HYDROGEN BOND ENERGY IN TORNADOES

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In a letter to the editor in *IE* #83[1] Barney Barnes proposes that the rupture of hydrogen bonds in water and the liberation of the bond energy might be at work in providing driving energy for tornadoes. What guided Barnes' thinking is the case made, in recent *IE* issues (70, 74, 79), for the driving of hurricanes by hydrogen bond energy of the ocean. Both hurricanes and tornadoes are cyclonic storms involving dense clouds of water fog. The cloud droplets which are small enough to float in air represent a considerable amount of liquid water which could possibly feed kinetic energy to tornadoes. In hurricanes the bond energy is provided by liquid water from the ocean.

When a hurricane sweeps over the ocean, drag forces on the water surface shear great quantities of small water droplets off the sea and spray them into the atmosphere. The shearing action ruptures hydrogen bonds between water molecules and liberates the chemical (potential) energy previously stored in the bonds. Experiments with water arcs[2] have revealed that in the tensile rupture of a hydrogen bond between water molecules, the positively charged nuclei in the bond repel each other electrostatically and thereby accelerate the wind responsible for bond breaking in the first place. This explains not only what drives the hurricane, but also what makes the storm self-intensifying.

Water sliding over the surface of blades in hydroelectric turbines should also produce tensile ruptures of hydrogen bonds. Not the hurricane itself, but the hurricane mechanism could possibly be exploited for electricity generation with water turbines. The high efficiency of hydroelectric turbines has already been attributed to hydrogen bond energy.[3] In other words, the search for new clean energy is likely to benefit from the study of hurricanes. Barney Barnes now suggests that the investigation of the driving force of tornadoes will uncover other ways of utilizing the internal energy of water for electricity generation.

A hurricane would last forever as long as it does not leave the warm ocean water of the sub-tropics or make an extended landfall. In both of these two sets of circumstances the storm runs out of hydrogen bond energy from the ocean water. This is obvious when the storm drifts ashore and over land. The hydrogen bond theory provides an explanation of the fact that colder water should restrain the self-intensification of hurricanes. A paper produced by the Naval Environmental Prediction Research Facility[4] clearly demonstrates that in order to retain consistency in the thermodynamics of water condensation and evaporation, energy must be stored in liquid water. They describe a parameter L', which they call the latent enthalpy which is approximately 30% larger than L, the latent heat of condensation. The difference between L' and L can be equated to the difference between the specific heats of water vapor and liquid water multiplied by the temperature and "is a necessary absorption by the liquid water to bring the post-condensation air-vapor-liquid system into thermal equilibrium." Inspection of the specific heats of water vapor and liquid reveal that the stored energy is very close to a linear function of temperature. Consequently, colder water stores less energy than the warm variety and thereby confines hurricanes to the hot climate.

The strength of the inter-molecular bond weakens as the temperature of the water increases because thermal vibrations strain the chemical bonds. Water heating can ultimately sever hydrogen bonds and allow the nuclear repulsion, which opposes the chemical attraction, to sever the bonds and drive the previously coupled atoms apart. This is thermal evaporation. Conversely, when water cools down, the bonding force holds the bond more firmly together. This is why a hurricane drifting north over cooler water decreases in strength and ultimately disappears. It also explains why hurricanes do not form over cool ocean water.

Although some tornadoes have lasted for hours, the great majority of them had a much shorter life, of the order of ten to twenty minutes. This should be a clue to the source of energy which is vital to the existence of tornadoes. If the duration of tornadoes is determined by the availability of hydrogen bond energy, they must consume liquid water. Over dry land, the only significant water reservoir connected to the tornado is a thunder cloud of floating small water droplets. We know that every tornado is associated with a thunder cloud. This is one of the few aspects which all tornadoes have in common.

Energy limitations appear to govern the duration of a tornado. It raises important questions. The first one is: where is the driving energy stored before it springs into action? It has to be located in the thunder cloud and the tornado appendix which leads to the ground. All the substance of the thunder cloud and the tornado is air, water vapor, and water fog droplets. The energies available to the storm are the kinetic energies of air, water vapor, and fog and the internal energies of these three media. The kinetic energies include heat in the form of molecular motion and vibration.

Large amounts of heat would simply evaporate fog and make the storm cloud disappear. It is also an observational fact that thunder clouds and tornadoes are cool phenomena. There is no indication in the literature that heat plays a significant role in tornado formation, other than producing thermal updraft convection. Heat dissipation and cool-down of air with increasing height above the surface of the earth causes water vapor to condense and form the thunder cloud. Every gram of condensed water raises 600 calories of latent heat of condensation. However, this heat does not appear to warm any particular part of the thunder cloud leading to thermal gradients which could be attributed to driving the tornado.

The wind velocity at a point in the tornado volume has a certain direction of flow. Heat deposited at this point should produce a gaseous expansion in all directions which does

not accelerate the storm in the wind direction. This is just one more argument reasoning against tornadoes being heat driven. It directs our attention to the internal energies of water, water vapor, and air which are primarily chemical bond energies. Before attributing the cause of tornadoes to the liberation of diatomic bond energy of N_2 and O_2 molecules in air or to the O-H bonds in water molecules (H_2O), we have to recognize that hydrogen bonds in water droplets are much weaker than diatomic bonds. The tensile rupture of the hydrogen bond is far easier than any other chemical dissociation in the tornado. Hydrogen bond rupture will happen before the stronger bonds are broken.

So we arrive at the suspicion that the likely store of energy which sustains the existence of the tornado is the hydrogen bond energy of the water droplets in the thunder cloud and the tornado funnel. What could possibly rupture these inter-molecular chemical bonds, causing them to yield their stored energy? Without a credible answer to this question it is futile to speculate how hydrogen bond energy could drive the tornado.

At this point we were reminded of a series of experiments performed by one of the authors (NG) at the University of Toronto in November 2004. This university was chosen because of the instruments available in one of their laboratories. The startling Toronto revelations have not been published because, at the time, we could not explain the observations. The experiments showed the apparent self-acceleration of high-speed cold fog jets fired into stationary laboratory air from a water arc accelerator.[2] Air friction should have decelerated the fog jets but the opposite took place reliably in some 30 shots.

The cold fog jets were fired with water arc explosions. A full description of the experimental technique is outlined in a booklet titled *Unlimited Renewable Solar Energy from Water*.[2] It shows how water arcs accelerate jets of fog to velocities as high as 500 m/s.

Now, four years later, it occurs to us that the collision of the fog droplets with the stationary air may have fractured some of the water droplets and broken a number of hydrogen bonds. The resulting liberated bond energy then became available for accelerating the fractured droplet pieces and any other droplets the pieces collide with. The details of the collision processes seem to be quite complex.

The bulk of the air with fog collisions occur at the leading edge of the jet. It appears to be the front of the jet which is driven forward, creating the illusion of self-acceleration. The fog density created by water arcs is high and far greater than the average fog density in ordinary clouds of the sky. Droplet density and diameter could not be measured in the Toronto experiments. The principal measurement was the velocity of the front of the fog jet.

The cross-sectional area of the vertical fog jets was approximately one square-centimeter. The first velocity measurement was taken a few millimeters above the accelerator muzzle. Further velocity determinations were made at about 5 mm distances up to as high as 200 mm above the muzzle. This required a high-speed video camera operating up to a frame rate of 16,000 fps. A very bright light was used to shine through the jet and cast a shadow into the camera for photography.

We will quote an example in which the height of the fog jet front, above the accelerator muzzle, was measured at four levels denoted by 1, 2, 3, and 4. The distance between adjacent levels was of the order of 20 mm. The corresponding time intervals during which the jet front advanced from one level to the next were determined from video print-outs. Average velocities v_{12}, v_{23}, and v_{34} were calculated from the experimental results for the three distances between the four levels. The results came to

$$v_{12} = 44 \text{ m/s}$$
$$v_{23} = 72 \text{ m/s}$$
$$v_{34} = 100 \text{ m/s}$$

This means over a distance of 60 mm the front of the flat-topped fog jet accelerated from, at least, 44 m/s to 100 m/s. Similar decisive accelerations were obtained for a total of 30 shots out of two different water guns.

The important outcome of these experiments is an indication that hydrogen bonds can be broken in the fog droplets of a cloud and will supply their stored energy in the form of kinetic energy of the droplet fragments. Whereas in water arc explosions and in hurricanes the bond energy is extracted from bodies of liquid water, the absence of pools of water in tornadoes does, therefore, not preclude hydrogen bond energy from being a factor of the tornado dynamics. It would seem that to influence the strength of the storm requires powerful collisions of the fog droplets with air, or with each other.

The tornado is always an appendix to a thunder cloud. In all probability the tornado funnel receives its energy from the cloud which is known to contain adjacent streams of updraft and downdraft. The substance of the storm cloud is primarily a mixture of air, water fog droplets, and water vapor molecules. The opposing flows of this mixture will have an interface in which water droplets collide with other water droplets and with air and water molecules. In this scenario it is quite possible that some water droplets are broken apart and spend hydrogen bond energy on accelerating the droplet fragments and so increase internal wind velocities. Events inside the tornado funnel are too complex to analyze here. We have shown experimentally that droplet fragmentation due to droplet collisions will supply energy to water fog so long as the cloud exists. This is not proof that tornadoes are driven by hydrogen bond energy. It should, however, cause meteorologists to look deeper into the molecular dynamics of all violent storms.

The short life of tornadoes, compared with hurricanes, is indicative of the exhaustion of the source of energy driving the storm. This source is unlikely to be heat because no significant temperature differences in the storm cloud have been observed. It leaves us with chemical bond explosions. The weakest bonds and the easiest to rupture are the hydrogen bonds between water molecules of fog droplets. Experiments performed several years ago at Toronto University have provided evidence that strong collisions between water droplets and still air lead to increased water droplet velocity, probably caused by hydrogen bond ruptures and the liberation of bond energy.

References

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