The puzzle of the steady-state rotation of a reverse sprinkler

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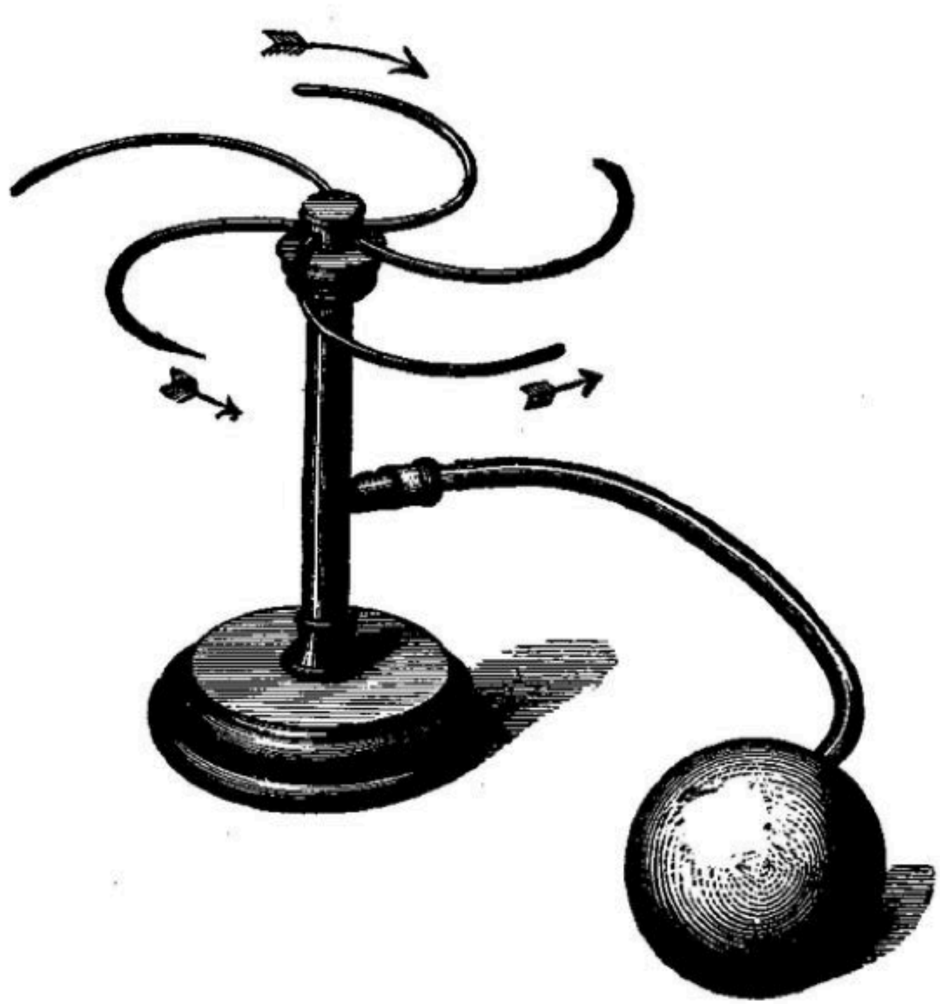
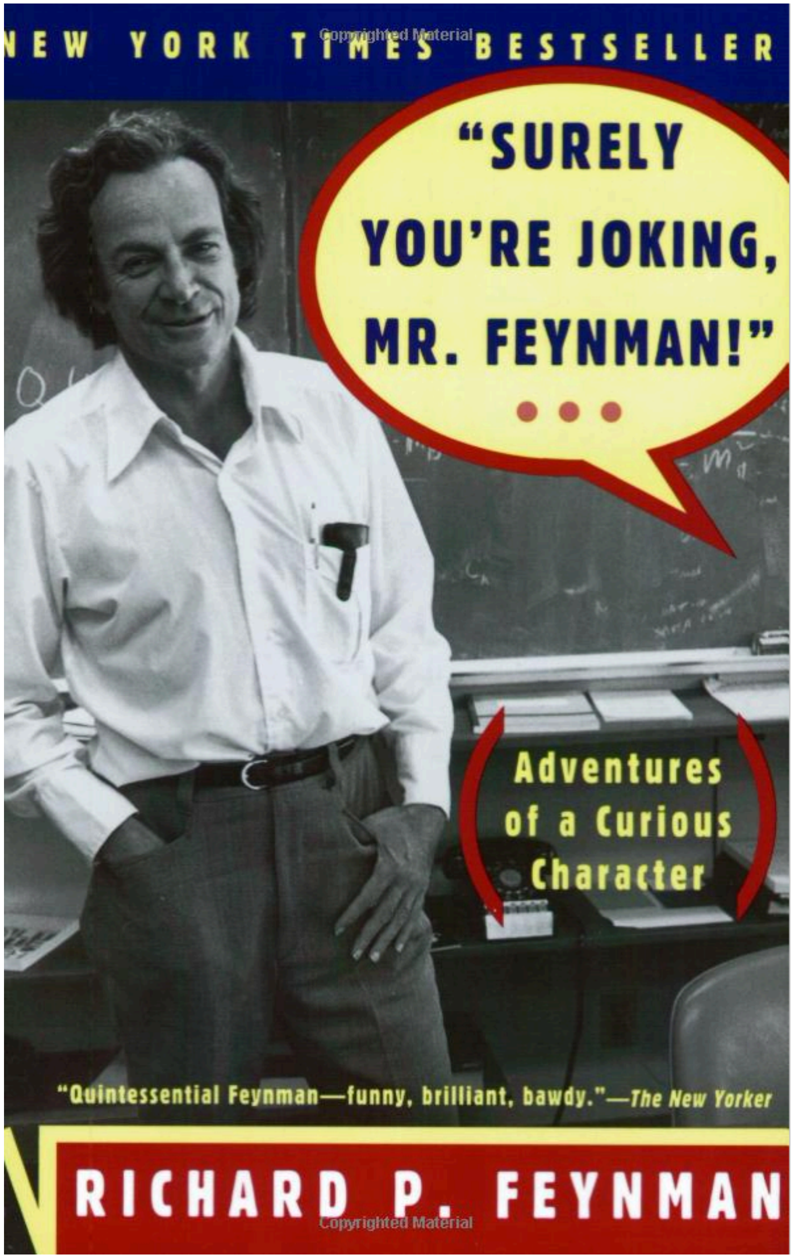
Am. J. Phys. **83**(4), 296-304 (2015)



First documented treatment of the sprinkler problem: Ernst Mach's textbook Die Mechanik in Ihrer Entwicklung Historisch-Kritisch Dargestellt, (1883)

Mach observed "no distinct rotation" in the reverse mode of operation.



R.P. Feynman, Surely You're Joking Mr. Feynman! (Adventures of a Curious Character), (Norton, NY, 1985), pp. 63-65

October 1987

The Inverse Sprinkler: A lesson in the misuse of a conservation principle

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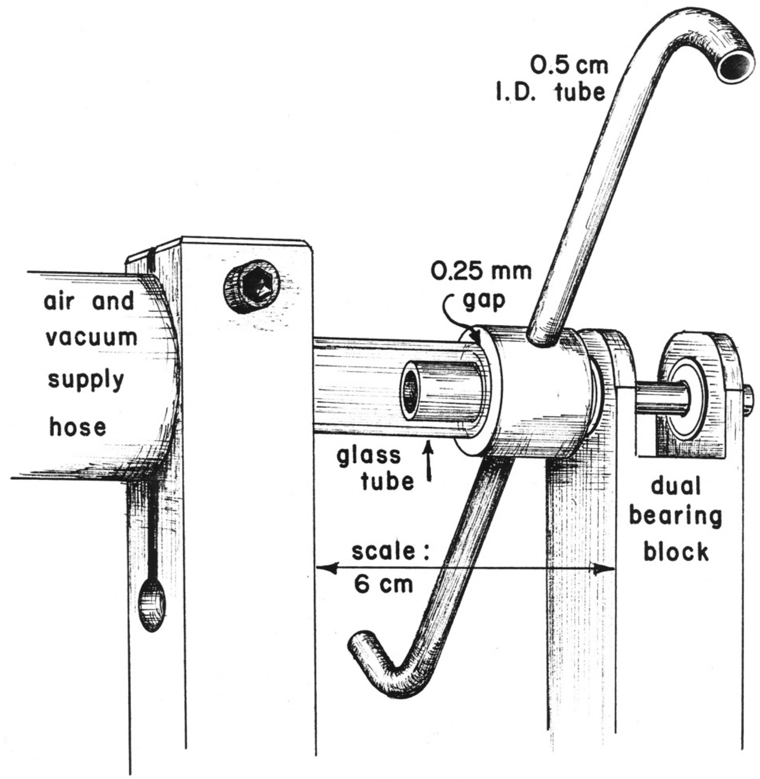
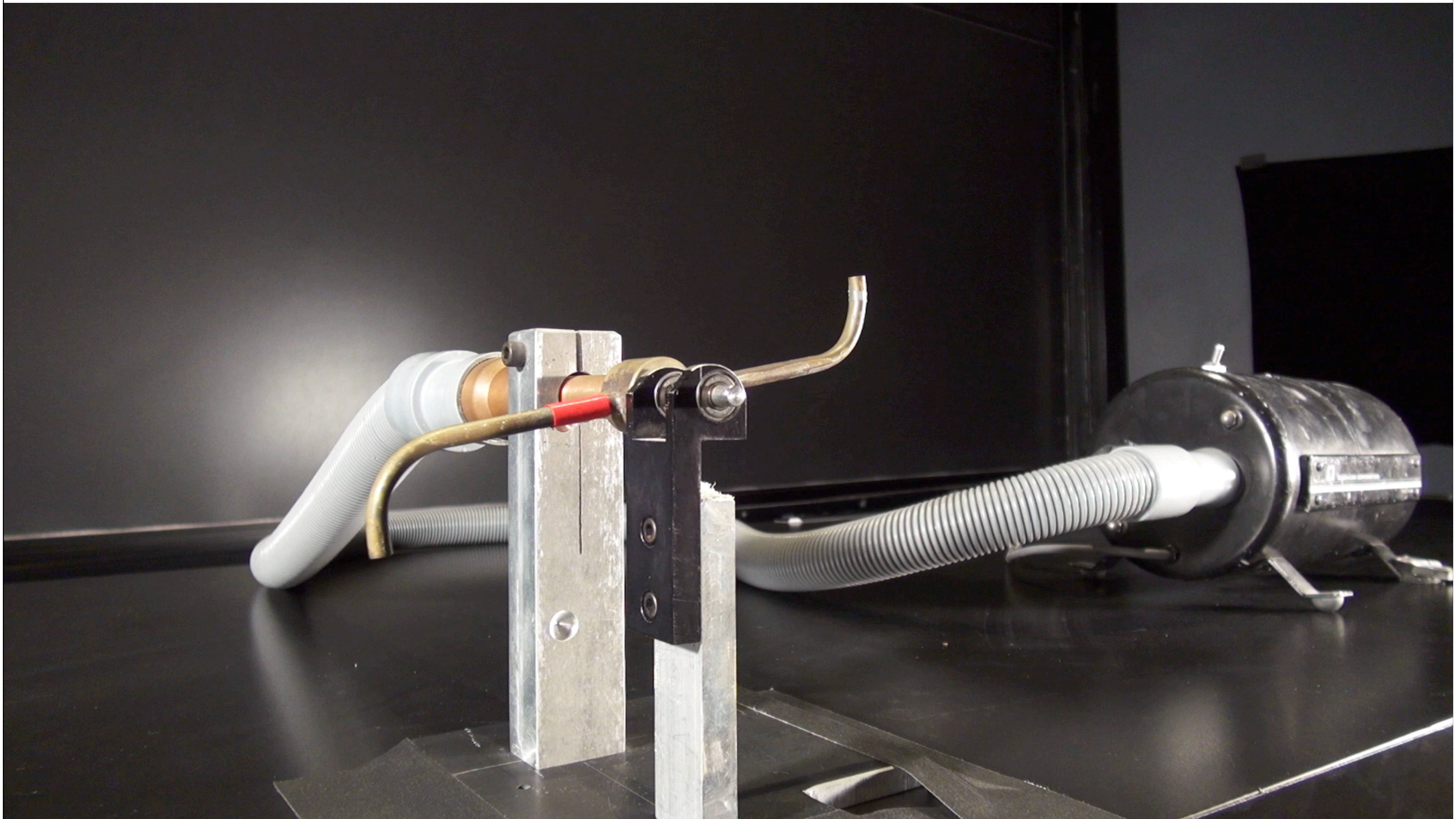


The inverse sprinkler has generated considerable interest recently. Several articles have appeared predicting different results for the direction of rotation. We have constructed such a sprinkler and find that the operation of the sprinkler is easily predicted when all the important forces are considered.



As I have said, probably to both of you, I find the inverse sprinkler problem one of the more frustrating ones that I have to deal with. This is partly the result of my own inadequate education. There are several areas in physics where I have neither a good intuitive sense of what is going on nor a command of the formalism. Fluid dynamics is one such area and general relativity is another. I would hope that publication of the Berg paper and the one that will, I hope, emerge from this one may back me up in declining further contributions on the subject for a while.

Perhaps you should all be warned that there does seem to be something strange about the Feynman inverse sprinkler problem. It seems that several of the people who have written on this subject have rather abruptly died. Some of the reviewers to whom we send manuscripts on this subject also seem to meet with sudden and mysterious deaths. At any rate, we seem to have several requests for reviews that have come back with the notation that the addressee is no longer living. Perhaps if I could write a form letter describing these various mysterious events, it would be a useful one for me to have in turning off future contributions on the subject. What you do now is your affair, though--talk of mysterious curses aside--I really am pleased that in this case we may have open non-anonymous collaboration between author and referee of a type that may result in a more valuable contribution to the Journal than we could otherwise expect.

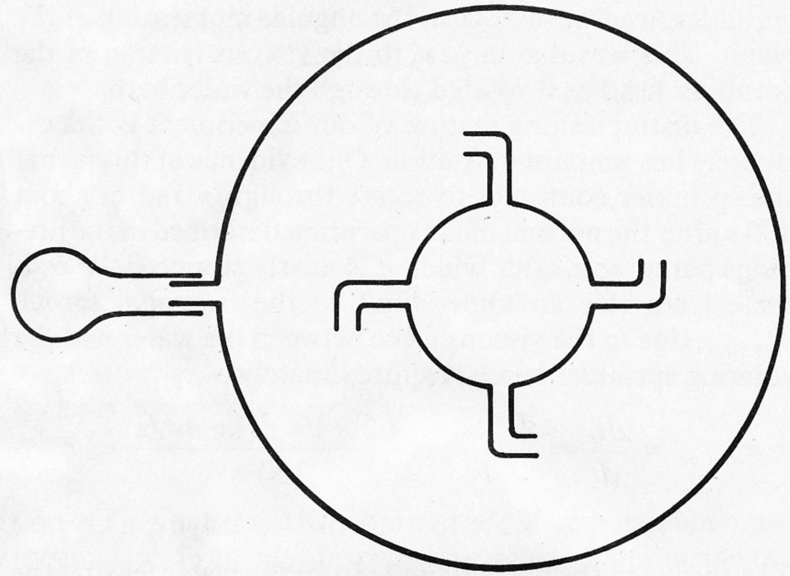
Thank you both in advance for your collaboration and cooperation. I am not at this time sending Berg's manuscript to you, but I trust that the two of you will begin corresponding.

Sincerely yours,

Robert H. Romer

Robert H. Romer

February 14, 1989



R.E. Berg and M.R. Collier, "The Feynman inverse sprinkler problem: A demonstration and quantitative analysis," Am. J. Phys. **57**(7), 654-657 (1989)

M.R. Collier, R.E. Berg, and R.A. Ferrell, "The Feynman inverse sprinkler problem: A detailed kinematic study," Am. J. Phys. **59**(4), 349-355 (1991)

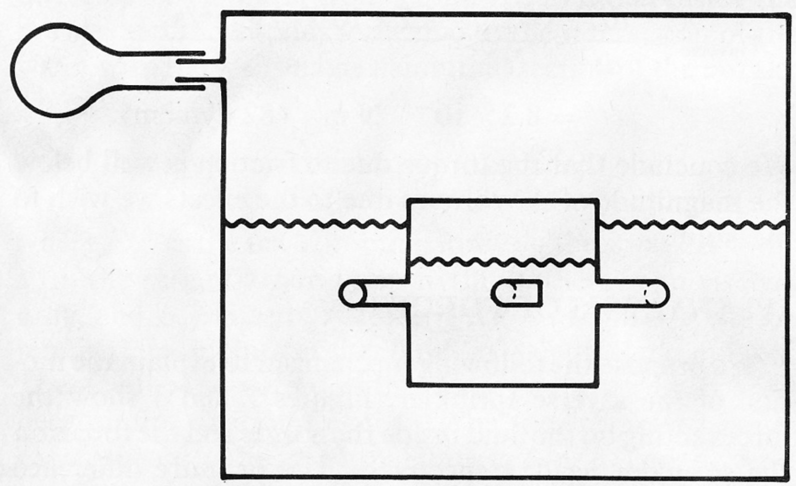
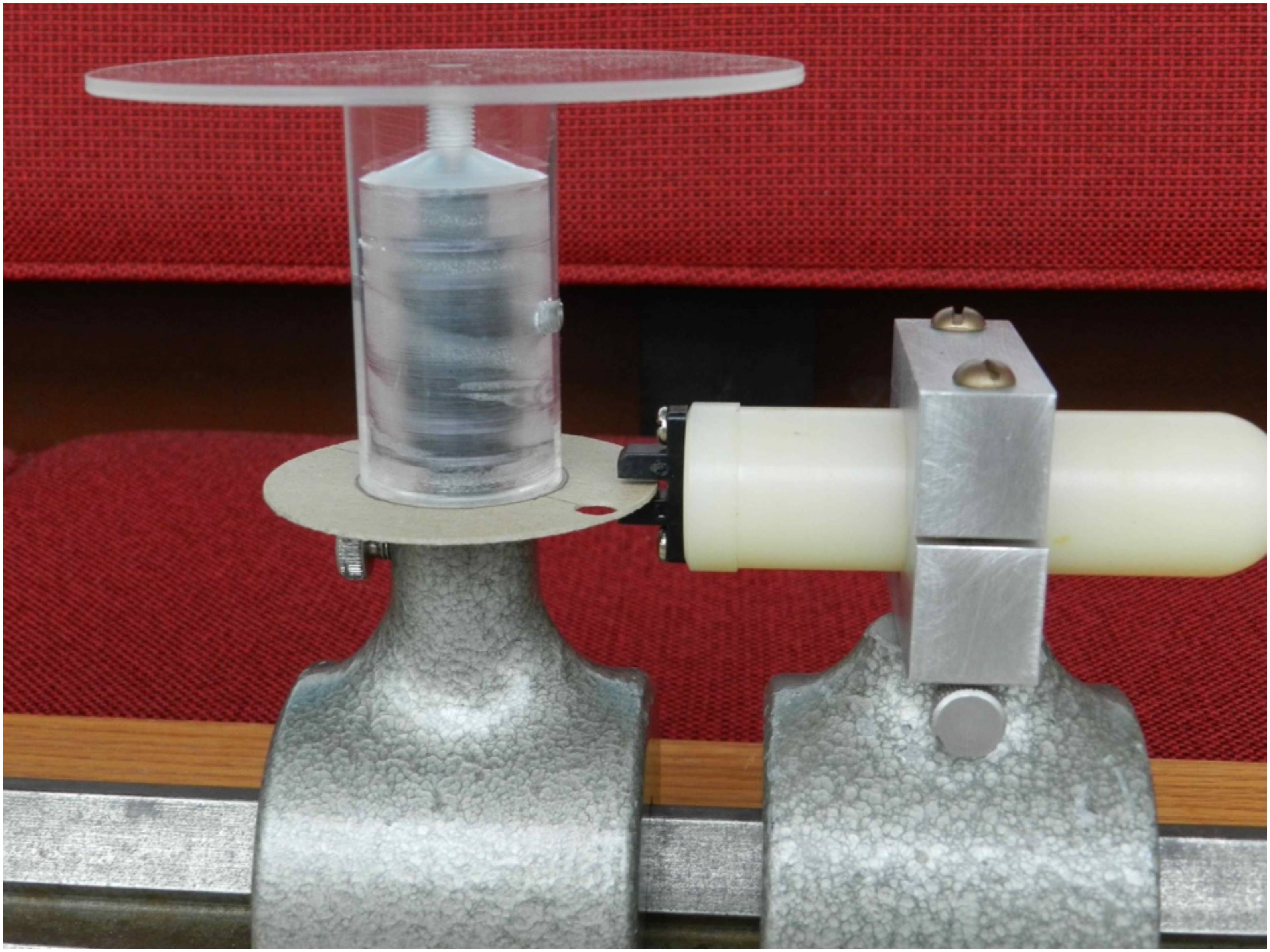


Fig. 1. Top view (above) and side view (below) of the University of Maryland inverse sprinkler model.

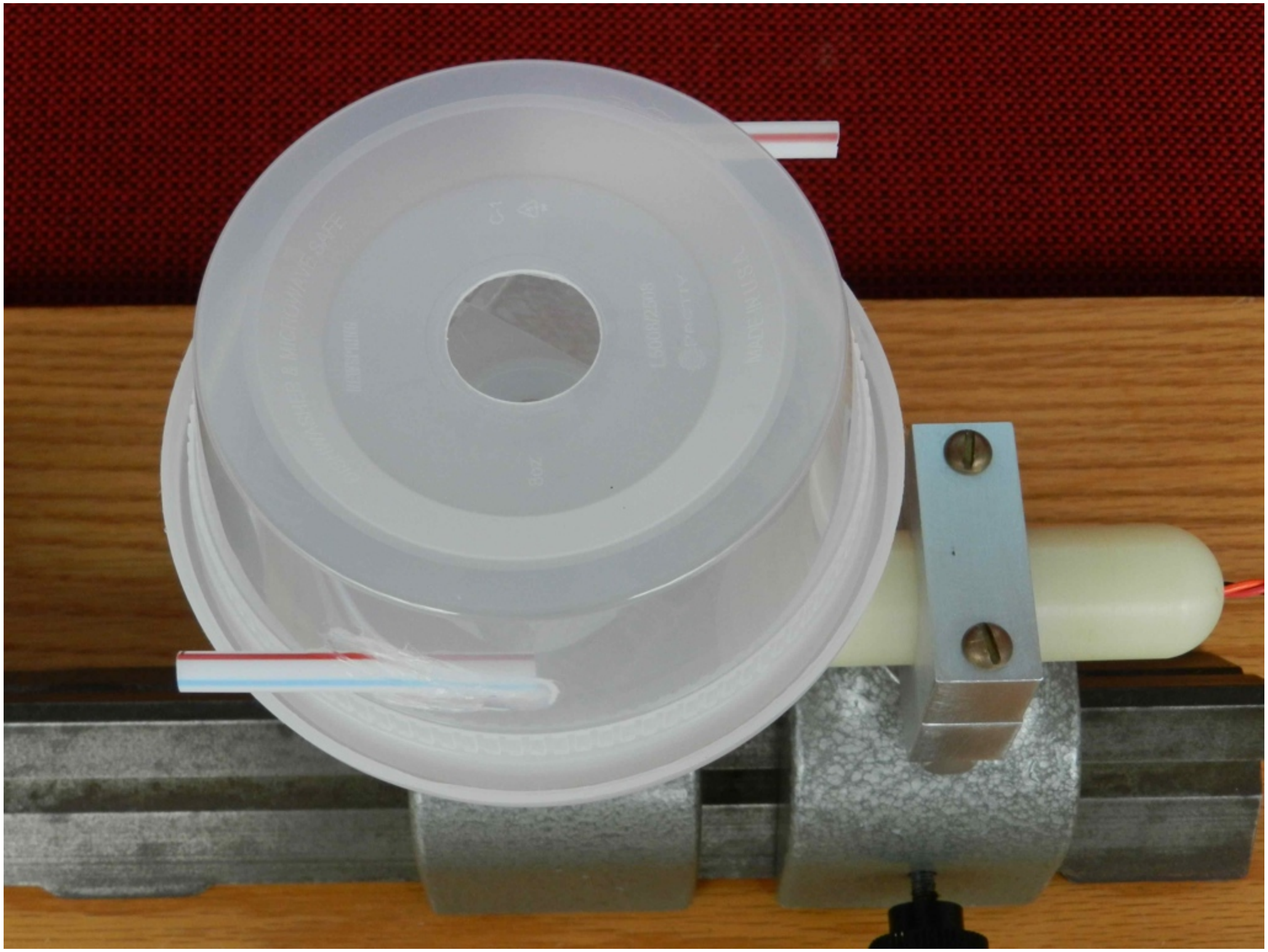
The “Dissipative Effects” Puzzle

Essential to the new design was the ability to easily change sprinkler parameters to determine which ones affect the rotation and to what extent

- length of the tangential section of the intake nozzle
- radius of the bend in the nozzle
- manner in which the fluid leaves the sprinkler

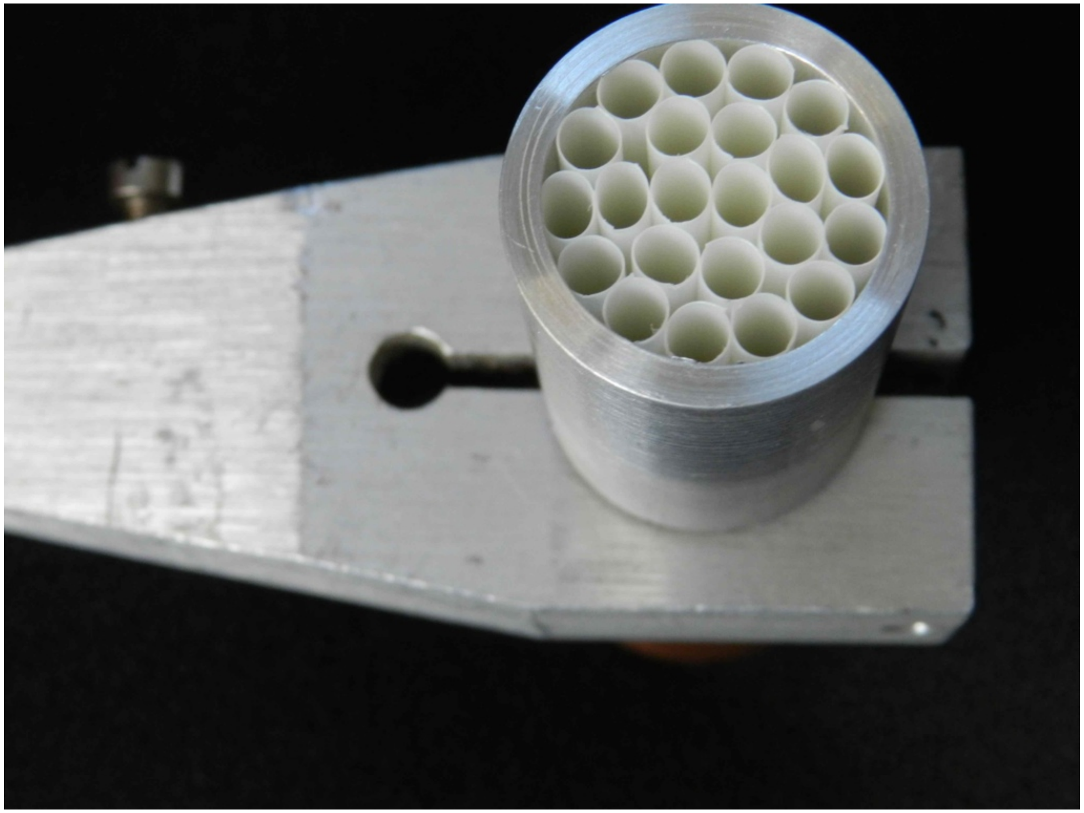


Acrylic turntable for holding sprinkler assemblies, mounted on optics rail.
An IR photo-gate monitors the rotation frequency.

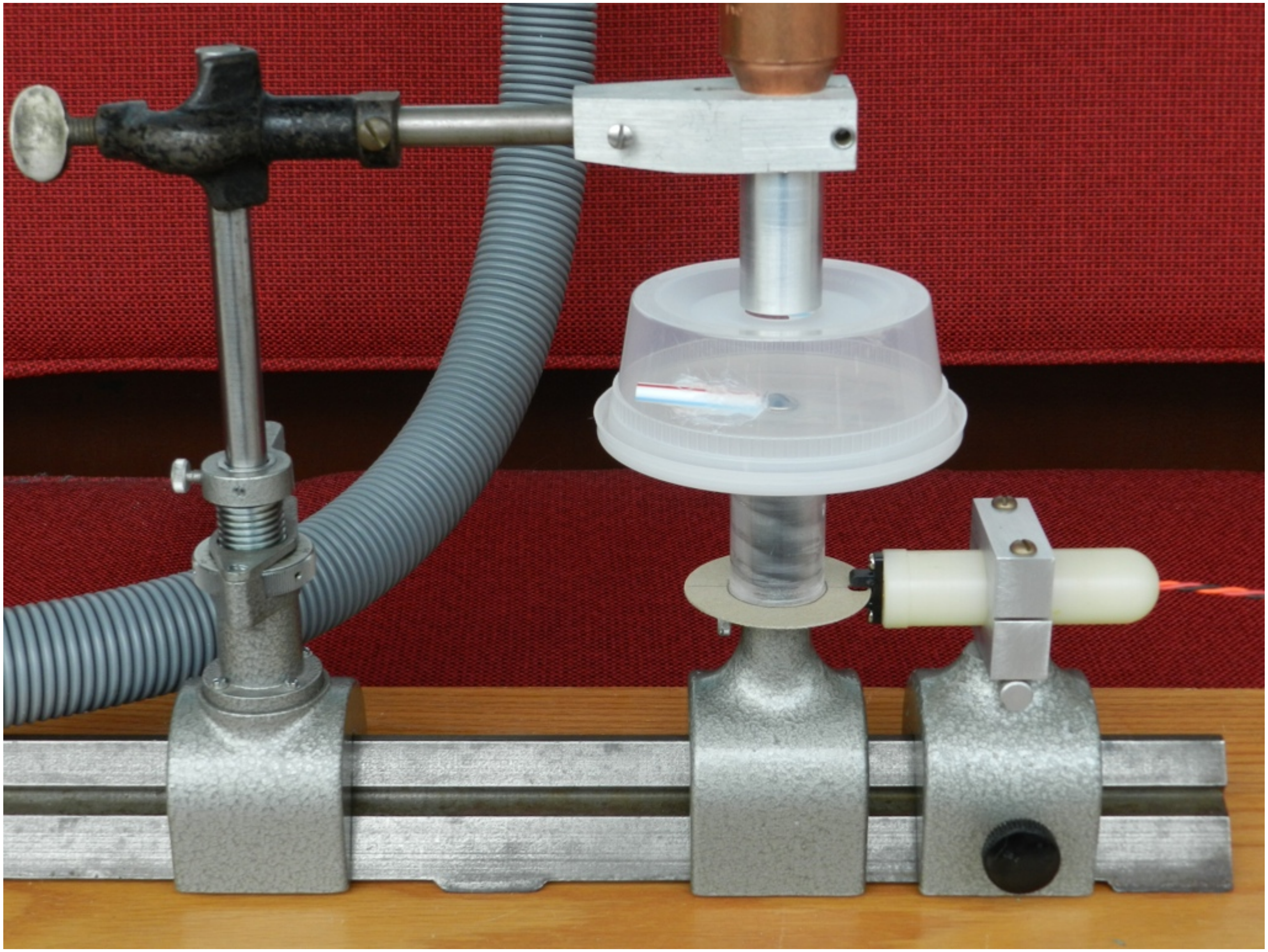


Deli container sprinkler mounted on turntable ...
the hole is for the evacuation hose adaptor.

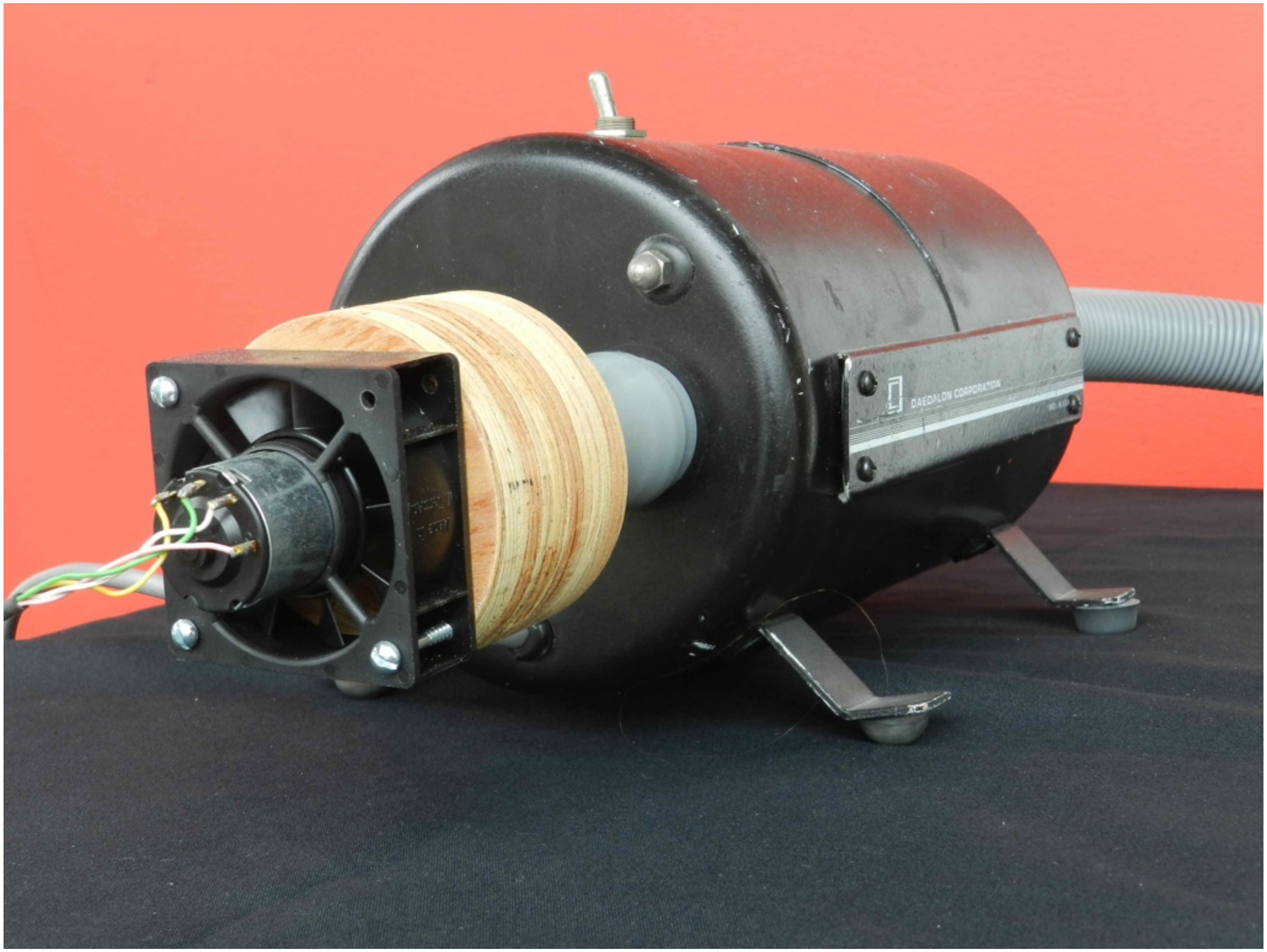
Exhaust hose coupler can be adjusted to be as close as possible to the sprinkler assembly without actually touching it.



Exhaust hose coupler packed with small straws to minimize rotation of air as it is removed from the sprinkler assembly



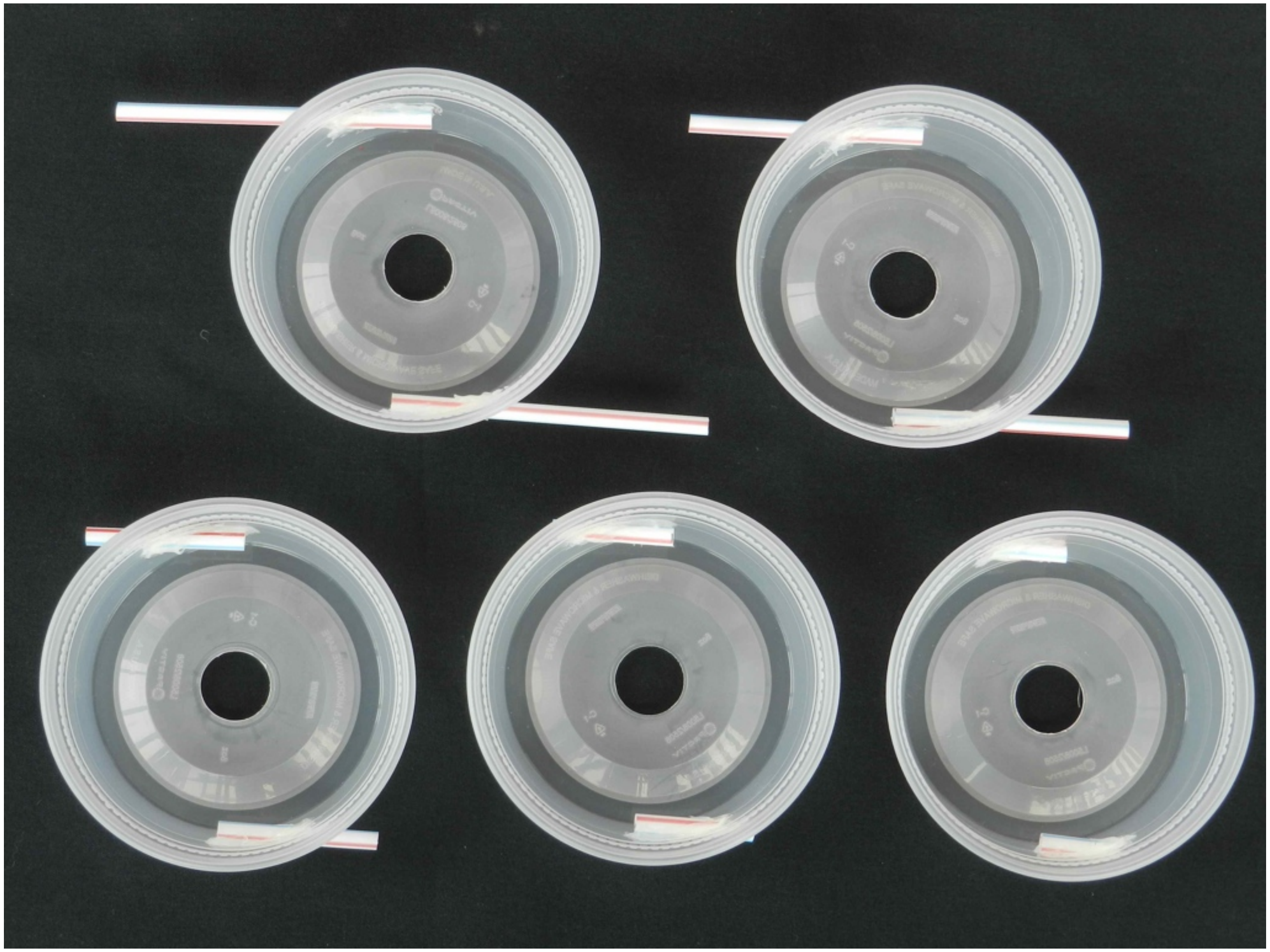
The entire set-up with deli container sprinkler in place.



Air flow monitor mounted on the Air Source output port ...
the muffin fan acts like an electric generator with an
output voltage of 19 VAC at maximum air flow.

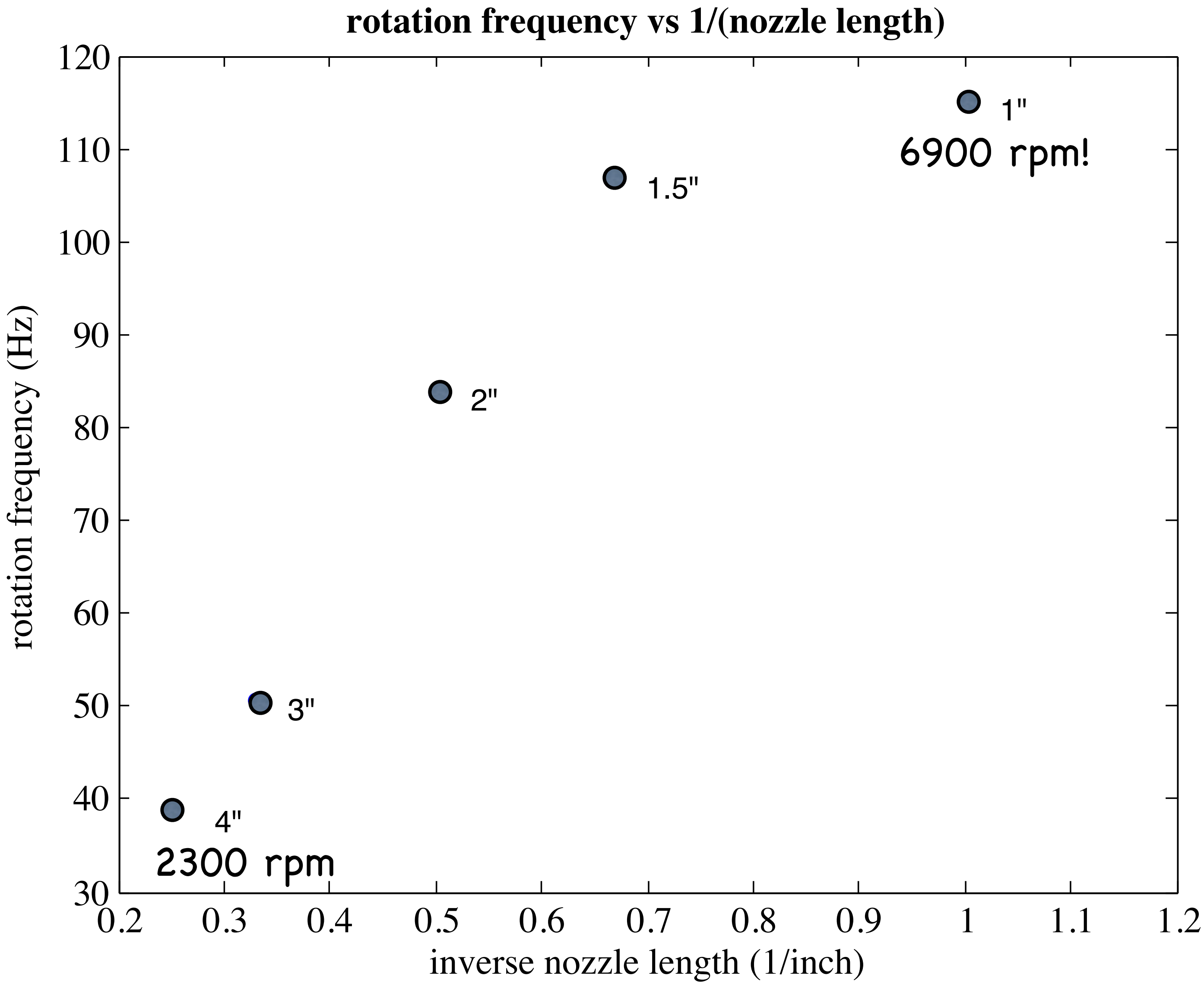
How does the length of the tangential section of the intake nozzle affect the rate of rotation?

Does the prolonged acceleration of the incoming air inside longer intake nozzles affect the rate of rotation?



Five sprinkler assemblies with nozzle straws ranging from 1 to 4 inches in length.

Air enters tangentially to the containers' walls to minimize the torque on the sprinkler.



Inverse relationship between rotation frequency and nozzle length. Shorter nozzles increase rotation up to a point.

C. Mungan, "Inverse lawn sprinkler," Phys. Teacher **43**, L1-L2 (2005)

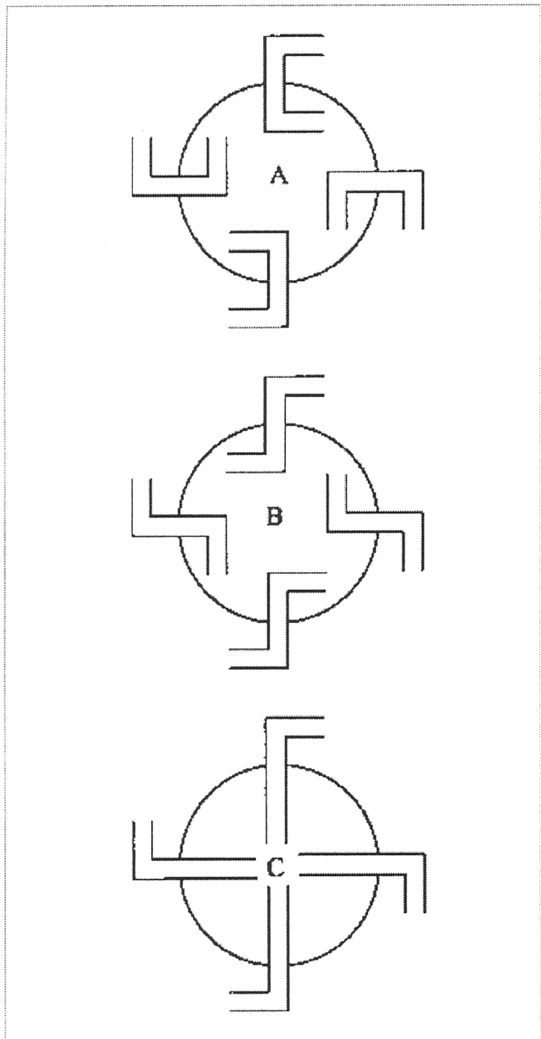
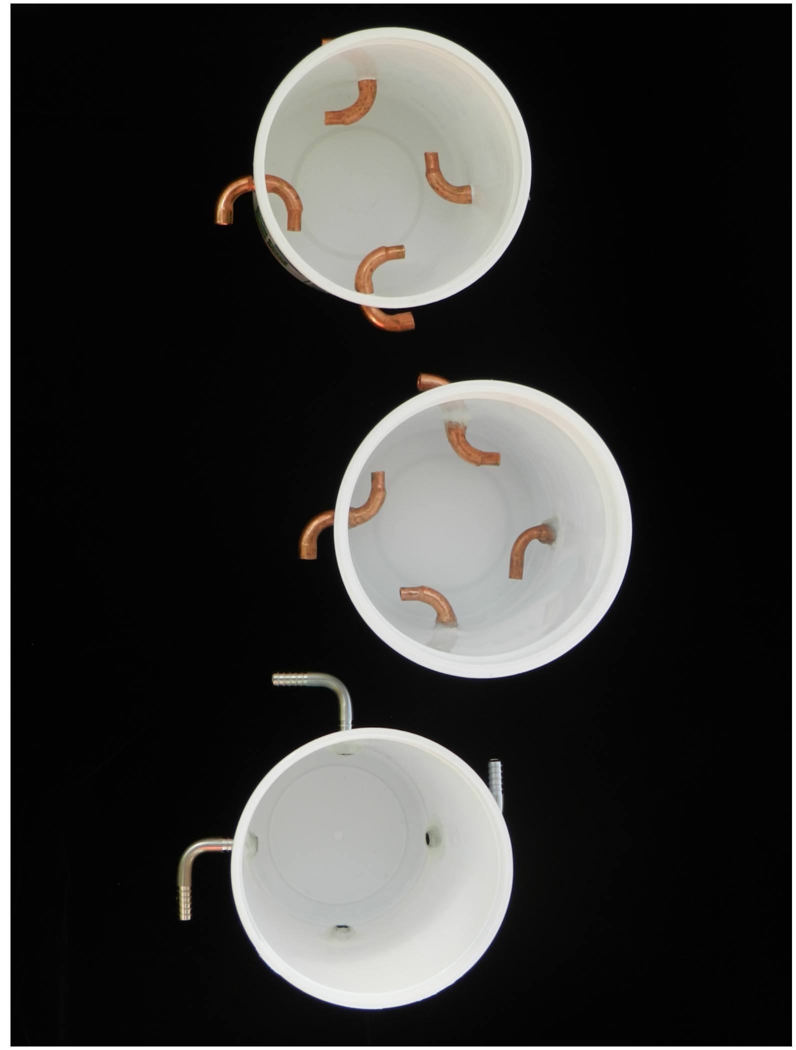
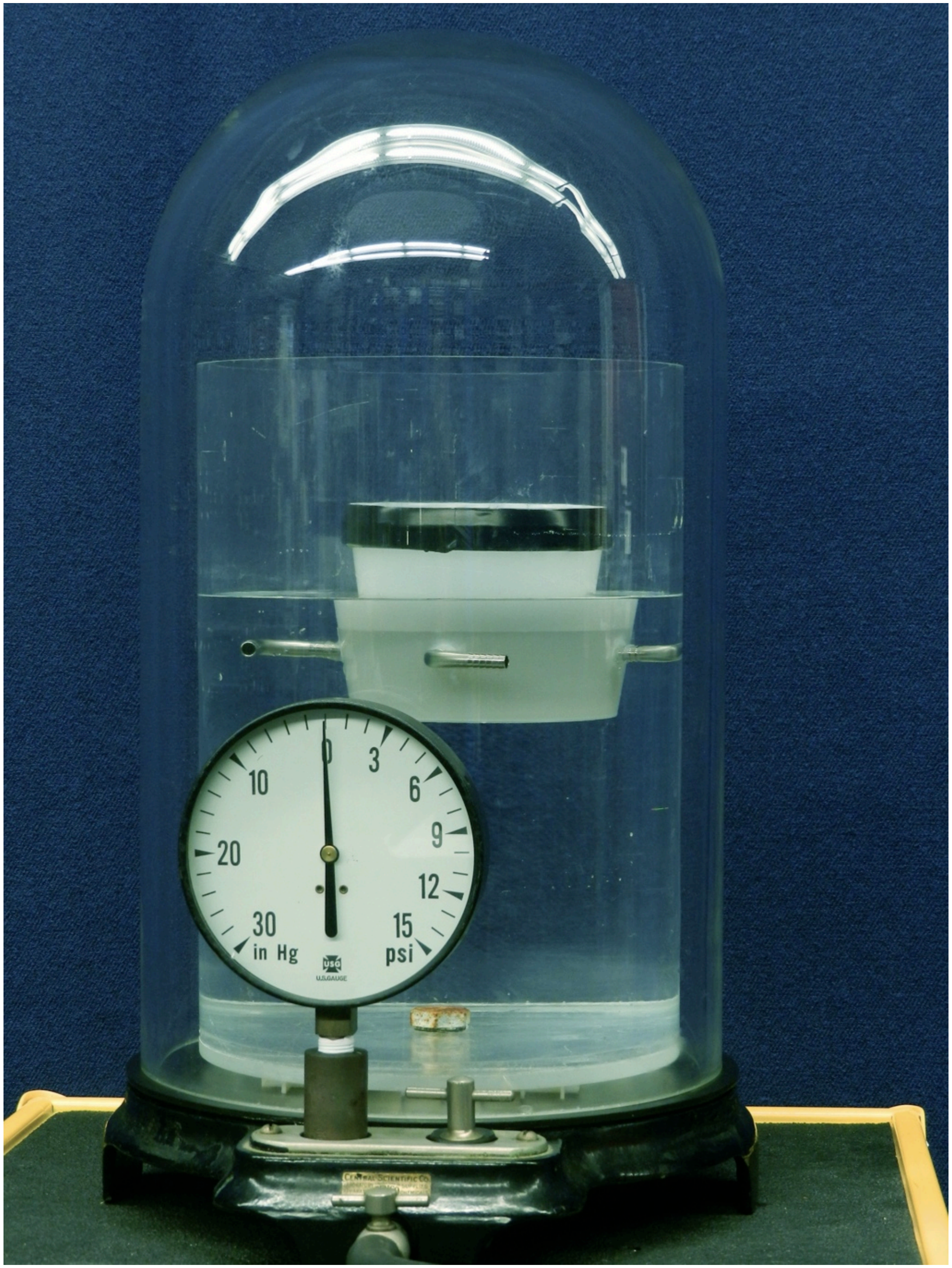


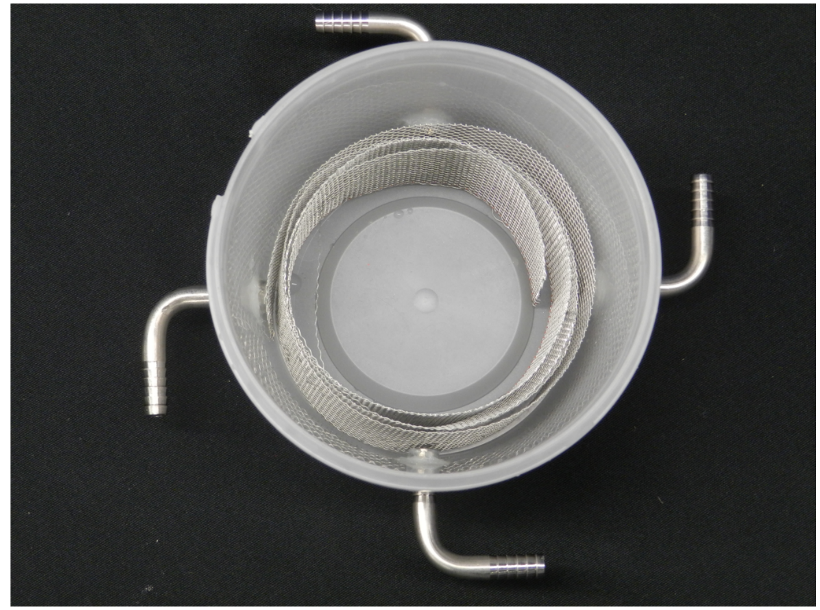
Fig. 2. Three geometries of the straws as seen from above. For simplicity, only four straws are shown.



A realization of Mungan's concept question

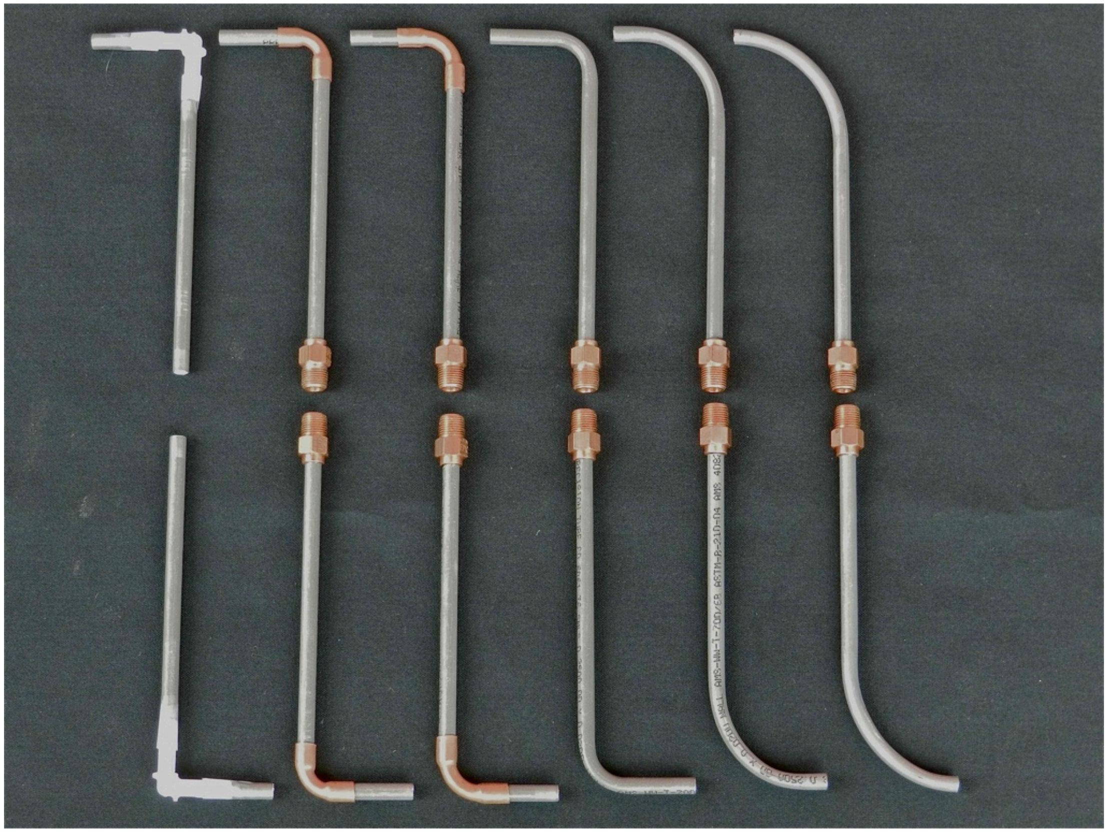


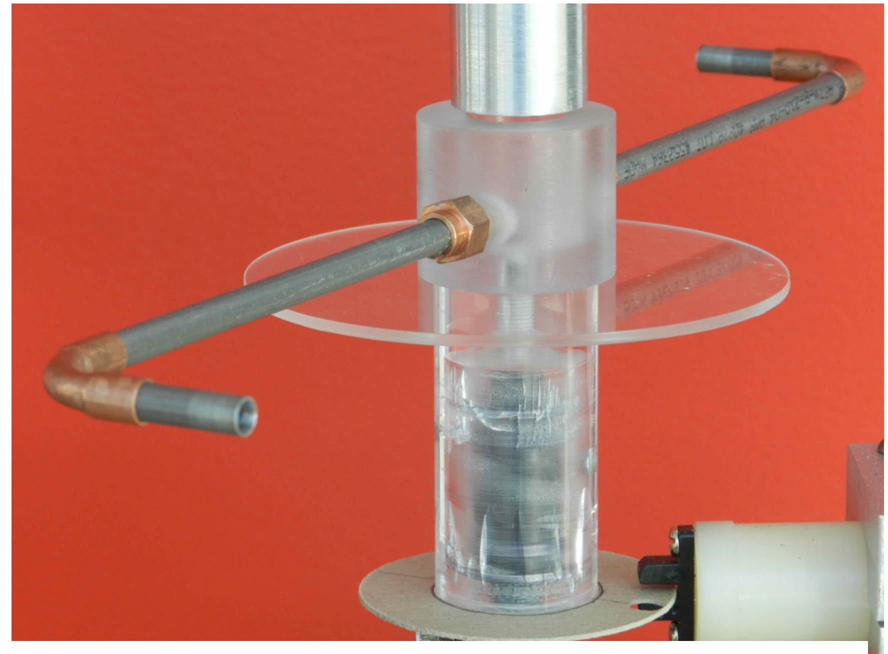
Aluminum window screening inside hub of water sprinkler



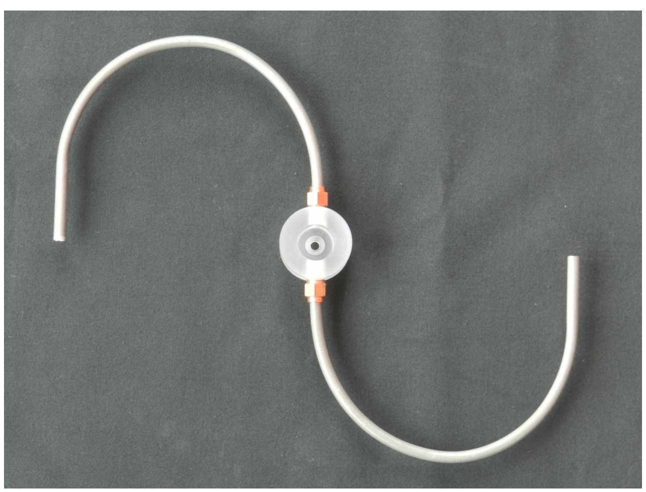
Replication of the UMD sprinkler experiment

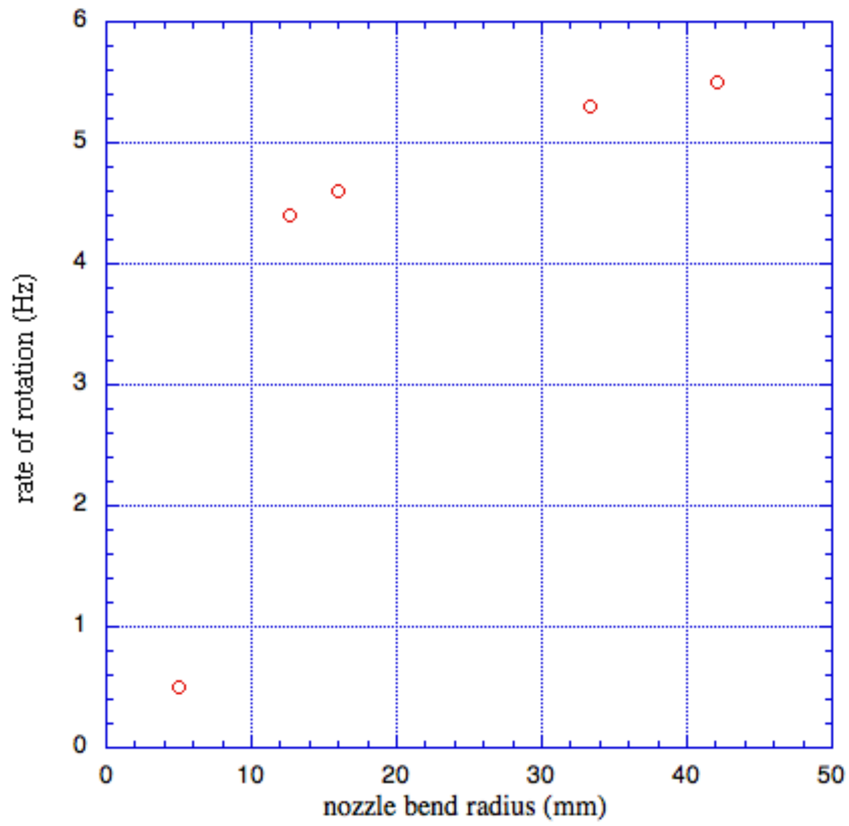
How does the radius of the bend of the intake nozzle affect the rate of rotation?





Six L-shaped and an S-shaped sprinkler arm



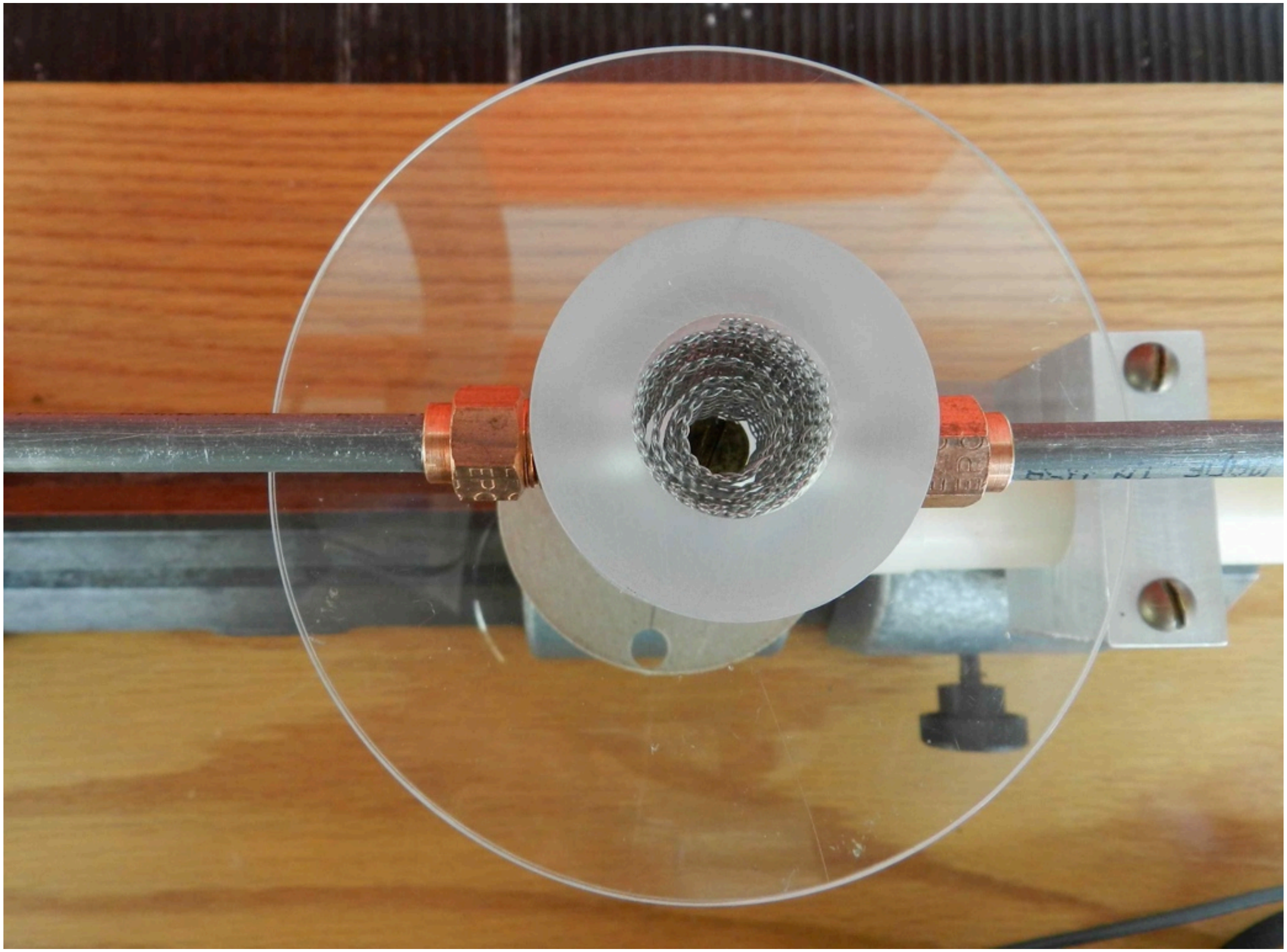


A fortuitous discovery

rotation rate = 5.8 Hz

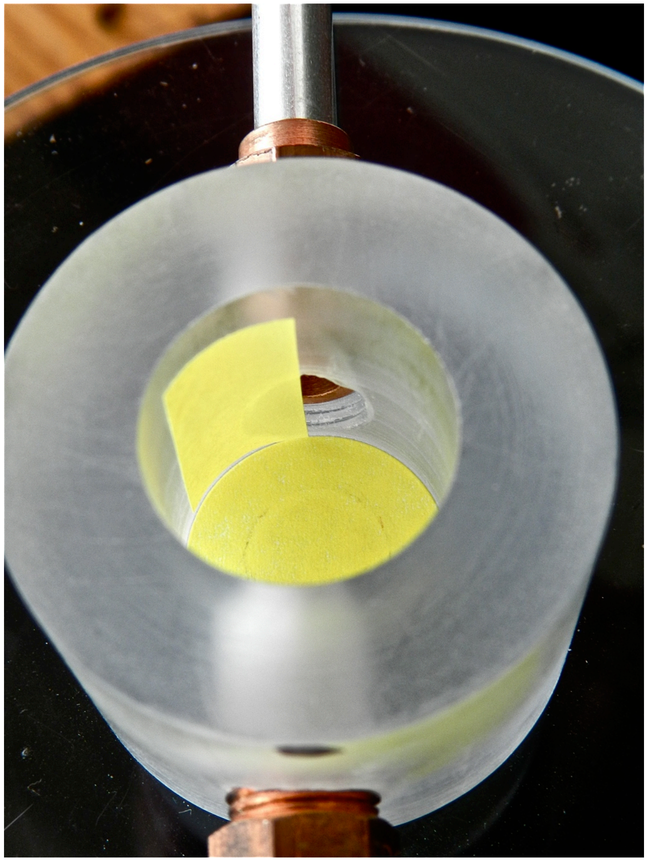
= 52 Hz w/o tube

= 136 Hz (8160 rpm!) w/o copper NPT fitting

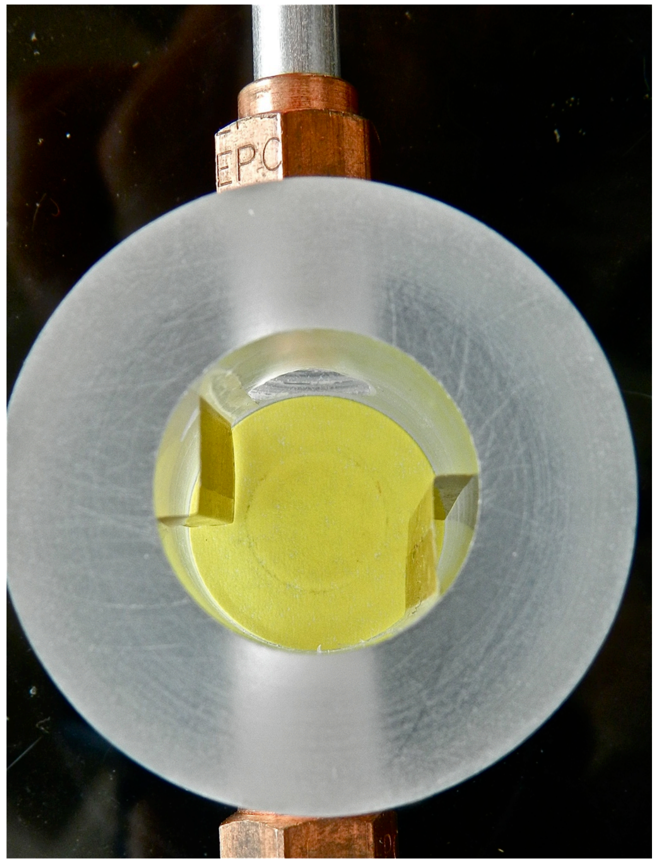


Strip of aluminum window screening inside hub
to suppress any vortex formation

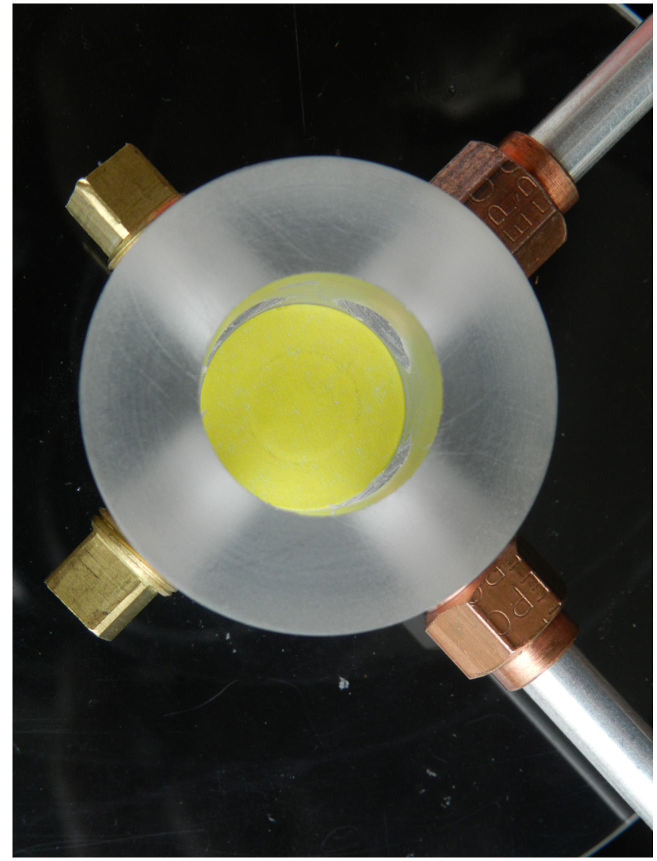
Sprinkler hub alterations



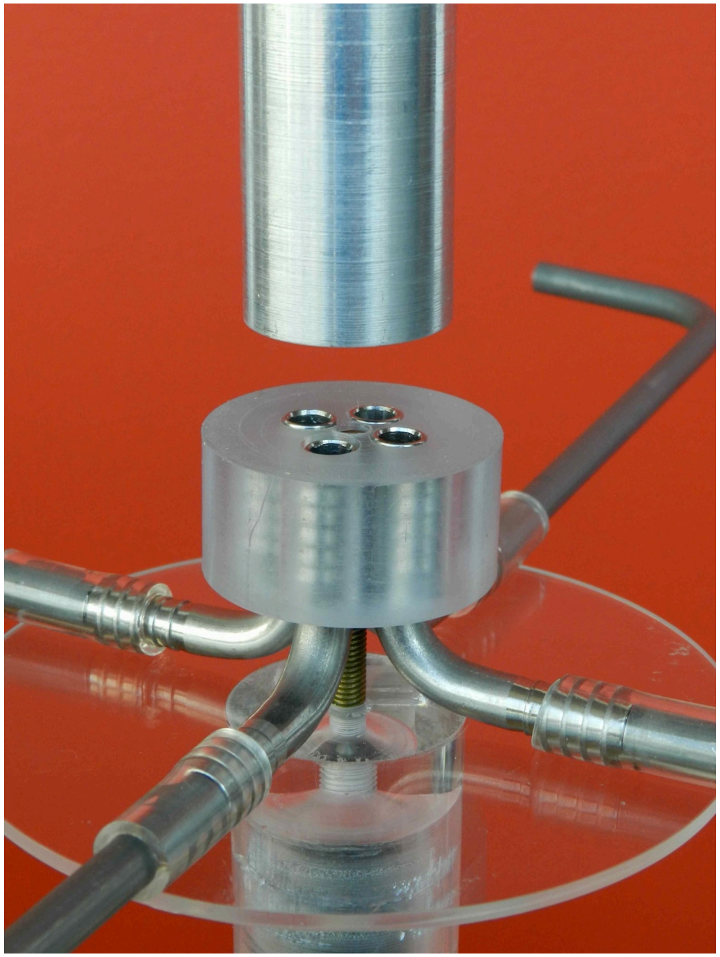
(a) partially blocking intake holes with tape

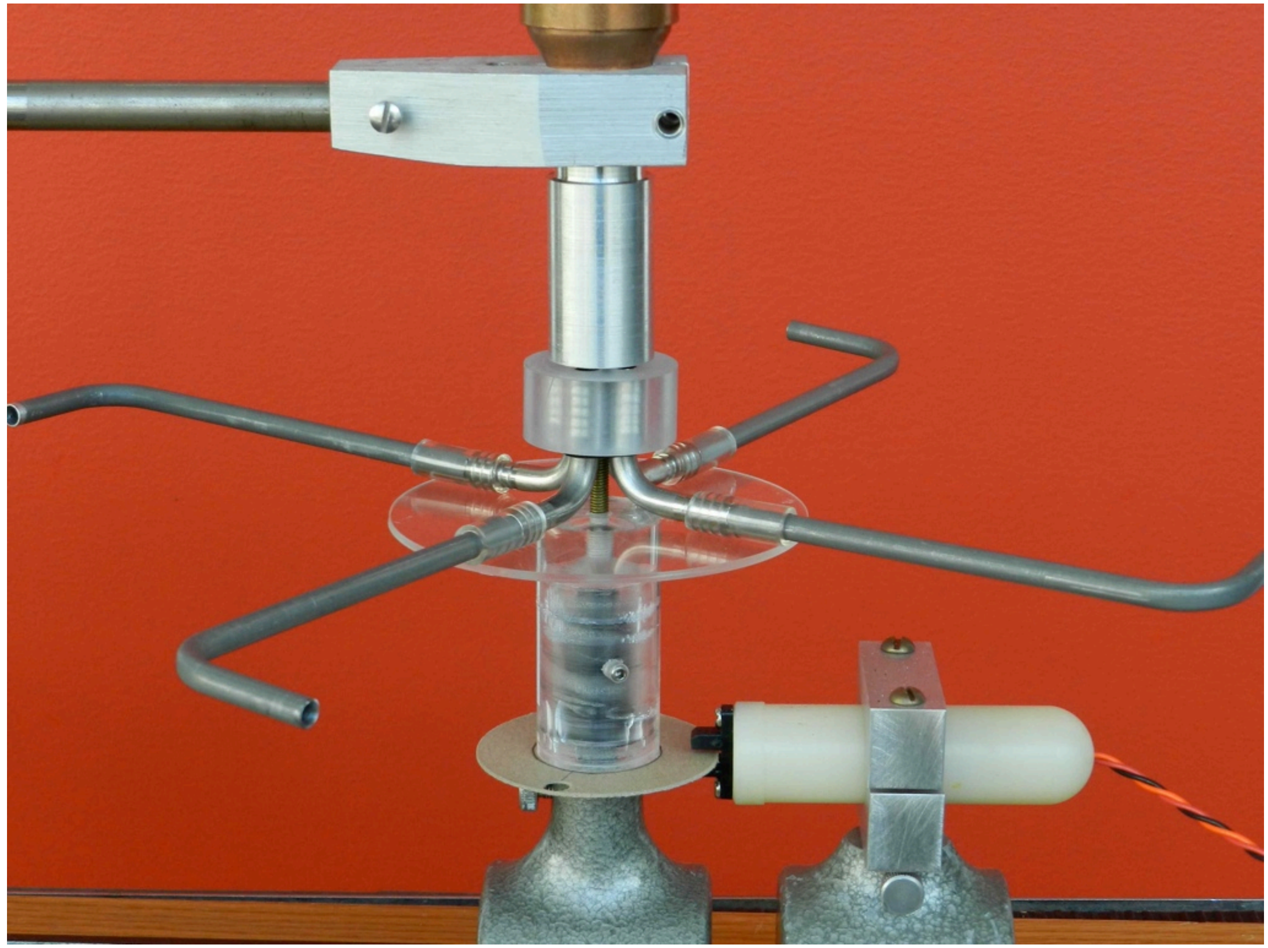


(b) wedge-shape on wall



(c) additional intake holes to accommodate various arm configurations





Four-arm L-shaped sprinkler with hub
designed to eliminate interaction of air jets

A force couple produces a rotation

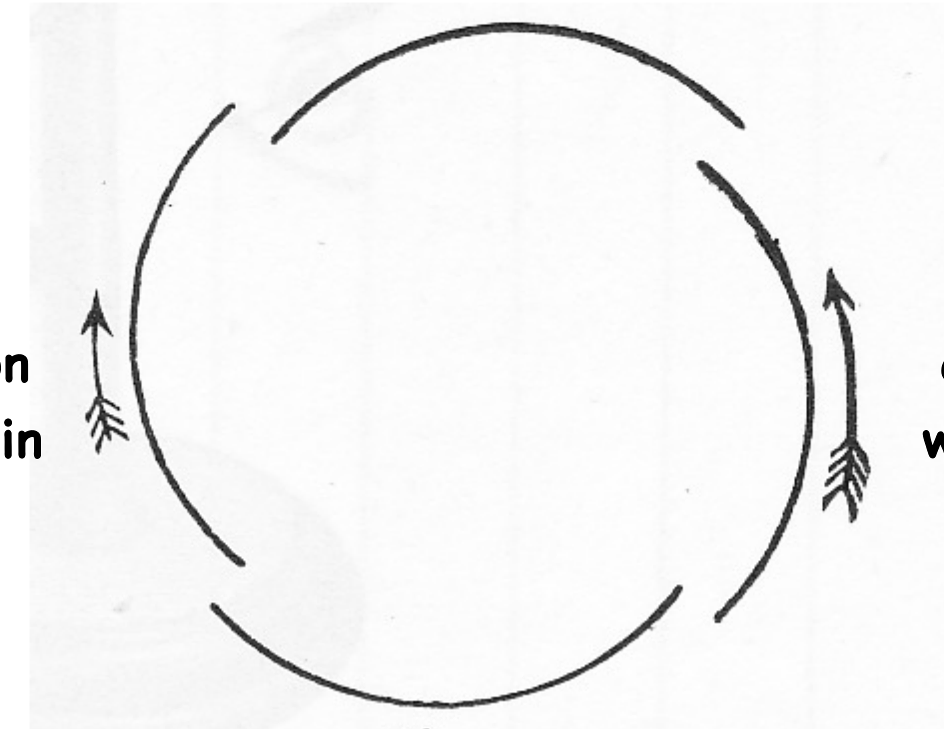


Fig. 154.

Ernst Mach's cylinder experiment (The Science of Mechanics, 1883)

"The air, on entering the cylinder is accordingly compensated for by rotation in the opposite direction."