NBS

Technical Note 170

PHOTOTYPESETTING OF COMPUTER OUTPUT

AN EXAMPLE USING TABULAR DATA

WILLIAM R. BOZMAN

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Phototypesetting of Computer Output

William R. Bozman

A photocomposition machine controlled by the magnetic tape output from a computer was used to prepare a 559-page table of atomic transition probabilities at the National Bureau of Standards. This method makes possible the publication of computed data in high quality typography in a reasonable time and at a reasonable cost. Many styles of type are readily available to the programmer including Greek, italic, mathematical symbols, upper and lower case alphabets, etc.

1. Photocomposition of Computer Output

Modern electronic computers are used to calculate and process large quantities of basic mathematical and physical data. Hundreds of pages of numerical or tabular information can be obtained in a few hours, or even a few minutes. When the final calculations are completed, the problem of publication of the data then arises.

This problem can be handled in two ways. Traditionally the information is set in metal type. This method produces high quality typography of graphic art quality, and is the preferred style. However, in order to minimize the time needed between the computer calculations and the final printed page, and also to reduce printing costs, it is frequently decided to forgo traditional typographic quality. In these instances the printing plates may be made from photographs of pages prepared on a high-speed computer printer.

Unfortunately these printed pages are usually much less clear than those that have been typeset, page formats may be wasteful of space, and the limitations on the styles of type and special characters available may be a severe handicap, leading to the use of nonstandard or even misleading notations.

A solution to this dilemma is now possible by using an automated photocomposition machine which can produce first class typography in a reasonable time and at a reasonable cost.

A recent publication of the National Bureau of Standards produced by this method is NBS Monograph 53, *Experimental Transition Probabilities for Spectral Lines of Seventy Elements* by C. H. Corliss and W. R. Bozman.

The transition probabilities were computed by an IBM 7090 electronic computer and written onto a magnetic tape in a Binary-Coded-Decimal (BCD) form. This BCD tape was printed on the IBM 1403 printer for reference purposes. A FORTRAN computer code was then written to convert this BCD tape into a binary tape which contained the proper bit-patterns to operate a magnetic-tape-controlled Linofilm photocomposition machine. This machine was located at the IBM Watson Research Center where it was being used in a language translation project.

The table of transition probabilities consists of 559 pages of data. Preparation of the film from the magnetic tape took about 80 hours. About twelve 50-foot rolls of 8-inch wide positive film were used. The plates for offset printing were made photographically, directly from the films. The computation of the data and preparation of the BCD tape took twenty minutes on a 7090 computer; the conversion from the BCD tape to the binary tape in Linofilm format took thirteen minutes. It would have taken about 300 hours to set the table by conventional methods. The proofreading and correcting of typographical errors would also have taken considerably more time, especially since the table produced was not completely proofread. (After proofreading the first few pages without finding an error, a decision was made to check only the first and last line of each page.)

Data for a second publication, *Spectral-Line Intensities and gf-Values in the First Spectrum of Copper* by Charles H. Corliss, National Bureau of Standards Journal of Research 66A (Physics and Chemistry), No. 6, 497 (Nov.–Dec. 1962), was prepared by using a magnetic-tape-to-paper-tape converter. The paper tape was then fed into a standard (paper-tape-controlled) photocomposition machine.

2. Description of Character Codes

The binary magnetic tape for input to the paper tape converter was recorded in "records" of 250 computer "words" of 36 bits each at high density (556 bits per inch). Each computer word contained two characters to be typeset, corresponding to two rows of holes on the 15-channel paper tape.

The binary information on the magnetic tape must correspond exactly to the binary holes to be punched on the paper tape, except for three bits per character which are not read from the magnetic tape. These extraneous bits are taken care of automatically by the proper choice of octal numbers which represent each character. For example, if the upper case letter, capital "A" is designated by the octal numbers 0504_8 followed by the proper width information for the font to be used, e.g., a width of thirteen units=15_8 units, then the octal number 050415_8 will write the proper bit pattern on the magnetic tape (eighteen bits) so that the correct fifteen-bit pattern will be punched on the paper tape. All letters, numbers and printed symbols start their code number with a zero. Instructions to the photocomposition machine such as "change grids," "change point size," "justify," or "quad left," etc., start with a 1, 2, or 3 as the first digit.

As each computer word (IBM7090) consists of 36 bits, it is possible to place two characters in each word. For example, the chemical symbol for sodium, Na, would be written on the magnetic tape as 040416022311, the 0404 representing the upper case "N" having a width of 16_8 units and the 0223 the lower case "a" having a width of 11_8 units.

These computer words are prepared by a computer code. Our data were converted from a BCD magnetic tape, in standard IBM format, to the binary magnetic tape, in Linofilm format, by a FORTRAN code containing a SUBROUTINE (FORTRAN subroutine) of the following type:

```
         ENTRY      LINOB
LINOB    SXA        XR1,1
         SXA        XR2,2
         AXT        1,1             INPUT
         AXT        1,2             OUTPUT
LOOP     LDQ        DATA+1,1
         ZAC
         CAQ        TABLE-127,0,1   FIRST CHARACTER
         ALS        18
         CAQ        TABLE-127,0,1   SECOND CHARACTER
         SLW        OUTPUT+1,2
         TXI        *+1,2,1
         ZAC
         CAQ        TABLE-127,0,1   THIRD CHARACTER
         ALS        18
         CAQ        TABLE-127,0,1   FOURTH CHARACTER
         SLW        OUTPUT+1,2
         TXI        *+1,2,1
         ZAC
         CAQ        TABLE-127,0,1   FIFTH CHARACTER
ALS18    ALS        18
         CAQ        TABLE-127,0,1   SIXTH CHARACTER
         SLW        OUTPUT+1,2
         TXI        *+1,2,1
         TXI        *+1,1,1
         TXL        LOOP,1,12
XR1      AXT        *,1
XR2      AXT        *,2
         TRA        1,4
DATA     COMMON     12
OUTPUT   COMMON     36
TABLE    COMMON     2584
PAGENO   COMMON     1
PRNTNO   COMMON     3
         END
```

This subroutine selects the proper Linofilm codes from a table in the following way: A word (36 bits in BCD) of DATA is loaded by the LDQ instruction into the Multiplier Quotient Register (MQ). (For example, "HG 198" would be loaded as 30276001-1110_8.) The Accumulator Register (AC) is cleared by the ZAC; then the CAQ instruction reads the first six bits of the DATA word in the MQ (the 30_8 representing the "H" in the example) and adds this number to TABLE-127 to form a new address, TABLE-127+30. This location contains the Linofilm bit pattern for the letter "h."

In the actual SUBROUTINE used for Monograph 53, the first letter of each chemical symbol was capitalized. This was done by having two tables, TABLE-127 containing the lower case or unshifted characters and TABLE-63 containing the upper case or shift position characters. The proper table was selected by the code; in the above example the address actually chosen would have been TABLE-63+30, containing the Linofilm bit pattern for the upper case "H" (033313, the 333 representing the letter "H", the 13 giving the width of the letter, and the left-most digit being zero since this is a character to be printed). This number is added into the AC which then contains 000000033313. The CAQ instruction rotates the DATA in the MQ six bits to the left so that the next character, represented by 27, is in the left six bits of the MQ. The contents of the AC are then shifted left 18 binary places by the ALS 18 instruction, in order to make room for the second character. The AC now contains 033313000000.

The next computer instruction, which is another CAQ, looks up the 27th (octal) entry in TABLE-127, which would be the Linofilm bit-pattern for lower case "g", and adds it to the contents of the AC:

$$\begin{array}{l} 033313000000_8 = \text{H} \\ \underline{000000012310_8 = \text{g}} \\ 033313012310_8 = \text{Hg.} \end{array}$$

This value is stored in the OUTPUT. The code then continues with the "space" and the numeral 1 which would be stored in the OUTPUT as 0000060-20511_8. In this case the "space" is given a value of 6 units, but it could be any value desired from 04_8 to 37_8 units. The last two digits, 98, would be stored as 021211022511_8.

Note that all the numerals have a constant width, in this instance 11_8. The width to be used is of course determined by the choice of type style. This SUBROUTINE will convert all BCD data into the proper bit patterns for the photocomposition machine. However, additional instructions are needed for the operation of the photocomposition machine. The first computer word on the output tape must contain the point size and film advance information as shown in the octal printout of figure 1. For example, if a 10 point type size with a 10 point film advance is specified, then the first word would be 240500221200_8 in which 2405 designates "change point size" to the fifth size listed. The next two zeros are ignored. The 2212 specifies the film advance to be 12_8 units, which equals 10 points. The next instruction is the grid selection; in order to simplify the coding problem this instruction was repeated, so that the second word on the magnetic tape was 260400260400 to instruct the machine to choose grid number 04. The right-hand half of this word could, of course, be the first character of the output information.

An "end-of-line" code must be given at the end of each line. This work, being tabular, was given a "Quad left" instruction. In order to simulate this instruction as punched on the standard paper tape, the following is written on the magnetic tape: 311400100000_8 followed by six words of zeros, i.e.: 000000000000 written six times.

Ten quad-lefts were written on the tape at the end of each page in order to give 10 blank lines between the pages for cutting them apart.

The output tape must be written in the binary mode and must not contain any extraneous words such as tape-checking words. This meant that the FORTRAN "WRITE TAPE" instruction cannot be used. However, a subroutine can be called by a FORTRAN statement such as:

```
CALL WTBA6 (BLOCK(J),K,IOERR)
```

where J, is the index for the end of each record, K, is the record size e.g. 250, and IOERR is the tape error exit. The following SUBROUTINE written in the FAP symbolic coding system was used:

```
        ENTRY   WTBA6
WTBA6   SXA     XRA,1
        AXT     10,1
        CLA     1,4
        STA     IO
        CLA*    2,4
        STD     IO
        WTBA    6
        RCHA    IO
        TCOA    *
        XEC     *-1
        TRCA    *+5
```

240500221200	260400260400	000031000031	000036000036	000036000030	030414022312	020312021411	030312000006
020511023105	000030260500	030413033407	022312032312	023407051406	042306051406	040311032312	000006060312
033407040311	020311022312	020311051406	021406051406	042306051406	030310023407	000006040311	052307000006
050310040311	060312060312	030310033407	260600040622	022415040311	032312042306	051405032312	053412030311
043412260100	311400100000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000
311400100000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	023304032313
042306030311	032313023407	051406042306	031511000022	040522022307	041511030311	021406030311	032313012310
042306041413	000036000025	042415032313	030311033410	012310031511	000006053314	030311041511	030311021406
023407000036	000036000023	012310050415	000036000036	000036000007	012310052307	000036000036	000022053314
040312012310	000006012310	052307000005	311400100000	000000000000	000000000000	000000000000	000000000000
000000000000	000000000000	000036000036	000036000036	000006050415	000036000036	000036000036	000027013317
000036000036	000036000027	020511053211	260200013307	260100030606	023407030311	050311260300	311400100000
000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	311400100000	000000000000
000000000000	000000000000	000000000000	000000000000	000000000000	000012000012	031212022512	000012000012
000012000012	000012000012	052512032512	052512032512	023105032512	022512000012	000012000012	000012000012
000012042512	053212021212	042512042512	000012012212	000012031212	021212053212	053212051212	000012000012
000012000012	000012000012	053212023105	053212042512	052512000012	000012000012	000012000012	000012000012
053212023105	053212053212	042512051212	000012000012	000012000012	000012000012	012212052512	023105051212
032512000012	311400100000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000
000012020512	051212020512	000012000012	000012000012	000012000012	052512032512	051212053212	023105053212
053212000012	000012000012	000012000012	000012051212	021212053212	020512021212	000012012212	000012031212
031212053212	051212020512	000012000012	000012000012	000012000012	053212023105	053212031212	053212000012
000012000012	000012000012	000012000012	053212023105	053212053212	031212051212	000012000012	000012000012
000012000012	012212052512	023105020512	042512000012	311400100000	000000000000	000000000000	000000000000
000000000000	000000000000	000000000000	000012020512	042512041212	000012000012	000012000012	000012000012
052512032512	051212042512	023105021212	051212000012	000012000012	000012000012	000012051212	021212053212
020512021212	000012012212	000012031212	032512021212	041212021212	000012000012	000012000012	000012000012
053212023105	053212031212	022512000012	000012000012	000012000012	000012000012	053212023105	053212053212
022512020512	000012000012	000012000012	000012000012	012212052512	023105053212	021212000012	311400100000
000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000012000012	042512020512
000012000012	000012000012	000012000012	052512032512	042512041212	023105051212	053212000012	000012000012
000012000012	000012042512						

053212020512	020512042512	000012012212	000012031212	031212021212	053212041212	000012000012	000012000012
000012000012	053212023105	053212052512	052512000012	000012000012	000012000012	000012000012	053212023105
053212053212	052512051212	000012000012	000012000012	000012000012	012212052512	023105032512	051212000012
311400100000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000012000012
032512053212	000012000012	000012000012	000012000012	052512032512	042512021212	023105022512	042512000012
000012000012	000012000012	000012042512	053212020512	020512042512	000012012212	000012031212	031212022512
042512020512	000012000012	000012000012	000012000012	053212023105	053212051212	051212000012	000012000012
000012000012	000012000012	053212023105	053212053212	051212042512	000012000012	000012000012	000012000012
012212052512	023105042512	031212000012	311400100000	000000000000	000000000000	000000000000	000000000000
000000000000	000000000000	311400100000	000000000000	000000000000	000000000000	000000000000	000000000000
000000000000	000012000012	020512041212	000012000012	000012000012	000012000012	052512022512	042512032512
023105042512	022512000012	000012000012	000012000012	000012042512	053212021212	042512042512	000012012212
000012031212	032512053212	032512042512	000012000012	000012000012	000012000012	053212023105	053212053212
022512031212	000012000012	000012000012	000012000012	053212023105	053212053212	020512020512	000012000012
000012000012	000012000012	012212052512	023105021212	022512000012	311400100000	000000000000	000000000000
000000000000	000000000000	000000000000	000000000000	000012020512	051212021212	000012000012	000012000012
000012000012	052512022512	041212022512	023105052512	052512000012	000012000012	000012000012	000012051212
021212053212	020512021212	000012012212	000012031212	051212021212	021212041212	000012000012	000012000012
000012000012	053212023105	053212022512	053212000012	000012000012	000012000012	000012000012	053212023105
053212053212	021212031212	000012000012	000012000012	000012000012	012212052512	023105053212	020512000012
311400100000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000012020512
022512041212	000012000012	000012000012	000012000012	052512022512	041212022512	023105031212	051212000012
000012000012	000012000012	000012020512	020512052512	053212051212	000012012212	000012042512	032512020512
031212051212	000012000012	000012000012	000012000012	053212023105	053212020512	053212000012	000012000012
000012000012	000012000012	053212023105	053212053212	020512051212	000012000012	000012000012	000012000012
012212052512	023105022512	021212000012	311400100000	000000000000	000000000000	000000000000	000000000000

FIGURE 1. *Octal print-out of data on magnetic tape used to prepare paper tape for the photocomposition machine.*

```
XRA     AXT     *,1
OUT     TRA     4,4
ERR     STZ     3,4
        TRA     4,4
        TNX     ERR,1,1
        BSRA    6
        TRA     B
IO      IOCD    **,,1
        END
```

An example of the data on the binary tape is given by the octal print-out in figure 1. The data of figure 1 may be interpreted by the use of the octal codes given in figures 2 and 3. The final result, as produced by the photocomposition machine, is shown in figure 4.

3. Conclusion

Computed and computer-processed data can now be prepared for publication by an automatic method that retains the high typographic quality of conventional typesetting. Better page formats with less waste space result in less cost for paper, with the added benefit of a smaller size which is easier to handle. Probably the most important improvement, however, is in readability. The printing is not only clear and distinct, but the availability of a choice of type styles, mathematical symbols, special symbols, and Greek and italic characters to fit each particular job contributes toward the publication of data which is easier to understand and a pleasure to read and use.

Keyboard Chart

Shift	502	335	402	202	235	302	406	316	535	522	215	306
Unshift	435	205	525	512	425	412	325	312	225	212	532	331
	1	2	3	4	5	6	7	8	9	10	11	12

	Q	W	E	R	T	Y	U	I	O	P	
Shift	505	405	424	413	304	432	213	233	324	124	321
Unshift	222	322	303	334	423	315	534	514	403	603	431
	13	14	15	16	17	18	19	20	21	22	23

	A	S	D	F	G	H	J	K	L		
Shift	504	513	313	204	604	333	613	133	533	615	416
Unshift	223	234	434	523	123	414	134	614	214	132	421
	24	25	26	27	28	29	30	31	32	33	34

	Z	X	C	V	B	N	M			
Shift	232	305	224	332	524	404	433	516	506	122
Unshift	515	422	503	415	203	323	314	221	231	605
	35	36	37	38	39	40	41	42	43	44

FIGURE 2. *Keyboard chart showing the octal code for each key position.*

Acknowledgment

I wish to thank all those who helped me with this problem, especially Charles DeWitt Coleman for his valuable suggestions and assistance with the computer programming.

Codes for Magnetic Tape Input to Linofilm Converter (Grid Font—Bodoni Book AS1)

Octal Code in Alphabetical Order

Keyboard Position	Decimal Width	Shift Position	Octal Code	BCD Code	Decimal Width	Unshift Position	Octal Code	BCD Code
24	13	A	050415	5 4 :	9	a	022311	2 T 9
39	12	B	052414	5 U @	10	b	020312	2 3 0
37	13	C	022415	2 U :	9	c	050311	5 3 9
26	13	D	031315	3 # :	10	d	043412	4 % 0
15	12	E	042414	4 U @	9	e	030311	3 3 9
27	11	F	020413	2 4 #	6	f	052306	5 T 6
28	13	G	060415	6 4 :	9	g	012311	1 T 9
29	14	H	033316	3 , >	10	h	041412	4 @ 0
20	7	I	023307	2 , 7	5	i	051405	5 @ 5
30	8	J	061310	6 # 8	5	j	013405	1 % 5
31	13	K	013315	1 , :	10	k	061412	6 @ 0
32	12	L	053314	5 , @	5	l	021405	2 @ 5
41	16	M	043320	4 , ¢	15	m	031417	3 @ √
40	14	N	040416	4 4 >	10	n	032312	3 T 0
21	14	O	032416	3 U >	9	o	040311	4 3 9
22	12	P	012414	1 U @	10	p	060312	6 3 0
13	14	Q	050516	5 5 >	10	q	022212	2 S 0
16	13	R	041315	4 # :	7	r	033407	3 % 7
25	11	S	051313	5 # #	8	s	023410	2 % 8
17	12	T	030414	3 4 @	6	t	042306	4 T 6
19	13	U	021315	2 # :	10	u	053412	5 % 0
38	13	V	033215	3 ‡ :	9	v	041511	4 : 9
14	18	W	040522	4 5 S	13	w	032215	3 S :
36	13	X	030515	3 5 :	9	x	042211	4 S 9
18	13	Y	043215	4 ‡ :	9	y	031511	3 : 9
35	11	Z	023213	2 ‡ #	8	z	051510	5 : 8
1	9	_	050211	5 2 9	18	—	043522	4 = S
2	15	ffi	033517	3 = √	9	1	020511	2 5 9
3	15	ffl	040217	4 2 √	9	2	052511	5 V 9
4	5	(	020205	2 2 5	9	3	051211	5 0 9
5	5	)	023505	2 = 5	9	4	042511	4 V 9
6	11	ff	030213	3 2 #	9	5	041211	4 0 9
7	18	—	040622	4 6 S	9	6	032511	3 V 9
8	15	&	031617	3 > √	9	7	031211	3 0 9
9	6	!	053506	5 = 6	9	8	022511	2 V 9
10	10	fi	052212	5 S 0	9	9	021211	2 0 9
11	10	fl	021512	2 : 0	9	0	053211	5 ‡ 9
12	6	/	030606	3 6 6	18	...	033122	3 Z S
23	9	?	032111	3 / 9	9	$	043111	4 Z 9
33	6	:	061506	6 : 6	6	;	013206	1 ‡ 6
34	5	‘	041605	4 > 5	5	’	042105	4 / 5
42	5	,	051605	5 > 5	5	,	022105	2 / 5
43	5	.	050605	5 6 5	5	.	023105	2 Z 5
44	9	*	012211	1 S 9	5	-	060505	6 5 5

Octal Code in Numerical Order

Decimal Width		Octal Code	BCD Code	Decimal Width		Octal Code	BCD Code
9	*	012211	1 S 9	15	ffl	040217	4 2 √
9	g	012311	1 T 9	9	o	040311	4 3 9
12	P	012414	1 U @	14	N	040416	4 4 >
6	;	013206	1 ‡ 6	18	W	040522	4 5 S
13	K	013315	1 , :	18	—	040622	4 6 S
5	j	013405	1 % 5	9	5	041211	4 0 9
5	(	020205	2 2 5	13	R	041315	4 # :
10	b	020312	2 3 0	10	h	041412	4 @ 0
11	F	020413	2 4 #	9	v	041511	4 : 9
9	1	020511	2 5 9	5	‘	041605	4 > 5
9	9	021211	2 0 9	5	’	042105	4 / 5
13	U	021315	2 # :	9	x	042211	4 S 9
5	l	021405	2 @ 5	6	t	042306	4 T 6
10	fl	021512	2 : 0	12	E	042414	4 U @
5	,	022105	2 / 5	9	4	042511	4 V 9
10	q	022212	2 S 0	9	$	043111	4 Z 9
9	a	022311	2 T 9	13	Y	043215	4 ‡ :
13	C	022415	2 U :	16	M	043320	4 , ¢
9	8	022511	2 V 9	10	d	043412	4 % 0
5	.	023105	2 Z 5	18	—	043522	4 = S
11	Z	023213	2 ‡ #	9	_	050211	5 2 9
7	I	023307	2 , 7	9	c	050311	5 3 9
8	s	023410	2 % 8	13	A	050415	5 4 :
5	)	023505	2 = 5	14	Q	050516	5 5 >
11	ff	030213	3 2 #	5	.	050605	5 6 5
9	e	030311	3 3 9	9	3	051211	5 0 9
12	T	030414	3 4 @	11	S	051313	5 # #
13	X	030515	3 5 :	5	i	051405	5 @ 5
6	/	030606	3 6 6	8	z	051510	5 : 8
9	7	031211	3 0 9	5	,	051605	5 > 5
13	D	031315	3 # :	10	fi	052212	5 S 0
15	m	031417	3 @ √	6	f	052306	5 T 6
9	y	031511	3 : 9	12	B	052414	5 U @
15	&	031617	3 > √	9	2	052511	5 V 9
9	?	032111	3 / 9	9	0	053211	5 ‡ 9
13	w	032215	3 S :	12	L	053314	5 , @
10	n	032312	3 T 0	10	u	053412	5 % 0
14	O	032416	3 U >	6	!	053506	5 = 6
9	6	032511	3 V 9	10	p	060312	6 3 0
18	...	033122	3 Z S	13	G	060415	6 4 :
13	V	033215	3 ‡ :	5	-	060505	6 5 5
14	H	033316	3 , >	8	J	061310	6 # 8
7	r	033407	3 % 7	10	k	061412	6 @ 0
15	ffi	033517	3 = √	6	:	061506	6 : 6

FIGURE 3. *Octal and BCD codes, including width values, for one specific grid font.*

TABLE 1. *Transition probabilities of copper*—Continued

Intensity	Wavelength A	Energy Levels K	gA 10^8/sec	gf	Log gf
78	2626.68	40944 – 79003	0.042	0.0043	–2.36
131	2630.00	39019 – 77031	0.070	0.0073	–2.14
145	2634.93	39019 – 76959	0.078	0.0081	–2.09
41	2645.30	40114 – 77905	0.022	0.0023	–2.63
60	2649.84	40114 – 77841	0.033	0.0034	–2.47
15	2846.48	40944 – 76064	0.0087	0.0011	–2.98
139	2858.22	39019 – 73995	0.080	0.0097	–2.01
185	2858.73	11203 – 46173	0.010	0.0013	–2.89
65	2890.84	44406 – 78988	0.038	0.0048	–2.32
56	2891.64	44544 – 79116	0.033	0.0042	–2.38
11	2931.70	40944 – 75044	0.0065	0.00084	–3.08
29	2933.06	39019 – 73103	0.017	0.0022	–2.66
119	2978.30	43514 – 77080	0.072	0.0096	–2.02
103	2979.38	43514 – 77068	0.063	0.0083	–2.08
98	2998.38	11203 – 44544	0.0036	0.00048	–3.32
161	3012.00	40114 – 73305	0.096	0.013	–1.88
54	3014.85	41153 – 74313	0.033	0.0045	–2.35
191	3021.54	40909 – 73995	0.12	0.016	–1.80
179	3022.61	39019 – 72093	0.11	0.015	–1.84
90	3024.99	30535 – 63585	0.044	0.0060	–2.22

FIGURE 4. *Portion of page from the machine that was produced from the data illustrated in figure 1.*

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U. S. DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS
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