Study of the Sealing Compound in Food Cans: Implications for the Occurrence of Seam Bump

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Abstract

Sealing compound extrusion observed after thermal processing remains a recurrent and poorly understood failure mode in metal food cans, directly affecting hermeticity and the reliability of commercial sterilization. This study investigates the mechanical, dimensional, and process-related factors that lead to compound migration beyond the double seam following retort conditions. A combined methodological approach, including dimensional analysis of seam geometry, cross-sectional metallography, and assessment of seaming parameters, was applied in accordance with international technical guidelines. Results demonstrate that compound extrusion is primarily associated with insufficient free volume within the double seam, resulting from excessive vertical and horizontal compactness or from applying a sealing compound volume incompatible with the effective seam height. The analysis further reveals that operational adjustments intended to correct micro-leaks, such as artificially increasing body flange width to raise seam overlap, unintentionally elevate Body Hook Butting (BHB), reducing internal clearance and promoting local deformations such as "R"-ing. These distortions intensify during thermal expansion in retorts, forcing compound displacement and facilitating post-process extrusion. The findings highlight BHB as a critical yet frequently neglected parameter in industrial practice, reinforcing the need for integrated dimensional evaluation, visual seam profiling, and adherence to compound-film specifications based on actual seam height. Addressing these factors is essential to prevent sealing defects that compromise food safety, regulatory compliance, and packaging integrity.

Keywords: *Double Seam, Seam Bump, Metal Packaging.*

1. Introduction

Food preservation represents one of humanity's most significant technological milestones, allowing agricultural products harvested in one season to be safely consumed in another (Petroski, 1992). The invention of the can by Peter Durand in 1810, following Nicolas

Appert's pioneering preservation system (Guilbot, 2010), revolutionized food safety and distribution by introducing a hermetically sealed metal container capable of withstanding thermal sterilization.

Despite its early complexity and high production costs, the subsequent development of seam closures (Ams, 1910) made large-scale canning economically feasible. Currently, metal packaging, particularly tinplate and aluminum cans, is one of the most reliable and recyclable systems for food preservation. In South America alone, annual production reaches approximately 50 billion beverage cans and 10 billion food cans (FAO, 2020).

The double seam process, which hermetically seals approximately 60 billion cans annually (ABRALATAS, 2020), plays a decisive role in ensuring food safety by preventing microbial contamination and preserving product integrity. A defect in this closure system can compromise the product's safety, quality, and shelf life, posing potential public health risks and financial losses across the supply chain.

The importance of this process extends beyond the industrial context. As consumer markets increasingly demand sustainability and food security, the performance and reliability of metal packaging systems have become essential to global discussions on the circular economy and waste reduction (CETEA, 2020; Mordor Intelligence, 2025).

2. Metal packaging market in Brazil

Brazil produces around 4,2 billion food cans yearly, distributed in round and non-round cans. Around 10% is exported to Canada, the USA, Europe, and some countries in Africa; therefore, the majority is dedicated to local consumption.

The per capita consumption of canned food in Brazil is estimated at 18,5 cans (Brazil, 2023).

The installed capacity is 10,2 billion of food cans. However, over the past 30 years, some foods have disappeared from cans, such as edible oil and tomato salsa, which has forced the industry to drastically reduce production of round cans 83mm and 73mm. Taking into account the 2022 Census and the installed full capacity, we can estimate that consumption per capita 3 decades ago was nearly 50 cans.

Most of the machinery was built in the 70s and 80s, and the decline in consumption explains the lack of renovation in the industrial park.

2.1 Hermetic sealing of packaging

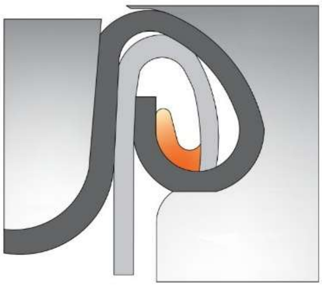
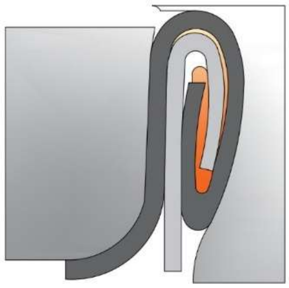
Throughout the double seam, the cans become hermetic. Darex (2002) defines hermetic seal as airtight. In general terms, keep the bacterias out of cans, preserve the contents inside the cans against leakage of liquids, vapors into or out of the cans. It can be summarized the objective of the double seam as nothing goes in and nothing comes out of the can.

Double seam assessment involves measuring critical dimensions, including thickness, seam height and countersink depth. The most determining parameter, however, is the overlap between the body hook and the cover hook. Continuous monitoring of these parameters, in accordance with regulatory guidelines and the technical literature (Dantas et al., 1996; Stumbo, 1965), is fundamental to ensure the commercial sterility and microbiological safety of the packaged product, as the quality of the sealing process is crucial to food safety.

2.2 Double seam process

The double seam consists of five layers of plate interlocked or folded and pressed firmly together (Deshwal, 2019). It is formed in two operations. A first operation roll tucks the curled edge of the cover underneath the flange on the can body. The seam is then completed by the second operation roll, which presses the folds of metal tightly together, squeezing the compound lining into the spaces where there is no metal to metal contact to make a hermetic seal (Figure 1).

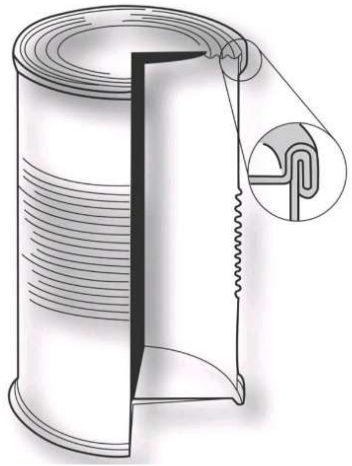
Figure 1: Seaming Roll profile engineering (first and second operation)

	
First Operation	Second Operation

Source: Silveira (2024)

The first operation double seam initiates the interlock between the flange of the can body and the curl of the ends, forming the internal hooks. Subsequently, the second operation applies controlled pressure to compress these five layers of metal and distribute the sealing compound, resulting in the compaction necessary to create an effective barrier against the entry of microorganisms (Figure 2).

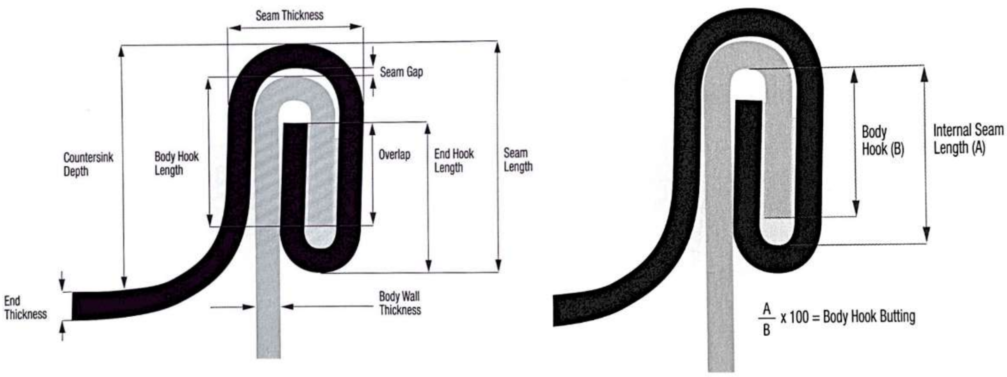
Figure 2: Cross section analyzed



Source: Authors

After the metal-forming process, the seam components must meet precise specifications to ensure proper formation of the double seam and, consequently, guarantee its airtightness (Figure 3). Mechanical forming is defined as a set of processes in which metallic raw material is subjected to mechanical stresses exceeding its yield strength, resulting in a permanent alteration of its geometry without material loss (Helman & Cetlin, 2015). The effectiveness of the forming process culminates in the formation of the double seam, an essential mechanical joint that, together with a sealing compound, creates an airtight seal.

Figure 3: Double seam measurements



Source: Darex (2006)

Double seam failures compromise this airtightness, allowing contaminants and gases to enter, which directly affects the effectiveness of heat treatment in autoclaves. Maintaining double seam integrity requires continuous inspection and rigorous control of closure variables, along with the application of overpressure during cooling to prevent ruptures and preserve the seal. Regulatory standards such as FDA (21 CFR Part 113), ANVISA (RDC 331/2019), and

European guidelines reinforce the need to validate the thermal process and monitor double seam as part of HACCP, ensuring microbiological safety and regulatory compliance.

2.3 Types of double seam

Each canmaker can design their own double seam. The European Secretariat of Manufactures of Light Metal Packaging (SEFEL) establishes seven types of double seam based on the Seam Height (Table 1).

Table 1: Types of double seam

Type	**OIII**	**OII**	**OI**	**I**	**II**	**III**	**IV**
Seaming Heigh	2.40	2.60	2.75	2.85	3.00	3.20	3.40

Source: SEFEL (1999)

The Technical Bulletin n° 003, Darex (2006), defining the film volume for round ends. That Bulletin divides the double seam in three types (Table 2).

Table 2: Relationship between double seam height and its classifications.

Type of seam	**Seam Heigh**	**SEFEL TYPE**
Mini Seam	≤2.74 mm	OI, OII and OIII
Midi Seam	2.77 mm to 2.95 mm	I
Conventional Seam	≥2.95mm	II, III and IV

Source: Darex (2006)

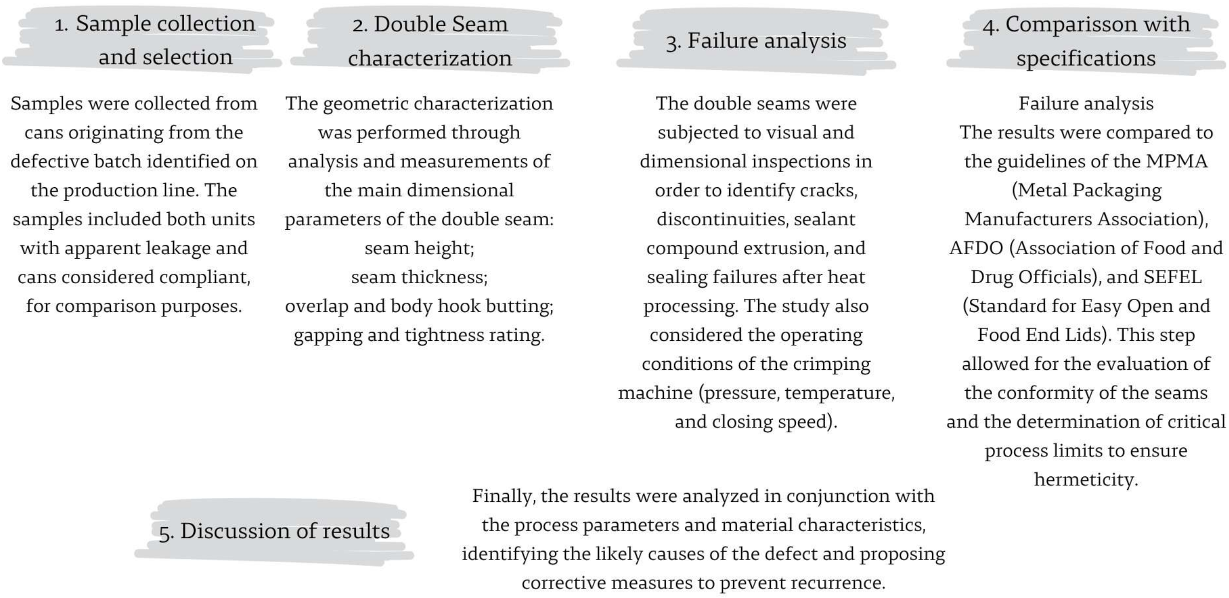
While Darex has as goal defines the film volume based on the Seam Heigh, SEFEL has as goal provide an interchangeability of cans ends and bodies. Although each canmaker can design its own double seam, SEFEL offers parameters to standardize the dimensional of the cans ends, bodies and seaming tools, therefore, it serves as a guide to be used as reference when the double seam presents construction defects.

Both standards will be used to guide the evaluation of this analysis.

3. **Methodology**

The methodology adopted in this study was structured in four main stages: sample collection, characterization of the double seam, failure analysis, and comparison with international technical specifications (Figure 4).

Figure 4: Methodological Flow



Source: Authors

The sample collection steps follow the standard for representative sample sizes outlined in the technical manuals incorporated into the corporation's internal procedures. Similarly, the analyses are based on technical manuals that have already been validated in the relevant study segment.

The problem identified in this research is the analysis of the double seam of steel cans. This scenario justifies the need for a more in-depth study to understand its causes and seek solutions.

The literature review began with the theme of Leakage or contamination in cans, focusing on the subtopics of metal forming and extrusion. Searches were conducted using the keywords seaming, hermeticity, and metal packaging, considering publications from the Scopus, Web of Science databases and specialized technical manuals.

To guide the structuring of the literature review, different categories of sources were considered, including scientific articles, books, institutional documents, and technical standards, as well as theoretical approaches such as empirical-analytical and quantitative-experimental, with a focus on the areas of double seam, seam bump, and metal packaging. These choices contributed to a consistent analysis aligned with the field's methodological recommendations.

This research adopts a qualitative-quantitative approach, combining elements of both qualitative and quantitative methods. Regarding its nature, this is an applied investigation whose purpose is to solve practical problems with direct application. In terms of objectives, the research is classified as explanatory, as it identifies the factors that determine or contribute to the occurrence of phenomena. To achieve these objectives, methodological procedures compatible with the study's proposal were adopted, including a case study, which is defined as the in-depth exploration of a specific case.

Data collection took place from November 3rd to November 28th, 2025. Data were collected through direct observation, photographic records, and on-site visits.

Data analysis was performed using Excel and Minitab software. Three main parameters were considered: Height Seam (mm), Type Seam, and Seam Classification. This analysis enabled a more precise interpretation of the results, thereby enhancing the reliability of the study's conclusions. Thus, the result was to justify the potential failure's origin through analysis of the technical manuals and manufacturing process parameters for the respective packaging.

4. **Applied case study**

Given the technological and safety relevance of the double seam, this paper presents a case study focused on the extrusion of sealing compound after sterilization process in food cans. The study arises from the practical need to identify and understand the root causes of this defect, which manifests as the migration or extrusion of the sealing compound beyond the double seam after thermal processing.

This phenomenon, although seemingly minor, can indicate inadequate mechanical parameters, improper compound application, or incompatibility between the sealing compound and the retort process conditions. Consequently, understanding its occurrence has both scientific and industrial implications, as it bridges the gap between materials science, process engineering, and quality assurance in food packaging.

To achieve a comprehensive understanding of this phenomenon, the study also incorporates principles of content analysis (Bardin, 2016), which emphasizes systematic and objective procedures for describing and interpreting the content of communications and technical documentation. This approach enables the categorization and interpretation of patterns in qualitative data from inspection reports, process logs, and failure analyses, ensuring analytical rigor and interpretative consistency.

The study adopts an applied approach through a case study methodology, enabling an in-depth examination of a real industrial context. The case study is an appropriate methodological strategy when the boundaries between the phenomenon and its context are not clearly defined, enabling comprehensive analysis through multiple sources of evidence, such as metallographic inspection, dimensional analysis, and normative comparison (Yin, 2018 & Eisenhardt, 1989).

The objective of this study is to analyze and characterize the occurrence of sealing compound extrusion after thermal processing in metal food cans:

i. Identify the mechanical and thermal conditions associated with the extrusion defect;

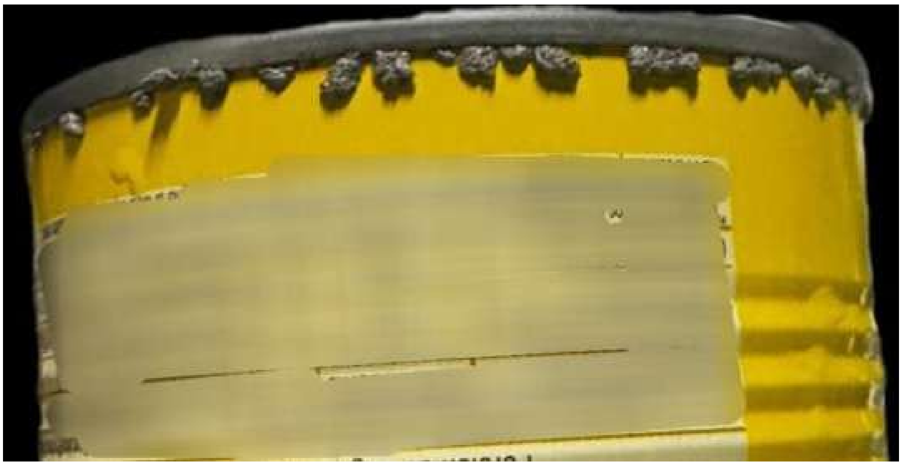
ii. Perform metallographic and dimensional analyses of the double seam in accordance with international standards;

iii. Correlate observed failure modes with process parameters and material properties to improve sealing performance and ensure food safety.

4.1 Analysis

After sterilization process (1h @ 121°C) bottoms of cans diameter of 73 mm, height of 95mm filled with meat, had presented compound extrusion to outside of the cans. This effect occurred only from 3/8 to 4/8 of the cans circumference. On the top, nothing is reported or it is observed, therefore the problem is concentrated in the bottoms only (Figure 5).

Figure 5: Extrusion of sealing compound



Double Seam Characterization

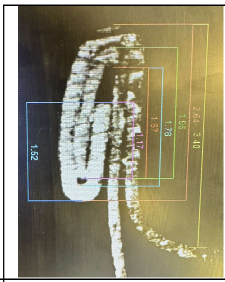
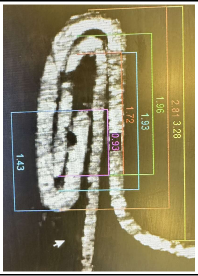
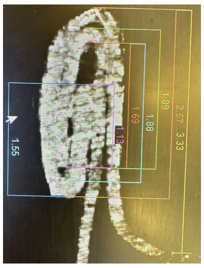
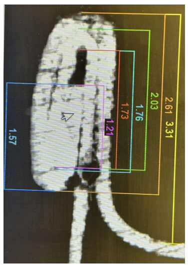
Four cross sections in the double seam were done, and the results and images are in Table 3. Cross section number 1 and 2 represent the regions where extrusion occurred, while cross sections 3 and 4 are in the opposite region of the cans where the extrusion didn't occur.

It was measured the tinplate thickness of the ends and body, what indicates 0.22 mm and 0.17mm respectively with the lithography/coatings layer already included. Considering these figures, the seaming thickness specification is (Darex, 2022) (Equation 1).

$$(2 * 0.17mm) + (3 * 0.22mm) + 0.13mm\ (free\ space) = 1.13mm \quad (1)$$

In the samples collected the seam thickness remains 1.18 mm in the region with extrusion and 1.11 to 1.14 mm in the region without extrusion (Table 3). Seam thickness variation between 0.05 mm and 0.075 mm are considered unacceptable (Darex, 2022).

Table 3: Analysis of double seam parameters

				
Cross Section	**#1**	**#2**	**#3**	**#4**
Height mm	2.70	2.82	2.57	2.61
Thickness mm	1.18	1.18	1.14	1.11
Overlap	66%	48%	60%	89%
BHB	94%	89%	90%	98%
Body hook mm	1.96	1.96	1.89	2.03

Source: Authors

4.2 Seam height

The seam height specification used by the canmaker is from 2.70 mm to 3.10 mm. Based on SEFEL (Table 1) could be classified between Type OII and III and based on DAREX (Table 2) can be classified in Mini, Midi and Conventional seam.

Based on the seam height mentioned in Table 2, it can be determined the amount of compound to be applied onto can ends (Table 4). Three types the seaming to determine the film volume to be applied (Darex, 2006).

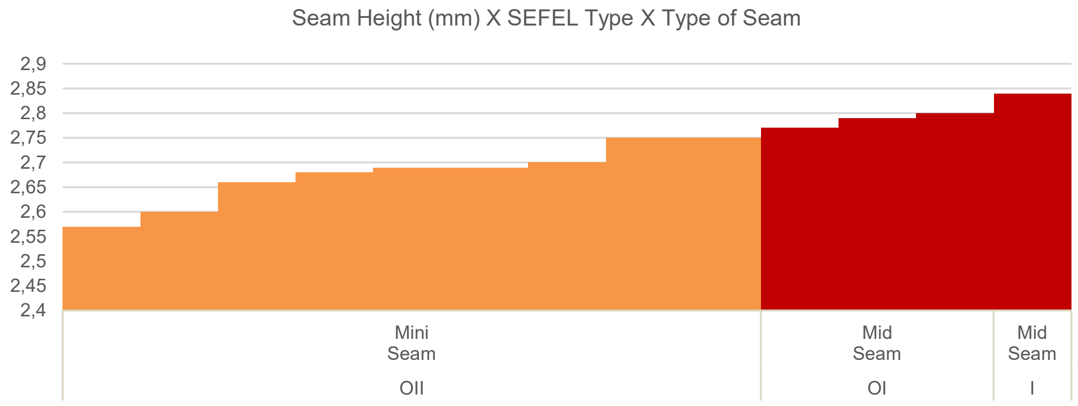
Table 4: Recommended Film Volume of compound applied as a function of the type of double seam

Diameter	**Mini Seam**	**Midi Seam**	**Conventional**
73 mm (Welded Can)	38 mm³	43 mm³	48 mm³

Source: Darex (2006)

Seam Height measured by micrometer in the can under evaluation remained between 2,64 mm to 2.80 mm in the region where the extrusion occurred; and 2.57mm to 2.61 mm in the region where the extrusion didn't occur. In order to realize the behavior of the seam height around the cans it was measured the seam height each 20 mm of the circumference. The results were plotted, and it was noted that the seam height increases specifically in a certain region related to extrusion (Figure 6).

Figure 6: Distribution of the seam height over the circumference of the can



Source: Authors

We identified that three types of seam (OII, I and II) can be found on the same cans (SEFEL, 1999), as well as Mini and Midi Seam (Darex, 2006).

As reference, canmaker informed the film volume applied in the ends was 45 mm³. Therefore, although the volume meets with the seam heigh specification (2.90 mm TYPE I, Conventional), it is too much for the real seam height produced in that can. Excess of compound can be squeezed out by the double seam (Silveira, 2024 & Darex, 2002).

4.3 Body Hook Butting (BHB)

The percentage of Body hook butting ensures that it is embedded into a great portion of sealing compound (CANADIAN, 1989). DAREX 2002 and CANADIAN 1989 indicates that the minimum percentage of BHB is 70% to ensure adequate seal. However, only DAREX indicates the maximum percentage is 90%. SILVEIRA 2024 analyzed cans with sealant extrusion, and in all samples with BHB greater than 90%, all showed compound squeezed out.

All of 4 cross sections analyzed presented BHB in the upper limit or above it. Cross section #4 presented correlatively excessive BHB and seam Overlap. It also presented a distortion of the body hook called by Hair-pinning or "R"-ing (DAREX, 2002). Although the cover hook is not pulled away from body wall, the body hook distortion is similar to described by DAREX 2022 as Seam Bump. Additionally, both DAREX 2002 and CANADIAN 1989 define that this defect causes an increase of the seam thickness in a small area of the cans. CANADIAN reports this increase are between 0,08 mm to 1,0 mm while DAREX reports an increase of 0,075 mm or more.

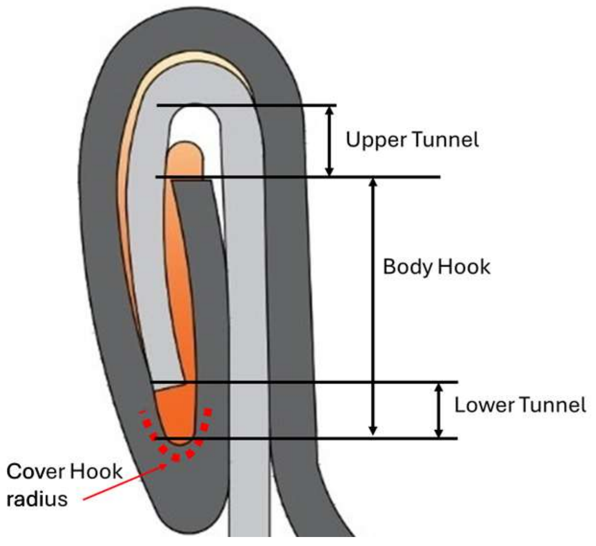
Therefore, the cans under evaluation presented:

- Distortion of body hook in "R-ing"
- Increase seam thickness in a small area around 0,07mm

Mechanism of "R-ing" formation

The distortion of the body hook in "R-ing" only happens after the sterilization process; therefore, it cannot be observed before. During the sterilization, it is normal that the cans expand and demand internal movement from the hooks inside of the double seam. Both hooks use the upper/lower tunnels for such movement. Then, the seam internal cavity reduces in size, and the hooks make the sealant compound flows along the seam where there is no metal-to-metal contact anymore. As soon as the sterilization process is finished the double seam turn back to its original format as well as the sealant compound to its original position.

The mechanism to obtain such deformation in "R-ing" in the can under study is that, due to excessive BHB, the free space for body hook movement (lower tunnel) doesn't exist. During the sterilization process of this can, naturally the body hook penetrates as much as it is possible while at the same time the cover hook makes the opposite movement, forcing the body hook to touch the cover hood radius which naturally offers a resistance against the movement. In the upper tunnel, the body hook finds a free space to release the compressive force exerted by the cover hook radius against the body hook, forming the "R-ing" shape.



Usually, in double seaming with >90% BHB the sealant compound is squeezed out right after the seaming process. In the case of the region represented by cross section #4, it probably was what happened but it wasn't noticed by operator. The body hook distortion occurred after sterilization.

For the sealant compound squeezed out after sterilization in the region represented by cross section #1 and #2, the movement of hooks described above makes the compound (which was embedded the body hook) flows to upper tunnel and after cooling down the retort and hooks turn back to position, the excess of compound was squeezed because there wasn't enough free space to accommodate its. That's why this defect is always related to leakage.

Excessive BHB is obtained when the operators request to increase the body flange length or increase the vertical force during the seam formation to obtain greater seam overlap.

4.4 Seam Overlap

Sufficient seams overlap percentage ≥ 55% ensures adequate compactness of the double seam (Darex, 2002). The seam overlap is considered insufficient when any portion of the double seam exhibits an optical overlap of less than 25% (Canadian Food Agency, 1989).

Seam overlap is related to the body flange width. Canmaker informed that such width is 2.50 ±0.20 mm. The overlap specification is not considered a characteristic to be evaluated in the construction of the double seam; on the contrary, only the length of the body hook is specified and controlled as 1.90 ± 0.20 mm.. As reference, this range of body flange width can classify the seaming and body hook length (SEFEL, 1999) (Table 5).

Table 5: Relationship between seam overlap and body flange width

SEFEL TYPE	Flange Width	Body hook length
OI	2.45 mm	1.85 mm
I	2.45 mm	1.90 mm
II	2.65 mm	2.00 mm

Source: SEFEL(1999)

All body hook length measurements meet the specification in all 4 cross sections of the double seam in Table 1. But the seam overlap fluctuates from 48% to 98%. BHB and Seam Overlap are linked to each other. The correct percentage of BHB and Seam Overlap ensure leak proof seams (Darex, 2022).

Canmaker and Packer are looking to meet the length of hooks specification, however, length is a recommended dimensional, while the percentage of overlap is critical seam dimensions. It means that the percentage of overlap is more critical than meets the dimensional in millimeters. In this case, complying with the dimensions led to defective and poor construction of the double seam.

5. Conclusion

Extrusion of sealant compound is a characteristic that indicates excess of compound for the free space available into the double seam. During the seaming, canmakers and packers may let few free space for the compound thru much compactness (vertical and horizontally) or occupy that with metal (>90% BHB)

Canmakers may apply much more compound than necessary if they consider only the ends diameter to determine the film weight without taking into consideration the seam heigh which classify the seaming in Mini, Midi and Conventional. The difference of film volume between each other can reach 20%. Indeed, if the double seam is midi (seam heigh ≤2,74 mm) but apply film volume based on conventional (seam height ≥2,90 mm) compound extrusion will occur.

When faced with cans with micro-leakage or the obligation to comply with dimensional requirements of the double seam, the seamer operator distorts the double seam to solve the problems. As if solving a micro-leakage or reaching a specific seam dimension at any cost, without considering the impact on the seal, did not have serious consequences for the robustness of the double seam to protect the food throughout its shelf life.

Most part or seam operators when asked what guarantee a good seal they said seam overlap. Therefore, the first think that comes to mind for the operator when faced with any problem is to increase the seam overlap or body hook length. The easiest and fastest way to do that is through the increase of body flange length. Sometimes, the reason behind the poor body hook/overlap is an incorrect setting of the seamer but due to a lack of deeper analysis, the decision is to change the dimensional of body flange length. Two wrongs don't make a right. The consequence of such actions will be to gain more overlap/body hook but on the other hands increase the BHB which occupy the free space allotted for the sealant compound. Naturally the compound will be squeezed out otherwise the seaming will present defects like Droop (AFDO, 2011) (DAREX, 2002) (CANADIAN, 1989)

Few canmakers and packer consider BHB as a critical parameter for the seaming. Usually, only seam thickness, heigh and overlap are measured. Due to this lack of knowledge about BHB and its importance to ensure the seal, when they have compound squeezed out they allege high compound film volume, poor compound adhesion to the substrate e/or poor compound dryness.

When in face of a compound extrusion, before taking measures, such as reducing the compound film volume, increasing the dry temperature or any other action on the sealing gasket, it is recommended that the BHB be checked and evaluated. Additionally, seam heigh must be evaluated in the faulty cans and check if the vertical compactness is less than the specification because this parameter can be compromised by operators to reach the seam overlap/body hook length, what reduce up to 20% of the free space of the double seam reserved to the sealant compound.

In the cans that were the subject of this study, the combination of actions such as: increase of the body flange length and increase the vertical compactness of the double seam just to reach the body hook length specification, led to excessive Body Hook Butting and only this single parameter out of recommendation was able to trigger two critical defects:

- extrusion of the sealant compound gasket and
- distortion of the body hook in "R"-ing.

Both defects potentiate each other to eliminate the robustness of the double seam and lead to leakage (vacuum loss) after sterilization process.

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