

Project Whirlwind  
Servomechanisms Laboratory  
Massachusetts Institute of Technology  
Cambridge, Massachusetts

**SUBJECT:** THE PHOTOELECTRIC CONVERSION PROGRAM (T-190-12)

**To:** Mathematics Group, 6673

**From:** John T. Gilmore, Jr.

**Date:** June 22, 1951

**Abstract:** With the introduction of the photoelectric reader as a new medium of transmission to electrostatic storage, it was necessary to rewrite the program which converts Flexowriter standard tape to 5-5-6 binary tape. (See M-1177 and M-1198.) The program's most important revision is a new method of reading in the standard tape (blocks of words) but its greatest asset is its flexibility which is mainly due to the influence exerted by special Flexowriter characters in controlling the program.

At the present time the program is still incomplete due to the limitations of electrostatic storage. However, sometime in the very near future because of the additional 48 registers now available, the program will be blessed with a new sub-program which will facilitate the use of a library of sub-programs on standard tape. When this is accomplished, a memo will be written which will describe the complete program in detail and introduce a procedure regarding the general use of subprograms.

This present memo is merely a collection of diagrams which should aid one in understanding the program as it stands now.

Signed

*John T. Gilmore Jr.*  
John T. Gilmore, Jr.

Approved

*R. R. Everett*  
R. R. Everett

JTG/del

Attached: SA-36800

A-45304

A-45303

A-45305

SA-50049

SB-36801

SB-50044

B-45229-1

SC-36776-1

C-36803-1

The Flexowriter Code as used by the Photoelectric

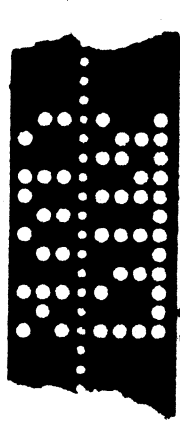
Conversion Program

	Character	Octal value	Decimal value
	a	000110	+ 6
	b	110010	- 13
	c	011100	+ 34
	d	010010	+ 22
	e	000010	+ 2
	f	011010	+ 32
	g	110100	- 13
	h	101000	- 27
	i	001100	+ 14
	j	010110	+ 26
	k	011110	+ 36
	l	100100	- 33
	m	111000	- 7
	n	011000	+ 30
	o	110000	- 17
	p	101100	- 23
	q	101110	- 21
	r	010100	+ 24
	s	001010	+ 12
	t	100000	- 37
	u	001110	+ 16
	v	111100	- 3
	w	100110	- 31
	x	111010	- 5
	y	101010	- 25
	z	100010	- 35
	2	100111	- 30
	3	000011	+ 3
	4	010101	+ 25
	5	100001	- 36
	6	101011	- 24
	7	001111	+ 17
	8	001101	+ 15
	9	110001	- 16
	0	101101	- 22
	-	000111	+ 7
	÷	011111	+ 37
	+	100011	- 34
	;	001011	+ 13
	/	111011	- 4
	.	111001	- 6
	,	011001	+ 31
	tab	111101	- 2
	back space	000001	+ 1
	car. return	010000	+ 20
	shift↓	110110	- 11
	shift↑	111110	- 1
	stop	110011	- 14
	nullify	111111	- 0
	space	001000	+ 10

0087E-00

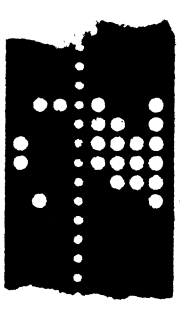
SA-366

Four different forms of "Standard Flexo Tape"



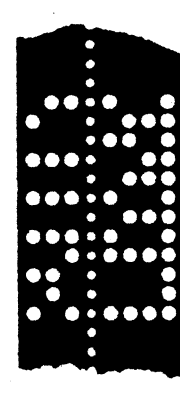
C  
0  
1  
2  
2  
3  
CARRIAGE  
RETURN

Checked  
decimal-addressed  
standard flexo tape



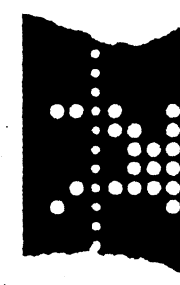
C  
0  
1  
1  
3  
CARRIAGE  
RETURN

Unchecked  
decimal-addressed  
standard flexo tape



C  
0  
3  
3  
7  
CARRIAGE  
RETURN

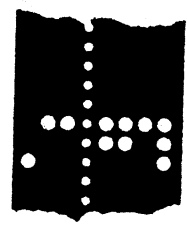
Checked  
octal-addressed  
standard flexo tape



C  
0  
3  
3  
7  
CARRIAGE  
RETURN

Unchecked  
octal-addressed  
standard flexo tape

5-5-6 Tape



1111  
00110  
100000

Binary Form

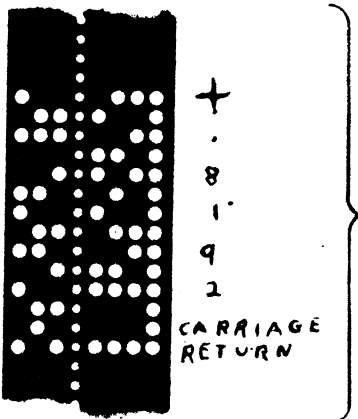
1 0 0 0 0 0 0 0 1 1 0 1 1 1 1 1

C01

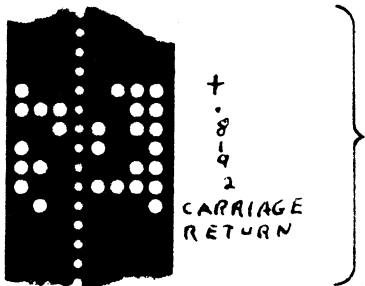
223(4)

337(0)

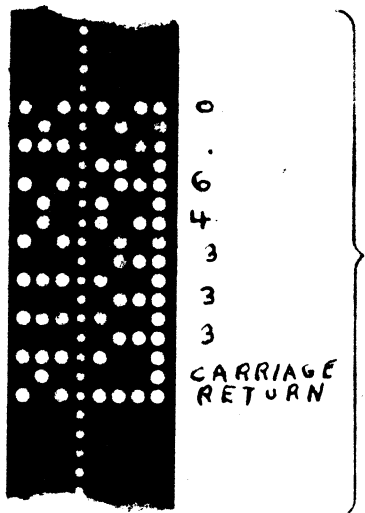
The constant  $10^{-4} \times 2^{13}$  may be represented on standard tape as:



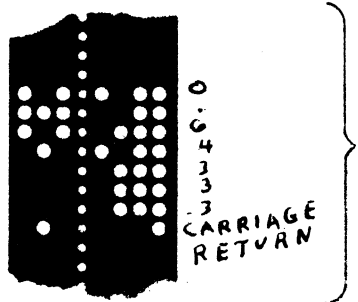
Decimal constant  
on checked standard  
flexo tape



Decimal constant  
on unchecked standard  
flexo tape

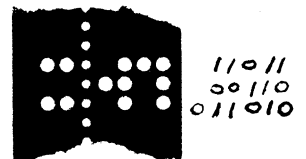


Octal constant  
on checked standard  
flexo tape



Octal constant  
on unchecked standard  
flexo tape

5-5-6 Tape

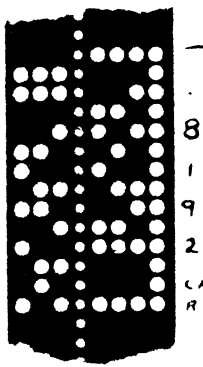


The binary form of  $10^{-4} \times 2^{13}$  is:

0110100011011011

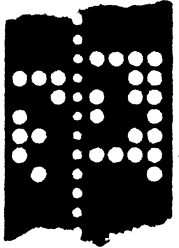
EXAMPLE OF HOW A POSITIVE CONSTANT MAY BE EXPRESSED ON STANDARD TAPE

The constant  $-10^{-4} \times 2^{13}$  may be represented on standard tape as:



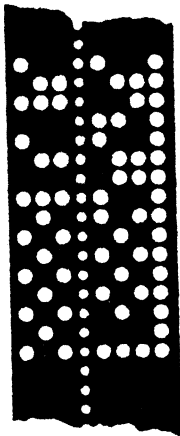
8  
1  
9  
2  
CARRIAGE  
RETURN

Decimal constant  
on checked standard  
flexo tape



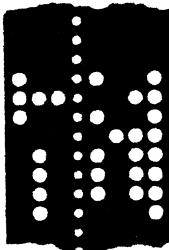
8  
1  
9  
2  
CARRIAGE  
RETURN

Decimal constant  
on unchecked standard  
flexo tape



8  
1  
3  
4  
4  
CARRIAGE  
RETURN

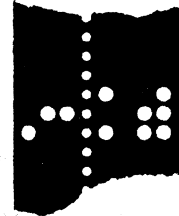
Octal constant  
on checked standard  
flexo tape



1  
1  
3  
4  
4  
CARRIAGE  
RETURN

Octal constant  
on unchecked standard  
flexo tape

5-5-6 Tape



00100  
11001  
100101

The binary form of  $-10^{-4} \times 2^{13}$  is:

1001011100100100

EXAMPLE OF HOW A NEGATIVE CONSTANT MAY BE EXPRESSED ON STANDARD TAPE



TITLE Example PROB.# 0 DIC # 6345  TAPE 623  
 AUTHOR P. Fox TYPIST P. F. DATE 4-17-51  MOD. 15  
 PARAM. 6

uo/→6→2→3→--→1→5→--→6→40t Feed out tape

40	r10	140		240		340	
41	rs1	141		241		341	
42	rf2	142		242		342	
43	rb3	143		243		343	
44	rd4	144		244		344	
45	rc5	145		245		345	
46	qh6	146		246		346	
47	qd7	147		247		347	
50	ts10	150		250		350	
51	td11	151		251		351	
52	tal2	152		252		352	
53	ck13	153		253		353	
54	qs14	154		254		354	
55	qe15	155		255		355	
56	cp16	156		256		356	
57	sp17	157		257		357	
60	ca20	160	0.12345	260		360	
61	cs21	161	1.23456	261		361	
62	ad22	162	0.34567	262		362	
63	su23	163	1.45670	263		363	
64	cm24	164	0.56701	264		364	
65	sa25	165	1.67012	265		365	
66	ao26	166	0.70123	266		366	
67	qf27	167	1.01234	267		367	
70	mr30	170	/→200d	270	Feed out	370	
71	mh31	171		271	tape	371	
72	dv32	172		272		372	
73	sl33	173		273		373	
74	sr34	174		274		374	
75	sf35	175		275		375	
76	qr36	176		276		376	
77	qp37b	177		277		377	
100	ca376	200	+ .9876	300		400	
101	ad211	201	- .8765	301		401	
102	su4	202	+ .7654	302		402	
103	ts101	203	- .6543	303		403	
104	/→160d	204	sp70.	304	Feed out	404	
105		205		305	tape	405	
106		206		306		406	
107		207		307		407	
110		210		310		410	
111		211		311		411	
112		212		312		412	
113		213		313		413	
114		214		314		414	
115		215		315		415	
116		216		316		416	
117		217		317		417	
120		220		320		420	
121		221		321		421	
122		222		322		422	
123		223		323		423	
124		224		324		424	
125		225		325		425	
126		226		326		426	
127		227		327		427	
130		230		330		430	
131		231		331		431	
132		232		332		432	
133		233		333		433	
134		234		334		434	
135		235		335		435	
136		236		336		436	
137		237		337		437	

The above program is to have an unchecked octal tape. The tape number is 623, modification 15, parameter 6. The first word of the program is in register 40. The words are stored in groups as indicated, and the first order of the program is in register 70.

SL-194 SB-36861

40	0.00163	100	ta 77	140	gf 77	200	af 77	240	ap -	CHAR	300	ta 316	340	ap 171	FEED OUT TAPE	400
41	ta 122	101	0.00006	141	0.04146	201	ca 77	241	gf 0	INPUT	301	ta 36	341	ap 51	PUNCH ADDRESS	401
42	ca 331	102	al 77	142	0.00010	202	al 77	242	ad 10	SUB	302	tl 113	342	ca 36	SET FF4	402
43	su 72	103	0.00000	143	al 77	203	cp 174	243	ch 155	PROGRAM	303	ca 113	343	ta 34	1st ADDRESS	403
44	tl 154	104	te 77	144	0.00007	204	sp -	244	ca 367		304	al 12	344	ca 132	PUNCH SPURIAL	404
45	ca 63	105	0.00125	145	1.03330	205	ca 77	245	ap 237		305	al 12	345	gp 0	CHAR	405
46	tl 331	106	0.04107	146	gf 77	206	ap 171	246	ap 232		306	gp 0	346	ap 246	TREAT NEXT WORD	406
47	tl 52	107	0.00011	147	1.02264	207	ca 63	247	ad 334		307	ca 113	347	sp 232	READ IN STOP CHAR	407
50	ap 54	110	1.03610	150	cp 77	210	ta 331	250	tl 252		310	al 5	350	ap 41	PUNCH OUT BLANK	410
51	ta 122	111	0.04152	151	0.04173	211	gf 0	251	ap 232		311	al 1452	351	ca 115	PUNCH OUT SUM	411
52	ca -	112	ap 77	152	0.00004	212	ca 10	252	ad -		312	gp 0	352	ap 300	SUM	412
53	ap 300	113	ni TEMPORARY	153	al 77	213	al 1455	253	tl 257		313	ca 36	353	ca 214	PUNCH 111010	413
54	ao 52	114	tl 77	154	ca -	214	al 72	254	al 1453		314	al 1452	354	gp 37		414
55	ap 120	115	SUM (MODULO ONE)	155	1.76000	215	cp 217	255	ad 243		315	gp 0	355	gp 1100	PUNCH BLANK SPACES	415
56	0.04072	116	gf 77	156	0.20000	216	gf 0	256	tl 326		316	ap -	356	gp 1100		416
57	al 77	117	1.03470	157	0.00163	217	ad 245	257	ca - 205		317	0.00036	357	gp 1100		417
60	mh 77	120	su 154	160	al 77	220	ta 336	260	ta 27		320	ta 132	360	ap 370		420
61	0.40165	121	cp 52	161	al 77	221	ap 232	261	tl 273		321	al 1443	361	ta 115		421
62	0.04104	122	ap -	162	al 77	222	al 4	262	ca 0		322	tl 332	362	ta 115	END OF BLOCK	422
63	ta 376	123	0.04103	163	0.00012	223	ad 207	263	tl 27		323	ao 34	363	ap 232		423
64	ao 77	124	0.44046	164	um 77	224	ta 77	264	ta 35		324	ao 331	364	ap 41		424
65	gl 77	125	ad 77	165	0.64333	225	ap 246	265	ap 232		325	ca 35	365	ap 51		425
66	1.03363	126	gl 77	166	1.13444	226	ap 232	266	ad 105		326	mh - 156	366	ap 246		426
67	0.00005	127	0.04135	167	af 77	227	ap 41	267	tl 270		327	al 2	367	Temp		427
70	0.00142	130	0.00003	170	al 77	230	ap 341	270	ca -		330	ad 27	370	ap 51	PUNCH SP TO FIRST ORDER AND 111000	430
71	gp 77	131	al 77	171	ta 204	231	ch 77	271	cp 310		331	ta -	371	ca 132	TREAT NEXT PROGRAM	431
72	0.00001	132	SPECIAL CHAR IN DIG POS 10-15	172	ca 317	232	ta 140	272	gp 35		332	ap -	372	gp 0		432
73	0.04076	133	mt 77	173	ts 10	233	gf 37	273	mh -		333	al 115	373	ap 206		433
74	0.04114	134	0.00031	174	ca 0	234	ad 10	274	al 17		334	ta 115	374			434
75	0.00002	135	1.02620	175	gp 1100	235	ta 367	275	ad 35		335	ap 246	375			435
76	1.00142	136	gl 77	176	ao 10	236	ap 237/241	276	ta 35		336	ta 115	376			436
77	DECIMAL OR OCTAL CONVERSION FACTOR	137	0.04062	177	ap 203	237	al 1452	277	ap 265		337	ap 41	377			437

STORAGE BLOCK OUTPUT SUB PROGRAM

WHAT TYPE OF WORD

NUMBER CONVERSION

TAPE FEED OUT SUB PROGRAM

CHAR INPUT SUB PROG

CHAR INPUT SUB PROGRAM

STORAGE BLOCK REGISTER

ELECTRONIC COMPUTER DIVISION  
SERVOMECHANISMS LABORATORY-MIT

OCTAL PROGRAM FORM

TITLE PHOTOELECTRIC CONVERSION

AUTHOR ADAMS - FOX - GILMORE

DIC # 6345

TAPE # T 170

PROBLEM # 10

MODIFICATION # 12

DATE APRIL 1951

PARAMETERS #



Start here for Input Program

Reg. 10  
Put the binary form of sr 810 in the AC. (1110001100101010)

Start here for Check Program

Reg. 11  
Add the binary form of ck 30 to the AC. (0101100000011110)

Reg. 12  
(Check Prog) The result is ck 30. Transfer to register 23.  
(Input Prog) The result is qd 841. Transfer to register 23.

Reg. 13  
Read digits 11-15 of a word into digital positions 1-5 of FF# 3 (sign digital position will contain a zero).

Reg. 14  
Put digits 11-15 of the word into digital positions 1-5 of AC. (sign digital pos. - zero)

Reg. 15-16  
Move digits 11-15 to digital positions 6-10 of AC and read digits 6-10 into digital pos. 1-5 of FF# 3 and then add them to the AC.

Reg. 17-18  
Move digits 6-15 to digital positions 6-15 of AC and read digits 6-5 into digital pos. 0-5 of FF# 3 and then add them to the AC.

Reg. 19-20  
Read the next character on tape into digital positions 0-5 of FF# 3. Exchange the contents of FF# 3 and AC.

Reg. 21  
If the sign digital position of the AC contains a zero, digital positions 1-5 will contain digits 11-15 of the next word. If the sign digital position contains a one, the AC will contain a special character (110011, 111010, 110100, or 111000 in digital positions 0-5) indicating that FF# 3 contains a special word other than a word of the program. Is the AC negative or positive?

Reg. 22  
(Positive) Exchange the contents of FF# 3 and AC. The AC now contains the binary form of a word of the program.

Reg. 5-7  
(Negative) Shift the contents of the AC to the right 10 digital positions. Result will be a small negative val. Add the binary value of sp 14. Exchange AC and FF# 3.

Reg. 23  
(Check) Check the word with assigned register.  
(Input) Transfer the word to its assigned register

Reg. (Special)  
(Special) Add the binary value of the contents of the "sum" register to the binary value of the word and eliminate any special add overflow. Transfer the result to the "sum" register.

Reg. 26-27  
Increase the address section of Reg. 23 by 1.

Reg. 9  
The binary form of the sum which was read from the 5-5-6 tape is in the AC. Check it with the "sum" register 30.

Reg. 2  
ri address of first reg. of program is in AC. Transfer the whole word to register 30. This will be the initial value of the sum.

Reg. 3  
ri(address to which next word is to be transferred) is in AC. Transfer this address into the address section of reg. 23.

5-5-6 Input or Check Program

- 0) +0
- 1) +1/4
- 2) ts 30
- 3) td 23
- 4) sp 13
- 5) sr810
- 6) ad 27
- 7) qe 8
- 8) FF# 3
- 9) ck 30
- 10) ca 5
- 11) ad 9
- 12) ts 23
- 13) qr 0
- 14) ca 8
- 15) qr 5
- 16) ad 8
- 17) qr 5
- 18) ad 8
- 19) qr 0
- 20) qe 8
- 21) cp 5
- 22) qe 8
- 23) FF# 0
- 24) sa 30
- 25) ts 30
- 26) ae 23
- 27) sp 14
- 28) FF# 4
- 29) FF# 1
- 30) FF# 2
- 31) qd2047

- Reg. 8
- sp 3(110100)
- sp 3(110011)
- sp 9(111010)
- sp 7(111000)

Reg. 7  
The binary form of sp(address of the register which contains the first order of the program) is in the AC. Exchange the contents of the AC and FF# 3.

Reg. 8  
Take the next order from electrostatic storage.

5-5-6 INPUT OR CHECK PROGRAM







- TABLE

40	0.00163
41	
42	
43	
44	
45	
46	

CASE TABLE

56	0.04072	t
57		
58		
59	0.40165	+ 1
60	0.04104	
61		
62		
63		
64		
65		
66		
67		
68		
69		
70		
71		
72		
73	0.04076	o
74	0.04114	g
75		
76		
77		
78		
79		
80		
81		
82		
83		
84		
85		
86	0.04107	m
87		
88		
89	0.04132	/
90		
91		
92		
93		
94		
95		
96		
97		
98		
99		
100		
101		
102		
103		
104		
105		
106	0.04103	a
107	0.44046	-
108		
109		
110	0.04135	S
111		
112		
113		
114		
115		
116		
117		
118		
119		
120		
121		
122		
123	0.04103	a
124	0.44046	-
125		
126		
127	0.04135	S
128		
129		
130		
131		
132		
133		
134		
135		
136		
137	0.04062	d
138		
139		
140		
141	0.04146	+ 1
142		
143		
144		
145		
146		
147		
148		
149		
150		
151	0.04173	c

2 TABLE

57	0. 77
60	
61	
62	

o TABLE

70	0.00142
71	
72	
73	
74	
75	
76	

1 TABLE

76	0.00142
77	
100	
101	
102	
103	
104	

g TABLE

65	94 77
66	
67	
70	
71	94 77
72	
73	
74	
75	
76	
77	
100	
101	
102	
103	
104	
105	
106	
107	
110	
111	
112	
113	
114	
115	
116	
117	
118	
119	
120	
121	
122	
123	
124	
125	
126	94 77
127	
128	
129	
130	
131	
132	
133	
134	
135	
136	
137	94 77
138	
139	94 77
140	
141	
142	
143	
144	
145	
146	94 77

t TA

73	
74	
75	
76	
77	
100	77
101	
102	
103	
104	77
105	
106	
107	
110	
111	
112	
113	
114	77

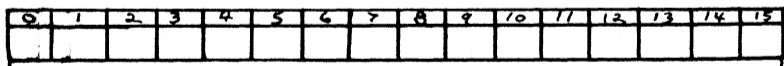
+ TABLE

157	0.00163
160	
161	
162	
163	
164	
165	

/ TABLE

152	
153	
154	
155	
156	
157	
160	
161	
162	77

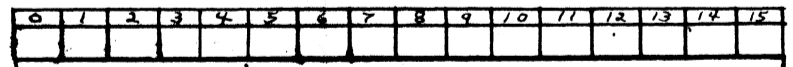
"CASE TABLE REGISTER"



MULTI-REGISTER DETERMINANT

KEY TO CORRESPONDING SPECIFICON TABLE

"SPECIFICON TABLE REGISTER"



SPECIFIC DIGITS

ADDRESS OF CORRESPONDING CONVERSION FACTOR

SPECIFIC TABLES

l TABLE

67	lv 77
68	
69	
70	

t TABLE

71	
72	
73	
74	
75	
76	
77	
100	ta 77
101	
102	
103	
104	ts 77
105	
106	
107	
110	
111	
112	
113	
114	td 77

m TABLE

60	mh 77
61	
62	
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162	ra 77
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200	rf 77
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s TABLE

102	sl 77
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c TABLE

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NUMBER TABLE

66	1.03363
67	0.00005
70	
71	
72	0.00001
73	
74	
75	0.00003
76	
77	
100	
101	0.00006
102	
103	0.00000
104	
105	
106	
107	0.00011
110	1.03610
111	
112	
113	
114	
115	
116	
117	1.03470
120	
121	
122	
123	
124	
125	
126	
127	
130	0.00003
131	
132	
133	
134	0.00031
135	1.02630
136	
137	
138	
139	
140	
141	
142	0.00010
143	
144	0.00007
145	1.03330
146	
147	1.02264
150	
151	
152	0.00004

MULTI-TABLE

155	
156	0.20000
157	
160	
161	
162	
163	
164	
165	0.44333
166	1.13444

"SYMBOL-NUMBER TABLE REGISTER"

12	13	14	15
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SPECIAL CHARACTER'S DIGITS

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1															

ADDRESS OF CORRESPONDING CONTROL REGISTER

CORRESPONDING FACTOR

TABLES USED BY THE PHOTOELECTRIC CONVERSION PROGRAM