Journal of Interdisciplinary Science Topics

Would You Like Some Ice for That Burn?

Alex Parry
The Centre for Interdisciplinary Science, University of Leicester
20/03/2017

Abstract
This paper aims to determine how much energy would have to be imparted in one spoken sentence to inflict a third-degree burn on a nearby person. Using an average skin temperature of $33.2\ °C$, the power of normal human speech as $1.25 \times 10^{-5}\ W$, and the understanding that it is necessary for $60\ °C$ water to be in contact with skin for $5\ s$ to cause a third-degree burn, it was calculated that $2.32 \times 10^{3}\ J$ would be needed to cause this damage to the recipient of the 'burn'. This would mean 5.88 years of continuous normal speech or five seconds of speech at $172.7\ dB$.

Introduction

Colloquial speech is an incredibly fast-evolving facet of language. Often, words will take on alternative meanings to those defined in printed dictionaries, simply because publishers cannot keep up. One such word is 'burn' – the Oxford English Dictionary has its main definition as "(of a fire) flame or glow while consuming a material such as coal or wood" [1], while Urban Dictionary defines it as "to disrespect someone (to diss); used by a third party after a first party makes fun of a second party" [2]. Unsurprisingly, when a particularly brutal quip is made, it is known as 'a third-degree burn'; an insult so ruinous that it is implied that the victim should be hospitalised.

Evidently, as a figure of speech, it is not expected that a well-executed witticism will cause direct physical harm to the recipient. However, this paper will discuss how much energy would be required for a single spoken sentence to cause an actual third-degree burn, and therefore how loud or how lengthy the verbal 'burn' would have to be.

Theory

A third-degree burn – also known as a full thickness burn – occurs when all three layers of skin (epidermis, dermis, and subcutis) are damaged [3]. A common way to burn in this manner is to be directly exposed to water or steam at $60\ °C$ for five seconds [4].

Taking the average temperature of human skin to be $33.2\ °C$ $(306.4\ K)$ [5], the change in temperature (ΔT) that would be required to reach scalding temperature is $26.8\ °C$ $(26.8\ K)$. The specific heat capacity (c) of human skin is estimated to be $3391\ J\ kg^{-1} K^{-1}$ [6]. If the area (A) being heated is arbitrarily taken to be $25\ cm^2$ (a $5 \times 5\ cm$ square) and the area density (ρ_A) of skin is $1.02\ g\ cm^{-2}$[7], then the mass of this section (m) is $25.5\ g$ since:

$$m = A\rho_A$$

Using these values in the following equation will allow the heat energy required (Q) to get a third-degree burn on this area of skin to be calculated:

$$Q = mc\Delta T$$

This shows that the energy required is $2.32 \times 10^{3}\ J$.

Taking the power (P) of a normally modulated human voice to be $125\ ergs\ s^{-1}$ $(1.25 \times 10^{-5}\ W)$ [8]; considering that power is the rate of energy transferred per unit time, it can be calculated that one would have to speak for $185\ 392\ 752$ seconds (5.88 years) in order to generate this much energy. It should be noted that this calculation optimistically presumes that all sound energy is transferred into heat energy upon skin contact, in order to produce this burn.

Alternatively, supposing that the sentence lasts five seconds, it can be calculated that the voice would have to have $463.5\ W$ in order to output the required energy. If it is assumed that the sound is distributed evenly across the burn area, we can determine the intensity of the sound (I) using the following:

$$I = \frac{P}{\mathrm{A}}$$

From this, it can be established that the intensity of this speech would be $1.85 \times 10^5\ W\,m^{-2}$. Since the decibel scale of sound intensity is a direct measure of how loud a sound is in relation to the sensitivity of human hearing, the following equation is used:

$$L_I = 10 \log\left(\frac{I}{I_0}\right)$$

The human hearing threshold is $10^{-12}\ W\,m^{-2}$; this can be considered to be the reference intensity I_0. This means that one would have to speak at $172.7\ dB$ for five seconds in order to give the recipient a third-degree burn. Considering that on average humans speak at around $70\ dB$ [9], the logarithmic nature of the decibel scale means that this speech would be around 10 billion times louder – and thus more intense – than usual speech. As if a third-degree burn was not enough; $110\ dB$ is the average human pain threshold for speech, and $150\ dB$ is the intensity at which eardrums are liable to rupture, and is the equivalent of listening to an aeroplane jet take-off from $25\ metres$ away [9].

Conclusion

It can be concluded that, in order to actually give a listener a third-degree burn of $25\ cm^2$ area, the speaker must stand directly next to the victim and either speak at normal modulation for 5.88 years continuously, or shout at $172.7\ dB$ for five seconds.

It should be noted that, at a socially acceptable conversational distance, the duration or volume of speech would increase dramatically. However, even at these comparatively small values, the unfortunate speaker would reach their pain tolerance before being able to reach the required volume, and both the speaker and listener would likely have punctured eardrums in addition to a serious burn. Additionally, in reality not all of the sound energy in a sentence would be transferred into heat energy on the skin, thus meaning that one would again have to speak either louder or for longer in order to cause a burn. Finally, humans cannot survive for almost 6 years without basic necessities such as food, water, and sleep, and this amount of talking would give one an awfully sore throat.

References

[1] Oxford Dictionaries (2017) *burn*, Oxford University Press, [Online]. Available: https://en.oxforddictionaries.com/definition/burn. [Accessed 15 February 2017].

[2] The All Knowing Amy, (2004) *burn*, Urban Dictionary, 5 May 2004. [Online]. Available: http://www.urbandictionary.com/define.php?term=burn. [Accessed 15 February 2017].

[3] National Health Service England (2015) *Burns and scalds*, National Health Service England, 16 November 2015. [Online]. Available: http://www.nhs.uk/conditions/Burns-and-scalds/Pages/Introduction.aspx. [Accessed 15 February 2017].

[4] Burn Foundation (2017) *Safety Facts on Scald Burns*, Burn Foundation, [Online]. Available: http://www.burnfoundation.org/programs/resource.cfm?c=1&a=3. [Accessed 15 February 2017].

[5] Karlsbad, A. & Kopp, S. (1991) *Intramuscular and skin surface temperatures of the resting human superficial masseter muscle*, Acta Odontologica Scandinavica, vol. 49, no. 4, pp. 225-231.

[6] Foundation for Research on Information Technologies in Society (2017) *Tissue Properties - Heat Capacity*, [Online]. Available: https://www.itis.ethz.ch/virtual-population/tissue-properties/database/heat-capacity/. [Accessed 15 February 2017].

[7] Liang, X. & Boppart, S.A. (2010) *Biomechanical Properties of In Vivo Human Skin From Dynamic Optical Coherence Elastography*, Transactions on Biomedical Engineering, vol. 57, no. 4, pp. 953-959.

[8] Crandall, I.B. & MacKenzie, D. (1922) *Analysis of the Energy Distribution in Speech*, Physical Review Letters, vol. 19, no. 3, pp. 221-232.

[9] Purdue University Chemistry Department (2000) *Noise Sources and Their Effects*, February 2000. [Online]. Available: https://www.chem.purdue.edu/chemsafety/Training/PPETrain/dblevels.htm. [Accessed 18 February 2017].