3.1 THE 1883 HOLDEN TORNADO WARNING SYSTEM AND ITS APPLICATIONS TODAY

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1. INTRODUCTION

During the latter part of the nineteenth century, the number of tornado deaths (per capita) in the United States was high by modern standards, averaging about 2 deaths per one million people per year. In some years, the number was much higher (as high as 7.9 tornado deaths per million people per year) (Brooks 1998). In 1882, Sgt. John P. Finley of the United States Army Signal Corps weather program (known as the "Division of Telegrams and Reports for the Benefit of Commerce and Agriculture") headed up a program to document and understand local storms, including tornadoes. About 1000 "reporters" were organized in the central and eastern U. S. to report tornado occurrences and damage (Bradford 1999). By 1884, Finley outlined the general weather patterns associated with tornadoes, including a well-defined surface low, a well-defined high behind the low, large temperature gradients, and high humidity in the southeast quadrant of the low (Finley 1884; Finley 1888; Schaefer 1986; Bradford 1999). Using these patterns, along with weather observations, Finley began to issue "tornado alerts" for large areas (on a scale similar to tornado watches today) beginning in March 1884, to some degree of success (e.g., Bradford 1999; Schaefer 1986).

Edward S. Holden's main work was in the field of astronomy. He worked for the U. S. Naval Observatory, and eventually became the president of the University of California in 1886, and director of its Lick Observatory in 1888. He also served as librarian of the United States Military Academy at West Point, New York (Campbell 1916). Upon examination of Finley's findings, Holden proposed a local tornado warning system in *Science* in 1883 (Holden 1883). He felt that a system that could provide

Figure 1. Photograph of Edward S. Holden (from Campbell 1916).

the residents of a town even five minutes' warning could save lives. However, Holden's suggestions may have been ignored, at least in part, due to the ban on tornado forecasting only three years later. There was a general feeling that public panic would ensue if tornado forecasts were issued, so the Signal Corps banned the use of the word "tornado" in its forecasts starting in 1886; this decision remained in effect until 1938, well after the nation's weather services were placed in the civilian U. S. Department of Agriculture in 1890 and would become the U. S. Weather Bureau (Bradford 1999; Galway 1984). The *Chicago Tribune* favored local tornado warnings in 1899 (Bradford 1999), but meteorologists of the time rejected this idea (e.g., Hazen 1890; Abbe 1899a, b). Even though, to the author's knowledge, Holden's system was never directly placed in a town, the system he proposed was not only fascinating, but three different aspects of it are still, either directly or indirectly, in use today. This system will be examined in this paper, and compared to systems in use for modern tornado warnings.

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2. HOLDEN'S SYSTEM

According to Holden (1883), saving property from a tornado was not feasible. However, he pointed out that lives may be saved if people were given five minutes' warning to utilize underground shelters. He felt that, given the state of knowledge at that time about the atmospheric conditions necessary to produce tornadoes, generalized warnings over large areas (ie., states) could be provided for the possibility of tornadoes (similar to the "tornado alerts" mentioned in section 1). However, he also felt that warnings from the "weather services" for a given tornado were not possible anytime soon. Therefore, Holden wished to devise a system in which some type of warning could be given to people that "a wind of a destructive force" was approaching (1883).

Holden points out two findings made by Finley (1884), in Finley's historical record of 600 tornadoes from 1794 to 1881: 1) 88% of some group of the 600 tornadoes (it is unknown which group was being referred to by Holden) moved from the directions between west and south-southwest, and 2) the average speed of movement was "about one mile in two minutes", or 30 mph.

Holden (1883) proposed a tornado warning system which would consist of a line of telegraph wire around the west through south-southwest directions from a town, at a radius of 2 to 2.5 miles. The line would be grounded at each end, and connected to a battery at the telegraph office which would provide a constant current through the line. The telegraph line would also have a connection in houses within the town, to an apparatus containing a bell, which rings using a coiled spring (similar to an alarm clock), and a magnet that prevents the bell from ringing *as long as current flows through the wire*. If the circuit were broken, the current would stop and the bell would begin to ring. A similar device could be connected to a cannon, which would fire when the circuit was broken, warning those outdoors. *Therefore, the circuit must be broken by an approaching destructive wind, or tornado.* A rough schematic of the circuit setup is shown in Figure 2.

Holden proposed that this be accomplished in following way. At each telegraph pole, a one-foot square board would be placed, which would effectively break the circuit if a wind of 70 mph or greater occurred at the board. A rough schematic of the telegraph pole system is shown in Figure 3.

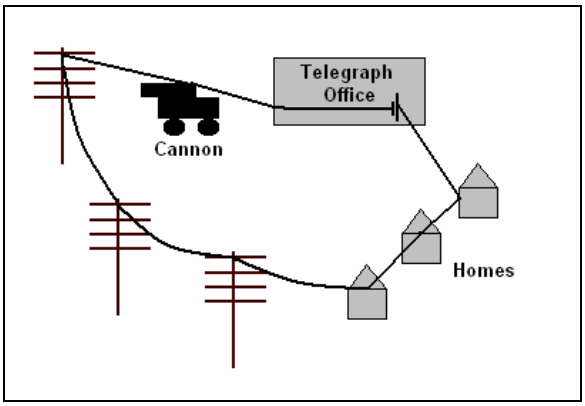

Figure 2. Schematic of setup for tornado warning circuit (after Holden 1883). North is considered upward in the schematic.

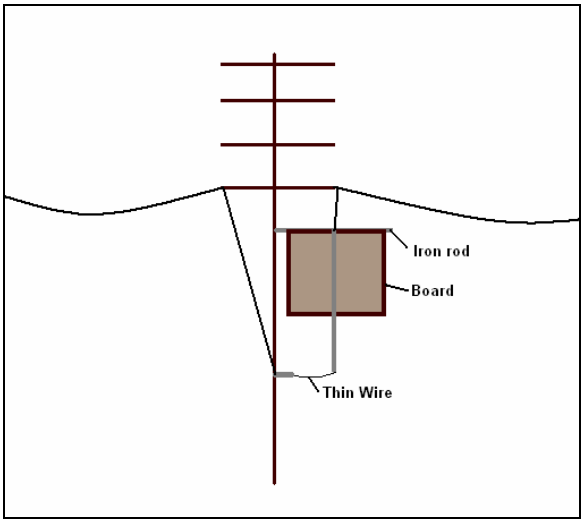

Figure 3. Schematic for telegraph pole system designed to break circuit in high winds. The board revolves freely on the iron rod, and high winds would put enough pressure on the vertical iron rod connected to the board carrying the current to break the thin wire attached to the bottom of the iron rod.

Holden had constructed a working example of such a device in a laboratory. However, he pointed out that some details may be resolved by individuals installing the systems.

3. SIMILARITIES TO MODERN SYSTEMS

Holden's proposed 1883 tornado warning system was very imaginative, and may have been successful if it had been implemented. Interestingly, there are several aspects of his simple system which are in use in

the tornado warning system in the United States today. These are discussed below.

a. Major line lockouts

The modern electrical grid in the United States consists of thousands of miles of major, high-voltage *transmission* lines, which reduce the current needed to transmit large amounts of power over relatively long distances and increase the efficiency of the power system. These transmission lines feed lower-voltage *distribution* lines, which bring power into our homes and businesses.

The major transmission lines, typically carrying voltages larger than 100 kV, are typically placed in areas where downed trees can not affect them, often on land that is kept clear of significant plant growth (an example of major transmission lines and tower is shown in Figure 4). Their location and design makes these major lines resistant to all but extreme winds, generally those caused by a tornado.

Such lines occasionally suffer surges and interruptions, and circuit breakers are placed in their circuits. These breakers are designed to trip in the event of a temporary short circuit or surge, but then reset automatically, closing the circuit, after a short period of time. If the transmission lines or their towers are damaged by extremely high winds, causing a more permanent short circuit, the circuit breaker will not be able to reset, becoming "locked out" (Hooks 2007, personal communication). Typical power companies can detect such a "major line lockout", and relay its approximate location to the local National Weather Service office. Figure 5 shows a map of the major power transmission lines in central Alabama. Since these major transmission lines are designed to withstand all but tornado-like wind speeds, such a lockout is considered as a strong indication that a tornado is on the ground. *If Doppler radar indicates any rotation in the area of the major line lockout, a tornado warning is issued almost automatically* (Peters 2008, personal communication). Interestingly, this practice of detecting damage to power lines, associating it with tornado winds, and issuing a tornado warning based on this damage, is extremely similar to the Holden (1883) system, in which broken telegraph wires would initiate a warning of a tornado.

Figure 4. Example photograph of major power transmission lines (courtesy rain.org).

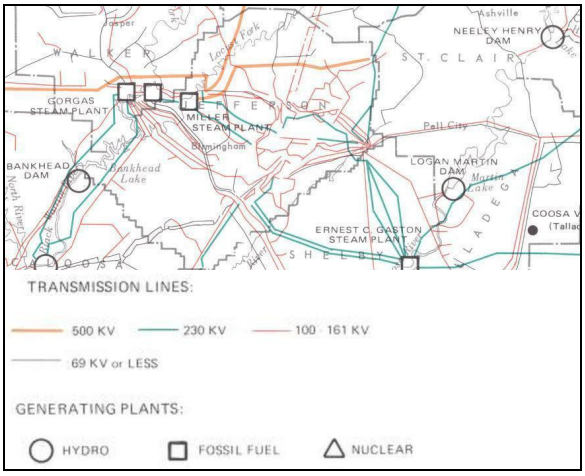

Figure 5. Major power transmission lines and generation plants in central Alabama in 1983 (courtesy Geological Survey of Alabama, and The University of Alabama Historical Map Archive)

b. NOAA Weather Radio

Prior to 1974, 50-60 radio stations were operated by the National Weather Service, providing continuous weather information, primarily in coastal areas. In response to the Super Outbreak of Tornadoes across the central and eastern United states in April 1974, Congress appropriated the money to expand the network to 330 stations, forming the NOAA Weather Radio network that is still being expanded today (NOAA, 1999). NOAA Weather Radio was also designated under a 1975 White House Policy Statement as the only

government-operated radio system to bring weather warning information directly to American homes. The system would also warn of enemy attack (NWS, 2007).

NOAA Weather Radio operates on several frequencies between 162.40 and 162.55 MHz. In the event of a tornado warning (or other hazard), a 1050 Hz tone is broadcast on the radio frequency, which activates specially designed receivers to sound an alarm, even when the receiver's audio is turned off (see Figures 6 and 7). Today, with Specific Area Message Encoding, an additional set of tones is broadcast, which activates only receivers in the areas affected by a given weather threat.

With respect to Holden's (1883) tornado warning system, the NOAA Weather Radio receiver in each home serves the same purpose as the bell which would ring when the telegraph circuit was broken by high winds. In each case, an alarm is activated in a person's home remotely, warning of a tornado.

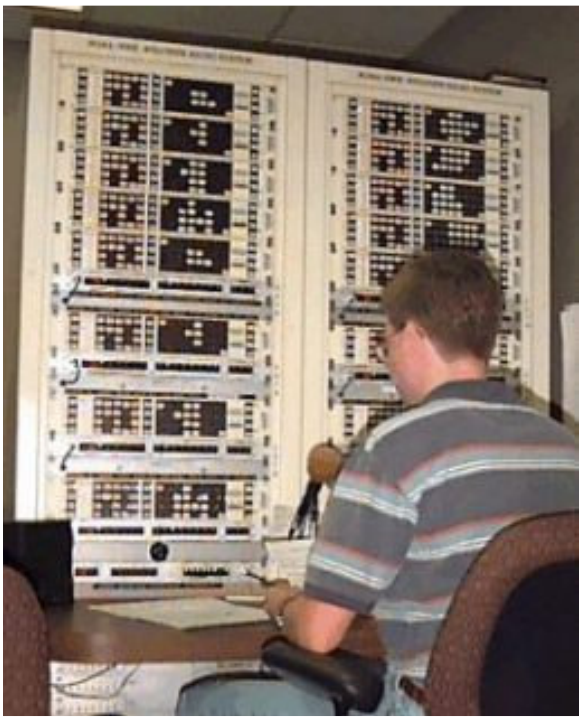

Figure 6. NOAA Weather Radio broadcast consoles at National Weather Service office, Birmingham, AL (courtesy NWS)

Figure 7. Various NOAA Weather Radio receivers. Clockwise from top left, 2007, 2005, c. 1982, c. 1989.

c. Outdoor tornado sirens

During the Cold War era, in response to fears of nuclear attack, the Federal Civil Defense Act of 1950 led to public warning systems (VictorySiren 2003). Outdoor warning sirens were placed in many parts of the United States. These sirens were typically operated by Civil Defense, and had different types of sounds for enemy attack and tornado warning. Eventually, once the Cold War came to and end, the sirens were used almost exclusively as tornado sirens. Figures 8 through 10 show examples of sirens and controls.

These outdoor warning sirens are similar to Holden's (1883) idea of firing a cannon to warn people outdoors of the approach of a tornado.

Figure 8. Example of civil defense siren used throughout the United States during the Cold War era. (courtesy civildefensemuseum.com)

Figure 9. Modern tornado siren. (Source of photo unknown).

Figure 10. Control panels for tornado siren in Dallas/Fort Worth, Texas. (courtesy bensware.com)

4. SUMMARY

In some ways, Holden was 50-75 years ahead of his time in devising an automatic tornado warning system in 1883 which would not only *detect* the tornado, but *warn* people in individual homes and outdoors of its approach. Unfortunately, due to the resistance of the Signal Corps and the Weather Bureau to tornado forecasts or warnings, Holden's system was never widely used (to the author's knowledge).

However, many of the concepts Holden developed in his tornado warning system are in use today, 125 years later. Major line lockouts, caused by the destruction of power transmission equipment, are detected remotely and usually indicate the presence of a tornado. The knowledge that a major line lockout has occurred is used in modern National Weather Service offices to help issue tornado warnings. Holden's idea of an alarm system within every home became available in 1975, when the NOAA Weather Radio network was expanded. Specialized receivers are designed to activate an alarm when the National Weather Service broadcasts a tone on the NOAA Weather Radio frequency, to warn of a tornado. Finally, Holden's idea of having a cannon fire to warn those outdoors of an approaching tornado is similar to the tornado sirens which have been warning people of tornadoes for decades.

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