HECTOR BEVERAGES PVT. LTD.

# Project: Coconut Water Bottle Cap Design

## Designing a Bottle Cap Intended to Help Consumers Pierce Film Used in Hermetically Sealed Bottles

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**7/7/2019**

## Problem Statement

200mL Coconut Water is currently sold in a bottle which is sealed using a composite film covering the mouth. This film is difficult to peel off the bottle due to strong adhesion between the film and the bottle, and is difficult to pierce without the help of a sharp implement. The goal is to improve the consumer experience by providing an easy means to remove the seal.

## Constraints

The following constraints are found:

- The design of the bottle itself cannot be changed, since this would be prohibitively expensive to implement.
- The sealing process cannot be changed, since it is dictated by food safety concerns.
- For the sake of hygiene, the proposed solution must not involve contact between the contents of the bottle and any part of the packaging normally exposed to the outside environment.
- Any changes to the packaging must be compatible with current filling equipment, or must call for nothing more than minor modifications to any such equipment.
- The solution must not call for any significant increase in the cost of production per bottle.

## Approach to Solution

It was decided that the appropriate approach to solving the problem is a redesign of the bottle cap, and only of the bottle cap, since the initial investment required for this would be acceptable, and no major changes may need to be made to the existing processes and equipment.

## Fundamental Functional Design Ideas

Functionally, three main design ideas were pursued, two of which were adaptations of existing designs and one which is believed to be novel. A fourth design idea was discarded due to the fact that it is not compatible with the nature of the sealing process.

1. For the cap to have a thin top with a spike on the inside, designed to flex under a force applied to the top of the cap, thereby piercing the seal due to the displacement of the spike.
2. For the cap to have a sharp portion within a notch cut out of the side, usable to manually pierce the seal after removal of the cap.
3. For the cap to contain multiple blades designed to cause indentations in the seal during tightening, and pivot downwards during unscrewing of the cap, cutting it in the process.
4. For a circular serrated cutting implement to be attached to the inside of the cap, intended to cut the seal upon a re-tightening of the cap. This idea is discarded because

it is practically incompatible with the provision of uniform clamping pressure for sealing.

## Implementation of Functional Ideas

**Idea 1 (hereafter referred to as the buckling dome design):** This is an adaptation of an existing design. 2 to 4 extra millimetres are added to the height of the bottle cap to allow for inclusion of a thin dome-shaped top. A three-edged spike for maximal area of puncture is attached to the inside of the dome, and an offset dimple is created in it, intended to encourage application of asymmetrical finger pressure to the top of the cap. When such pressure is applied, the dome is expected to buckle inwards, causing the spike to puncture the seal. A rim around the edge of the cap, extending to the maximum height of the dome, is included to protect the seal from accidental puncture during transport and handling (See Figure 3-a). The profile of the rim of the dome (Figure 1) connecting it to the cylindrical wall of the cap is designed to dip down and sweep up to aid in buckling by minimizing local angular deflection.

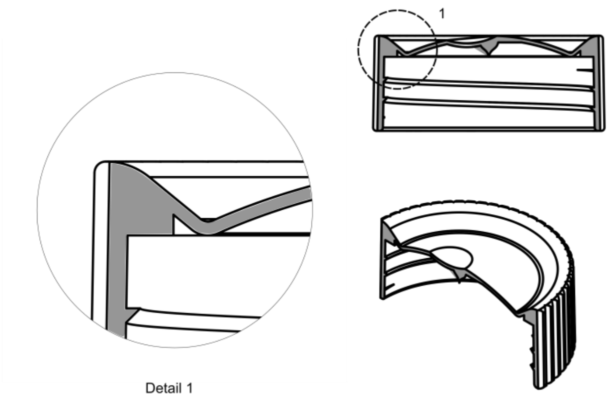



Figure 1: Cross-section of rim of buckling dome

**Idea 2 (hereafter referred to as the concealed notch design):** This is an adaptation of an existing design. The most fundamental change introduced is the addition of an integral breakaway cover intended to conceal and protect the sharp notch prior to opening of the bottle. Designs for covers, both intended to be removed manually (See Figure 3-b) and intended to detach automatically when the bottle is opened (See Figure 3-c and 3-d), were explored.

**Idea 3 (hereafter referred to as the pivoting blade design):** This design is believed to be novel. A blade with a transition between a steep edge angle for piercing and a shallower angle for cutting was designed to transmit force in a straight line of compression while pivoting downwards from the top of the bottle cap about a hinge consisting of a thin strip of flexible plastic, after breaking away from it along a designated fracture zone. The force required for this, and to pivot the blade downwards is a result of the reaction between the tip of the blade and the surface of the film as the cap is unscrewed. The shape of the blade (Figure 2-a) is derived from a geometrical construction (Figure 2-b) modelling the change in angle of force transmission as the length of material between the point of cutting and the hinge changes, as well as the radial displacement of the cutting point due to the circular motion of the blade (See Figure 3-e).

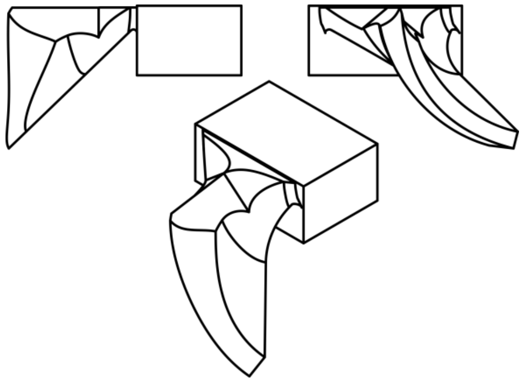


**Figure 2-a: Pivoting blade with hinge and back stop**

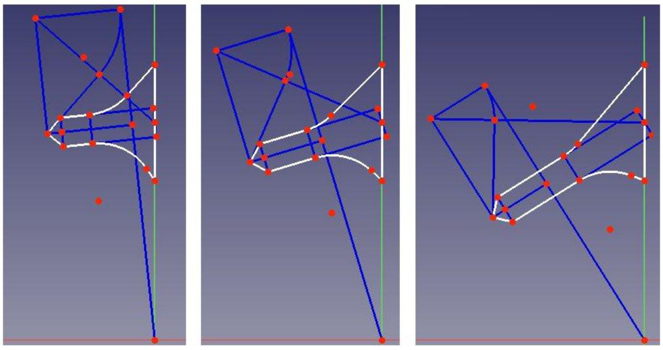


**Figure 2-b: Geometric construction to derive angle of blade Given distance between point of cutting and hinge**

# Visualizations of Bottle Cap Designs

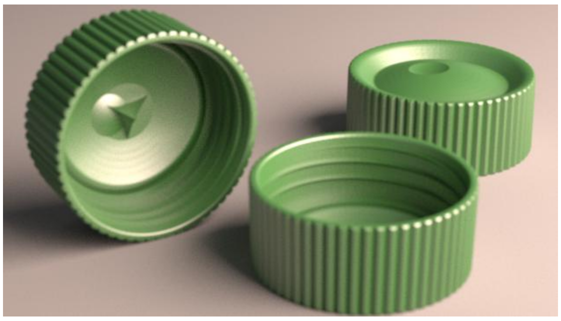


**Figure 3-a: Buckling dome design**

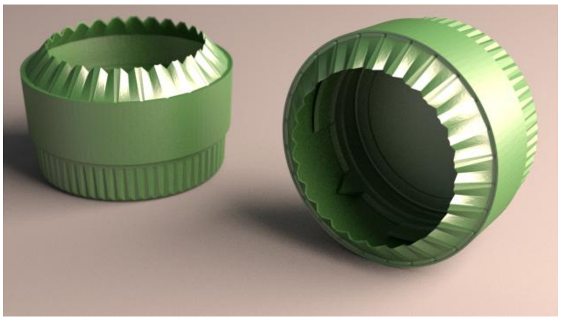


**Figure 3-d: Concealed notch design, self-removing cover, version 2**

**Figure 3-b: Concealed notch design, manually uncovered notch**

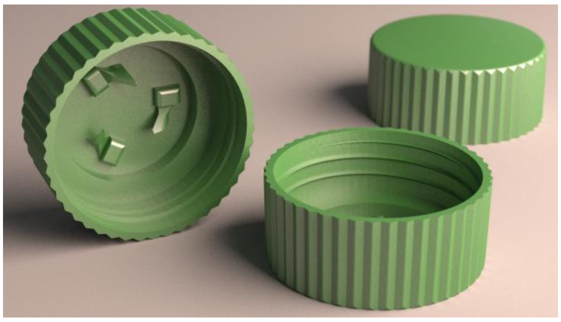


**Figure 3-e: Pivoting blade design**

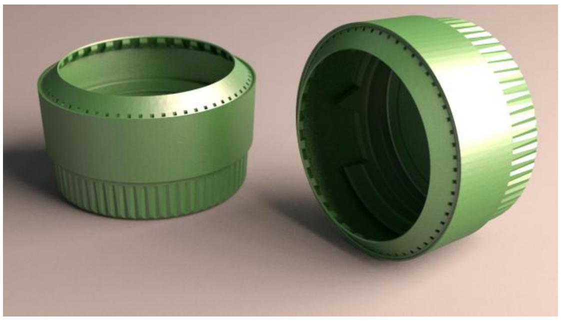


**Figure 3-c: Concealed notch design, self-removing cover**

## Concerns, Drawbacks and Challenges – Choice of a Design

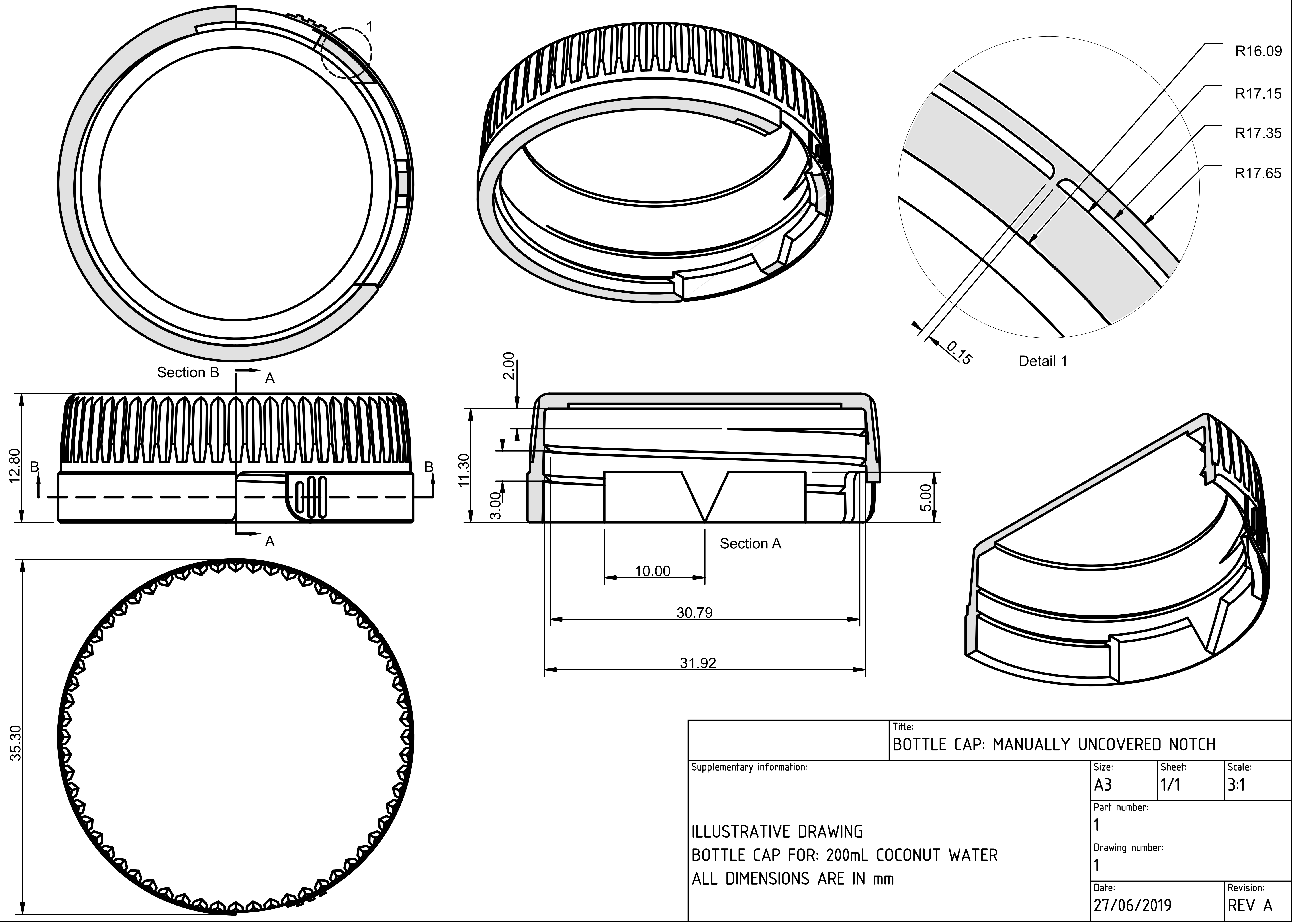
A layer of refractory foam is used to insulate the cap from the composite film and to provide uniform clamping pressure during the sealing process. This foam is a highly resilient material both mechanically and thermally. Through simple experiments it was concluded that it is unreasonable to expect any plastic object to cut it. As such, all of the designs must depend on manual removal of the cap and the foam layer before cutting or piercing of the film can take place.

At this point we may remove the pivoting blade design from our consideration, since it does not allow for opening of the cap, once tightened, without attempting to cut the seal. The design remains promising, however, if the foam layer were to be discarded or modified so as to make it easier to cut.

The buckling dome design was found to be promising from preliminary tests with the first 3D Printed prototypes. However, the process of removing the cap, removing the foam, replacing the cap, pressing down on the dome, removing the cap again and manually widening the hole in the film, is unnecessarily time consuming, and the design is rejected on this basis. Like the pivoting blade design, it remains promising if the foam were to be removed or modified.

The concealed notch design with the self-removing cover causes a significant dimensional change in the cap, as well as a significant increase in volume of material required. This raises concerns of compatibility with current filling machines and of cost of production.

The concealed notch design with the manually uncovered notch is suggested as the best solution to the problem stated within the constraints identified. An illustrative drawing of the design follows.

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|---|---|---|---|
| | Title: BOTTLE CAP: MANUALLY UNCOVERED NOTCH | | |
| Supplementary information: ILLUSTRATIVE DRAWING BOTTLE CAP FOR: 200mL COCONUT WATER ALL DIMENSIONS ARE IN mm | Size: A3 | Sheet: 1/1 | Scale: 3:1 |
| | Part number: 1 | | |
| | Drawing number: 1 | | |
| | Date: 27/06/2019 | | Revision: REV A |

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# A Proposal for a Change in the Spouting Process

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**Prepared by**
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## Objective

Spouting and stick-feeding are two of the most manpower intensive processes at the paper boat plant. Our goal is to increase efficiency in the stick feeding section, thereby reducing unnecessary allocation of manpower.

## Inefficiency being addressed

Currently, spouted pouches fall off the spouting machine into boxes in which they are stored until they are stick fed. The fall is unpredictable and therefore pouches are arbitrarily oriented in the boxes. These pouches need to be manually aligned so that they can be stick fed.

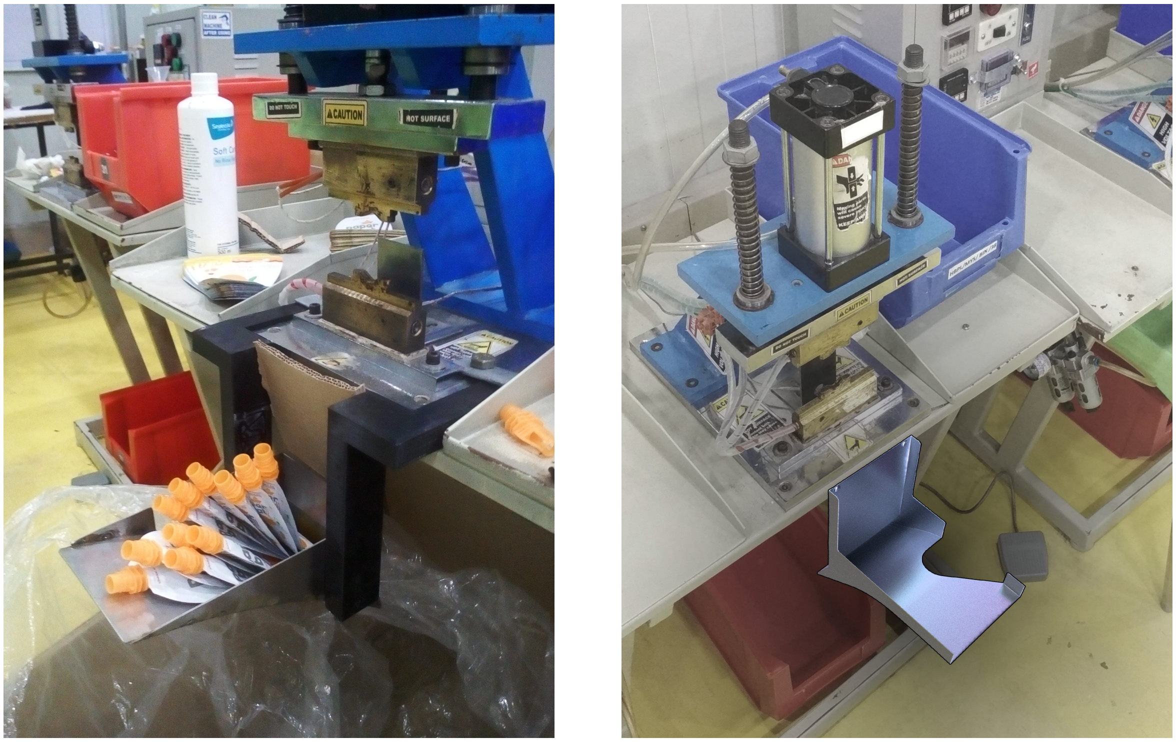
Here, we present a way to better organize spouted pouches inside the box.

## Description of the proposed workflow

The pouches falling off the spouting machine are collected in a tray (Figure 1) attached to the spouting table. Each time a certain number of pouches (10 to 15) are collected in the tray, they are manually removed from the tray and placed in the box.

This ensures that the spouted pouches are all stored either face up or face down, pointing roughly in the same direction. As a result, the amount of manual effort required to align pouches during stick-feeding is reduced significantly.

# Tray used



(a) (b)

Figure 1: (a) Pouches collected in prototype pouch tray (b) Illustration of a pouch tray bolted onto the spouting table (See drawing on page 9)

## Summary of expected improvements

Based on trials, we expect to require two fewer workers on Filler 3 and three fewer workers on Filler 1 and on Filler 2. Taking into account a 13% reduction in the speed of spouting we estimate that effectively, a total of three fewer workers will be needed overall, in the stick-feeding and spouting sections combined (see pages 4 and 5 for details).

## Other advantages

Reducing the number of people near the filler room, and the number of people who handle the pouches, is likely to result in lower contamination rates. Reducing overcrowding in the stick-feeding section may lead to a more productive work environment.

## Investment required

The stainless steel prototype trays used in the trials cost Rs. 800 each, plus taxes. We expect this cost to go down with larger orders, especially if the material is changed. One of these trays would be required for each machine. At Rs. 800 per tray for 45 machines, this adds up to Rs. 36,000 plus taxes. Separately there may be minor costs related to installation of the trays.

## Concerns and potential drawbacks

Apart from the reduction in the speed of spouting, there may be concerns regarding the nature of the new workflow; for instance the action required to manually place the spouted pouches in the box might prove physically taxing over the course of a day's work.

While the number of spouted pouches stored in the median box will likely not change, the maximum packing density might go down slightly. This is because currently, boxes are sometimes manually shaken to accommodate more pouches. This would disturb the orientation of pouches in the box and therefore must be avoided within the proposed workflow.

Decreasing margins in manpower allocation for stick-feeding may reduce effectiveness of auxiliary tasks such as making log entries, transportation of boxes etc.

## Bundling of pouches

Organising pouches in bundles (Figure 2) of eight or more would allow for greater savings in manpower in stick-feeding (see page 7 for details). However from trials using binder clips for bundling, with the clips placed in a bin at the spouting table, the reduction in the speed of spouting was found to be too high to make this a feasible option. Using a dispenser for clips, elastic bands or other similar fasteners, or developing an organized way to store such fasteners might address this issue in the future.

(a) 250 ml pouches

(b) 150 ml pouches

Figure 2: Bundled pouches

Another concern with bundling is an inevitable reduction in packing density. We expect a 30% reduction from what is currently achieved (see page 8 for details).

# Trial 1: Effect on rate of spouting (no bundling)

## Description of the trial

The spouting operator Ms. Chaithra was timed under the current workflow and under the proposed new workflow. These times were used to calculate the percentage reduction in speed in terms of pouches per minute (ppm).

## Baseline - Current Workflow

Time : 30 min

Number of pouches spouted : 647

Speed : 21.57 ppm

## Batch 1 - New Workflow

Number of pouches spouted : 647

Time : 36 min 30 sec

Speed : 17.73 ppm

## Batch 2 - New Workflow

Number of pouches spouted : 647

Time : 34 min 30 sec

Speed : 18.75 ppm

## Calculations

Since we expect the speed to increase gradually as the operators become accustomed to the new workflow, we use the time recorded for Batch - 2 in the calculations below.

Original speed : 21.57 ppm

New speed : 18.75 ppm

Percentage reduction : 13.07%

## Implications

To make up for 13.07% reduction in speed we would require

$$(\frac{13.07}{100-13.07} * 100)\% = 15.04\%$$

extra workers.

Assuming a current number of 30 workers, we would require 4.5 extra workers in the spouting section. As the workers become better accustomed to the process we can expect this number to go down to 4.

## Trial 2: Stick-feeding (no bundling)

### Description of the trial

Pouches were stick fed from boxes filled with and without using the pouch tray and the results were compared.

### Baseline - Current Workflow

Number of pouches stick fed : 1300

Time : 17 min 40 sec

Number of workers involved : 3

Speed : 24.52 ppm per worker

### Batch 1 - New Workflow

Number of pouches stick fed : 647

Time : 7 min

Number of workers involved : 2

Speed : 46.22 ppm per worker

### Batch 2 - New Workflow

Number of pouches stick fed : 1200

Time : 13 min 55 sec

Number of workers involved : 2

Speed : 43.10 ppm per worker

### Calculations

Original speed : 24.52 ppm per worker

New speed (average) : 44.67 ppm per worker

Percentage increase : 82.18%

### Implications

An 82.18% increase in speed would allow for allocation of

$$\left(\frac{82.18}{100+82.18} * 100\right)\% = 45.11\%$$

less manpower (purely for stick-feeding).

Assuming a current number of 16 workers, we would require 7.21 fewer workers in the stick-feeding section.

## Trial 3: Effect on rate of spouting (with bundling)

### Description of the trial

The spouting operator Ms. Chaithra was timed under the following workflow:

Once eight pouches collect in the tray, they are removed from the tray and clipped together using a binder clip retrievd from a bin similar to those used for spouts. The bundle is then placed manually in the box.

The time recorded was compared with Ms. Chaithra's baseline under the current workflow.

### Baseline - Current Workflow

Time : 30 min

Number of pouches spouted : 647

Speed : 21.57 ppm

### Batch 1 - New Workflow

Number of pouches spouted : 647

Time : 54 min 30 sec

Speed : 11.91 ppm

### Calculations

Original speed : 21.57 ppm

New speed : 11.91 ppm

Percentage reduction : 44.78%

### Implications

Even accounting for a slight improvement from acclimatization to the process, the speed observed here is too low for bundling in this manner to be considered feasible. The workflow can be improved upon by implementing a more organized system for storing clips/fasteners.

# Trial 4: Stick-feeding (with bundling)

## Description of the trial

Pouches were stick fed from boxes filled with and without using the pouch tray and the results were compared.

## Baseline - Current Workflow

Number of pouches stick fed : 1300

Time : 17 min 40 sec

Number of workers involved : 3

Speed : 24.52 ppm per worker

## Batch 1 - New Workflow

Number of pouches stick fed : 856

Time : 12 min

Number of workers involved : 1

Speed : 71.33 ppm per worker

## Batch 2 - New Workflow

Number of pouches stick fed : 856

Time : 11 min 26 sec

Number of workers involved : 1

Speed : 74.89 ppm per worker

## Calculations

Original speed : 24.52 ppm per worker

New speed (average) : 73.11 ppm per worker

Percentage increase : 198.16%

# Trial 5: Packing density of pouches in boxes (with bundling)

## Description of the trial

Pouches were clipped in bundles of eight and were placed in one of the boxes currently used for pouch storage. The number of pouches to fit in the box was recorded.

## Baseline - Current Packing Density

From inquiries, we determined that 1300 pouches per box is a fairly representative value for the current packing density. This varies since there are different sizes of box used.

## Packing density achieved with bundling

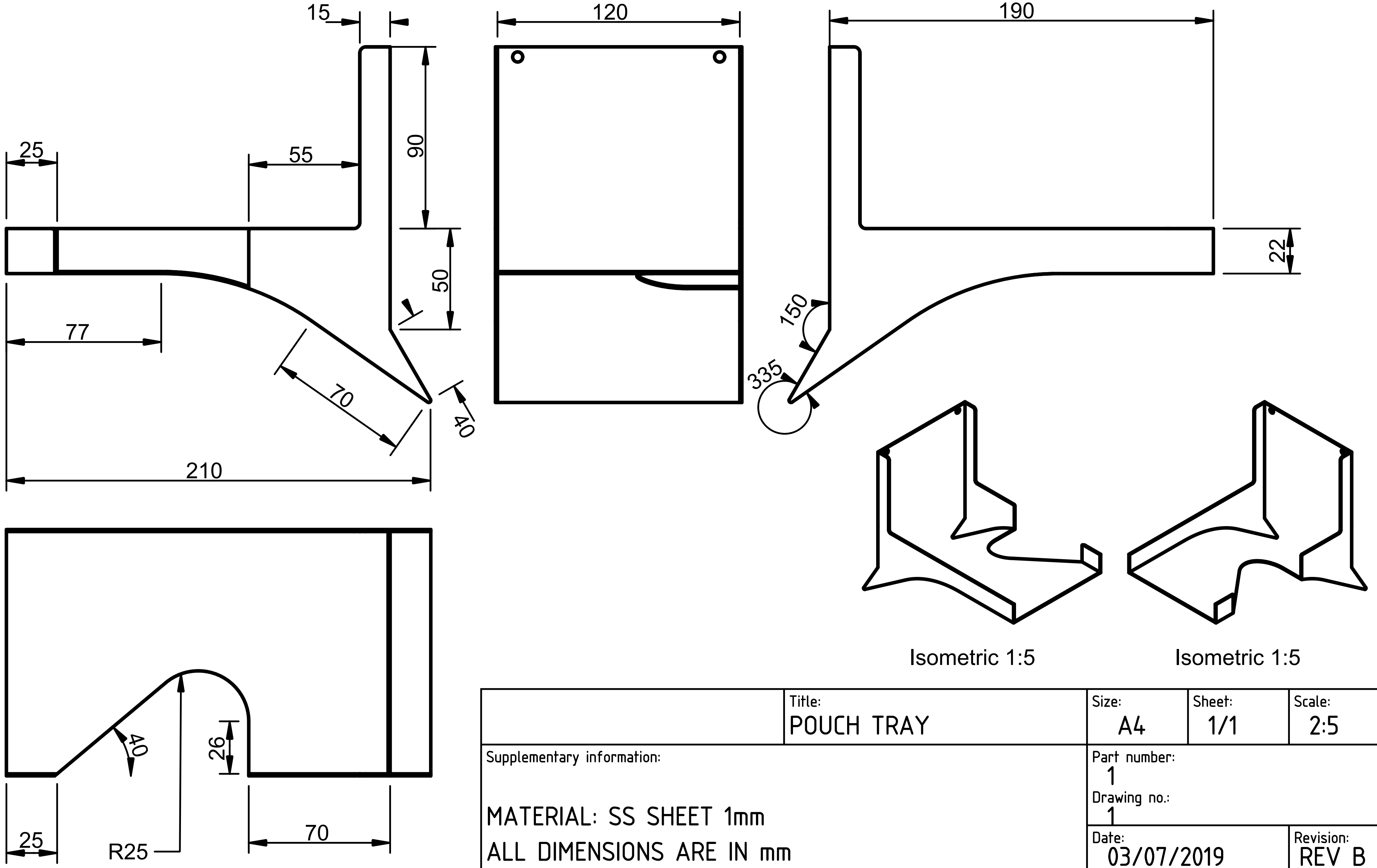
We observed that we were able to store around 900 pouches in a box.

## Calculation

Current packing density : 1300 pouches per box

New packing density : 900 pouches per box

Percentage reduction in packing density : 30.77%

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|---|---|---|---|---|
| | Title: POUCH TRAY | Size: A4 | Sheet: 1/1 | Scale: 2:5 |
| Supplementary information: MATERIAL: SS SHEET 1mm ALL DIMENSIONS ARE IN mm | | Part number: 1 Drawing no.: 1 | | |
| | | Date: 03/07/2019 | | Revision: REV B |