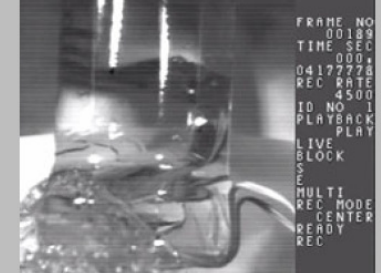
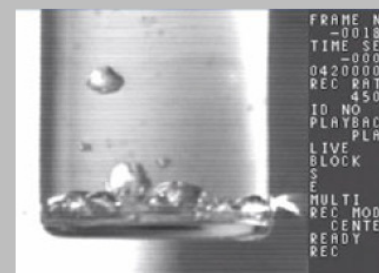
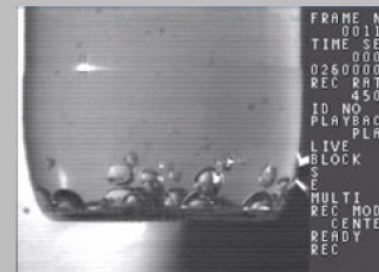
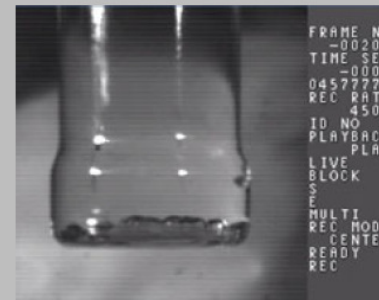
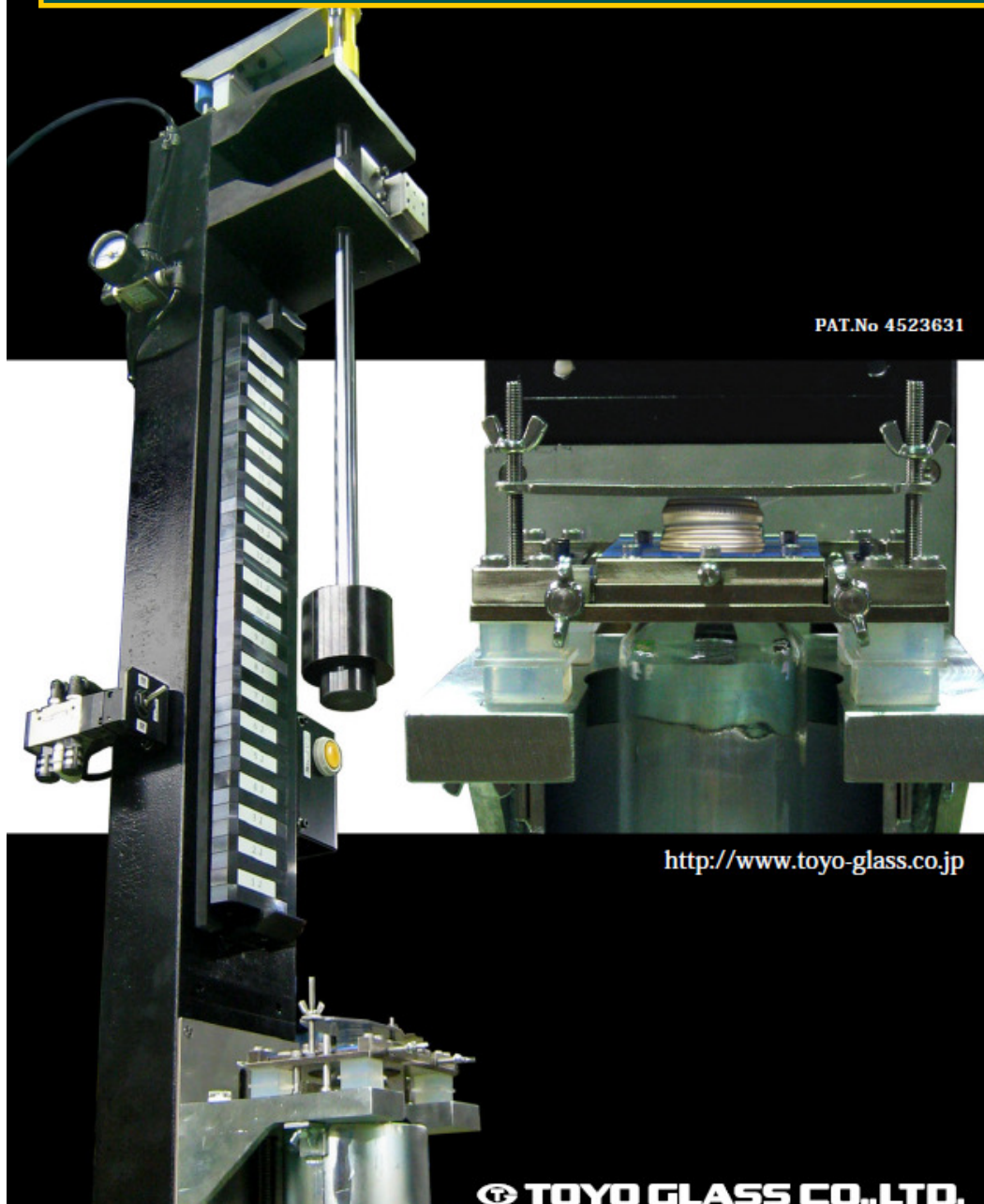


Single Container Water Hammer Tester



At AFGM Sept, 2013

Toyo Glass Co., Ltd.

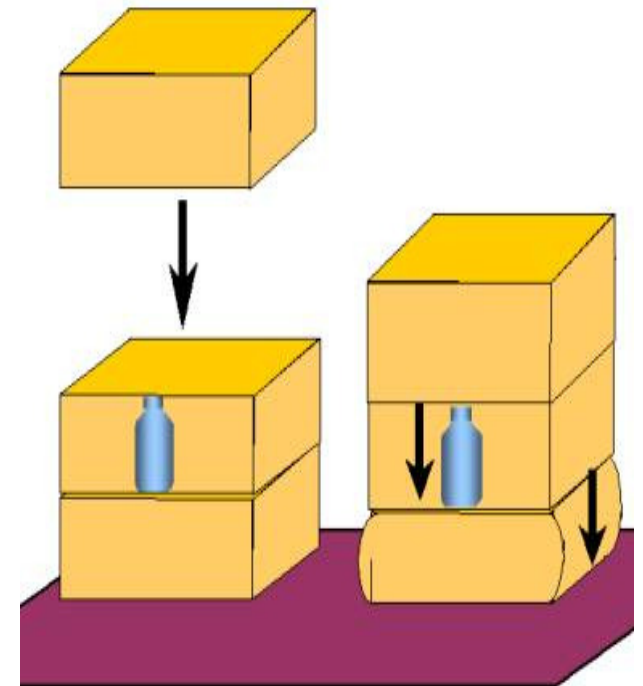
Glass Bottle Breakage by Water Hammer Phenomenon (1)

What is the water hammer phenomenon?

During distribution of filled glass bottles packed in a carton, a carton positioned at the bottom may be crushed by the downward impact through rough manual handling.

That is, glass bottles in the carton just above the bottom carton suddenly drop, and some of them may break.

This is usually called the “water hammer phenomenon”.



Glass Bottle Breakage by Water Hammer Phenomenon (2)

When a glass bottle breaks by the water hammer phenomenon in a carton, non-defective bottles inside the same carton may be contaminated by liquid contents or broken glass pieces.

Also, in many cases, a partially cracked but unbroken glass bottle whose inside is negative-pressured is delivered to a consumer.

When the bottle is opened by the consumer, the bottom of the bottle breaks due to release of the negative pressure inside the bottle. This breakage may dirty the consumer's clothing or hurt the consumer.



Patterns of Glass Bottle Breakage

- * Inside Pressure Breakage**

- CO₂ gas in the contents and the fermentation of the contents

- * Impact Breakage**

- Contact between bottles or a bottle and another object

- * Thermal Shock Breakage**

- Rapid temperature change

- * External Pressure Breakage**

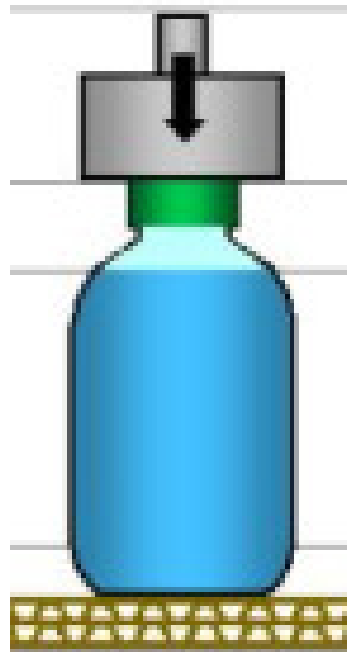
- External pressure (vertical load or lateral load) on a bottle

Breakage attributed to the **water hammer phenomenon** is classified as **“Inside Pressure Breakage”**.

Detailed Occurrence Process of Water Hammer Phenomenon

Step 1

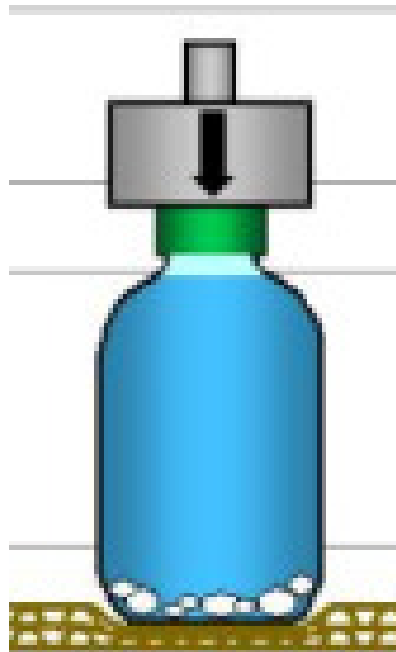
A filled glass bottle rapidly falls down by the downward impact.



Step 2

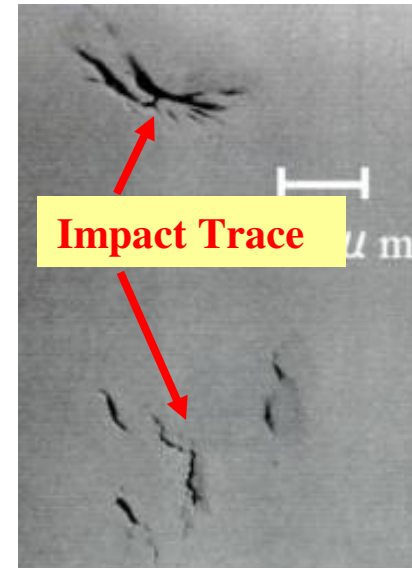
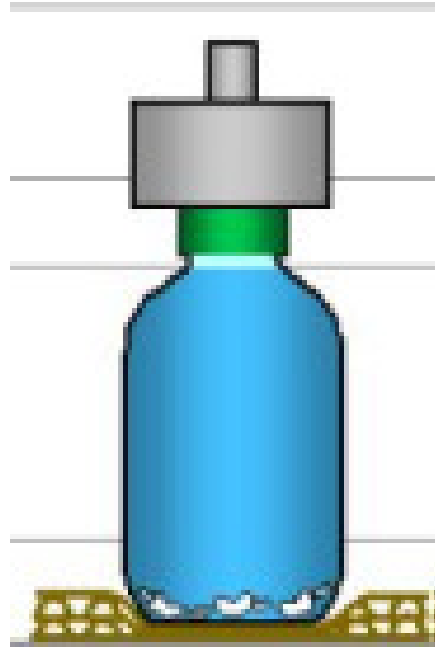
On the other hand, the liquid contents remain in the same position inside the bottle by its inertia force.

Therefore, the bottle bottom becomes negative-pressured and then cavities are generated at the bottom area of the liquid contents.



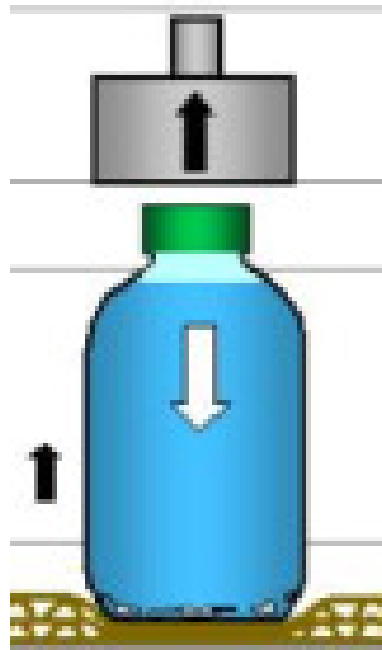
Step 3

When the cavity collapses, it affects its surrounding water and microjet arises. Then tiny scratches (impact traces) are formed on the heel and the bottom of a glass bottle.



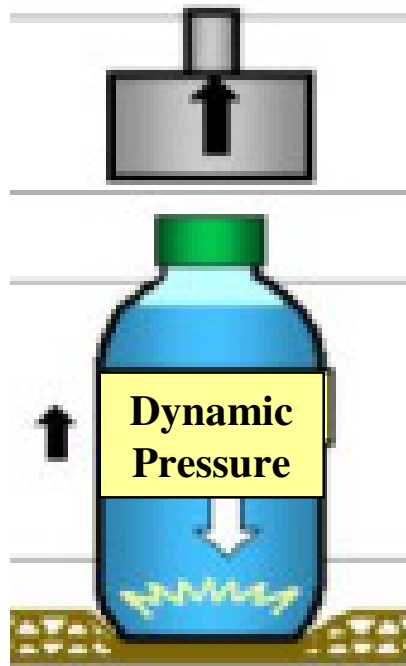
Step 4

Next, the liquid contents fall down due to the high pressure in the head space and gives a strong impact on the bottle bottom.

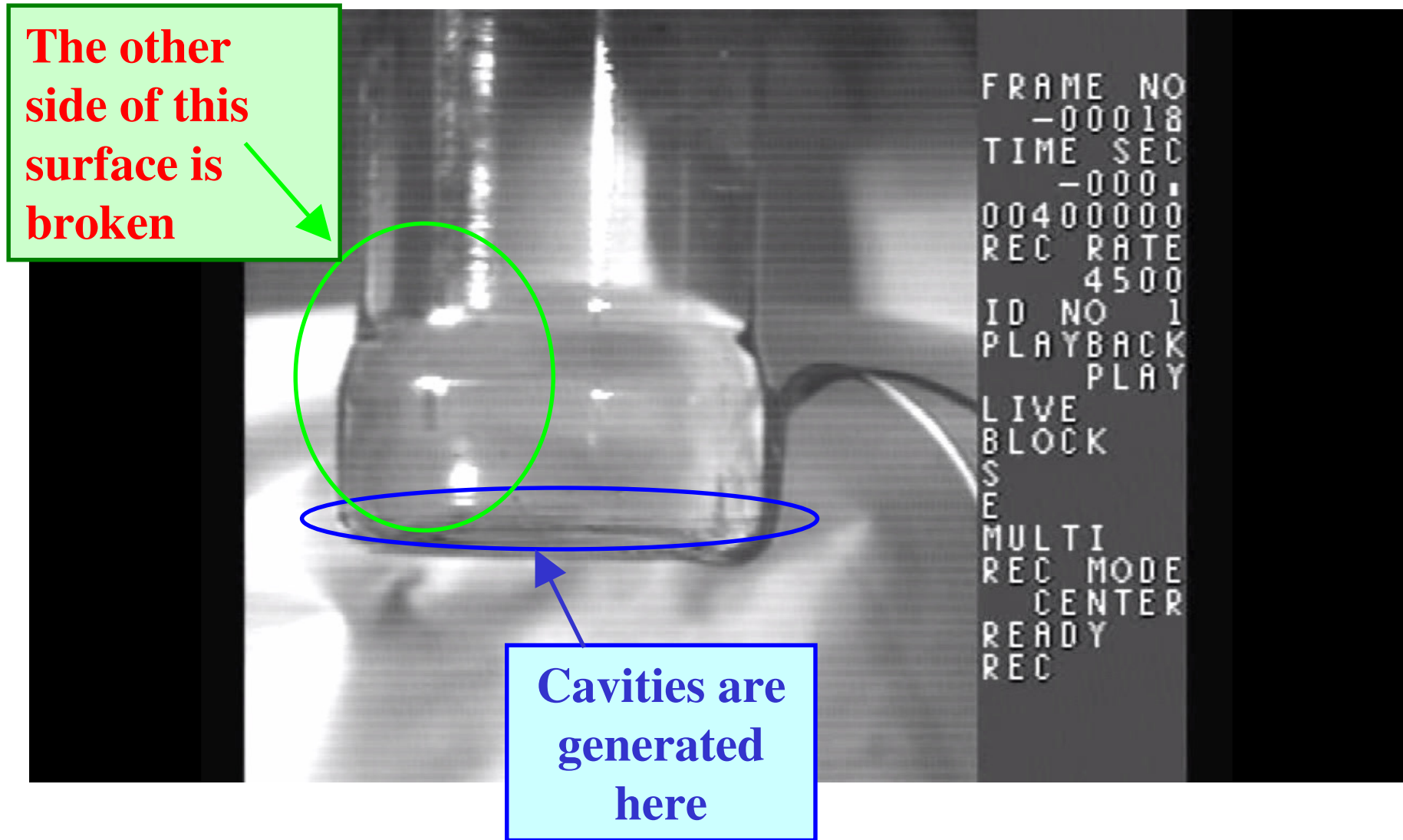


Step 5

Stress is concentrated on the inside surface of the heel area and the glass bottle starts to break originating from the tiny scratches (impact traces).



Bottle Breakage by Water Hammer Phenomenon



Problems in Improvement of Water Hammer Strength

— Lack of Strength Verification Method —

*** Even when the thickness distribution of a glass bottle is improved to enhance the water hammer strength, it is not possible to immediately verify the enhanced strength by the conventional strength testing method.**

— Strength vs. Lightweighting —

*** Excessive thickness of a glass bottle preventing the water hammer breakage may sometimes impede lightweighting of the bottle.**

Conventional Water Hammer Strength Test Method

■ The conventional water hammer strength test requires time-consuming and labor-intensive work and its repeatability is very low.

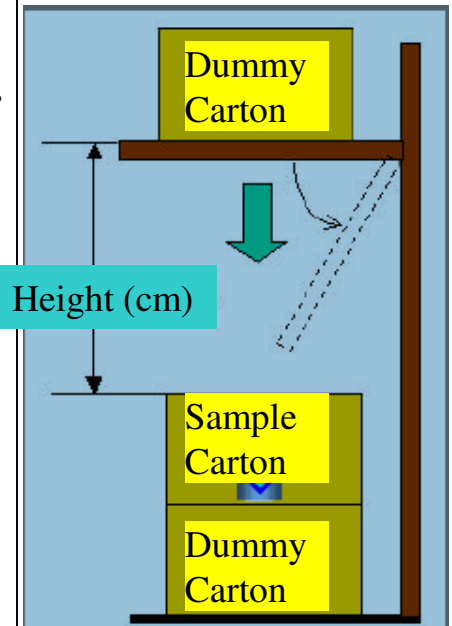
① **This conventional test method replicates glass bottle breakage originated from the water hammer phenomenon during manual handling of filled glass bottles.** A customer needs cartons which are actually used for their product as well as 100-200 filled glass bottles in order to conduct this test.

② This test requires complicated work such as packing bottles into a carton, lifting and dropping a carton, checking a crushed carton and verifying a broken bottle.

③ Since this test is dependent on conditions which are hard to repeat such as crushing of a carton, its repeatability is very low.

■ As it is not possible to recognize the water hammer strength of a bottle immediately after the bottle is filled, prompt reaction for process improvement cannot be taken.

■ The water hammer strength of a glass bottle itself cannot be numerically recognized.



Development of Single Container Water Hammer Tester

— Goals—

- **Prompt recognition of the water hammer strength of a glass bottle which has just been filled with hot water**
- **Measurement of the water hammer strength of a bottle itself without a carton**
- **High repeatability of measurement**
- **Use for a wide range of glass containers from a narrow neck bottle to a wide mouth jar**
- **Easy operation and no individual variation**

Features of Single Container Water Hammer Tester

■ Neck Holding

- * A glass bottle falls exactly vertically.
(to ensure the repeatability)
- * No undesired reaction force occurs since a glass bottle is hung in the air.
- * The downward impact can be stably given to a bottle.

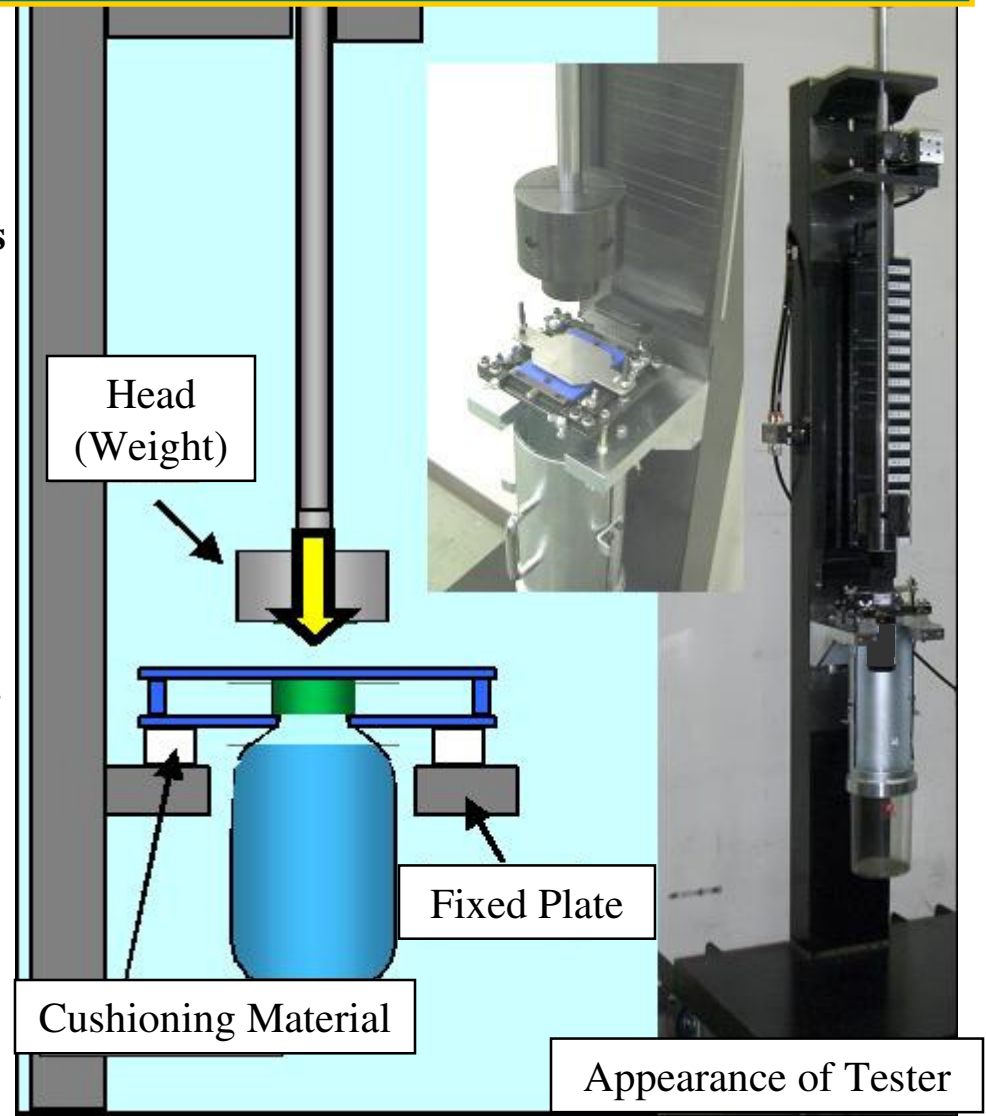
■ With a single bottle without a carton

- * A test can be conducted immediately after a bottle is filled and less sample bottles are required (About 20 bottles),.
- * The strength of a glass bottle itself can be examined.
- * The strength can be examined by mold number to check if there is any tendency among mold numbers.

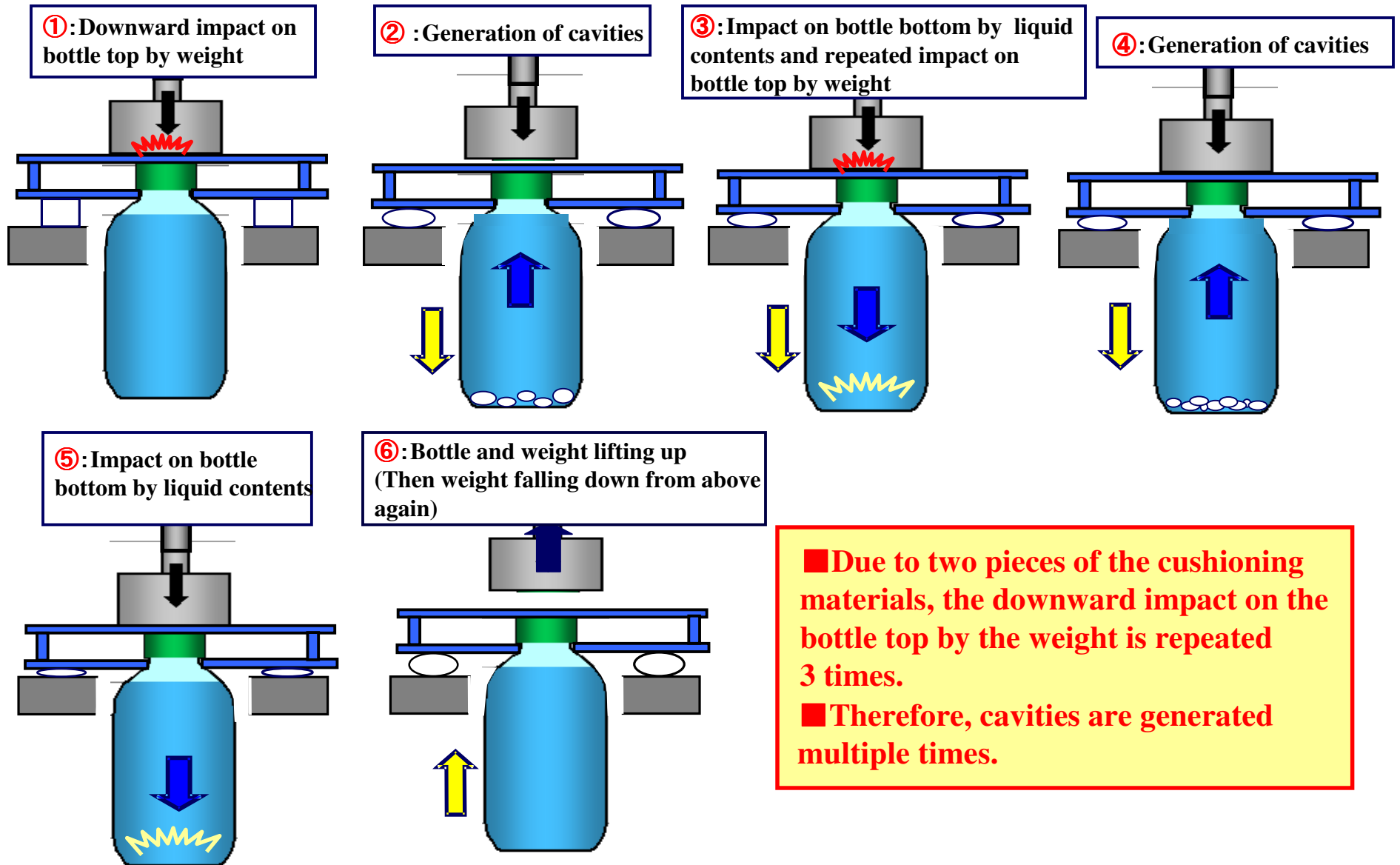
■ Improved work efficiency

- * The test can be conducted quickly and simply.

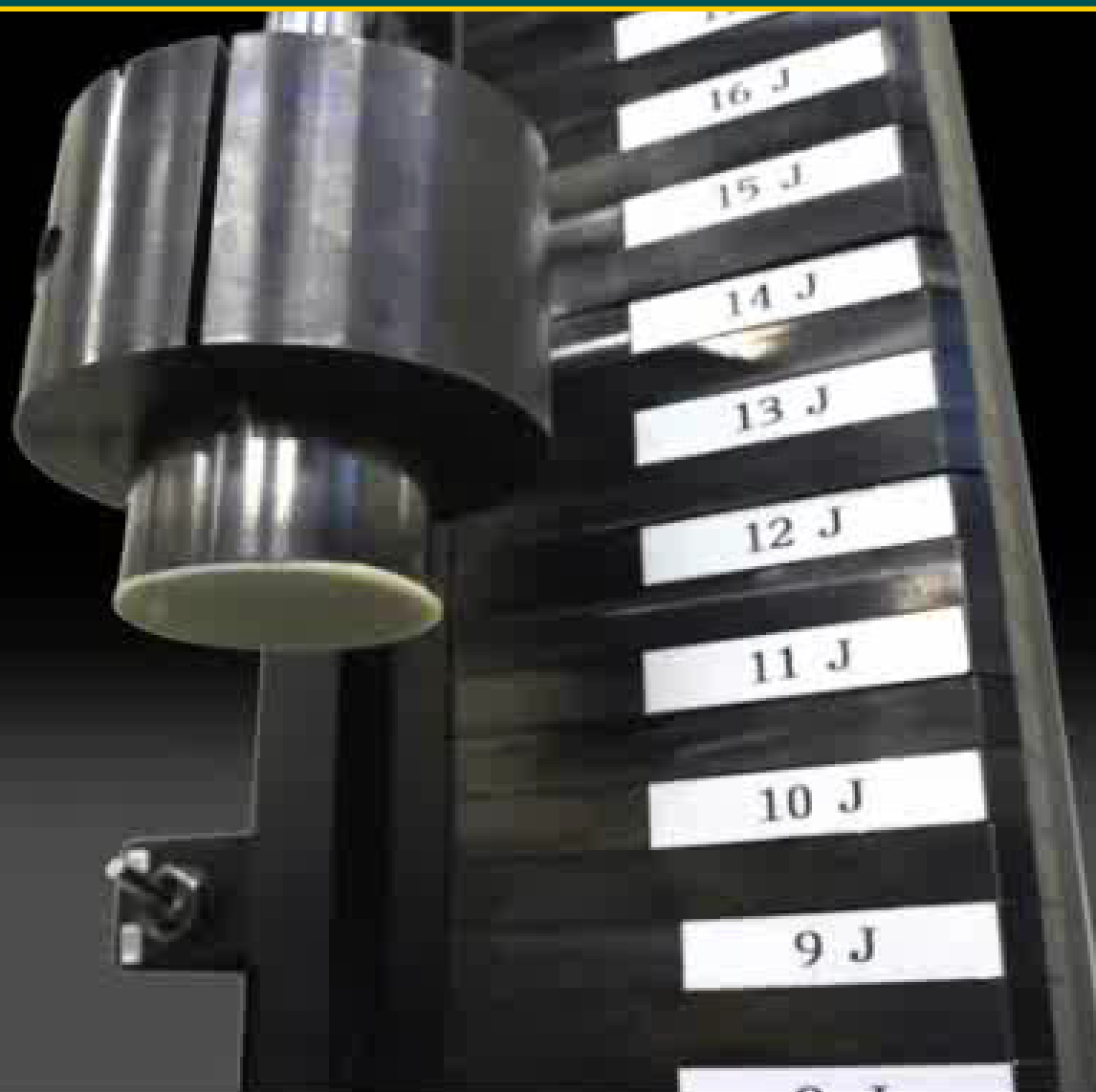
☆Patented in 2010



Behavior of a glass bottle being tested



Movie of Single Container Water Hammer Tester



Generation of Cavities

**Heel of 500ml
Beverage Bottle**

No. of Pictures filmed by High-Speed
Camera : 4500 pictures/Second
Duration of Movie : About 0.3 seconds

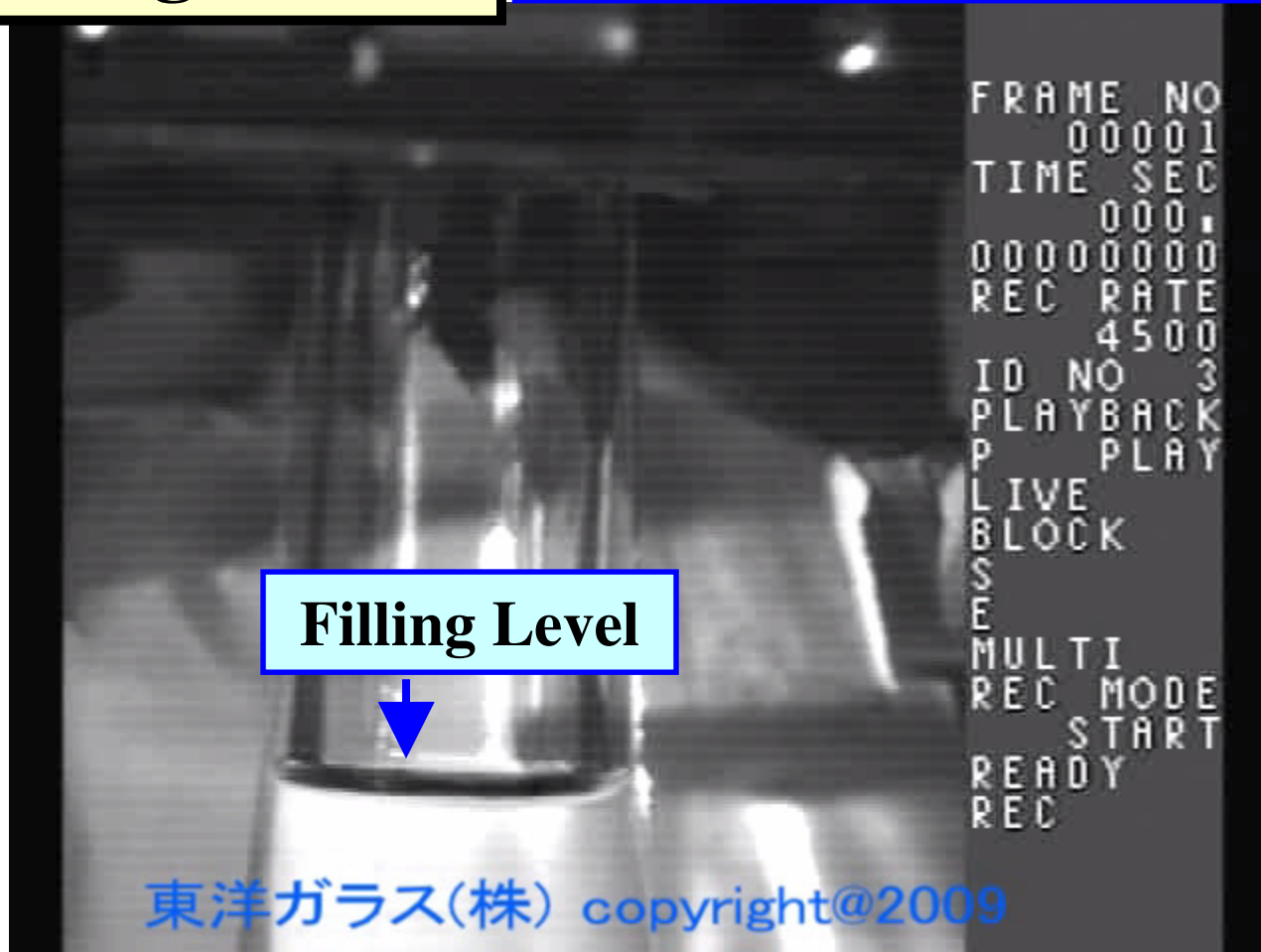


**Large and small cavities are
generated 6 times.**

Filling Level Fluctuation

**Neck of 500ml
Beverage Bottle**

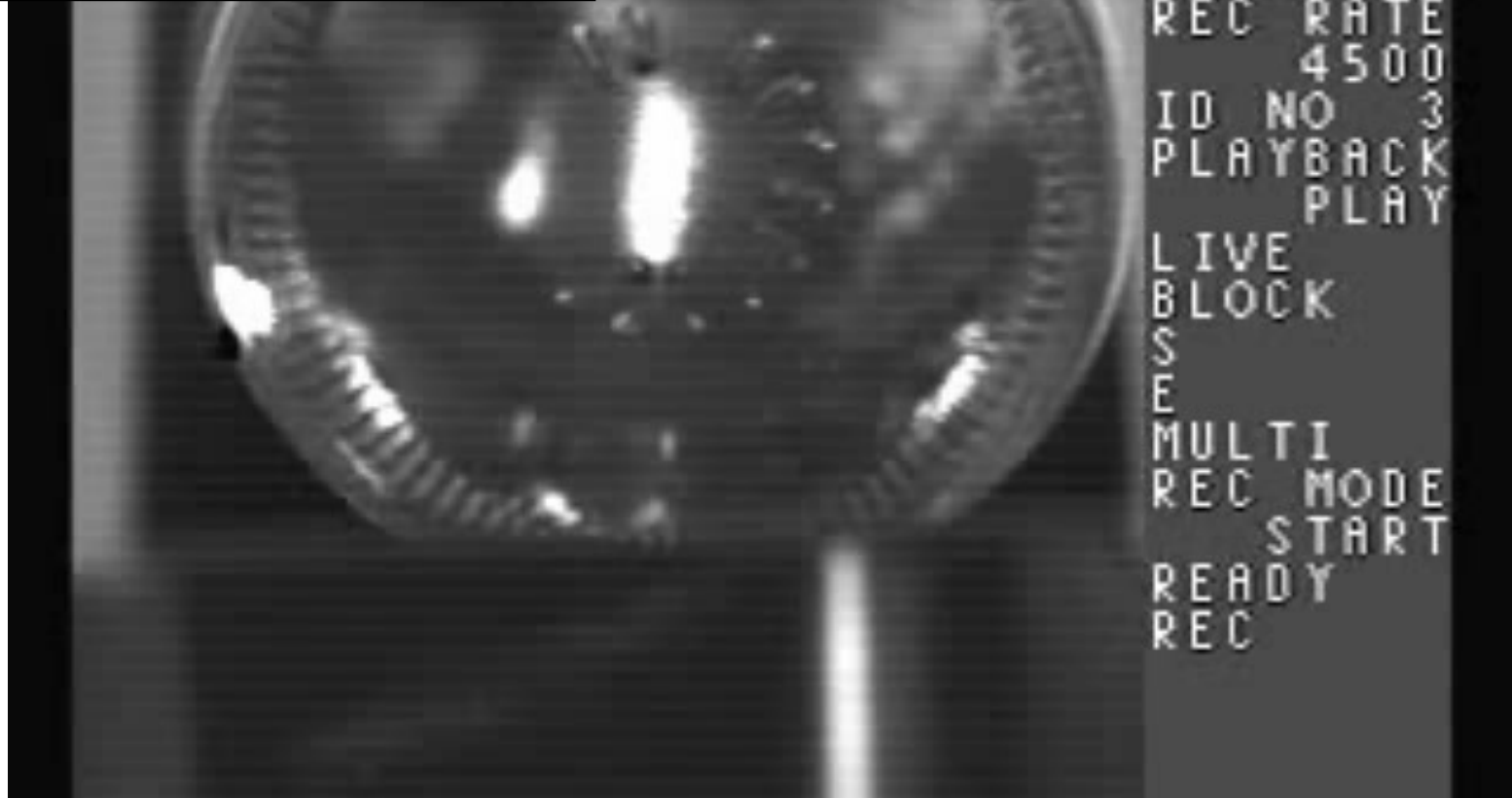
No. of Pictures filmed by High-Speed
Camera: 4500 pictures/second
Duration of Movie: About 0.6 seconds



Generation of Cavities at Bottom

**Bottom of
500ml Beverage
Bottle**

**No. of Pictures filmed by High-Speed
Camera: 4500 pictures/second
Duration of Movie: About 0.4 seconds**



– Conclusion –

■ Benefits Brought by Single Container Water Hammer Tester

- * Since the water hammer strength of a bottle can be recognized in a short time after the bottle is filled, the bottle quality can be assured promptly based on measured bottle strength.**
- * It enables a user to easily understand a relationship between liquid contents and required water hammer strength of a bottle.**
- * It facilitates improvement of the water hammer strength of a bottle.**
- * It satisfies request for improvement in the water hammer strength from bottle customers**
- * Some customers may designate bottle strength based on the Single Container Water Hammer Tester.**

■ Purchasers of Single Container Water Hammer Tester

- * Glass container manufacturers**
- * Glass bottle customers**

びん入りを飲もう！！ グラスで飲もう！！



— Thank you for your attention —

— END —

– Operation of Single Container Water Hammer Tester –

