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CONSIDER THIS

The monthly essay formerly found at the Standards Blog tab has been rechristened "Consider This…" We will continue to bring diverse and eclectic reflections on life, standards, and everything to you each month under this new title. Such as this.

[][][] July 21, 2005

#30 *Standards Relativity and the Return of the Shuttle*

Last time around in ***For Your Reference***, we took a look at the lighter side of one of the less-often noticed types of commonalities: reference materials. As we noted in that piece, a bewildering array of reference materials (some of which are surprising, obscure, or downright scary) can be purchased for use in standards conformity work.

As with most other types of standards, the value of a reference material lies in its uniformity (e.g., this much of that weighs this). A reference material, then, is the physical instantiation of a standard, just as a yardstick or a kilogram balance weight is the physical representation of a unit of measurement. By their nature, then, the utility of uniform reference materials used to establish properties such as weight, purity, ductility and the like is dependent on the justifiable assumption that those properties will remain uniform throughout their use.

All of that sounds rather neat and tidy. But really, it isn't. Let's start by looking at some definitions to see why using standards that involve physical properties (even ones that can be instantiated by reference materials) is much more complicated that it sounds.

For example: you probably remember from high school science classes that a calorie (or, more properly speaking, a kilocalorie) is the amount of heat that it takes to raise one gram of pure liquid water by one degree Celsius, right? Well, not quite. What a calorie really represents is the amount of heat that it takes to raise that gram of water by one degree Celsius, when the water sample is subject to one atmosphere of pressure, and was at a temperature of 50 degrees Celsius before you put it over your Bunsen burner.

In other words, if you are conducting an experiment using a Bunsen burner that is not located at sea level, or even if a high front happens to be in place as you heat your beaker, you will need to recalibrate your experiment in order to prevent a degree of error from entering into your test results. And not necessarily a small one, either, which is why people in places like Denver, Colorado (aka. the "Mile High City") use pressure cookers to boil their potatoes if they wish to eat dinner at a reasonable hour of the evening.

In short, there are two standards being employed rather than one in this example: a standard for an assumed set of conditions, and a standard based upon those assumed conditions. If you don't know both standards, then you don't have a useful tool for performing precise measurements.

Nor is the calorie an isolated example. Take the speed of sound, for instance. Do you recall that the "speed of sound" is 741.5 miles per hour? In point of fact, that is a similarly meaningless (or at least relativistic) statement. You'll begin to see why when I remind you that, yes, this is the speed of sound through a "standard atmosphere", which means a specific mix of gases, at a specific temperature (a major factor) and humidity (a minor factor). Air pressure, surprisingly enough, doesn't matter, but since temperature and humidity both decrease with altitude, the speed of sound can be roughly calculated by reference to altitude. You don't have to go too far in looking into the speed of sound before you begin to run into statements like this:

An analysis based on conservation of mass and momentum shows that the speed of sound **a** is equal to the square root of the ratio of specific heats **g** times the gas constant **R** times the temperature **T**.

a = sqrt [g * R * T]

Got that? Good. Now we can move along to where things get complicated.

Take ballistics, for example. If you are trying to figure out where an artillery shell will land after traveling several miles, you are not working with just adjustments that must be made from your "standards" at the point of departure of the shell, but at every point along its trajectory until it reaches its hoped-for (assuming that you are on the giving, and not the receiving end) point of arrival. To work that out, you'll also need to know things like the fact that the formula for acceleration due to gravity is : 32.174 fps = 9.80665 m/s (yes, this will be on the final).

It's easy to understand how this incredibly complex type of calculation would matter quite a bit if you are firing a 16-inch diameter shell with the weight of a Volkswagen from the decks of the battleship New Jersey at a target 15 miles away. It's also easy to see why the calculation of ballistics problems in the military was one of the first applications imagined for computers.

It might be handy, though, to have a little processing power behind you when hunting with a high-powered rifle as well. Or at least that's the opinion of the developers of the Infinity Suite of ballistics software for recreational use:

> Suppose that a hunter living near St. Louis, MO, has a Model 70 Winchester rifle in 300 Winchester Magnum that he uses to hunt mule deer and elk in western Colorado at an altitude near 8500 feet above sea level. His gun is telescope sighted. He loads Sierra's .308" dia 200 grain Spitzer Boat Tail (SBT) GameKing bullet at 2800 fps muzzle velocity for hunting. He sights his gun in at a target range near St. Louis that is located at an altitude near 500 feet above sea level. The question is, if he sights his rifle in at the target range near St. Louis on a late summer day in St. Louis when the temperature at the target range is 92°F, and a local weather report lists the barometric pressure at 30.25 in Hg and the relative humidity at 90 percent, where will his gun shoot in western Colorado where he intends to hunt? Sierra's Infinity program will be used to answer this question.

In short, what the above example indicates is that when precision matters, the second half of our pair of standards (assumption of conditions and the traditional, resulting standard) may be standard, but the first half is likely to be (literally) all over the map. Not only do you have to recalibrate before you start to use such a relativistic standard, but every time a variable changes, so also must your calculations.

In the days of Wilbur and Orville Wright, very little of this type of recalibration was necessary (except for wind, which represented a variable with too large an impact to ignore). But as airplanes, and then jets, flew higher, farther and faster, margins of error introduced by failing to take changes in variables into account increased exponentially.

As science advanced, things almost seemed to get worse rather than better. The good news was that more variables were identified and understood and more ambitious things could be done where those variables mattered. The bad news was that all of those variables needed to be taken into account in order to take advantage of these new discoveries and abilities.

Let's go back to an example to demonstrate this. We all know that mass and gravity are different, and that while a kilogram would have a different weight (i.e., gravitational attraction) on Mars than on Earth, its mass would be the same on each planet. But wouldn't its weight be uniform on earth?

Well, no again. Since gravity is the sum of the attractive force between two masses, if you increase the mass of either, you increase the attractive force, and therefore the weight of the object being measured. As a result, something will weigh slightly more on top of a mountain than it would at sea level, because there is more mass lying between the top of the mountain and the center of the earth than there is between a beach and the earth's center. And that should theoretically be taken into account, if you are (for example) firing a projectile over the top of a mountain and you wish to be as accurate as possible in your aim.

Or how about the energy needed to achieve orbital velocity? Wouldn't that be the same everywhere? You guess. No again, which is why launch facilities are located as close to the equator as possible, so that the earth's rotational speed can offer a significant boost to the launch vehicle, thus allowing more precious payload weight for the same amount of fuel.

At least time must be a constant, one would assume, offering at least one fixed standard in a sea of variables. Well, Einstein took that one away from us one hundred years ago this year. With the general acceptance of Einstein's theory of relativity and the development of instruments precise enough to test its effects, it was found that the passage of time is sufficiently different at the altitudes at which commercial jets travel that adjustments must be made to prevent aircraft from wandering off course.

In short, the designers of civil and military aircraft must not only meet highly exacting materials standards in order to build airframes that can withstand the aerodynamics, temperature and other extremes that sub-, trans- and supersonic flight requires, but those who pilot those aircraft must be supplied with instruments of incredible sophistication in order to travel and arrive predictably and safely.

Even with massive computational resources, it would be difficult to impossible to pull off such a feat, since inevitably minute errors in measuring such variables would compound and become magnified. What avoids this type of outcome is recourse, through other high-tech tools, to a trick that is as old as the history of maritime navigation: getting a fix.

Prior to the discovery of the techniques of celestial navigation, mariners relied on a process known as "dead reckoning." In principal, all of the calculations that modern navigational instruments make that do not rely on "taking a fix," and all targeting software, rely on the same basic concept. At sea, dead reckoning is worked out like this: every hour the speed and direction of a ship is estimated and recorded, together with all known variables as well as they can be estimated, such as drift downwind, and the direction and speeds of the currents in which a ship might be found. Over time, errors in estimating these variables multiplied.

Even with celestial navigation, which could establish location with reasonable accuracy, a series of cloudy days would leave a navigator totally dependent on dead reckoning, resulting in tense moments on moonless nights or in fog when treacherous waters were known to lie ahead. Until about twenty years ago, even the navigators of aircraft carriers were required to know – and use – celestial navigation, but could still find themselves in such a situation.

To find a known reference point – such as an island – therefore permitted all accumulated errors to be erased, and a new course of dead reckoning to begin from this known starting point. With the development of (first) coastal LORAN and (later) global systems such as GPS, sea and air navigators were able to spend more and more of their time in areas where a reliable electronic fix was readily and constantly available, eliminating the need for dead reckoning at all, except as a fall back in the event of instrument failure.

With the advent of orbital, and then interplanetary space vehicles, however, new challenges arose, some in matters of degree, and some that were entirely new. For example, a vehicle need not only survive atmospheric conditions as well as space conditions to attain orbit, but its navigational and steering mechanisms must be able to take into account a corresponding (and incredibly rapid) change in variables as well.

But, strangely, having left the surface of the earth, spaceships do reach a realm where, at last, there is a true, single-component standard that does not change with (at least naturally-occurring) conditions: the speed of light. Unlike sound, there is no "Doppler effect" of light, and a beam of light projected from the bow of a spaceship forward would travel at the same speed, relative to the same point in space, as a beam of light projected in the opposite direction from the same spaceship.

Thus it is that when Discovery finally leaves earth behind on the first Shuttle mission since the Columbia tragedy, it will enter an environment that is, at least in one way (and perhaps others) more serene and rational than the highly variable and complex one that it has left behind.

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Useful Links and Information:

Calculating the speed of sound:
http://www.grc.nasa.gov/WWW/K-12/airplane/sound.html