The Evolution of Character Codes, 1874-1968

Eric Fischer
enf@pobox.com

Abstract

Émile Baudot's printing telegraph was the first widely adopted device to encode letters, numbers, and symbols as uniform-length binary sequences. Donald Murray introduced a second successful code of this type, the details of which continued to evolve until versions of Baudot's and Murray's codes were standardized as International Telegraph Alphabets No. 1 and No. 2, respectively. These codes were used for decades before the appearance of computers and the changing needs of communications required the design and standardization of a new code. Years of debate and compromise resulted in the ECMA-6 standard in Europe, the ASCII standard in the United States, and the ISO 646 and International Alphabet No. 5 standards internationally.

Introduction

Today we take it for granted that a ''plain text'' file on a computer can be read by nearly any program, printed on any printer, displayed on any screen, transmitted over any network, and understood equally easily by any other make or model of computer. Plain text is plain, though, only because of a near-universal agreement about what symbols and actions correspond to what arbitrary arrangement of bits, an agreement that was reached only after many years of design work, experimentation, and compromise.

The first portion of the paper will cover the origins of International Telegraph Alphabet No. 2 (often called ''Baudot''), the five-unit code standardized in the 1930s. The second portion will cover the design and standardization of its successor, the seven-bit international standard code now used by the majority of the world's computers and networks. This second topic has previously been addressed from different perspectives in a paper by Robert W. Bemer[1] and a book by Charles E. Mackenzie.[2]

Émile Baudot

On July 16, 1870, twenty-four-year-old Jean-Maurice-Émile Baudot (Figure 1) left his parents' farm and began a new career in France's Administration des Postes et des Télégraphes. He had received only an elementary school education, but began studying electricity and mechanics in his spare time. In 1872, he started research toward a telegraph system that would allow multiple operators to transmit simultaneously over a single wire and, as the transmissions were received, would print them in ordinary alphabetic characters on a strip of paper. He received a patent for such a system on June 17, 1874.[3, 4, 5]

Baudot's was not the first printing telegraph, but it made considerably more efficient use of communications lines than an earlier system invented by David E. Hughes. Hughes's printer contained a continually rotating wheel with characters engraved on it in the order shown in Figure 2. A character could be printed by sending a single pulse over the telegraph line, but depending on the current position of the wheel it might take nearly a complete rotation before the correct character would be ready to print.[6] Instead of a variable delay followed by a single-unit pulse, Baudot's system used a uniform six time units to transmit each character. I have not been able to obtain a copy of Baudot's 1874 patent, but his early telegraph probably used the six-unit code (Figure 3) that he attributes to Davy in an 1877 article.[7]

(In Figure 3, and in other figures to follow, each printable character is shown next to the pattern of impulses that is transmitted on a telegraph line to represent it. In this figure, dots (·) specifically represent the positive voltage of an idle telegraph line and circles (○) the negative voltage of an active line. In related systems using punched paper tape, circles represent a hole punched in the tape and dots the absence of a hole.)

It may seem surprising that Hughes and Baudot invented their own telegraph codes rather than designing printers that could work with the already-standard Morse code. Morse code, though, is extremely

Figure 1. Émile Baudot (1845-1903).[3]

	letters	figures		letters	figures		letters	figures		letters	figures
1	A	1	8	H	8	15	O	?	22	V	=
2	B	2	9	I	9	16	P	!	23	fig spc	
3	C	3	10	J	0	17	Q	’	24	W	(
4	D	4	11	K	.	18	R	+	25	X	)
5	E	5	12	L	,	19	S	−	26	Y	&
6	F	6	13	M	;	20	T	×	27	Z	"
7	G	7	14	N	:	21	U	/	28	let spc	

Figure 2. Order of characters on Hughes printing telegraph typewheel.[6] Some equipment replaced the letter W by the accented letter É and the multiplication sign (×) by a section sign (§).

difficult to decode mechanically because its characters vary both in their length and in their pattern. It was not until the beginning of the twentieth century that F. G. Creed was able to develop a successful Morse printer, and even his invention could not print messages immediately as they were received, but instead required that they first be punched onto paper tape.[8] Hughes simplified the task by adopting a code in which characters varied only with time, not in their pattern. Baudot chose the opposite simplification: his

○·····	A	·○○···	N
·○····	B	··○··○	O
··○···	C	···○○·	P
···○··	D	○····○	Q
····○·	E	·○··○·	R
·····○	F	○·○·○·	S
○·○···	G	···○·○	T
·○·○··	H	○·○··○	U
··○·○·	I	·○·○○·	V
···○·○	J	○··○·○	W
○···○·	K	·○○··○	X
·○···○	L	○··○○·	Y
○··○··	M	·○○·○·	Z

Figure 3. Six-unit code (alphabet only) from an 1877 article by Émile Baudot.[7]

characters had varying patterns but were always transmitted in the same amount of time.

A six-unit code can encode 64 (2^6) different characters, far more than the twenty-six letters and space that are needed, at a minimum, for alphabetic messages. This smaller set of characters can be encoded more efficiently with a five-unit code, which allows 32 (2^5) combinations, so in 1876 Baudot redesigned his equipment to use a five-unit code. Punctuation and digits were still sometimes needed, though, so he adopted from Hughes the use of two special *letter space* and *figure space* characters that would cause the printer to shift between cases at the same time as it advanced the paper without printing.

The five-unit code he began using at this time (Figure 4)[9] was structured to suit his keyboard (Figure 5), which controlled two units of each character with switches operated by the left hand and the other three units with the right hand.[10] Such “chorded” keyboards have from time to time been reintroduced.[11, 12] The Hughes system had used a piano-like keyboard (Figure 6). The typewriter was still too new an invention to have any impact on the design of telegraph equipment.

Donald Murray

By 1898, though, typewriters had become much more common. In that year,[15] Donald Murray (Figure 7), “an Australian journalist, without prior practical experience in telegraph work,”[16] invented a device which operated the keys of a typewriter or typesetting machine according to patterns of holes punched in a strip of paper tape. In 1899 he received a United States patent for this invention[17] and came to New York, where he worked to develop a complete telegraph system around it for the Postal Telegraph-Cable

	let	fig		let	fig
· · · · ·	unused		· · · ○○	*	*
○ · · · ·	A	1	○ · · ○○	K	(
○○ · · ·	É	&	○○ · ○○	L	=
· ○ · · ·	E	2	· ○ · ○○	M	)
· ○○ · ·	I	°	· ○○ ○○	N	Nº
○○○ · ·	O	5	○○○ ○○	P	%
○ · ○ · ·	U	4	○ · ○ ○○	Q	/
· · ○ · ·	Y	3	· · ○ ○○	R	−
· · ○ ○ ·	B	8	· · ○ · ○	S	;
○ · ○ ○ ·	C	9	○ · ○ · ○	T	!
○○○ ○ ·	D	0	○○○ · ○	V	’
· ○○ ○ ·	F	f	· ○○ · ○	W	?
· ○ · ○ ·	G	7	· ○ · · ○	X	,
○○ · ○ ·	H	h	○○ · · ○	Z	:
○ · · ○ ·	J	6	○ · · · ○	t	.
· · · ○ ·	figure space		· · · · ○	letter space	

Figure 4. Émile Baudot’s five-unit code.[9, 10, 13]

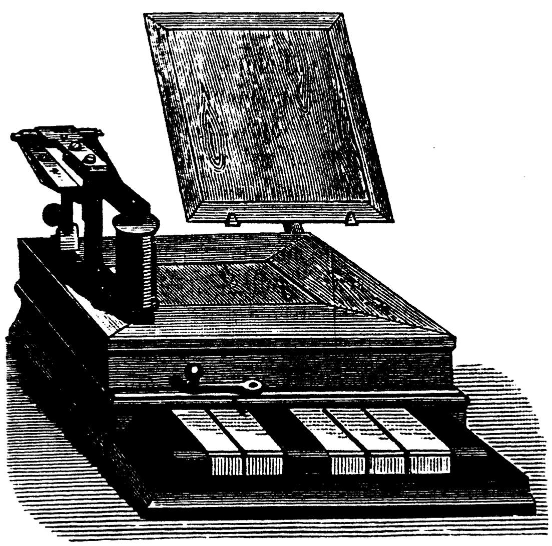

Figure 5. Baudot’s five-key keyboard.[10]

1	2	3	4	5	6	7	8	9	0	.	,	;	:
A	B	C	D	E	F	G	H	I	J	K	L	M	N
	"	&	)	(		=	/	§	−	+	’	!	?
	Z	Y	X	É		V	U	T	S	R	Q	P	O

Figure 6. Hughes printing telegraph keyboard.[14]

Figure 7. Donald Murray (1866-1945). Photo provided by and reproduced courtesy of Bob Mackay.

Company.[15, 18, 19]

Murray’s printer, like Baudot’s telegraph, represented each character as a sequence of five units and employed special shift characters to switch between cases. Baudot’s system had only letter and figure cases, but Murray’s first printer had three: figures, capitals, and miniscules (“release”). To maximize the structural stability of the tape,[20] Murray arranged the characters in his code so that the most frequently used letters were represented by the fewest number of holes in the tape. Figure 8 shows the codes he assigned to the letters, control characters, and comma and period. His patent unfortunately gives no indication of what characters were available in the figures case or in what order they were arranged.

On January 25, 1901, William B. Vansize (identified as Murray’s attorney in several of his patents)[21] described Murray’s invention to the American Institute of Electrical Engineers, and Murray demonstrated the printer in operation.[16] By this time, his equipment used a code (Figure 9a) that was almost identical to the one from 1899, except that the codes for the *space*

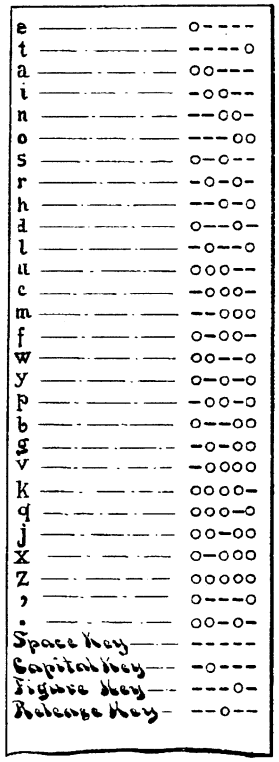

Figure 8. Murray printer code, 1889.[17]

	rls	cap	fig	cap	fig	let	fig	let	fig
○ · · · ·	e	E	−	E	3	E	3	E	3
· · · · ○	t	T	unk	T	5	T	5	T	5
○○ · · ·	a	A	/	A	&	A	cor	A	:
· ○○ · ·	i	I	unk	I	8	I	8	I	8
· · ○○ ·	n	N	unk	N	£	N	−	N	−
· · · ○○	o	O	unk	O	9	O	9	O	9
○ · ○ · ·	s	S	(	S	:	S	£	S	¹
· ○ · ○ ·	r	R	%	R	4	R	4	R	4
· · ○ · ○	h	H	unk	H	;	H	;	H	⁵/
○ · · ○ ·	d	D	)	D	−	D	¹	D	²
· ○ · · ○	l	L	unk	L	%	L	prf	L	/
○○○ · ·	u	U	unk	U	7	U	7	U	7
· ○○○ ·	c	C	unk	C	(	C	’	C	(
· · ○○○	m	M	unk	M	?	M	?	M	,
○ · ○○ ·	f	F	unk	F	"	F	"	F	¹/
○○ · · ○	w	W	£	W	2	W	2	W	2
○ · ○ · ○	y	Y	unk	Y	6	Y	6	Y	6
· ○○ · ○	p	P	unk	P	0	P	0	P	0
○ · · ○○	b	B	unk	B	/	B	/	B	?
· ○ · ○○	g	G	unk	G	’	G	³/	G	³/
· ○○○○	v	V	unk	V	)	V	)(	V	)
○○○○ ·	k	K	unk	K	½	K	⁹/	K	⁹/
○○○ · ○	q	Q	"	Q	1	Q	1	Q	1
○ · ○○○	x	X	3	X	¾	X	%	X	£
○○ · ○○	j	J	unk	figures		figures		fig spc	
○○○○○	z	Z	2	capitals		letters		erasure	
○ · · · ○	,	unk	unk	Z	!	Z	,	Z	.
○○ · ○ ·	.	unk	unk	J	¼	J	⁷/	J	⁷/
· · · · ·	release			line		page		unused	
· ○ · · ·	capitals			,	,	line		column	
· · · ○ ·	figures			.	.	+	.	car ret	
· · ○ · ·	space			space		space		let spc	
	1901 a			1905 b		1908 c		1929 d	

Figure 9. Murray Printing Telegraph codes, 1901-1929.[16, 22, 23, 24] Character assignments shown as *unk* are unknown.

and *release* characters had been reversed. Again only the codes for the letters were listed in the paper, but an illustration (redrawn as Figure 10) shows the keyboard positions of some of the punctuation and digits. These would have had the same codes as the letters with which they share keys.

It is unclear why Murray should have chosen this arrangement for the figures case, as it is not the same as that of any identifiable typewriter. It also has no connection to the key arrangement of the Columbia Bar-Lock typewriter,[25] which Murray named at the 1901 demonstration as the typewriter used in his printer, and the distinctive silhouette of which can be recognized in his 1899 patent. Whatever its origin, this arrangement of punctuation and digits did not last long. Another patent, filed July 20, 1901, shows a new keyboard arrangement (Figure 11).[26]

One of the criticisms of Murray's printer at its 1901 demonstration was its lack of automation. An operator had to turn a crank to make it print and had to return the typewriter carriage manually at the end of each line. By February 23, 1905, when Murray spoke at a London meeting of the Institution of Electrical Engineers,[22] he had introduced a *line* control character which automatically returned the carriage and advanced the paper. This took the place of the former *release* control, so the system now had only two cases: figures and capitals. The code was further changed to give the *capitals* character, rather than the letter Z, the all-holes-punched code, so that errors in punching could be erased invisibly by repunching the *capitals* code, which did not print, over the mistyped sections of the tape. The 1905 code is shown in Figure 9b and the keyboard that generated it in Figure 12.

By 1908, Murray's code and keyboard had undergone further changes, as can be seen in Figure 13 and Figure 9c.[23] The comma (,) was removed from the

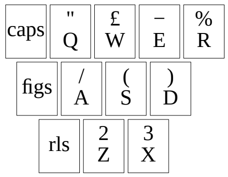

Figure 10. Fragment of Murray keyboard, 1901.[16]

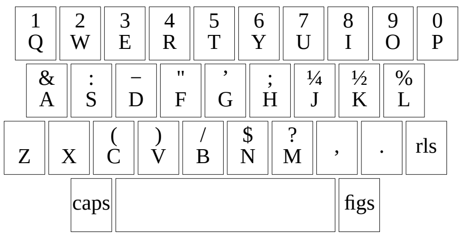

Figure 11. Murray keyboard, 1902.[26]

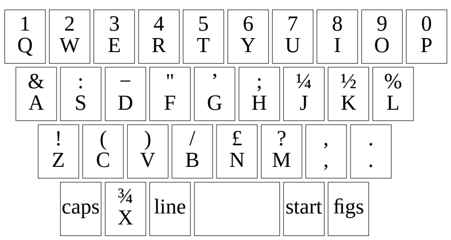

Figure 12. Murray keyboard, 1905.[22]

letters case (as the former capitals case had been renamed) to make room for a new *page* control character indicating the end of a page of text. The movement of the comma into the figures case required the rearrangement of other figures and the combination of the left (() and right ()) parentheses into a single character (()). In 1911, Murray explained a further reason for the extent of the reorganization: to move the most important punctuation onto the bottom row of the keyboard so that the middle row of the figures case could be reserved for ‘‘national use’’ characters needed in particular countries but not used in international communications.[27] Figure 14 is the international version of the keyboard.

The Murray code diverges

On April 12, 1912, Donald Murray announced that he had sold his United States patents to the Western Union Telegraph Company.[28] After this date, American and English Murray equipment and codes began to diverge because of their independent development. The most significant change in England was the reintroduction of the *letter space*, *figure space*,

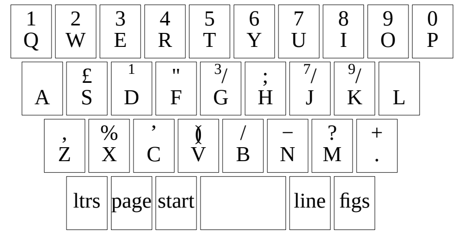

Figure 13. Murray keyboard, 1908.[23]

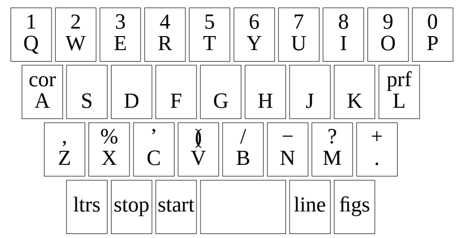

Figure 14. Murray keyboard, 1911.[27]

and *erasure* control characters, which Baudot had used, in place of the *space*, *figures*, and *letters* codes of earlier Murray models.[29] In addition, the *line* control was separated into independent *column* (sometimes known as *line feed*) and *carriage return* characters. The added control code displaced the period (.) from the letters case and resulted in the rearranged punctuation shown in the code of Figure 9d.[24]

The different changes that took place in the United States were the result of influence from another printing telegraph system, the Morkrum. The Morkrum company was founded in 1901 by Joy Morton, the owner of Morton Salt, and Charles L. Krum, a mechanical engineer. Krum, later joined by his son Howard, an electrical engineer, built his early telegraph printers around the Blicksenderfer and Oliver typewriters.[30] It appears, though, that the Hammond typewriter’s ‘‘Universal’’ model may also have had an impact on the design of Morkrum equipment. The Morkrum keyboard (Figure 15) is more similar to the Hammond keyboard (Figure 16) than to that of any other identifiable typewriter, and both machines use similar typewheel-based printing mechanisms.[31, 25]

Figure 17 shows the Morkrum five-unit code, which was evidently based, like Murray’s, on a study of the relative frequency of use of the characters, but with the idea of making the typewheel move the shortest distance rather than minimizing the number of holes punched. The most frequently used letters are clustered in the middle of the first column, which represents one side of the typewheel; the least frequently used are clustered in the middle of the second column, a complete half-turn of the wheel away.

By January 15, 1915, the Western Union Telegraph Company had begun using a printing telegraph system that combined aspects of the Murray and Morkrum codes. It used Murray’s codes for the letters and controls, but generally followed the Morkrum conventions for which figures should be paired with which letters.[37] Like the Morkrum code and the later English Murray code, the Western Union code used separate *line feed* and *carriage return* characters instead of a single *line* character. Some changes to the Morkrum figures were necessary so that the period (.) could be moved from the letters case to the figures case and so that three new controls could be added: *signal*, which rang a bell, *city*, which switched the receiver from retransmitting to printing, and *thru*, which switched from printing to retransmitting.[38] The Morkrum and Western Union codes are compared in Figure 18a and 18b. Western Electric also began using this code on its telegraph equipment, as well as a related one (Figure 18c) which retained the Morkrum placement of the apostrophe (’) because it contained fewer controls.[39]

Code standardization

By 1916, Donald Murray could say that “the inventive stage is nearly over. The mystery is gone and printing telegraphy has become one of the exact arts.”[41] With the experimental era at its end, there was little reason for the world’s telegraphers to continue using several similar but incompatible five-unit codes, but no progress had been made toward standardization as late as 1924, when the German telegraphic administration began publishing articles advocating the adoption of an international standard code. Later that year in England, A. E. Thompson and Donald Murray also declared their support for standardization. Murray had previously had the habit of referring to any five-unit code, including his own, as “the Baudot alphabet,”[27, 28] as if all five-unit codes were interchangeable, but now agreed that standardization was “a matter which will have to receive the attention of the telegraph administations in the near future.”[42] In early 1925, German articles advocating standardization were reprinted in France and Switzerland.[43, 44]

In November, 1926, the Comité Consultatif International des Communications Télégraphiques (CCIT) met for the first time in Berlin.[45] Its parent organization, the Bureau International de l’Union Télégraphique, had, decades earlier, standardized Morse code[46] and the list of characters that could be transmitted with Baudot equipment (but not their codes).[47] Among the many standards issues the newly formed committee was to consider (another was the invention of the “baud” as the standard unit of communications speed) was the establishment of a uniform five-unit code. Delegate Stahl provided a lengthy review of the characteristics of existing codes and proposed a new standard code (Figure 19) based on a recalculation of the frequency with which letters were used. The French delegation objected that this was impossible because the operators of the many existing Baudot installations could not be forced to memorize a wholly new code. The technical subcommittee concluded that indeed, any new standard would have to be closely related to the original Baudot code.

The British delegation expressed its preference for a code with *figure space* and *letter space* characters rather than separate *figures*, *letters*, and *space* codes.

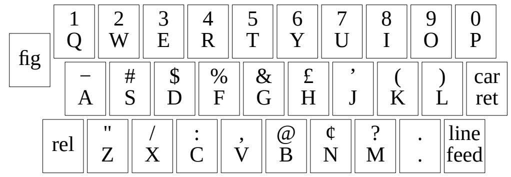

Figure 15. Morkrum keyboard.[32, 33]

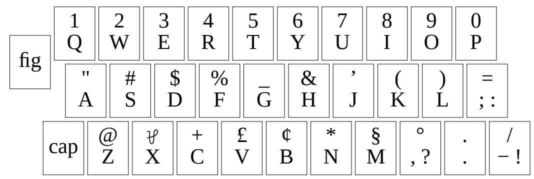

Figure 16. Hammond “Universal” keyboard.[34]

	let	fig		let	fig
○○○○ ·	carriage return		· · · · ○	Y	6
·○○○ ·	line feed		· · ·○ ○	P	0
○○○· ·	D	$	· ·○· ○	B	@
· ·○○ ·	R	4	·○· · ○	K	(
·○·○ ·	S	#	○· · · ○	J	’
○○· · ·	A	−	·○○· ○	Z	"
○○·○ ·	T	5	○·○· ○	X	/
○·○○ ·	E	3	○· ·○ ○	Q	1
○· ·○ ·	N	¢	○·○○ ○	V	,
○·○· ·	I	8	○○·○ ○	G	&
·○○· ·	O	9	○○· · ○	W	2
○· · · ·	H	£	·○·○ ○	F	%
·○· · ·	L	)	· ·○○ ○	C	:
· ·○· ·	U	7	○○○· ○	space	
· · ·○ ·	M	?	·○○○ ○	figure shift	
· · · · ·	.	.	○○○○ ○	letter shift	

Figure 17. Morkrum code.[32, 35, 36, 33]

	let	fig		let	fig	let	fig
○○···	A	−	○○···	A	−	A	−
··○·○	B	@	○··○○	B	?	B	?
··○○○	C	:	·○○○·	C	:	C	:
○○○··	D	$	○··○·	D	$	D	$
○·○○·	E	3	○····	E	3	E	3
·○·○○	F	%	○·○○·	F	city	F	!
○○·○○	G	&	·○·○○	G	&	G	&
○····	H	£	··○·○	H	£	H	£
○·○··	I	8	·○○··	I	8	I	8
○···○	J	’	○○·○·	J	sig	J	’
·○··○	K	(	○○○○·	K	(	K	(
·○···	L	)	·○··○	L	)	L	)
···○·	M	?	··○○○	M	.	M	.
○··○·	N	¢	··○○·	N	,	N	,
·○○··	O	9	···○○	O	9	O	9
···○○	P	0	·○○·○	P	0	P	0
○··○○	Q	1	○○○·○	Q	1	Q	1
··○○·	R	4	·○·○·	R	4	R	4
·○·○·	S	#	○·○··	S	thru	S	bell
○○·○·	T	5	····○	T	5	T	5
··○··	U	7	○○○··	U	7	U	7
○·○○○	V	,	·○○○○	V	;	V	;
○○··○	W	2	○○··○	W	2	W	2
○·○·○	X	/	○·○○○	X	/	X	/
····○	Y	6	○·○·○	Y	6	Y	6
·○○·○	Z	"	○···○	Z	"	Z	"
·····	.	.					
○○○·○	space		··○··	space		space	
·○○○○	figure shift		○○·○○	figure shift		figure shift	
○○○○○	letter shift		○○○○○	letter shift		letter shift	
○○○○·	carriage ret		···○·	carriage ret		carriage ret	
·○○○·	line feed		·○···	line feed		line feed	
	Morkrum a			Western Union b		Western Electric c	

Figure 18. Morkrum, Western Union, and Western Electric codes.[32, 33, 37, 40, 39]

	let	fig		let	fig
·····	carriage return		○○○··	z	
○····	e	3	·○○○·	line feed	
·○···	letter space		··○○○	m	.
··○··	a	−	○·○○·	f	
···○·	n	,	○··○○	b	?
····○	t	5	○○·○·	j	=
○○···	u	7	○○··○	w	2
·○○··	i	8	○·○·○	y	6
··○○·	figure space		·○○·○	p	0
···○○	o	9	·○·○○	g	
○·○··	s	;	○○○○·	k	(
·○·○·	r	4	·○○○○	v	
··○·○	h	:	○·○○○	x	/
○··○·	d	!	○○○·○	q	1
·○··○	l	)	○○·○○	stop	
○···○	c		○○○○○	error	

Figure 19. Stahl’s proposed standard code, September, 1926.[45]

The delegation from the USSR preferred to separate the shifts from the spaces because the Cyrillic alphabet has too many letters to fit only in the letters case and requires that five codes from the figures case be used for additional letters. The Czechoslovakian delegation asked that the committee address the long-neglected problem of how to encode accented letters. F. G. Creed raised the possibility of abandoning the traditional five-unit code for a six-unit standard, which would eliminate most shifting and, with shifts, would make room for non-Roman letters, but this suggestion went nowhere.

Many details of the Baudot-derived standard-to-be were worked out in advance of the next CCIT meeting, which was to be held in June, 1929.[24] The accented letter E (É) and the superscript letter T (^{t}) would be sacrificed for the *carriage return* and *line feed* codes, respectively. The period (.), which had been the upper case of the superscript T, would replace the semicolon (;). The following punctuation marks were considered essential to retain: period (.), comma (,), question mark (?), dash (−), apostrophe (’), colon (:), parentheses ((and)), and fraction bar (/). Other essentials were a *stop* signal and the two punctuation marks that were conventionally used to separate the address from the message (=) and to indicate the end of the message (+).

The obstacle to universal adoption of this modified Baudot code (Figure 20) was that when combined with a QWERTY keyboard it put the digits in nonsensical locations (Figure 21). Booth and Willmot of the British Post Office had provided a possible solution when they invented a keyboard (Figure 22) that was arranged like Murray’s but used complicated mechanical means to transmit the Baudot code,[48] but many attendees of the June 11, 1929 session of the CCIT conference preferred the Murray code’s direct association of letters and figures.[49] A morning of debate only managed to reaffirm that the Baudot code should be modified as little as possible, but the possibility was raised that another code might be more appropriate for start-stop equipment.

After a break from 12:00 to 2:15 and further debate, the delegate from the Netherlands proposed

	let	fig		let	fig
○ · · · ·	A	1	○ · ○○○	Q	/
· · ○○ ·	B	8	· · ○○○	R	−
○ · ○○ ·	C	9	· · ○ · ○	S	.
○○○○ ·	D	0	○ · ○ · ○	T	!
· ○ · · ·	E	2	○ · ○ · ·	U	4
· ○○○ ·	F	§	○○○ · ○	V	’
· ○ · ○ ·	G	7	· ○○ · ○	W	?
○○ · ○ ·	H	&	· ○ · · ○	X	,
· ○○ · ·	I	"	· · ○ · ·	Y	3
○ · · ○ ·	J	6	○○ · · ○	Z	:
○ · · ○○	K	(	· · · · ○	letter space	
○○ · ○○	L	=	· · · ○ ·	figure space	
· ○ · ○○	M	)	· · · ○○	stop	
· ○○○○	N	+	· · · · ·	idle	
○○○ · ·	O	5	○○ · · ·	new line	
○○○○○	P	%	○ · · · ○	line feed	

Figure 20. Proposed International Telegraph Alphabet, March 22, 1929.[24]

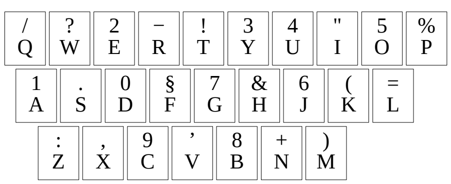

Figure 21. Proposed International Telegraph Alphabet, arranged on QWERTY keyboard.[24]

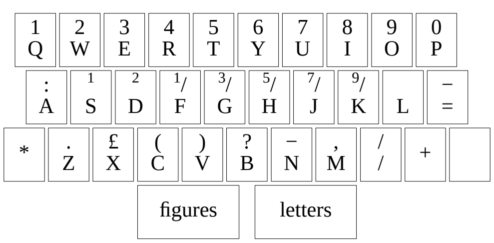

Figure 22. Major Booth and Mr. Willmot’s New Keyboard Perforator for the Baudot Printing Telegraph System.[48] Some keys show replacement of standard Baudot figures with alternate characters by the British Post Office.

that a subcommittee investigate what code was most appropriate for start-stop equipment. The committee adjourned and the subcommittee met from 3:20 to 5:50. It returned with a code (Figure 23), to be known as International Telegraph Alphabet No. 2, that, for the most part, combined the Baudot codes for the letters with the English Murray pairings of the letters and figures, and reserved four positions for national use. (The new code reversed Baudot’s assignments for *error* and the letter P so that the *error* character would have the all-holes-punched code and could be repunched over a mistyped character.) The next day, the proposed International Telegraph Alphabet No. 1, as the Baudot-style standard code would be known, was also modified to reserve four characters for national use, and other specifications were worked out to ensure that systems would be compatible.

The proposal to standardize two International Telegraph Alphabets was vigorously opposed by the USSR, so a committee continued to meet to try to come up with a better idea.[50] On January 21, 1931, British delegate Mr. Booth informed members of the committee of a British plan to introduce a teletypewriter exchange service of the type then also being introduced in the United States.[51] The service would place teleprinters in ordinary offices, so to avoid confusing new customers with keyboards with dual space bars, as would be found on equipment that used either the British Murray code or either of the proposed International Telegraph Alphabets, they planned to use an American-style Murray code and a keyboard with separate space and shift keys. The USSR also expressed a preference to use the Murray code, rather than the proposed International Telegraph Alphabets, for international communication. Feuerhahn of Germany urged the CCIT to carry on with its original plan, but at its June, 1931 meeting the committee resolved to replace the proposed International Telegraph Alphabet No. 2 with a code based on Murray’s.[52] Figure 24 and Figure 25 show International Telegraph Alphabets Nos. 1 and 2 as they were finally adopted.[53]

The next generation

In the years that followed, International Telegraph Alphabet No. 1 fell into disuse, while equipment using Alphabet No. 2 came to dominate the world’s international non-voice communications. In May, 1948, the United States delegation to the CCIT proposed “the adoption, with reservations, of the 5-unit code Alphabet No. 2, as the code for general use in international telegraphy,” and the proposal was accepted. A British proposal to turn the code’s *not used* character into a third shift “received general support” but was first to be subjected to further study.[54] It was not until 1988 that Alphabet No. 2 was finally extended to support both upper and lower case letters.[55]

The four characters reserved for national use in International Telegraph Alphabet No. 2 were not a very general solution to the problem of encoding

	let	fig		let	fig
○····	A	:	○·○○○	Q	1
··○○·	B	?	··○○○	R	4
○·○○·	C	(	··○·○	S	nat
○○○○·	D	,	○·○·○	T	5
·○···	E	3	○·○··	U	7
·○○○·	F	/	○○○·○	V	)
·○·○·	G	nat	·○○·○	W	2
○○·○·	H	+	·○··○	X	nat
·○○··	I	8	··○··	Y	6
○··○·	J	bell	○○··○	Z	.
○··○○	K	nat	····○	letter space	
○○·○○	L	=	···○·	figure space	
·○·○○	M	’	○○○○○	error	
·○○○○	N	−	·····	idle	
○○○··	O	9	○○···	new line	
···○○	P	0	○···○	line feed	

Figure 23. Proposed International Telegraph Alphabet No. 2, June 11, 1929.[49]

	let	fig		let	fig
○····	A	1	○·○○○	Q	/
··○○·	B	8	··○○○	R	−
○·○○·	C	9	··○·○	S	.
○○○○·	D	0	○·○·○	T	nat
·○···	E	2	○·○··	U	4
·○○○·	F	nat	○○○·○	V	’
·○·○·	G	7	·○○·○	W	?
○○·○·	H	+	·○··○	X	,
·○○··	I	nat	··○··	Y	3
○··○·	J	6	○○··○	Z	:
○··○○	K	(	○○···	carriage return	
○○·○○	L	=	○···○	line feed	
·○·○○	M	)	····○	letter space	
·○○○○	N	nat	···○·	figure space	
○○○··	O	5	···○○	*	*
○○○○○	P	%	·····	idle	

Figure 24. International Telegraph Alphabet No. 1.[53]

letters with accent marks, especially since their use was prohibited in international communications. At the December, 1956 meeting of the CCIT, one of the issues brought up was the ‘‘possible need for extending the facilities offered by the present 5-unit telegraph alphabet, perhaps by the introduction, under agreed conditions, of a 6-unit code.’’[56] The proposed expanded code would provide for ‘‘the inclusion of diacritical signs and additional characters required in some languages and... the needs of data processing.’’[57]

	let	fig		let	fig
○○···	A	−	○○○·○	Q	1
○··○○	B	?	·○·○·	R	4
·○○○·	C	:	○·○··	S	’
○··○·	D	wru	····○	T	5
○····	E	3	○○○··	U	7
○·○○·	F	nat	·○○○○	V	=
·○·○○	G	nat	○○··○	W	2
··○·○	H	nat	○·○○○	X	/
·○○··	I	8	○·○·○	Y	6
○○·○·	J	bell	○···○	Z	+
○○○○·	K	(	···○·	carriage return	
·○··○	L	)	·○···	line feed	
··○○○	M	.	○○○○○	letter shift	
··○○·	N	,	○○·○○	figure shift	
···○○	O	9	··○··	space	
·○○·○	P	0	·····	not used	

Figure 25. International Telegraph Alphabet No. 2.[53]

On January 1, 1957, the CCIT and its former telephonic counterpart, the Comité Consultatif International Téléphonique (CCIF), were merged into a single International Telegraph and Telephone Consultative Committee (CCITT).[58] So it was the CCITT that held a special meeting in Warsaw in May, 1958 to consider an expanded code. There was ‘‘general agreement... that it was premature at that time to standardise a new telegraph alphabet,’’[57] but the meeting did result in a list of the diacritical marks that would have to appear in any code that was standardized: the acute (´), grave (`), circumflex (^), umlaut (¨), and tilde (˜) accents.[59] At its December, 1960 meeting, the CCITT established a Working Party responsible for further development of the new telegraph code.

In the United States, accented letters were not a concern but there was nevertheless interest in the possibility of a six-unit replacement for International Telegraph Alphabet No. 2. In 1952, I. S. Coggesgall, the Director of Planning for Western Union’s International Communications Department, observed that ‘‘a 6-unit general purpose printer would afford $2^6 = 64$ combinations of characters and controls and has been proposed to increase the usefulness of printers in certain language applications. Among other things, it would make possible tabulators and back-spacers.’’[60]

It was Western Union’s competitor AT&T, though, that was most convinced of the value of a six-unit code. The company was planning to replace its manually switched teletypewriter exchange network with a new direct dial network on August 31, 1962.[61] It saw the transition as an ideal opportunity to introduce a new code that would eliminate the need to shift manually between letters and figures cases and would use a keyboard as similar as possible to that of a standard typewriter. The new network would not make old equipment or codes obsolete, but it would allow faster connections than the old one for those who wanted greater speed, and most of the installed equipment would not be able to keep up. Replacement equipment designed to work at high speed (by AT&T's Teletype subsidiary, the company once known as Morkrum) would also be designed for the new code.[62]

Figure 26 shows the proposed new code and Figure 27 the keyboard that would transmit it. Notice that characters that appear on the same key of the keyboard are located in the same row of columns 2 and 3 of the code. This arrangement makes the operation of the keyboard's Shift key mechanically simpler, because the codes for characters in row 2 differ from the codes for characters in row 3 by only a single bit.

(Unlike the previous code charts in this paper, Figure 26 does not show the pattern of electrical signals that would be transmitted across a telegraph line to represent each of its characters. Instead, it is arranged in numbered rows and columns. A character in column x, row y, sometimes referred to as character x/y, represents character number $16x + y$, and is transmitted as a sequence of impulses corresponding to the binary representation of its column and row numbers, in reverse order. For example, in Figure 26, the apostrophe (’) is in column 3, row 10, so it is character 3/10, number 58. Three in binary is 11_2, and ten is 1010_2, so the character's binary code is 111010_2 and is transmitted in reverse order as · ○ · ○○○. Most of the remaining code charts in this paper will use the same conventions.)

The character in Figure 26 labelled *blank*, also called *null* or *master space*, corresponds to an idle transmission line or a section of paper tape with no holes punched and is ignored. (Confusingly, in some other codes the *blank* name refers to the *space* function instead.) Similarly, *rubout*, also called *delete*, is the character with all holes punched, and is also ignored. It is used to correct errors by punching it over a mispunched character, the same function for which the *letter shift* code could be used in Murray's codes and in International Telegraph Alphabet No. 2. The characters *uc* and *lc* would shift between upper case and lower case on printers that supported two cases. The *lf*, *cr*, and *sp* characters are shorter names for the *line feed*, *carriage return*, and *space* functions also seen on earlier equipment. The *bell* control rings a bell. The *wru* control stands for "who are you" and causes the receiving equipment to transmit back information identifying itself so the sender can be sure he or she is sending to the correct destination. The character named *stunt* was intended to be used as the first character in a two-character sequence that would cause some special function. For example, it was anticipated that "the STUNT followed by a letter T might be used to perform a tabulate function."[63] The character was named after the programmable "stunt box" that performed these sorts of functions in the earlier Teletype Model 28.[64]

	0	1	2	3
0	blank	K	)	0
1	uc	L	!	1
2	lc	M	bell	2
3	lf	N	#	3
4	cr	O	$	4
5	sp	P	%	5
6	A	Q	wru	6
7	B	R	&	7
8	C	S	*	8
9	D	T	(	9
10	E	U	"	’
11	F	V	:	;
12	G	W	?	/
13	H	X	_	−
14	I	Y	,	stunt
15	J	Z	.	rubout

Figure 26. "Proposed Six-Unit Code for Teletypewriter and Other Data Communications to Operate with Four-Row Electric Typewriter Keyboard," December 19, 1960.[63]

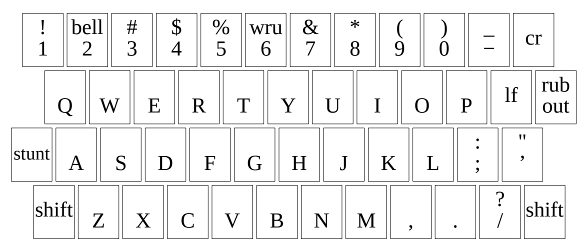

Figure 27. "Keyboard Format Based on Electric Typewriter Format to go with Six-Unit Code," December 19, 1960.[63]

The code of Figure 26 was intentionally similar to a proposed U.S. military standard, the FIELDATA code (Figure 28) designed by Captain William F. Luebbert of the U.S. Army Signal Research and Development Laboratory, but with some punctuation rearranged or replaced to make its keyboard more like that of a standard electric typewriter. FIELDATA was an "integrated family of data processing and data transmission equipment" noted for the "almost complete disappearance of conventional distinctions between communications and data processing.”[65] The use of the FIELDATA code was the key to eliminating those distinctions, because communications equipment would otherwise invariably use a version of International Telegraph Alphabet No. 2, while computer makers would not even consider using it because of the nonsensical order of its characters when sorted by their binary codes (Figure 29).

Unfortunately there was no other established standard for character codes, despite an increasing need for one. In 1951, UNIVAC had been billed as “the first computer which can handle both alphabetic and numerical data to reach full-scale operation.”[68] There were soon many others, each with its own character code. Sometimes there were even multiple character codes in use within a single company. IBM had been using the same representation for alphanumeric characters on punch cards since the 1930s (about which more will be said below), but not all IBM computers mapped those punch card codes to the same internal binary representation, and certain codes corresponded to different punctuation marks on “scientific” equipment than on “commercial” equipment.[69]

By 1955, Herbert Grosch had become sufficiently concerned about the growing incompatibility of character codes that he urged the attendees of the Eastern Joint Computer Conference to “register common codes so that ‘a’ will always be ‘a’ and ‘7’ will always be ‘7,’ or so that we can program the translation.”[70] It was not until nearly five years later, though, by which time at least twenty-nine incompatible codes were in use,[71] that industry organizations began to show an interest in establishing a character code standard for computers. The first to make a move was the Electronic Industries Association (EIA), which on May 25, 1960 proposed that the codes for the letters and digits be tentatively standardized as in Figure 30.[72]

	0	1	2	3
0	master sp	K	)	0
1	upper case	L	−	1
2	lower case	M	+	2
3	line feed	N	<	3
4	carriage ret	O	=	4
5	space	P	>	5
6	A	Q	_	6
7	B	R	$	7
8	C	S	*	8
9	D	T	(	9
10	E	U	"	’
11	F	V	:	;
12	G	W	?	/
13	H	X	!	.
14	I	Y	,	□ / special
15	J	Z	⊕ / stop	idle

Figure 28. FIELDATA code, June 21, 1960.[66] Versions of the code given in Luebbert’s 1959[65] and 1960[67] articles differ in minor details.

00000	· · · · ·	null		10000	· · · · ○	T	4
00001	○ · · · ·	E	3	10001	○ · · · ○	Z	+
00010	· ○ · · ·	line fd		10010	· ○ · · ○	L	)
00011	○○ · · ·	A	−	10011	○○ · · ○	W	2
00100	· · ○ · ·	space		10100	· · ○ · ○	H	nat
00101	○ · ○ · ·	S	’	10101	○ · ○ · ○	Y	6
00110	· ○○ · ·	I	8	10110	· ○○ · ○	P	0
00111	○○○ · ·	U	7	10111	○○○ · ○	Q	1
01000	· · · ○ ·	car ret		11000	· · · ○○	O	9
01001	○ · · ○ ·	D	nat	11001	○ · · ○○	B	?
01010	· ○ · ○ ·	R	4	11010	· ○ · ○○	G	nat
01011	○○ · ○ ·	J	bell	11011	○○ · ○○	figures	
01100	· · ○○ ·	N	,	11100	· · ○○○	M	.
01101	○ · ○○ ·	F	nat	11101	○ · ○○○	X	/
01110	· ○○○ ·	C	:	11110	· ○○○○	V	=
01111	○○○○ ·	K	(	11111	○○○○○	letters	

Figure 29. International Telegraph Alphabet No. 2, arranged in binary order.

The X3.2 subcommittee

The American Standards Association (ASA) got involved in character code standardization on August 4, 1960, when it created the X3.2 subcommittee for Coded Character Sets and Data Format. X3.2’s parent organization, the X3 committee for Computer and Information Processing standards, had been formed on January 13, 1960. Five other X3 subcommittees were also created in August to address other computer-related standards issues.[73, 74] The X3.2 subcommittee (or X3-2, as its name was often spelled until late 1961) met for the first time on October 6, 1960. Its members decided that they should first determine what characters should be in the standard character code, then in what order they should appear, and finally how they should be represented in media.[75]

By the December 2, 1960 meeting of X3.2, the work on the first part of that procedure had led to an agreement that the standard would have to contain ten digits, the letters A to Z, a blank, and probably about ten punctuation marks and eight business symbols. The meeting was also attended by Mr. Craig of AT&T and Allen L. Whitman of Bell Laboratories, who presented the modified FIELDATA code described above. X3.2 chairman Irving Liggett was enthusiastic about it: “This could be the X3-2 code if we work fast enough.”[76]

	0	1	2	3
0			K	0
1			L	1
2			M	2
3			N	3
4			O	4
5			P	5
6		A	Q	6
7		B	R	7
8		C	S	8
9		D	T	9
10		E	U	
11		F	V	
12		G	W	
13		H	X	
14		I	Y	
15		J	Z	

Figure 30. Electronic Industries Association tentative standard for Basic Character Set Code, May 25, 1960.[72]

Many people in data processing, though, didn't want to standardize a FIELDATA-derived code. ''The computer industry representatives' most fundamental objection to the character arrangement in the DOD Fieldata code,'' L. L. Griffin wrote, ''is that the special characters (punctuation symbols) are placed higher in the code structure than the alphabetic characters.''[77] In data processing, punctuation had traditionally been sorted earlier than letters, and letters earlier than digits; the FIELDATA order was letters, symbols, digits, and more symbols. A second point of dispute was that FIELDATA, and especially the Bell System rearrangement of it, mixed control and printing characters together rather than isolating them in separate parts of the code table. As the X3.2 code developed, many characters would be repeatedly relocated to satisfy either the data processing desire to group related characters together or the communications desire to arrange characters as they were arranged on keyboards.

X3.2 was, however, still officially at the stage of choosing what characters to standardize and would not decide until later in what order they should appear. By the January 11-12, 1961 meeting, X3.2 members were able to agree that the set should contain, in addition to the letters, digits, and blank previously agreed upon, a period or decimal point (.), minus sign or hyphen (−), left and right parentheses ((and)), slash (/), asterisk (*), number sign (#), comma (,), percent sign (%), and an *escape* code that would give access to other useful sets of characters. No other characters were unanimously supported.[78] Members were asked to bring to the following meeting complete lists what characters they thought should appear in the main 64-character set and in what order. Figure 31 and Figure 32 are two of these proposals. The latter is actually cut down from a 256-character superset that also included lower case, Greek and Russian letters, and numerous special symbols.

The March 8-9, 1961 meeting of X3.2 finally led to a code (based on a proposal by Robert W. Bemer, Howard J. Smith, and F. A. Williams) that nearly everyone could agree upon—but there is some disagreement about exactly what it was that was agreed. According to the minutes of the meeting, two codes (Figure 33a and 33b) ''were identified which seemed to accomplish most of the objectives. These are to be studied so that a single proposed code can be identified at the next meeting.''[80] According to Roy Reach's report to fellow Honeywell employees, though, it was the code in Figure 33c, which left several assignments still to be determined, that ''was agreed upon as a first approach, meeting almost unanimous agreement.''[81] And in the May, 1961 *Communications of the ACM* article by Bemer, Smith, and Williams, it is the two codes Figure 33d and 33e that have the caption of ''the proposed standard code.''[82] Of these five codes, the second one from the minutes (Figure 33b) is notable for its attempt to place characters that would appear on the same key of a keyboard in the same row of columns 0 and 1.

A seven-bit code

Whatever may have been agreed, the basic structure of the code was not yet settled. At an April 26-27 meeting, X3.2 members discussed the idea of creating a family of related codes of different sizes rather than a single code. There would be a four-bit numeric set, a shifted five-bit set like International Telegraph Alphabet No. 2, a six-bit set for data processing, a seven-bit set for communications or data processing, and an eight-bit expanded set.[83] At an informal meeting held during the Western Joint Computer Conference, May 8-11, 1961 the seven-bit set ''was identified as the prime set for information interchange and communication.''[84]

In May, the seven-bit set was conceived as having 64 control characters in the first half and 64 printing characters in the second half, the same arrangement used in a seven-bit, extended version of the FIELDATA code. But this was impossible because the *delete* control character had to be the character with all bits set, and therefore had to be located at the bottom of the rightmost row. It was also impossible to make the first half of the code a block of 64 printing characters, because the *null* control character had to have no bits set and therefore had to occupy the top position of the

	0	1	2	3
0	0	space	P	(
1	1	A	Q	)
2	2	B	R	,
3	3	C	S	%
4	4	D	T	:
5	5	E	U	"
6	6	F	V	;
7	7	G	W	?
8	8	H	X	escape
9	9	I	Y	line feed
10	#	J	Z	start
11	*	K	&	stop
12	−	L	$	↑
13	+	M	Cr	↓
14	/	N	=	carriage ret
15	.	O	@	null

Figure 31. Roy Reach's proposed major usage subset, January 24, 1961.[78]

	0	1	2	3
0	0	’	↑	M
1	1	#	↓	N
2	2	*	←	O
3	3	$	☞	P
4	4	%	A	Q
5	5	/	B	R
6	6	@	C	S
7	7	?	D	T
8	8	<	E	U
9	9	>	F	V
10	space	Σ	G	W
11	+	:	H	X
12	.	=	I	Y
13	,	&	J	Z
14	×	(	K	£
15	−	)	L	Δ

Figure 32. 64-character subset of S. Porter's ‘‘preliminary symbol and code assignment for a 256 character set,’’ January 25, 1961.[79]

leftmost row. So at the June 7-8, 1961 meeting, the printing characters were shifted into the middle 64 of the 128 characters of a seven-bit set (Figure 34).[85]

Several characters appear in the June 7-8, 1961 code that have not been previously mentioned. In particular there seems to have been an attempt to fill column three entirely with mathematical symbols in an effort to make it suitable for use as a four-bit numeric subset. The angular tilde (⁓) had appeared before, in IBM's June 1960 Extended Character Set (Figure 35),[69, 2] where it represented a hyphen, and where the horizontal line symbol (−) was used only for the minus sign. Here the situation seems to have been

	a	b	c	d	e
0 / 0	mstr sp	mstr sp	mstr sp	null	mstr sp
0 / 1	blank	blank	blank	blank	blank
0 / 2	car ret	"	car ret	"	"
0 / 3	line fd	#	line fd	$	$
0 / 4	#	$	#	#	#
0 / 5	%	%	%	’	’
0 / 6	:	’	:	(	(
0 / 7	;	&	;	)	)
0 / 8	(	(	(	:	:
0 / 9	)	)	)	;	;
0 / 10	/	?	/	,	,
0 / 11	’	wru	’	*	*
0 / 12	−	−	−	.	.
0 / 13	+	+	+	−	−
0 / 14	.	.	.	+	+
0 / 15	,	,	,	/	/
1 / 0	0	0	0	<	0
1 / 1	1	1	1	>	1
1 / 2	2	2	2	A	2
1 / 3	3	3	3	B	3
1 / 4	4	4	4	C	4
1 / 5	5	5	5	D	5
1 / 6	6	6	6	E	6
1 / 7	7	7	7	F	7
1 / 8	8	8	8	G	8
1 / 9	9	9	9	H	9
1 / 10	$	/	$	I	?
1 / 11	*	*	*	J	!
1 / 12	?	:		K	line fd
1 / 13	!	;		L	car ret
1 / 14	upper	upper	upper	M	figures
1 / 15	lower	lower	lower	N	letters
2 / 0	<			O	
2 / 1	=			P	
2 / 2	>	A		Q	A
2 / 3	@	B		R	B
2 / 4	A	C	A	S	C
2 / 5	B	D	B	T	D
2 / 6	C	E	C	U	E
2 / 7	D	F	D	V	F
2 / 8	E	G	E	W	G
2 / 9	F	H	F	X	H
2 / 10	G	I	G	Y	I
2 / 11	H	J	H	Z	J
2 / 12	I	K	I	=	K
2 / 13	J	L	J	@	L
2 / 14	K	M	K	%	M
2 / 15	L	N	L	□	N
3 / 0	M	O	M	0	O
3 / 1	N	P	N	1	P
3 / 2	O	Q	O	2	Q
3 / 3	P	R	P	3	R
3 / 4	Q	S	Q	4	S
3 / 5	R	T	R	5	T
3 / 6	S	U	S	6	U
3 / 7	T	V	T	7	V
3 / 8	U	W	U	8	W
3 / 9	V	X	V	9	X
3 / 10	W	Y	W	?	Y
3 / 11	X	Z	X	!	Z
3 / 12	Y	car ret	Y	control	
3 / 13	Z	line fd	Z	control	
3 / 14	escape	escape	escape	control	escape
3 / 15	delete	delete	delete	control	delete

Figure 33. Conflicting reports of the March, 1961 X3.2 code proposal. (a) first proposal, from minutes; (b) second proposal, from minutes;[80] (c) proposal, as reported by Reach;[81] (d) data processing code, from CACM; (e) transmission code, from CACM.[82]

	0	1	2	3	4	5	6	7
0	null		blank	0	=	K		
1	upper		!	1	≠	L		
2	lower		"	2	#	M		
3	car ret		?	3	%	N		
4	line fd		$	4	↑	O		
5			’	5	←	P		
6			&	6	A	Q		
7			−	7	B	R		
8			(	8	C	S		
9			)	9	D	T		
10			;	+	E	U		
11			:	∼	F	V		
12			*	<	G	W		
13			/	>	H	X		
14			,	×	I	Y		escape
15			.	$\vert$	J	Z		delete

Figure 34. X3.2 code, June 7-8, 1961.[85]

	0	1	2	3	4	5	6	7
0	blank	[	&	c	k	s	0	8
1	±	⊂	+	C	K	S	$_{\mathit{0}}$	$_{\mathit{8}}$
2	→	]	$	d	l	t	1	9
3	≠	°	=	D	L	T	$_{\mathit{1}}$	$_{\mathit{9}}$
4	∧	←	*	e	m	u	2	.
5	{	≡	(	E	M	U	$_{\mathit{2}}$	:
6	↑	¬	/	f	n	v	3	−
7	}	√	)	F	N	V	$_{\mathit{3}}$	?
8	∨	%	,	g	o	w	4	
9	∀	\	;	G	O	W	$_{\mathit{4}}$	
10	↓	◊	’	h	p	x	5	
11	‖	$\vert$	"	H	P	X	$_{\mathit{5}}$	
12	>	#	a	i	q	y	6	
13	≥	!	A	I	Q	Y	$_{\mathit{6}}$	
14	<	@	b	j	r	z	7	
15	≤	∼	B	J	R	Z	$_{\mathit{7}}$	

Figure 35. An Extended Character Set Standard, June 1, 1960.[69]

reversed, as the tilde is grouped with the mathematical symbols and the horizontal line with the punctuation. In either case, the angular tilde appears to be unrelated to the tilde diacritical mark (˜).

The up (↑) and left (←) arrows are probably in the code for the convenience of Algol programmers (although a 1978 article by Robert W. Bemer[86] seems to suggest that the two characters were included at Teletype’s request). In contrast to the Fortran programming language, in which ‘‘there is a separate key on the keypunching device for each character used in FORTRAN statements... [and] keypunching a FORTRAN program is therefore a process similar to that of typing the program,’’[87] Algol programs are written on paper in a ‘‘reference language,’’ printed in a ‘‘publication language,’’ and entered into a particular computer by transliterating them into a ‘‘hardware representation’’ appropriate to that computer.[88] Transliterating the reference language into anything very far removed from it tends to make programs unreadable,[89] so character codes were soon proposed that would allow the hardware representation to be as close as possible to the reference language.[90, 91, 92]

In the Algol publication language, exponents are written using superscripts. In Algol 58, the corresponding reference language used paired arrows to suggest the start and end of the superscript. For example, 2^5 in the publication language became 2↑5↓ in the reference language. In 1959, Herbert Kanner proposed that a single arrow be used instead (2↑5),[93] and his suggestion was adopted in Algol 60.[94] The left arrow (←) has a less direct connection to Algol. The *do* statement in Algol 58 used a right arrow character (→), but according to Herb Bright, many Americans would have preferred to use a left arrow instead. They ‘‘yielded on this item to the Europeans,’’ but one of Bright’s Algol-oriented character code proposals left open the option to point it left instead.[90]

The code of Figure 34 was designed with politics as well as technical issues in mind. On April 25, 1961, the Committee on Military Systems Technical Standards had informed a delegation from X3.2 (John Auwaerter, L. L. Griffin, Irving Liggett, and Allen L. Whitman) that ‘‘the military, for lack of an industry standard and lack of definitive action to establish such a standard, developed their own standard, Fieldata.... An industry standard which is different from the mil[itary] standard would have to present strong advantages over the mil[itary] standard before it would gain acceptance by the military.’’[95] So the June X3.2 code was designed so that reordering code columns 4, 5, 2, and 3 as columns 0, 1, 2, and 3, respectively, would at least put the letters and digits in the same places FIELDATA put them. This would maximize the palatability of the X3.2 code to the Department of Defense and minimize the difficulty of building translators to interoperate with existing FIELDATA equipment. There was even talk of naming the code Fieldata II or Fieldata 1961 to emphasize the codes’ similarities.[96]

There was also a second version of the X3.2 code, with the characters arranged for international compatibility rather than military compatibility. In January, 1961, Hugh McGregor Ross had published an article about the character code of the Ferranti Orion and Atlas computers.[97] Several versions of this code were proposed to the British Standards Institution (BSI) as possible standards, notably the six-bit code shown in Figure 36. Ross and X3.2 alternate Robert W. Bemer had met in February, 1960,[1] and the second version of the X3.2 code (Figure 37) was arranged so that the most important characters in its columns 2, 3, 4, and 5 would match Ross's columns 0, 1, 2, and 3.

The June 7-8 proposal, in either of its versions, made only minimal concessions to keyboard design. On July 11, 1961, John Auwaerter sketched the keyboard that would naturally result from the X3.2 code (Figure 38), leading Allen L. Whitman to comment that ‘‘from the standpoint of ordinary Bell System teletypewriter operation, this keyboard is in my opinion a monstrosity.’’[100] It appears that, as a result, on August 4, either X3.2 members or Whitman designed an altered code (Figure 39) that could be produced by a keyboard much closer to that of a standard electric typewriter (Figure 40).

	0	1	2	3
0	space	0		P
1		1	A	Q
2	carriage ret	2	B	R
3	line feed	3	C	S
4	tabulate	4	D	T
5	backspace	5	E	U
6	shift out	6	F	V
7	shift in	7	G	W
8	(	8	H	X
9	)	9	I	Y
10		10	J	Z
11	£	11	K	
12			L	
13	&	+	M	arq
14	*	−	N	escape
15	/	.	O	erase

Figure 36. BSI Proposed Standard 6-Track Tape Code, January 23, 1961.[98]

	0	1	2	3	4	5	6	7
0	null		blank	0	=	P		
1			!	1	A	Q		
2			"	2	B	R		
3			?	3	C	S		
4			$	4	D	T		
5			’	5	E	U		
6			&	6	F	V		
7			−	7	G	W		
8			(	8	H	X		
9			)	9	I	Y		
10			;	+	J	Z		
11			:	~	K	≠		
12			*	<	L	#		
13			/	>	M	%		
14			,	×	N	↑		escape
15			.	|	O	←		delete

Figure 37. ‘‘X3-2 Code Alphabet Set Being Studied for International Compatibility,’’ June, 1961.[99]

Movement toward a draft standard

The September 14-15, 1961 meeting of X3.2 saw further revisions of the printing characters of the code and the most elaborate plans so far for the arrangement of the control characters. The angular tilde (~), multiplication sign (×), and vertical line (|) were deleted and replaced by an at sign (@) and less-than-or-equal-to (≤) and greater-than-or-equal-to (≥) operators. A motion was specifically passed ‘‘to try to design a 7 bit set with due consideration for the requirements of an 8 bit set and the keyboard,’’ so the code that resulted from this meeting made for a better keyboard than the one from June (but not as good as the proposal from August). Figure 41 is the code as it appeared in the minutes of the meeting.[102] (Honeywell representative Roy Reach's drawing of the code chart showed a lowercase alphabet in columns 6 and 7, an addition that would not officially be made until the end of 1963.) According to Reach, the committee was ‘‘attempting to prepare a report to X3 for a recommended standard Character Set by early November.’’ He further reported that all members were in agreement except Howard Smith of IBM, and that IBM's alternate member, Robert W. Bemer, had nevertheless indicated that IBM ‘‘would be very pleased with this proposed Character Set and would go along with it.’’[103]

On September 28, 1961, Bemer wrote to the members of X3.2 that he should have suggested at the meeting that the committee not add less-than-or-equal-to (≤) and greater-than-or-equal-to (≥) signs to the code, but instead also remove the not-equal-to (≠) sign and assign the three characters' positions to left ([) and right (]) brackets and a reverse slash (\).[104] He cited statistics indicating that the three symbols he proposed to replace were rarely used in actual Algol programs and that the brackets were very frequently used. The reverse slash, he explained, could be combined with the slash to form approximations of Algol's logical *and* (∧, /\) and logical *or* (∨, \/) operators, and by itself could represent a ‘‘reverse division’’ operator, as it had in the IBM Extended Character Set.[69] In addition to this prior use in computing, there was also a precedent for including the reverse slash in communications codes: a 1937 manual and 1945 parts list show the character on the keyboard of a Teletype Wheatstone Perforator.[105, 106]

At the November 8-10, 1961 X3.2 meeting, the proposed character substitutions were unanimously approved and the control characters were repeatedly rearranged. (The *acknowledge* character was placed

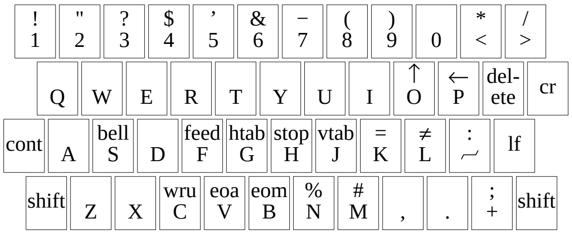

Figure 38. ‘‘Proposed Keyboard Layout Based on X3-2 Subcommittee 7-Bit Code of June 9, 1961.’’[100]

	0	1	2	3	4	5	6	7
0	blank		space	0		P		feed
1			!	1	A	Q		stop
2			*	2	B	R		upper
3			#	3	C	S		lower
4			$	4	D	T		wru
5			%	5	E	U		eoa
6			=	6	F	V		eom
7			&	7	G	W		eot
8			(	8	H	X		ans bk
9			)	9	I	Y		h tab
10			.	↑	J	Z		v tab
11			,	←	K			car ret
12			−	+	L			bell
13			"	’	M			line fd
14			?	/	N			stunt
15			:	;	O			rubout

Figure 39. X3.2 code, August 4, 1961.[101]

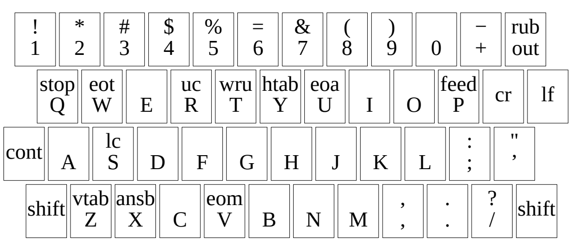

Figure 40. ‘‘Keyboard Layout Based on X3-2 Subcommittee 7-Bit Code of August 4, 1961.’’[101]

in position 7/12 because that position’s bit pattern, 1111100_2, is easy to generate mechanically. The September, 1961 code had put it in position 6/0, which also has a mechanically convenient bit pattern: 1100000_2. Some International Telegraph Alphabet No. 2 equipment used the letter V (· ○○○○) as an acknowledgement character[61] for the same reason.) A motion was passed to give the draft the name ‘‘Proposed American Standard Code for Information Interchange,’’ the word ‘‘proposed’’ to be deleted when the code was approved as a standard.[107] The

	0	1	2	3	4	5	6	7
0	null	dd	blank	0	!	P	ans bk	
1	ru	dd	’	1	A	Q		
2		dd	"	2	B	R		
3		dd	<	3	C	S		
4	wru	dd	>	4	D	T		
5	mt stp	dd	$	5	E	U		
6	v tab	dd	%	6	F	V		
7	h tab	dd	&	7	G	W		
8	feed		(	8	H	X		
9	tra sta		)	9	I	Y		
10	bell		:	;	J	Z		
11	r1 on		*	+	K	#		
12	r1 off	line fd	/	?	L	@		
13	r2 off	car ret	−	=	M	≠		
14	r2 on	upper	,	←	N	≤		escape
15	tra stp	lower	.	↑	O	≥		delete

Figure 41. X3.2 code, September 14-15, 1961.[102]

corresponding acronym, ASCII, was pronounceable enough that it became the colloquial name for the code. A draft of the proposed standard (Figure 42) was distributed on November 28.[108]

Internationalization

While the letters, digits, and parentheses of the X3.2 code had been arranged for compatibility with a proposed British standard, and X3.2 had been represented at the first meeting of the International Organization for Standardization Technical Committee 97 Working Group B (ISO/TC 97/WG B) on May 18, 1961,[109] most of the details of the proposed American standard had been worked out without any coordination with other standards organizations. To rectify this, in January, 1962, John Auwaerter and Leon Bloom travelled to Europe to meet many of the people who were working on character code standards there.

Their first destination was Paris, France, where they spent January 3-5.[110] There they learned from H. Feisell, the chairman of TC 97, that only three groups were likely to have character code proposals ready to present before TC 97’s October meeting: the American Standards Assocation (ASA), the British Standards Institution (BSI), and possibly the European Computer Manufacturers Association (ECMA).[111] All three of these groups were already in agreement about the locations of the digits and letters in a six-bit code. The BSI and ECMA further agreed that, in the six-bit code, the controls should be in the first half of column 0 and the most important symbols in the bottom half of the same column, while the Americans had stopped including controls in their six-bit set and had spread symbols through the entire column.

	0	1	2	3	4	5	6	7
0	null	r1 on	blank	0	!	P		
1	som	r2 on	’	1	A	Q		
2	m off	x on	"	2	B	R		
3	ru	eoa	<	3	C	S		
4	wru	r1 of	>	4	D	T		
5	eot	r2 of	$	5	E	U		
6	h tab	x off	%	6	F	V		
7	ff	eom	&	7	G	W		
8	v tab	dd	(	8	H	X		
9		dd	)	9	I	Y		
10	bell	dd	.	↑	J	Z		
11		dd	,	←	K	@		
12	cr	dd	*	+	L	\		ack
13	lf	dd	:	;	M	[		
14	uc	dd	-	=	N	]		esc
15	lc	dd	/	?	O	#		del

Figure 42. Proposed American Standard Code for Information Interchange, November 28, 1961.[108]

This was only a minor incompatibility, though, and it was agreed that ‘‘it would be highly desirable if a single proposal from all three groups could be developed in time for the TC-97 meeting so as to avoid further solidifying each of their positions along different lines.’’ In Munich, Germany, January 16-17, Dr. Lockemann, the chairman of ECMA TC-1, ‘‘expressed wholehearted approval’’ of the idea of a unified proposal and invited X3.2 representatives to attend the March meeting of TC-1.

At that March meeting,[112] Hugh McGregor Ross proposed that the seven-bit code be structured for six-bit compatibility by dividing the controls into four distinct sections of eight characters apiece: switching system controls, page format controls, information separators, and terminal controls. As Dr. Neubauer of Lorenz had proposed January 18-19,[111] the page format controls (*carriage return*, *line feed*, *horizontal tab*, *vertical tab*, and *form feed*) would be arranged in a hierarchical order so that they could also be used as data delimiters in the six-bit set.

There was also discussion of how to arrange the punctuation in a universally acceptable way. The British wanted a four-bit decimal subset to include digits 0 through 9 plus 10 and 11, period (.), slash (/), minus (−) and plus (+). ECMA wanted the following additional symbols to be included in the six-bit set: parentheses ((and)), comma (,), asterisk (*), ampersand (&), percent (%), equals (=), apostrophe (’), and semicolon (;). Six-bit (Figure 43) and seven-bit (Figure 44) codes were arranged that would meet most of these requirements, but the percent sign was left out of the six-bit code. The colon and dollar sign, which had no international support, were arranged so that they would be displaced by the 10 and 11 when necessary.

Allen L. Whitman remained dissatisfied with the keyboard that would correspond to this code. On April 2, 1962, he observed that ‘‘the X3.2 Subcommittee at its regular meeting in Chicago on April 11-13 will consider the possibility of making changes in the proposed American Standard Code’’ and submitted another proposal of his own because ‘‘this is the last minute at which such changes could be considered at all.’’[113] Whitman’s proposal (Figure 45) paired, for the first time, the comma (,) and period (.) with the less-than (<) and greater-than (>) signs, respectively, and ordered the symbols paired with the numbers approximately as they would have been on the keyboard of a manual typewriter. The April X3.2 meeting yielded yet another possible code (Figure 46), this one incorporating some of Whitman’s proposals but in other ways remaining closer to the proposed standard from the previous November.

Working Group B meets

The design of the possible international standard solidified further at the May 2-4, 1962 meeting of ISO/TC 97/WG B.[115] First the German Standards Organization presented a code (Figure 47) similar to the one being proposed by the BSI, ECMA, and ASA, but with the alphabet beginning at the top of the column rather than offset by one position. (The reason for the one-character offset has never been explained very well. Ross’s 1961 article only says that ‘‘it has been found preferable that letter A should have position 1, B, 2, etc., as in most British 5-track computer codes.’’)[97] E. G. Cluff presented the joint proposal from the BSI, ECMA, and ASA. A small group was then formed to work out a compromise. Its members were Leon Bloom (NCR, U.S.A.), Mr. Durand (Bull, France), Mr. Lockemann (Siemens & Halske, Germany), and Hugh McGregor Ross (Ferranti, U.K.), who had submitted the proposals; P. Bienfait (Union Internationale des Chemins de Fer), E. G. Cluff (I.C.T., ECMA), and Richard Gottlieb (Olivetti, Italy), who would observe; and H. Feisell (Bull, France), the president of WG B.

The group met the morning of May 3 and returned with two possible arrangements of the controls (A and B, Figure 48) and a preliminary arrangement of the printing characters. No agreement could be reached that afternoon about which ordering of the controls was better. The next morning, the group met again from 8:45 to 10:30, and returned with a complete plan for ordering the characters in the symbols and digits columns. The characters in the column adjacent to the digits were specifically chosen so they would be

	0	1	2	3
0	space	0	’	P
1	ht	1	A	Q
2	nl	2	B	R
3	vt	3	C	S
4	ff	4	D	T
5	bs / cr	5	E	U
6	so	6	F	V
7	si	7	G	W
8	(	8	H	X
9	)	9	I	Y
10	*	$ / 10	J	Z
11	,	: / 11	K	
12	.	;	L	
13	/	?	M	
14	−	=	N	esc
15	+	&	O	del

Figure 43. Six-bit code from ECMA TC-1 and ASA X3.2 joint meeting, March 8-9, 1962.[112]

	0	1	2	3	4	5	6	7
0	nul	r1on	sp	0	’	P		
1		r2on	!	1	A	Q		
2	ru	xon	"	2	B	R		
3	wru	bel	#	3	C	S		
4	som	r1of	@	4	D	T		
5	eoa	r2of	%	5	E	U		
6	eom	xof	<	6	F	V		
7	eot	mof	>	7	G	W		
8		dd	(	8	H	X		
9	ht	dd	)	9	I	Y		
10	lf	dd	*	$	J	Z		
11	vt	dd	,	:	K	↑		
12	ff	dd	.	;	L	\		ack
13	cr	dd	/	?	M	←		
14	uc	dd	−	=	N	[		esc
15	lc	dd	+	&	O	]		del

Figure 44. Seven-bit code from ECMA TC-1 and ASA X3.2 joint meeting, March 8-9, 1962.[112]

paired appropriately on a keyboard (Figure 49). Code tables were worked out for the combination of each of the two possible arrangements of the controls with these symbols. In an informal vote, Germany supported arrangement A; France, Great Britain, and the U.S.A. supported arrangement B; and Italy abstained. Figure 50 and Figure 51 are the six- and seven-bit codes of the majority preference, solution B.

In the United States, X3.2 quickly revised its code to match what was agreed upon at the ISO meeting. They proposed, though, to interchange the agreed positions of the asterisk (*) and plus (+) signs with those of the colon (:) and semicolon (;), respectively,[117] so that the plus and asterisk would be

	0	1	2	3	4	5	6	7
0			sp	0	@	P		
1			!	1	A	Q		
2			"	2	B	R		
3			#	3	C	S		
4			$	4	D	T		
5			%	5	E	U		
6			’	6	F	V		
7			&	7	G	W		
8			(	8	H	X		
9			)	9	I	Y		
10			.	>	J	Z		
11			,	<	K	↑		
12			=	+	L	\		
13			;	:	M	←		
14			−	*	N	[		
15			/	?	O	]		

Figure 45. Printing characters from seven-bit code proposed by Allen L. Whitman, April 2, 1962.[113] Heavy borders indicate characters paired differently from the March 8-9 code.

	0	1	2	3	4	5	6	7
0	nul		sp	0	@	P		
1	eot	stop	’	1	A	Q		
2	eom	dc3	"	2	B	R		
3	eoa	dc2	!	3	C	S		
4	som	dc1	#	4	D	T		
5	wru		%	5	E	U		
6	ru	err	$	6	F	V		
7	bel	eob	&	7	G	W		
8	tc1	lem	(	8	H	X		
9	ff	s4	)	9	I	Y		
10	vt	s3	:	;	J	Z		
11	lf	s2	*	+	K	[		
12	ht	s1	,	<	L	\		ack
13	cr	s0	.	>	M	]		
14		so	−	=	N	↑		esc
15		si	/	?	O	←		del

Figure 46. Code from X3.2 meeting, April, 1962.[114] Heavy borders indicate characters paired differently from Whitman’s April 2 proposal.

retained when the 10 and 11 characters were needed, a change also supported by ECMA.[1] A copy of the code, dated May 25, 1962, was submitted to the X3 committee for consideration as the proposed American Standard Code for Information Interchange.[118]

The Hollerith challenge

Not everyone, though, was happy about the idea of standardizing a character code that had never been tried on any existing equipment, even if it did have international support. On March 9, 1962, the Office

	0	1	2	3
0	nul	0	A	Q
1	end job	1	B	R
2	end form	2	C	S
3	new line	3	D	T
4	hor tab	4	E	U
5	space	5	F	V
6	shift out	6	G	W
7	shift in	7	H	X
8	& / [	8	I	Y
9	% /]	9	J	Z
10	(	;	K	
11	)	:	L	
12	/	+	M	
13	,	*	N	cs / 10
14	−	=	O	esc
15	.	’	P	del

Figure 47. German code proposal, April, 1962.[115]

A: seven-bit

null	
eot	stop
eom	dc3
eoa	dc2
som	dc1
wru	error
ru	sync
bell	eob
	lem
ff	s4
vt	s3
lf	s2
ht	s1
cr	s0
so	
si	

A: six-bit

null
ff
vt
nl
ht
space
so
si

B: seven-bit

null	
som	dc1
eoa	dc2
eom	dc3
eot	stop
wru	error
ru	sync
bell	eob
	s0
ht	s1
nl	s2
vt	s3
ff	s4
cr	lem
so	
si	

B: six-bit

space
ht
nl
vt
ff
f5
so
si

Figure 48. Control arrangements A and B, ISO/TC 97/WG B meeting, May 2-4, 1962.[115]

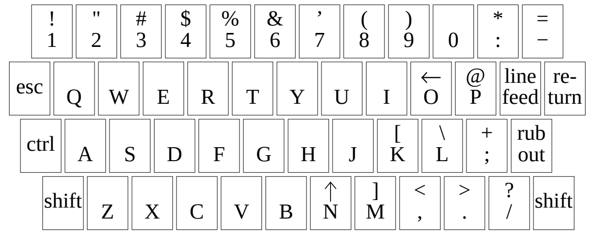

Figure 49. Keyboard of Teletype Model 35 teleprinter (1964),[116] showing character pairings established in 1962 by the ISO/TC 97/WG B character code proposal.

	0	1	2	3
0	space	0	null	P
1	f_1 / ht	1	A	Q
2	f_2 / nl	2	B	R
3	f_3 / vt	3	C	S
4	f_4 / ff	4	D	T
5	f_5 /	5	E	U
6	so	6	F	V
7	si	7	G	W
8	(	8	H	X
9	)	9	I	Y
10	:	10 / *	J	Z
11	;	11 / +	K	nat / [
12	,	cs / <	L	nat / \
13	−	% / =	M	nat /]
14	.	& / >	N	esc
15	/	’	O	del

Figure 50. Six-bit code B, ISO/TC 97/WG B meeting, May 2-4, 1962.[115]

Machines Group Engineering Committee of X3.2’s sponsor, the Business Equipment Manufacturers Association, declared that the proposed standard code could not be implemented economically in office equipment and recommended that the X4 committee on Office Equipment urge X3 ‘‘to direct X3.2 to consider rearrangement of the proposed graphic subset so as to make it more closely compatible with the Hollerith Code’’ as used on punch cards.[119]

Punch card codes have been neglected so far in this paper. According to Brian Randell’s summary of an anonymous article in his Annotated Bibliography on the Origins of Digital Computers,[120] Charles Foster invented the first alphabetic printing mechanism for tabulating equipment in 1916. This date is called into question, however, by Foster’s 1918 U.S. patent,[121] in which he refers to a British patent he had received for an alphabetic printer in 1915. Whenever he may have invented his first printer, it did not do a completely satisfactory job of printing alphabetic characters because his code (Figure 52) did not provide for the letters J, V, and X. By November, 1915, Robert Neil Williams had developed a second alphabetic printer for punch cards that used a different encoding (Figure 53) to support the entire alphabet.[122]

One descendant of the Williams code that was still in use decades later can be seen in an April, 1961 article by Hugh McGregor Ross,[123] as can several others designed along different lines. IBM’s earliest alphabetic code (Figure 54a) was mostly a copy of the Williams code but replaced the hyphen (−) with a character for Mc and shifted the remaining characters so they were still in alphabetical order. IBM employees then experimented for several years with many other possible ways to assign letters to punch card

	0	1	2	3	4	5	6	7
0	nul	dc_0	sp	0	@	P		
1	som	dc_1	!	1	A	Q		
2	eoa	dc_2	"	2	B	R		
3	eom	dc_3	#	3	C	S		
4	eot	stop	$	4	D	T		
5	wru	err	%	5	E	U		
6	ru	sync	&	6	F	V		
7	bel	eob	’	7	G	W		
8	fe_0	s_0	(	8	H	X		
9	ht	s_1	)	9	I	Y		
10	nl	s_2	:	*	J	Z		
11	vt	s_3	;	+	K	nat/ [		
12	ff	s_4	,	<	L	nat/ \		
13	cr	s_5	−	=	M	nat/]		
14	so	s_6	.	>	N	↑		esc
15	si	s_7	/	?	O	←		del

Figure 51. Seven-bit code B, ISO/TC 97/WG B meeting, May 2-4, 1962.[115]

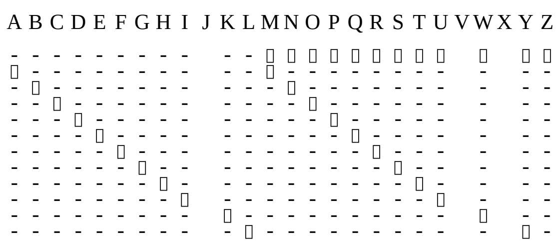

Figure 52. Charles Foster’s alphabetic card code, September 18, 1917.[121]

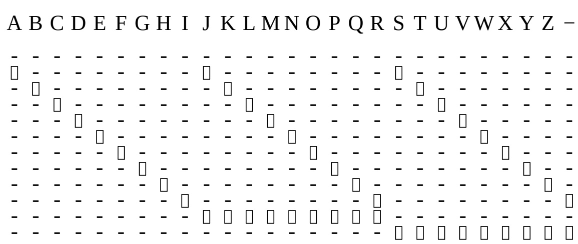

Figure 53. Robert Neil Williams’s alphabetic card code, November 13, 1915.[122]

codes (Figures 54b-54g) before eventually settling on the code in Figure 54h. Unlike most of the other codes in Figure 54, this code preserves the traditional use of punches 0 to 9 to encode the digits, arranges the letters in such a way that they are easy to sort, and preserves the structural stability of cards by never punching holes in adjacent rows of the same column.

This is the ‘‘Hollerith’’ code with which the X4 committee wanted the standard code to preserve compatibility. Charles E. Mackenzie of IBM brought one possibility for a Hollerith-compatible code to the attention of X3.2 in August, 1962, when he attended

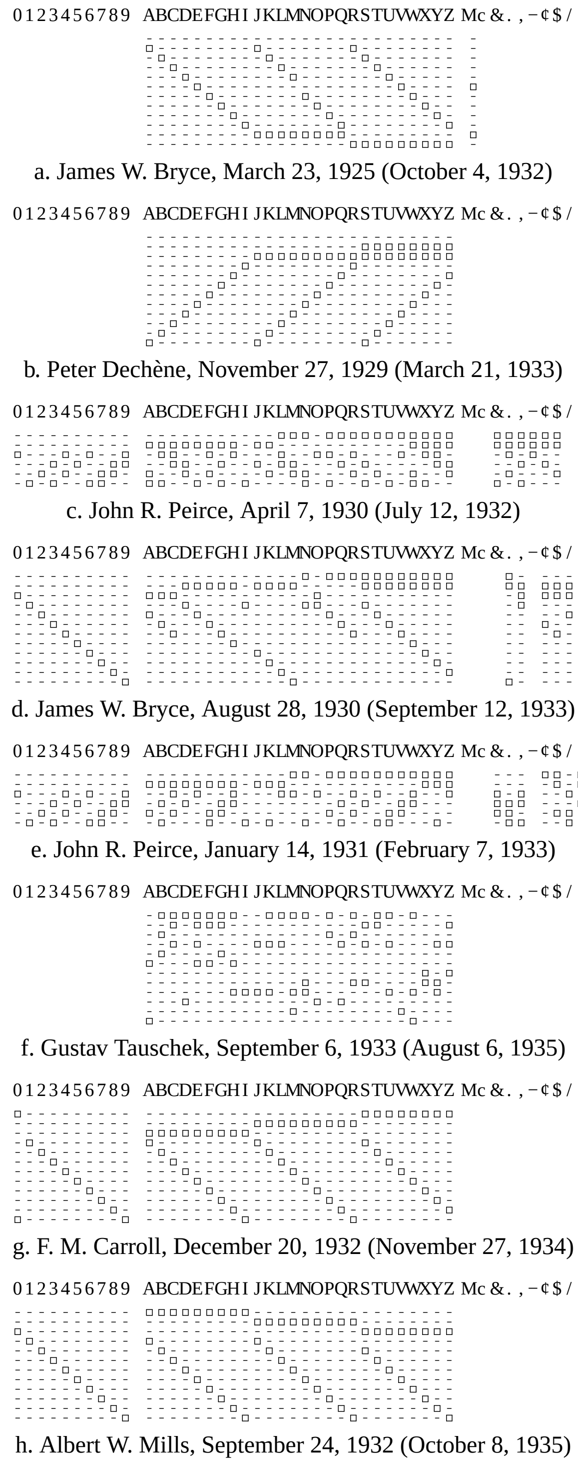

Figure 54. Some of the punch card codes cited by inventors who assigned patents to IBM in the late 1920s and early 1930s.[124, 125, 126, 127, 128, 129, 130, 131]

the subcommittee’s meeting and presented an eight-bit ‘‘extended character set’’ or ECS (Figure 55). Like the proposed standard code, Mackenzie’s was structured for easy sorting: control characters would sort earliest, then space, then punctuation, then letters, and then digits. And to an even greater extent than the proposed standard, his code was designed so that the type of a character could generally be distinguished by its binary pattern (for instance, any character with the code 1111xxxx would be a digit).

The main appeal of Mackenzie’s code, though, was its relationship to the Hollerith code. Earlier in 1962, IBM had established an internal standard for the six-bit binary representation of the decimal-oriented Hollerith card code, which was referred to as the Binary Coded Decimal Interchange Code, BCDIC (Figure 56). Mackenzie’s paper claimed that eight-bit ECS characters could be trivially translated into BCDIC-compatible six-bit characters by stripping off the two most signficant bits.[132] The actual code presented in the paper seems to require a somewhat more complicated transformation to get from ECS to BCD.

The members of X3.2 were not convinced. John B. Booth moved that ‘‘the material proposed by Mr. Mackenzie... has been reviewed and, since it is based on a structure which was rejected earlier by X3.2, the X3.2 subcommittee does not recommend revision or withdrawal of ASCII of May 25, 1962.’’ After a seven-to-one vote (with one abstention) in favor of Booth’s motion, discussion of the proposed code was terminated.[134] But despite the X3.2 subcommittee’s rejection of the ECS code, with several changes it eventually evolved into EBCDIC (Figure 57), the character code of IBM’s 360 series computers.[135]

Meanwhile, for the existing proposal there was still the question of what should appear in the two rightmost columns of the seven-bit code. In September, 1962, X3.2 formed a task group, X3.2.4, to study the possibilities.[136] E. J. Lewis and W. H. McKenzie believed that the columns should be used for additional control characters and listed 88 possibilities. ‘‘That certain groups need the lower case alphabet is insufficient reason for putting the alphabet into the unassigned area,’’ they believed. ‘‘Those that actually use the lower case alphabet represent a small specialized group.’’[137] (Their typed proposal, naturally, used lower case.) But John Auwaerter wrote to K. J. Amos that he believed control characters were the least likely use to which the unassigned area might be put. He thought a lower case alphabet was the most popular idea and that additional programming language characters were second in popularity.[138] Hugh McGregor Ross named the additional possibilities of superscript and subscript digits and common fractions.[139] In the first draft of the proposed ISO standard, issued in

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0					sp							↑	?	!	rm	0
1			lem	som			/		a	j		↓	A	J		1
2				eoa					b	k	s	←	B	K	S	2
3				eom	.	$	,	=	c	l	t	→	C	L	T	3
4				wru	)	*	(	’	d	m	u	{	D	M	U	4
5				ru	[	]	ws	:	e	n	v	}	E	N	V	5
6				bel	<	;	\	>	f	o	w	∧	F	O	W	6
7				sk	gm	mc	sm	tm	g	p	x	∨	G	P	X	7
8				vt	+	−	sb		h	q	y	∀	H	Q	Y	8
9				ff					i	r	z	¬	I	R	Z	9
10		syil	eb	err								≡				
11				ack								≠				
12	re	pf	pn	by												
13	ht	cr	lf	rs												
14	lc	bs	il	uc												
15	et		e1													

Figure 55. ‘‘A Compatible 8-Bit ECS Code for Information Interchange,’’ August 17, 1962.[132]

	0	1	2	3
0	space	ƀ	−	& / +
1	1	/	J	A
2	2	S	K	B
3	3	T	L	C
4	4	U	M	D
5	5	V	N	E
6	6	W	O	F
7	7	X	P	G
8	8	Y	Q	H
9	9	Z	R	I
10	0	ǂ	!	?
11	# / =	,	$	.
12	@ / ’	% / (	*	□ /)
13	:	∨	]	[
14	>	\	;	<
15	√	⧻	Δ	⧧

Figure 56. IBM’s Binary Coded Decimal Interchange Code, 1962.[133]

January, 1963, the area remained unassigned.[140]

In March, 1963, ECMA published a six-bit code corresponding to the ISO draft as standard ECMA-1 (Figure 58).[141] On June 17, the American Standards Assocation followed with X3.4-1963, its seven-bit, ISO-compatible, American Standard Code for Information Interchange (Figure 59).[142, 143]

The CCITT gets involved

The CCITT’s Working Party on the New Telegraph Alphabet, organized in December, 1960, finally met for the first time from May 13-15, 1963.[59] There was no reason to start from scratch when the ISO character code proposal was already so well

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	nul	dle	ds		sp	&	−									0
1	soh	dc1	sos				/		a	j			A	J		1
2	stx	dc2	fs	syn					b	k	s		B	K	S	2
3	etx	tm							c	l	t		C	L	T	3
4	pf	res	byp	pn					d	m	u		D	M	U	4
5	ht	nl	lf	rs					e	n	v		E	N	V	5
6	lc	bs	etb	uc					f	o	w		F	O	W	6
7	del	il	esc	eot					g	p	x		G	P	X	7
8		can							h	q	y		H	Q	Y	8
9		em							i	r	z		I	R	Z	9
10	smm	cc	sm		¢	!		:								
11	vt	cu1	cu2	cu3	.	$	,	#								
12	ff	ifs		dc4	<	*	%	@								
13	cr	igs	enq	nak	(	)	_	’								
14	so	irs	ack		+	;	>	=								
15	si	ius	bel	sub	|	¬	?	"								

Figure 57. Extended Binary-Coded Decimal Interchange Code (EBCDIC), revision of August, 1970.[135]

	0	1	2	3
0	f_0 / space	0	null	P
1	f_1 / ht	1	A	Q
2	f_2 / lf	2	B	R
3	f_3 / vt	3	C	S
4	f_4 / ff	4	D	T
5	f_5 / cr	5	E	U
6	so	6	F	V
7	si	7	G	W
8	(	8	H	X
9	)	9	I	Y
10	*	: / 10	J	Z
11	+	; / 11	K	nat / [
12	,	< / cs	L	nat / \
13	−	= / %	M	nat /]
14	.	> / &	N	escape
15	/	? / ’	O	delete

Figure 58. ECMA Standard for a 6 Bit Input/Output Character Code, March, 1963.[141]

developed, so it was used as a starting point. The ISO proposal, though, did not include the lower case alphabet and the five accent marks that the CCITT considered essential. The unassigned area was the natural place to add the lower case alphabet, but adding the accents as well would have put the total number of necessary printing characters and controls at 135, seven too many for a seven-bit character code. ISO representatives ‘‘stated that there were certain parts of the 7-bit code which were ‘softer’ than others and which were, therefore, more readily subject to replacement’’ so that the character count could be reduced. The ‘‘softest’’ were the three characters following the alphabet, which were already reserved for

	0	1	2	3	4	5	6	7
0	null	dc$_0$	spc	0	@	P		
1	som	dc$_1$	!	1	A	Q		
2	eoa	dc$_2$	"	2	B	R		
3	eom	dc$_3$	#	3	C	S		
4	eot	dc$_4$	$	4	D	T		
5	wru	err	%	5	E	U		
6	ru	sync	&	6	F	V		
7	bell	lem	’	7	G	W		
8	fe$_0$	s_0	(	8	H	X		
9	ht / sk	s_1	)	9	I	Y		
10	lf	s_2	*	:	J	Z		
11	vtab	s_3	+	;	K	[		
12	ff	s_4	,	<	L	\		ack
13	cr	s_5	−	=	M	]		
14	so	s_6	.	>	N	↑		esc
15	si	s_7	/	?	O	←		del

Figure 59. American Standard Code for Information Interchange, June 17, 1963.[142]

national use; then the at sign (@) and arrows (↑, ←), and finally, if necessary, the exclamation point (!), quotation mark ("), number sign (#), and currency symbol, all four of which were already excluded from the six-bit code.

At its October 29-31, 1963 meeting,[144] ISO/TC 97/SC 2 made changes to the proposed ISO code to meet the CCITT’s needs. It voted to place the lower case letters in columns 6 and 7; only France supported adding a note indicating possible other uses for the former unassigned area. The formerly unspecified *format effector 0* was assigned to be the *backspace* character; accented letters were to be transmitted as a sequence of three characters: the letter, *backspace*, and the accent. The quotation mark (") and apostrophe (’) were modified in appearance so they could also serve as umlaut (¨) and acute (´) accents, and the up (↑) and left (←) arrows were removed and replaced with circumflex (^) and grave (`) accents. The number sign (#) was given an alternate meaning as the tilde (~). If the three characters following the lower case were to be reserved for national use, as the characters following the upper case alphabet were, the *acknowledge* control would have to be moved. Italy proposed that it be relocated to position 6/0 (as in the September, 1961 X3.2 code) and print as an underline (_).

By the end of the meeting, the code table looked like Figure 60. A second draft proposal, incorporating the changes, was distributed in December, 1963.[145] It gave this explanation of the dual assignment of the tilde and number sign: ‘‘In position 2/3 of the 7-bit set, [a] unique choice should be made between the preferred proposal to use tilde (~) and the second proposal to use the number sign (#). (This note is not intended to be included in the final Recommendation),'' and included the following note for position 6/0: ''If an 'Acknowledge' (Ack) signal is required it should be coded in this position and the 'Underline' sign becomes its graphical representation.'' The code chart shows positions 2/2 and 2/7 as accent marks, but it is clear from the text that they still were intended as punctuation as well.

At its December 17-18, 1963 meeting, ASA task group X3.2.4 concluded that it would rather keep the number sign (#) than the exclamation point (!) so it would rather see the tilde (~) replace the latter rather than the former. Further motions established a preference to place the underline (_) in position 4/0, not 6/0 and the at sign (@) in position 6/0, not 4/0. An ad hoc committee (Eric Clamons, O. R. Arne, C. J. Davis, W. Y. Lang, and L. R. Turner) was established to consider what characters should be assigned in the United States to the national use positions following the lower case alphabet. They decided that a left brace ({), vertical line (|), and right brace (}) would be useful and would remain comprehensible when they were mapped onto the brackets and backslash in upper-case-only versions of the code. They further decided that if the tilde did replace the exclamation point, then the exclamation point could replace the vertical line.[146]

There is no explanation in the minutes of why the task group thought it was a good idea to switch the at sign (@) and underline (_). Charles Mackenzie, who was present at the meeting, explains in his book, *Coded Character Sets, History and Development*, that ''it was forecast that, in the French national variant of the ISO 7-Bit Code, @ would be replaced by à. Since à is an accented small letter, it should be in columns 6 or 7 where the other small alphabetics were positioned.'' He goes on to say that the U.S.A. requested the at sign in position 4/0 and France in position 6/0 and that ''it actually moved back and forth at successive meetings,''[2] a statement that seems to contradict both the X3.2.4 minutes and the later ISO drafts. Unfortunately other countries' comments on the ISO second draft do not make the situation any clearer. It is recorded that the U.K. supported the switch ''having in mind assistance to certain countries who may have difficulties with certain extended letters''[147] and that Germany also proposed the change so that the underline ''will then be nearer to the other special symbols.''[148] Whatever the reason, the underline and at sign traded places in the May 20, 1964 third draft (Figure 61).[149]

The third draft incorporated several additional changes resulting from the May, 1964 meeting of several ISO subcommittees in New York.[150] The number of *information separators* was reduced to four (and they were given names) to make room for changes to the control characters, most notably the relocation of *acknowledge* to position 0/6 and *escape* to position 1/11. The third draft also deleted the dollar sign ($) and backslash (\) and made their former positions into first and second currency symbols to be assigned by each country. Positions 2/2 and 2/7 returned to being shown in the code table as quotation mark (") and apostrophe (') symbols rather than umlaut (¨) and acute (´) accents, though the characters continued to serve dual purposes. The tilde (~) was removed from the number sign's position (#), but the latter gained a new alternate appearance (N°). (At the time, the ''#'' symbol was not used internationally. Hugh McGregor Ross's attempt to justify to British readers why it was in the code in the first place does not sound very convincing: ''The symbol # means the same as No., and it can be very useful.'')[151] The displaced tilde became an alternate graphic for the circumflex (^) accent, as it was (erroneously) believed that no language used both accents.

The relocation of *escape* had opened up a fourth national use position following the lower case alphabet. At its July 14-15, 1964 meeting, task group X3.2.4 voted to use it in the United States for a logical *not* sign or overline (¯). A second motion that would have reversed the positions of the backslash (\, which the U.S. intended to keep rather than replace it with a second currency symbol) and vertical line (|) was defeated.

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	nat/ @	P	ack/ _	p
1	som	dc_1	!	1	A	Q	a	q
2	eoa	dc_2	¨	2	B	R	b	r
3	eom	dc_3	~ / #	3	C	S	c	s
4	eot	stop	cs	4	D	T	d	t
5	wru	error	%	5	E	U	e	u
6	ru	sync	&	6	F	V	f	v
7	bel	lem	´	7	G	W	g	w
8	bs	is_0	(	8	H	X	h	x
9	ht	is_1	)	9	I	Y	i	y
10	lf	is_2	*	:	J	Z	j	z
11	vt	is_3	+	;	K	nat/ [	k	nat
12	ff	is_4	,	<	L	nat/ \	l	nat
13	cr	is_5	−	=	M	nat/]	m	nat
14	so	is_6	.	>	N	^	n	esc
15	si	is_7	/	?	O	`	o	del

Figure 60. ISO second draft code chart, December, 1963.[145] Heavy borders indicate additions and changes from the first draft.

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	_	P	nat/@	p
1	soh	dc_1	!	1	A	Q	a	q
2	stx	dc_2	"	2	B	R	b	r
3	etx	dc_3	#/Nº	3	C	S	c	s
4	eot	stop	cs_1	4	D	T	d	t
5	enq	nack	%	5	E	U	e	u
6	ack	sync	&	6	F	V	f	v
7	bel	etb	’	7	G	W	g	w
8	bs	cncl	(	8	H	X	h	x
9	ht	em	)	9	I	Y	i	y
10	lf	ss	*	:	J	Z	j	z
11	vt	esc	+	;	K	nat/ [	k	nat
12	ff	fs	,	<	L	nat/cs_2	l	nat
13	cr	gs	−	=	M	nat/]	m	nat
14	so	rs	.	>	N	^	n	nat
15	si	us	/	?	O	`	o	del

Figure 61. ISO third draft, May 20, 1964.[149] Heavy borders indicate changes from the second draft.

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	nat/ `	P	nat/@	p
1	soh	dc_1	!	1	A	Q	a	q
2	stx	dc_2	"	2	B	R	b	r
3	etx	dc_3	#	3	C	S	c	s
4	eot	stop	¤	4	D	T	d	t
5	wru	nack	%	5	E	U	e	u
6	ack	sync	&	6	F	V	f	v
7	bel	etb	’	7	G	W	g	w
8	bs	cncl	(	8	H	X	h	x
9	ht	em	)	9	I	Y	i	y
10	lf	ss	*	:	J	Z	j	z
11	vt	esc	+	;	K	nat/ [	k	nat
12	ff	fs	,	<	L	nat/ ~	l	nat
13	cr	gs	−	=	M	nat/]	m	nat
14	so	rs	.	>	N	nat/ ^	n	nat
15	si	us	/	?	O	_	o	del

Figure 62. CCITT New Alphabet proposal, October 6-9, 1964.[152] Heavy borders indicate changes from the ISO third draft.

The CCITT Working Group on the New Alphabet met again in Geneva, October 6-9, 1964.[152] The German and Swiss delegations made the case for accent characters that did not cause a space and therefore did not require the use of a *backspace* character between them and the letter to be accented. The proposal was defeated because *backspace* can also be used with the underline character (_) to underline text. The Portuguese delegation informed the working group that both the tilde (~) and circumflex (^) are used in the Portuguese language with different meanings. To accomodate both accents, the working group removed the second currency symbol from position 5/12 and put the tilde there.

The underline (_) was moved again after the USSR informed the working group that it needed 31 characters to accomodate each case of the Cyrillic alphabet. The upper case would occupy all of columns 4 and 5 except for position 5/15. The grave accent (`), which had been in position 5/15, was useless for Russian, but the underline was not, so the two characters had their positions reversed. It was further decided that it was too dangerous in international communications to use currency symbols that could be localized. Data processing representatives insisted that it was nevertheless essential that the code contain provisions for a currency symbol of some sort. To allow the use of a currency symbol, but to force it to be defined explicitly, the Italian delegation proposed that the position for the currency symbol be assigned to a new symbol (¤) that would denote no particular currency. At the end of the discussions, the code table was as shown in Figure 62.

The ill-fated ASCII-1965

Through all of these changes, the X3.2.4 task group had been continually updating a proposed revision to the American Standard Code for Information Interchange to match the changes in the international proposals. At a meeting October 19-21, 1964 in New York City, the draft proposed revision (Figure 63) was updated to incorporate the CCITT changes.[153] There was every expectation that the next ISO draft would make the same changes. When the revised ISO draft appeared in March, 1965, though, it included the new locations of the underline (_) and grave accent (`) but did not assign the tilde (~) to position 5/12, and instead left that position for one of two unspecified currency symbols. The ISO draft did not make it to the American Standards Assocation until April 27, 1965,[154] by which time the slightly incompatible Proposed Revised ASCII had already been printed in the *Communications of the ACM*.[155]

Comments began to come in concerning the proposed revision. W. E. Andrus wrote to suggest that that the vertical line (|, logical *or*) and overline (¬, logical *not*) should be located somewhere other than national use positions because of their importance to programming languages, and that the at sign (@) be placed in the middle four columns so that it could be used in uppercase-only applications. Figure 64 is his suggested arrangement of the code, which makes both the overline and tilde (~) alternate graphics for the circumflex (^) and adds a cent sign (¢).[156] The ISO draft standard would have allowed the at sign to be the national assignment for position 5/12, satisfying that part of his request, but the CCITT draft would not, so

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	`	P	@	p
1	soh	dc1	!	1	A	Q	a	q
2	stx	dc2	"	2	B	R	b	r
3	etx	dc3	#	3	C	S	c	s
4	eot	dc4	$	4	D	T	d	t
5	enq	nak	%	5	E	U	e	u
6	ack	syn	&	6	F	V	f	v
7	bel	etb	’	7	G	W	g	w
8	bs	can	(	8	H	X	h	x
9	ht	em	)	9	I	Y	i	y
10	lf	ss	*	:	J	Z	j	z
11	vt	esc	+	;	K	[	k	{
12	ff	fs	,	<	L	~	l	¬
13	cr	gs	−	=	M	]	m	}
14	so	rs	.	>	N	^	n	|
15	si	us	/	?	O	_	o	del

Figure 63. Proposed Revised ASCII, October 19-21, 1964.[153] Heavy borders indicate additions and changes since X3.4-1963.

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	`	P	¢	p
1	soh	dc1	|	1	A	Q	a	q
2	stx	dc2	"	2	B	R	b	r
3	etx	dc3	#	3	C	S	c	s
4	eot	dc4	$	4	D	T	d	t
5	enq	nak	%	5	E	U	e	u
6	ack	syn	&	6	F	V	f	v
7	bel	etb	’	7	G	W	g	w
8	bs	can	(	8	H	X	h	x
9	ht	em	)	9	I	Y	i	y
10	lf	ss	*	:	J	Z	j	z
11	vt	esc	+	;	K	[	k	{
12	ff	fs	,	<	L	@	l	
13	cr	gs	−	=	M	]	m	}
14	so	rs	.	>	N	^ / ¬	n	!
15	si	us	/	?	O	_	o	del

Figure 64. Proposed Revised ASCII, as modified by W. E. Andrus, June 9, 1965.[156] Heavy borders indicate differences from October, 1964 proposed revised ASCII.

the X3.2.4 task group responded that no action could be taken until the differences between the two proposals were resolved.[157] Thomas E. Kurtz, the director of the Dartmouth College computation center, wrote to express his regret that the up arrow (↑) had been eliminated and suggested that it take the place of the vertical line (|). John L. Little replied that the proposal should have stated that that the character in position 5/14 was still intended to represent an up arrow when it was not used with *backspace* to overstrike a circumflex accent (^), but later revisions never restored this language.[158]

By the end of 1965, in spite of these criticisms and the lack of international agreement, the proposed revision had been approved as the American Standard Code, but it had not yet been published.[159] The ISO and CCITT had agreed in October to hold a joint meeting at which they hoped to resolve the differences between their character code proposals. At the January 25-26 meeting of X3.2.4, John B. Booth moved that X3 request that the American Standards Assocation delay publication of the revised standard until after the ISO/CCITT meeting, which might allow the at sign (@) to be relocated back into the center four columns as had been requested. The group then voted to relocate the at sign, tilde (~), vertical line (|), and overline (‾) as in Figure 65 if the international code that resulted from the reconcilation would allow it.[160]

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	`	P	‾	p
1	soh	dc1	!	1	A	Q	a	q
2	stx	dc2	"	2	B	R	b	r
3	etx	dc3	#	3	C	S	c	s
4	eot	dc4	$	4	D	T	d	t
5	enq	nak	%	5	E	U	e	u
6	ack	syn	&	6	F	V	f	v
7	bel	etb	’	7	G	W	g	w
8	bs	can	(	8	H	X	h	x
9	ht	em	)	9	I	Y	i	y
10	lf	ss	*	:	J	Z	j	z
11	vt	esc	+	;	K	[	k	{
12	ff	fs	,	<	L	@	l	|
13	cr	gs	−	=	M	]	m	}
14	so	rs	.	>	N	^	n	~
15	si	us	/	?	O	_	o	del

Figure 65. X3.2.4 proposal to ISO and CCITT, January 25-26, 1966.[160] Heavy borders indicate diffences from October, 1964 proposed revised ASCII (X3.4-1965).

The ISO/CCITT joint meeting

ISO and CCITT representatives met jointly in Paris, France, April 26-28, 1966.[161, 162] An Austrian proposal (Figure 66) might have caused a large-scale rearrangement of the code,[163] but it had been ‘‘resolved to discuss only those points on which CCITT and I.S.O. did not completely agree.’’ The first such disagreement was resolved with a decision to place a character which could represent either a tilde (~) or an overline (‾) in position 7/14, with notes indicating that it could be preempted for other national use if necessary. The at sign (@) was returned to position 4/0, its location in X3.4-1963 and in the early ISO drafts. The grave accent (`), which had been in that position, was relocated to 6/0. A proposal, related to what W. E. Andrus had suggested, to make the vertical line (|) an alternate graphic for the exclamation point (!) and the logical not sign (¬) an alternate for the circumflex (^),[164] was rejected.

The main issue still to be resolved was the currency signs. The options were (1) to use a generic currency symbol (¤) or (2) to give the dollar ($) and pound (£) signs permanent assignments. Italy, Portugal, Switzerland, and the USSR preferred option 1; Canada, France, Germany, the Netherlands, Sweden, and the United Kingdom preferred option 2. The United States wanted to see the dollar sign included but did not have an opinion about the pound sign; Japan wanted one currency symbol to be assigned internationally and a second to be reserved for national use. This was considered sufficient agreement to get the dollar sign assigned to position 2/4.

Discussion continued about the location and appearance of the second currency symbol. One proposal was to put the pound sign (£) in position 2/3 internationally. The U.S. proposed that if this assignment were made, there should also be a note allowing the number sign (#) to be used in countries that did not need the pound sign. The CCITT proposed that the pound sign be in position 2/3 and that the number sign be relocated to the national use position 5/12. Another proposal put the same two symbols in the opposite locations. The chairman preferred the CCITT proposal (pound sign in 2/3, number sign in 5/12) and took a vote in support of it, which passed. The U.S. delegation asked that a vote also be taken on their proposal (pound in 2/3, except when not required), and this also passed its vote.

The chairman then ruled that the U.S. proposal was accepted, over the objections of ECMA: ‘‘This proposal which had the sole objective of keeping the code table unchanged for the U.S., was presented under the disguise of a compromise, and when it obtained approval in an obscure fashion only the U.S. delegation was happy, the other delegations had obviously not realized what they had been tricked into.’’ The X3.2.4 task group later attempted to restore a good relationship with ECMA by offering to accept the pound sign (£) in position 5/12 where the British were also willing to accept it.[165, 166]

In the United States on May 9, 1966, D. A. Kerr edited the still unpublished revised American Standard Code to incorporate the new international changes. He took the national option to put the number sign (#) rather than the pound sign (£) in position 2/3, and returned the backslash (\) to the now-open national use position 5/12 that it had occupied in X3.4-1963.[167] In additional revisions May 12, he drew

	0	1	2	3	4	5	6	7
0			sp	0	$ / £	P	¢ / $	p
1			(	1	A	Q	a	q
2			)	2	B	R	b	r
3			’	3	C	S	c	s
4			.	4	D	T	d	t
5			,	5	E	U	e	u
6			:	6	F	V	f	v
7			;	7	G	W	g	w
8			=	8	H	X	h	x
9			&	9	I	Y	i	y
10			!	?	J	Z	j	z
11			^	"	K	@ / nat	k	{ / nat
12			+	<	L	# / nat	l	} / nat
13			−	>	M	□ / nat	m	| / nat
14			*	[	N	%	n	` / nat
15			/	]	O	_	o	del

Figure 66. Austrian character code proposal, April, 1966.[163]

position 7/14 as a wavy overline (⁀) to suggest its dual meanings as tilde (~) and overline (‾).[168] The resulting proposed Revised American Standard Code for Information Interchange (Figure 67)[169] was sent to X3.2 members May 20, 1966[170] and to X3 on May 24.[159]

Trouble with SHARE

In June, 1966, the ISO distributed its new draft proposal (Figure 68).[171] It looked at this point as if all the important issues that had been holding up the international character code standard had been resolved. But on June 8, 1966, H. W. Nelson, the chairman of the SHARE (IBM user group) character set committee, sent an angry letter saying that ‘‘the ‘Proposed Revised (1966) American Standard Code for Information Interchange’ dated May 20, 1966 does *not* meet the needs of computer programmers! There are no characters in the international use section of center four column subset (2-5) which can be used satisfactorily to represent the logical operations OR and NOT.’’ He disapproved of the vertical line (|) and overline (⁀) because they were in the lower case region, and of the exclamation point (!) and circumflex (^) because the exclamation point is used for factorials and the circumflex looks too much like the standard symbol for logical *and* (∧). Neither did he approve of two-character sequences (such as \/) using the backslash. He proposed that the code table be rearranged as in Figure 69.[172] Additional letters from Philip H. Dorn, manager of the SHARE PL/I Project,[173] and Herb Van Brink, manager of the SHARE FORTRAN Project,[174] indicated that the programmers they represented might boycott the

<table>
<tr><th></th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>0</td><td>nul</td><td>dle</td><td>sp</td><td>0</td><td>@</td><td>P</td><td>`</td><td>p</td></tr>
<tr><td>1</td><td>soh</td><td>dc1</td><td>!</td><td>1</td><td>A</td><td>Q</td><td>a</td><td>q</td></tr>
<tr><td>2</td><td>stx</td><td>dc2</td><td>"</td><td>2</td><td>B</td><td>R</td><td>b</td><td>r</td></tr>
<tr><td>3</td><td>etx</td><td>dc3</td><td>#</td><td>3</td><td>C</td><td>S</td><td>c</td><td>s</td></tr>
<tr><td>4</td><td>eot</td><td>dc4</td><td>$</td><td>4</td><td>D</td><td>T</td><td>d</td><td>t</td></tr>
<tr><td>5</td><td>enq</td><td>nak</td><td>%</td><td>5</td><td>E</td><td>U</td><td>e</td><td>u</td></tr>
<tr><td>6</td><td>ack</td><td>syn</td><td>&</td><td>6</td><td>F</td><td>V</td><td>f</td><td>v</td></tr>
<tr><td>7</td><td>bel</td><td>etb</td><td>’</td><td>7</td><td>G</td><td>W</td><td>g</td><td>w</td></tr>
<tr><td>8</td><td>bs</td><td>can</td><td>(</td><td>8</td><td>H</td><td>X</td><td>h</td><td>x</td></tr>
<tr><td>9</td><td>ht</td><td>em</td><td>)</td><td>9</td><td>I</td><td>Y</td><td>i</td><td>y</td></tr>
<tr><td>10</td><td>lf</td><td>sub</td><td>*</td><td>:</td><td>J</td><td>Z</td><td>j</td><td>z</td></tr>
<tr><td>11</td><td>vt</td><td>esc</td><td>+</td><td>;</td><td>K</td><td>[</td><td>k</td><td>{</td></tr>
<tr><td>12</td><td>ff</td><td>fs</td><td>,</td><td><</td><td>L</td><td>\</td><td>l</td><td>|</td></tr>
<tr><td>13</td><td>cr</td><td>gs</td><td>−</td><td>=</td><td>M</td><td>]</td><td>m</td><td>}</td></tr>
<tr><td>14</td><td>so</td><td>rs</td><td>.</td><td>></td><td>N</td><td>^</td><td>n</td><td>~</td></tr>
<tr><td>15</td><td>si</td><td>us</td><td>/</td><td>?</td><td>O</td><td>_</td><td>o</td><td>del</td></tr>
</table>

Figure 67. Proposed Revised ASCII, May 12, 1966.[168] Heavy borders indicate differences from X3.4-1965.

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	@	P	nat/ `	p
1	soh	dc$_1$	!	1	A	Q	a	q
2	stx	dc$_2$	"	2	B	R	b	r
3	etx	dc$_3$	£	3	C	S	c	s
4	eot	dc$_4$	$	4	D	T	d	t
5	enq	nak	%	5	E	U	e	u
6	ack	syn	&	6	F	V	f	v
7	bel	etb	’	7	G	W	g	w
8	bs	can	(	8	H	X	h	x
9	ht	em	)	9	I	Y	i	y
10	lf	sub	*	:	J	Z	j	z
11	vt	esc	+	;	K	nat/ [	k	nat
12	ff	fs	,	<	L	nat	l	nat
13	cr	gs	−	=	M	nat/]	m	nat
14	so	rs	.	>	N	nat/ ^	n	nat/ ¬
15	si	us	/	?	O	_	o	del

Figure 68. ISO draft 1052, June, 1966.[171] Heavy borders indicate differences from the fourth draft and from the October, 1964 CCITT proposal.

proposed revised standard if it was not altered.

The X3.2.4 task group met June 28, 1966[165] and tried to figure out a compromise, but could not find any reasonable way of moving an overline (¬) and vertical line (|) into the center four columns without disrupting the international agreement that had finally been reached. At the June 30 meeting of X3,[176] John Auwaerter proposed a way to solve half the problem: the hybrid wavy overline (~) would become exclusively a tilde (~), and the circumflex (^) would get a new curved shape (⌒) and represent both the circumflex accent and the logical *not*.

The change to the tilde was voted in, but the shape of the circumflex remained as it was. SHARE was satisfied with the change to the tilde but still wanted a vertical line somewhere in the center four columns. ‘‘If X3 will agree to one last, simple change to the proposed Revised ASCII, the final requirement of PL/I users will be satisfied.... We ask that X3 agree to interchange ! (Exclamation Point) and | (Vertical Line) in ASCII. We are sure that the European programming community will accept and support a similar change to the ISO 7-bit code.’’ They threatened that ‘‘if X3 rejects this suggestion [it] should be aware of the consequence, which is that ASCII will be bypassed by the programming community, and by many users and manufacturers, and fail to become a de facto standard.’’[177]

It was inconceivable to make such a change when ‘‘to comply with the SHARE suggestion would undoubtably lose more support than would be gained because of the loss of international compatibility and the displacement of two characters from the center 64

<table>
<tr><th></th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>0</td><td>nul</td><td>dle</td><td>sp</td><td>0</td><td>@</td><td>P</td><td>`</td><td>p</td></tr>
<tr><td>1</td><td>soh</td><td>dc1</td><td>!</td><td>1</td><td>A</td><td>Q</td><td>a</td><td>q</td></tr>
<tr><td>2</td><td>stx</td><td>dc2</td><td>"</td><td>2</td><td>B</td><td>R</td><td>b</td><td>r</td></tr>
<tr><td>3</td><td>etx</td><td>dc3</td><td>|</td><td>3</td><td>C</td><td>S</td><td>c</td><td>s</td></tr>
<tr><td>4</td><td>eot</td><td>dc4</td><td>¬</td><td>4</td><td>D</td><td>T</td><td>d</td><td>t</td></tr>
<tr><td>5</td><td>enq</td><td>nak</td><td>%</td><td>5</td><td>E</td><td>U</td><td>e</td><td>u</td></tr>
<tr><td>6</td><td>ack</td><td>syn</td><td>&</td><td>6</td><td>F</td><td>V</td><td>f</td><td>v</td></tr>
<tr><td>7</td><td>bel</td><td>etb</td><td>’</td><td>7</td><td>G</td><td>W</td><td>g</td><td>w</td></tr>
<tr><td>8</td><td>bs</td><td>can</td><td>(</td><td>8</td><td>H</td><td>X</td><td>h</td><td>x</td></tr>
<tr><td>9</td><td>ht</td><td>em</td><td>)</td><td>9</td><td>I</td><td>Y</td><td>i</td><td>y</td></tr>
<tr><td>10</td><td>lf</td><td>sub</td><td>*</td><td>:</td><td>J</td><td>Z</td><td>j</td><td>z</td></tr>
<tr><td>11</td><td>vt</td><td>esc</td><td>+</td><td>;</td><td>K</td><td>[</td><td>k</td><td>{</td></tr>
<tr><td>12</td><td>ff</td><td>fs</td><td>,</td><td><</td><td>L</td><td>#</td><td>l</td><td>\</td></tr>
<tr><td>13</td><td>cr</td><td>gs</td><td>−</td><td>=</td><td>M</td><td>]</td><td>m</td><td>}</td></tr>
<tr><td>14</td><td>so</td><td>rs</td><td>.</td><td>></td><td>N</td><td>$</td><td>n</td><td>^</td></tr>
<tr><td>15</td><td>si</td><td>us</td><td>/</td><td>?</td><td>O</td><td>_</td><td>o</td><td>del</td></tr>
</table>

Figure 69. Proposed Revised ASCII, as rearranged by the SHARE PL/I Project, June 7, 1966.[172, 175] Heavy borders indicate differences from the May 12, 1966 proposed revision.

positions which have had both national and international support for inclusion.’’[178] But in a final attempt to appease SHARE, on December 13, 1966 X3.2 members changed the shape of their code’s vertical line (|) to a broken line (¦) so that it could not be mistaken for a logical *or* symbol, and added notes to the exclamation point (!) and circumflex (^) characters suggesting that ‘‘it may be desirable to employ distinctive styling to facilitate their use for specific purposes as, for example, to stylize the graphics in code positions 2/1 and 5/14 to those frequently associated with logical OR (|) and logical NOT (¬) respectively.’’[179]

These changes (which were undone in the 1977 revision of ASCII)[180] were sufficient to gain SHARE’s support without causing any serious incompatibility with the international standards, and X3.4-1967 (Figure 70) became the United States character code standard July 5, 1967.[181] ECMA had published its revised code, ECMA-6, in June.[182] The ISO code was published as Recommendation 646 in December, 1967,[1] and the CCITT adopted International Alphabet No. 5 at its 1968 conference.[183]

Epilogue

Even before X3.4-1967 was published, there was already interest in two more minor revisions. First, the ISO code had since its first draft allowed the use of character 0/10 for *new line* as well as for *line feed*, but ASCII had not. On July 5, 1967, John B. Booth proposed that ASCII also include this dual meaning.[184] Second, prior to the publication of X3.4-1967 the American Standards Assocation had become the USA Standards Institute, meaning that the code was now formally the USA Standard Code for Information Interchange, USASCII. On November 20, 1967, D. A. Kerr proposed that the code continue to be known by its traditional name, ASCII.[185] On October 10, 1968, a revised USA Standard with these changes was accepted.[186]

The U. S. Department of Defense’s MIL-STD-188 continued to document FIELDATA through its 1969 edition, but encouraged the use of ASCII.[187] EBCDIC and ASCII were reconciled, to an extent, by a 1970 American standard that defined a one-to-one correspondence between the two codes.[188] The CCITT was dissolved February 28, 1993, but its successor, ITU-T, the Telecommunications Standardization Sector of the International Telecommunication Union, continues to maintain the standard for International Telegraph Alphabet No. 2.[189] It enjoyed a brief resurgence of popularity in the mid-1970s among computer hobbyists who discovered that five-unit teleprinters were available for much lower prices than comparable seven-bit equipment.[190, 191]

Several revisions of ISO 646,[192, 193] International Alphabet No. 5,[194] ECMA-6,[182] and ASCII[180, 195] have made small changes to details of the code and removed the anachronistic six-bit code tables, but retain almost complete compatibility with the seven-bit standards published in 1967-8. The eight-bit ISO 8859-1[196] and ECMA-94 codes,[197] and the sixteen-bit Unicode,[198, 199] are compatible supersets of the seven-bit standard.

	0	1	2	3	4	5	6	7
0	nul	dle	sp	0	@	P	`	p
1	soh	dc1	!	1	A	Q	a	q
2	stx	dc2	"	2	B	R	b	r
3	etx	dc3	#	3	C	S	c	s
4	eot	dc4	$	4	D	T	d	t
5	enq	nak	%	5	E	U	e	u
6	ack	syn	&	6	F	V	f	v
7	bel	etb	’	7	G	W	g	w
8	bs	can	(	8	H	X	h	x
9	ht	em	)	9	I	Y	i	y
10	lf	sub	*	:	J	Z	j	z
11	vt	esc	+	;	K	[	k	{
12	ff	fs	,	<	L	\	l	¦
13	cr	gs	−	=	M	]	m	}
14	so	rs	.	>	N	^	n	~
15	si	us	/	?	O	_	o	del

Figure 70. USA Standard Code for Information Interchange, July 5, 1967.[181]

Acknowledgements

This paper could not have been written without access to the Honeywell, Inc. X3.2 Standards Subcommittee Records, Herbert S. Bright Papers, and Calvin N. Mooers Papers archived at the Charles Babbage Institute at the University of Minnesota, Minneapolis; the Computer Standards Collection and Western Union Telegraph Collection at the Archives Center of the National Museum of American History, Smithsonian Institution, Washington, D.C.; and the collections of the University of Chicago’s Crerar, Regenstein, and Eckhart libraries. Bob Mackay provided the photograph of Donald Murray. Tony Duell, Dik T. Winter, and John Savard corrected several of my misconceptions about the Baudot and Murray codes. Dennis Ritchie and Dan Strychalski encouraged my interest in the history of the ASCII code. Alain Roy suggested several improvements to the paper.

References

1. R. W. Bemer, ‘‘A View of the History of the ISO Character Code,’’ *Honeywell Computer Journal*, vol. 6, no. 4, 1972, pp. 274-286.
2. Charles E. Mackenzie, *Coded Character Sets, History and Development*, Addison-Wesley, 1980, especially pp. 435-441.
3. E. Montoriol, ‘‘Baudot et son Oeuvre,’’ *Annales des Postes, Télégraphes, et Téléphones*, vol. 5, no. 4, December, 1916, pp. 367-403.
4. H. H. Harrison, *Printing Telegraph Systems and Mechanisms*, Longmans, Green, and Co., 1923, pp. 1-3.
5. André Frouin, ‘‘Necrologie: † Emile Baudot,’’ *Journal Télégraphique*, vol. 27, no. 4, April 25, 1903, pp. 90-91.
6. T. E. Herbert, *Telegraphy*, Whittaker & Co., 1906, pp. 370-395.
7. E. Baudot, ‘‘Des Appareils Télégraphiques à Signaux Indépendants,’’ *Annales Télégraphiques*, vol. 4, no. 1, January-February, 1877, pp. 20-32.

8. F. G. Creed, ''The Creed High Speed Morse Printing Telegraph System,'' *Electrical Communication*, vol. 8, no. 1, 1929, pp. 52-60.
9. Major Webber, ''Multiple and Other Telegraphs at the Paris Exhibition,'' *Journal of the Society of Telegraph Engineers*, vol, 7, November 27, 1878, pp. 434-467.
10. M. Rothen, ''Le télégraphe imprimeur Baudot,'' *Journal Télégraphique*, vol. 8, no. 12, December, 1884, pp. 241-253.
11. Sid Owen, ''QWERTY is Obsolete,'' *Interface Age*, vol. 3, no. 1, January, 1978, pp. 56-59.
12. Doug Engelbart, ''The Augmented Knowledge Workshop,'' in Adele Goldberg, ed., *A History of Personal Workstations*, ACM Press/Addison-Wesley, 1988, pp. 187-236.
13. H. W. Pendry, *The Baudôt Printing Telegraph System*, second edition, Sir Isaac Pitman & Sons, Ltd., 1919, pp. 43-44.
14. E. E. Blavier, *Nouveau Traite de Télégraphie Électrique*, vol. 2, Librarie Scientifique, Industrielle, et Agricole, 1867, p. 239.
15. H. H. H., ''Obituary Notices: Donald Murray, M. A.,'' *The Journal of the Institution of Electrical Engineers*, vol, 92, part I, no. 60, December, 1945, p. 471.
16. William B. Vansize, ''A New Page-Printing Telegraph,'' *Transactions of the American Institute of Electrical Engineers*, vol. 18, 1902, pp. 7-43.
17. Donald Murray, ''Actuating Mechanism for Key-Operated Machines,'' U. S. Patent 638,591, December 5, 1899.
18. Geo. Carl Mares, *The History of the Typewriter*, Guilbert Pitman, 1909, pp. 306-308.
19. The addresses given in Murray's patents (Sydney, New South Wales in U. S. Patent 638,591, filed May 4, 1899; New York in U. S. Patent 653,934, filed November 28, 1899) support the 1899 date for his move to New York.
20. ''Telegraphy,'' *The Post Office Electrical Engineers' Journal*, vol. 49, part 3, October, 1956, pp. 166-172.
21. Donald Murray, ''Page Printing Telegraph,'' U. S. Patent 653,934, July 17, 1900; ''Automatic Actuating Mechanism for Key Operated Machines,'' U. S. Patent 685,427, October 29, 1901; ''Actuating Mechanism for Key Operated Machines,'' U. S. Patent 698,845, April 29, 1902; ''Keyboard Perforator,'' U. S. Patent 710,163, September 30, 1902.
22. Donald Murray, ''Setting Type by Telegraph,'' *Journal of the Institution of Electrical Engineers*, vol. 34, 1904-1905, pp. 555-608.
23. Arthur Crotch, *Telegraphic Systems and Other Notes*, Charles Griffin & Company, Ltd., 1908, pp. 151-170.
24. *Documents de la Deuxième Réunion du Comité Consultatif International des Communications Télégraphiques*, Berlin, June, 1929, vol. 1, pp. 143-178.
25. Wilfred A. Beeching, *Century of the Typewriter*, new edition, British Typewriter Museum Publishing, 1990, pp. 108-113, 195-198.
26. Donald Murray, ''Keyboard Perforator,'' U. S. Patent 710,163, September 30, 1902.
27. Donald Murray, ''Practical Aspects of Printing Telegraphy,'' *Journal of the Institution of Electrical Engineers*, vol. 47, 1911, pp. 450-529.
28. Donald Murray, *The Murray Printing Telegraph Journal*, English Edition, vol. 1, no. 2, August 30, 1912, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1, folder 9.
29. C. E. Easterling and J. H. Collins, ''The Teleprinter No. 11,'' *The Post Office Electrical Engineers' Journal*, vol. 46, part 2, July, 1953, pp. 53-58.
30. M. D. Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years (1875-1925)*, Bell Telephone Laboratories, 1975, pp. 759-760.
31. *Theory of Tape System: The Morkrum Telegraph Printers*, bulletin no. 16, Morkrum Company, October, 1916, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 75, folder 3.
32. *Directions for Operating the Morkrum Telegraph Printers*, Morkrum Company, 1911, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 75, folder 3.
33. *Theory of Tape System: The Morkrum Telegraph Printers*, bulletin no. 9, Morkrum Company, June, 1914, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 75, folder 3.
34. Otto Burghagen, *Die Schreibmaschine*, Verlag der Handels-Akademie, 1898, pp. 94-95.
35. *Directions for Operating the Morkrum Telegraph Printers*, bulletin no. 2, Morkrum Company, 1912, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 75, folder 3.
36. *The Morkrum Telegraph Printers: Special Instructions for Improving "Copy,"* bulletin no. 4, Morkrum Company, March, 1913, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 75, folder 3.
37. *The Multiplex Printing Telegraph System*, specification 263 B, part 1, The Western Union Telegraph Company, January 15, 1915, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 54, folder 1.
38. W. A. Houghtaling, ''The Multiplex Printing Telegraph System,'' *The Electric Journal*, vol. 23, no. 9, September, 1926, pp. 455-461.
39. *Printing Telegraphy: A Technical Description of the Western Electric Printing Telegraph Systems*, bulletin A-1, Western Electric Company Engineering Department, October, 1919.
40. *Specifications for the Cardwell Printing Telegraph System: Operation and Maintenance*, specifications 732-A, The Western Union Telegraph Co., Plant Department, August 1, 1918, Western Union Telegraph Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 43, folder 7.
41. H. H. Harrison, ''The Principles of Modern Printing Telegraphy,'' *The Journal of the Institution of Electrical Engineers*, vol. 54, no. 256, February 15, 1916.
42. Donald Murray, ''Speeding Up the Telegraphs: A Forecast of the New Telegraphy,'' *The Journal of the Institution of Electrical Engineers*, vol. 63, no. 339, March, 1925, pp. 245-280.
43. ''Unification de la Télégraphie Internationale,'' *Annales des Postes, Télégraphes, et Téléphones*, vol. 14, no. 2, February, 1925, pp. 177-184, translated from *Telegraphen- und Fernsprech-Technik*, November, 1924.
44. ''Unification des appareils télégraphiques dans le service international,'' *Journal Télégraphique*, vol. 49, no. 5, May 25, 1925, pp. 81-86; vol. 49, no. 6, June 25, 1925, pp. 101-106.
45. *Documents de la Première Réunion du Comité Consultatif International des Communications Télégraphiques*, Berlin, November, 1926, vol. 2, pp. 43-102.
46. *Documents de la Conférence Télégraphique Internationale de Rome*, Bureau International des Administrations Télégraphiques, 1872, pp. 170-172.
47. *Documents de la Conférence Télégraphique Internationale de Londres*, Bureau International des Administrations Télégraphiques, 1904, p. 301.
48. A. E. Thompson, ''A New Keyboard Perforator for the Baudot Printing Telegraph System,'' *Electrical Communication*, vol. 3, no. 4, April, 1925, pp. 295-300.
49. *Documents de la Deuxième Réunion du Comité Consultatif International des Communications Télégraphiques*, Berlin, June, 1929, vol. 2, pp. 18-26, 40-45, 67-68, 120-124.
50. *Documents de la Troisième Réunion du Comité Consultatif International des Communications Télégraphiques*, Berne, May, 1931, vol. 1, pp. 258-272.
51. Arthur W. Page, *The Bell Telephone System*, third edition, Harper & Brothers, 1941, pp. 26-27.

52. *Documents de la Troisième Réunion du Comité Consultatif International des Communications Télégraphiques*, Berne, May, 1931, vol. 2, p. 136.
53. *Règlement Télégraphique*, Bureau de l'Union Internationale des Télécommunications, 1938, pp. 34-43.
54. ''Sixth Plenary Meeting of the C.C.I.T., Brussel, May 1948,'' *The Post Office Electrical Engineers' Journal*, vol. 41, part 2, July, 1948, pp. 108-109.
55. ''Coding Scheme Using International Telegraph Alphabet No. 2 (ITA2) to Allow the Transmission of Capital and Small Letters,'' Recommendation S.2, Fascicle VII.1, CCITT, 1988.
56. ''Eighth, and Last, Plenary Assembly of the C.C.I.T., Geneva, 1956,'' *The Post Office Electrical Engineers' Journal*, vol. 50, part 1, April, 1957, pp. 45-46.
57. R. N. Renton, letter to J. F. Auwaerter, October 11, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
58. W. E. Bloecker and G. A. Caldwell, ''The Work of the International Telecommunication Union in the Field of Telephony,'' *Communication and Electronics*, no. 33, November, 1957, pp. 543-552.
59. J. F. Auwaerter, ''Brief Report: Meeting of CCITT Working Party on the New Telegraph Alphabet, May 13-15, 1963,'' Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 11.
60. I. S. Coggeshall, ''The Transmission of Intelligence in Typescript,'' *Western Union Technical Review*, vol. 7, no. 1, January, 1953, pp. 6-12; vol. 7, no. 2, April, 1953, pp. 56-62.
61. E. J. Tyberghein, ''TWX Goes Dial,'' *Bell Laboratories Record*, vol. 40, no. 7, July-August, 1962, pp. 232-237.
62. J. F. Auwaerter, ''A New Standard Code for Teletypewriters,'' *Bell Laboratories Record*, vol. 41, no. 10, November, 1963, pp. 395-400.
63. Allen L. Whitman, ''Proposed 6-Unit Code for Teletypewriter and Other Data Communications to Operate with 4-Row Electric Typewriter Keyboard,'' December 19, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
64. A. S. Benjamin and W. J. Zenner, ''A Step Forward in Printing Telegraphy,'' *Communication and Electronics*, no. 11, March, 1954, pp. 10-15.
65. W. F. Luebbert, ''Data Transmission Equipment Concepts for FIELDATA,'' *Proceedings of the Western Joint Computer Conference*, San Francisco, March 3-5, 1959, pp. 189-196.
66. ''Proposed Addendum to MIL-STD-188A,'' June 21, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
67. William F. Luebbert, ''Data Processing as a Tool for Generalizing Communications Systems,'' *Communications and Electronics*, no. 50, September, 1960, pp. 431-436.
68. J. Presper Eckert, Jr., H. Frazer Welsh, James R. Weiner, and Herbert F. Mitchell, ''The UNIVAC System,'' *Proceedings of the Eastern Joint Computer Conference*, Philadelphia, December 10-12, 1951, pp. 6-16.
69. R. W. Bemer and W. Buchholz, ''An Extended Character Set Standard,'' TR 00.721 (Rev.), Product Development Laboratory, Data Systems Division, International Business Machines Corporation, June 1, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
70. H. R. J. Grosch, ''Standardization of Computer Interconnections,'' *Proceedings of the Eastern Joint Computer Conference*, Boston, November 7-9, 1955, pp. 87-89.
71. Minutes of the Meeting of the TR 24.4 Subcommittee on Language and Media, Electronics Industry Association, Feb 1-2, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
72. ''Tentative Standards Proposal: Basic Character Set Code,'' May 25, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
73. C. E. Macon, ''Summary of Data Processing Standards Activities,'' June 9, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
74. R. E. Utman ''Standards for Information Processing: A Progress Report,'' *Computers and Automation*, vol. 12, no. 7, July, 1963, pp. 8-15.
75. X3.2 Subcommittee Minutes, October 6, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
76. I. C. Liggett, ''X3-2 Meeting—December 2, 1960,'' December 7, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
77. L. L. Griffin ''Status of ASA X3-2 subcommittee—3 May 1961,'' May 5, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
78. R. W. Reach, memorandum to W. W. Finke and J. E. Smith, January 24, 1961, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 1.
79. S. Porter, memorandum to Leon Bloom, January 25, 1960, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
80. X3.2 Subcommittee Minutes, March 8-9, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
81. R. W. Reach, memorandum to J. E. Smith and W. W. Finke, March 14, 1961, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 1.
82. R. W. Bemer, H. J. Smith, Jr., and F. A. Williams, Jr., ''Design of an Improved Transmission/Data Processing Code,'' *Communications of the ACM*, vol. 4, no. 5, May, 1961, pp. 212-217, 225.
83. X3.2 Subcommittee Minutes, April 26-27, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
84. X3.2 Subcommittee Minutes, May 8-11, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
85. X3.2 Subcommittee Minutes, June 7-8, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
86. R. W. Bemer, ''Inside ASCII,'' *Interface Age*, vol. 3, no. 5, May, 1978, pp. 96-102; vol. 3, no. 6, June, 1978, pp. 64-74; vol. 3, no. 7, July, 1978, pp. 80-87.
87. J. W. Backus, R. J. Beeber, S. Best, R. Goldberg, L. M. Haibt, H. L. Herrick, R. A. Nelson, D. Sayre, P. B. Sheridan, H. Stern, I. Ziller, R. A. Hughes, and R. Nutt, ''The FORTRAN Automatic Coding System,'' *Proceedings of the Western Joint Computer Conference*, Los Angeles, February 26-28, 1957, pp. 188-198.
88. A. J. Perlis and K. Samuelson for the ACM-GAMM Committee, ''Preliminary Report—International Algebraic Language,'' *Communications of the ACM*, vol. 1, no. 12, December, 1958, pp. 8-22.
89. Jean E. Sammet, *Programming Languages: History and Fundamentals*, Prentice-Hall, Inc., 1969, pp. 139-143.
90. H. S. Bright, SHARE XI, San Francisco, September 11, 1958, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
91. H. S. Bright, letter to the editor, *Communications of the ACM*, vol. 2, no. 5, May, 1959, pp. 6-9.

92. R. W. Bemer, ‘‘A Proposal for a Generalized Card Code for 256 Characters,’’ *Communications of the ACM*, vol, 2, no. 9, September, 1959, pp. 19-23.
93. Herbert Kanner, letter to the editor, *Communications of the ACM*, vol. 2, no. 6, June, 1959, pp. 6-7.
94. Peter Naur, ed., J. W. Backus, F. L. Bauer, J. Green, C. Katz, J. McCarthy, A. J. Perlis, H. Rutishauer, K. Samuelson, B. Vaquois, J. H. Wegstein, A. van Wijngaarden, and M. Woodger, ‘‘Report on the Algorithmic Language ALGOL 60,’’ *Communications of the ACM*, vol. 3, no. 5, May, 1960, pp. 299-314.
95. X3.2 Subcommittee Minutes, April 26-27, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
96. C. E. Macon, ‘‘Summary of Data Processing Standards Activities,’’ June 9, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
97. H. McG. Ross, ‘‘Considerations in Choosing a Character Code for Computers and Punched Tapes,’’ *The Computer Journal*, vol. 3, no. 3, January, 1961, pp. 202-210.
98. *Punched Tape Codes*, list CS 394, Computer Department, Ferranti Limited, April, 1961.
99. ‘‘X3-2 Code Alphabet Set Being Studied for International Compatibility,’’ Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
100. Allen L. Whitman, letter to T. L. Dimond, July 12, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
101. ALW, ‘‘Basic Structure for 7-Bit Code As Proposed by X3-2 Subcommittee for Combined Communications & Data Processing,’’ August 14, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
102. X3.2 Subcommittee Minutes, September 14-15, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
103. R. W. Reach, memorandum to R. F. Clippinger, September 18, 1961, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 1.
104. R. W. Bemer, letter to members of X3.2, September 28, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
105. *Description and Adjustments of the Teletype Wheatstone Perforator*, bulletin 125, issue 2, Teletype Corporation, August, 1937.
106. ‘‘Changes and Additions: Bulletin No. 1025 (Issue 3): Parts—Teletype Wheatstone Perforator,’’ EE-503, issue 1, Teletype Corporation, July, 1945.
107. X3.2 Subcommittee Minutes, November 8-10, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
108. G. M. Wilson, memorandum to members of X3.2, November 28, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
109. ISO/TC 97 Brief Minutes, May 18, 1961, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 1.
110. ‘‘Agenda: European Trip on Code Alphabet,’’ Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
111. Leon Bloom, ‘‘Report on Discussions between John Auwaerter and Leon Bloom of ASA X3.2 and Members of European Data Processing Community,’’ January 25, 1962, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 2.
112. J. B. Booth, ‘‘ECMA TC-1 and ASA X 3.2 Joint Meeting, Rome, Italy, March 8 & 9, 1962,’’ March 14, 1962, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 3.
113. Allen L. Whitman, letter to W. T. Rea, April 2, 1962, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
114. ‘‘Recommended Code for Information Interchange for Consideration by ISO TC97 Working Group B (Based on Discussion at April ASA X3.2 Meeting)’’, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
115. ISO/TC 97/GT B minutes, May 2-4, 1962, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
116. Fred W. Smith, ‘‘New American Standard Code for Information Interchange,’’ *Western Union Technical Review*, vol. 18, no. 2, April, 1964, pp. 50-58.
117. Leon Bloom, letter to J. Birle, May 28, 1962, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
118. ‘‘Proposed American Standard Code for Information Interchange,’’ May 25, 1962, Herbert S. Bright Papers (CBI 42), Charles Babbage Institute, University of Minnesota, Minneapolis, box 5, folder 12.
119. ‘‘Resolution X4-A4 Subcommittee (Input-Output) to the X4 Sectional Committee,’’ Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
120. Brian Randell, ‘‘An Annotated Bibliography on the Origins of Digital Computers,’’ *Annals of the History of Computing*, vol. 1, no. 2, October, 1979, pp. 101-207.
121. Charles Foster, ‘‘Tabulating-Machine,’’ U. S. Patent 1,274,528, August 6, 1918.
122. Robert Neil Williams, ‘‘Tabulating-Machine and Cards Therefor,’’ U. S. Patent 1,274,484, August 6, 1918.
123. H. McG. Ross, ‘‘Further Survey of Punched Card Codes,’’ *Communications of the ACM*, vol. 4, no. 4, April, 1961, pp. 182-183.
124. James W. Bryce, ‘‘Alphabetical Code Punching Device,’’ U. S. Patent 1,880,408, October 4, 1932.
125. Peter Dechène, ‘‘Printing Mechanism,’’ U. S. Patent 1,902,060, March 21, 1933.
126. J. R. Peirce, ‘‘Combinational Hole Punch,’’ U. S. Patent 1,867,025, July 12, 1932.
127. J. W. Bryce, ‘‘Printing Mechanism,’’ U. S. Patent 1,926,892, September 12, 1933.
128. J. R. Peirce, ‘‘Rotary Printing Machine,’’ U. S. Patent 1,896,555, February 7, 1933.
129. G. Tauschek, ‘‘Printing Mechanism,’’ U. S. Patent 2,010,652, August 6, 1935.
130. F. M. Carroll, ‘‘Printing Mechanism,’’ U. S. Patent 1,981,990, November 27, 1934.
131. Albert W. Mills, ‘‘Printing Mechanism,’’ U. S. Patent 2,016,682, October 8, 1935.
132. C. E. Mackenzie, ‘‘The Construction of 8-Bit Coded-Character Sets,’’ Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
133. ‘‘Standard BCD Interchange Code,’’ IBM 1401, 1410, 7044 and 7044 Data Processing Systems Bulletin, 1962, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
134. X3.2 Subcommittee Minutes, August 22-23, 1962, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 3.
135. *A Programmer’s Introduction to IBM System/360 Assembler Language*, minor revision, International Business Machines

Corporation, August, 1970, pp. 140-141.
136. L. L. Griffin, memorandum to chairman of X3, January 8, 1963, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 11.
137. E. J. Lewis and W. H. McKenzie, ‘‘Proposal to Place Additional Controls in the Unassigned Area of ASCII (Preliminary),’’ Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 7.
138. J. F. Auwaerter, letter to K. J. Amos, November 13, 1962, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 7.
139. Hugh McG. Ross, letter to J. F. Auwaerter, May 3, 1963, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 4.
140. ‘‘ISO Draft proposal: 6 and 7 Bit Character Codes for Information Interchange,’’ January, 1963, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 10.
141. *ECMA Standard for a 6 Bit Input/Output Character Code*, ECMA-1, European Computer Manufacturers Assocation, March, 1963, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 4.
142. *American Standard Code for Information Interchange*, ASA X3.4-1963, American Standards Assocation, June 17, 1963, United States National Bureau of Standards Computer Literature Collection (CBI 32), Charles Babbage Institute, University of Minnesota, Minneapolis, box 228, folder 4.
143. ‘‘American Standard Code for Information Interchange,’’ *Communications of the ACM*, vol. 6, no. 8, August, 1963, pp. 422-426.
144. L. L. Griffin, memorandum to members, alternates, and consultants of ASA X3.2 and task groups, November 29, 1963, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 4.
145. ‘‘Second ISO draft proposal: 6 and 7 Bit Character Codes for Information Interchange,’’ December, 1963, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 4.
146. X3.2.4 Task Group Minutes, December 17-18, 1963, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 4.
147. ‘‘Letter Ballot concerning the Second Draft Proposal for an ISO Recommendation laid down in document ISO/TC 97/SC 2 (Secr.-22)75 F/E,’’ March 31, 1964, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 3, folder 1.
148. ‘‘German Comments on Document ISO/TC 97/SC 2 (Secr.-22)75: Second ISO Draft Proposal, 6 and 7 Bit Character Codes for Information Interchange,’’ March, 1964, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 3, folder 1.
149. ‘‘Revised Technical Contents to be Included into a Third Draft Proposal on ISO 6 and 7 Bit Codes,’’ May 20, 1964, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 12.
150. ‘‘Brief Report of Meetings held by TC 97; 97/SC 2; 97/SC 4; 95/SC 8; 53D in New York, May, 1964,’’ Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 5.
151. H. McG. Ross, ‘‘The I.S.O. character code,’’ *The Computer Journal*, vol. 7, no. 3, October, 1964, pp. 197-281.
152. L. Durand and G. Willibald, ‘‘Report on Meeting of CCITT Working Group on Alphabets, held October 6-9, 1964 in Geneva, Switzerland,’’ November 2, 1964, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 3, folder 3.
153. X3.2.4 Task Group Minutes, October 19-21, 1964, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 5.
154. V. G. Grey, letter to the P and O members of ISO TC/97, April 27, 1965, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 24.
155. ‘‘Proposed Revised American Standard Code for Information Interchange,’’ *Communications of the ACM*, vol. 8, no. 4, April, 1965, pp. 207-214.
156. W. E. Andrus, Jr., letter to Vico Henriques, June 9, 1965, Herbert S. Bright Papers (CBI 42), Charles Babbage Institute, University of Minnesota, Minneapolis, box 5, folder 13.
157. ASA Task Group X3.2.4, ‘‘Comments Received on ASCII Publication of prASCII, and X3 Ballot on prASCII,’’ July 1, 1965, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 3, folder 8.
158. Thomas E. Kurtz, letter to Secretary, X3, December 21, 1965, Calvin N. Mooers Papers (CBI 81), Charles Babbage Institute, University of Minnesota, Minneapolis, box 20, folder 1.
159. Paul B. Goodstat, memorandum to Members of Sectional Committee X3 and DPG Standards Committee, May 24, 1966, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 5.
160. X3.2.4 Task Group Minutes, January 25-26, 1966, Calvin N. Mooers Papers (CBI 81), Charles Babbage Institute, University of Minnesota, Minneapolis, box 20, folder 2.
161. A. J. Raphael and W. Bohn, ‘‘I.S.O.—TC97/SC2, Character Sets and Coding, Paris, 25th-29th April, 1966,’’ Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 5.
162. ‘‘Conclusion of the Joint Meeting: ISO/TC 97/SC 2—CCITT/GM ALP, Paris, April 26th-28th, 1966’’ amended April, 1966, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 5.
163. ‘‘Proposal for a Change of the ISO 7 Bit Code,’’ April, 1966, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 5.
164. Mr. Durand, ‘‘Contribution on 7 bit Code Modification,’’ September 10, 1965, Computer Standards Collection, Archives Center, National Museum of American History, Smithsonian Institution, box 5.
165. ‘‘ASA X3.2.4,’’ June 28, 1966, Calvin N. Mooers Papers (CBI 81), Charles Babbage Institute, University of Minnesota, Minneapolis, box 20, folder 1.
166. ASA Task Group X3.2.4, memorandum to ASA Subcommittee X3.2, June 29, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 21.
167. D. A. Kerr, memorandum to ASA X3.2 and Associated Task Groups, May 9, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 23.
168. D. A. Kerr, memorandum to members of ASA X3.2.4, May 12, 1966, Calvin N. Mooers Papers (CBI 81), Charles Babbage Institute, University of Minnesota, Minneapolis, box 20, folder 1.
169. ‘‘Proposed Revised American Standard Code for Information Interchange,’’ advance manuscript, May 18, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI

67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 2, folder 12.

170. T. R. Bousquet, ''Summary of Proposed Changes to the American Standard Code for Information Interchange (X3.4-1965),'' May 20, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 23.

171. ''Draft ISO Recommendation No. 1052: 6 and 7 Bit Coded Character Sets for Information Interchange,'' June, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 22.

172. H. W. Nelson, letter to Thomas B. Steel, June 8, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 23.

173. Philip H. Dorn, letter to C. A. Phillips, June 15, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 21.

174. Herb Van Brink, letter to L. L. Griffin, June 23, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 21.

175. Mary L. Douglas, letter to John L. Little, June 17, 1966, Calvin N. Mooers Papers (CBI 81), Charles Babbage Institute, University of Minnesota, Minneapolis, box 20, folder 1.

176. ''X3 Meeting,'' January 30, 1966, Calvin N. Mooers Papers (CBI 81), Charles Babbage Institute, University of Minnesota, Minneapolis, box 20, folder 2.

177. Ben Faden, memorandum to SHARE members, August 11, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 21.

178. C. A. Phillips, memorandum to Chairman, Information Processing Systems Standards Board, November 21, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 22.

179. X3.2 document X3.2/475, December 13, 1966, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 22.

180. *American National Standard Code for Information Interchange*, ANSI X3.4-1977, American National Standards Institute, Inc., June 9, 1977, reprinted in Harold C. Folts, ed., *McGraw Hill's Compilation of Data Communications Standards*, edition II, McGraw-Hill, 1982, pp. 911-930.

181. *USA Standard Code for Information Interchange*, USAS X3.4-1967, revision of X3.4-1965, United States of America Standards Institute, July 7, 1967.

182. *7-Bit coded Character Set*, ECMA-6, sixth edition, ECMA, December, 1991, reprinted August, 1997.

183. ''International Alphabet No. 5,'' Recommendation V.3, Facsicle VIII.1, CCITT, reprinted in Harold C. Folts, ed., *McGraw Hill's Compilation of Data Communications Standards*, edition II, McGraw-Hill, 1982, pp. 13-24.

184. J. B. Booth, letter to L. L. Griffin, July 5, 1967, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 1, folder 17.

185. D. A. Kerr, memorandum to members of USASI X3.2 and X3.2.4, November 20, 1967, Honeywell Inc. X3.2 Standards Subcommittee Records, 1961-1969 (CBI 67), Charles Babbage Institute, University of Minnesota, Minneapolis, box 2, folder 21.

186. *USA Standard Code for Information Interchange*, USAS X3.4-1968, revision of X3.4-1967, October 10, 1968, United States of America Standards Institute, Herbert S. Bright Papers (CBI 42), Charles Babbage Institute, University of Minnesota, Minneapolis, box 5, folder 13.

187. *Military Standard Military Communication System Technical Standards*, MIL-STD-188C, United States of America Department of Defense, November 24, 1969, pp. 279-300.

188. *American National Standard Hollerith Punched Card Code*, ANSI X3.26-1980, revision of ANSI X3.26-1970, American National Standards Institute, Inc., May 2, 1980.

189. *Telegraphy—Alphabetical Telegraph Terminal Equipment—International Telegraph Alphabet No. 2*, ITU-T Recommendation S.1, Telecommunication Standardization Sector of ITU, March, 1993.

190. Michael S. McNatt, ''A Guide to Baudot Machines,'' *Byte*, vol. 2, no. 4, April, 1977, pp. 12-17, 154-158; vol. 2, no. 5, May, 1977, pp. 98-104.

191. *American National Standard for Information Systems—Microprocessors—Hexadecimal Input/Output, Using 5-Bit and 7-Bit Teleprinters*, ANSI X3.95-1982, American National Standards Institute, Inc., August 24, 1982.

192. *7-bit coded character set for information processing interchange*, International Standard ISO 646, first edition, International Organization for Standardization, July 1, 1973.

193. *Information Technology—ISO 7-bit coded character set for information interchange*, International Standard ISO/IEC 646, third edition, ISO, December 15, 1991.

194. *International Reference Alphabet (IRA) (formerly International Alphabet No. 5 or IA5)—Information Technology—7-Bit Coded Character Set for Information Interchange*, recommendation T.50, International Telegraph and Telephone Consultative Committee, September, 1992.

195. *American National Standard for Information Systems—Coded Character Sets—7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)*, ANSI X3.4-1986, revision of ANSI X3.4-1977, American National Standards Institute, Inc., March 26, 1986.

196. *American National Standard for Information Processing—8-Bit Single-Byte Coded Graphic Character Sets—Part 1: Latin Alphabet No. 1*, ANSI/ISO 8859-1-1987, American National Standards Institute, Inc., September 22, 1992.

197. *8-Bit Single-Byte Coded Graphic Character Sets: Latin Alphabets No. 1 to No. 4*, ECMA-94, second edition, European Computer Manufacturers Association, June, 1986.

198. Joan Aliprand, Joe Becker, Lee Collins, Mark Davis, Asmus Freytag, Rick McGowan, and Ken Whistler, as The Unicode Consortium, *The Unicode Standard: Worldwide Character Encoding*, version 1.0, volume 1, Addison-Wesley, 1991.

199. Joan Aliprand, Julie Allen, Joe Becker, Mark Davis, Michael Everson, Asmus Freytag, John Jenkins, Mike Ksar, Rick McGowan, Lisa Moore, Michel Suignard, and Ken Whistler, as The Unicode Consortium, *The Unicode Standard*, version 3.0, Addison-Wesley, 2000.