

# 00564C PROGRAM DESCRIPTION I

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Program Title **FUNCTION SCANNER**

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Program Description, Equations, Variables

With this program the user supplies a function  $f(x)$  to be examined for maxima, minima and roots, all within a certain range of  $x$  and at a specified search step size. One main feature is that the user has the option of getting estimates (rough guesses) for any or all the maxima, minima and roots. One may obtain only guesses, since it is faster, or by contrast ask for accurate roots, minima, maxima. A combination of, say, obtaining exact roots and estimates for the maxima and minima is possible. The display will indicate search nature. Here is how the search is carried out:

Necessary Accessories **1 MEMORY MODULE (TO ENABLE USER TO KEY  $f(x)$ )**

Operating Limits and Warnings  **$f(x)$  should be continuous within the range considered.**

Reference(s)

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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## (CONTINUATION PAGE)

(1) Root Finding: As we march from  $x_1$  to  $x_2$ ,  $f_1$  and  $f_2$  are calculated and test for  $f_1 \cdot f_2 \leq 0$ . If the test is TRUE (see Fig. 1) a root lies between  $x_1$  &  $x_2$ .  $x_{\text{GUESS}} = x_G = x_1 + \Delta x/2$

(2) Minima Location: (See Fig. 2) As we march through  $x_1, x_2, x_3$  we test for  $(f_1 - f_2)(f_2 - f_3) < 0$ . If test is TRUE, there is a minimum in the vicinity.  $x_{\text{GUESS}} = x_2 + \frac{\Delta x}{2}$ . If  $x_2$  lies to the right of the real minimum (see Fig. 3) the algorithm will think that  $x_2 < x_{\text{min}} < x_3$ , while actually  $x_1 < x_{\text{min}} < x_2$ . As  $\Delta x$  is smaller the offset becomes less significant.

(3) Maxima Location: (See Fig. 4) The same test used to test for minima, plus checking  $(f_1 - f_2) < 0$  are carried out to trace a maximum. Also an offset in the guess (see Fig. 5) may exist for the same reason as for minima.

(CONTINUATION PAGE)

Fig. 1

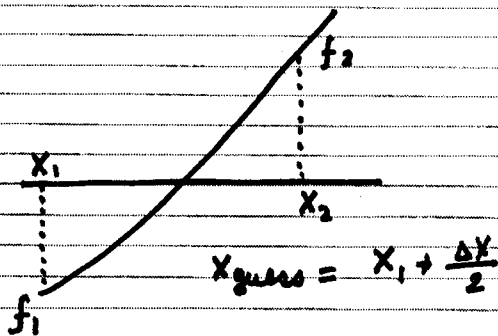


Fig. 2

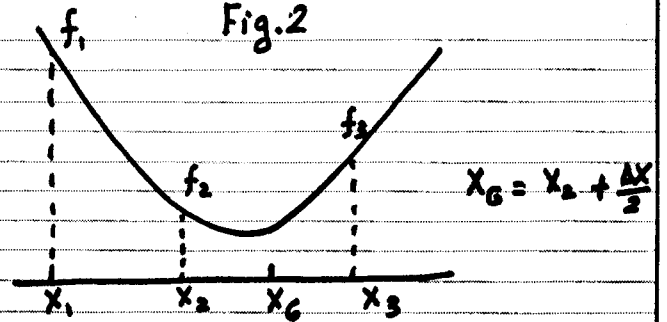


Fig. 3.

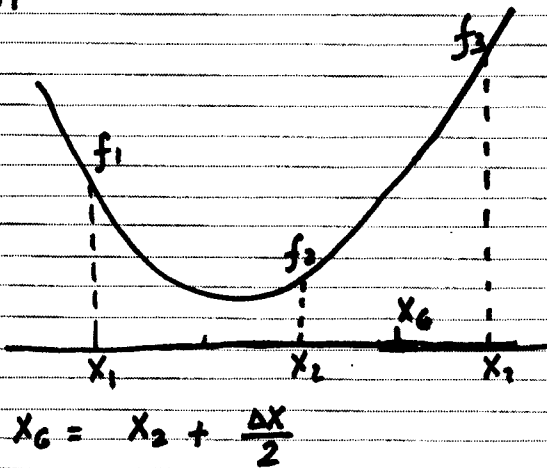


Fig. 4

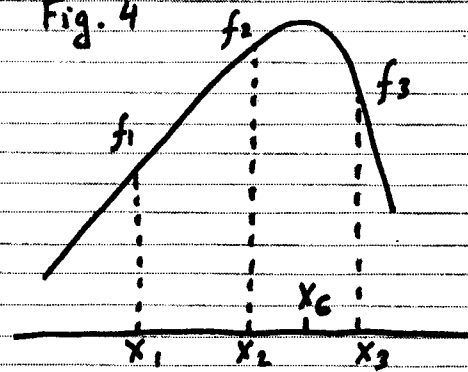
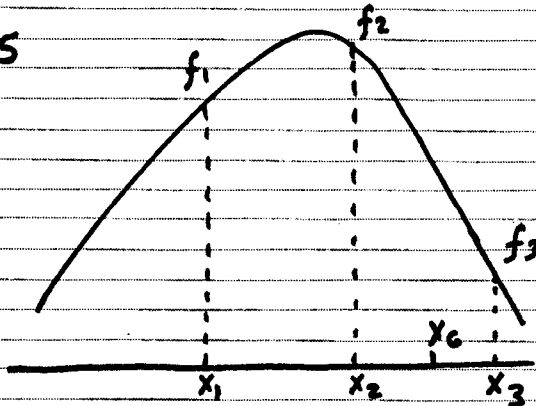


Fig. 5





# USER INSTRUCTIONS

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| SIZE: 012<br>(HP-41C)                                                       |                                                                                                |            |                     |                                                                     |
|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------|---------------------|---------------------------------------------------------------------|
| STEP                                                                        | INSTRUCTIONS                                                                                   | INPUT      | FUNCTION            | DISPLAY                                                             |
| 1                                                                           | Load program.                                                                                  |            |                     |                                                                     |
| 2                                                                           | Go to step 053                                                                                 |            | GTO. 053            |                                                                     |
| 3                                                                           | Switch to PRGM mode                                                                            |            | PRGM                |                                                                     |
| 4                                                                           | Key in $f(x)$ .                                                                                |            |                     |                                                                     |
| 5                                                                           | Switch back to RUN mode                                                                        |            | PRGM                |                                                                     |
| 6                                                                           | (Optional) To obtain all minima set flag 0 or else clear it, if rough guesses are only needed. |            | SF 00<br>or (CF 00) |                                                                     |
| 7                                                                           | (Optional) To obtain all roots set flag 1, or else clear it if rough guesses are needed.       |            | SF 01<br>or (CF 01) |                                                                     |
| 8                                                                           | (Optional) To obtain all maxima set flag 2, or else clear it if rough guesses are needed.      |            | SF 02<br>or (CF 02) |                                                                     |
| 9                                                                           | (Optional) Adapt the FIX format to accuracy of roots, maxima or minima                         |            | FIX $n$             |                                                                     |
| 10                                                                          | Start running the program                                                                      |            | XEQ <sup>T</sup> FF | X, MIN?                                                             |
| 11                                                                          | Input $x$ at which search starts                                                               | $x_{min}$  | R/S                 | X, MAX?                                                             |
| 12                                                                          | Input $x$ at which search ends                                                                 | $x_{max}$  | R/S                 | DX?                                                                 |
| 13                                                                          | Input $\Delta x$ search                                                                        | $\Delta x$ | R/S                 | (X = (x)) <sup>*</sup><br>(x) <sup>**</sup><br>RESULTS <sup>†</sup> |
| <sup>*</sup> view $x$ during march<br><sup>**</sup> Occurs when a root, max |                                                                                                |            |                     |                                                                     |

# USER INSTRUCTIONS

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|      |                                                                                                                                                                                                                     |       |                                          | SIZE:<br>(HP-41C)                                                                                                                                                                                                                                                                      |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| STEP | INSTRUCTIONS                                                                                                                                                                                                        | INPUT | FUNCTION                                 | DISPLAY                                                                                                                                                                                                                                                                                |
|      | or min. are sought.<br>†: Results will depend on the status of flags 0, 1 & 2 any combination of the list to the right, depending also on $f(x)$ . R/S is needed to be pressed when printer is OFF or disconnected. |       |                                          | $X_{ROOT} = (x_{\text{root}})$<br>$X_{MIN} = (x_{\text{min}})$<br>$Y = (y_{\text{min}})$<br>$X_{MAX} = (x_{\text{max}})$<br>$Y = (y_{\text{max}})$<br>$GRT = (x_{\text{guess}}^{\text{root}})$<br>$GMIN = (x_{\text{guess}}^{\text{min}})$<br>$GMAX = (x_{\text{guess}}^{\text{max}})$ |
| 14   | ON ERROR: If root, maximum or minimum finding search does not converge or DATA ERROR shows up, then stop program (if still running). Restore $x_{\text{search}}$ in $R_{00}$ , go to label 00, then run.            |       | R/S<br>RCL 07<br>STO 00<br>GTO 00<br>R/S |                                                                                                                                                                                                                                                                                        |

□ 67 □ 97 ■ 41C

| STEP/<br>LINE | KEY ENTRY | KEY CODE<br>(67/97 only) | COMMENTS                                                                | STEP/<br>LINE | KEY ENTRY | KEY CODE<br>(67/97 only) | COMMENTS                                                   |
|---------------|-----------|--------------------------|-------------------------------------------------------------------------|---------------|-----------|--------------------------|------------------------------------------------------------|
| 01            | LBL       | "FF"                     |                                                                         | 50            | X<=Y?     |                          |                                                            |
| 02            | SF        | 21                       |                                                                         | 51            | GTO 00    |                          | TEST                                                       |
| 03            | "X, MIN?" |                          |                                                                         | 52            | LBL F     |                          | X > X <sub>max</sub>                                       |
| 04            | PROMPT    |                          |                                                                         | 53            | RCL 00    |                          | ← INSERT                                                   |
| 05            | STO 00    |                          | INPUT                                                                   | 54            | RTN       |                          | f(x) here                                                  |
| 06            | "X, MAX?" |                          | DATA FOR                                                                | 55            | LBL 01    |                          | after RCL 00                                               |
| 07            | PROMPT    |                          | SEARCH RANGE                                                            | 56            | SF 21     |                          | X <sub>GUESS</sub> =                                       |
| 08            | STO 01    |                          | & STEP SIZE.                                                            | 57            | RCL 00    |                          | X <sub>2</sub> - $\frac{\Delta X}{2}$                      |
| 09            | "DX?"     |                          |                                                                         | 58            | RCL 06    |                          |                                                            |
| 10            | PROMPT    |                          |                                                                         | 59            | 2         |                          |                                                            |
| 11            | STO 06    |                          | → f <sub>1</sub>                                                        | 60            | /         |                          |                                                            |
| 12            | XEQ F     |                          |                                                                         | 61            | -         |                          |                                                            |
| 13            | STO 02    |                          |                                                                         | 62            | "G RT="   |                          | IF FLAG1 IS                                                |
| 14            | RCL 06    |                          |                                                                         | 63            | ARCL X    |                          | SET FIND ROOT                                              |
| 15            | ST+ 00    |                          | → f <sub>2</sub>                                                        | 64            | FC? 01    |                          |                                                            |
| 16            | XEQ F     |                          |                                                                         | 65            | AVIEW     |                          |                                                            |
| 17            | CHS       |                          |                                                                         | 66            | FS? 01    |                          |                                                            |
| 18            | RCL 02    |                          |                                                                         | 67            | XEQ "RT"  |                          |                                                            |
| 19            | +         |                          | → (f <sub>1</sub> - f <sub>4</sub> )                                    | 68            | RTN       |                          |                                                            |
| 20            | STO 04    |                          |                                                                         | 69            | LBL 02    |                          | ROUTINE TO                                                 |
| 21            | RCL 06    |                          |                                                                         | 70            | RCL 00    |                          | FIND MAX. OR                                               |
| 22            | ST- 00    |                          |                                                                         | 71            | SF 21     |                          | MIN.                                                       |
| 23            | ADV       |                          |                                                                         | 72            | RCL 06    |                          | X <sub>GUESS</sub> = X <sub>2</sub> - $\frac{\Delta X}{2}$ |
| 24            | ADV       |                          |                                                                         | 73            | 2         |                          |                                                            |
| 25            | LBL 00    |                          |                                                                         | 74            | /         |                          |                                                            |
| 26            | CF 21     |                          | VIEW X                                                                  | 75            | -         |                          |                                                            |
| 27            | "X="      |                          |                                                                         | 76            | RCL 04    |                          | TEST f <sub>1</sub> - f <sub>2</sub> > 0                   |
| 28            | ARCL 00   |                          |                                                                         | 77            | X>0?      |                          |                                                            |
| 29            | AVIEW     |                          |                                                                         | 78            | GTO 03    |                          |                                                            |
| 30            | RCL 06    |                          | → f <sub>2</sub>                                                        | 79            | X<>Y      |                          |                                                            |
| 31            | ST+ 00    |                          |                                                                         | 80            | "G MIN="  |                          | IF FLAG 0 IS                                               |
| 32            | XEQ F     |                          |                                                                         | 81            | ARCL X    |                          | SET FIND                                                   |
| 33            | STO 03    |                          | TEST f <sub>1</sub> · f <sub>2</sub> ≤ 0                                | 82            | FC? 00    |                          | MINIMUM                                                    |
| 34            | RCL 02    |                          |                                                                         | 83            | AVIEW     |                          |                                                            |
| 35            | *         |                          |                                                                         | 84            | FS? 00    |                          |                                                            |
| 36            | X<=0?     |                          |                                                                         | 85            | XEQ "MN"  |                          |                                                            |
| 37            | XEQ 01    |                          |                                                                         | 86            | RTN       |                          |                                                            |
| 38            | RCL 02    |                          | TEST                                                                    | 87            | LBL 03    |                          |                                                            |
| 39            | RCL 03    |                          | (f <sub>1</sub> - f <sub>2</sub> ) · (f <sub>2</sub> - f <sub>3</sub> ) | 88            | X<>Y      |                          |                                                            |
| 40            | -         |                          | < 0                                                                     | 89            | "G MAX="  |                          | IF FLAG 2 IS                                               |
| 41            | X<> 04    |                          |                                                                         | 90            | ARCL X    |                          | SET FIND                                                   |
| 42            | RCL 04    |                          |                                                                         | 91            | FC? 02    |                          | MAXIMUM                                                    |
| 43            | *         |                          |                                                                         | 92            | AVIEW     |                          |                                                            |
| 44            | X<0?      |                          |                                                                         | 93            | FS? 02    |                          |                                                            |
| 45            | XEQ 02    |                          | f <sub>2</sub> = f <sub>2</sub>                                         | 94            | XEQ "MX"  |                          |                                                            |
| 46            | RCL 03    |                          |                                                                         | 95            | RTN       |                          |                                                            |
| 47            | STO 02    |                          |                                                                         | 96            | LBL "RT"  |                          | ROUTINE TO                                                 |
| 48            | RCL 01    |                          |                                                                         | 97            | X<> 00    |                          | CALCULATE                                                  |
| 49            | RCL 00    |                          |                                                                         | 98            | STO 07    |                          |                                                            |

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| STEP/<br>LINE | KEY ENTRY | KEY CODE<br>(67/97 only) | COMMENTS                                                          | STEP/<br>LINE | KEY ENTRY | KEY CODE<br>(67/97 only) | COMMENTS                        |
|---------------|-----------|--------------------------|-------------------------------------------------------------------|---------------|-----------|--------------------------|---------------------------------|
| 99            | LBL       | 05                       | ROOT BY<br>RICHMOND'S<br>METHOD                                   | 146           | STO       | 08                       | ROUTINES FOR<br>MINIMA & MAXIMA |
| 100           | XEQ       | 04                       |                                                                   | 147           | XEQ       | F                        |                                 |
| 101           | RCL       | 10                       |                                                                   | 148           | STO       | 09                       |                                 |
| 102           | ST+       | X                        |                                                                   | 149           | RCL       | 08                       |                                 |
| 103           | -         |                          |                                                                   | 150           | ST+       | 00                       |                                 |
| 104           | RCL       | 09                       |                                                                   | 151           | XEQ       | F                        |                                 |
| 105           | +         |                          |                                                                   | 152           | STO       | 10                       |                                 |
| 106           | RCL       | 08                       |                                                                   | 153           | RCL       | 08                       |                                 |
| 107           | X↑2       |                          |                                                                   | 154           | ST+       | 00                       |                                 |
| 108           | /         |                          |                                                                   | 155           | XEQ       | F                        |                                 |
| 109           | STO       | 05                       |                                                                   | 156           | STO       | 11                       |                                 |
| 110           | RCL       | 09                       |                                                                   | 157           | RCL       | 08                       |                                 |
| 111           | ST-       | 10                       |                                                                   | 158           | ST+       | X                        |                                 |
| 112           | RCL       | 08                       |                                                                   | 159           | ST-       | 00                       |                                 |
| 113           | ST/       | 10                       |                                                                   | 160           | RCL       | 11                       |                                 |
| 114           | RCL       | 09                       | ROUTINE TO<br>CALC. $f(x)$<br>$f(x+\Delta x)$<br>$f(x+2\Delta x)$ | 161           | RTN       |                          | DISPLAY PROP-<br>ER COMMENT     |
| 115           | RCL       | 10                       |                                                                   | 162           | LBL       | "MH"                     |                                 |
| 116           | *         |                          |                                                                   | 163           | SF        | 03                       |                                 |
| 117           | RCL       | 10                       |                                                                   | 164           | LBL       | "MX"                     |                                 |
| 118           | X↑2       |                          |                                                                   | 165           | X<>       | 00                       |                                 |
| 119           | RCL       | 05                       |                                                                   | 166           | STO       | 07                       |                                 |
| 120           | RCL       | 09                       |                                                                   | 167           | LBL       | 07                       |                                 |
| 121           | *         |                          |                                                                   | 168           | XEQ       | 04                       |                                 |
| 122           | 2         |                          |                                                                   | 169           | RCL       | 11                       |                                 |
| 123           | /         |                          |                                                                   | 170           | RCL       | 09                       |                                 |
| 124           | -         |                          |                                                                   | 171           | -         |                          |                                 |
| 125           | /         |                          |                                                                   | 172           | 2         |                          |                                 |
| 126           | ST-       | 00                       |                                                                   | 173           | /         |                          |                                 |
| 127           | ABS       |                          |                                                                   | 174           | RCL       | 08                       |                                 |
| 128           | RND       |                          |                                                                   | 175           | *         |                          |                                 |
| 129           | X≠0?      |                          |                                                                   | 176           | RCL       | 09                       |                                 |
| 130           | GTO       | 05                       |                                                                   | 177           | RCL       | 10                       |                                 |
| 131           | SF        | 21                       |                                                                   | 178           | ST+       | X                        |                                 |
| 132           | "X ROOT=" |                          |                                                                   | 179           | -         |                          |                                 |
| 133           | ARCL      | 00                       | ROUTINE TO<br>CALC. $f(x)$<br>$f(x+\Delta x)$<br>$f(x+2\Delta x)$ | 180           | RCL       | 11                       | DISPLAY PROP-<br>ER COMMENT     |
| 134           | TONE      | 9                        |                                                                   | 181           | +         |                          |                                 |
| 135           | AVIEW     |                          |                                                                   | 182           | /         |                          |                                 |
| 136           | ADV       |                          |                                                                   | 183           | ST-       | 00                       |                                 |
| 137           | RCL       | 07                       |                                                                   | 184           | ABS       |                          |                                 |
| 138           | STO       | 00                       |                                                                   | 185           | RND       |                          |                                 |
| 139           | RTN       |                          |                                                                   | 186           | X≠0?      |                          |                                 |
| 140           | LBL       | 04                       |                                                                   | 187           | GTO       | 07                       |                                 |
| 141           | RCL       | 00                       |                                                                   | 188           | SF        | 21                       |                                 |
| 142           | CF        | 21                       |                                                                   | 189           | "X MAX="  |                          |                                 |
| 143           | VIEW      | 00                       |                                                                   | 190           | FS?C      | 03                       |                                 |
| 144           | .1        |                          |                                                                   | 191           | "X MIN="  |                          |                                 |
| 145           | %         |                          |                                                                   | 192           | ARCL      | 00                       |                                 |
|               |           |                          |                                                                   | 193           | TONE      | 9                        |                                 |
|               |           |                          |                                                                   | 194           | AVIEW     |                          |                                 |

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## REGISTERS, STATUS, FLAGS, ASSIGNMENTS

| DATA REGISTERS |                        |  |  | STATUS                                                                                                                    |           |                   |                           |
|----------------|------------------------|--|--|---------------------------------------------------------------------------------------------------------------------------|-----------|-------------------|---------------------------|
| 00             | X                      |  |  | SIZE 012                                                                                                                  | TOT. REG. | USER MODE         |                           |
| 01             | X MAY                  |  |  | ENG                                                                                                                       | FIX 5     | SCI               | ON OFF                    |
| 02             | $f_1$                  |  |  | DEG                                                                                                                       | RAD       | GRAD              |                           |
| 03             | $f_2$                  |  |  |                                                                                                                           |           |                   |                           |
| 04             | $f_1 - f_2$            |  |  |                                                                                                                           |           |                   |                           |
| 05             | USED                   |  |  |                                                                                                                           |           |                   |                           |
| 06             | $\Delta X$             |  |  |                                                                                                                           |           |                   |                           |
| 07             | USED                   |  |  |                                                                                                                           |           |                   |                           |
| 08             | $\Delta X$ (ITERATION) |  |  |                                                                                                                           |           |                   |                           |
| 09             | } USED                 |  |  |                                                                                                                           |           |                   |                           |
| 10             |                        |  |  |                                                                                                                           |           |                   |                           |
| 11             |                        |  |  |                                                                                                                           |           |                   |                           |
|                |                        |  |  | <div> <div> <div>INIT</div> <div>#</div> <div>S/C</div> </div> <div>SET INDICATES</div> <div>CLEAR INDICATES</div> </div> |           |                   |                           |
|                |                        |  |  | 00                                                                                                                        | C         | FIND MINIMA       | OBTAIN ROUGH GUESSES ONLY |
|                |                        |  |  | 01                                                                                                                        | C         | FIND ROOTS        | ROUGH GUESSES FOR ROOTS   |
|                |                        |  |  | 02                                                                                                                        | C         | FIND MAXIMA       | ROUGH GUESSES FOR MAXIMA  |
|                |                        |  |  | 03                                                                                                                        | C         | MINIMA ARE SOUGHT | MAXIMA ARE SOUGHT         |
|                |                        |  |  | <div> <div>ASSIGNMENTS</div> <div> <div>FUNCTION</div> <div>KEY</div> <div>FUNCTION</div> <div>KEY</div> </div> </div>    |           |                   |                           |

PROGRAM REGISTERS NEEDED: 52

ROW 1 (1 : 3)



ROW 2 (3 : 8)



ROW 3 (9 : 15)



ROW 4 (16 : 25)



ROW 5 (26 : 32)



ROW 6 (32 : 41)



ROW 7 (42 : 51)



ROW 8 (52 : 62)



ROW 9 (62 : 67)



ROW 10 (67 : 76)



ROW 11 (77 : 81)



ROW 12 (82 : 89)



ROW 13 (89 : 93)



ROW 14 (94 : 97)



ROW 15 (98 : 107)



ROW 16 (108 : 118)



ROW 17 (119 : 130)



ROW 18 (130 : 133)





ROW 19 (134 : 143)



ROW 20 (144 : 151)



ROW 21 (151 : 159)



ROW 22 (159 : 164)



ROW 23 (164 : 170)



ROW 24 (171 : 182)



ROW 25 (183 : 189)



ROW 26 (189 : 192)



ROW 27 (192 : 198)



ROW 28 (199 : 203)



