

**The case for managed energetic rinsing in
surface finishing operations involving
aqueous processes.**

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1. Cleaning process
- 2. Water rinse**
3. Anti-corrosion process
- 4. Water rinse**
5. Dry
6. Paint process

A simple finishing process

The rinses are intended to provide barriers between the processes.

Otherwise there can be contamination of successive processes by materials from preceding processes.

Retained chemicals on the treated surface in or under successive layers can result in appearance and performance problems.

1. Cleaning process
[Alkali]
2. Water rinse
3. Anti-corrosion process
[Acid]
4. Water rinse
5. Dry
6. Paint process
[No free electrolytes]

A simple finishing process

The rinses are intended to provide barriers between the processes.

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Retained chemicals on the treated surface in or under successive layers can result in appearance and performance problems.

The finishing process with operating conditions:

1. **Alkaline cleaner:** *Ultrasonic, 35gm/l, 50°C, 2 minutes.*
2. Rinse
3. **Phosphate:** *Total acid 40gm/l, 45°C, 4 minutes.*
4. Rinse
5. **Dry:** *Blown hot air.*
6. **Paint.**

Very often, the energy requirements for rinsing are not indicated.

Theoretical Perfect Aqueous Rinse.

- Completely removes surface contaminants, replacing them with pure water.
- Essentially – it is a 100% efficient cleaning process.

Murphy's law of the conservation of dirt:

'To make something clean, you have to make something else dirty.'

Corollary:

'The quantity of dirt in the universe is constant, the action of cleaning only moves it from one place to another'

Law of conservation of energy:

'The quantity of energy in a system is constant, it can only be transformed from one state to another.'

An amusing correlation?

A Kinetic Energy theory of Rinsing?

- Nothing moves without energy.
- Removal and replacement of any quantity of material must be governed by provision of kinetic energy.

Step process model of rinsing.

1. Impingement (contact).
2. Mixing and dilution.
3. Removal.

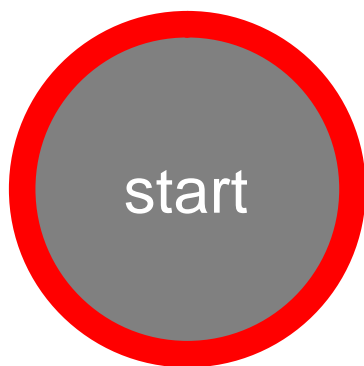
Each step involves kinetic energy.

Why is management required?

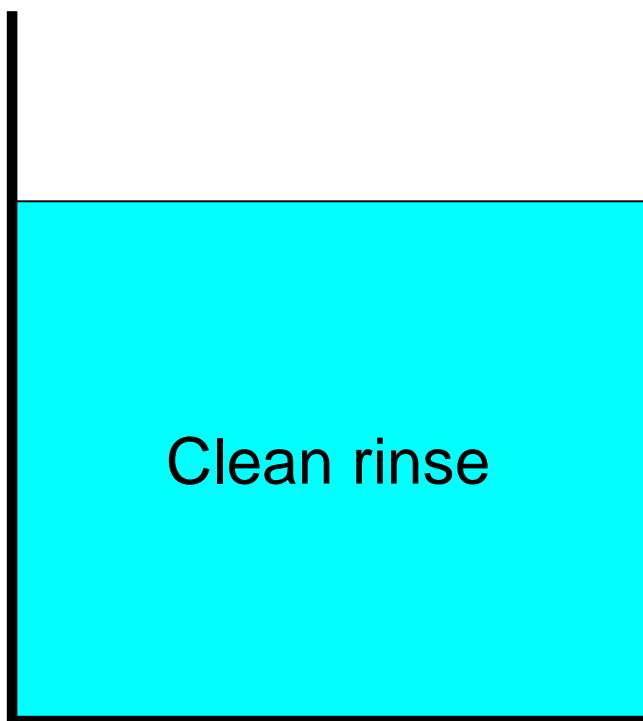
- Sufficient energy must be applied to achieve 100% rinsing effect.
- ‘Surplus energy’ can change or damage the rinsed surface depending upon:
 - The chemistry of the rinsed surface.
 - The structure of the surface.
 - The method of rinsing.

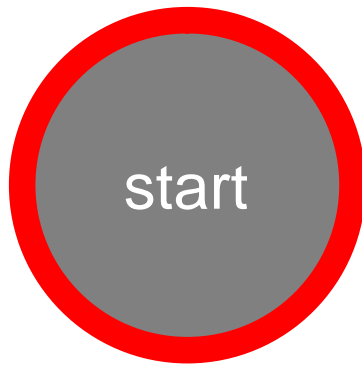
Basic rinsing methods.

- Immersion: - most capable of accessing all surfaces for impingement. Requires continuous purification.
- Spraying: - continuous source of clean water but has problems with access for impingement.



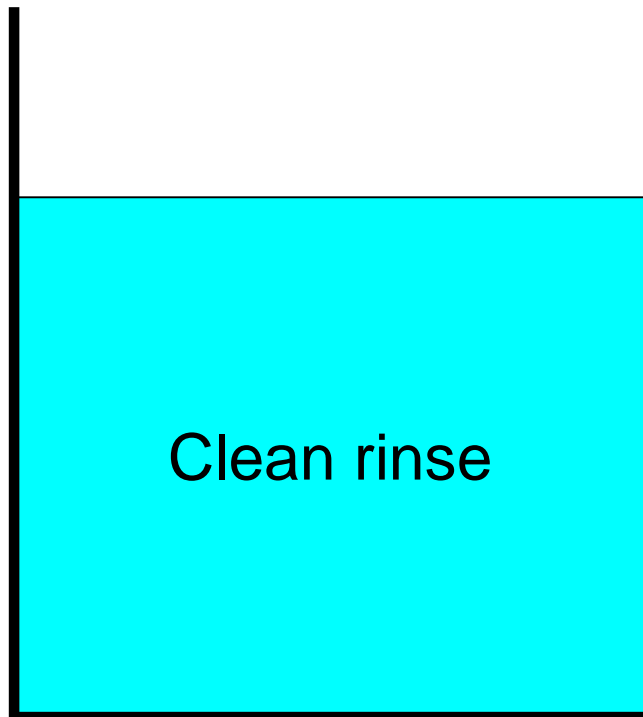
Blue = clean water
Red = surface contamination
Grey = cross section of substrate





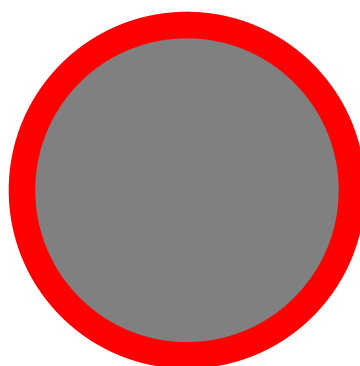
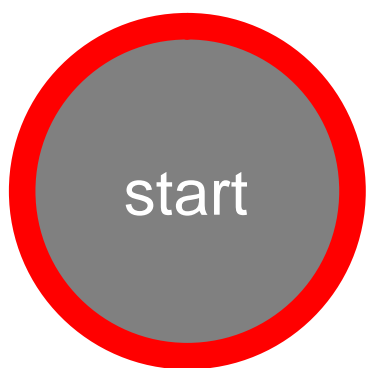
Immersion rinsing.

Sphere geometry – minimum
Surface area for bulk.

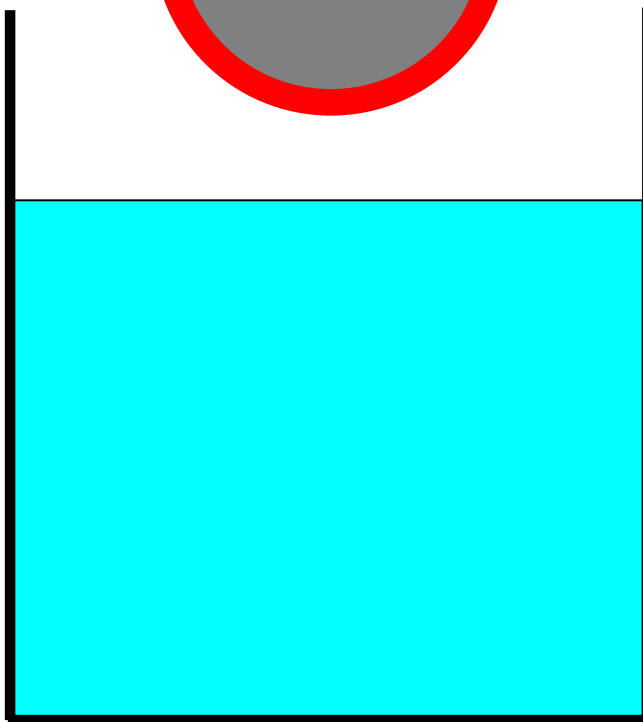


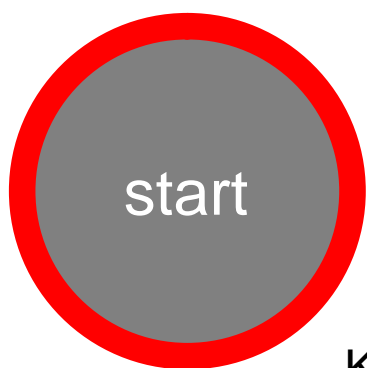
A 'wet' surface will
retain 50 – 100ml+
of liquid per m²

The target is to
have only clean
water on the surface



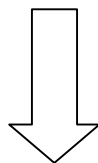
original level





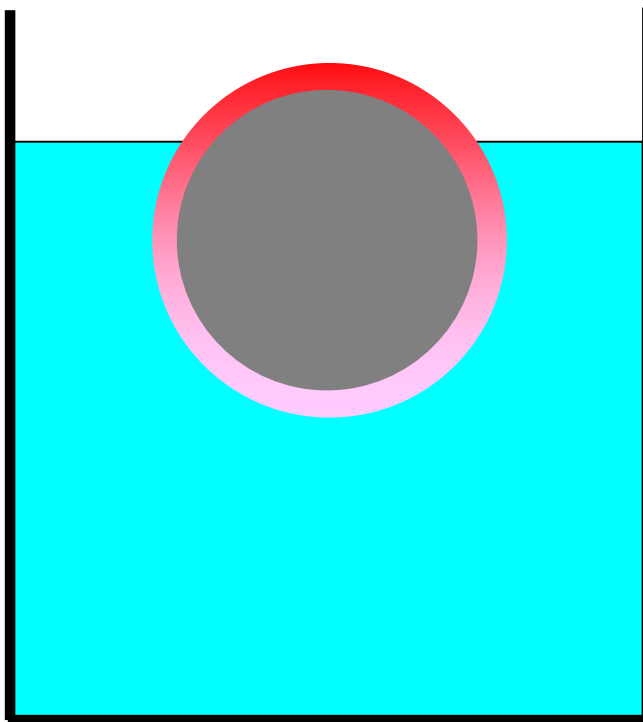
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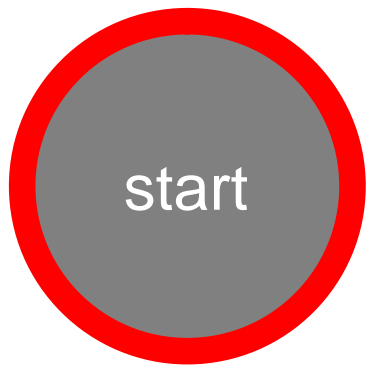
Kinetic energy
added to substrate



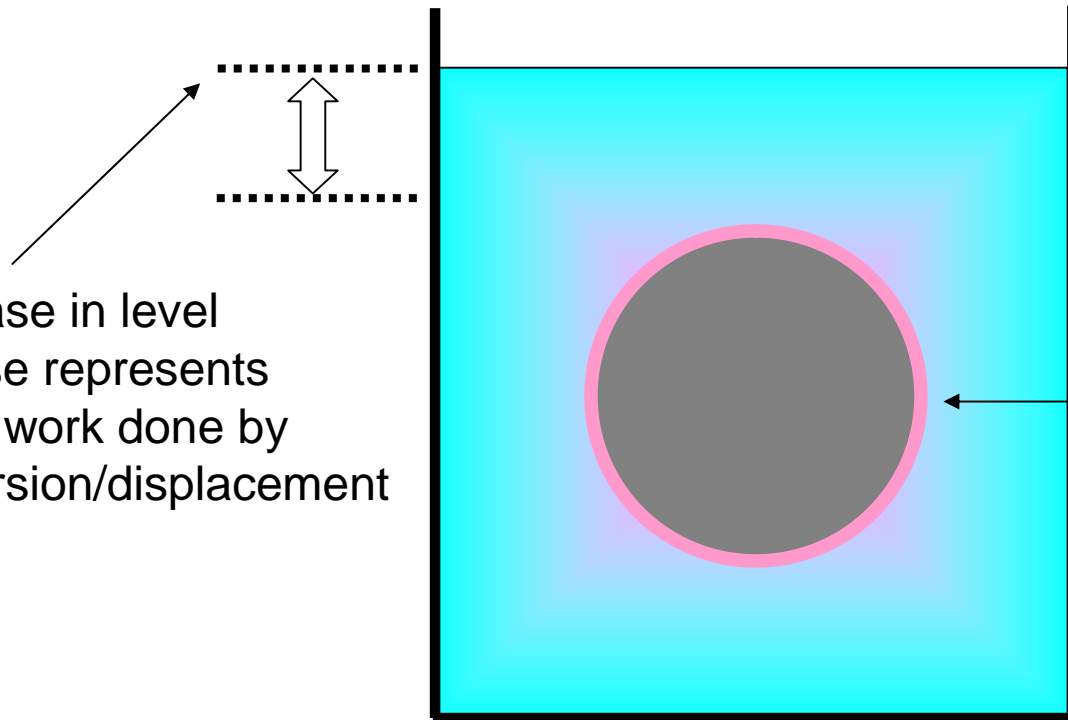
target

original level





Increase in level
of rinse represents
some work done by
immersion/displacement



Mixing and dilution
requires kinetic
energy.



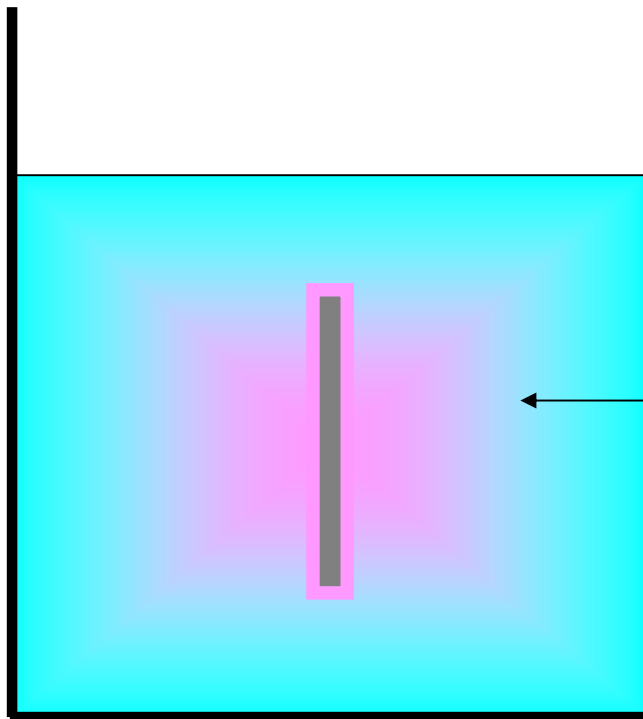
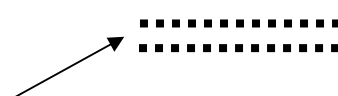
start

Change in geometry – minimum bulk
(for example a flat sheet).



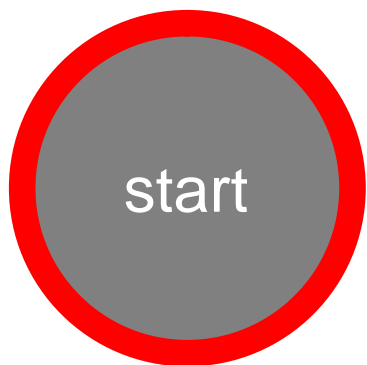
target

Small Increase in level
of rinse represents
negligible work done by
immersion/displacement

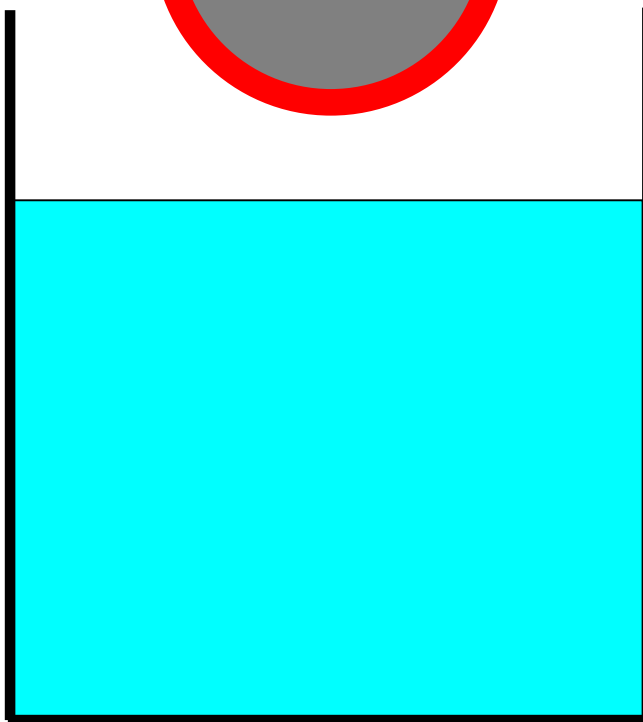
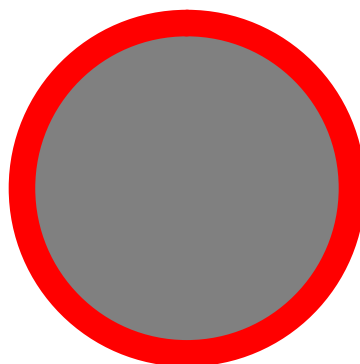


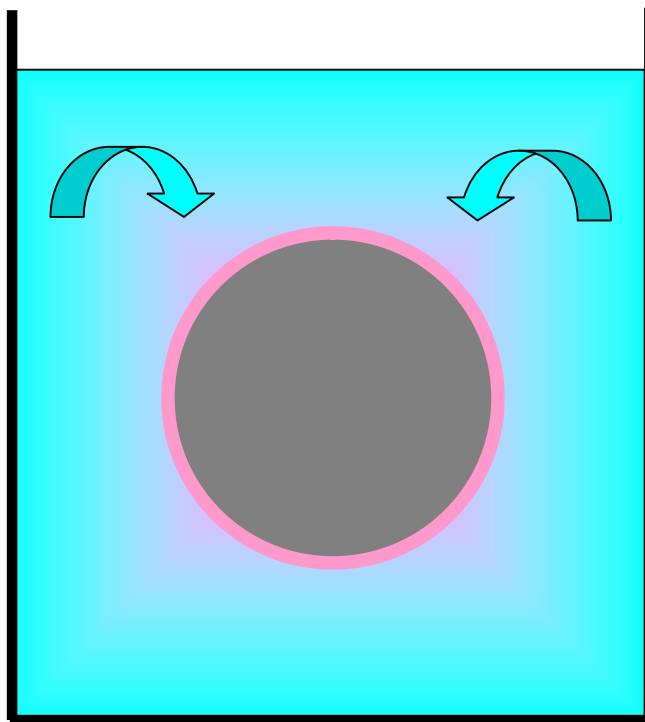
Mixing and dilution
requires more kinetic
energy.

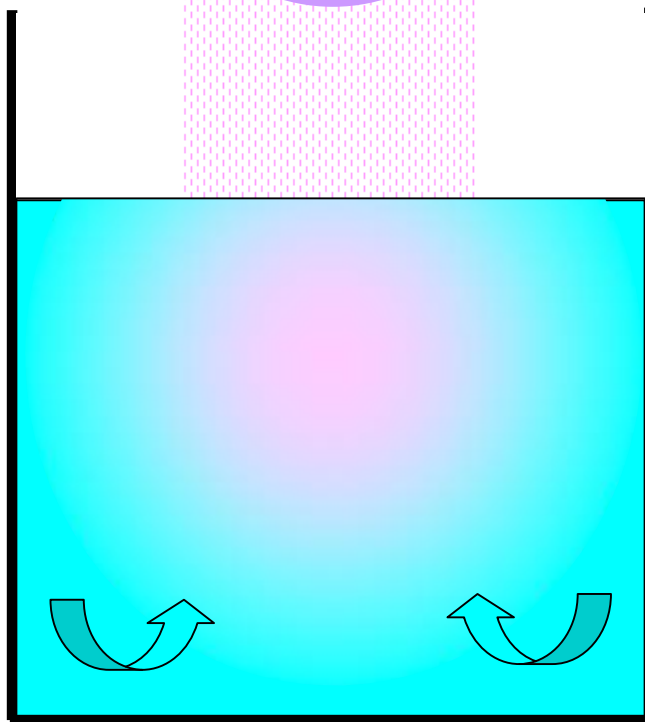
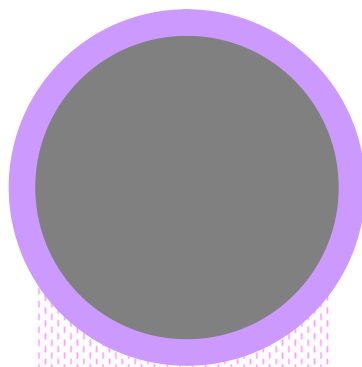
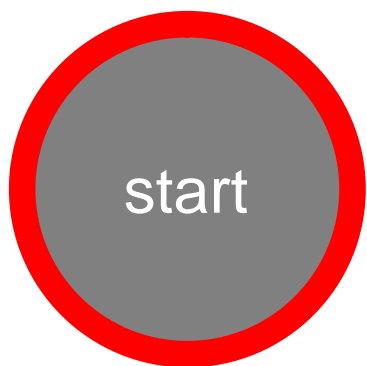


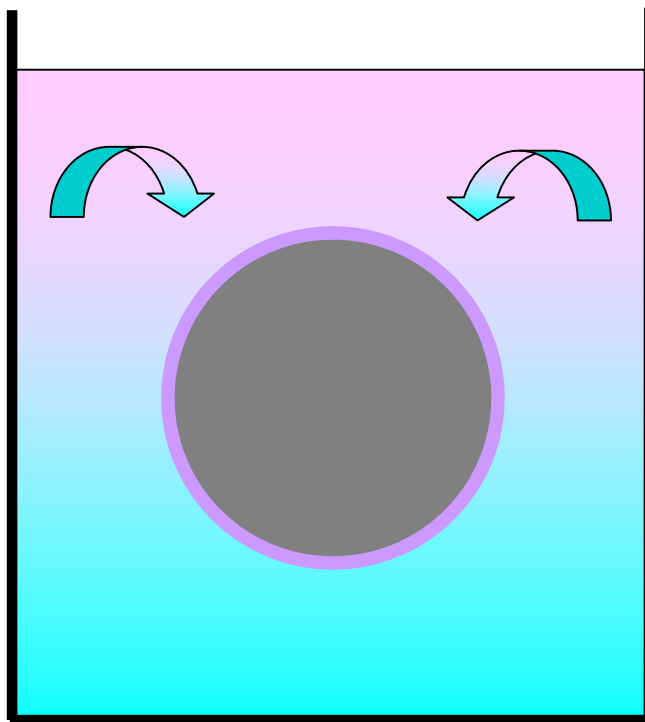
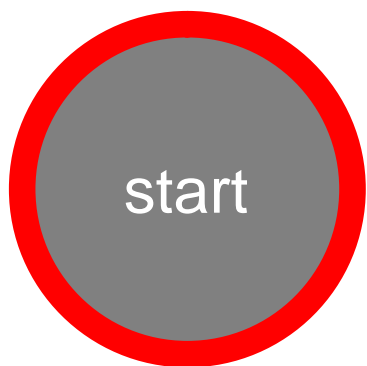


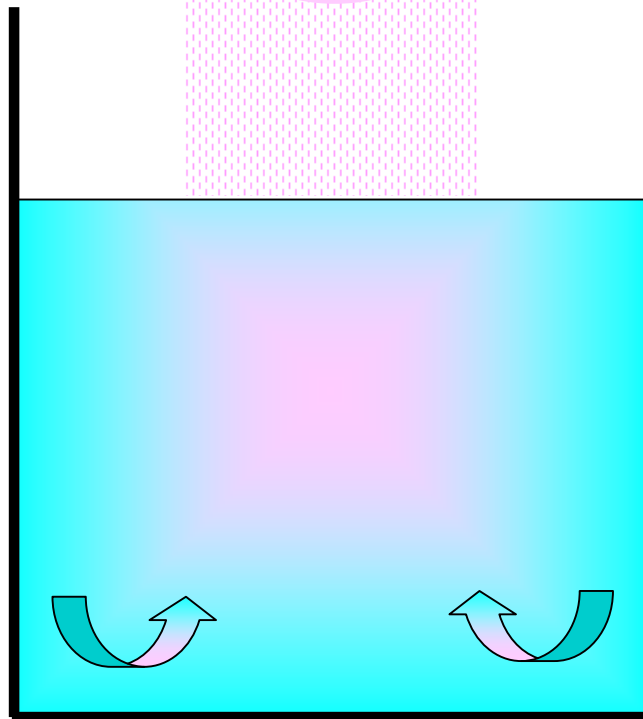
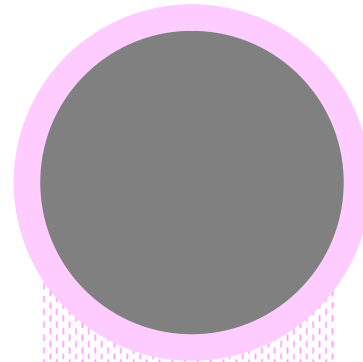
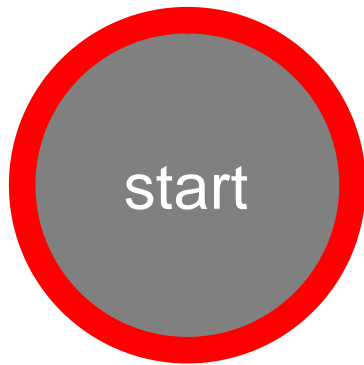
Repeated immersions....



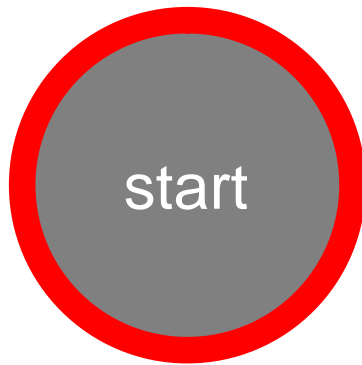




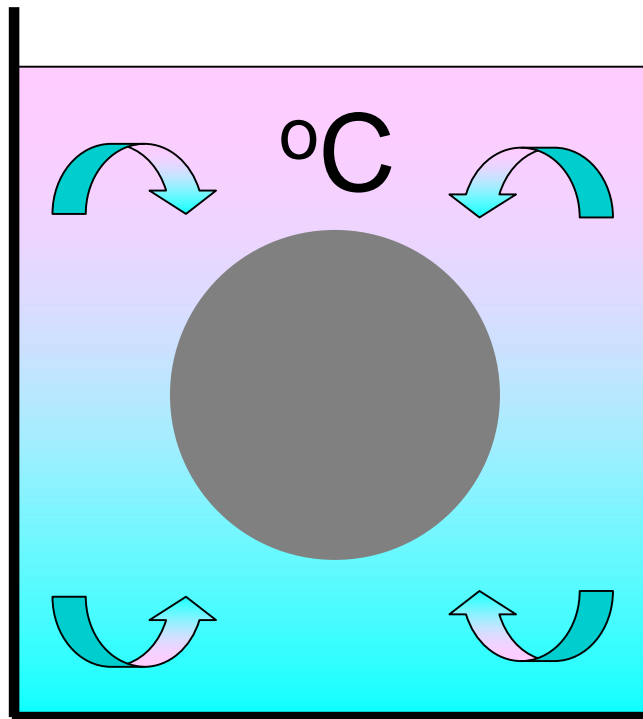




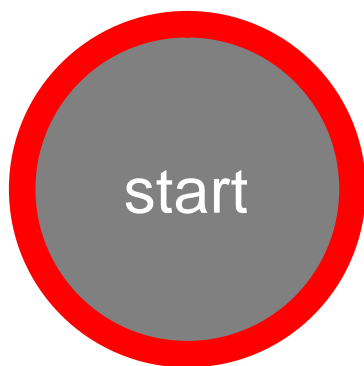
Efficiency depends upon bulk displacement factors, number of immersions and velocity of immersion.



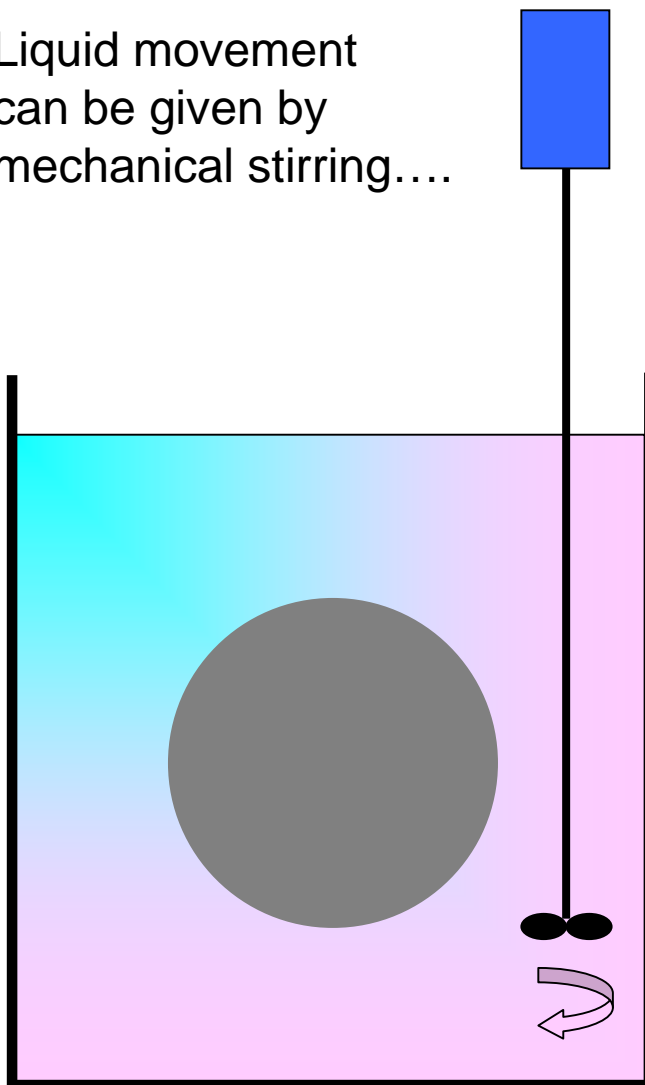
Temperature will have a mixing effect due to increased kinetic energy of the molecules + bulk movement from convection.

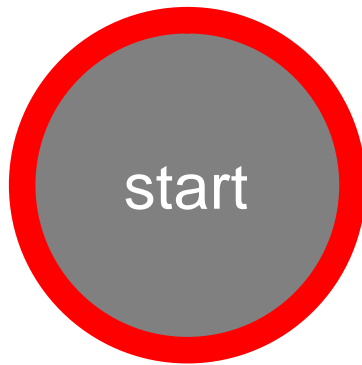


Too high temperature can have damaging effects on the treated surface.

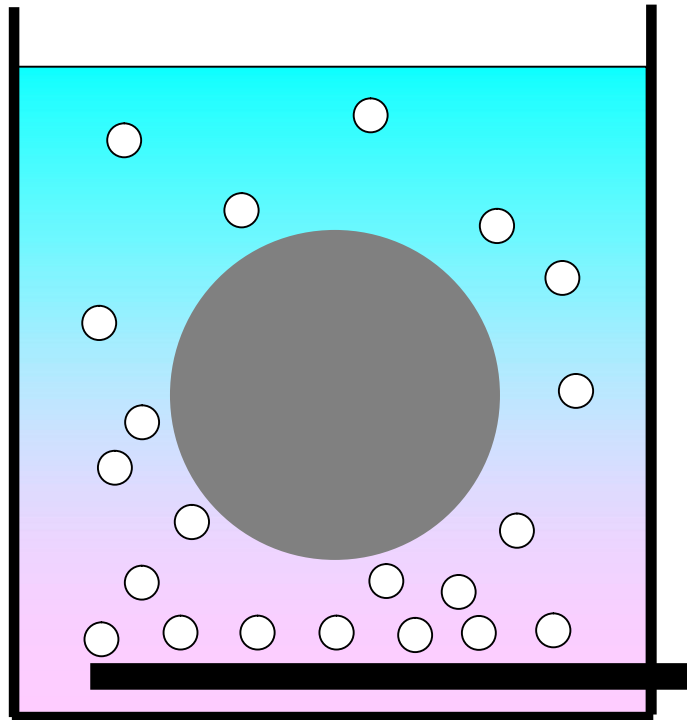


Liquid movement
can be given by
mechanical stirring....

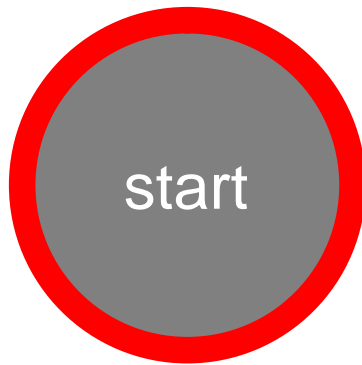




...air agitation



Aerated rinses can be corrosive to certain surfaces (presence of oxygen and carbon dioxide).

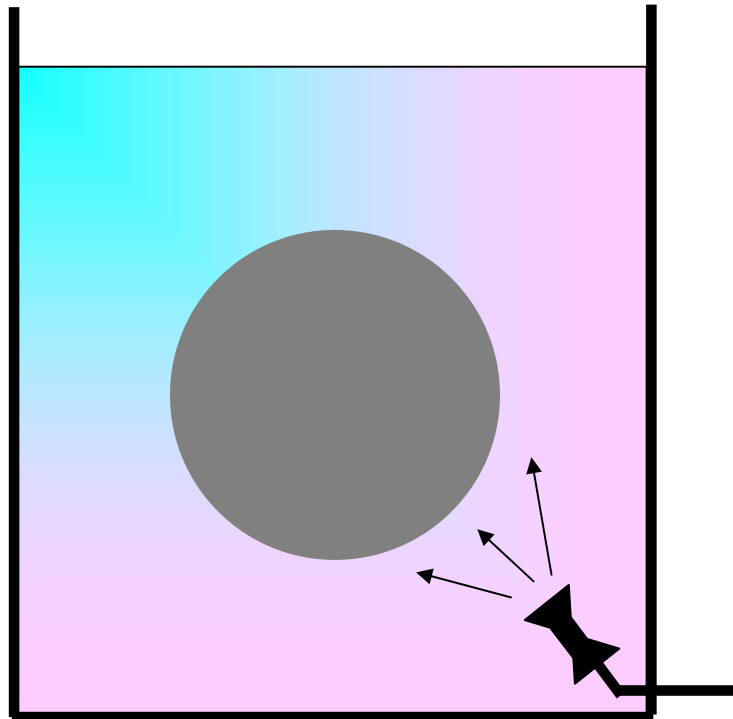


start

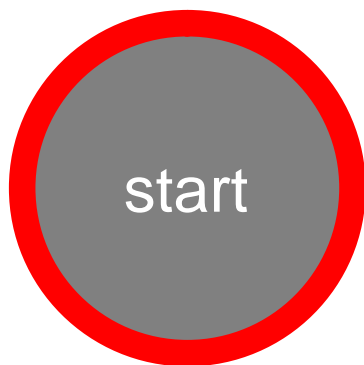
.....educators or spargers.



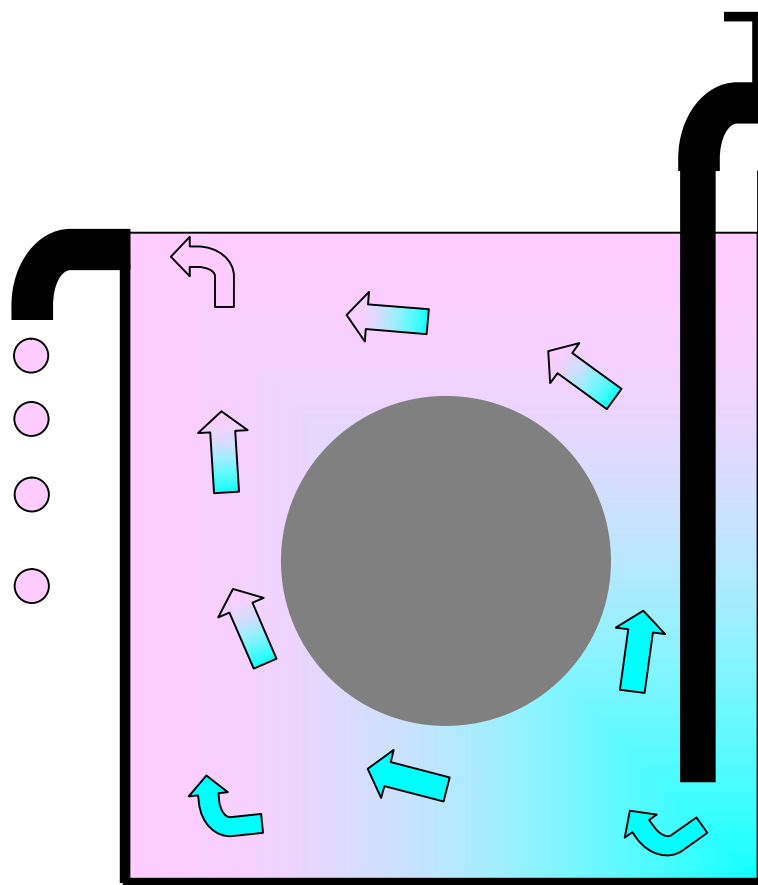
target



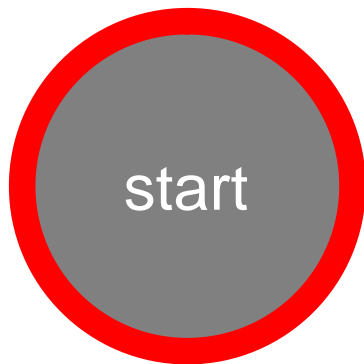
Efficient method
of mechanical
agitation without
adverse effects.



...by flowing in clean water to overflow

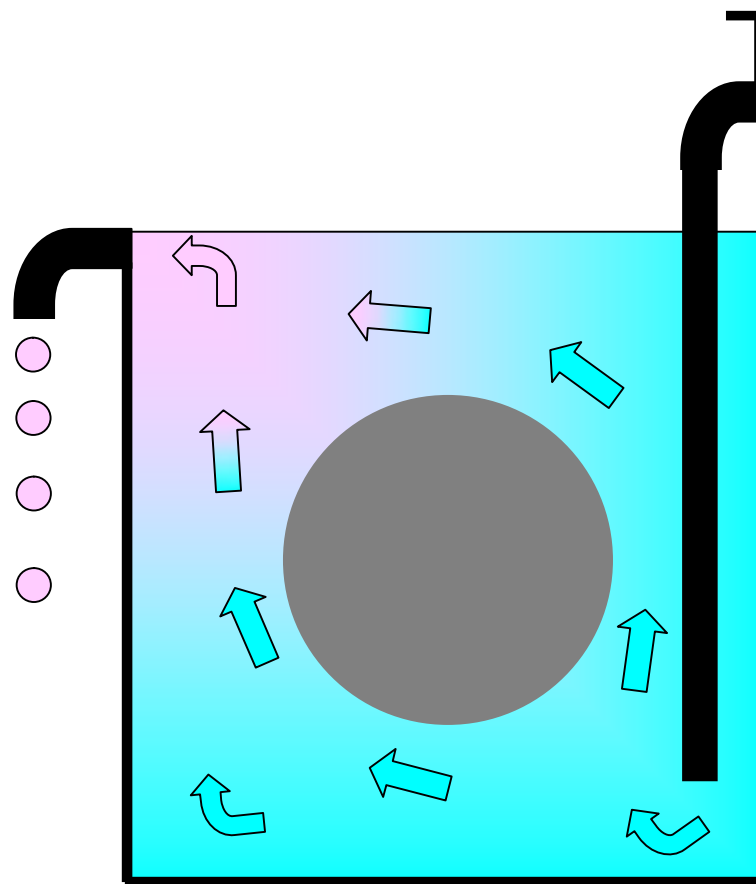


Introduces clean water at the same time as mixing and diluting.

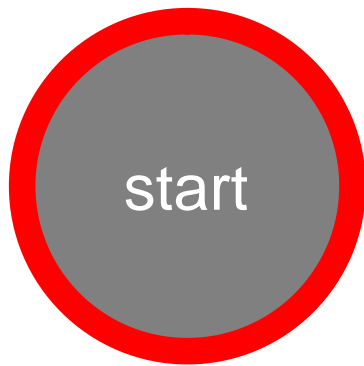


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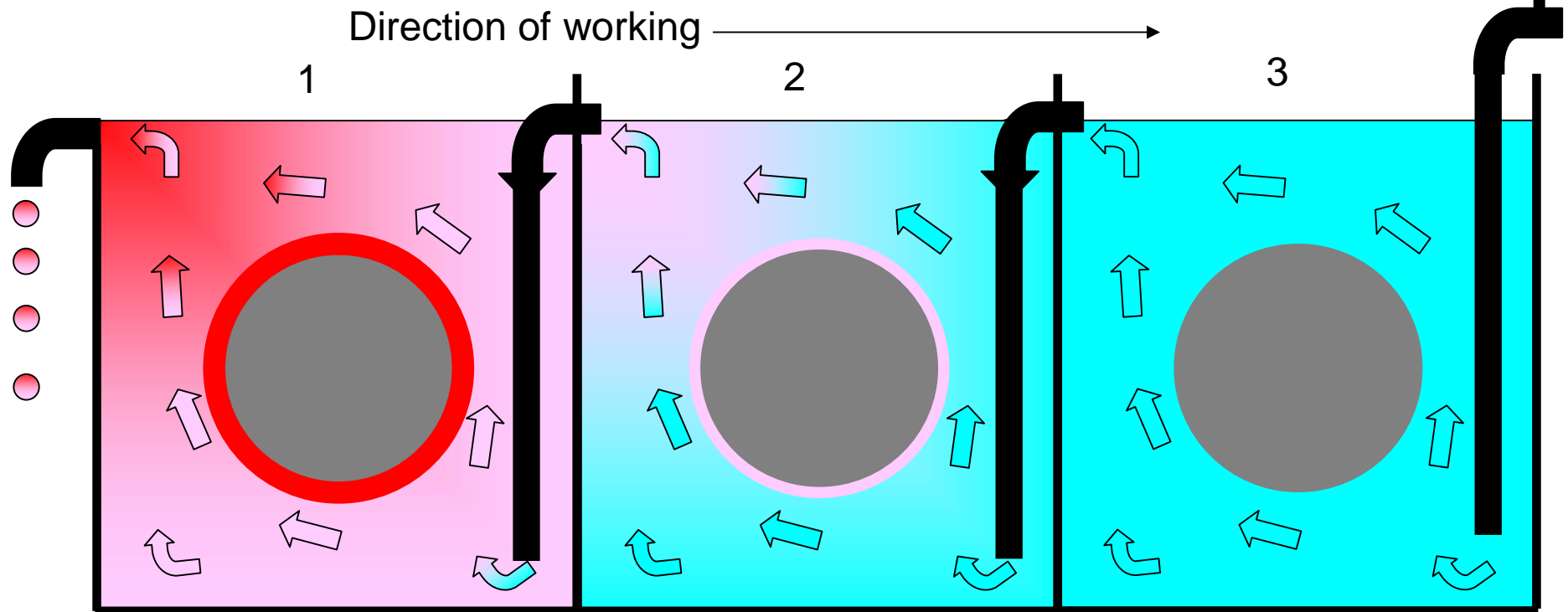
Contaminated
rinse water can
go to waste or
be purified and
recycled.



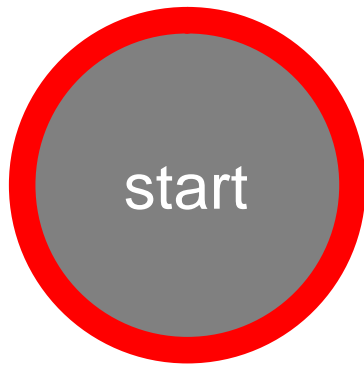
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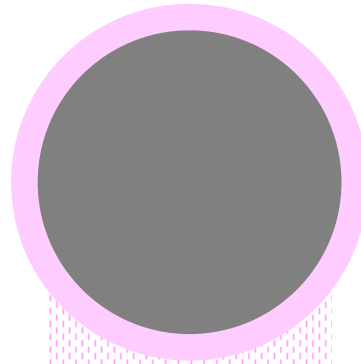
Counterflowing through cascading rinses



Objective – rinse No. 3 is ~ 100% clean water by serial dilution effect.

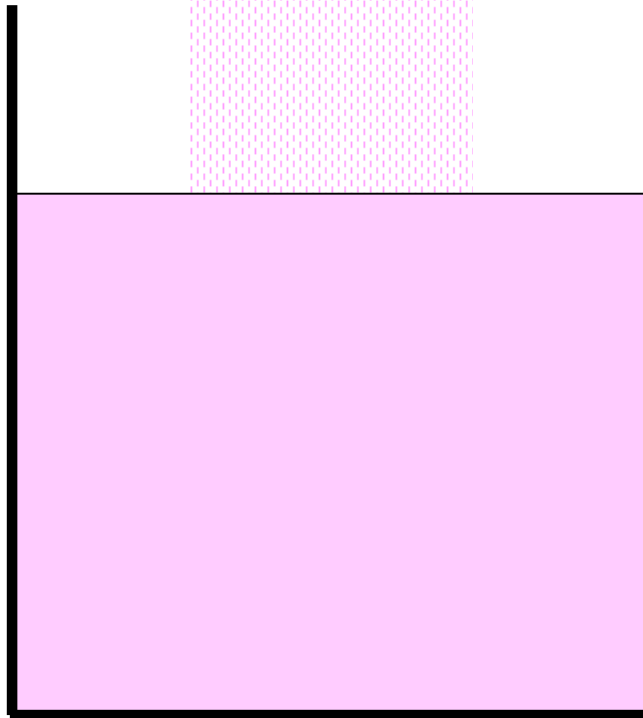


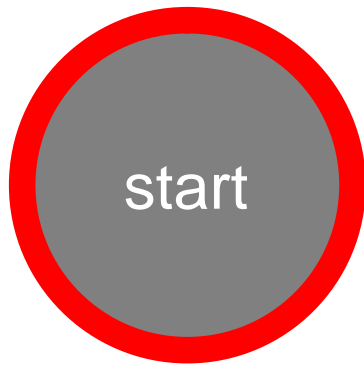
start



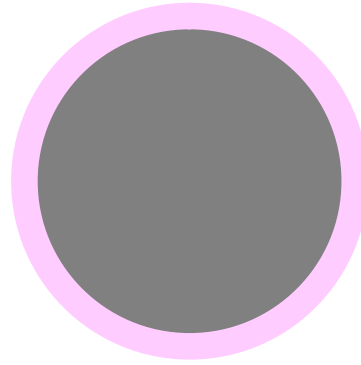
target

Coming from a contaminated rinse does not achieve the target condition



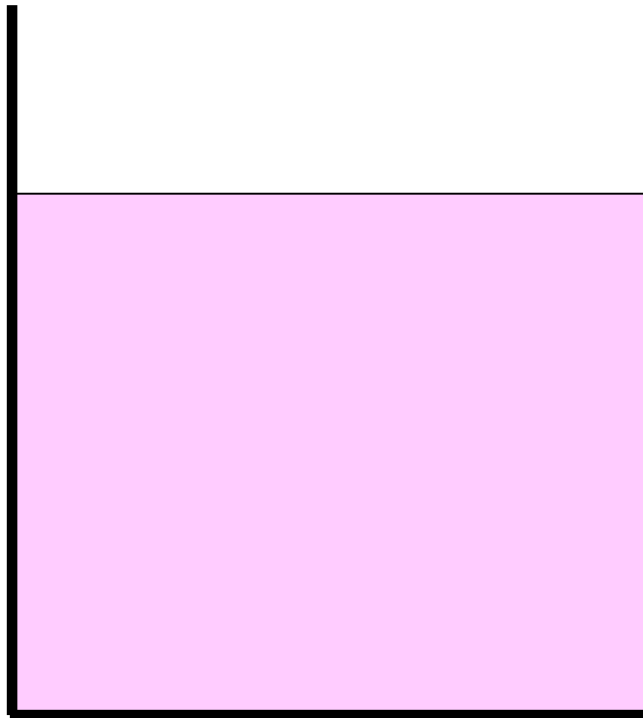


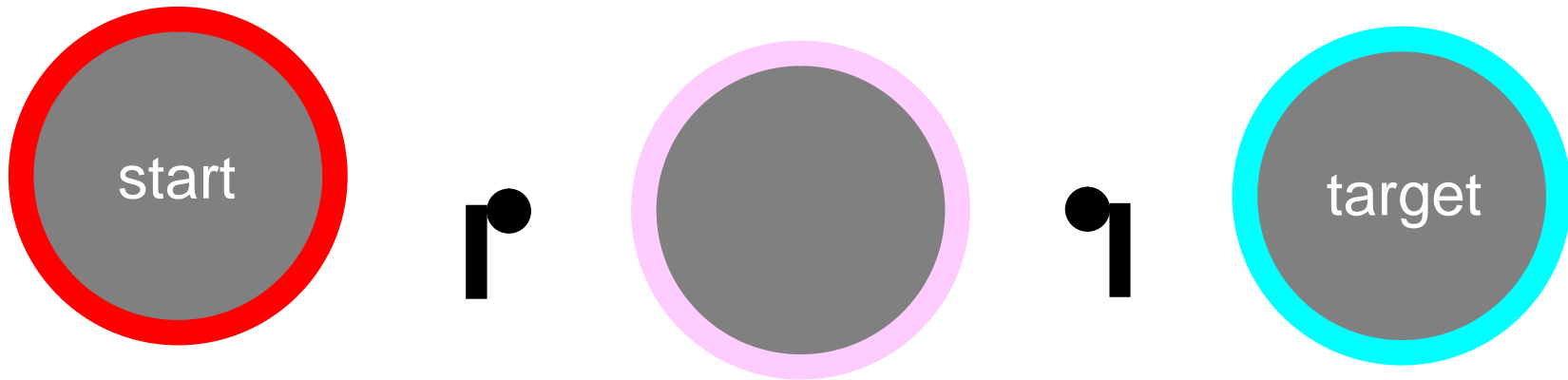
start



target

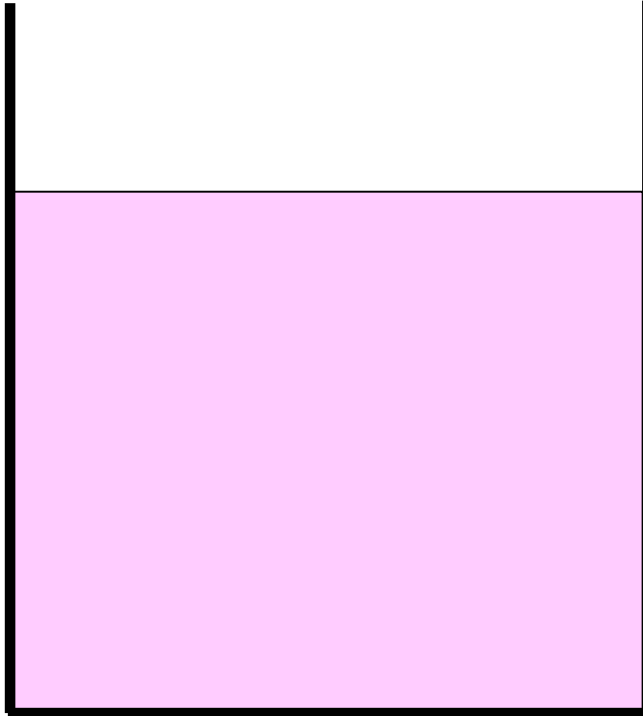
Coming from a
contaminated rinse
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target condition

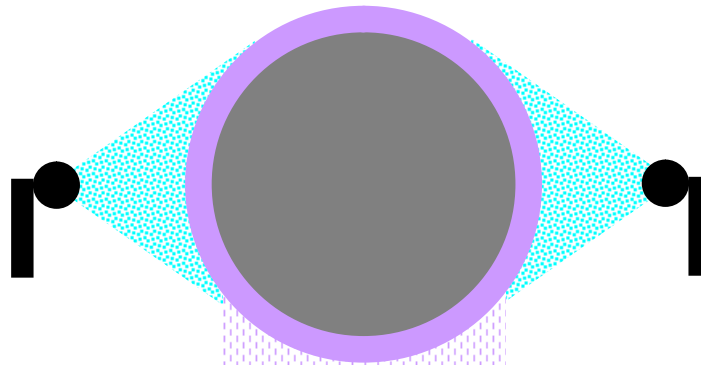




Coming from a contaminated rinse does not achieve the target condition

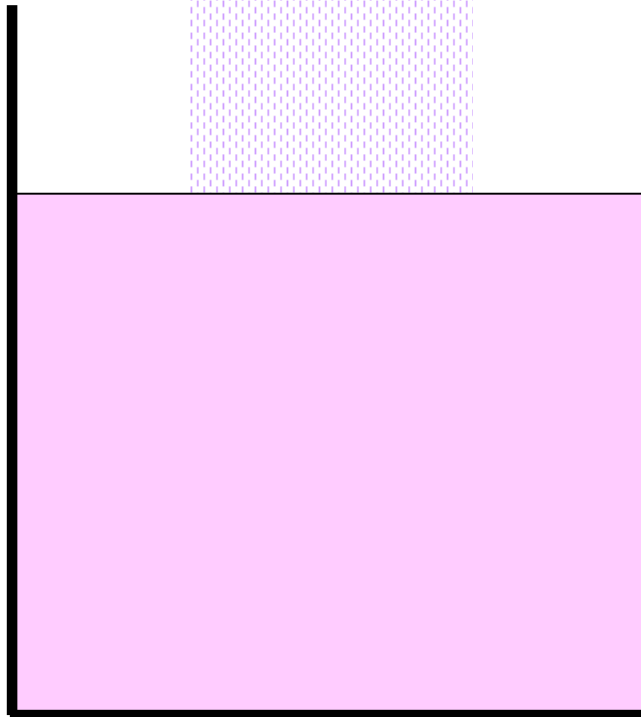
A solution is spraying with clean water.

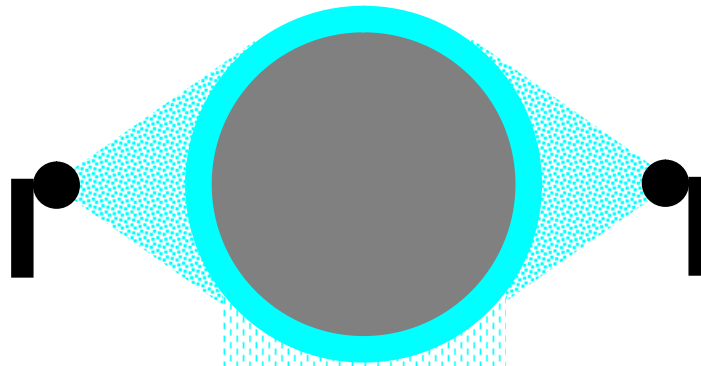
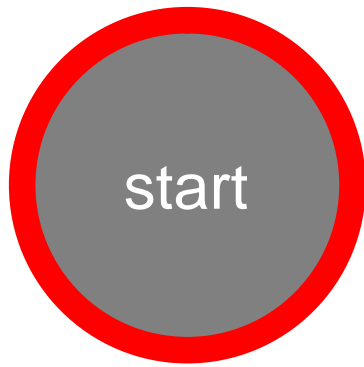




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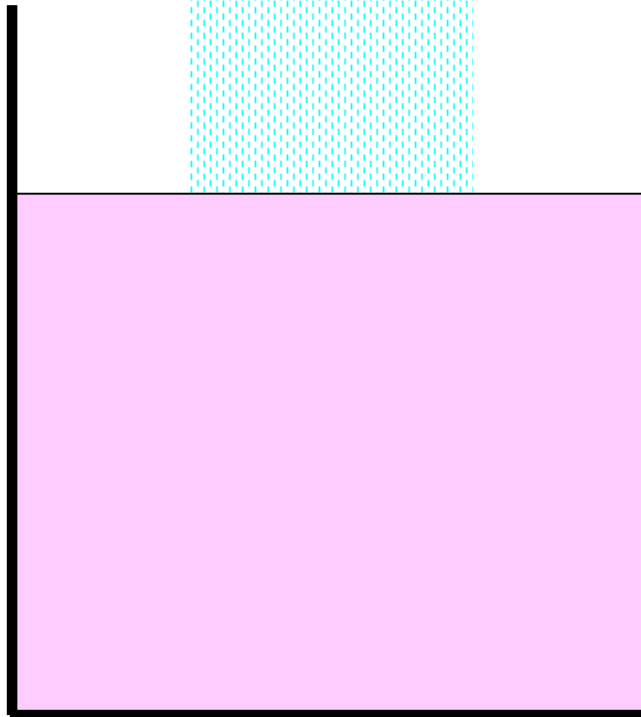
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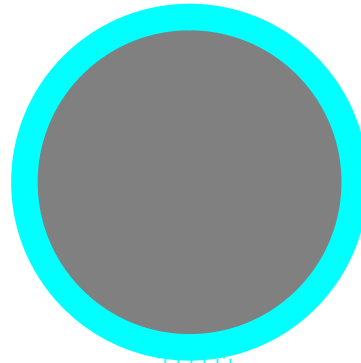




Coming from a contaminated rinse does not achieve the target condition

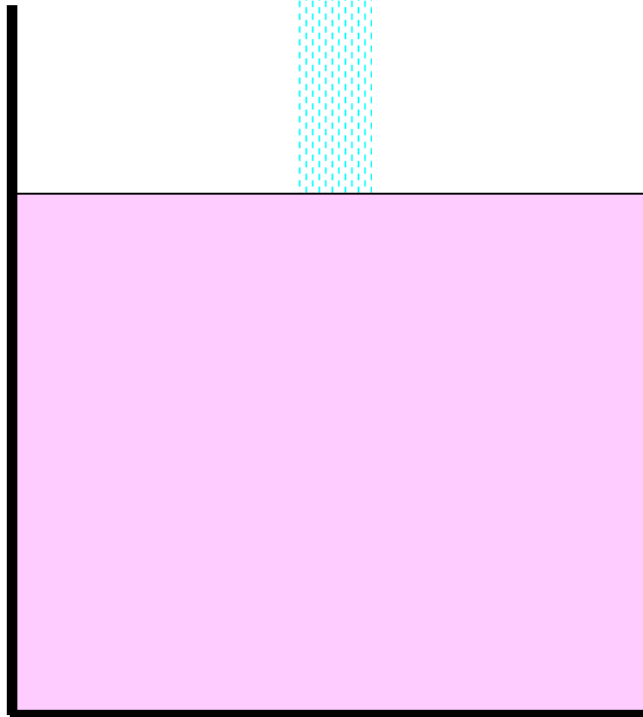
A solution is spraying with clean water.





Coming from a contaminated rinse does not achieve the target condition

A solution is spraying with clean water.



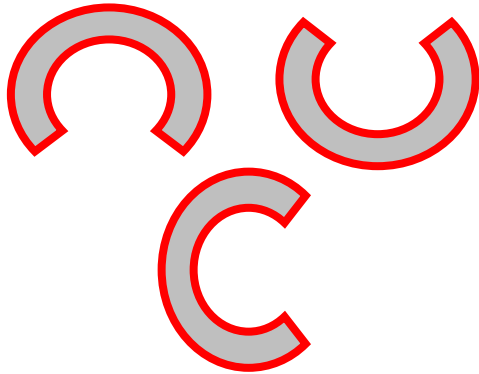
Sprayed water is aerated and so can be corrosive.

It does not access internal cavities or other 'shielded' surfaces efficiently.

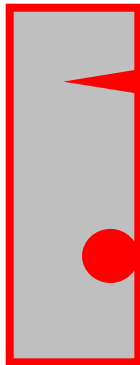
Deviations from the ideal shape.



Through cavity - for example a tube.
Internal surface not easily accessible by spray.
Immersion rinsing essential.



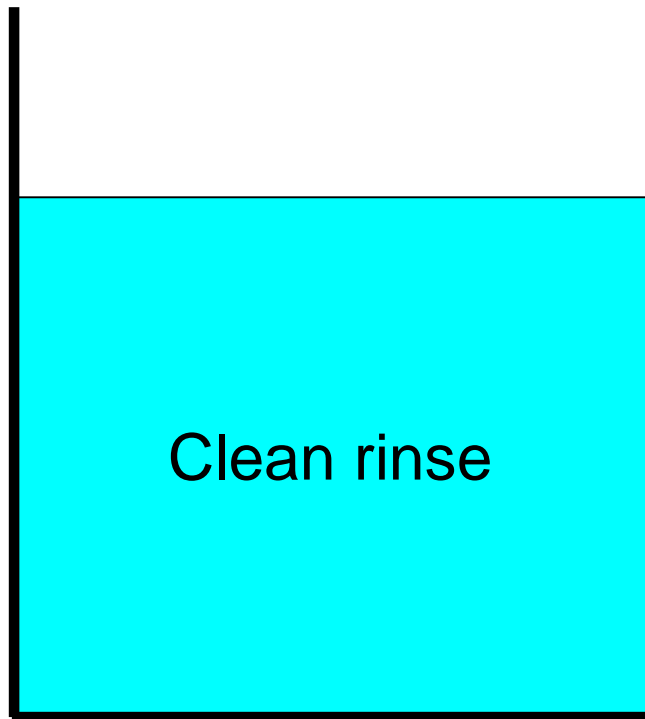
Cup – depending on orientation can create
air traps or excess retention of process fluids.
Requires changes in orientation during processing
To enable access and removal of process fluids.

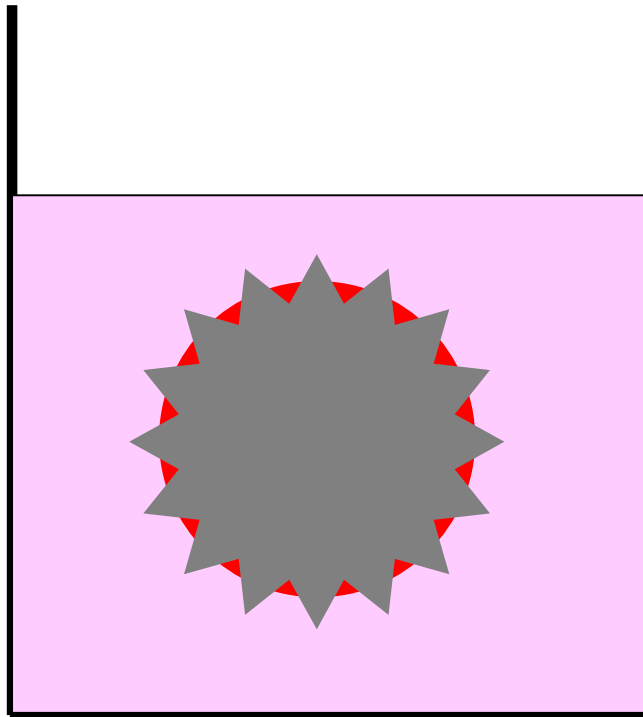


Crevice or porosity - internal surfaces not easily
accessible by spray or simple immersion.
Immersion + ultrasonic action normally necessary
for access

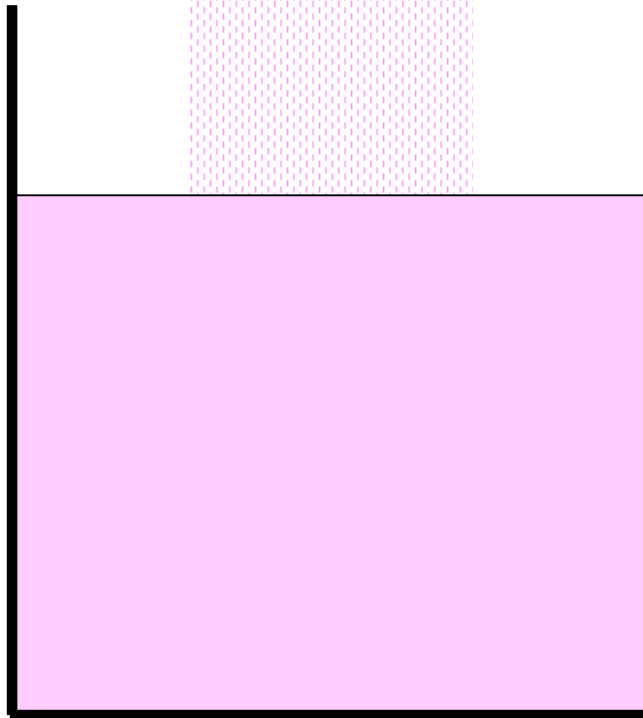
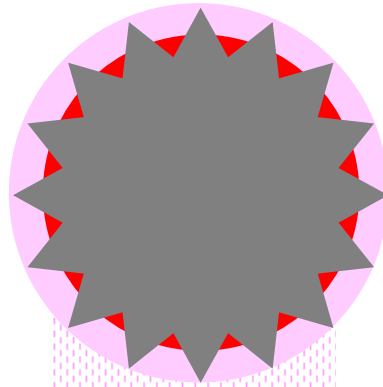


Rough, porous or structured surfaces.

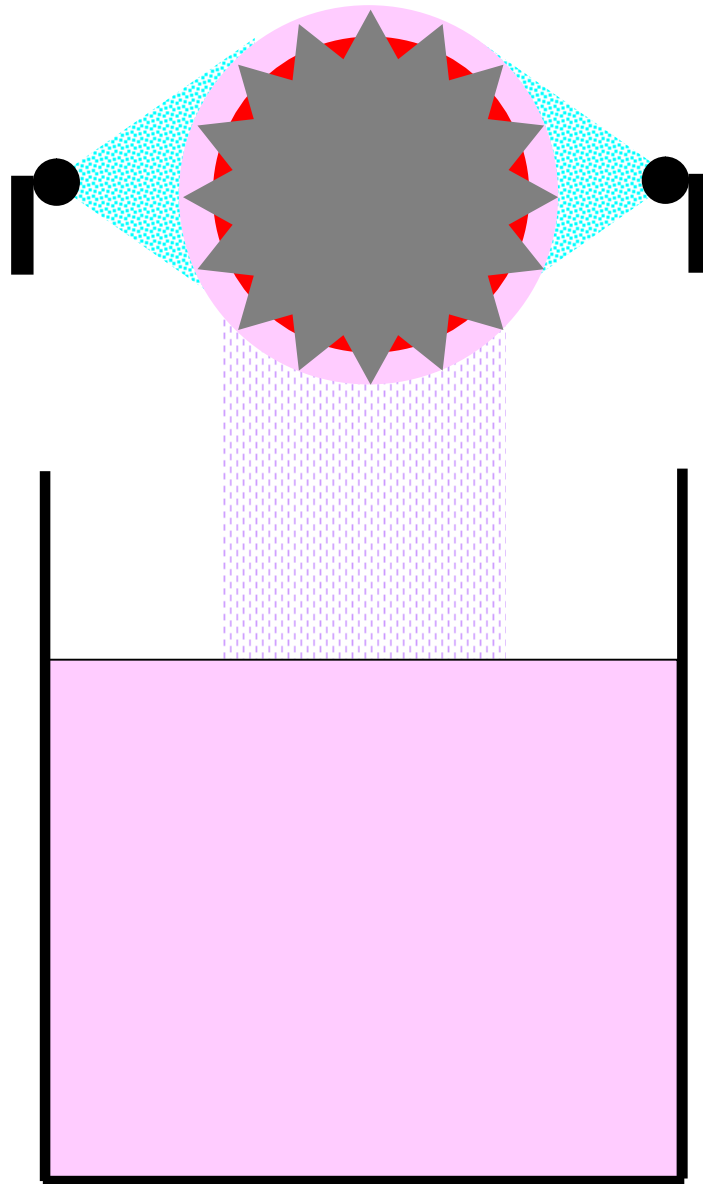




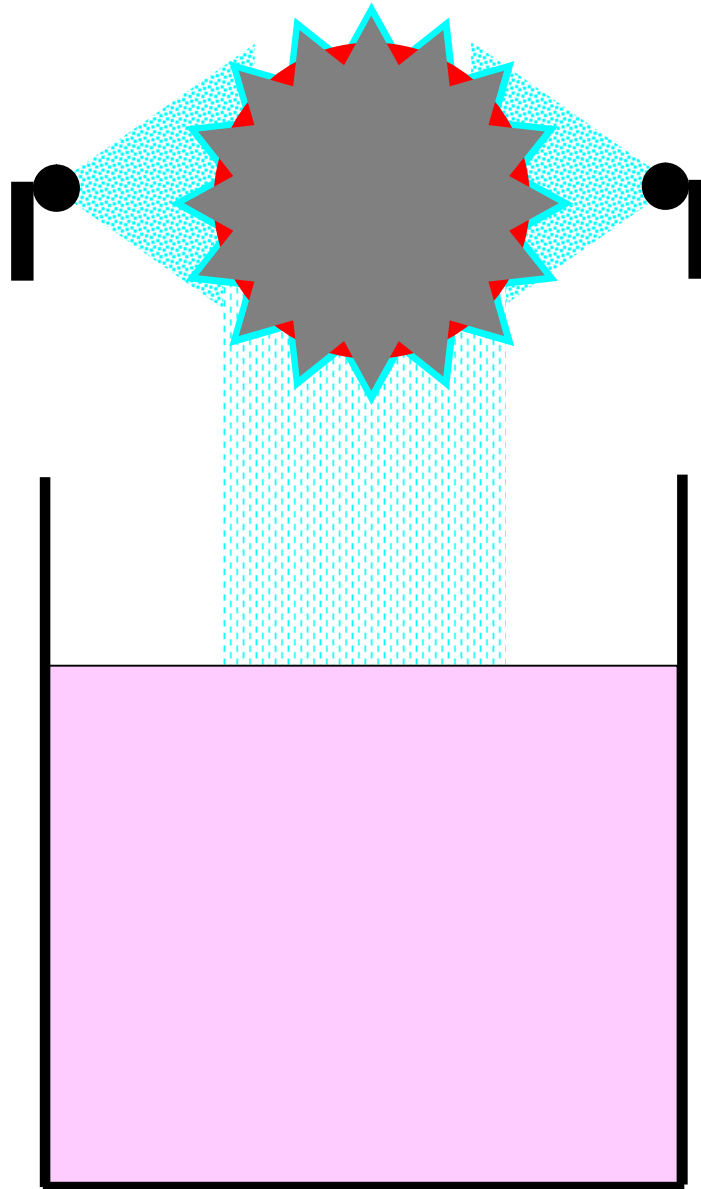
Immersion only does not enable access for mixing, dilution and removal.



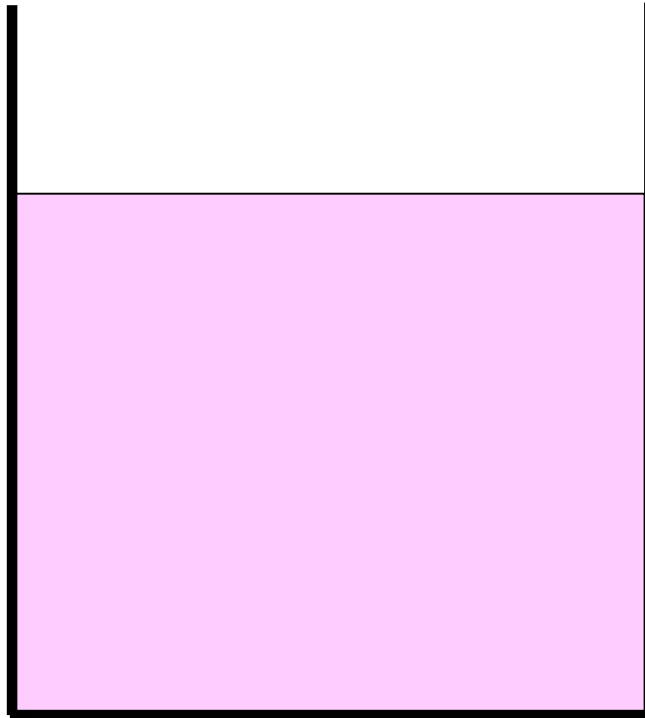
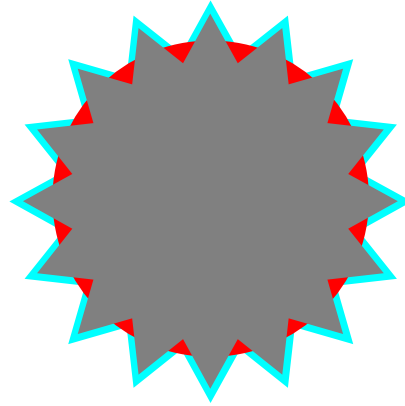
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Spraying is more effective.....

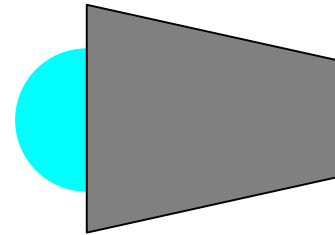
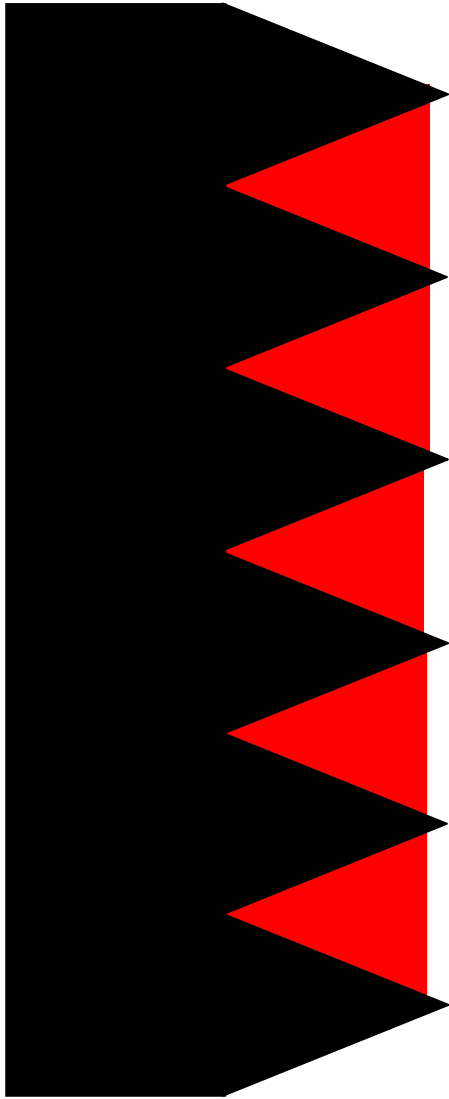


Spraying is more effective, but dependent upon the size and geometry of the surface structure = the 'real' surface area.

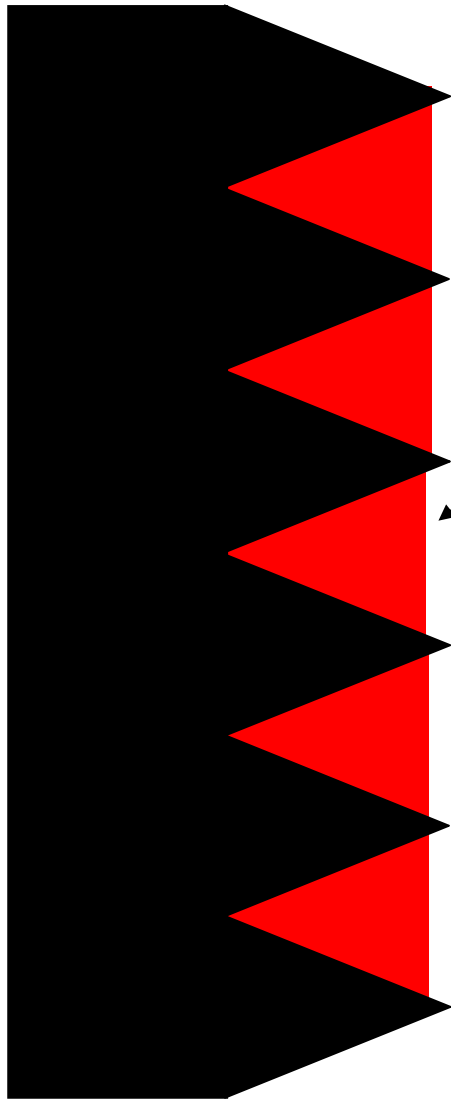


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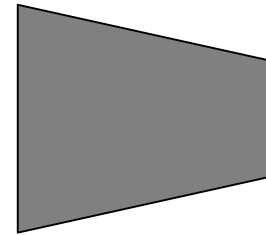
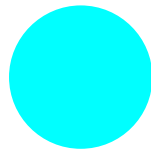
**Spray rinsing dynamics
on rough or structured surfaces.**



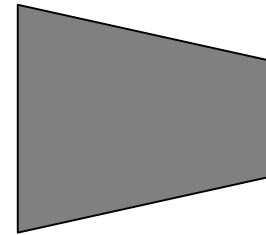
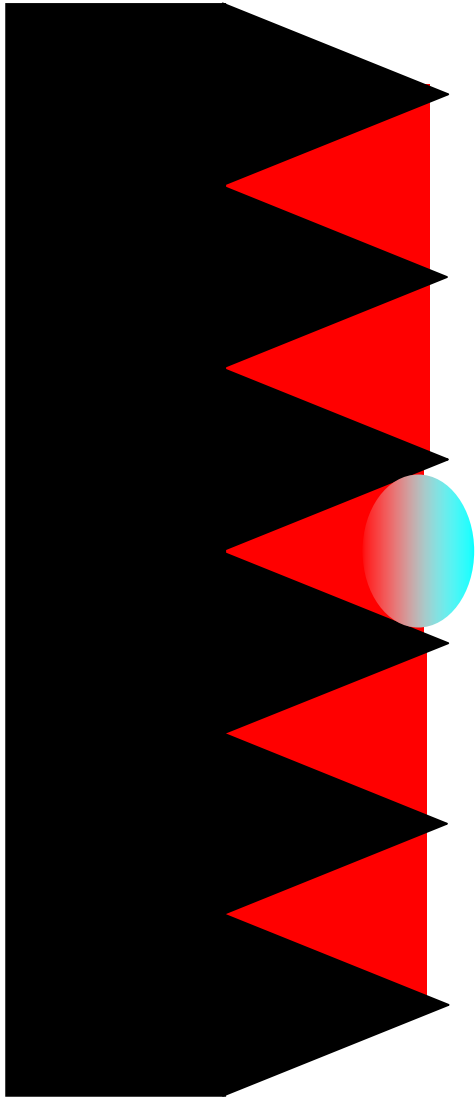
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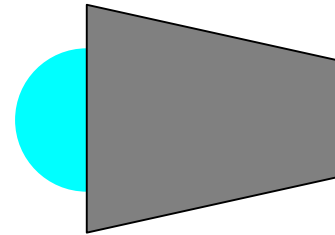
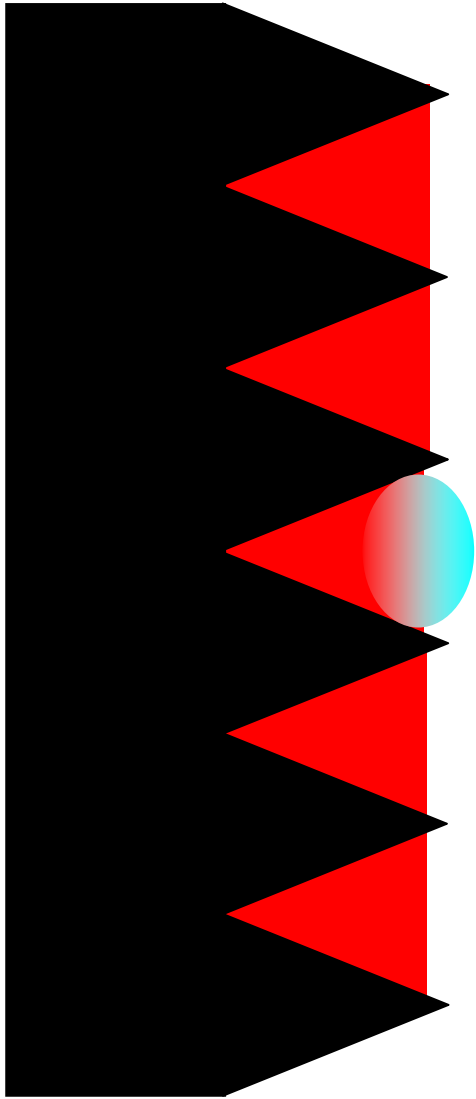
Water drop diameter similar to, or smaller
than the recess (drops are 10 – 100 microns)



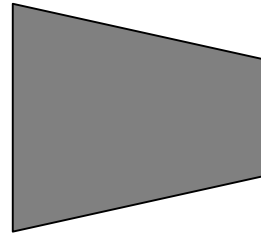
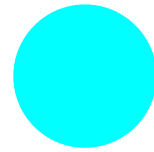
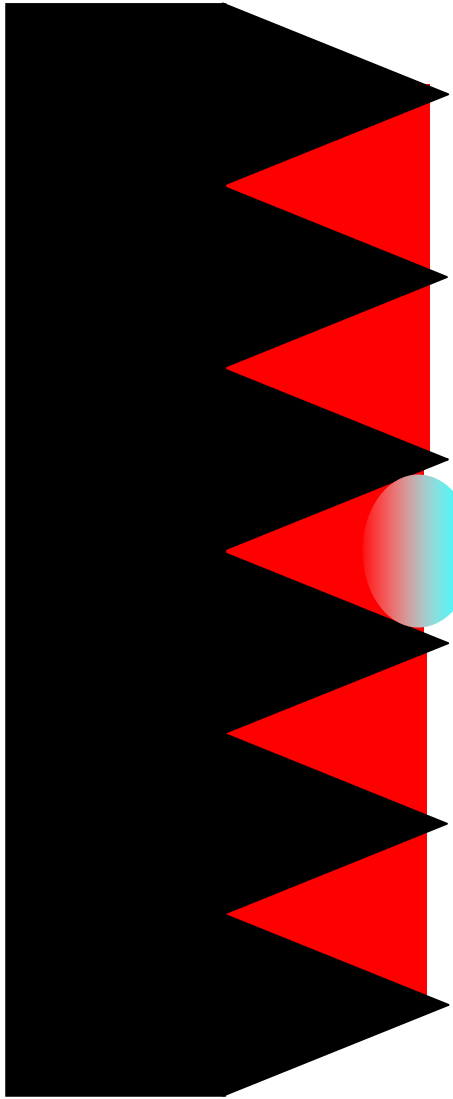
**Spray rinsing dynamics
on rough or structured surfaces.**



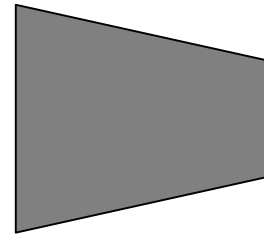
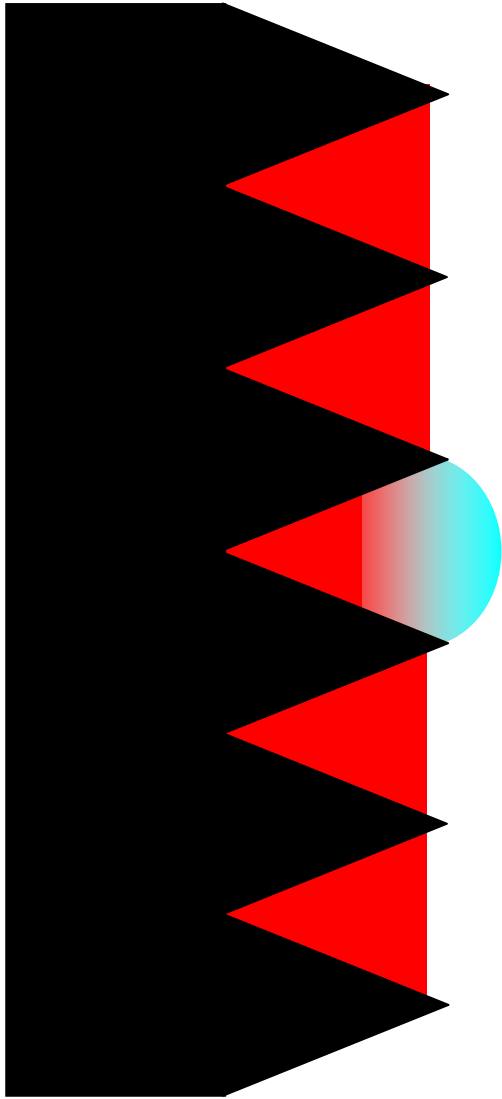
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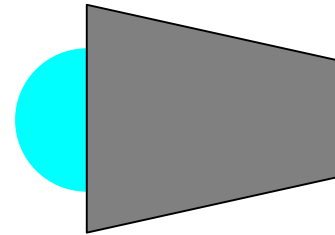
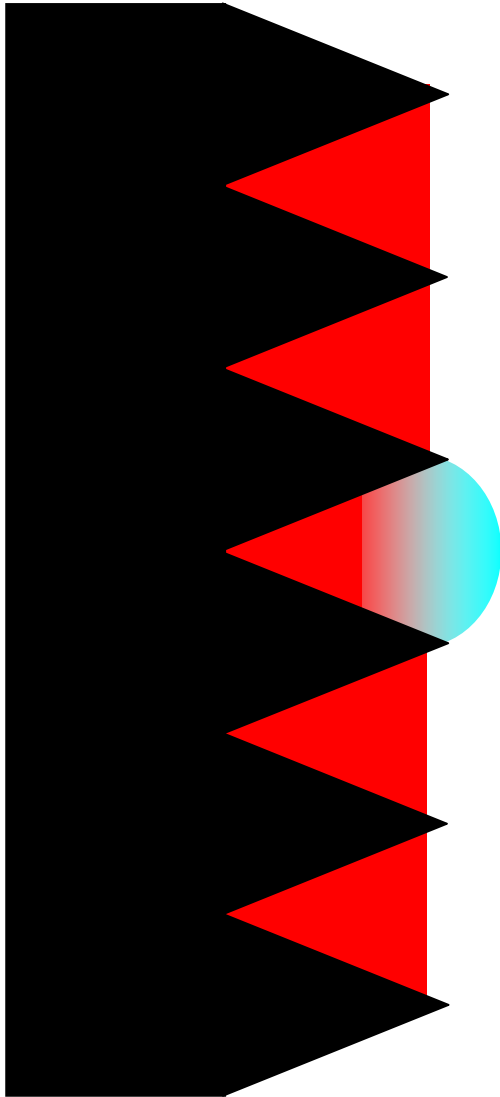
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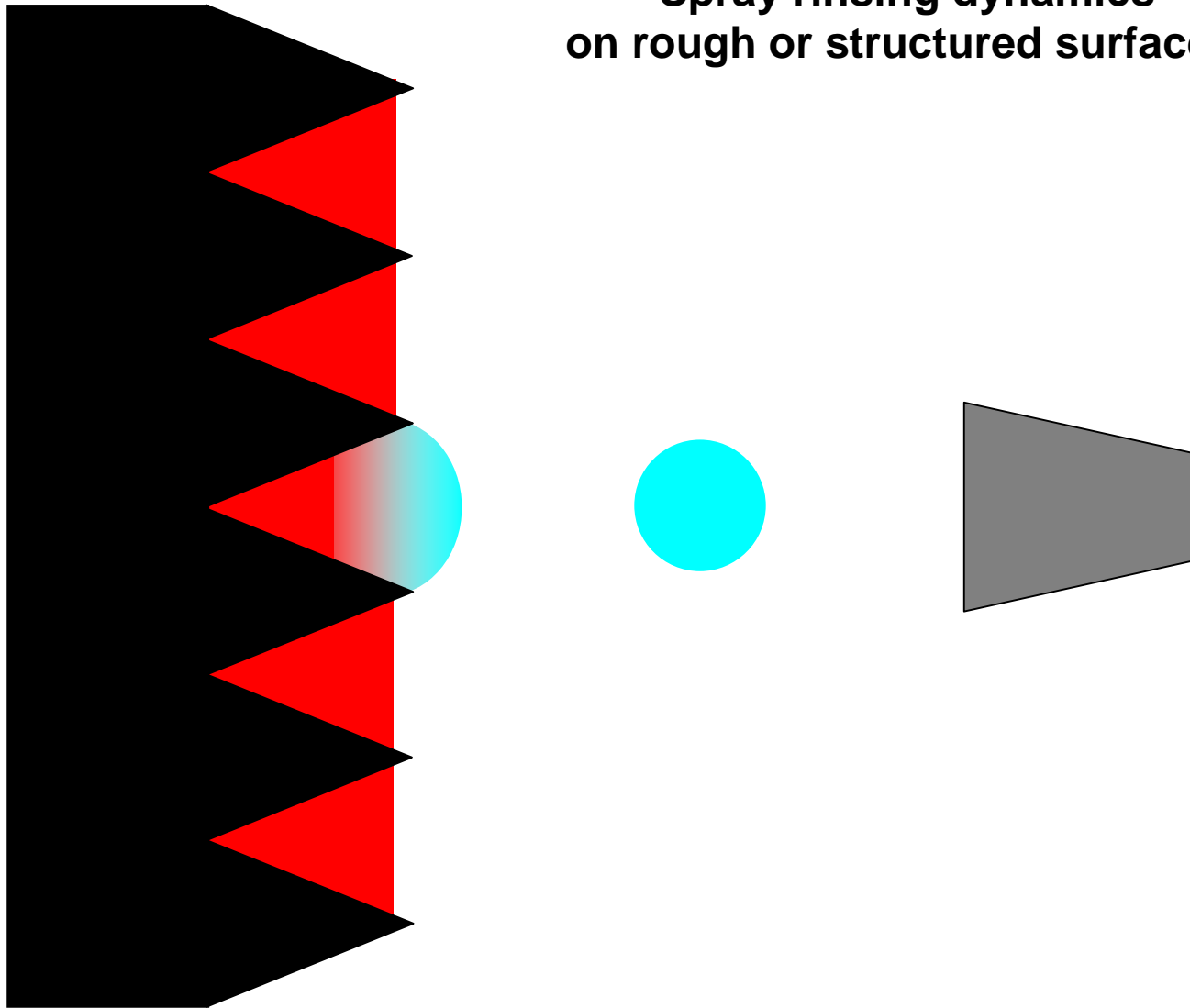
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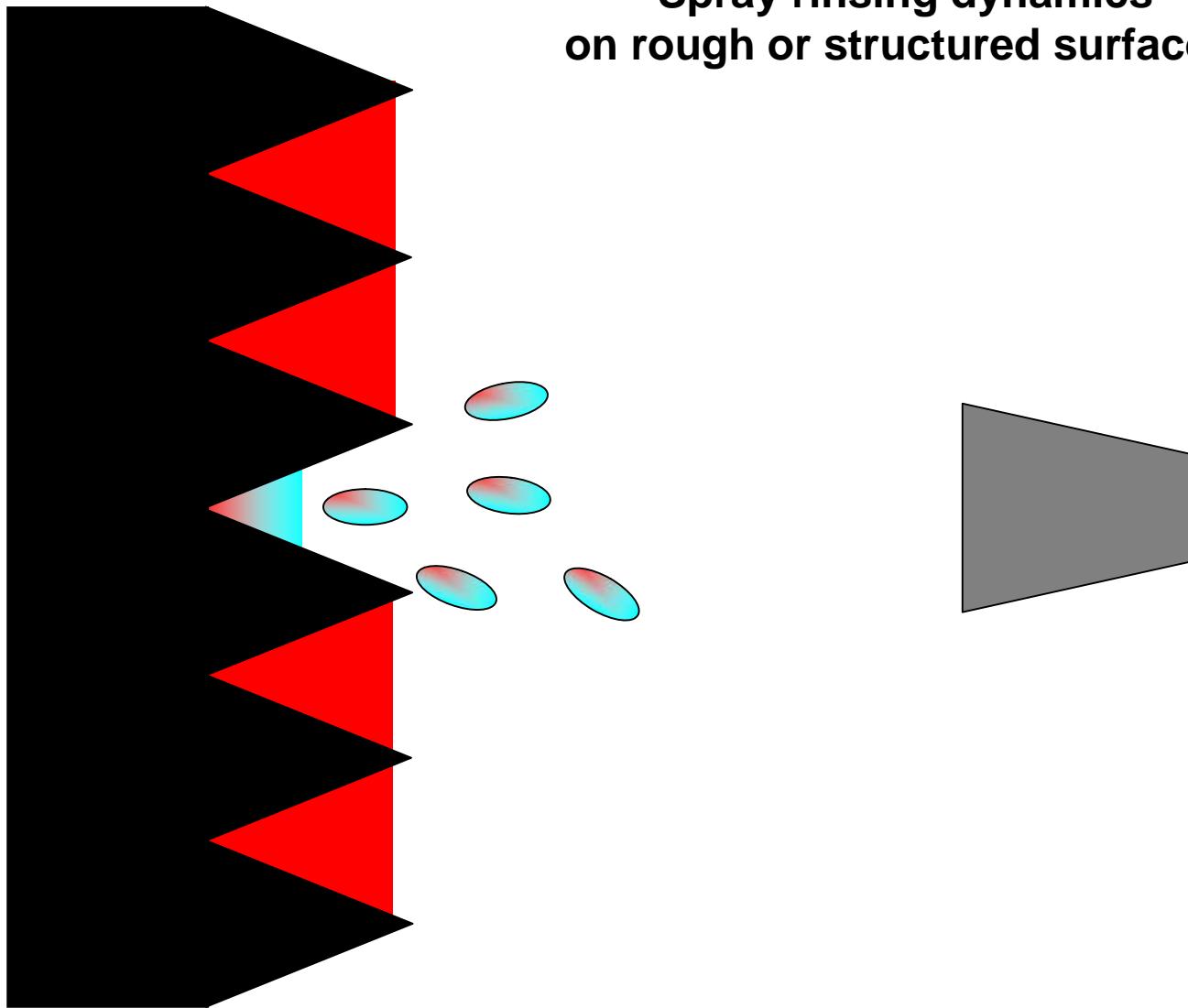
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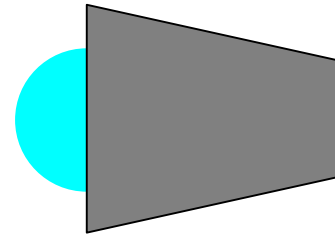
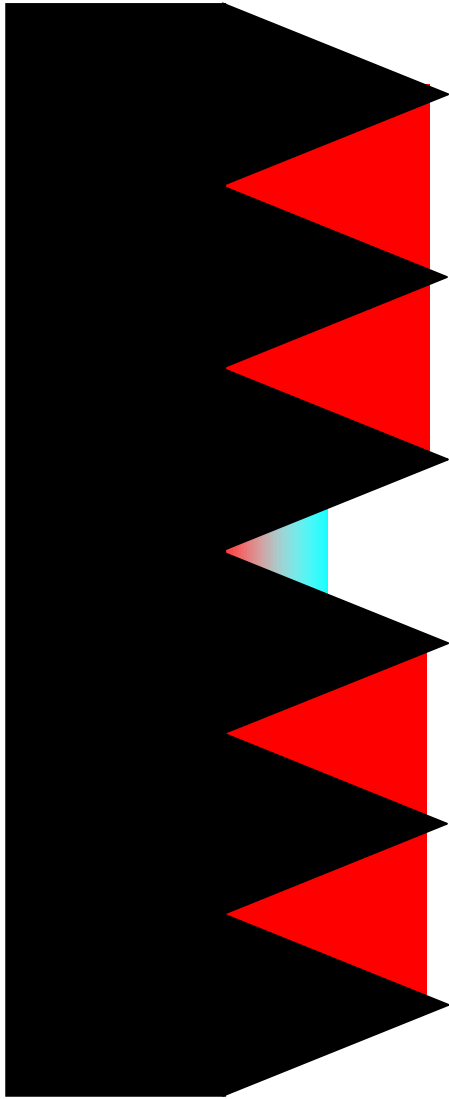
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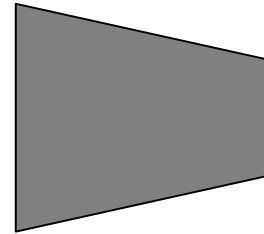
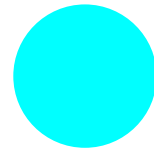
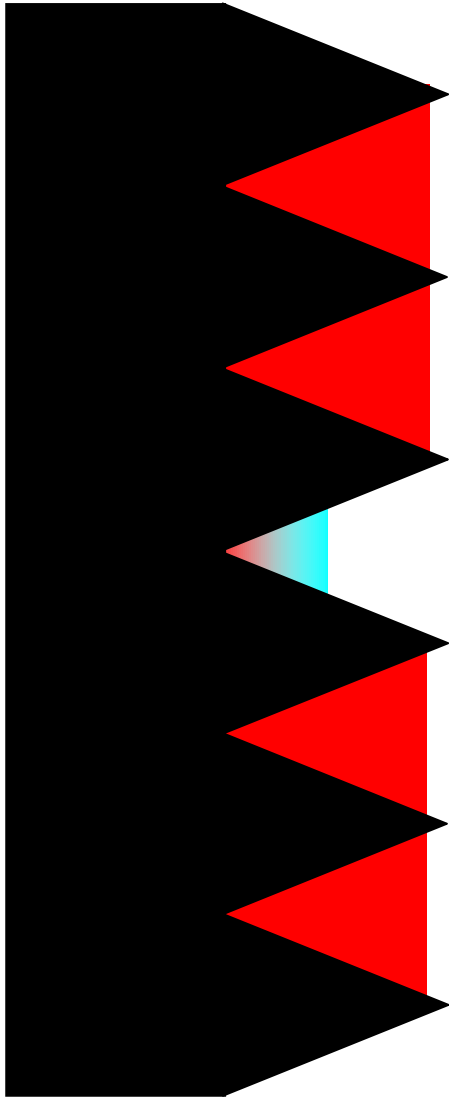
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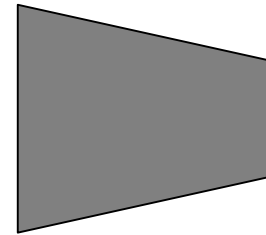
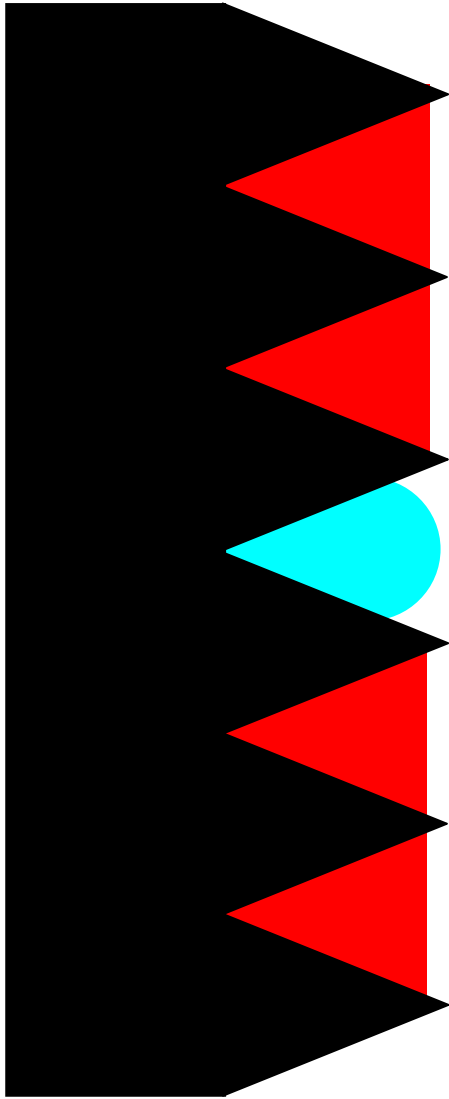
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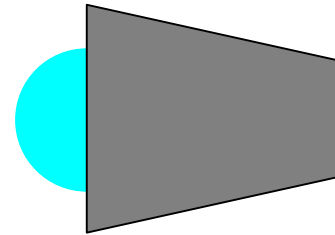
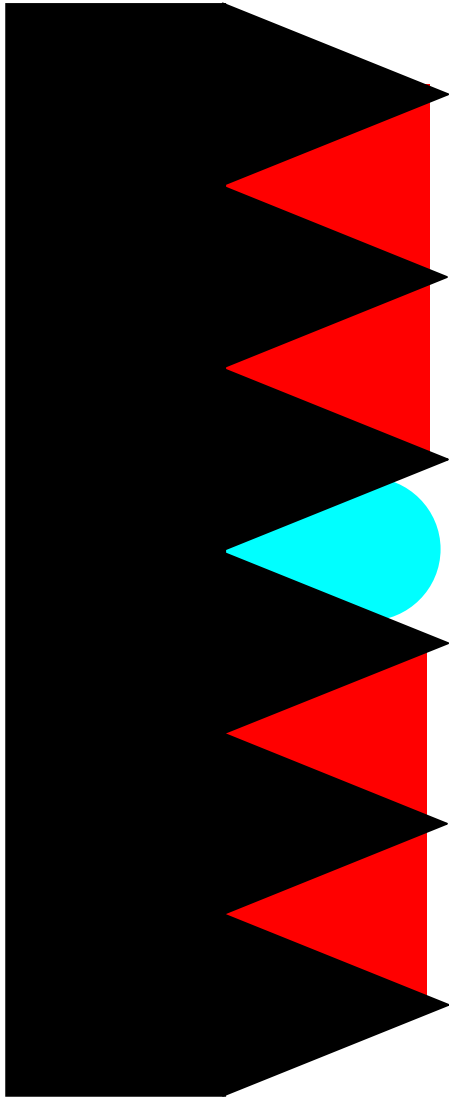
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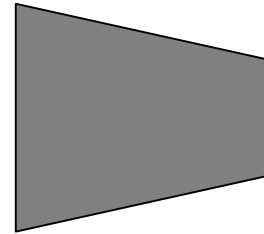
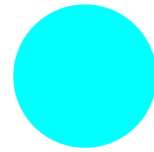
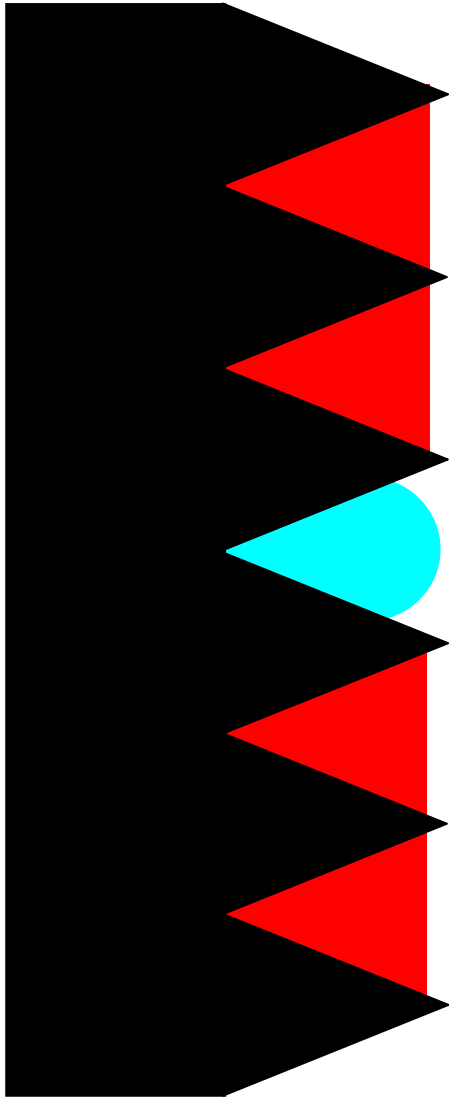
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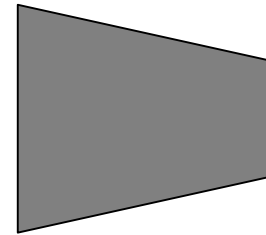
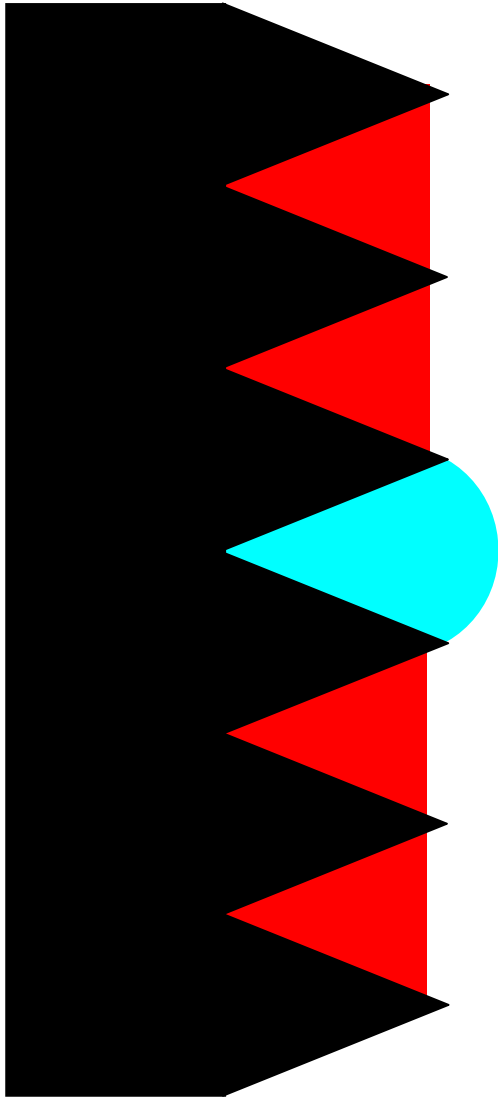
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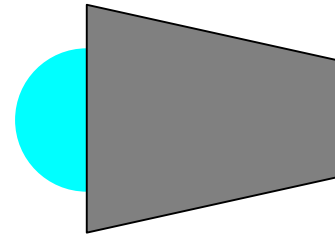
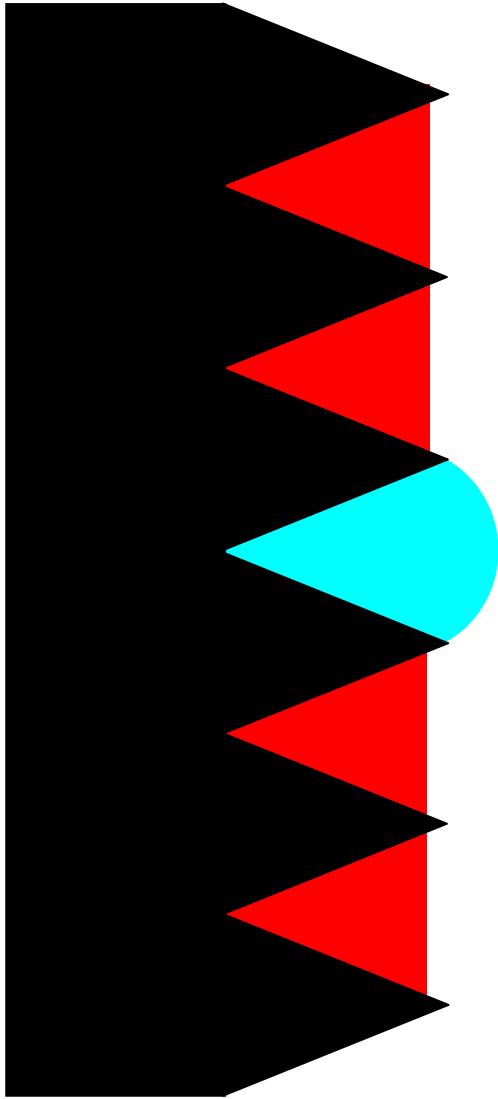
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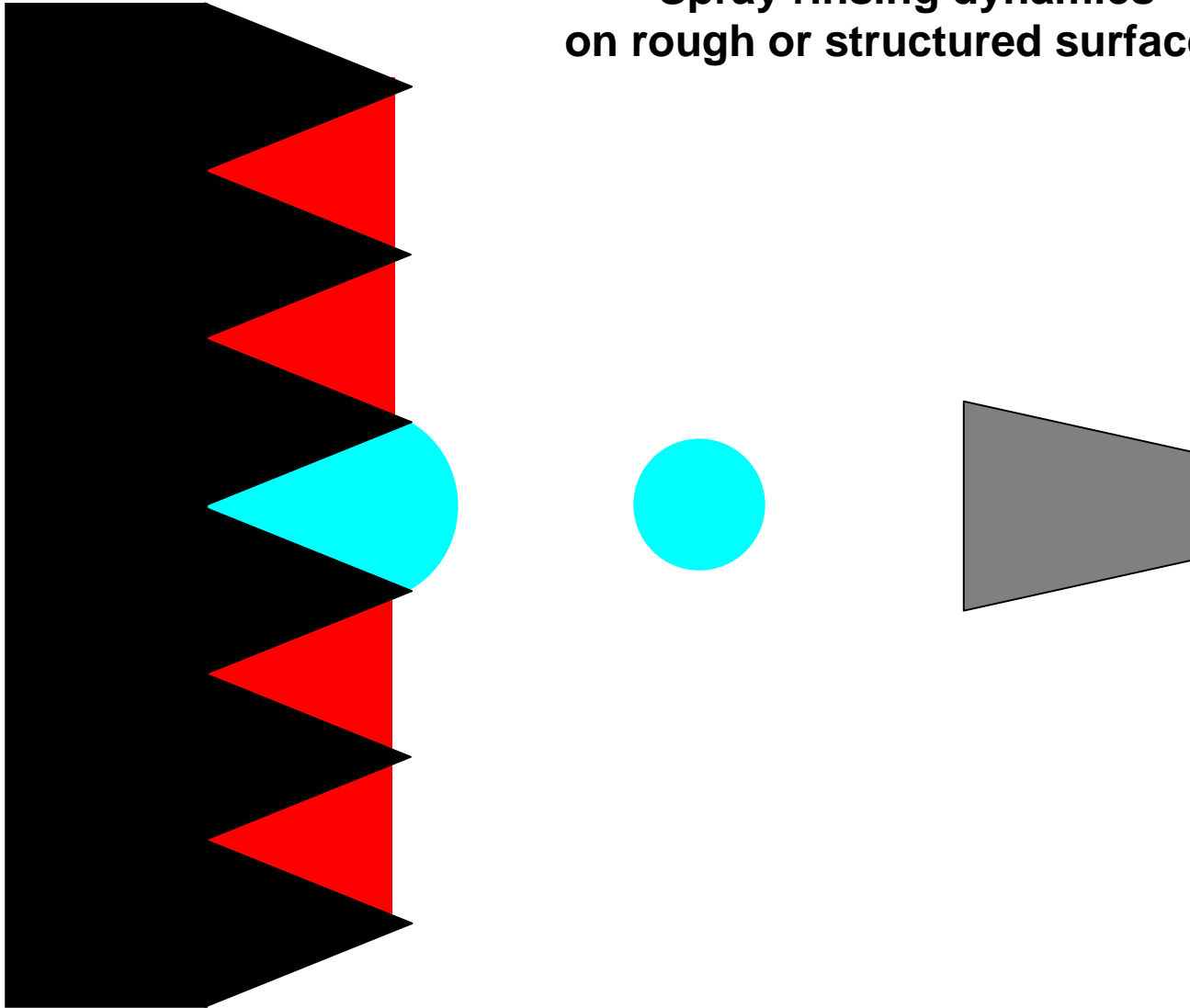
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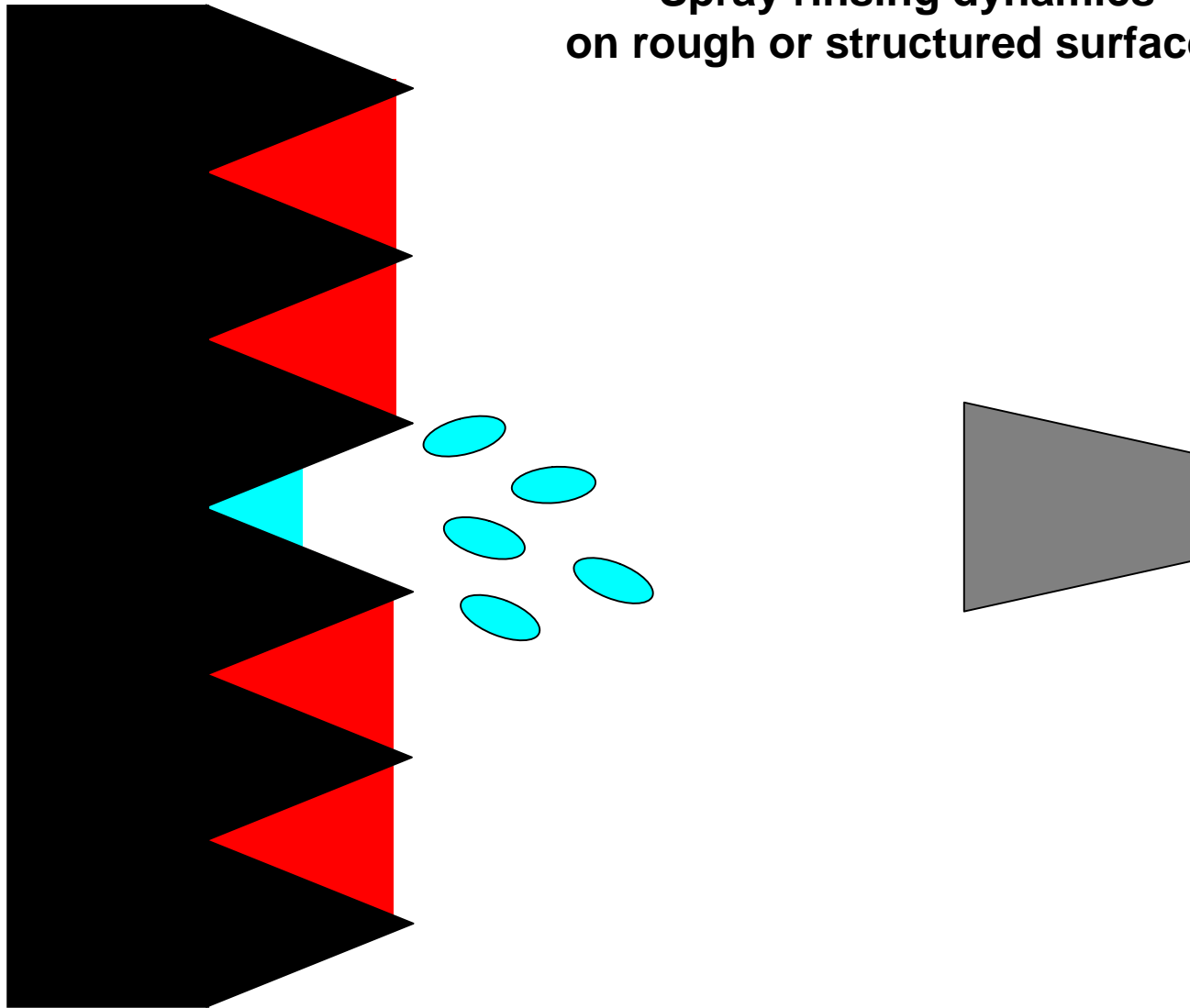
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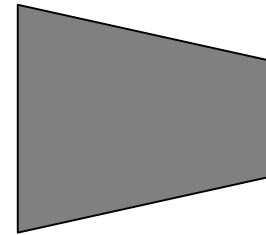
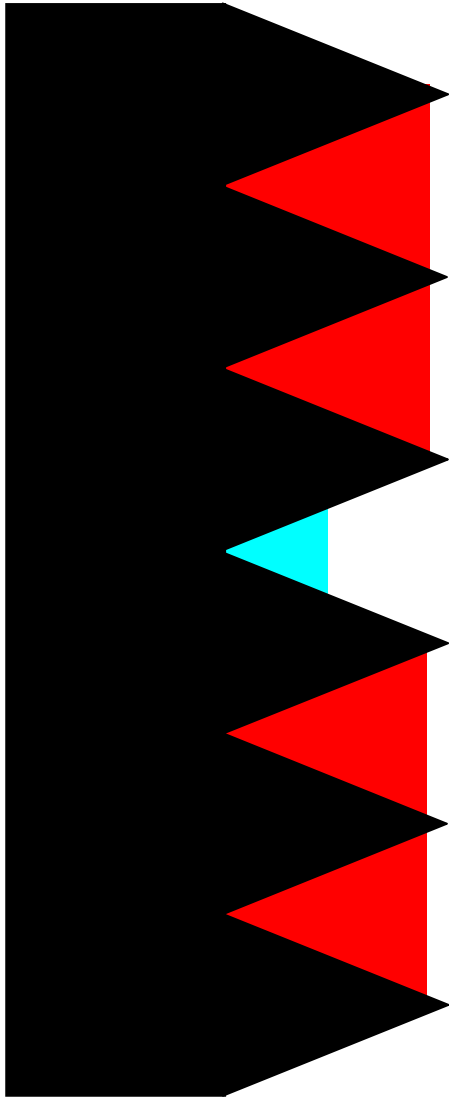
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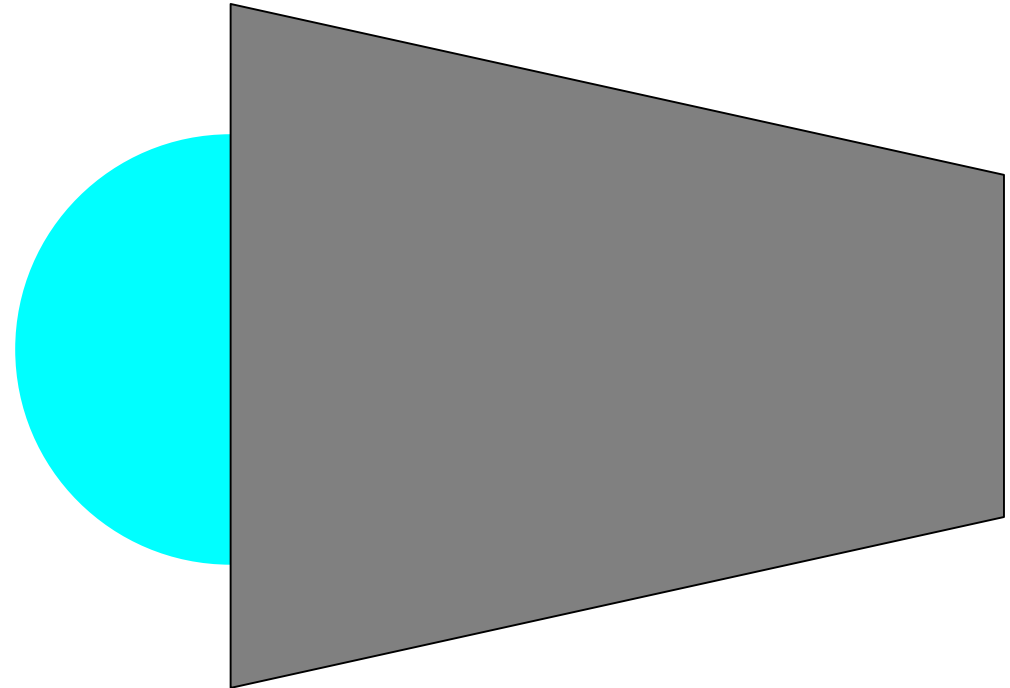
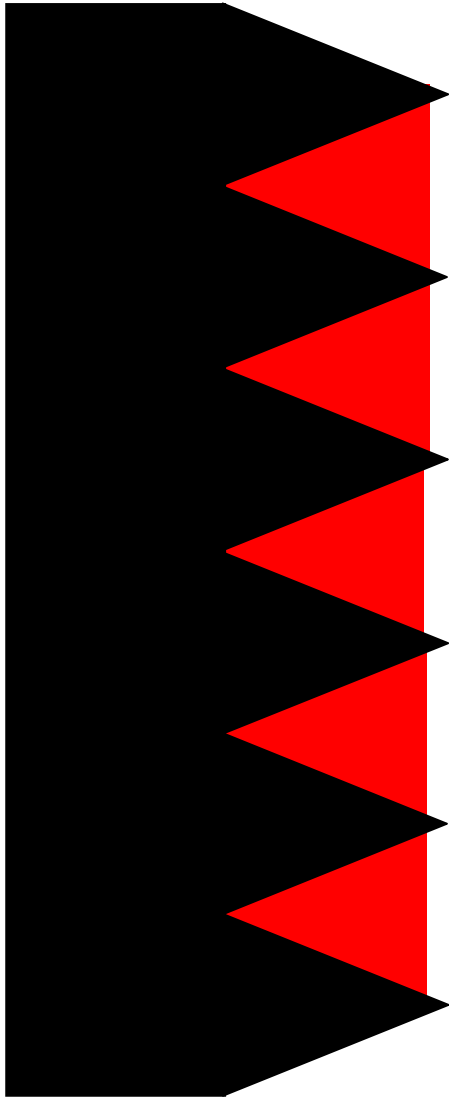
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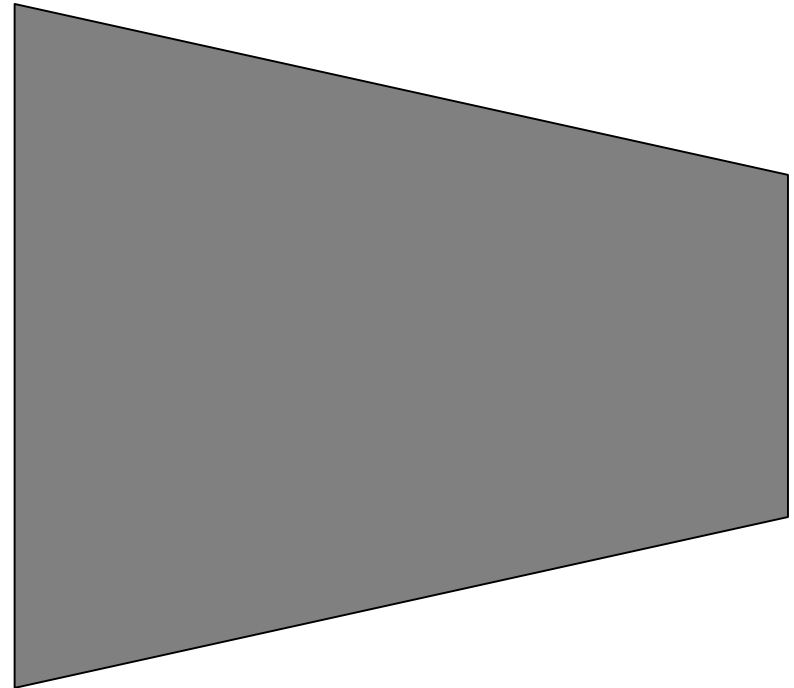
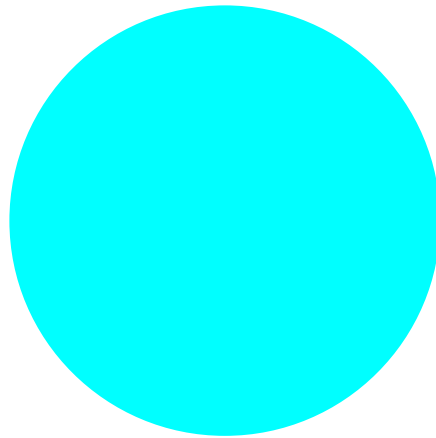
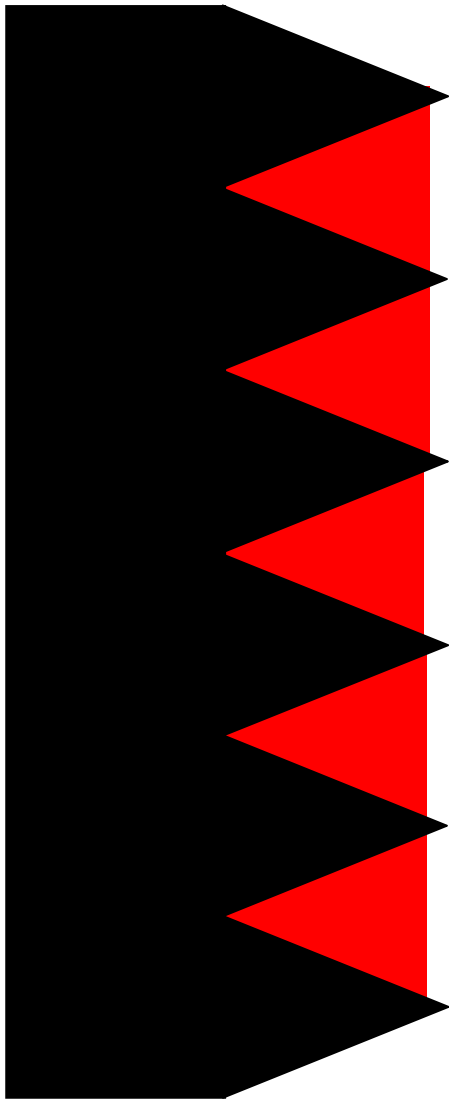


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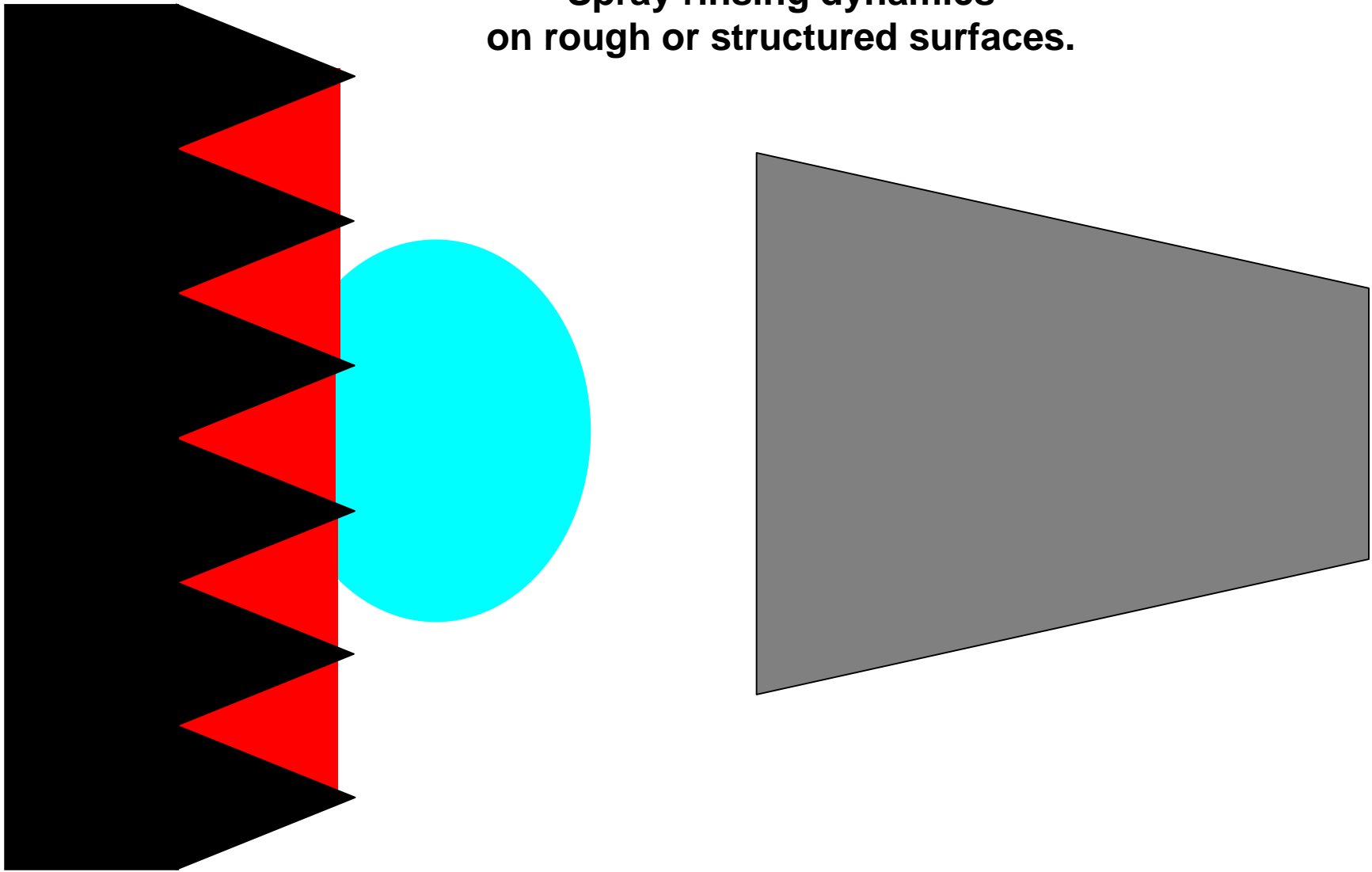
Drop diameter significantly greater than recess

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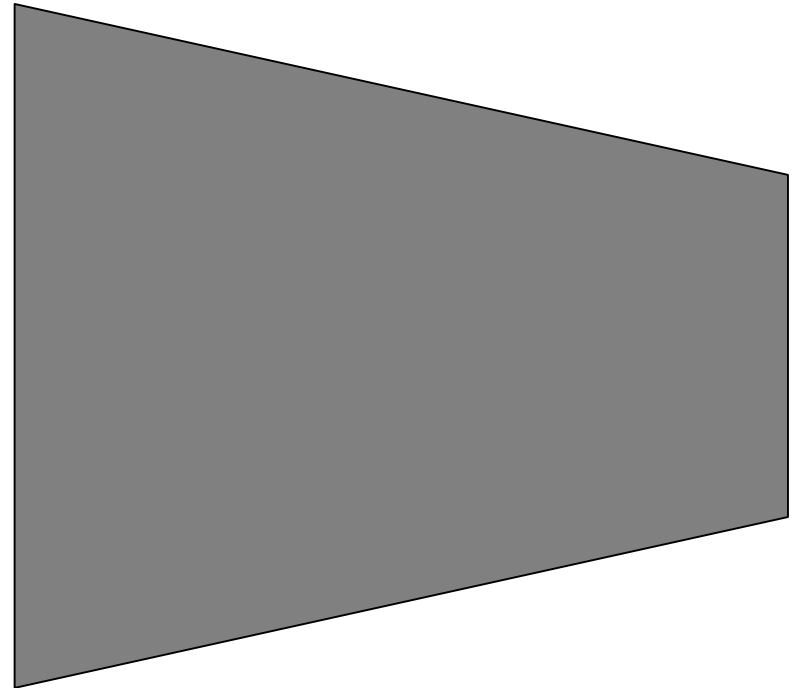
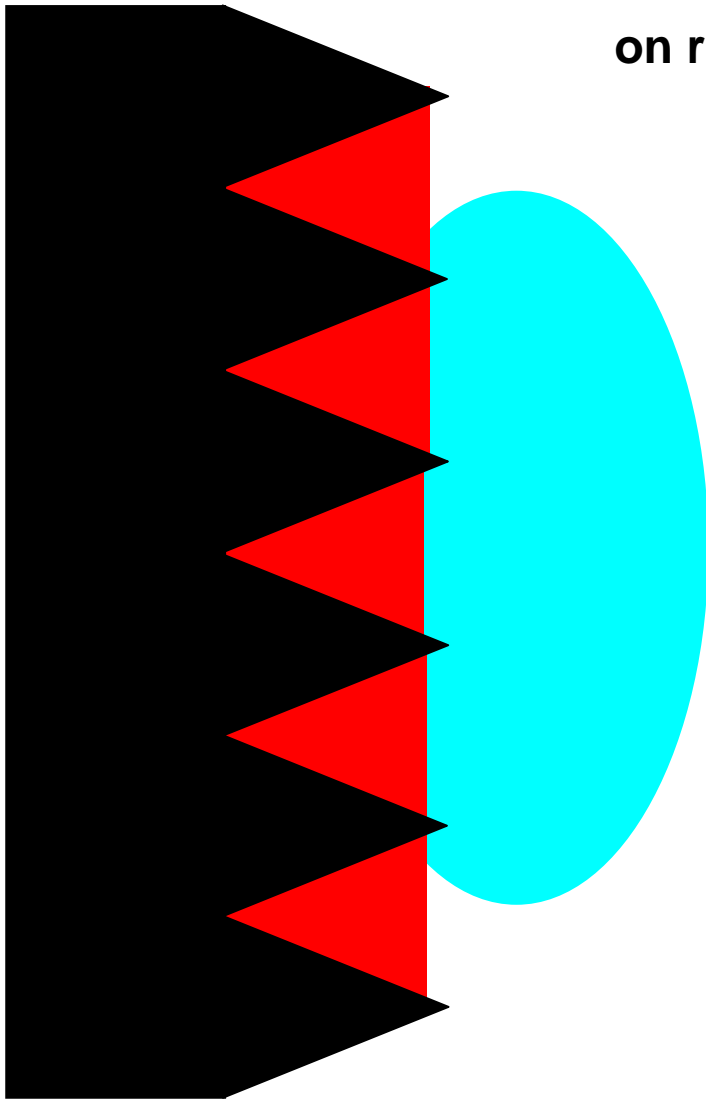


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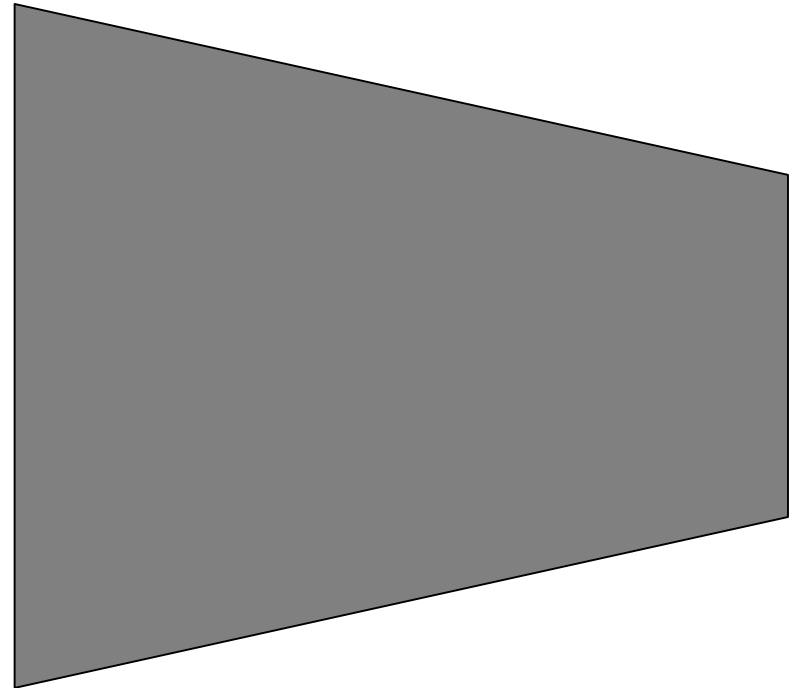
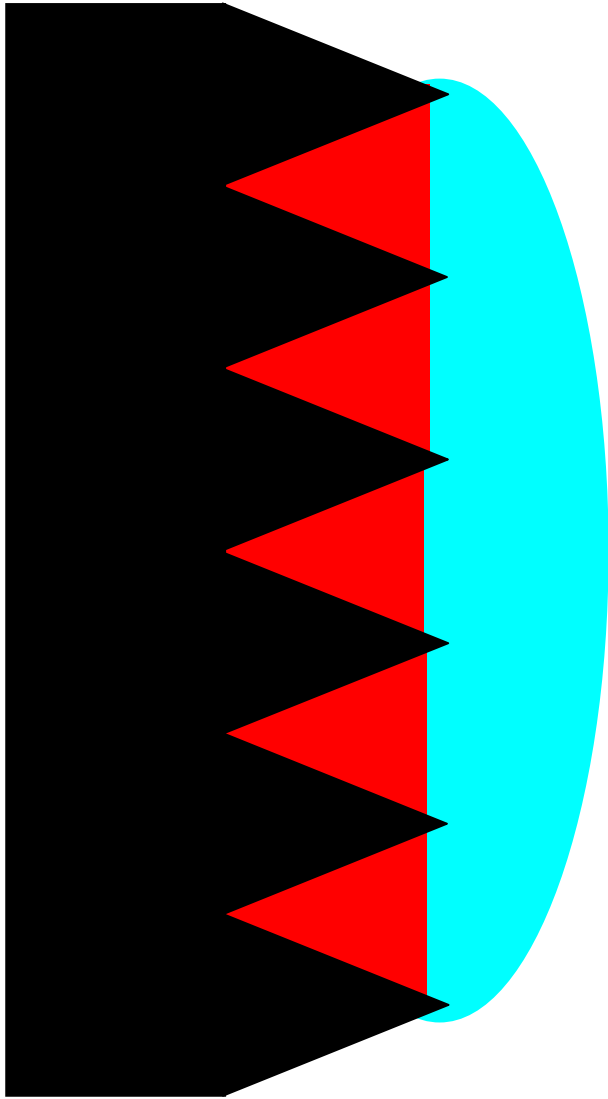
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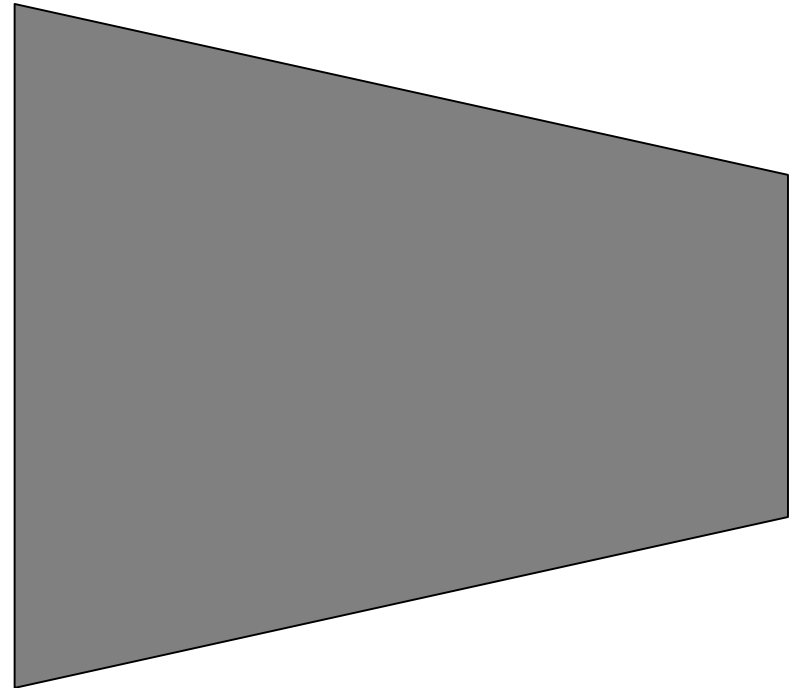
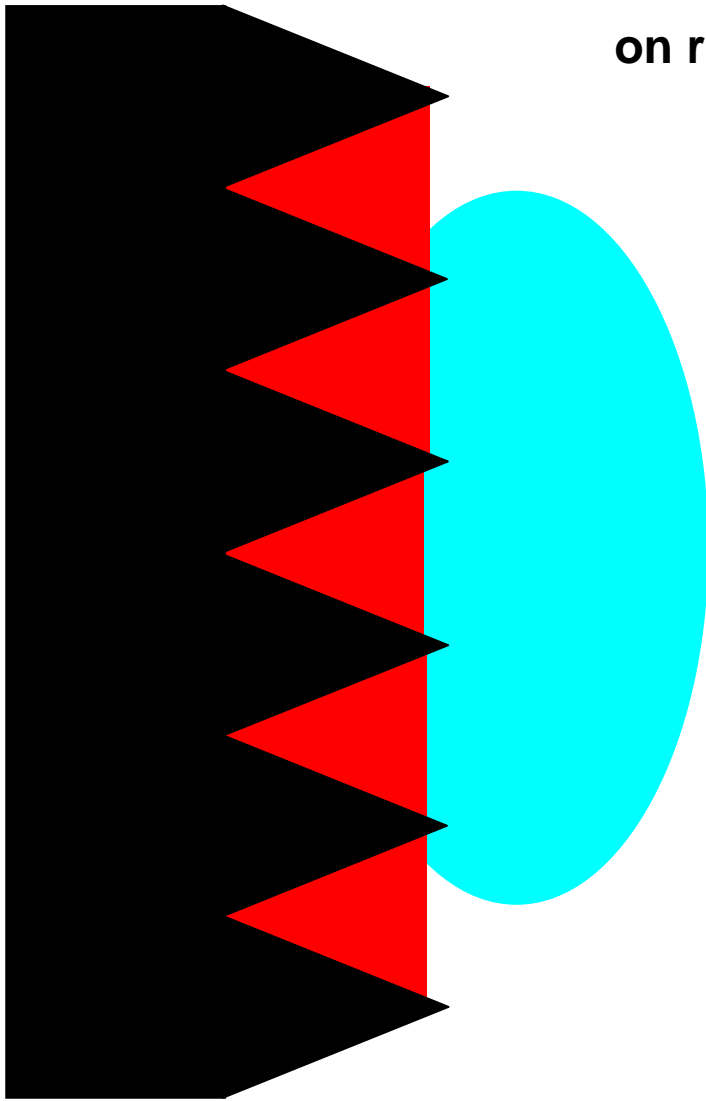
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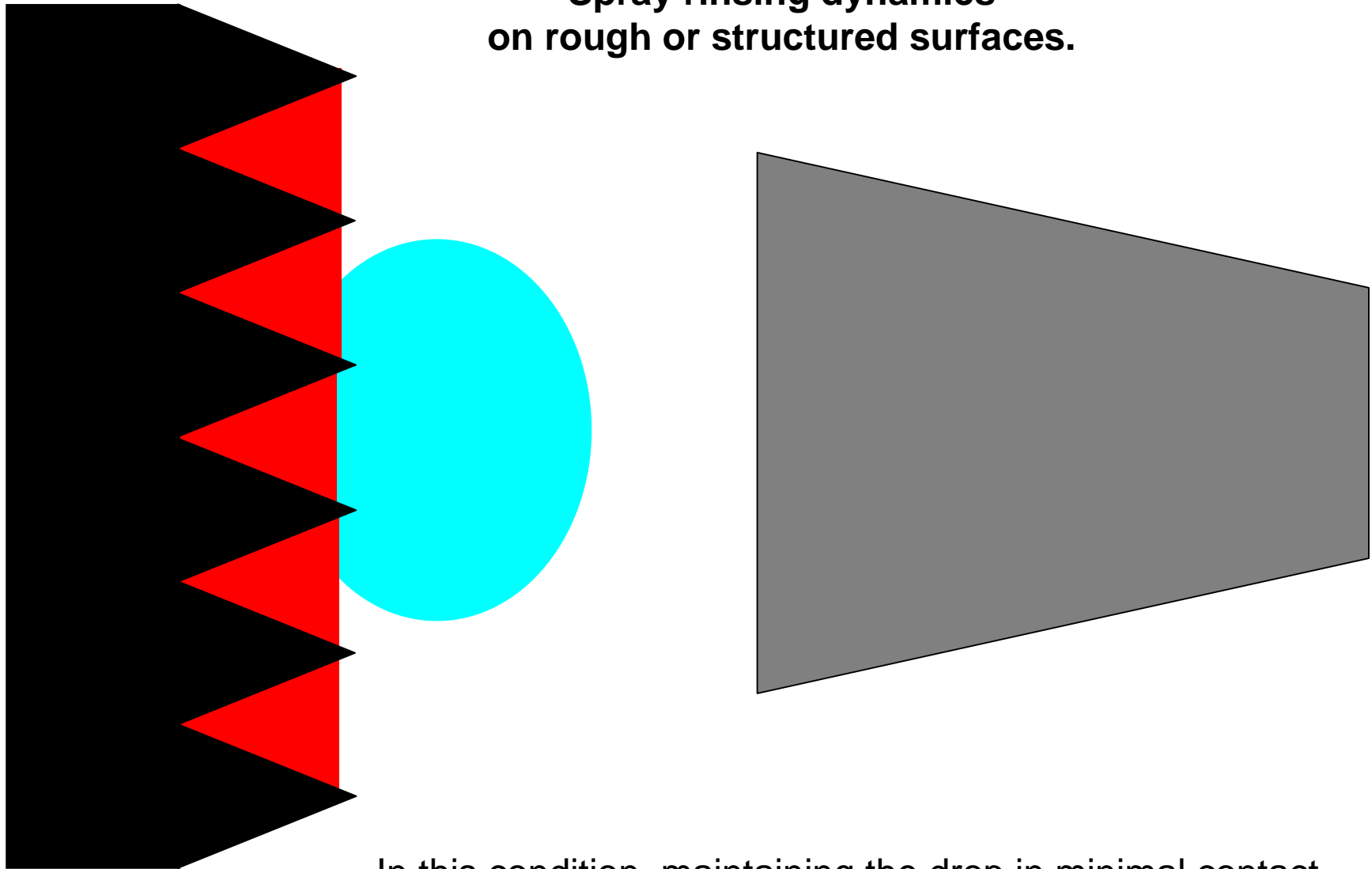
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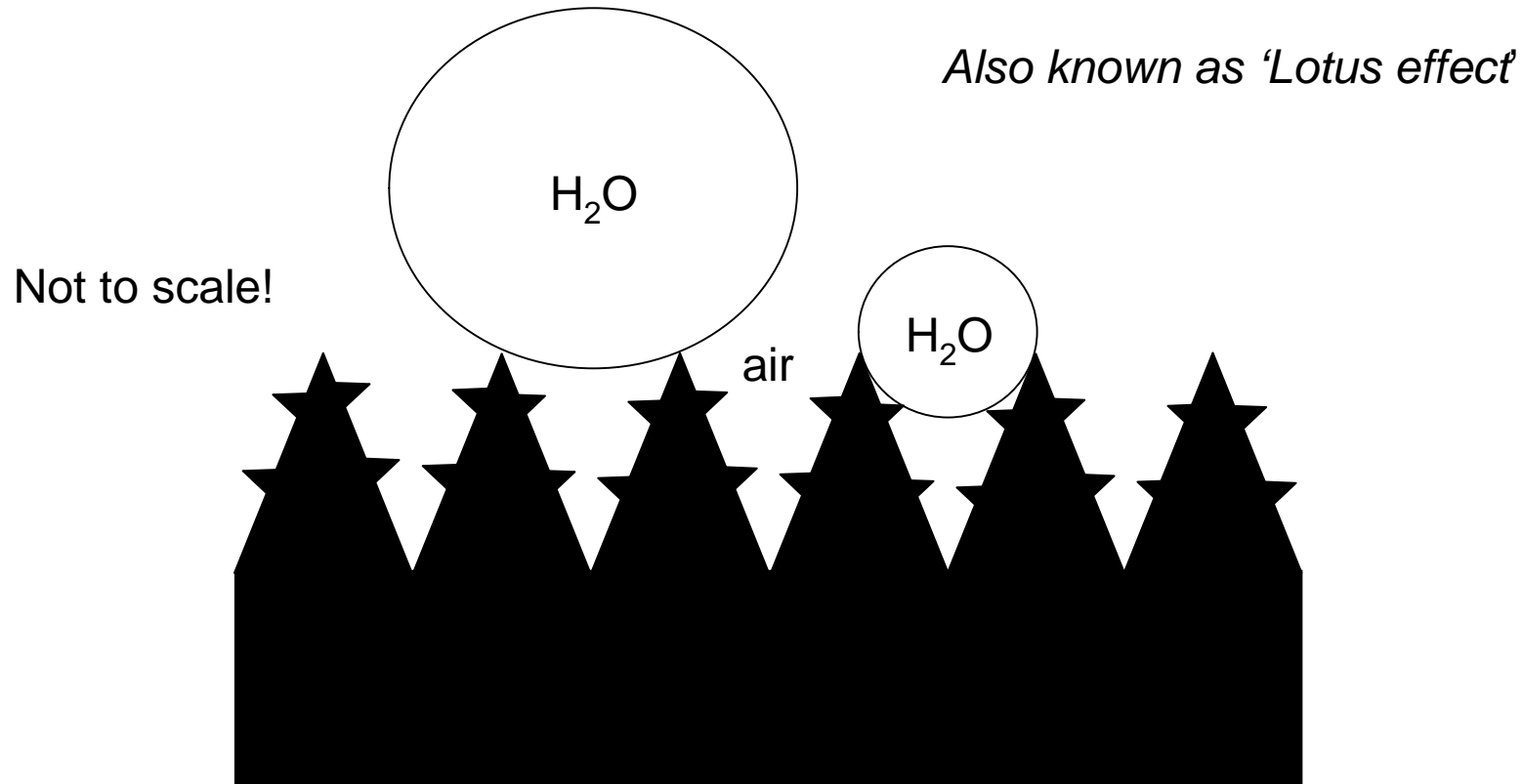


In this condition, maintaining the drop in minimal contact with the substrate is energetically favourable.

Water unable to wet micro-structured surfaces (Wenzel, Cassie & Baxter).

- It is not necessary for the surface material to be intrinsically hydrophobic.

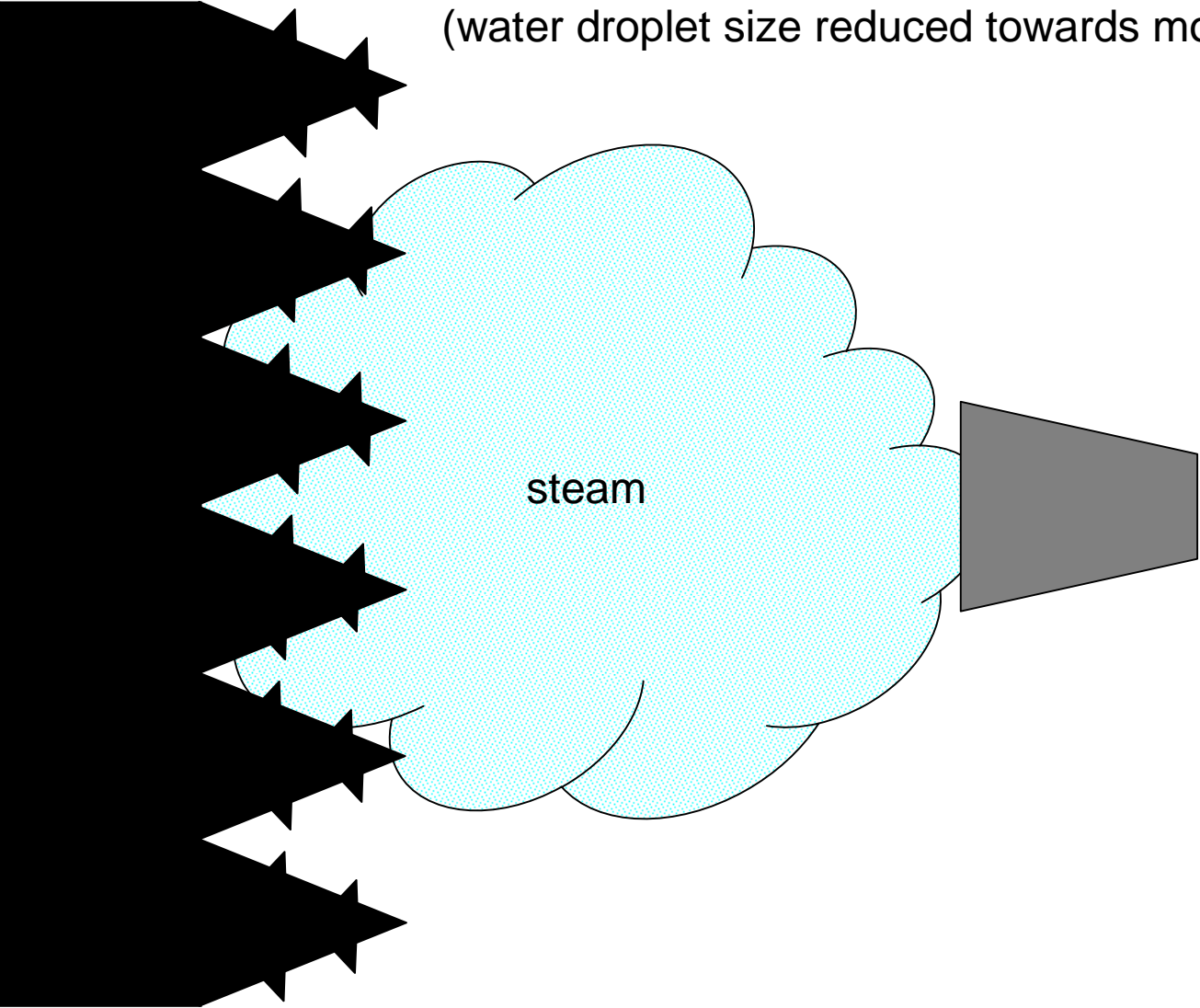
If the 'real' surface area is too great for the surface energy at the drop surface to displace gas (air) molecules.



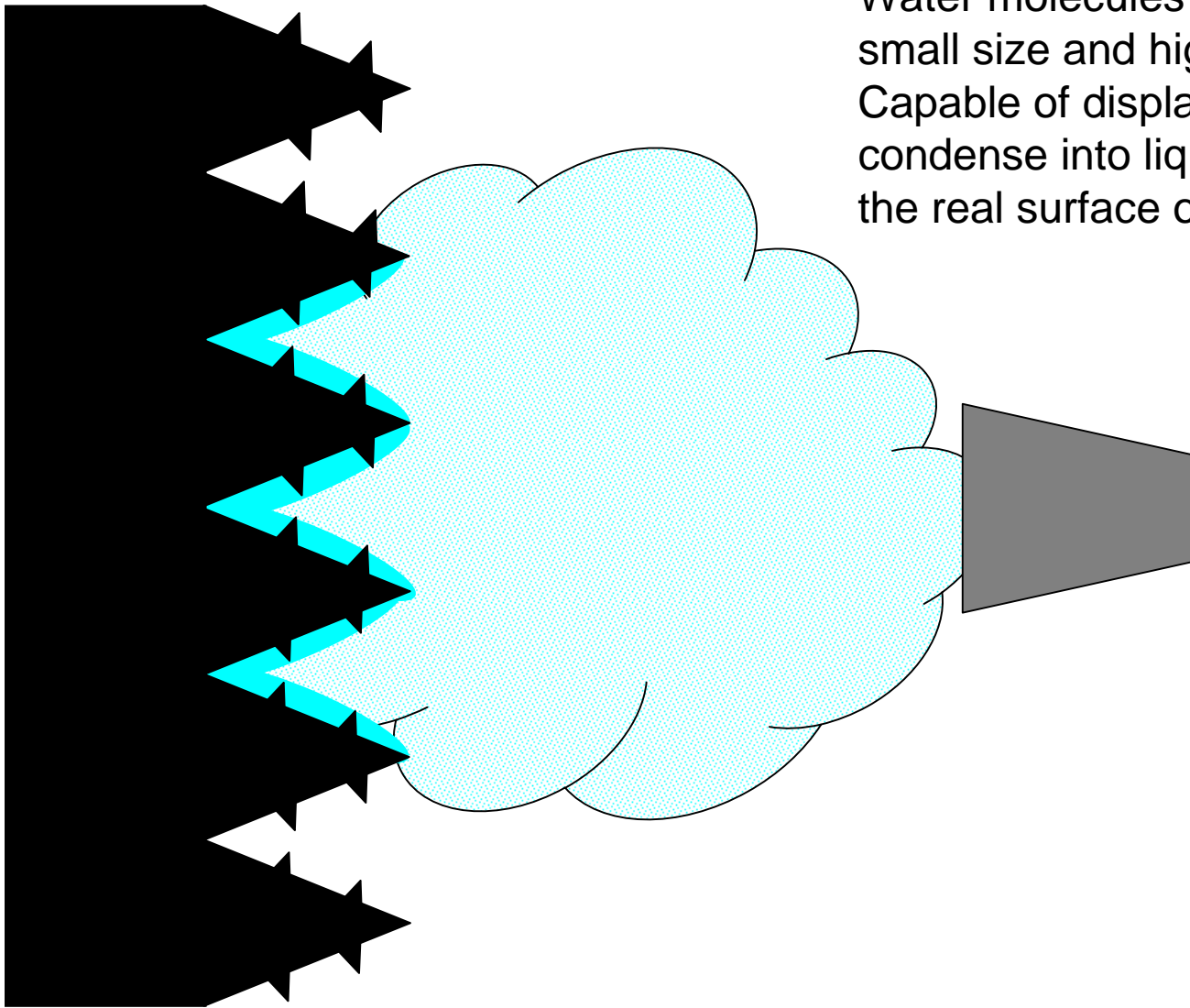
Water drop on a bird's feather.

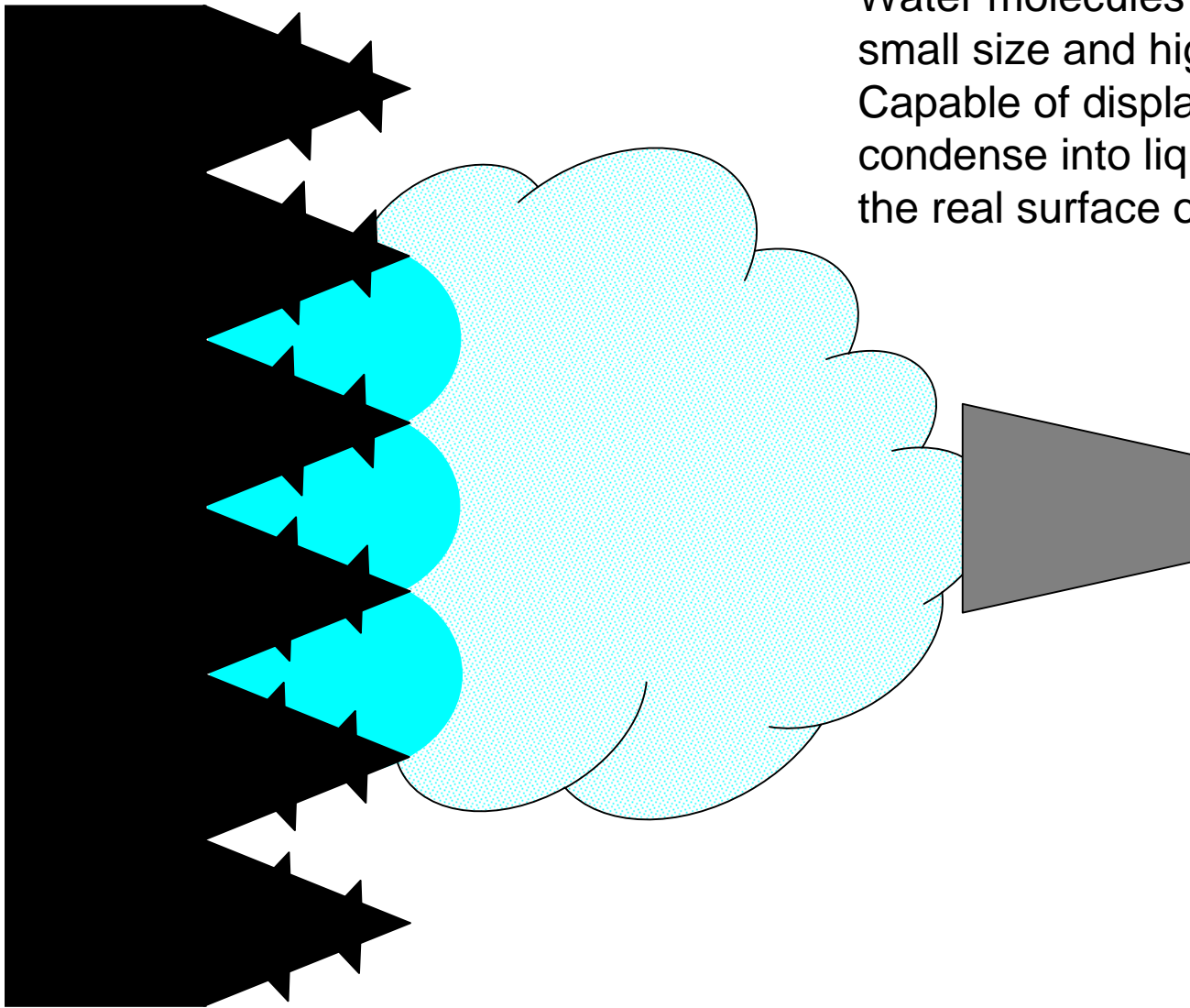


Extreme solution – high pressure steam
(water droplet size reduced towards molecular level).

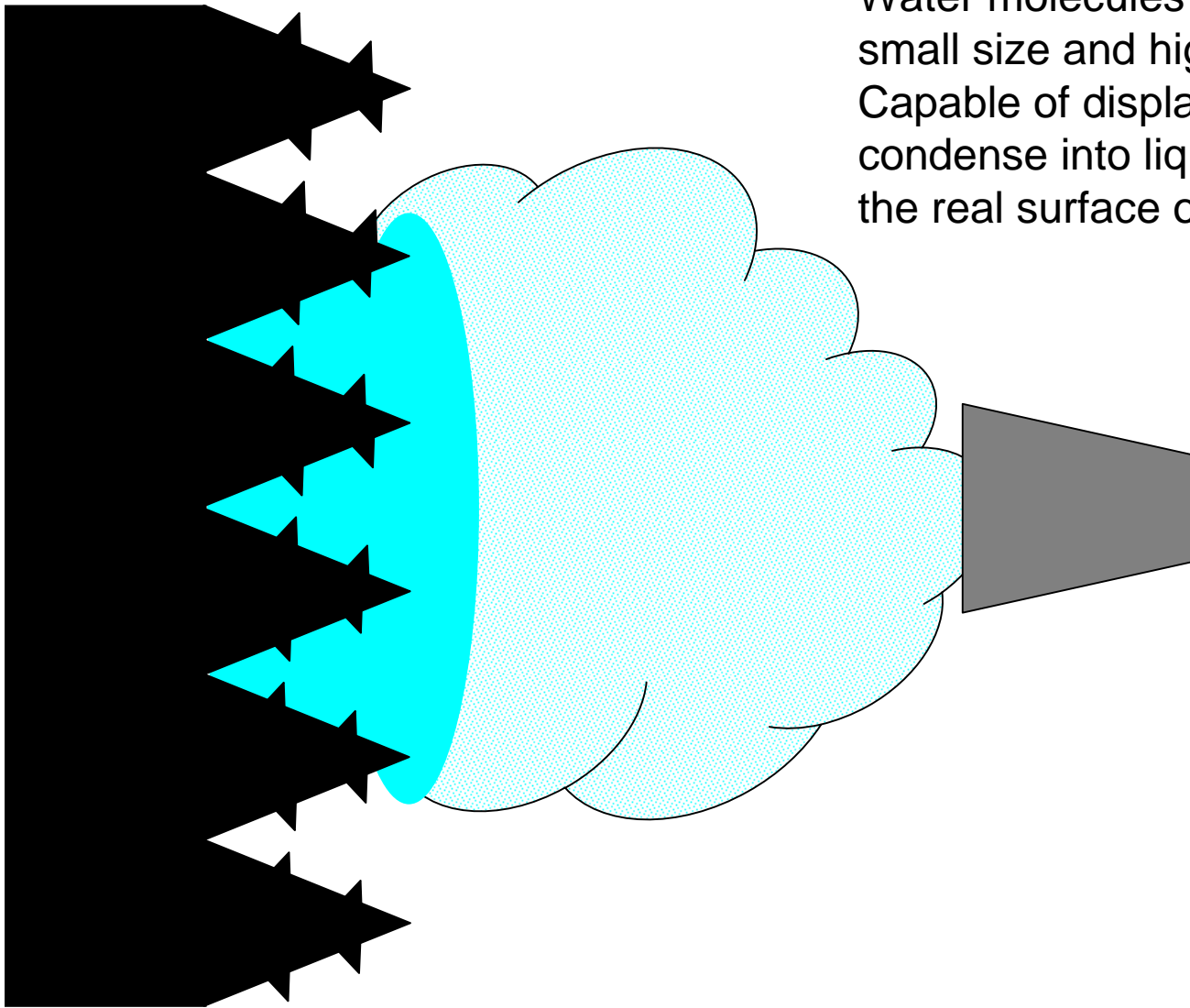


Water molecules in steam have small size and high kinetic energy. Capable of displacing air and condense into liquid water against the real surface of the target.

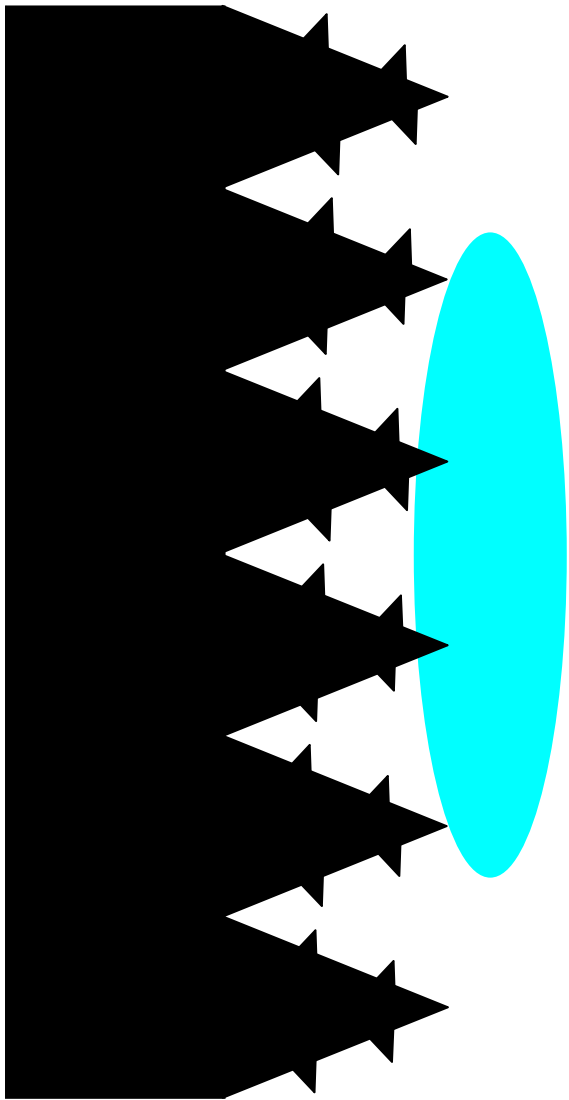




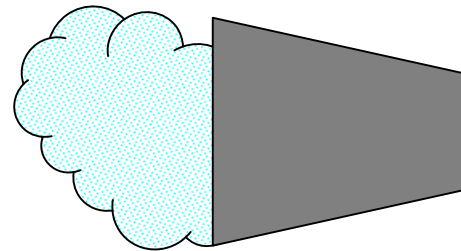
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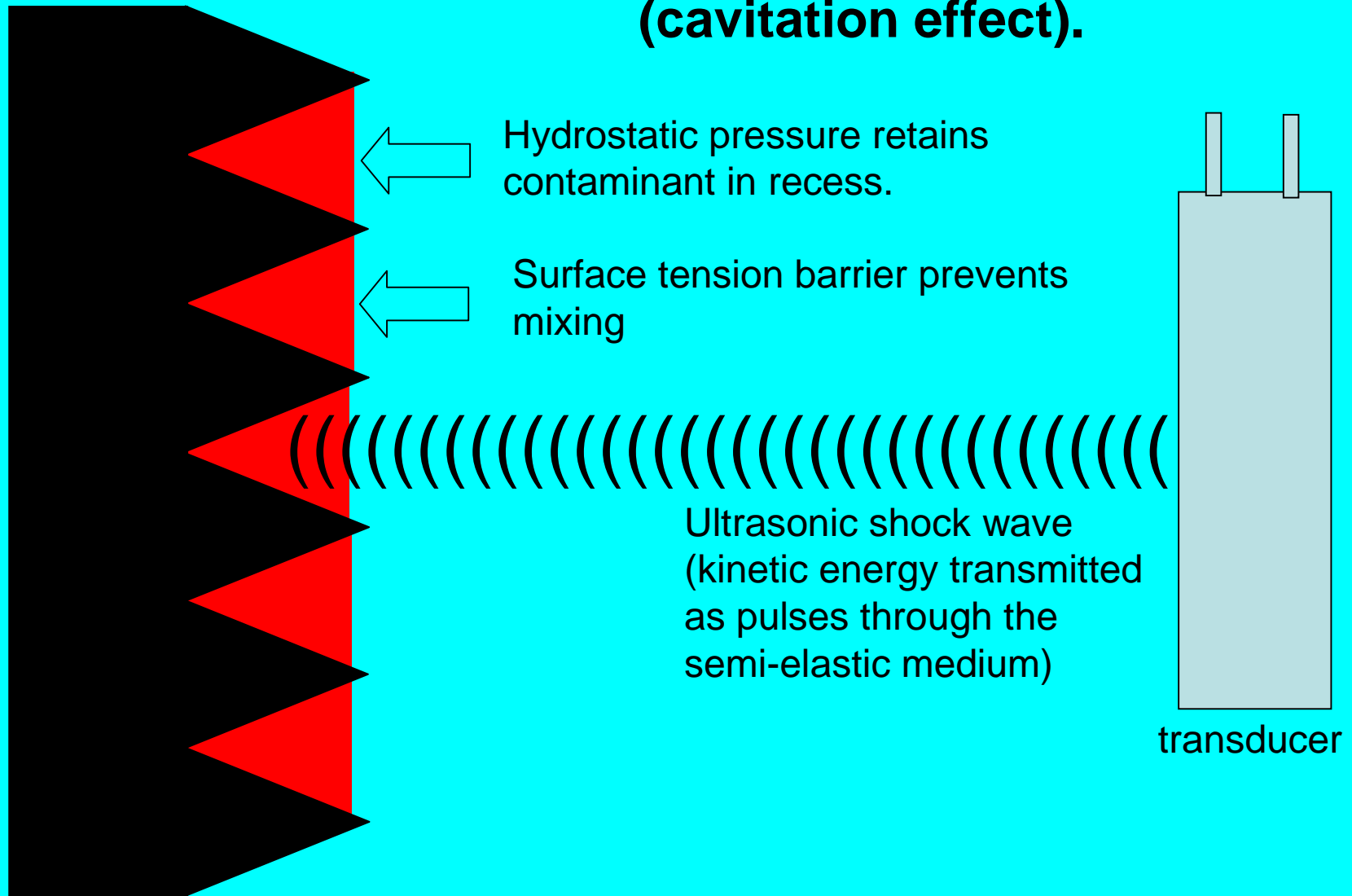
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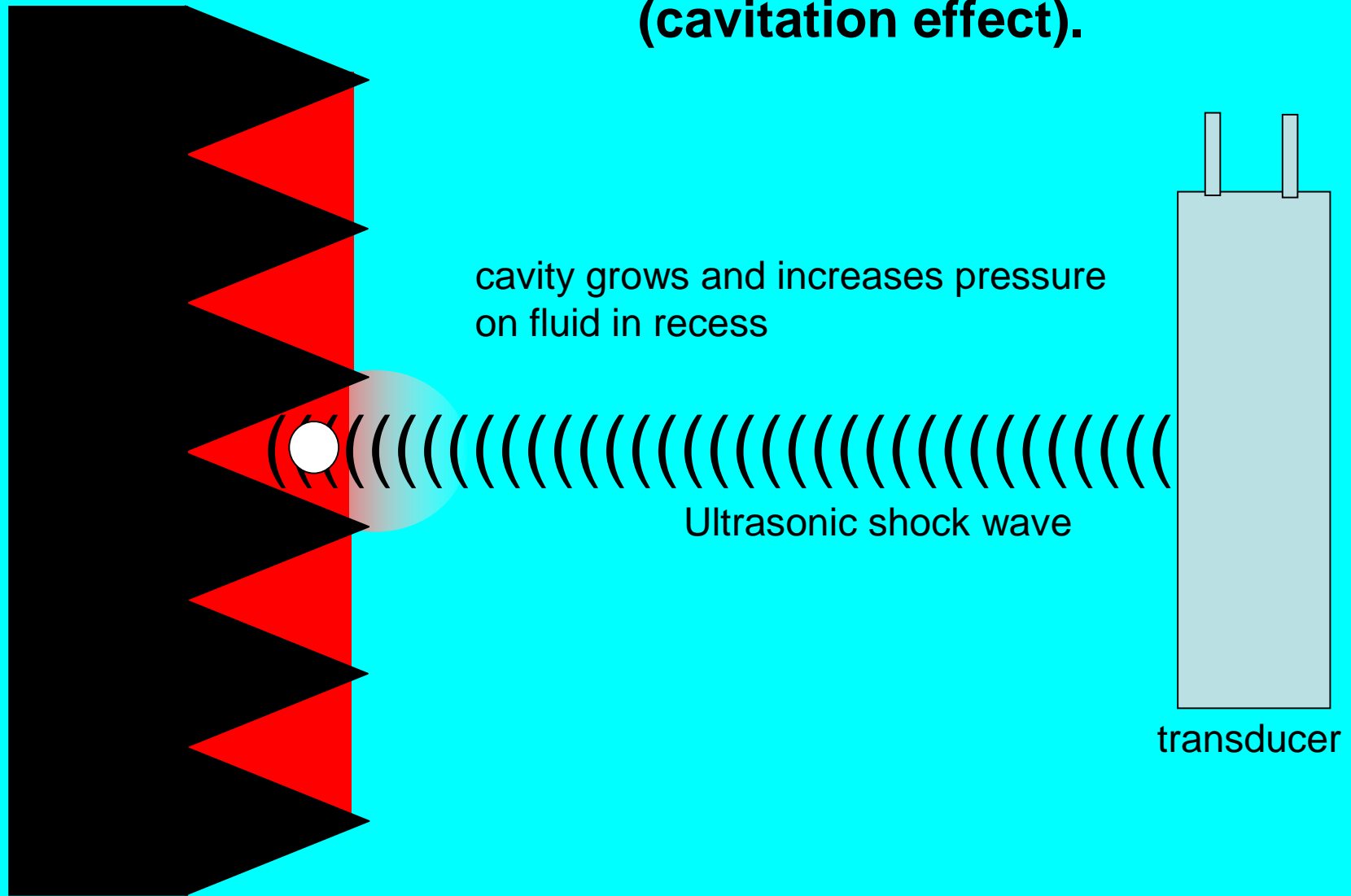
Steam off – the condensed water will revert to the energetically favourable 'Lotus effect'.

*Highly energetic and hazardous method
- only suitable for certain applications.*

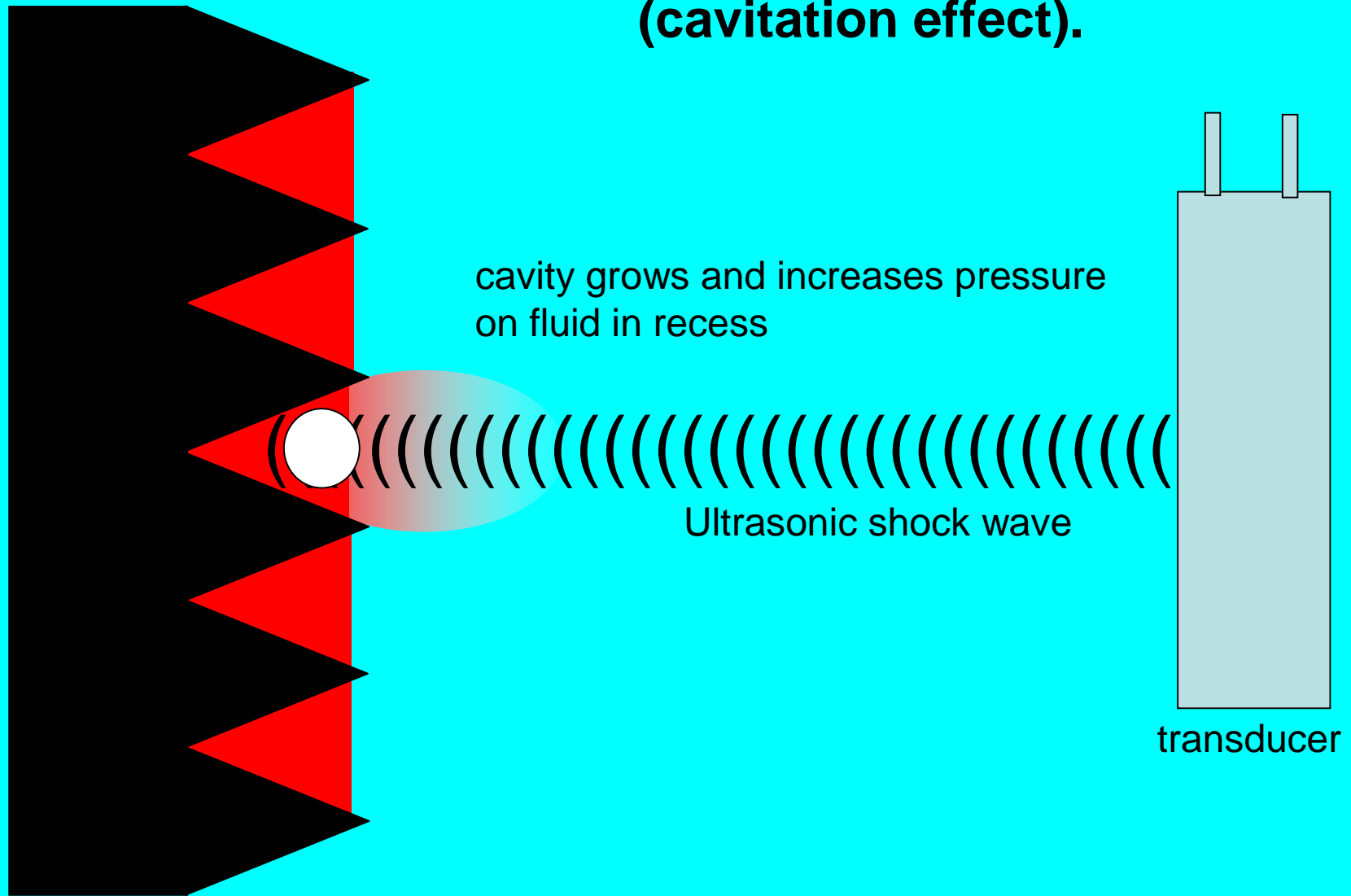
Ultrasonic effect on micro-structures: (cavitation effect).



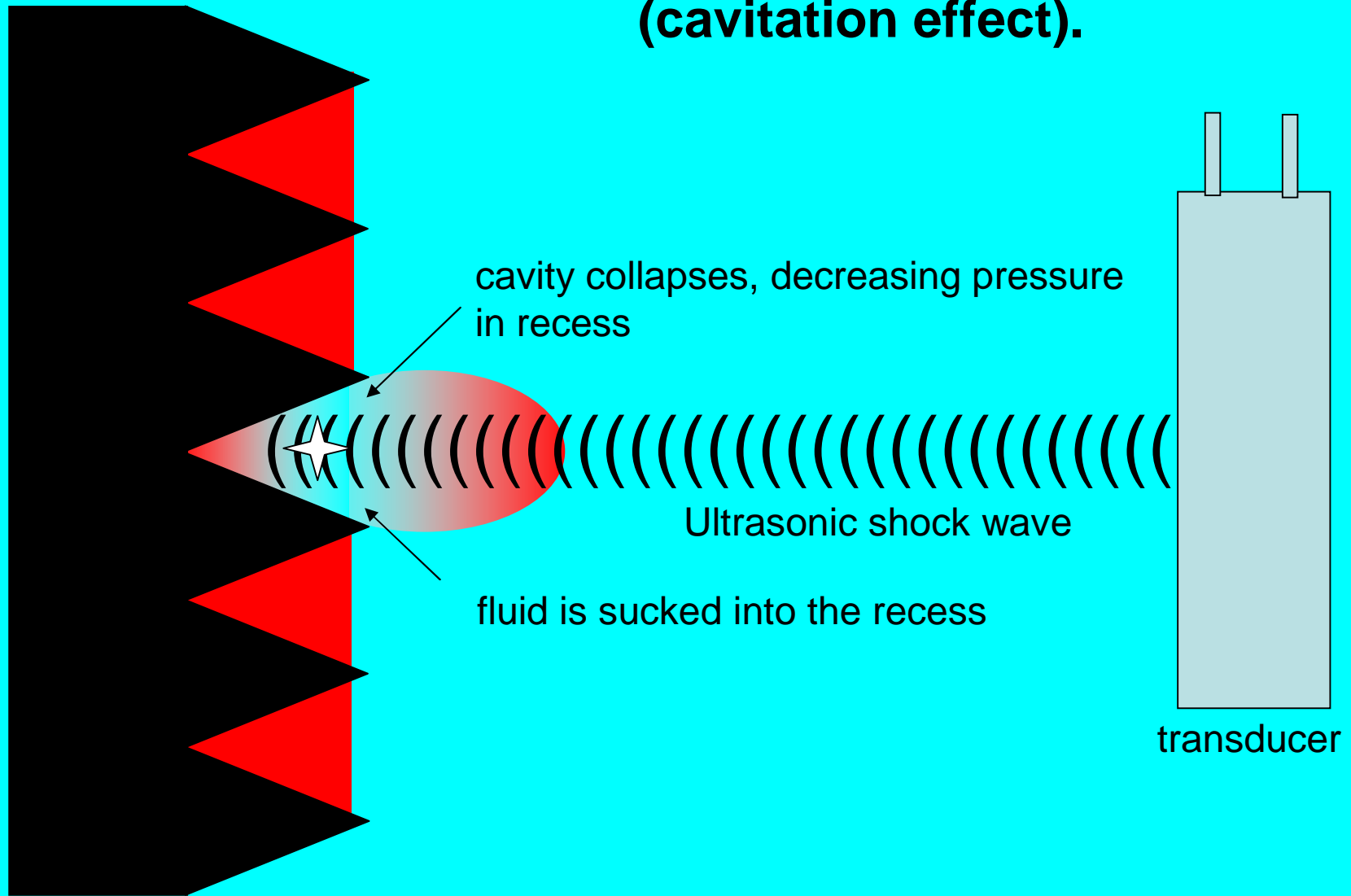
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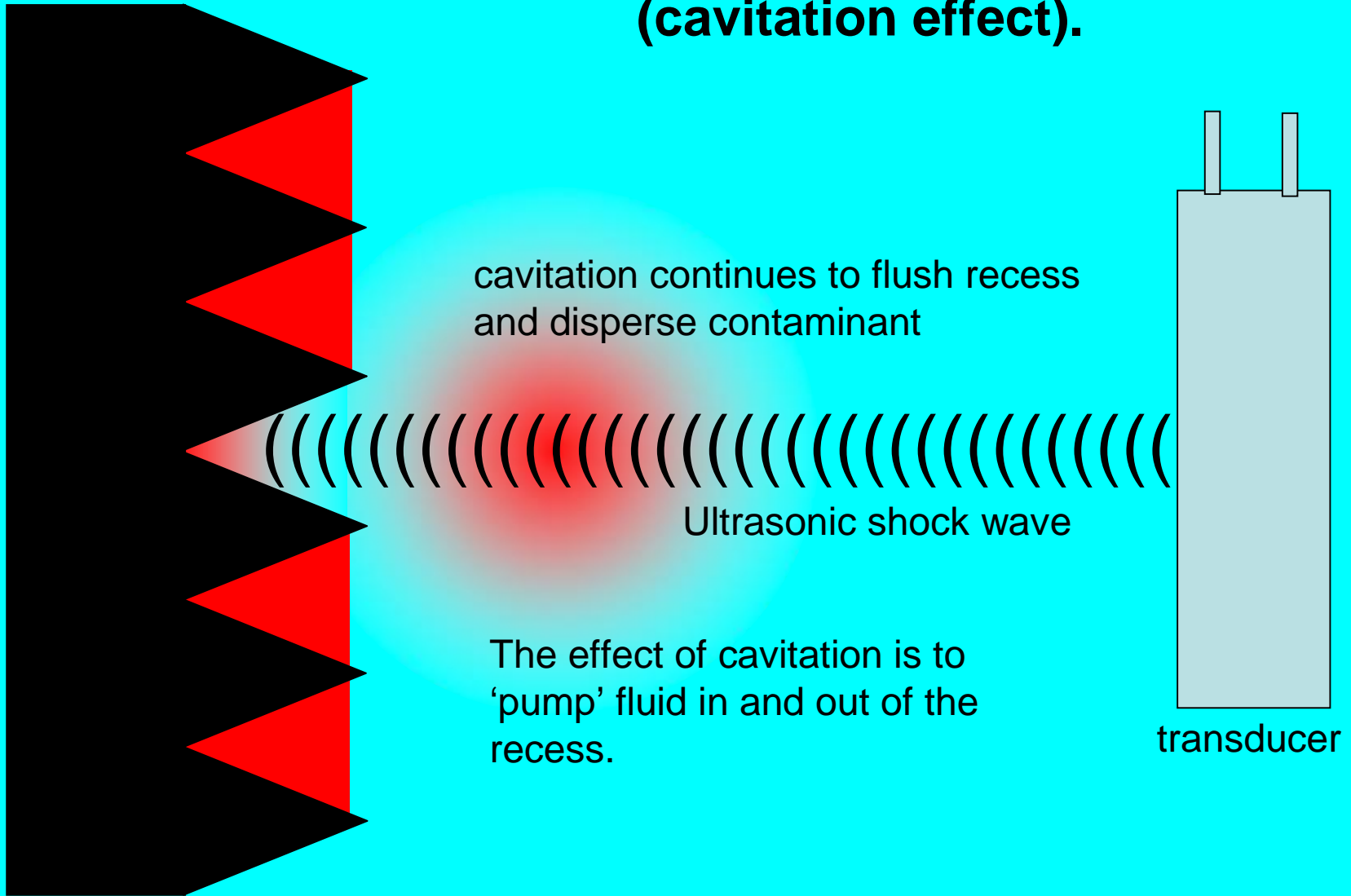
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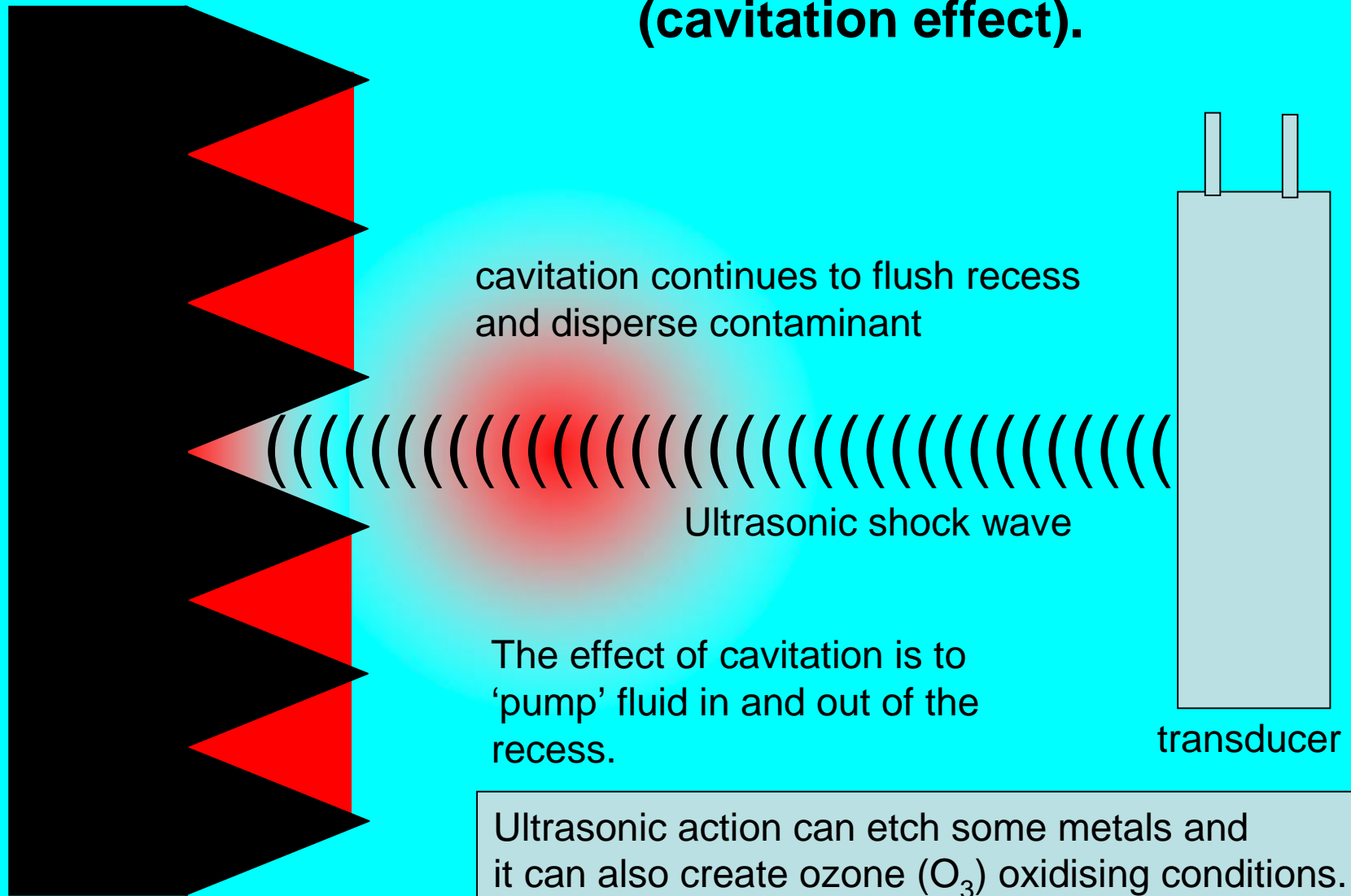
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Conclusions:

- Aqueous rinsing is a kinetic process.
- Its effectiveness is governed by the energetic interactions between the treated surface and the rinse water.
- Rinsing methods should be selected and managed based on an analysis of the physical and chemical properties of the treated surface.

Conclusions:

- The 'perfect' rinsing method is able to deliver sufficient energy to satisfy the surface energy demands of the *real* surface area of the rinsed substrate, without adverse affects.
- Therefore, effective rinsing is a matter of energy management.

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We need to look at rinsing in a different way?