# Comparability of External Ambient and Internal Probed TTR Measurements

*Refrigerated transportation study summary; produce lanes excluded; all operational identifiers anonymized*

## 1. Executive Summary

This white paper evaluates whether a Time–Temperature Recorder (TTR) placed externally on a pallet can reasonably represent product temperature measured by an internal probe. The analysis uses a controlled dataset from a study conducted in 2020. Supplier, distribution center, and route names are anonymized throughout.

**Bottom line:** External ambient TTR readings were closely aligned with internal product temperatures on average, but they were much more variable. This means the external TTR is useful as a conservative indicator of temperature conditions, but it should not be treated as an exact substitute for a probed product reading when the actual internal product temperature must be confirmed.

- **Average temperatures were similar:** lane-level ambient minus product differences ranged from -0.99 °F to +2.67 °F.
- **External readings were much more variable:** ambient variance was roughly 20x to 40x higher than product variance across the four analyzed lanes.
- **Ambient extremes were not matched by product extremes:** ambient values ranged as low as -13.8 °F and as high as 74.0 °F; product values stayed within 28.6 °F to 46.2 °F.
- **Practical interpretation:** an external TTR is more likely to overstate short-term temperature stress than understate product exposure.

## 2. Purpose and Study Design

The purpose of the study was to compare two ways of measuring temperature during refrigerated transport: (1) ambient temperature captured by a TTR positioned on the outside of a case or pallet area, and (2) internal product temperature captured by a probe inserted between packaged product. The goal was to determine how closely the external reading tracks the internal product reading, and whether external monitoring can support a reliable interpretation of product condition.

Each shipment used a dual-sensor TTR monitor so the ambient and internal channels were collected from the same shipment and placement location. This paired setup is important because it allows direct comparison between the surrounding environment and the product-adjacent reading. The analyzed dataset includes two refrigerated commodities across four anonymized lanes, totaling 140 shipments.

## 3. Data Included in the Analysis

| Lane | Commodity | n | Avg Trip h | Ambient Mean | Product Mean | Ambient SD | Product SD |
|---|---|---|---|---|---|---|---|
| A-1 | Cheese | 26 | 17.97 | 36.42 °F | 37.02 °F | 2.84 | 0.45 |
| A-2 | Cheese | 24 | 16.26 | 37.74 °F | 35.07 °F | 2.78 | 0.54 |
| B-1 | Beef | 42 | 58.68 | 31.66 °F | 32.65 °F | 1.73 | 0.37 |
| B-2 | Beef | 48 | 57.86 | 32.31 °F | 33.04 °F | 2.34 | 0.52 |

Table 1. Summary statistics from the included lanes. SD = average within-trip standard deviation.


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# 4. Main Findings

## 4.1 Average Temperatures Were Similar

Across the four analyzed lanes, the average ambient readings were close to the average internal product readings. The largest lane-level difference was +2.67 °F, and three of the four lanes had an ambient mean slightly below the product mean. A paired comparison of the four-lane means did not show a meaningful systematic offset (paired $t = 0.10$; $p = 0.93$).

## 4.2 External Readings Were Much More Variable

External ambient readings varied more than product readings. In every lane, the ambient standard deviation was substantially higher. Variance ratios ranged from about 20x to 40x, meaning external readings captured many short-term swings that were not seen in the product channel.

This pattern is expected in refrigerated transport. The product, packaging, and surrounding cases reduce the effect of short-term air temperature changes. As a result, an external TTR can detect brief hot or cold events quickly, while the internal product reading changes more slowly.

| Lane | Mean Difference Ambient-Product | Variance Ratio | Ambient Span | Product Span |
|---|---|---|---|---|
| A-1 | -0.60 °F | 39.8x | 41.9 °F | 7.9 °F |
| A-2 | +2.67 °F | 26.5x | 23.9 °F | 10.5 °F |
| B-1 | -0.99 °F | 21.9x | 46.4 °F | 10.84 °F |
| B-2 | -0.73 °F | 20.2x | 87.8 °F | 17.6 °F |

Table 2. Key comparison metrics. Span = maximum minus minimum observed temperature.

## 4.3 External TTRs Acted as Conservative Indicators

External ambient readings showed larger warm and cold spikes than the internal product readings. For example, one lane recorded an ambient minimum of -13.8 °F and an ambient maximum of 74.0 °F, while the corresponding product temperature range was far narrower. This shows that external monitoring can identify potential exposure events before those events fully affect the product.

The practical implication is important: an external alarm may not always mean the product reached the same temperature. It may indicate a short-term air temperature condition that was buffered before reaching the product. For routine oversight, that makes the external TTR conservative. For product disposition decisions, a probed reading remains the better confirmation method.

# 5. Interpretation for Use

## 5.1 Supported Findings

- **External and internal readings were close on average** across the included lanes.
- **External readings were consistently more variable** than internal product readings.
- **External readings captured higher and lower extremes** than the product channel.
- **The internal product temperature changed more slowly** and stayed within a narrower range.

## 5.2 Practical Conclusion

The data support using an external ambient TTR as a conservative monitoring tool. It is a practical way to identify conditions that could create temperature risk during transport. Because the external reading is more sensitive to short-term air temperature changes, it is more likely to flag a potential issue than to miss one.

The data do not support treating the external TTR as an exact one-to-one replacement for an internal probed TTR. The two readings are similar in average trip temperature, but not equivalent at every moment. If a specific decision depends on actual product temperature, a probed reading provides the stronger evidence.

## 5.3 Recommended Operating Approach

- **Use external TTRs** for lane monitoring, trend review, and screening for possible temperature exposure.
- **Treat external excursions** as conservative alerts that may require review of duration, severity, and shipment context.
- **Use internal probed TTRs** or direct product checks when product disposition depends on actual internal temperature.
- **Avoid applying a fixed correction factor** between external and internal readings; the direction and size of the difference varied by lane.


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## 6. Deviations and Edge Cases

The main edge case was the lane with the largest ambient span. Ambient temperature ranged from -13.8 °F to 74.0 °F, while product ranged from 28.6 °F to 46.2 °F. This does not weaken the monitoring value of the external TTR; it clarifies how the result should be interpreted. External readings identify environmental stress, while internal readings confirm what the product experienced.

Another important result was a single product excursion above specification in one lane. This confirms that product temperature can move upward when exposure is sufficient. The overall pattern still shows that product temperature responded more slowly and less sharply than ambient air temperature.

## 7. Limitations

- **The analysis is based on** the available summarized dataset, not the raw time-aligned reading file.
- **Formal point-by-point regression** and correlation could not be calculated from the provided summary data.
- **The study covers four** refrigerated lanes and two analyzed commodities, so results should be applied to similar conditions with appropriate judgment.
- **Data were collected** during a specific study window and may not capture every seasonal or operational condition.
- **One monitor placement** approach was used; different placement strategies may produce different ambient extremes.

## 8. Conclusion

Based on the attached dataset, external ambient TTR readings are directionally comparable to internal probed product readings when evaluating overall trip temperature conditions. The averages were close across the analyzed lanes, and there was no meaningful systematic offset in lane-level mean temperatures.

At the same time, external readings were much more variable and captured larger temperature extremes than internal product readings. This means the external TTR should be framed as a conservative indicator of product temperature risk, not as an identical measurement of internal product temperature.


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