NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

A Challenging Case of Data Analysis

by

Connar G. Franklin
Office of Teaching Innovation and Digital Education
University of Alabama, Tuscaloosa, AL

Part I –Reschedule?

You are teaching an introduction to chemistry course at a local university and plan to do a demonstration of the reaction between iron (III) oxide and aluminum (the thermite reaction) for the class. The reaction produces large amounts of heat and molten iron, so you must perform the experiment outdoors. You are very busy, so you task your teaching assistant (Connar) with conducting the experiment many times under different conditions to ensure that on demonstration day everything goes as planned (you do not want to look like a fool in front of your students, after all). Connar is instructed to alert you if he runs into any issues when performing the experiments. Your main concern is that the reaction will not perform well under certain weather conditions. It is generally very warm in your area, but a cold front is expected to produce unseasonably cold temperatures on demonstration day.

After running the experiment many times at many different temperatures over the course of a few weeks, Connar provides you with the printout seen in Figure 1. The *y*-axis label of "number of incidents" confuses you, so you ask for further clarification. Connar explains that it simply refers to the number of experiments that had any type of issues at that given temperature. Issues could be anything ranging from cracks forming in the reaction vessel to the reaction not proceeding at all. You are aware that there are certain unavoidable risk factors involved in the experiment and are mainly concerned with the possible existence of a correlation between decreasing temperatures and the increasing likelihood of reaction incidents.

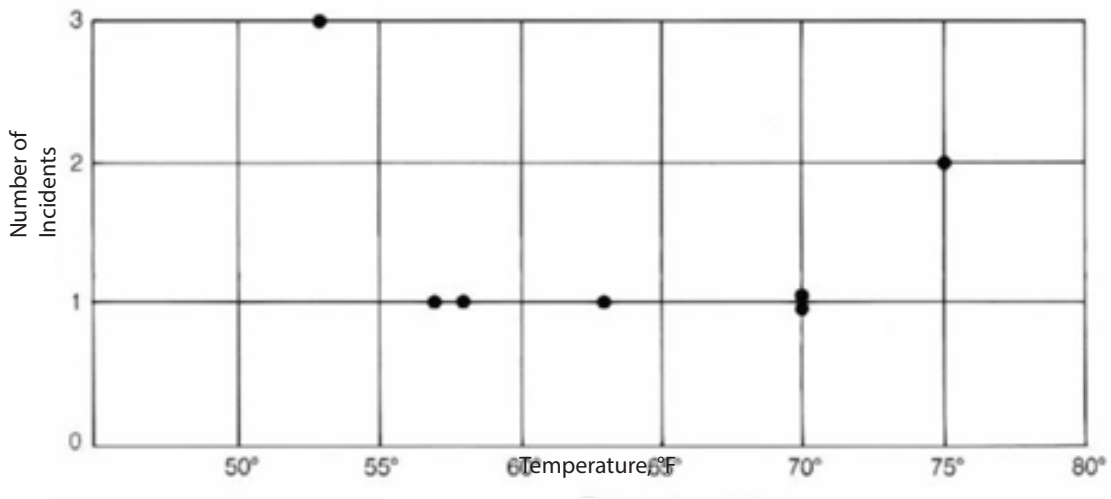

Figure 1. Incidents during thermite reaction at different temperatures.

You wake up on the day for which the demonstration is scheduled and the temperature for class time is predicted to be 38 °F.

Questions

1. Is there an apparent trend between either increasing or decreasing temperature and reaction incidents? Explain.

2. Given your answer to the question above and your knowledge of the weather forecast, do you think the demonstration should be rescheduled for a warmer day? Explain.

3. Would your scheduling decision for the previous question be different if the situation were one of life and death, such as a medical procedure or skydiving trip, and not just a chemistry demonstration? Explain.

4. Is there any other data that you would have liked to have received from Connar? If yes, what data and why?

Part II – More Data

On your way to perform the demonstration you run into Connar, who seems surprised that you are performing the demonstration on such a cold day. You explain to him that you saw no correlation between decreased temperature and experiment failure. He seems shocked and shows you Figure 2 below. "I thought you only wanted to see the data points that provided the largest number of incidents," he says.

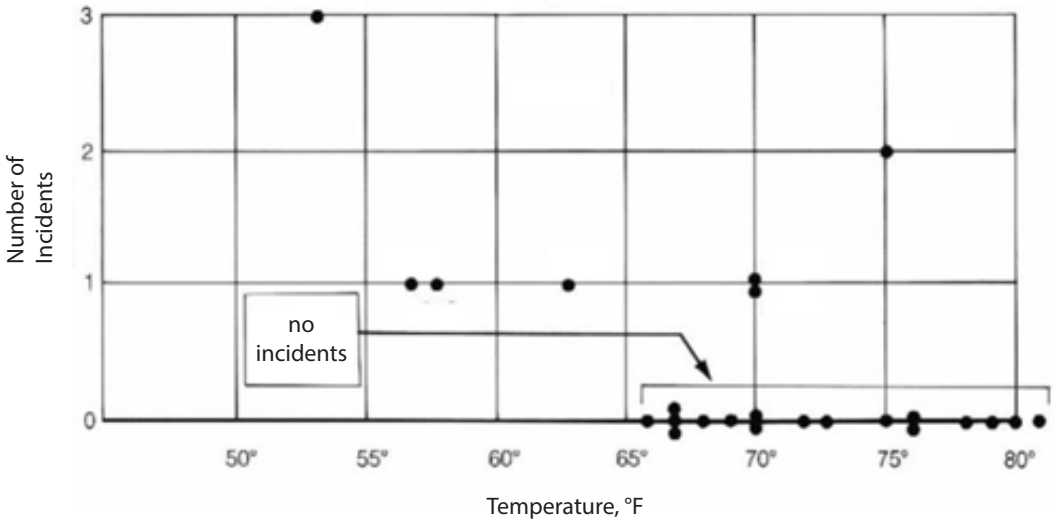

Figure 2. Incidents during thermite reaction at different temperatures, with the addition of normal trials ("no incidents").

Questions

5. Given the new data is there an apparent trend between either increasing or decreasing temperature and reaction incidents? Explain.

6. Given your answer to Question 5 and your knowledge of the weather forecast, do you think the demonstration should be rescheduled for a warmer day? Explain.

7. How does the data from Figure 2 illustrate the need for ample amounts of data to be collected and examined?

8. The terms "sampling" and "selective data use" are used to describe when we choose to examine only the data that we feel is most relevant and ignore the rest. This is illustrated in Connar's statement of "I thought you only wanted to see the data points that provided the largest number of incidents." Articulate an opinion on these practices based on Parts I and II of this case study.

Part III – Disaster

The data in Figures 1 and 2 and the temperature on demonstration day were taken directly from the Report of the Presidential Commission on the Space Shuttle Challenger Accident (which Nobel Prize winner Richard Feynman helped write) with only trial numbers being removed (see Figures 6 and 7 on p. 147 of the report). The figures were for the test data collected by NASA and contractor Morton Thiokol for the failure of rubber O-rings that separated fuel segments in the rockets. The term "incidents" in the chart refers to the erosion of the rubber rings or "blow-by," which is when hot gases blow past the rubber seal. The failure of the O-rings in the fuel segments was determined to be the ultimate cause of the shuttle's explosion and the loss of seven lives. The following excerpt is from the Presidential Commission's report. (Note that the use of italics below for emphasis does not appear in the original report.)

> The record of the fateful series of NASA and Thiokol meetings, telephone conferences, notes, and facsimile transmissions on January 27th, the night before the launch of flight 51 -L, shows that only limited consideration was given to the past history of O-ring damage in terms of temperature. *The managers compared as a function of temperature the flights for which thermal distress of O-rings had been observed—not the frequency of occurrence based on all flights* [Figure 1]. In such a comparison, there is nothing irregular in the distribution of O-ring "distress" over the spectrum of joint temperatures at launch between 53 degrees Fahrenheit and 75 degrees Fahrenheit. *When the entire history of flight experience is considered, including "normal" flights with no erosion or blow-by, the comparison is substantially different* [Figure 2].
>
> This comparison of flight history indicates that only three incidents of O-ring thermal distress occurred out of twenty flights with O-ring temperatures at 66 degrees Fahrenheit or above, whereas, all four flights with O-ring temperatures at 63 degrees Fahrenheit or below experienced O-ring thermal distress.
>
> *Consideration of the entire launch temperature history indicates that the probability of O-ring distress is increased to almost a certainty if the temperature of the joint is less than 65.*
>
> *—Report to the President, p. 146.*

Question

9. Reflecting on the information presented above and your response to Question 3, discuss how relaxed or improper practices in data collection and analysis in trivial situations such as described in Parts I and II of this case study can create habits that can have severe impacts such as in Part III.

Reference

United States. (1986). Report to the President. Washington, D.C: Presidential Commission on the Space Shuttle Challenger Accident. Ch.VI: An Accident Rooted in History. <https://sma.nasa.gov/SignificantIncidents/assets/rogers_commission_report.pdf>