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USING NEWTON'S LAW OF COOLING

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Synopsis:

This is a recall of a solution to an Engineering Problem using Newton's Law of Cooling!

Using Newton’s Law of Cooling

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This presentation is how I achieved my 15 minutes of fame from something I had done during my collegiate days.

As a Physics Major at Drexel University, I was required to take a course named “Applied Differential Equations”. There were many types of Differential Equations, but Newton’s Law of Cooling was fascinating to me. It appeared to be so simple, but the solution resulted in an exponential equation.

I decided to commit it to memory.

About two decades later I worked at the Advanced Development and Engineering Center (ADEC). This facility is now closed and was then located in Swarthmore, Pennsylvania. Over 100 engineers were employed there in this three-story building. These engineers included electrical, mechanical, aeronautical to name a few. This was the Engineering Arm of the Fortune 100 Company of Gulf & Western. In addition to Paramount Pictures, there were hundreds of other companies in many areas such as automotive, connectors, bedding, aviation, postal and lumber, just to mention the vast array of Gulf & Western.

One of our Engineering Groups was working with the High-Speed Heating of Brass Tubes using Induction Heating Coils. Following a section of heating, the heated material would be formed or machined before going to the next turret. In between certain turrets Induction Heating would again heat the material as required. A new step or turret for the process was being considered. As part of the innovative design, after exiting the Induction area, the time and temperature had to be known until the next forming operation was introduced. This required a knowledge of how the tubes were cooling.

This was not my project, but Engineers throughout the building were being asked if they had an idea of how to solve this question. When I was asked, I stood at the board in my office and solved Newton's Law of Cooling. I asked the Project Engineer if he had two points of time & temperature. When he said yes, I told him he would have a solution.

This was solved by using the little known or little used differential equation known as "Newton's Law of Cooling". The Law states that: The rate of temperature change of a body is proportional to the difference in temperature between the body and its surroundings. This seemingly simple statement becomes powerful when expressed in its differential equation form.

Mathematically this is written:

$dT/dt = -k (T – T_O)$ Eq. (1)

Where; T = temperature of the body, T_O = ambient temperature.

Solving by separation of variables, Temperature on left, time on right:

$dT/ (T – T_O) = -k\, dt$ Eq. (2)

Integrating both sides:

$\int dT/ (T – T_O) = \int -k\, dt$

$\ln(T – T_O) = -k t + \ln c$ Eq. (3)

Here the constant of Integration is chosen to be ln to make

The math easier to handle,

And

$T – T_O = c\, e^{-kt}$ Eq. (4)

For a given set of conditions we need to find c and k.

Therefore, I needed two points to solve the boundary conditions.

If the initial temperature is known at t = 0: say for example

T = 115 @ t = 0 & T_O = 30:

Then; c = 115 – 30 = 85 and if, T = 95 @ t = 30

Then, substituting into Eq. (3):

ln(65/85) = -k 30 and k = .008942

Then, substituting into Eq. (4):

[$\boldsymbol{T = 85\, e^{-.008942t}}$ + 30] is the Equation for Cooling Temperature at any time t for the given conditions.

This method can solve any cooling problem given the time & temperature for two points and a relatively stable ambient temperature condition.

This solution method was tested in the actual conditions previously described. Results were found to be spot on accurate and I was awarded two "Atta-boys" by my Engineering Manager.