Breaking the Silk Dress Cryptogram

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ABSTRACT
A solution to the "Silk Dress cryptogram" is presented. The cryptogram was found to be a telegraphic code used for transmitting weather observations by the U.S. Army Signal Service (Signal Corps) and later by the U.S. Weather Bureau. The decoded messages were weather observations for a number of American and Canadian stations in 1888.

KEYWORDS
telegraphic code; weather code; U.S. Army Signal Corps; U.S. Weather Bureau; Meteorological Service of Canada; Victorian clothing

1. Introduction

In December 2013, archaeological curator Sara Rivers-Cofield discovered two ostensibly encrypted notes in a hidden pocket of a Victorian-era silk dress (see Figure 1). Rivers-Cofield, who collects vintage costumes in her spare-time, had purchased the dress at an antique mall in Maine during the holiday season. By Rivers-Cofield's estimate, the two-piece bustle dress made of bronze-colored silk is believed to date from the mid-1880s (Rivers-Cofield, 2014).

The so-called "Silk Dress cryptogram" has remained unsolved since its discovery and is on cryptologist Klaus Schmeh's list of the top 50 unsolved codes and ciphers in the world on his "Cipherbrain" blog (Klaus Schmeh, "The Top 50 Unsolved Encrypted Messages: 32. The Silk Dress Cryptogram", May 13, 2017, https://scienceblogs.de/klausis-krypto-kolumne/2017/05/13/the-top-50-unsolved-encrypted-messages-32-the-silk-dress-cryptogram/).

Cryptologist Nick Pelling also blogged about the cryptogram on his "Cipher Mysteries" site (https://ciphermysteries.com). Pelling stated that the cryptogram had stymied the cryptanalytic community, despite many proposed theories and decoding attempts (Nick Pelling, "The Silk Dress Cipher ...," May 21, 2017, https://ciphermysteries.com/2017/05/21/silk-dress-cipher).

In this article, a solution to the Silk Dress cryptogram is presented.

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Figure 1. The Victorian-era silk dress containing coded messages in a hidden pocket. (Image courtesy of Sara Rivers-Cofield.)

2. The Dress and Discovered Notes

According to Sara Rivers-Cofield, the dress was of a style that was in fashion in the mid-1880s and would have been worn by a woman of at least middle-class means. Such dresses were commonly found in department store catalogs of the era.

A name tag was roughly stitched to the bodice of the dress, with the name "Bennett" written on it (Figure 2).

In examining the silk dress closely, Rivers-Cofield found a hidden pocket when she turned the skirt inside-out (Figure 3). Although pockets in dresses of this era were not uncommon, they were typically accessible via a slit in the overskirt. In this case, however, the opening of the pocket was completely covered by the overskirt and would have required the wearer to hike up the skirt to access the pocket.

Inside the pocket, Rivers-Cofield found a balled-up wad of paper, which turned out to be two crumpled sheets of translucent paper, each measuring approximately 7.5 in. x 11 in. (19 cm x 28 cm) (see Figures 4 and 5). Each sheet contained 12 lines of cursive writing, with each line containing 2–7 words in English. The sheets were unnumbered, so it is not clear if there was an order to them. There were wide margins on the left and right sides of the text and some lines were continued underneath and indented to indicate that the words belonged to the same line. Most lines had a numeral near the start of the line which appeared to indicate the number of words in the line. In the left margin, there were stroke marks beside each line of text made with a blue-green pencil. These markings seem to indicate that the line had been checked in some way. In the top-left corner, there appears to be a time of day written. On one sheet, the time was "101 PM" and on the other sheet, there were two times present: "1115 PM" was written next to the first line, and "1124 P" was written adjacent to the fifth line.

Figure 2. Name tag sewn on bodice of dress. (Image courtesy of Sara Rivers-Cofield.)

3. Transcription of Text

Tables 1 and 2 show a transcription of the text on the two sheets of paper. The sheets have been arbitrarily numbered 1 and 2 for ease of reference. Capitalization of words was retained from the original sheets. Where there was uncertainty in how a word was interpreted, it is followed by a question mark in parentheses. The line numbering in the first column of the tables was added for ease of reference.

Note that this transcription differs from some others (e.g., Dunin and Schmeh (2022)). It is based on my interpretation of the handwriting and informed by the subsequent decoding of the messages.

A cursory inspection of the words finds some commonalities. The first word of each line seems to be mainly place names (e.g., Vicksburg). The third word of lines on Sheet 1 tends to start with the letter "L". Repeated words between lines are common, but repetition within a line occurs only once in Message 2.2 (Line 2 of Sheet 2) (the word "event" is repeated). Finally, the structure of the lines, with a place name at the beginning of each, suggests that each line is a separate message rather than all the lines forming a single message.

Figure 3. Hidden pocket of dress. (Image courtesy of Sara Rivers-Cofield.)

4. Determining the Codebook

Based on its appearance, the Silk Dress cryptogram is more likely a code rather than a cipher[1] because of its use of plaintext words in English. From the time period of the dress, it is hypothesized that the code could be a telegraph code. These types of codes were common in the late 19th century and were mainly used either to reduce the cost of sending telegrams or for privacy. A proliferation of commercial and private codebooks were published during the telegraph era. Different industries had specialized codebooks and companies often had their own in-house codes. For example, the mining industry (Moreing, 1888), seed merchants (Albert Dickinson Co., 1891), grocers (Habersham & Co., 1871), banks (American Code Co., 1919), railways (Sheahan, 1892; Canadian Pacific Railway, 1916) and even the cinema industry (Poillon, 1923) all had their own telegraph codes.

Since telegraph companies charged by the number of words in a telegram, codes to compress a message to reduce the number of words became popular. Many codebooks replaced phrases with single words to save money. A phrase such as "The crew are all drunk" may be substituted with a codeword such as "CRIMPING" (this example comes from the *ABC Code* (Clauson-Thue, 1881), which was one such codebook).

In addition to cost-cutting, codes were also created to ensure privacy, since telegrams passed through many hands between the sender and the recipient. *Slater's Telegraphic Code* (Slater, 1888) was a popular codebook used to ensure confidentiality, which was used by the Canadian government and the North-West Mounted Police (the forerunner of the Royal Canadian Mounted Police (RCMP) (Benoit, 2016).

The words in the Silk Dress cryptogram appear similar to the codewords found

[1]A cipher involves substitution at the level of letters, whereas a code deals with substitution at the level of words or phrases (Singh, 2000, 30).

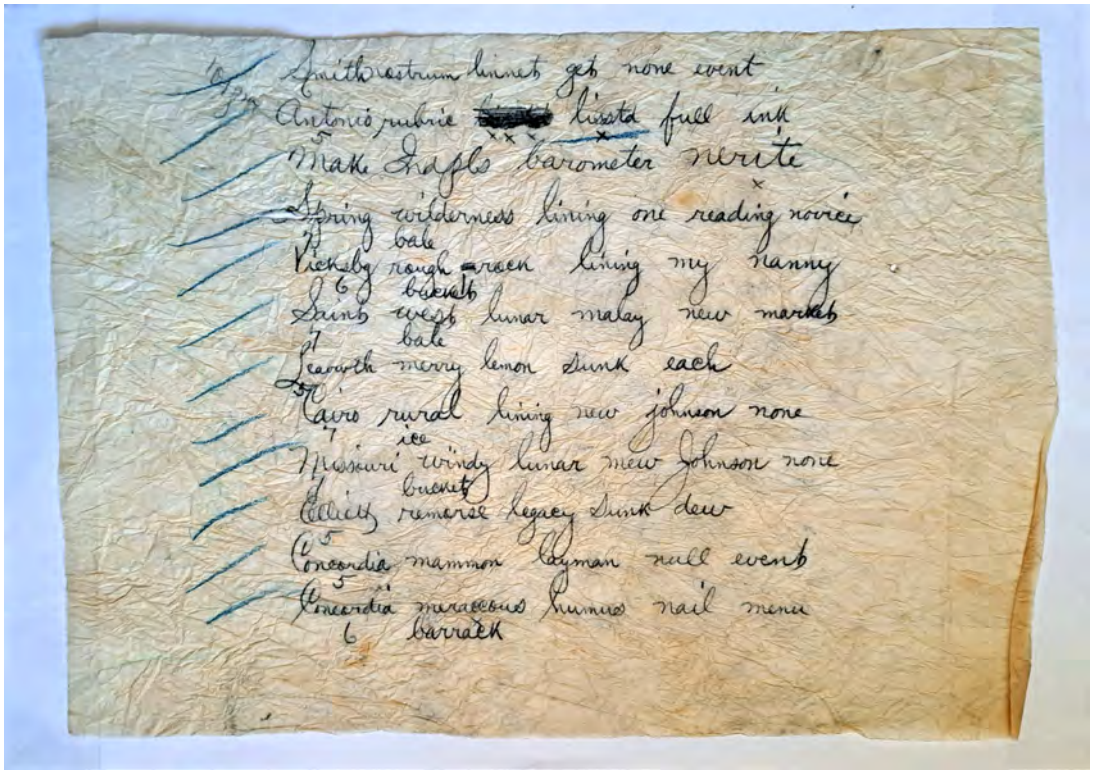


Figure 4. Code sheet 1. (Image courtesy of Sara Rivers-Cofield.)

in many telegraph codebooks from the 19th and early 20th century. The challenge would be to find the correct one. Unfortunately, during the roughly 100 years of the telegraphic era, there were hundreds, if not thousands of codebooks published. Some were commercial codebooks which were widely available and others were private codebooks with limited distribution. Some codebooks are now quite rare and others may no longer have any extant copies. Only a small fraction of them have been digitized and made available online.

I examined approximately 170 codebooks that were available online or otherwise obtainable. John McVey's online compilation of telegraphic codebooks (McVey, 2014) was very useful in this regard, as was S. Tomokiyo's list of codes (Tomokiyo, 2013). Some codebooks could be ruled out immediately as they used only numeric codes, three- or five-letter codewords, or used artificial words rather than words from a natural language. It was decided to search the codebooks for the rarer codewords from the cryptogram that were not commonly found in most codebooks. These included "GINNED", "NANNY" and "FAGAN".

One difficulty encountered was that coded telegrams were often a mix of codetext and cleartext (Bellovin, 2009), so some of the words on the code sheets may actually be unencoded. For instance, it was uncertain whether the place names in Sheets 1 and 2 were codewords or cleartext words. Codebooks could be incorrectly ruled out because they did not contain words that are actually cleartext. In addition, it was uncertain whether some of the words were spelling errors or intentional spellings.

The search uncovered two commercial codebooks that contained the most matches to the codetext: *Slater's Telegraphic Code* (Slater, 1888) and the *Simplex Cryptograph* (Simplex Cryptograph, 1902). Slater's code had been suggested by several telegraphic

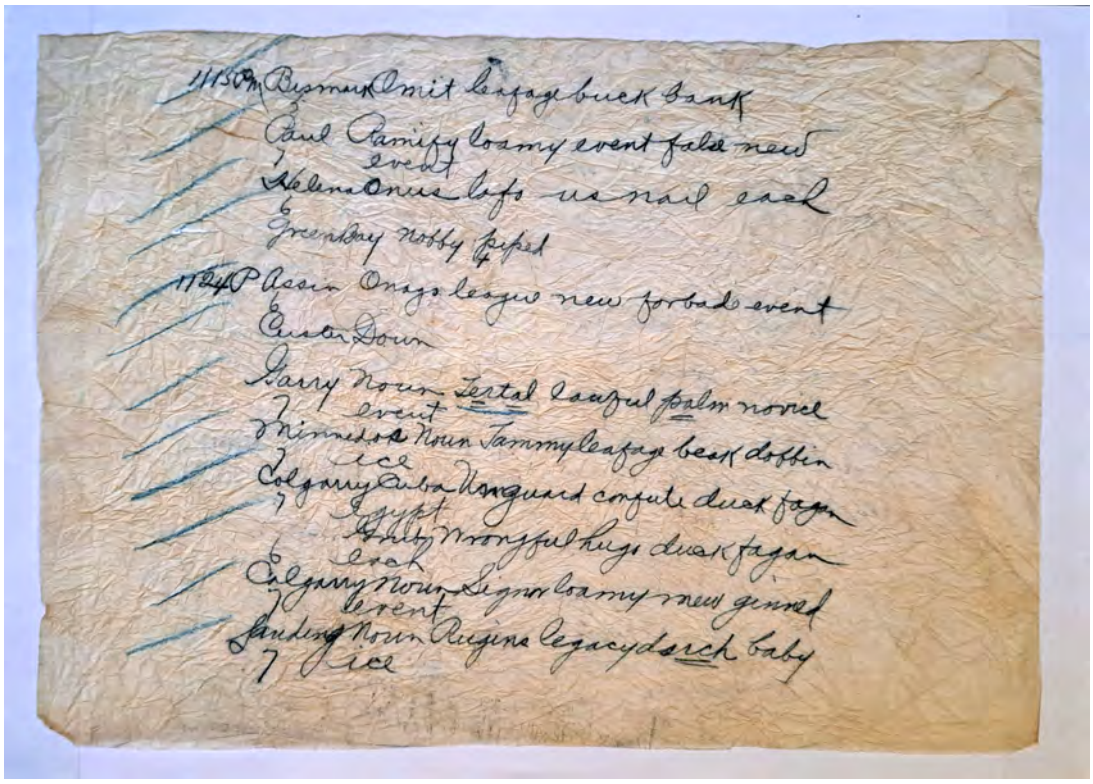


Figure 5. Code sheet 2. (Image courtesy of Sara Rivers-Cofield.)

code experts on Klaus Schmeh's and Nick Pelling's crypotology blogs as being a possible candidate for the Silk Dress cryptogram, but the latter had more words that matched the codetext. Both codebooks assigned a number to each word in the codebook and required a key (either a simple offset value or a more complex mathematical transformation) that would convert the number for a plaintext word to a number corresponding to the codeword. However, both codebooks were missing words from the code sheets that were probable codewords.

After the search of available codebooks proved to be largely unsuccessful, I decided to learn more about the telegraphic era and came across an old book called *Telegraphic Tales and Telegraphic History* (Johnston, 1880). In one section, the role of the U.S. Army Signal Service in weather reporting was discussed (Johnston, 1880, 168–178), and an example of the telegraph code was provided: "YORK, MONDAY, DEAD, FIRE, GRIND, HIMSELF, ILL, OVATION, VIEW". The style of the code and the fact that it began with a place name suggested a close match to the Silk Dress codetext. This was the key that led to the decoding of the cryptogram. I later discovered that McVey's list of telegraph codes had a discussion of the weather codes as well (`https://www.jmcvey.net/cable/observational/index.htm`).

5. U.S. Weather Observation Network

The advent of the electrical telegraph in the 1840s allowed for rapid dissemination of weather information from disparate corners of a country, which could be collated, analyzed and plotted to create national weather maps within hours of the observations.

1.1	Smith	nostrum	linnet	get	none	event	
1.2	Antonio	rubric	lisstd (?)	full	ink		
1.3	Make	Indpls	barometer	nerite			
1.4	Spring	wilderness	lining	one	reading	novice	bale
1.5	Vicksbg	rough-rock	lining	my	nanny	bucket	
1.6	Saint	west	lunar	malay	new	market	bale
1.7	Leawth	merry	lemon	sunk	each		
1.8	Cairo	rural	lining	new	johnson	none	ice
1.9	Missouri	windy	lunar	mew	Johnson	none	bucket
1.10	Elliott	remorse	legacy	sunk	dew		
1.11	Concordia	mammon	layman	null	event		
1.12	Concordia	meraccous (?)	humuss	nail	menu	barrack	

Table 1. Transcription of Sheet 1.

2.1	Bismark	Omit	leafage	buck	bank		
2.2	Paul	Ramify	loamy	event	false	new	event
2.3	Helena	onus	lofo	us	nail	each	
2.4	Green Bay	nobby	piped				
2.5	Assin	Onago	league	new	forbade	event	
2.6	Custer	Down					
2.7	Garry	noun	Tertal	lawful	palm	novice	event
2.8	Minnedos	noun	Tommy	leafage	beak	doffin	
2.9	Calgarry	Cuba	Unguard	confute	duck	fagan	egypt
2.10	Grub	wrongful	hug	duck	fagan	each	
2.11	Calgarry	noun	Signor	loamy	mew	ginned	
2.12	Landing	noun	Rugins	legacy	dsrch (?)	baby	ice

Table 2. Transcription of Sheet 2.

For the first time in history, information about the weather could travel faster than the weather itself. This enabled the prospect of operational weather forecasts on a nationwide scale.

Systematic nationwide weather observations in the United States began under the auspices of the Smithsonian Institution in 1849 (Hochfelder, 2012, 59). Observations were conducted by volunteers and were made three times a day and transmitted by telegraph to the Smithsonian. At the end of 1849, there were 150 volunteer weather observers, and by 1860, there were 500 weather stations across the United States reporting their tri-daily observations by telegraph (National Weather Service, 2015). Observations were paused during the American Civil War, but resumed thereafter. In 1870, oversight of the observation network was transferred to the United States Army Signal Service (Signal Corps)[2], under the command of Albert J. Myer, its founder and first chief signal officer (Weber, 1922, 3–4).

Observations were not limited to the continental United States. Beginning in 1871, there was an agreement between the weather services of the United States and Canada to exchange daily meteorological observations via telegraph (Thomas, 1991, 158–161). By 1892, stations in Jamaica, Barbados, Bermuda and Cuba were also exchanging

[2]The name "Signal Service" was in use between 1865 and 1890 (Hawes, 1966), which is the focus of the present article.

observations with the Signal Service (U.S. Department of Agriculture, 1892, 5).

According to the "General Instructions to Observers of the Signal Service" (War Department, 1887a, 6), there were three orders (levels) of weather station: stations of the first order kept continuous records using self-registering instruments; stations of the second order took three or more observations daily; and third order stations took one observation daily. In addition to the three orders of observing stations, the Signal Service had repair stations and several different types of special stations, such as river stations that measured the level of water in rivers, and cotton-region stations that made one daily observation in cotton-growing areas.

Standardized meteorological instruments were provided by the Signal Service for each weather station, which were manned by soldiers of the Signal Service. The times of day for the three daily observations changed several times over the years. Initially, the observations were at 7:35 a.m., 4:35 p.m., and 11:35 p.m. (Washington, D.C. time)[3]. All Signal Service observers across the United States were required to keep a clock set to Washington time so that the observations could be made as coincident in time as possible (War Department, 1887a, 73). In 1885, observations were taken at 7:00 a.m., 3:00 p.m., and 11:00 p.m., and a change was made to use 75th meridian time, which was eight minutes faster than Washington time. In 1887, the evening observation was changed to 10:00 p.m., and on July 1, 1888, the number of observations was reduced to twice a day at 8 a.m. and 8 p.m. (75th meridian time) (War Department, 1887–1891, 1).

After the meteorological instruments were read (which began approximately 15 minutes before the appointed observation time) (Weber, 1922, 18), the Signal Service observer encoded the readings according to the weather codebook. The coded message was then conveyed to a telegraph office where it was transmitted. Signal Service weather reports had priority over all other telegraphic traffic, so the lines had to be held open by the telegraph company during the times of the observations (Moore, 1910, 54).

All stations relayed their reports to the Washington, D.C. weather office through a series of telegraphic circuits. A number of stations were on each circuit, and the stations in a circuit would send their reports one at a time in a round-robin manner. All stations on the same circuit received each report, which was copied by the operator at each station.

The *1881 General Orders and Circulars* (War Department, 1881b) provides a detailed account of the telegraphic circuit system:

> At 7.25 a. m., 3.25 p. m. and 11.25 p. m., Washington mean time [by 1888, these times had changed to 7:00 a.m., 3:00 p.m., and 10:00 p.m.], the station farthest from the Central Office [Washington, D.C.] on each circuit running directly into that Office starts his report; it is copied by every station on the circuit; as soon as this station is through, the next station sends; he is followed by the next, and so on until every station has sent its report. While this is being done, all other circuits are collecting reports at the terminal office of each nearest Washington; the station on each circuit nearest this terminal sending first, being followed by the others in regular succession, the last to send being that station of the circuit farthest from Washington. As this is a simultaneous movement on the various circuits, it has the effect of converging the reports at the same instant of time, by various paths, upon the central office. When the signal hour is up, the circuits, by a preconcerted signal, close, and missing reports have to wait till the next signal hour.

[3]Standard time zones were not in usage until the 1880s and not formally adopted by the United States until 1918.

Within three hours after the observations were conducted, national weather maps were generated by the Washington office, printed, and sent to the press and posted in public spaces (Moore, 1910, 56).

In July 1891, the Signal Service transferred responsibility of the weather observation network to the newly-formed United States Weather Bureau within the U.S. Department of Agriculture, ending the Signal Service's twenty-one year tenure as the national weather service and passing oversight to civilian hands (Moore, 1910, 45).

6. U.S. Army Signal Service/U.S. Weather Bureau Code

As weather stations needed to transmit reports several times a day, it was desired to reduce the number of words required in a weather report to lessen the cost. Available commercial codebooks were not wholly suitable because of the specialized nature of the reports, so a specific telegraph code for meteorology was developed. The initial weather code that was employed by the Signal Service consisted of a series of numbers that were used to represent the name of the weather station, instrument readings, state of the weather, and cloud conditions. Twenty numbers were used for the morning report and ten for the afternoon and evening report, because the relative humidity and precipitation readings were omitted for those reports (Gariott, 1905). In 1871, a new code was adopted that was more economical – it could encode a full meteorological report with only ten words, using one word for each of: station name, barometric pressure, temperature, relative humidity, wind speed, wind direction, state of weather, cloud conditions, precipitation, and time and day of month of the observation.

An even more economical code was developed by Chief Signal Officer A.W. Greely and adopted in 1887. It could encode a full report with an average of only six words. The biggest change was that the code could be read on sight with practice. The previous code used arbitrarily selected words to represent different attributes, whereas the 1887 code mainly used words that followed a particular pattern in its use of consonants and vowels which could be interpreted (Gariott, 1905).

New weather codebooks were published every few years, sometimes with significant revisions. Between 1888 and 1900, editions were published in 1889, 1892, and 1896, with the latter two codebooks being published by the U.S. Weather Bureau, which had taken over from the Signal Service in 1891. In addition, revisions were often made between editions, with the changes being mailed to observers.

New editions of the weather codebook continued to be issued well into the mid-twentieth century. In 1939, the Weather Bureau overhauled the weather code yet again and switched back to a numeric code instead of a word code (U.S. Weather Bureau, 1939).

The focus here will be on the 1887 Weather Code, which is the one that pertains to the Silk Dress cryptogram (this will be explained in Section 7.1). The code was in effect between July 16, 1887 (War Department, 1887b, 3) and March 31, 1889 (War Department, 1889c, 3). The format of the telegraphic weather report for the 1887 code consisted of up to 11 fields (codewords):

(1) Name of station. A list of stations and the names to be used in telegrams were provided in the codebook. The 1887 codebook lists 182 stations, with 23 of them being Canadian stations[4] and three being outside of North America (War Department, 1887b, 5).

[4]These include stations that were in British North America, but are now in present-day Canada.

(2) Pressure and temperature. Air temperature and barometric pressure (corrected to sea level) were encoded to the nearest even integer. According to Paragraph 17 of the 1887 codebook, "When a thermometer or barometer reading is exactly half way between two even numbers, the next lowest even number, as given in the code, will be used" (War Department, 1887b, 9).

If the temperature was above 100°F or below 0°F, the codewords represented two possible values for temperature. According to Paragraph 20 of the 1887 Weather Code (War Department, 1887b, 9), "Whenever the temperature exceeds 100°, the one hundred is omitted, and only the excess of one hundred is enciphered and sent. In cases where the temperature is below zero, the *complementary* word is sent, the code word being that which stands for the temperature found after subtracting the number of degrees below zero from the one hundred degrees. That is, the complement of -1° is 99°; the complement of -10° is 90°, &c. The intelligence of the translators will prevent any error arising when temperatures exceed 100°or are below zero."

For barometric pressure, only the fractional portion of the pressure value (in inches of mercury, inHg) was transmitted. Paragraph 18 of the 1887 codebook stated that "the receiving observers will be sufficiently intelligent to supply for all stations east of the 97th meridian (see Form 106b) the missing inches, whether they be 28, 29, 30, or 31. At stations to the westward of the 97th meridian, the code will have the words eight, nine, thirty, or one precede the code word when the barometer reads either below 29.40 or above 30.38. These words, as the case demands, indicate that the inches are 28, 29 (below .40), 30 (above .38) or 31, as the case may be" (War Department, 1887b, 9).

(3) Dew point and time of observation. Three columns of codewords represented the dew point for the three daily observations. The first column was for the 7:00 a.m. observation and consisted of words starting with "C"; the second column was for the 3:00 p.m. observation and consisted of word starting with "K"; and the third column had words starting with "L" for the 10:00 p.m. observation (see Figure 6). Note that by the date of the observations in the Silk Dress cryptogram, these codewords had been revised (see Section 7.1).

(4) Wind direction, state of weather, and precipitation. Selected codewords could represent either zero or trace precipitation. According to Paragraph 34 of the 1887 codebook, if there is a trace of precipitation, the codeword "JOHNSON" immediately followed the codeword for wind direction/state of weather/precipitation. Otherwise, the codeword represented zero precipitation, along with the wind direction and state of weather.

(5) Upper clouds (if $\geq$ 2 tenths cloud cover, otherwise the field was omitted).

(6) Lower clouds (if $\geq$ 2 tenths cloud cover, otherwise the field was omitted), except nimbus clouds, which were only encoded if the cloud direction differed from the surface wind direction.

(7) Current wind velocity and maximum temperature; or current wind velocity and minimum temperature; or current wind velocity and sunset observation. Which of these three meanings was employed was determined by the time of day of the observation. If it was the 7:00 a.m. observation, then the meaning of the codeword was interpreted as current wind velocity and minimum temperature. If it was the 3:00 p.m. observation, the meaning was current wind velocity and maximum temperature. Finally, for the 10:00 p.m. observation, the codeword represented the current wind velocity and the character of the sunset.

(8) Maximum wind velocity and direction (specially designated stations only).

(9) Report on river observations (specially designated stations and certain authorized reports only).
(10) District cotton-region reports (cotton-region centers only).
(11) Special monthly reports, as required by orders.

The order of the words was important – the first codeword had to be the station name, followed by the codeword representing the pressure and temperature, etc. The codewords for each weather element were not mutually exclusive – the same codeword might be used for more than one weather element, hence the position of the word on the line was salient in determining its meaning. Nevertheless, the position of a particular field was not absolute. For instance, if the codeword for the fourth field (wind direction, state of weather and precipitation) indicated that the sky was clear[5] then the next two fields, normally reserved for upper and lower cloud observations, may be omitted and the current wind velocity field would be the fifth field. In addition, in the absence of either upper or lower clouds, only one field would be used for cloud observations. It was up to the recipient to understand the type of clouds represented by the codeword and determine whether it was an upper or lower cloud observation.

Fields 8–10 were for special stations only, and Field 11 was for special monthly reports. None of these fields appeared in any of the messages in the Silk Dress cryptogram.

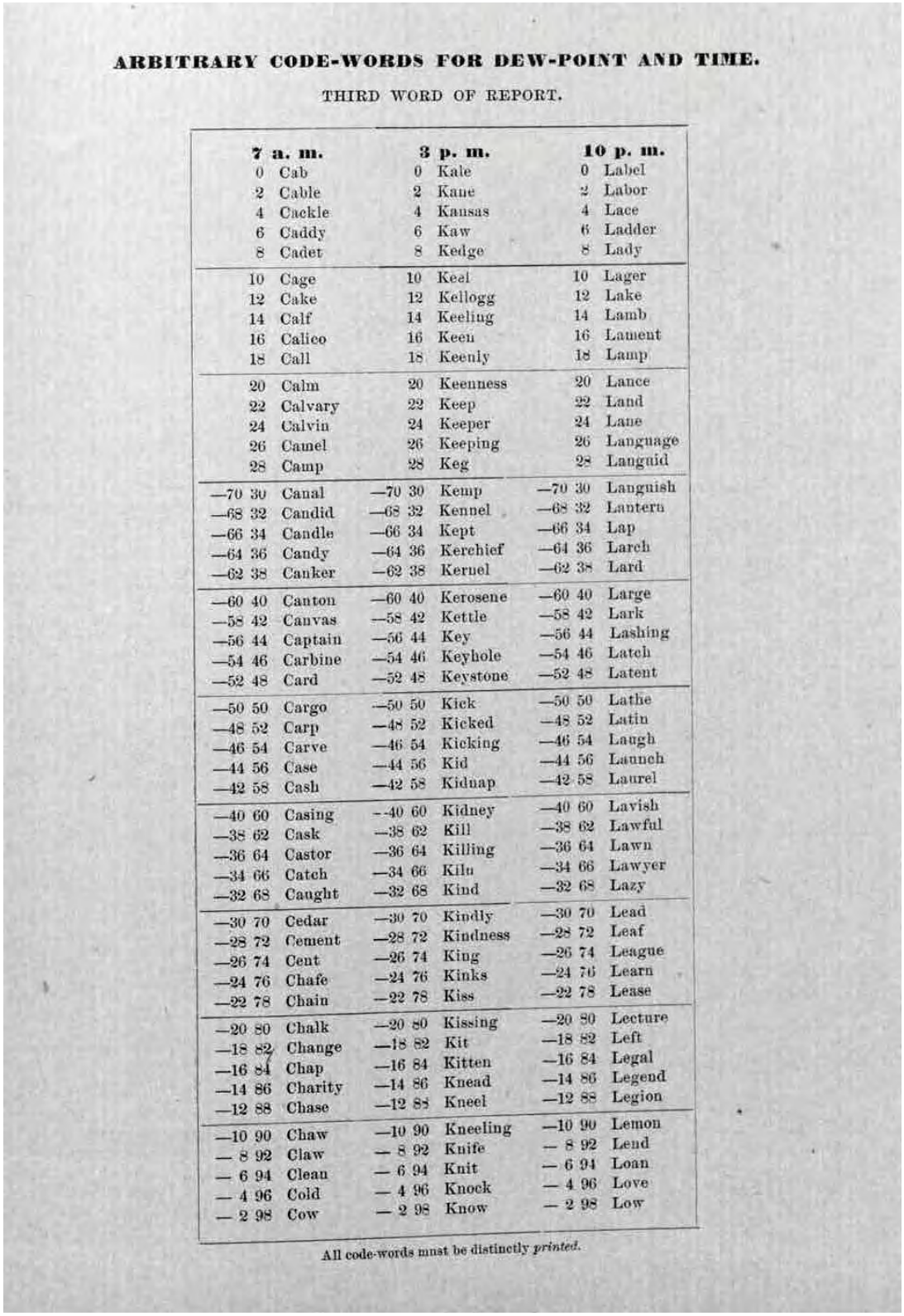
As mentioned, starting with the 1887 Weather Code, the code could be interpreted on sight with practice. The consonants B, D, F, G, M, N, R, S, and T represented 10, 20, 30, 40, 50, 60, 70, 80, and 90, while the vowels A, E, I, O, and U/Y represented 2, 4, 6, 8, and 0, respectively. The list of consonants except T were also used to encode the cardinal directions, with B representing north, D representing northeast, etc. The vowels were also used to encode the weather conditions, with A = "fair", E = "cloudy", I meaning "rain", O for "snow", and U/Y for "clear". The first consonant and following vowel for each syllable of a codeword represented different weather elements. For instance, the initial consonant and subsequent vowel of the first syllable of a codeword may represent barometric pressure, while the leading consonant and following vowel of the second syllable may represent air temperature.

Although most of the codewords could be translated on sight in the 1887 codebook, there were still some words, starting with "W", that were not directly translatable and had to be looked up. These were referred to as "arbitrary" codewords. By the 1889 codebook, these exceptions were largely eliminated (War Department, 1890, 131). The 1889 Weather Code also saw a significant change to the order of the fields of the telegram, as well as a new field being added for the occurrence of frost.

6.1. *Example*

An example of the Signal Service weather code for a 7:00 a.m. observation is the following message: "PAUL, BURNETT, CARP, MEMBER, DANUBE, NIMMER, IMMENSE". This decodes to the plaintext in Table 3. Note that for the last codeword ("IMMENSE"), the meaning is interpreted as current wind velocity and minimum temperature because it is the 7:00 a.m. observation. If it had been a 3:00 p.m. observation, the temperature would have been interpreted as the maximum daily temperature, and

[5]According to the *Instructions to Observers of the Signal Service* (War Department, 1881c, 63), a clear sky was recorded if the cloud cover was three tenths or less. So there could still be cloud observation fields if the sky was considered clear, if the cloud cover was at least two tenths. If the sky was actually cloudless, then the two cloud observation fields would be omitted.



ARBITRARY CODE-WORDS FOR DEW-POINT AND TIME.

THIRD WORD OF REPORT.

7 a. m.		3 p. m.		10 p. m.	
0	Cab	0	Kale	0	Label
2	Cable	2	Kane	2	Labor
4	Cackle	4	Kansas	4	Lace
6	Caddy	6	Kaw	6	Ladder
8	Cadet	8	Kedge	8	Lady
10	Cage	10	Keel	10	Lager
12	Cake	12	Kellogg	12	Lake
14	Calf	14	Keeling	14	Lamb
16	Calico	16	Keen	16	Lament
18	Call	18	Keenly	18	Lamp
20	Calm	20	Keenness	20	Lance
22	Calvary	22	Keep	22	Land
24	Calvin	24	Keeper	24	Lane
26	Camel	26	Keeping	26	Language
28	Camp	28	Keg	28	Languid
—70 30	Canal	—70 30	Kemp	—70 30	Languish
—68 32	Candid	—68 32	Kennel	—68 32	Lantern
—66 34	Candle	—66 34	Kept	—66 34	Lap
—64 36	Candy	—64 36	Kerchief	—64 36	Larch
—62 38	Canker	—62 38	Kernel	—62 38	Lard
—60 40	Canton	—60 40	Kerosene	—60 40	Large
—58 42	Canvas	—58 42	Kettle	—58 42	Lark
—56 44	Captain	—56 44	Key	—56 44	Lashing
—54 46	Carbine	—54 46	Keyhole	—54 46	Latch
—52 48	Card	—52 48	Keystone	—52 48	Latent
—50 50	Cargo	—50 50	Kick	—50 50	Lathe
—48 52	Carp	—48 52	Kicked	—48 52	Latin
—46 54	Carve	—46 54	Kicking	—46 54	Laugh
—44 56	Case	—44 56	Kid	—44 56	Launch
—42 58	Cash	—42 58	Kidnap	—42 58	Laurel
—40 60	Casing	—40 60	Kidney	—40 60	Lavish
—38 62	Cask	—38 62	Kill	—38 62	Lawful
—36 64	Castor	—36 64	Killing	—36 64	Lawn
—34 66	Catch	—34 66	Kiln	—34 66	Lawyer
—32 68	Caught	—32 68	Kind	—32 68	Lazy
—30 70	Cedar	—30 70	Kindly	—30 70	Lead
—28 72	Cement	—28 72	Kindness	—28 72	Leaf
—26 74	Cent	—26 74	King	—26 74	League
—24 76	Chafe	—24 76	Kinks	—24 76	Learn
—22 78	Chain	—22 78	Kiss	—22 78	Lease
—20 80	Chalk	—20 80	Kissing	—20 80	Lecture
—18 82	Change	—18 82	Kit	—18 82	Left
—16 84	Chap	—16 84	Kitten	—16 84	Legal
—14 86	Charity	—14 86	Knead	—14 86	Legend
—12 88	Chase	—12 88	Kneel	—12 88	Legion
—10 90	Chaw	—10 90	Kneeling	—10 90	Lemon
— 8 92	Claw	— 8 92	Knife	— 8 92	Lend
— 6 94	Clean	— 6 94	Knit	— 6 94	Loan
— 4 96	Cold	— 4 96	Knock	— 4 96	Love
— 2 98	Cow	— 2 98	Know	— 2 98	Low

All code-words must be distinctly *printed*.

Figure 6. Codewords for dew point and time of observation from 1887 Weather Code.

for a 10:00 p.m. observation, a different set of codewords would have been used which coded for the character of the sunset in addition to the wind velocity. For a 6 mph wind velocity and a clear sunset, for instance, the codeword would have been "INK". Figure 7 shows an excerpt of the 1887 codebook for the last codeword (current wind velocity/minimum or maximum temperature/sunset).

PAUL	Station Name: St. Paul, Minnesota
BURNETT	Air Temperature: 64°F Barometric Pressure: 0.10 inHg
CARP	Dew Point: 52 °F Observation time: 7:00 a.m.
MEMBER	State of weather: Cloudy Precipitation: 0.14 in. Wind direction: South
DANUBE	Cloud type (upper): Cirro-cumulus Cloud cover (upper): 2–3 tenths Cloud direction (upper): Southwest
NIMMER	Cloud type (lower): Stratus Cloud cover (lower): 6–7 tenths Cloud direction (lower): South
IMMENSE	Current wind velocity: 6 mph Minimum temperature: 54°F

Table 3. Weather code example.

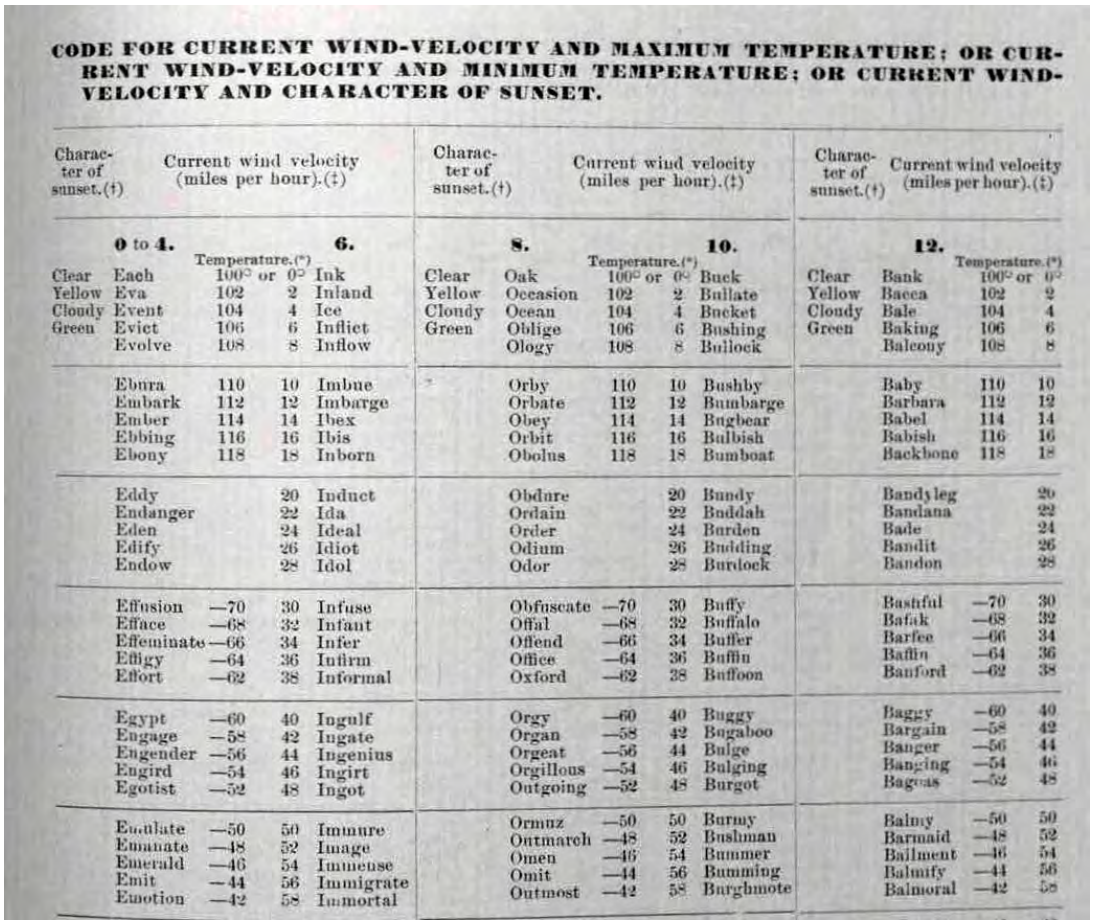
The code's feature of being translatable on sight can be seen in the second codeword ("BURNETT"). The letter "B" represents 10 and "U" is 0. This provided the barometric pressure value (0.10 inHg). The next consonant-vowel pairing is "NE", which translates to 64, giving the air temperature in degrees Fahrenheit.

7. Decoding the Cryptogram

Before any decoding could be performed, the date of the observations had to be ascertained, as this would determine the edition of the Signal Service codebook to use. Section 7.1 explains how this was accomplished.

It was apparent from the station names (generally the first word of each line) that the last six messages on Code Sheet 2 were for Canadian stations, as their names matched ones found in the station listing of the 1887 Weather Code (War Department, 1887b, p.5). In attempting to decode these messages, it was discovered that the Canadian messages differed in format from messages for U.S. stations. This format had to be reverse engineered. This will be discussed in Section 7.2.

The stations on the two code sheets appear to be grouped geographically. The stations in Code Sheet 1 are all south of 40°N latitude, whereas the stations in Code



CODE FOR CURRENT WIND-VELOCITY AND MAXIMUM TEMPERATURE; OR CURRENT WIND-VELOCITY AND MINIMUM TEMPERATURE; OR CURRENT WIND-VELOCITY AND CHARACTER OF SUNSET.

Character of sunset.(†)	Current wind velocity (miles per hour).(‡)			Character of sunset.(†)	Current wind velocity (miles per hour).(‡)			Character of sunset.(†)	Current wind velocity (miles per hour).(‡)		
	0 to 4.	Temperature.(*)	**6.**		**8.**	Temperature.(*)	**10.**		**12.**	Temperature.(*)	
		100° or	0°			100° or	0°			100° or	0°
Clear	Each			Ink	Oak			Buck	Bank		
Yellow	Eva	102	2	Inland	Occasion	102	2	Bullate	Bacca	102	2
Cloudy	Event	104	4	Ice	Ocean	104	4	Bucket	Bale	104	4
Green	Evict	106	6	Inflict	Oblige	106	6	Bushing	Baking	106	6
	Evolve	108	8	Inflow	Ology	108	8	Bullock	Balcony	108	8
	Ebnra	110	10	Imbue	Orby	110	10	Bushby	Baby	110	10
	Embark	112	12	Imbarge	Orbate	112	12	Bumbarge	Barbara	112	12
	Ember	114	14	Ibex	Obey	114	14	Bugbear	Babel	114	14
	Ebbing	116	16	Ibis	Orbit	116	16	Bulbish	Babish	116	16
	Ebony	118	18	Inborn	Obolus	118	18	Bumboat	Backbone	118	18
	Eddy		20	Induct	Obdure		20	Bundy	Bandyleg		20
	Endanger		22	Ida	Ordain		22	Buddah	Bandana		22
	Eden		24	Ideal	Order		24	Burden	Bade		24
	Edify		26	Idiot	Odium		26	Budding	Bandit		26
	Endow		28	Idol	Odor		28	Burdock	Bandon		28
	Effusion	—70	30	Infuse	Obfuscate	—70	30	Buffy	Bashful	—70	30
	Efface	—68	32	Infant	Offal	—68	32	Buffalo	Bafak	—68	32
	Effeminate	—66	34	Infer	Offend	—66	34	Buffer	Barfee	—66	34
	Effigy	—64	36	Infirm	Office	—64	36	Buffin	Baffin	—64	36
	Effort	—62	38	Informal	Oxford	—62	38	Buffoon	Banford	—62	38
	Egypt	—60	40	Ingulf	Orgy	—60	40	Buggy	Baggy	—60	40
	Engage	—58	42	Ingate	Organ	—58	42	Bugaboo	Bargain	—58	42
	Engender	—56	44	Ingenius	Orgeat	—56	44	Bulge	Banger	—56	44
	Engird	—54	46	Ingirt	Orgillous	—54	46	Bulging	Banging	—54	46
	Egotist	—52	48	Ingot	Outgoing	—52	48	Burgot	Bagpas	—52	48
	Emulate	—50	50	Immure	Ormuz	—50	50	Burmy	Balmy	—50	50
	Emanate	—48	52	Image	Outmarch	—48	52	Bushman	Barmaid	—48	52
	Emerald	—46	54	Immense	Omen	—46	54	Bummer	Bailment	—46	54
	Emit	—44	56	Immigrate	Omit	—44	56	Bumming	Balmify	—44	56
	Emotion	—42	58	Immortal	Outmost	—42	58	Burghmote	Balmoral	—42	58

Figure 7. Excerpt of 1887 Weather Code for current wind velocity/minimum or maximum temperature/character of sunset.

Sheet 2 are in Canada and the northern United States. This suggests that the stations on the two code sheets were on different telegraphic circuits.

A full decoding of all the messages is found in Appendix A.

7.1. *Date of the Observations*

Determining the year of the observations in the cryptogram was of paramount importance, as it dictated which edition of the Signal Service codebook was used. In addition, since some of the weather variables, such as temperature, had two possible values when decoded, it was important to determine the date or at least the time of year when the observations were made.

An upper bound for the year of the observations was determined by the fact that Message 2.5 was for Fort Assiniboine, Montana, a station that was discontinued in 1892 (U.S. Department of Agriculture, 1893, 17). Similarly, a lower bound of 1886 could be established because the Green Bay, Wisconsin station (Message 2.4) did not start operating until that year. These bounds narrowed the possible editions of the codebook to 1887, 1889, and 1892. (Although the 1872 codebook was a possibility, as it was still in effect in 1886, its message format was different from the later editions and its codewords did not match the cryptogram.)

Examining the two possible values for temperature for each decoded message, some values seemed highly improbable given the station's location. As an example, Message 1.10 for Fort Elliott, Texas had -42°F or 58°F as possibilities. The first temperature is well below the lowest recorded temperature for the state of Texas (-23°F or -30.56°C) (National Weather Service, 2023). This was the case for a number of the messages in the cryptogram, so it was concluded that the second value for temperature was more likely. Given that many of the temperatures were over 60°F (15.56°C) for stations in Canada and the northern United States, it was assumed that the time of year was most likely in the spring, summer or fall.

The key to narrowing the date was found in the messages for the Canadian stations. Although messages for the American stations did not encode the date, it was found that the Canadian messages did encode the day of the month as the second field of the message. Messages 2.7, 2.8, and 2.11 for Fort Garry, Minnedosa, and Calgary, respectively, contained the word "NOUN" as the second field, meaning the evening observation for the 27th of the month. Additionally, Messages 2.9 and 2.10 for Calgary contained "CUBA" and "GRUB", which represented the morning and afternoon observations for the 27th.

The original daily Signal Service weather maps for the continental United States are available online at the NOAA Central Library (`https://library.noaa.gov/Collections/Digital-Collections/US-Daily-Weather-Maps`). These maps provided the temperature, barometric pressure, precipitation, wind direction and wind speed for the Signal Service weather stations across the United States. Maps were published for the morning, afternoon, and evening observations. By systematically examining the maps for a number of stations for the 27th of the month between April and October for the years 1886 to 1892 and comparing the temperature and barometric pressure from the maps with the decoded observations[6], it was found that May 27,

[6]Although the exact edition of the codebook was not known at this stage, the three possibilities (1887, 1889, and 1892) all had temperature and pressure as the second field, and the codewords for these weather elements were largely similar between the editions, with the biggest change being the elimination of arbitrary words starting with "W" in the 1889 edition. Trial decodings were performed with all three editions, to look for any differences. The presence of words starting with "W" in Messages 1.4, 1.6, and 1.9 confirmed that the 1887

1888 was an excellent match for the decoded observations from both code sheets of the Silk Dress cryptogram.

Since 1888 was the year of the observations, the 1887 edition of the codebook was the appropriate one to use, as the next edition was not until 1889. However, it was discovered that a number of revisions had been made to the 1887 code after its publication and before the next edition. These revisions were issued as general orders by the Signal Service. Hence, these changes had to be factored in when decoding the messages.

An example of such a change is the list of codewords for dew point and time of observation. On December 1, 1887, the codewords were changed according to 1887 General Order No. 62 (Nov. 8, 1887) (War Department, 1887–1891, 296), thus invalidating the words in the 1887 Weather Code. The general order did not provide the new list of words, which was apparently sent separately to the observers, but it appears that the new words were the same as those in the subsequent 1889 Weather Code. The main change was that the words for representing the dew point for the 3:00 p.m. observation started with "K" in 1887 and "H" in 1889. According to General Order No. 62, this was done to make the codewords conform to the format used by the other weather elements, making them translatable on sight.

However, by the publication of the 1889 Weather Code, the number of daily observations had been reduced to two, although there were still three columns of codewords for dew point and time of observation, representing the 8:00 a.m. observation; the 8:00 p.m. observation with a local prediction of fair weather; and the 8:00 p.m. observation with a local prediction of foul weather (see Figure 8). (The fair and foul weather prediction and the relabelling of the times of the columns were according to General Order No. 21 (May 21, 1888), taking effect July 1, 1888 (War Department, 1887–1891, 241).)

Thus, in order to use the 1889 codeword list for dew point and time of observation for readings that took place in May 1888, the column headings had to be changed back to what they were before General Order No. 21 was issued, with the first column being for 7:00 a.m., the second for 3:00 p.m., and the third column for 10:00 p.m.

7.2. *Canadian Weather Code*

The Canadian weather service relied on the U.S. Signal Service telegraph code (Thomas, 1991, 163–64), with some apparent changes. The times of day for Canadian observations were the same as for U.S. stations to enable all observations to be as close to simultaneous as possible (Kingston, 1878, 167). Whenever the U.S. Signal Service changed the observation times, the Canadian Meteorological Service followed suit (Carpmael, 1892, xiii).

The last six messages of Code Sheet 2 contain observations for a number of Canadian weather stations. "GARRY" in Message 2.7 refers to Fort Garry, a Hudson's Bay Company fur trading post located near the confluence of the Red and Assiniboine Rivers in present-day Winnipeg, Manitoba. This was the name chosen for the meteorological station, but the observations were not actually taken at the fort (which was demolished in 1882), but rather at St. John's College, a constituent college of the University of Manitoba (Thomas, 1991, 252). (Note that according to 1888 Signal Service General Order No. 15 (April 19, 1888) (War Department, 1887–1891, 251), the station should have been called "Winnipeg" after May 1, 1888. The observer seems to be in

codebook was the correct one.

CODE FOR DEW-POINT AND TIME.

		Local Prediction.			
		Fair.		Foul.	
8 a. m.		8 p. m.		8 p. m.	
0	Cab	0	Heck	0	Lack
2	Cavalry	2	Holland	2	Lilac
4	Clean	4	Hale	4	Lace
6	Calling	6	Holiday	6	Lavish
8	Callow	8	Hollow	8	Lincoln
10	Carbuncle	10	Hamburg	10	Lobby
12	Cabal	12	Herbage	12	Libation
14	Cumber	14	Habel	14	Libel
16	Cabin	16	Habit	16	Labiated
18	Carbon	18	Harbor	18	Labor
20	Candy	20	Handy	20	Lady
22	Cedar	22	Hidalgo	22	Laudation
24	Cadet	24	Hidden	24	Lode
26	Cordial	26	Hiding	26	Landing
28	Candor	28	Haddock	28	London
—70 30	Confute	—70 30	Huffy	—70 30	Lawful
—68 32	Carfare	—68 32	Holdfast	—68 32	Leafage
—66 34	Coffee	—66 34	Heifer	—66 34	Life
—64 36	Confine	—64 36	Hadfield	—64 36	Loafing
—62 38	Comfort	—62 38	Hartford	—62 38	Lofo
—60 40	Coagulate	—60 40	Handgun	—60 40	League
—58 42	Cigar	—58 42	Haggard	—58 42	Legacy
—56 44	Cage	—56 44	Hinge	—56 44	Linger
—54 46	Cogitate	—54 46	Hanging	—54 46	Logic
—52 48	Cargo	—52 48	Hugo	—52 48	Lingo
—50 50	Commute	—50 50	Humus	—50 50	Loamy
—48 52	Comma	—48 52	Homage	—48 52	Layman
—46 54	Camel	—46 54	Home	—46 54	Lament
—44 56	Commit	—44 56	Humid	—44 56	Limit
—42 58	Common	—42 58	Harmon	—42 58	Lemon
—40 60	Connubial	—40 60	Horny	—40 60	Lanyard
—38 62	Canal	—38 62	Hannah	—38 62	Lunar
—36 64	Cane	—36 64	Hone	—36 64	Linnet
—34 66	Canine	—34 66	Hernia	—34 66	Lining
—32 68	Canopy	—32 68	Honor	—32 68	Linnock
—30 70	Carry	—30 70	Hairy	—30 70	Lerry
—28 72	Curate	—28 72	Harass	—28 72	Library
—26 74	Careen	—26 74	Hebrew	—26 74	Lure
—24 76	Carriage	—24 76	Hearing	—24 76	Lurid
—22 78	Carroll	—22 78	Harrow	—22 78	Latrobe
—20 80	Casual	—20 80	Hirsute	—20 80	Lawsuit
—18 82	Corsage	—18 82	Hersal	—18 82	Losable
—16 84	Casement	—16 84	Hose	—16 84	Lease
—14 86	Casing	—14 86	Hissing	—14 86	Lassitude
—12 88	Cassock	—12 88	Hansom	—12 88	Lesson
—10 90	Capture	—10 90	Hasty	—10 90	Lecture
— 8 92	Cantata	— 8 92	Hostage	— 8 92	Lactant
— 6 94	Canteen	— 6 94	Halter	— 6 94	Later
— 4 96	Caution	— 4 96	Halting	— 4 96	Lasting
— 2 98	Castor	— 2 98	Hector	— 2 98	Lictor

All code words must be distinctly *printed*.

Figure 8. Codewords for dew point and time of observation from 1889 Weather Code.

error in continuing to refer to it as "Fort Garry", since the date of the observations in the messages is May 27.)

"MINNEDOS" in Message 2.8 is Minnedosa, Manitoba, a town west of Winnipeg. "CALGARRY" is Calgary, Alberta. It should be noted that the misspelling with a double "r" is how it was spelled in the 1887 and 1889 Signal Service codebooks. This was corrected in the 1892 edition. In Message 2.12, "LANDING" refers to Prince Arthur's Landing, Ontario, which is now called Thunder Bay.

Messages 2.9–2.11 are noteworthy as they represent all three daily observations for Calgary. This was determined by matching the decoded weather readings with the original meteorological registers. Message 2.9 is the morning (7:00 a.m.) observation, 2.10 is for 3:00 p.m., and Message 2.11 is the evening (10:00 p.m.) observation. The station name in Message 2.10 was omitted, likely because it was not necessary.

The format of the telegraph messages for the Canadian stations seems to differ from the messages for American stations. This became apparent when I attempted to decode the last six messages of Code Sheet 2. The codewords "NOUN" and "CUBA", which appear in the second field of several of the messages, were not found in the 1887 Weather Code. The format of the code had to be reverse engineered, as there was very little information about the code used by the Canadian stations in either the U.S. Signal Service documentation or its Canadian counterpart, the Meteorological Service of the Dominion of Canada. The format appears to rely on the Signal Service codebook, but does not exactly follow the message format used by the U.S. stations.

The derived format for the Canadian weather telegrams is as follows:

(1) Name of station.

(2) Day of month and time of observation. The 1889 and 1892 codebooks (War Department, 1889c; U.S. Department of Agriculture, 1892) provide a list of special codewords for Canadian stations to represent the day of the month and time of day of the observation. (Messages for U.S. stations did not encode the date by this point.) This list did not appear in the 1887 codebook, but it is assumed that a revision had been issued between the publication of the 1887 and 1889 codebooks and that this list of codewords was in use at the time of the messages in May 1888.

    By 1889, there were only two daily observations (8:00 a.m. and 8:00 p.m.), so the list in the 1889 codebook provides a column of codewords for the a.m. observation and another column for the p.m. observation. The a.m. codewords all start with the letter "C", while the p.m. codewords begin with "N". It is probable that a similar list of codewords was in use in 1888, but with a third column to represent the afternoon observations that were still in effect at that time. A clue as to the missing column of codewords for the 3:00 p.m. observations was found in the 1872 codebook (War Department, 1872, 169–180). In this earlier edition of the code, day of the month was encoded in messages for U.S. stations. (This was omitted by the time of the 1887 Weather Code.) Three columns of codewords (to represent the morning, afternoon, and evening observations) were provided. The codewords for the afternoon observation all started with the letter "G". There is evidence that this list of codewords was still in use in the 1880s, as Table IV of 1884 General Order No. 21 (March 1, 1884) (War Department, 1885), showed a nearly identical list of codewords for the special 5:00 p.m. observations for cotton-region stations (see Figure 9). The only difference from the 1872 list was that the word "GIRD" (meaning the afternoon observation for the 18th of the month) was changed to "GIMP". The word "GRUB" (found in Message 2.10)

represented the 27th of the month, which fits the date of the other messages in the cryptogram (and provides additional confirmation that May 27, 1888 was the correct date for all the observations). It is believed that this list of codewords starting with "G" was used for the regular 3:00 p.m. observations for Canadian stations.

(3) Pressure and temperature. Same codewords as for U.S. stations.

(4) Relative humidity and time of observation. Based on a comparison with the original meteorological records, the third codeword appears to represent relative humidity rather than dew point, but it uses the dew point codewords from the Signal Service codebook.

(5) Wind direction, state of weather, and precipitation. Same codewords as for U.S. stations.

(6) Clouds (if $\geq$ 2 tenths cloud cover). Same codewords as for U.S. stations., but there seems to be only one field for cloud observations. A comparison of the decoded codewords and the original meteorological records shows that both upper and lower cloud types were found in this field.

(7) Current wind velocity and maximum temperature; or current wind velocity and minimum temperature; or current wind velocity and sunset observation (same as Field 7 in the code for U.S. stations).

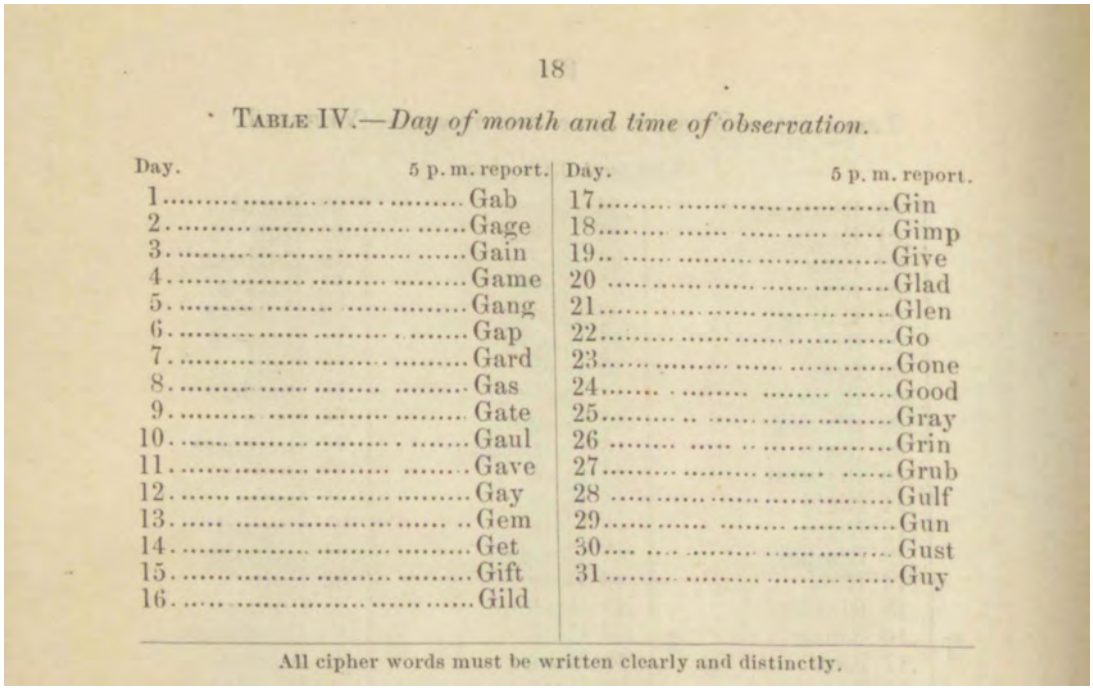


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TABLE IV.—*Day of month and time of observation.*

Day.	5 p. m. report.	Day.	5 p. m. report.
1	Gab	17	Gin
2	Gage	18	Gimp
3	Gain	19	Give
4	Game	20	Glad
5	Gang	21	Glen
6	Gap	22	Go
7	Gard	23	Gone
8	Gas	24	Good
9	Gate	25	Gray
10	Gaul	26	Grin
11	Gave	27	Grub
12	Gay	28	Gulf
13	Gem	29	Gun
14	Get	30	Gust
15	Gift	31	Guy
16	Gild		

All cipher words must be written clearly and distinctly.

Figure 9. Codeword list for 5:00 p.m. cotton-region observations. (from 1884 General Order No. 21.)

7.3. *Some Aspects of the Decoding*

7.3.1. Frequency of Third Words Starting with "L"

In Section 3, it was noted that the third word of the messages often started with the letter "L". The third word represents the dew point and time of observation. Because

the majority of the weather observations were for the 10:00 p.m. observation, and the dew point codewords representing this time of day all started with "L" (see Figures 6 and 8), this explains the high frequency of these words.

7.3.2. Atypical Messages

The decoding of the cryptogram also revealed some atypical messages that contain illustrative elements of the weather code:

- Message 1.3 ("MAKE INDPLS BAROMETER NERITE") is a correction to the barometric pressure reading for Indianapolis. A previous message was likely sent with an incorrect value. The message is to be interpreted partially as cleartext, with "NERITE" being the only codeword. It is curious that "NERITE" has an "x" underneath it, seeming to indicate an error, as this appears to be the correct codeword for the observed temperature and pressure readings. The instruction is to "Make the barometric pressure for Indianapolis 0.64 inHg". The format follows Paragraph 110 of the 1887 Weather Code regarding corrections to telegraphic reports (War Department, 1887b, 18). This message is also a good example of how many of the station names were abbreviated (e.g., "INDPLS" for "Indianapolis"). As long as the shortened name was still clear to the recipient, there was no need to write the full name of the station. This conserved the number of characters that had to be telegraphed.
- Message 1.4 ("SPRING WILDERNESS LINING ONE READING NOVICE BALE") is an example of how a precipitation reading was sent if it exceeded one inch. The whole number value (in this case, 1 in.) is sent as cleartext ("ONE"), followed by the fractional portion (0.26 in.) as a codeword ("READING"). These two values were added together to get the final precipitation measurement (1.26 in.). This format follows the instructions of Paragraph 35 of the 1887 codebook (War Department, 1887b, 11). See Table A4 for the full decoding of this message.
- Message 2.6 ("CUSTER DOWN" is notable in that it is meant to be interpreted literally as the Fort Custer station being down (not functioning or the telegraph line was down).

7.4. *Problematic Decodings*

Several messages were problematic to decode as they did not appear to follow the regular format of the Signal Service code, had words that were not in the codebook, or had misspellings that were difficult to interpret or reconcile. These messages and their resolution are detailed here.

7.4.1. Message 1.2

The fifth word in the message for San Antonio (1.2) appears to be "LISSTD", which is not found in any Signal Service/Weather Bureau codebook between 1887 and 1896. It could be a misspelling of "LISTED", but this word was not in the codebooks, either. The original meteorological records for this station (Midwestern Regional Climate Center, 2014–2021) provided a dew point of 64°F, which gives "LINNET" as the correct codeword.

7.4.2. Message 1.6

The fifth and sixth words ("NEW" and "MARKET") for Message 1.6 (St. Louis, Missouri) should be the upper and lower cloud observations. However, "MARKET" is not found in either the 1887 or 1889 codebooks. "NEWMARKET", though, is a codeword that represents stratus or cumulo-stratus clouds moving from the south and 4–5 tenths cloud cover. These types of clouds are low-level clouds, so if "NEWMARKET" is the correct codeword, there was no upper cloud observation. Unfortunately, these readings could not be confirmed, as the original cloud observations for May 1888 were unavailable for St. Louis.

7.4.3. Message 2.4

Message 2.4 for Green Bay, Wisconsin was unusual in that it only contained three words ("GREEN BAY, NOBBY, PIPED"), but unlike the "CUSTER DOWN" message (2.6), the words did not appear to be cleartext. Furthermore, if the second word ("NOBBY") is to be interpreted as temperature and pressure, it would decode to either 110°F or 10°F, neither of which matched the recorded temperature for Green Bay for any observation on May 27, 1888. The third word is "PIPED", but there is a "x" underneath it, which may indicate an error. The closest match to any word in the codebook is "BIPED".

Since the 1888 meteorological register for Green Bay was available (Midwestern Regional Climate Center, 2014–2021), an encoding was performed of what the message should have been for the 10:00 p.m. observation. The message should have read: "GREEN BAY, NEMESIS, LAYMAN, BIBBER, NOBBY, BIPED". This was highly informative, because it indicates that "NOBBY" wasn't actually the second codeword representing temperature and pressure. It should have been the fifth codeword, representing the lower cloud observation. It is evident that the second, third and fourth words were lost in the message. The meaning of the codewords can be found in Table A16.

7.4.4. Message 2.7

Message 2.7 for Fort Garry (Winnipeg), Manitoba was somewhat problematic to decode. The fifth codeword ("PALM") should have coded for wind direction/state of weather/precipitation. However, there were no codewords starting with the letter "P" for any weather element in either the 1887 or 1889 codebook. The 1892 codebook does have words starting with "P", including "PALMY", but the words are reserved for reporting the river height for special river stations (Fort Garry was not such a station). The word "PALM" was found in the old 1872 Weather Code, and denoted calm conditions and heavy rainfall (War Department, 1872, 174), which did not match the recorded conditions in Winnipeg. The word is underlined on the code sheet, however, possibly indicating an error.

What should the word have been? For the 10:00 p.m. observation for May 27, the wind was from the north at four miles per hour and conditions were fair. There was nearly complete (9/10) cloud cover and no precipitation at the time of observation, with a trace amount earlier in the evening (Meteorological Service of Canada, 1888a). The codeword that represents a northerly wind direction, no (or trace) precipitation, and state of weather being fair, was "BANK" in the 1887 codebook. This word should have been the fifth codeword of the message. It is uncertain how "PALM" was arrived at, unless it was a misinterpretation of the American Morse Code that was received.

Another discrepancy in the message is the use of "LAWFUL" in the fourth field to represent relative humidity and observation time. The recorded relative humidity for the station was 62% (Meteorological Service of Canada, 1888a). Assuming the hypothesis is correct that the fourth field for Canadian stations was for relative humidity but used the dew point codewords, and using the revised codeword list for dew point and time of observation (as discussed in Section 7.1), the word should have been "LUNAR" for a relative humidity of 62%, whereas "LAWFUL" represented either -70 or 30 (see Figure 8). The recorded dew point was in fact 30°F, though, so was the dew point being represented? This is unlikely, because it is clear for the other five messages for Canadian stations that the fourth field matched the recorded relative humidity rather than the dew point (in two cases, the relative humidity and dew point were the same, so the same codeword could have been used, but in the remaining cases, the dew point and relative humidity differed significantly and the codeword could only have represented relative humidity). This may have been a situation in which the observer mistakenly used the old codeword list, since "LAWFUL" in the unrevised 1887 Weather Code does indeed represent a value of 62 (compare Figure 6 and Figure 8 to see the changes in the codeword list).

Finally, the presence of a trace amount of precipitation should have required the codeword"JOHNSON" after the fifth field, assuming Canadian stations coded for trace precipitation in the same way as U.S. stations.

7.4.5. Message 2.10

The first word in Message 2.10 was difficult to read on the code sheet. It was initially thought to be possibly "GRIT", but when the meteorological record for Calgary on May 27, 1888 was examined, it was determined that the readings matched the 3:00 p.m. observation for that day. The codeword representing the afternoon observation on the 27th of the month should have been "GRUB".

The last word in the message ("EACH") correctly represents the recorded wind velocity at 3:00 p.m., but as this was an afternoon observation, the word should also have coded for the maximum daily temperature. However, "EACH" represents either 100°F or 0°F, whereas the maximum temperature in Calgary for this day was 75°F (Meteorological Service of Canada, 1888b). Assuming that Canadian stations coded for the maximum temperature in the same way as U.S. stations, the correct codeword should have been "ERIN", rather than "EACH".

7.4.6. Message 2.12

The fifth word in Message 2.12 for Prince Arthur's Landing (present-day Thunder Bay, Ontario) was unreadable on the code sheet. It looked like "DSRCH", which is not a codeword found any of the Signal Service or Weather Bureau codebooks. Based on the recorded weather observations for this station (clear conditions, no precipitation, and northeast wind) (Meteorological Service of Canada, 1888b), the correct codeword should have been "DUCK".

7.5. *Times Written in Margin*

The apparent times of day written in the left margin of the code sheets may be the times when the telegrams were received. All stations transmitted their reports within an hour and a half of the readings, so 11:15 p.m. and 11:24 p.m. are plausible for 10:00

p.m. (75th meridian time) or earlier observations. If these are local times, it would mean that the person who wrote the messages was probably in the same time zone (i.e., eastern United States or eastern Canada).

The 1:01 p.m. time on the other code sheet is more difficult to reconcile. With the exception of one 3:00 p.m. observation, the weather observations on the sheet were for 10:00 p.m. (75th meridian time), so 1:01 p.m. would be far too early. Did the person mean to write "10:11 p.m.", or perhaps "10:01 p.m.", but omitted the leading zero in the minutes? Another possibility is that there was an issue at the telegraph office and the reports could not be received until the day after the observations. Problems with the telegraph office appear to have been a common enough occurrence – during a one week period in May 1888, the meteorological register for Winnipeg twice recorded that the morning weather report could not be sent because the telegraph operator was not at the telegraph office (Meteorological Service of Canada, 1888a).

8. Who was the Owner of the Dress?

During the time period in question, the regular Signal Service weather stations were operated by enlisted men of the Signal Service. It is very unlikely that a woman would have worked as an observer for the Signal Service. However, in addition to the official stations, there were many other weather stations in the United States which supplemented the Signal Service observation network and were operated by civilian volunteers. The 1888 Signal Service annual report lists a number of women who were voluntary weather observers, including a "Miss Mary C. Bennett" who was a voluntary weather observer in Fairview, Fulton County, Illinois. Could she be the "Bennett" to which the name tag on the dress referred?

Mary C. Bennett was 22 years old in 1888. She was the second child and only daughter of Dr. Stephen B. Bennett and Angeline Taylor of Fairview, Illinois. Stephen Bennett was a physician and the county coroner (Chapman, 1879, 631). A search through various issues of the *Monthly Weather Review of the Illinois State Weather Service* shows that Mary Bennett's service as a voluntary observer was apparently between 1886 and 1888. She first appears as an observer in the December 1886 report (Illinois State Weather Service, 1886, 11). Between May 1888 and January 1889, the Fairview station is listed in the report, with Bennett as the observer, but the station did not report any meteorological readings. Her name is absent from the state weather service reports after January 1889. (Note, however, that the monthly state reports were unavailable for the remainder of 1889, and from 1890 to 1894, the report was much briefer and often did not list the names of the observers.) In the 1900 U.S. Census, Bennett was found to be living with her father in Galesburg, Illinois after the death of her mother in 1898 (U.S. Census Bureau, 1900). It is unclear what became of her after this date[7].

Whether Mary C. Bennett was the owner of the dress is uncertain. The link is tenuous and based on only the name tag that was attached to the bodice. The tag may not have been coincident in time with the code sheets and may have belonged to a subsequent owner of the dress.

Although Mary Bennett was a weather observer, it is not clear why she would have the coded meteorological reports for a number of Signal Service stations. Unlike Signal Service observers, voluntary observers did not telegraph their weather reports. Instead,

[7] A Mary C. Bennett with the same birth year (1866) married a man named Reuben Parr in August 1888, but she had a different date of birth and different parents listed on the marriage certificate (McCullough, 1888).

they mailed abstracts of their daily meteorological logs at the end of each month to their state weather service. The state service, in turn, collated and summarized the data and forwarded the monthly summaries to the Washington weather office (War Department, 1889a, 105). If a state weather service did not exist, the reports were mailed directly to the Washington office.

One possibility is that Mary Bennett also worked as a telegraph operator. It was not unusual for women to be employed in this capacity in the late 19th century – between 1870 and 1920, the percentage of female telegraphers in the United States increased from four percent to twenty percent (Jepsen, 2000, 52–53). If Bennett was a telegrapher, it may explain why she had copies of the weather reports from a number of stations, since all stations along a telegraphic circuit copied the reports from the other stations, as stated in Section 5. Furthermore, it is known that some telegraph operators did double duty as weather observers (Raines, 1996, 51). However, to date, I have not found any evidence that Mary Bennett was employed in such a role.

Yet, one curious fact remains: the date of the weather observations in the coded messages (May 27, 1888) was Mary Bennett's birthday (Chapman, 1879, 631). This may be simply a coincidence, but it is an intriguing point of correspondence.

If Mary Bennett wasn't the owner of the dress, it may have been another woman who was a telegrapher or employed in some capacity that brought her in contact with the coded weather telegrams. The next section will show that the latter is the most likely scenario, based on the probable location of the person.

9. Where was the Owner of the Dress?

The stations on the two code sheets are organized roughly geographically – the stations on Code Sheet 1 are all south of 40°N latitude, whereas the stations on Code Sheet 2 are in Canada or the northern United States. This suggests that the stations on the two sheets were on different telegraphic circuits. Someone in possession of messages from both circuits had to be in a location where the circuits first converged or at some point after it. The final destination of all messages was the central Signal Service office in Washington, D.C. A traffic analysis was conducted of the telegraphic message routes for the 21 unique stations from the two code sheets to see if it could provide information on the location of the owner of the silk dress.

A detailed description of the telegraphic circuits is found in some of the annual reports of the Signal Service. The one closest in time to the observations was the 1881 report (War Department, 1881a, 790–799). There were 28 circuits at the time. Figure 10 shows the telegraphic circuit routes for all the stations from the Silk Dress cryptogram.

Examining the circuit routes for the stations on Code Sheet 1, the messages from all stations converged at Cincinnati before being forwarded to Washington. Some stations sent directly to Cincinnati, while others went through St. Louis, or New Orleans, for the stations in Texas. Two stations, Vicksburg and San Antonio, also had a secondary route through Chicago and New York. For Vicksburg, the messages seem to have terminated in New York, whereas messages for San Antonio were forwarded from New York to Washington. Therefore, the only path from Vicksburg to Washington was the one through Cincinnati.

There were three stations on Code Sheet 1 that were missing from the 1881 list of telegraphic circuits: Springfield, Missouri, Concordia, Kansas, and Fort Smith, Arkansas. These stations had not been established yet in 1881. Based on the mes-

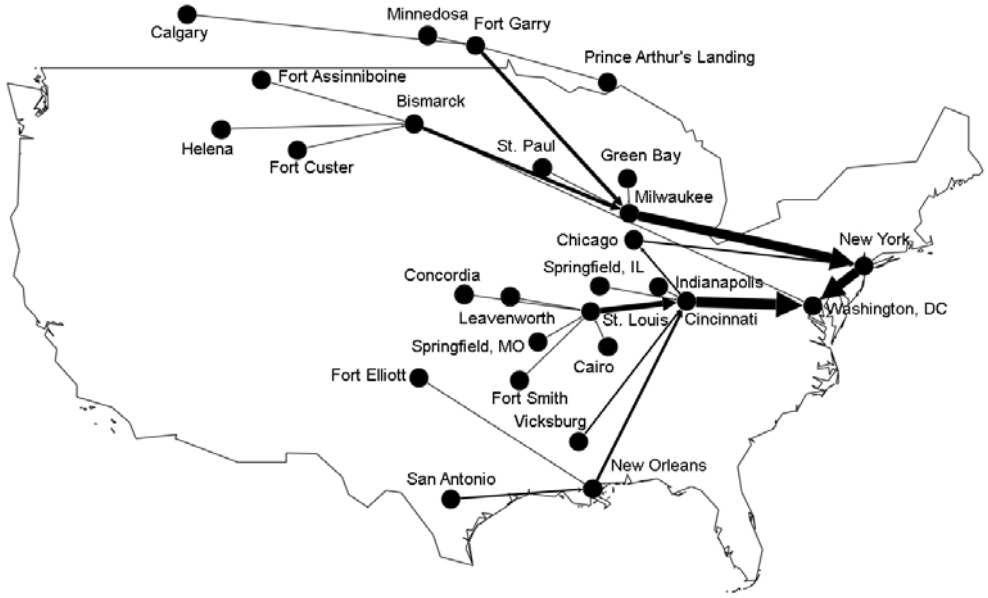

Figure 10. Telegraphic circuit routes for stations in the Silk Dress cryptogram. Thicker lines indicate higher traffic volume.

sage paths for the other stations, it appears likely that the route for these stations would have gone through Cincinnati as well.

For the stations on Code Sheet 2, it was found that the telegrams from Canadian stations were collected in Fort Garry (Winnipeg) and transmitted to Milwaukee, then to New York, and finally to Washington, D.C. The stations in the northern United States were collected in Milwaukee and then followed the same route as the Canadian messages. The exception to this was the Helena, Montana station. Helena was on a military telegraph line that served the northwestern United States. A number of U.S. Army forts were on this line, which terminated in Bismarck, North Dakota. From there the messages were sent to Washington via "special message service"[8]. Although Fort Assinniboine and Fort Custer were also on the military line, their messages were sent via circuit and followed the route of the other stations' messages through Bismarck, Milwaukee, New York, and Washington.

Three stations from Code Sheet 2 were not found in the description of the telegraphic circuits: Calgary, Minnedosa, and Green Bay. Messages from Calgary and Minnedosa probably converged at Winnipeg and then followed the route of the other Canadian messages, while messages from Green Bay likely went through Milwaukee.

Thus, there is no earlier point of convergence for all the messages from the two code sheets than Washington, D.C. The telegrams were received directly by the telegraph room of the Washington Signal Service office (War Department, 1873, 65–66), which was run by enlisted men of the service – in 1888, it employed eight telegraph operators (War Department, 1889a, 161). Although none of the operators was female, the Wash-

[8]Despite its name, a special message meant "nothing more than sending as an ordinary government message, at usual government rates. Such messages have no peculiar privileges like those sent over circuit. They take their chances for transmission with other government business, although priority in transmission is claimed for them by this office." (War Department, 1881a, 791)

ington office did employ over a dozen women as clerks, copyists, typists, and book stitchers and folders (War Department, 1889b). It is therefore quite possible that the clerical staff may have handled the coded messages and that the owner of the dress could have been among them.

A caveat to this traffic analysis is that the 1881 list of circuits is seven years out of date from the time of the observations in 1888. However, a more recent summary of the circuits[9] was found in 1888 Special Order No. 70 (War Department, 1888) which showed that there were 22 circuits by 1888, with nine from the 1881 list being absent and three new circuits being introduced; these changes did not appear to alter the circuits for the stations from the code sheets. Another caveat is that problems with telegraph lines may have altered the circuits on any given day and temporarily changed the routes that messages may have followed.

If the preceding analysis is correct, it would tend to rule out Mary Bennett in Fairview, Illinois having been involved, as it does not appear that Fairview was part of any telegraphic circuit used by the Signal Service, nor was it in the right location to receive all the messages in the cryptogram.

10. Conclusions

The weather observations decoded in the Silk Dress cryptogram represent an era in which the telegraph played an instrumental role in advancing the state of operational meteorology. For the first time in history, observations from distant locations could be rapidly disseminated, collated, and analyzed to provide a synopsis of the state of weather across an entire nation and to allow regional weather forecasts to be made. Telegraphic weather codes were the forerunners of modern meteorological codes such as METAR (Nav Canada, 2017), which can be encoded automatically by software and transmitted by automated weather stations, or encoded manually by human observers.

The Silk Dress cryptogram proved challenging for cryptanalysts for several reasons. First, the messages contained a mixture of cleartext and codetext, and it was not certain which was which. Second, although the code followed a set of rules and was even considered translatable on sight, there was insufficient text to identify definitive patterns in a codetext-only attack. Third, although it was a telegraph code, it was not a commercial code as widely thought. The Signal Service weather code had limited distribution and circulation and is not a commonly known telegraph code. Fourth, because the cryptogram was a code rather than a cipher, modern computational cryptanalysis was of little use in this situation. Lastly, it is instructive to note that even though secrecy was not the intent of the weather code, its rather complex and frequently changing set of rules, the presence or absence of some fields depending on the value of other fields, the reuse of codewords for different meanings depending on the position of the word and the time of the observation, posed a difficult cryptanalytic problem.

The availability of the original meteorological records for many American and Canadian stations was invaluable in the solution of the Silk Dress cryptogram. They provided cribs to confirm the decodings and to determine what the coding should have been in situations where there were errors in the messages or uncertainty in the transcription. It is fortunate that these early records often still exist and that many of them have been digitized or are in the process of being digitized and made available.

[9]This summary listed only the endpoints of each circuit and lacked the detailed description of which stations' messages were forwarded by each circuit, unlike the list from the 1881 Signal Service annual report.

Although many of the original observational weather records have survived, there appear to be relatively few extant examples of coded weather telegrams from this pivotal time period. Despite the fact that hundreds of coded weather telegrams were sent each day, it is probable that the messages were considered ephemera and rarely archived, as the unencoded observations contained the same information and were more important to retain. As such, the discovery of the messages is invaluable in this regard.

Further research is needed to confirm the format of the Canadian weather telegrams. There may be documentation in an archive that could hold the key. The NOAA Central Library and the U.S. National Archives have collections pertaining to the U.S. Signal Service/U.S. Weather Bureau, while the University of Western Ontario holds a collection from the early years of the Meteorological Service of Canada. A thorough search would be needed to determine whether any information about the Canadian weather telegram format still exists.

As to the identity of the original owner of the silk dress, the available evidence points towards someone working at the central Signal Service office in Washington, D.C., perhaps as a member of the clerical staff.

When the Silk Dress cryptogram was first published online, theories abounded about the content of the mysterious messages. Were they secret spy messages? Did they relate to illicit gambling? The reality of the messages being meteorological observations is somewhat more prosaic in nature. Writing for *The New Yorker* magazine during the telegraphic era, Jack Littlefield (1934, 18)(quoted in Kahn (1967)) could commiserate with this:

> Every time I receive a cablegram in code, I have the same feeling of pleasurable excitement. There is the familiar envelope lying on my desk, marked "Cablegram: Urgent." I rip it open and discover inside the single mysterious word BIINC. The message is from our Venezuela office. Visions at once loom of secret documents, beautiful women, and dark Latin-American intrigue. Then I turn to my code book and find "BIINC: *What appliances have you for lifting heavy machinery?"* This sort of thing can be very debilitating.

A few mysteries still surround the cryptogram. Why were coded weather observations in a hidden pocket of the dress? What was the person's motivation for retaining the messages? The answers to these questions may never be known, but we have at least shed light on much of the Silk Dress cryptogram.

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The author reports there are no competing interests to declare.

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Appendix A. Decoded Messages

The following tables present the decoded lines for the two code sheets of the Silk Dress cryptogram.

SMITH	Station name: Fort Smith, Arkansas
NOSTRUM	Air temperature: 70°F Barometric pressure: 0.68 inHg
LINNET	Dew point: 64°F Observation time: 10:00 p.m.
GET	State of weather: Cloudy Precipitation: None Wind direction: Southeast
NONE	Cloud type (upper): Stratus or cumulo-stratus Cloud cover (upper): 8–10 tenths Cloud direction (upper): Southwest
EVENT	Current wind velocity: 0–4 mph Sunset: Cloudy

Table A1. Decoding of Message 1.1.

ANTONIO	Station name: San Antonio, Texas
RUBRIC	Air temperature: 76°F Barometric pressure: 0.70 inHg
LISSTD (LINNET)	Dew point: 64°F Observation time: 10:00 p.m.
FULL	State of weather: Clear Precipitation: None Wind direction: East
INK	Current wind velocity: 6 mph Sunset: Clear

Table A2. Decoding of Message 1.2.

MAKE	Make
INDPLS	Station name: Indianapolis, Indiana
BAROMETER	Barometer
NERITE	Air temperature: 76°F Barometric pressure: 0.64 inHg

Table A3. Decoding of Message 1.3. This is a message to correct a barometer reading.

SPRING	Station name: Springfield, Illinois
WILDERNESS	Air temperature: 68°F Barometric pressure: 0.64 inHg
LINING	Dew point: 66°F Observation time: 10:00 p.m.
ONE	1 in.
READING	State of weather: Cloudy Precipitation: 0.26 in. (+1.0 in. = 1.26 in.) Wind direction: West
NOVICE	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 8–10 tenths Cloud direction (lower): Calm
BALE	Current wind velocity: 12 mph Sunset: Cloudy

Table A4. Decoding of Message 1.4.

VICKSBG	Station name: Vicksburg, Mississippi
ROUGHROCK	Air temperature: 78°F Barometric pressure: 0.78 inHg
LINING	Dew point: 66°F Observation time: 10:00 p.m.
MY	State of weather: Clear Precipitation: None Wind direction: South
NANNY	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 2–3 tenths Cloud direction (lower): Southwest
BUCKET	Current wind velocity: 10 mph Sunset: Cloudy

Table A5. Decoding of Message 1.5.

SAINT	Station name: St. Louis, Missouri
WEST	Air temperature: 70°F Barometric pressure: 0.60 inHg
LUNAR	Dew point: 62°F Observation time: 10:00 p.m.
MALAY	State of weather: Fair Precipitation: 0.02 in. Wind direction: South
(NEW)MARKET	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 4–5 tenths Cloud direction (lower): South
BALE	Current wind velocity: 12 mph Sunset: Cloudy

Table A6. Decoding of Message 1.6.

LEAWTH	Station name: Leavenworth, Kansas
MERRY	Air temperature: 70°F Barometric pressure: 0.54 inHg
LEMON	Dew point: 58°F Observation time: 10:00 p.m.
SUNK	State of weather: Clear Precipitation: None Wind direction: Northwest
EACH	Current wind velocity: 0–4 mph Sunset: Clear

Table A7. Decoding of Message 1.7.

CAIRO	Station name: Cairo, Illinois
RURAL	Air temperature: 72°F Barometric pressure: 0.70 inHg
LINING	Dew point: 66°F Observation time: 10:00 p.m.
NEW	State of weather: Cloudy Precipitation: None or trace Wind direction: Southwest
JOHNSON	Trace precipitation
NONE	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 8–10 tenths Cloud direction (lower): Southwest
ICE	Current wind velocity: 6 mph Sunset: Cloudy

Table A8. Decoding of Message 1.8.

MISSOURI	Station name: Springfield, Missouri
WINDY	Air temperature: 68°F Barometric pressure: 0.66 inHg
LUNAR	Dew point: 62°F Observation time: 10:00 p.m.
NEW	State of weather: Cloudy Precipitation: None or trace Wind direction: Southwest
JOHNSON	Trace precipitation
NONE	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 8–10 tenths Cloud direction (lower): Southwest
BUCKET	Current wind velocity: 10 mph Sunset: Cloudy

Table A9. Decoding of Message 1.9.

ELLIOTT	Station name: Fort Elliott, Texas
REMORSE	Air temperature: 58°F Barometric pressure: 0.74 inHg
LEGACY	Dew Point: 42°F Observation time: 10:00 p.m.
SUNK	State of weather: Clear Precipitation: None Wind direction: Northwest
DEW	Current wind velocity: 24 mph Sunset: Clear

Table A10. Decoding of Message 1.10.

CONCORDIA	Station name: Concordia, Kansas
MAMMON	Air temperature: 58°F Barometric pressure: 0.52 inHg
LAYMAN	Dew point: 52°F Observation time: 10:00 p.m.
NULL	State of weather: Clear Precipitation: None Wind direction: Southwest
EVENT	Current wind velocity: 0–4 mph Sunset: Cloudy

Table A11. Decoding of Message 1.11.

CONCORDIA	Station name: Concordia, Kansas
MERACCOUS (MERACIOUS)	Air temperature: 72°F Barometric pressure: 0.54 inHg
HUMUSS (HUMUS)	Dew point: 50°F Observation time: 3:00 p.m.
NAIL	State of weather: Fair Precipitation: None Wind direction: Southwest
MENU	Cloudy type (lower): Cumulus Cloud cover (lower): 4–5 tenths Cloud direction (lower): Southwest
BARRACK	Current wind velocity: 12 mph Maximum temperature: 72°F

Table A12. Decoding of Message 1.12.

BISMARK	Station name: Bismarck, Dakota Territory (in present-day North Dakota)
OMIT	Air temperature: 56°F Barometric pressure: 0.08 inHg
LEAFAGE	Dew point: 32°F Observation time: 10:00 p.m.
BUCK	State of weather: Clear Precipitation: None Wind direction: North
BANK	Current wind velocity: 12 mph Sunset: Clear

Table A13. Decoding of Message 2.1.

PAUL	Station name: St. Paul, Minnesota
RAMIFY	Air temperature: 56°F Barometric pressure: 0.72 inHg
LOAMY	Dew point: 50°F Observation time: 10:00 p.m.
EVENT	State of weather: Cloudy Precipitation: 0.04 in. Wind direction: Calm
FALSE	Cloud type (upper): Cirro-stratus Cloud cover (upper): 2–3 tenths Cloud direction (upper): Northwest
NEW	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 4–5 tenths Cloud direction (lower): Calm
EVENT	Current wind velocity: 0–4 mph Sunset: Cloudy

Table A14. Decoding of Message 2.2.

HELENA	Station name: Helena, Montana
ONUS	Air temperature: 60°F Barometric pressure: 0.08 inHg
LOFO	Dew point: 38°F Observation time: 10:00 p.m.
US	State of weather: Clear Precipitation: None Wind direction: Calm
NAIL	Cloud type (upper): Stratus or cumulo-stratus Cloud cover (upper): 2–3 tenths Cloud direction (upper): Calm
EACH	Current wind velocity: 0–4 mph Sunset: Clear

Table A15. Decoding of Message 2.3.

GREEN BAY	Station name: Green Bay, Wisconsin
(NEMESIS)	Air temperature: 54°F Barometric pressure: 0.64 inHg
(LAYMAN)	Dew point: 52°F Observation time: 10:00 p.m.
(BIBBER)	State of weather: Rain Precipitation: 0.14 in. Wind direction: North
NOBBY	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 8–10 tenths Cloud direction (lower): North
PIPED (BIPED)	Current wind velocity: 16 mph Sunset: Cloudy

Table A16. Decoding of Message 2.4.

ASSIN	Station name: Fort Assinniboine, Montana
ONAGO	Air temperature: 62°F Barometric pressure: 0.08 inHg
LEAGUE	Dew point: 40°F Observation time: 10:00 p.m.
NEW	State of weather: Cloudy Precipitation: None Wind direction: Southwest
FORBADE	Cloud type (upper): Cirro-stratus Cloud cover (upper): 8–10 tenths Cloud direction (upper): North
EVENT	Current wind velocity: 0–4 mph Sunset: Cloudy

Table A17. Decoding of Message 2.5.

CUSTER	Station name: Fort Custer, Montana
DOWN	Station is down

Table A18. Decoding of Message 2.6.

GARRY	Station name: Fort Garry, Manitoba, Canada (present-day Winnipeg, Manitoba)
NOUN	Day of month: 27th
TERTAL (TERGAL)	Air temperature: 42°F Barometric pressure: 0.94 inHg
LAWFUL	Relative humidity: 30% Observation time: 10:00 p.m.
PALM	Codeword is not found in either 1887 or 1889 codebook. Based on weather readings, codeword should have been BANK.
NOVICE	Cloud type (lower): Stratus or cumulo-stratus Cloud cover (lower): 8–10 tenths Cloud direction (lower): Calm
EVENT	Current wind velocity: 0–4 mph Sunset: Cloudy

Table A19. Decoding of Message 2.7.

MINNEDOS	Station name: Minnedosa, Manitoba, Canada
NOUN	Day of month: 27th
TOMMY	Air temperature: 50°F Barometric pressure: 0.98 inHg
LEAFAGE	Relative humidity: 32% Observation time: 10:00 p.m.
BEAK	State of weather: Cloudy Precipitation: None Wind direction: North
DOBBIN	Cloud type (upper): Cirro-cumulus Cloud cover (upper): 8–10 tenths Cloud direction (upper): North
ICE	Current wind velocity: 6 mph Sunset: Cloudy

Table A20. Decoding of Message 2.8.

CALGARRY	Station name: Calgary, North-West Territories (in present-day Alberta, Canada)
CUBA	Day of month: 27th
UNGUARD	Air temperature: 40°F Barometric pressure: 0.00 inHg
CONFUTE	Relative humidity: 30% Observation time: 7:00 a.m.
DUCK	State of weather: Clear Precipitation: None Wind direction: Northeast
FAGAN	Cloud type (upper): Cirro-stratus Cloud cover (upper): 2–3 tenths Cloud direction (upper): Southeast
EGYPT	Current wind velocity: 0–4 mph Minimum temperature: 40°F

Table A21. Decoding of Message 2.9. (Morning observation for Calgary.)

GRUB	Day of month: 27th
WRONGFUL	Air temperature: 70°F Barometric pressure: 0.96 inHg
HUGO	Relative humidity: 48% Observation time: 3:00 p.m.
DUCK	State of weather: Clear Precipitation: None Wind direction: Northeast
FAGAN	Cloud type (upper): Cirro-stratus Cloud cover (upper): 2–3 tenths Cloud direction (upper): Southeast
EACH	Current wind velocity: 0–4 mph The maximum temperature should have been coded by this word as well for a 3:00 p.m. observation, but this codeword represents either 100°F or 0°F, whereas the recorded maximum temperature for this day was 75°F. The correct codeword should have been "ERIN".

Table A22. Decoding of Message 2.10. (Afternoon observation for Calgary.)

CALGARRY	Station name: Calgary, North-West Territories (in present-day Alberta, Canada)
NOUN	Day of month: 27th
SIGNOR	Air temperature: 68°F Barometric pressure: 0.86 inHg
LOAMY	Relative humidity: 50% Observation time: 10:00 p.m.
MEW	State of weather: Cloudy Precipitation: None Wind direction: South
GINNED	Cloud type (upper): Cumulus Cloud cover (upper): 6–7 tenths Cloud direction (upper): Southwest
EVENT	Current wind velocity: 0–4 mph Sunset: Cloudy

Table A23. Decoding of Message 2.11. (Evening observation for Calgary.)

LANDING	Station name: Prince Arthur's Landing, Ontario, Canada (present-day Thunder Bay, Ontario)
NOUN	Day of month: 27th
RUGINS	Air temperature: 46°F Barometric pressure: 0.70 inHg
LEGACY	Relative humidity: 42% Observation time: 10:00 p.m.
DSRCH (DUCK)	State of weather: Clear Precipitation: None Wind direction: Northeast
BABY	Cloud type (upper): Cirrus Cloud cover(upper): 2–3 tenths Cloud direction(upper): North
ICE	Current wind velocity: 6 mph Sunset: Cloudy

Table A24. Decoding of Message 2.12.