.16	2.09
1.14-16	60.08	39.61	2.34	2.37
1.14-20	61.01	40.21	2.23	2.25
1.15-8	60.94	39.87	2.17	1.17
1.15-12	59.95	35.61	2.92	2.29
1.15-16	60.99	42.63	1.85	1.94
1.15-20	61.56	43.77	1.93	1.82



(a) Overhead Temperature Variation of T1-S and T2 (b) Variation of C_3+ Content in Feedstock and No.1 Reflux Drum

Figure 4. Variation Trends of Key Parameters and C_3 Content after Implementing the Improved Control Method during Feedstock Composition Fluctuations

Statistical monitoring data from Table 2 and Figure 4 indicate that the optimized parameter regulation strategy can effectively cope with elevated C_3+ content in feedstock composition. It stabilizes the overhead temperatures of the isobutane column and purification column within the specified standard range, alleviates the accumulation of C_3+ inside the No.1 reflux drum, and eliminates the need for full-unit total reflux for isobutane purification.

In addition, production report data before the implementation of the improved control scheme show that within a 120-hour production cycle when the raw material supplier intermittently adjusted its production process, the unit could only maintain normal feeding and discharging for 85.5 hours over five days. During the remaining 34.5 hours, production had to be suspended and switched to total reflux for deep purification to guarantee product quality, cutting the effective production duration by 34.5 hours. After adopting the control method proposed in this paper, the unit realized continuous discharging for the full 120 hours even when C_3+ content in feedstock exceeded the limit, adding 34.5 hours of effective operation compared with the original process, while the purity of industrial isobutane products consistently met the required standards.

5. Summary

Aiming at the actual operating condition that intermittent adjustments of production processes by the raw material supplier lead to excessive C_3+ content in supplied feedstock, the improved control method proposed in this paper stabilizes two critical indicators: the C_3+ concentration in the No.1 reflux drum and column overhead temperatures. It inhibits the accumulation of C_3+ within the reflux drum and eliminates unplanned unit shutdowns for total reflux operation. Accordingly, multi-stage purification of isobutane via condensation and reflux can be maintained efficiently, enabling continuous and stable production of industrial-grade isobutane whose tested purity meets customer requirements.

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