UTILITY COMMANDS

UTILITY (or CMD) (REFERENCE MANUAL SECTION) COMMAND PROMPTS

UTILITY (CMD) COMMANDS - The main program level is known as the CMD level. The program is at the CMD level when it begins to execute. Commands entered at this level from the keyboard are executed in an immediate mode. All commands issued from the keyboard are known as CMD level commands, except those commands which cause the program to enter a level other than the CMD level. Commands such as "MACRO" or "MEDIT" or "LENS" are, therefore, not considered to be CMD level commands. The following commands are CMD level commands. They may be issued from the keyboard, from input files like CARDTEXT.DAT and EDITTEXT.DAT or they may be included in, and issued from, a macro or macro function.

PART 1-GENERAL CMD LEVEL COMMANDS - The first part of the CMD section deals with commands which do not relate directly to the optical system being modeled. They are general commands which control overall program behavior.

SPECIAL ASSISTANCE COMMANDS - Special assistance commands can be issued at any time and from any program level. The only instance in which they will not be immediately executed is when they are entered as part of a macro definition. They will, however, be executed when the macro is executed. Only some of these commands may be included as part of a macro.

C , (comment - up to 69 characters in length) - The "C", or comment, command is provided for macro documentation. It performs no other operation and produces no output. Comment commands within a macro are not processed during macro execution. The comment command may be included in a macro and used to document features of that macro. When the comment command followed by a comment is issued from the CMD level and when "ECHO ON" is set, the comment command and comment are echoed to the terminal display.

M , (message - up to 69 characters in length) - If the input included with the "M" command is an alphanumeric string message, that string is sent to the current output device. The message command may be used in order to produce any desired text output. The message command may be included in a macro.

"?"- The "?" command generates a message as to the type of input the program next expects. It is a universal command valid from all program levels. For example, at the CMD level, "?" produces the message "READY FOR CMD LEVEL INPUT". "?" may not occur in a macro since it is always processed immediately after it is issued. In some cases, issuing a command followed by a "?" or by a space and a "?" will generate an output of additional information about that command. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

GETTING HELP - There are no commands, other than "?", for requesting program help. All "HELP" features are accessed from the program "HELP" menu.

"PROGSIZE" - The "PROGSIZE" command displays the number of lens surfaces per lens, the number of lines per macro and the maximum number of macros allowed in the current program. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

"blank input" - "blank input generated using a carriage return via the RETURN key, when it is the only input on a command line (no multiple commands stacked on a line), produces a message specifying the name of the current program level. When given as part of a stacked command line, no output is produced. The "blank input" command may not occur as an instruction in a macro since it is always processed immediately after it is issued. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

UTILITY COMMANDS

EJECT - If the default output device is defined to be LP (PRINTER.DAT), "EJECT" sends a page eject to the file PRINTER.DAT which causes the printer to position itself at the top of the next page when the file PRINTER.DAT is finally printed. "EJECT" may be used in a macro.

ECHO ON or **ECHO OFF** - When the program is first begun, the echo feature is off. If it is set to on, then each input command will be echoed to the current output device. "ECHO ON" and "ECHO OFF" may also be used in a macro . The program default is "ON". It causes the command issued with the keyboard to be echoed to the output window appended to a ">" character. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

EXIT or EXI - The "EXIT" or "EXI" command terminates program execution, closes all open files and returns control to the computer operating system. "EXIT" or "EXI" may be used in a macro. This command causes immediate exit from the program. If the dialog close program or exit menu items are selected, the program will prompt the user for an exit confirmation.

SYS or **SYSTEM (alphanumeric string)** - The "SYS" or "SYSTEM" command causes program execution to be temporarily suspended and the operating system command in the alphanumeric string to be executed. If no string is issued, no action is taken. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

WSYS or **WSYSTEM** - The "WSYS" or "WSYSTEM" command causes program execution to be temporarily suspended and a process spawned to the operating system. The user may then issue any operating system commands. The user must type "EXIT" to stop the spawned process and return to the program. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

EDIT (file name) - The "EDIT" command causes program execution to be temporarily suspended. The file with name "file name" is edited using the built-in full screen editor. When the editor command, which would act to file the edited file, is issued, the editor will stop and program execution will resume. If no file name is supplied, the EDITTEXT.DAT file will be opened by default. If the file associated with the "file name" does not exist, it will be created and then opened. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

DATE - The "DATE" command displays the current date.

TIME - The "TIME" command displays the current time.

STAMPD (ON or OFF) - The "STAMPD" command turns date stamping "on" or "off" whenever the "lens identifier" is displayed in a textual or graphical context. The current date will be appended to the beginning of the "lens identifier" display. Issued with a "?", the current status of date stamping will be displayed. The default is "off".

STAMPT (ON or OFF) - The "STAMPT" command turns time stamping "on" or "off" whenever the "lens identifier" is displayed in a textual or graphical context. The current time will be appended to the beginning of the "lens identifier" display. Issued with a "?", the current status of date stamping will be displayed. The default is "off". If time and date stamping are both "ON", the time will always precede the date.

SETTIMER - The "SETTIMER" command sets the internal program timer to zero.

SEETIMER - The "SEETIMER" command displays the elapsed time, in seconds, since the program timer was set to zero.

LENDIR , (qualifier word) By default when the program begins execution, the lens library is located in the directory LIBLEN which sits just below the directory into which the main program was installed and from which the main program runs. The "LENDIR" command is used to change the current lens library directory to the directory named by the first six characters of the "qualifier word". If this directory exists, then only the internal program pointer, pointing to the lens library directory, is changed. If the directory does not yet exist, it is created. After creation of a new lens library directory, a new lens library must be initialized in this new directory via the "ILF" and "PROCEED" commands. The "LENDIR" command makes it possible to have access to as many user-created lens libraries as desired or to update and modify the manufacturer lens catalogs. The only limitation is available disk space. If "LENDIR" is issued followed by a "?", the name of the current lens library directory will be displayed. The new directory name designated by the "qualifier word" must contain exactly six non-blank characters.

MACDIR or CHGMAC , (qualifier word) - By default when the program begins execution, the macro library is located in the directory LIBMAC which sits just below the directory into which the main program was installed and from which the main program runs. The "MACDIR" command is used to change the current macro library directory to the directory named by the first six characters of the "qualifier word". If this directory exists, then only the internal program pointer, pointing to the macro library directory, is changed. If the directory does not yet exist, it is created. After creation of a new macro library directory, a new macro library must be initialized in this new directory via the "IMF" and "PROCEED" commands. The "MACDIR" command makes it possible to have access to as many macro libraries as desired, only limited by available disk space. If "MACDIR" is issued followed by a "?", the name of the current macro library directory will be displayed. The new directory name designated by the "qualifier word" must contain exactly six non-blank characters.

TRADIR , (qualifier word) - By default when the program begins execution, the transmission file library is located in the directory TRALEN which sits just below the directory into which the main program was installed and from which the main program runs. The "TRADIR" command is used to change the current transmission file library directory to the directory named by the first six characters of the "qualifier word". If this directory exists, then only the internal program pointer, pointing to the transmission file library directory, is changed. If the directory does not yet exist, it is created. After creation of a new transmission file library directory, a new transmission file library must be initialized in this new directory via the "ITF" and "PROCEED" commands. The "TRADIR" command makes it possible to have access to as many transmission file libraries as desired, only limited by available disk space. If "TRADIR" is issued followed by a "?", the name of the current transmission file library directory will be displayed. The new directory name designated by the "qualifier word" must contain exactly six non-blank characters.

PLTDIR , (qualifier word) - By default when the program begins execution, the plot library is located in the directory LIBPLO which sits just below the directory into which the main program was installed and from which the main program runs. The "PLTDIR" command is used to change the current plot library directory to the directory named by the first six characters of the "qualifier word". If this directory exists, then only the internal program pointer, pointing to the plot library directory, is changed. If the directory does not yet exist, it is created. After creation of a new plot library directory, a new plot library must be initialized in this new directory via the "IPF" and "PROCEED" commands. The "PLTDIR" command makes it possible to have access to as many plot libraries as desired, only limited by available disk space. The new directory name designated by the "qualifier word" must contain exactly six non-blank characters. NOTE: If, each time the program is started, it is desired to go to an alternate lens, macro, transmission file and/or plot file library directory, then any or all or the preceding four commands, including the target directory name, may be included in the DEFAULTS.DAT file in the main program directory.

PRINT (P or L) The "PRINT" command, not to be confused with the SPECT level command of the same name, causes the contents of the current printer file to be printed to the attached printer. The default is a “P” or “portrait” orientation. Issuing the qualifier “L” causes a “landscape” orientation. Output to the printer file is controlled using the "OUTPUT LP" command discussed previously. If no printer file exists, a warning message is issued and no printed output is generated. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

FUNNAME (alternate name) , i - The "FUNNAME" command causes the macro function desinated by "i" to be given the alternate name "alternate name". "alternate name" is entered as a qualifier word and may be up to eight characters in length. "alternate name" should not be the name of any existing macro or program command or unexpected program behavior will result. To give the macro function FUN03 the alternate name "DOTHIS", the command would be: **FUNNAME DOTHIS , 3.** Macro function alternate names remain in effect until they are changed or until the program execution ends.

REPETITION COMMANDS

DO (qualifier word) , i , j - The "DO" command is a rather special and useful repetition command. It is used in combination with any CMD level command which takes as its argument a current lens surface number for its numeric word #1 input and which does not require explicit numeric word #2 through #5 input. An example of its use would be : **DO RTG 3 5.** This causes repeated "RTG" commands to be issued for surfaces 3, 4 and 5. Another example would be the sequence of commands: **FOB** followed by **RAY 1** followed by **DO PRY 8 20.** These commands trace a ray from relative fractional field position 0.0. The ray will intersect the reference surface at a fractional reference Y-height of 1.0 and fractional reference X-height of 0.0. YZ-plane ray data will then be displayed for this ray at surfaces 8 through 20. The default for "i" is always the current object surface number. The default for "j" is always the current image surface number.

INPUT/OUTPUT REDIRECTION

INPUT/OUTPUT REDIRECTION - The following commands act to redirect program input and output:

INPUT TP	**INPUT CR**	**INPUT ED**	**INPUT PU**
OUTPUT TP	**OUTPUT CP**	**OUTPUT ED**	**OUTPUT PU**
REWIND CP	**OUTPUT NULL**		

In all cases, "IN" and "OUT" may be used as short forms of the words "INPUT" and "OUTPUT These "INPUT"/"OUTPUT" commands are used to redefine the device from which input is received or to which output is sent. "TP" refers to the keyboard, console, terminal(input) or screen(output). "LP" refers to the disk file PRINTER.DAT. This file is used to direct printer output to the attached printer. "CP" and "CR" refer to a file named CARDTEXT.DAT. This file is useful for storing program data which is to be post-processed by other programs or different sections of the program. This file may be rewound using the "REWIND CP" command. The "REWIND CP" command sets the file pointer back to the beginning of the file CARDTEXT.DAT and allows overwriting of data. "PU" and "ED" refer to two other auxiliary input/output disk files "PUNCH.DAT" and "EDITTEXT.DAT". The EDITTEXT.DAT file is used by the "EDIT" command described earlier. "NULL" refers to the device NUL and is used for hiding output. Input and output redirection become effective with the first input or output command processed following the issuance of the

redirection. An output redirection command remains in effect until another redirection command is issued or until the program is exited. The startup default output directions are "INPUT TP" and "OUTPUT TP". Input redirection commands cause the associated targeted files to be read immediately after the "INPUT" command is processed, whether the input redirection command is issued from the keyboard or from within a macro. If there is a desire to output to or input from other data files, simply use the "SYS" command to issue a DOS level copy command in order to copy the desired data to or from one of the standard files described above. Commands read in from the associated file are sequentially processed by the program's command processor until the file has been completely read. The files designated by "LP", "CR"/"CP", "PU" and "ED" are all FORMATTED/SEQUENTIAL ASCII files. All disk files associated with output redirection are kept in the same drive and directory as the main EXE file. **NOTE: "OUT" and "OUTPUT" are not allowed in an input script though they are allowed in MACROS.**

USER SPECIFIED FILENAMES - The "INPUT" or "IN" and "OUTPUT" or "OUT" commands have an alternate syntax which allows the user to specify a file name for output and input.
OUTPUT T (optional file name of up to 12 characters) or
OUTPUT FILE (non-optional file name of up to 12 characters) or
INPUT FILE (non-optional file name of up to 12 characters) - The command "OUTPUT T" without the optional file name reverts to the previous command "OUTPUT TP". If an optional file name is specified, output is sent both to the screen and to the specified file. The "OUTPUT FILE" command sends output to the file specified. A file name is required as part of the input for this command. The "INPUT FILE" command attempts to read valid program commands from the file specified. If invalid program commands are encountered, appropriate error messages are generated.

FILE APPEND/REPLACE - The next two commands allow the user to set the "append/replace" characteristic of the files PRINTER.DAT, EDITTEXT.DAT, PUNCH.DAT and CARDTEXT.DAT.
APPEND - The "APPEND" command sets the files PRINTER.DAT, EDITTEXT.DAT, CARDTEXT.DAT and PUNCH.DAT to be defined as "append" type files. After "APPEND" is issued, then each time one of these files is selected as the output file using the "OUT" or "OUTPUT" command, output will be appended to the bottom of that file.
REPLACE - The "REPLACE" command sets the files PRINTER.DAT, EDITTEXT.DAT, CARDTEXT.DAT and PUNCH.DAT to be defined as "sequential" type files. After "REPLACE" is issued, then each time one of these files is selected as the output file using the "OUT" or "OUTPUT" command, the file will be wiped clean and new output will be placed at the top of the file. "REPLACE" is the program default.

PART II - RETRIEVAL OF PROGRAM DATABASE VALUES FOR FURTHER PROCESSING
(THE "GET" COMMAND) - The "GET" command, and the wide range of program database items which it can retrieve, make this program more flexible and powerful than any other optical design and analysis code. Using the "GET" command, most program database items can be quickly retrieved into the ACCUMULATOR (X-register) or into any one of the MAXREG general purpose storage registers. These retrieved values may then be displayed, manipulated interactively at the CMD level or manipulated from within a user-written macro or macro function. The intrinsic speed of macro function execution, together with the power of the "GET" command, gives the optimization and tolerancing operations their great power and flexibility.

GET (database item name) , i , j , k ,, r or
SHOW (database item name) , i , j , k ,, r - The "GET" command retrieves into the ACCUMULATOR (X-register), and optionally into the general purpose storage register designated by "r", the program database item with name = "database item name". The numeric input values "i", "j" and "k" are not always required, and their use will be made clear by referring to the "GET" table starting on the next page. Some data items which are automatically placed into the X-register or accumulator during the execution of specific program commands do not appear in the "GET" list because they do not need to be there. The "GET" command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5". The "SHOW" command, when used with a qualifier word, acts exactly as the "GET" command does except that it issues an automatic "WRITE" command which displays the new contents of the accumulator to the screen. This is the second usage of the "SHOW" command.

GETABLE LENS DATABASE PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
UNITS	(not used)	(not used)	(not used)	Returns value of units: 1 = inches 2 = centimeters 3 = millimeters 4= meters
ISN	(not used)	(not used)	(not used)	Current image surface number
OSN	(not used)	(not used)	(not used)	Current object surface number
REFS	(not used)	(not used)	(not used)	Current reference surface number
ASTOP	(not used)	(not used)	(not used)	Current aperture stop surface number
WV	wavelength number	(not used)	(not used)	Wavelength in microns corresponding to given wavelength number
SPTWT	wavelength number	(not used)	(not used)	Spectral weighting factor for wavelength "i".
CW	(not used)	(not used)	(not used)	Control wavelength number
MODE	(not used)	(not used)	(not used)	Returns value of MODE: 1 = FOCAL 2= UFOCAL 3 = AFOCAL 4 = UAFOCAL
RD	surf #	(not used)	(not used)	Radius of curvature at surface "i"

CV	surf #	(not used)	(not used)	Curvature at surface "i"
TH	surf #	(not used)	(not used)	Thickness at surface "i"
CC	surf #	(not used)	(not used)	Conic constant at surface "i"
AC	surf #	(not used)	(not used)	2nd order aspheric (plano surfaces only) at surface "i"
AD	surf #	(not used)	(not used)	4th order aspheric at surface "i"
AE	surf #	(not used)	(not used)	6th order aspheric at surface "i"
AF	surf #	(not used)	(not used)	8th order aspheric at surface "i"
AG	surf #	(not used)	(not used)	10th order aspheric at surface "i"
AH	surf #	(not used)	(not used)	12th order aspheric at surface "i"
AI	surf #	(not used)	(not used)	14th order aspheric at surface "i"
AJ	surf #	(not used)	(not used)	16th order aspheric at surface "i"
AK	surf #	(not used)	(not used)	18th order aspheric at surface "i"
AL	surf #	(not used)	(not used)	20th order aspheric at surface "i"
RDTOR	surf #	(not used)	(not used)	Toric radius of curvature at surface "i"
CVTOR	surf #	(not used)	(not used)	Toric curvature at surface "i"
CCTOR	surf #	(not used)	(not used)	Toric conic constant at surface "i"
ADTOR	surf #	(not used)	(not used)	4th order anamorphic coefficient at surface "i"
AETOR	surf #	(not used)	(not used)	6th order anamorphic coefficient at surface "i"
AFTOR	surf #	(not used)	(not used)	8th order anamorphic coefficient at surface "i"
AGTOR	surf #	(not used)	(not used)	10th order anamorphic coefficient at surface "i"
ALPHA	surf #	(not used)	(not used)	ALPHA surface tilt angle (degrees) at surface "i"
BETA	surf #	(not used)	(not used)	BETA surface tilt angle (degrees) at surface "i"
GAMMA	surf #	(not used)	(not used)	GAMMA surface tilt angle (degrees) at surface "i"
TCODE	surf #	(not used)	(not used)	Returns the surface "i" tilt code: 0 = (no tilt) 1 = TILT -1 = RTILT 2 = TILT AUTO 3 = TILT AUTOM 4 = TILT BEN 5 = TILT DAR
VNUM	surf #	(not used)	(not used)	V-number or Abbe number for the MODEL glass at surface "i". It is equal to: $VNUM = \frac{(N_{cw} - 1)}{(N_{pcw1} - N_{pcw2})}$ Where: pcw1 and pcw2 are the primary wavelength pair defined in the lens database.
PARTL	surf #	(not used)	(not used)	Partial Dispersion for the MODEL glass at surface "i". It is equal to: $PARTL = \frac{(N_{cw} - N_{pcw2})}{(N_{pcw1} - N_{pcw2})}$ Where: pcw1 and pcw2 are the primary wavelength pair defined in the lens database.
INDEX	surf #	(not used)	(not used)	Refractive index of MODEL glass at surface "i".

MCODE	surf #	(not used)	(not used)	Returns: 0.0 if surface is surrounded by "AIR" 1.0 if material type is "REFL" 2.0 if material is a catalog glass 3.0 if material type is "MYGLASS" 4.0 if material type is "MODEL" 5.0 if material is "PERFECT" 6.0 if material is "IDEAL" 7.0 if material is "REFLTIRO" 8.0 if material is "REFLTIR"
XD	surf #	(not used)	(not used)	X-surface decentration at surface "i"
YD	surf #	(not used)	(not used)	Y-surface decentration at surface "i"
ZD	surf #	(not used)	(not used)	Z-surface decentration at surface "i"
CLAP	surf #	(not used)	(not used)	Clear aperture semi-diameter at surface "i" for a circular clear.
COBS	surf #	(not used)	(not used)	Obscuration semi-diameter at surface "i" for a circular obscuration
CLAPE	surf #	(not used)	(not used)	Clear aperture erase semi-diameter at surface "i" for a circular clear aperture
COBSE	surf #	(not used)	(not used)	Obscuration erase semi-diameter at surface "i" for a circular obscuration
CLRAD	surf #	(not used)	(not used)	Racetrack radius at surface "i" for a racetrack clear aperture
CORAD	surf #	(not used)	(not used)	Racetrack radius at surface "i" for a racetrack obscuration
CLRADE	surf #	(not used)	(not used)	Racetrack radius at surface "i" for a racetrack clear aperture erase
CORADE	surf #	(not used)	(not used)	Racetrack radius at surface "i" for a racetrack obscuration erase
CLDECX	surf #	(not used)	(not used)	Clear aperture X-decentration
CLDECY	surf #	(not used)	(not used)	Clear aperture Y-decentration
CODECX	surf #	(not used)	(not used)	Obscuration X-decentration
CODECY	surf #	(not used)	(not used)	Obscuration Y-decentration
CLDECXE	surf #	(not used)	(not used)	Clear aperture erase X-decentration
CLDECYE	surf #	(not used)	(not used)	Clear aperture erase Y-decentration
CODECXE	surf #	(not used)	(not used)	Obscuration erase X-decentration
CODECYE	surf #	(not used)	(not used)	Obscuration erase Y-decentration
CLTILT	surf #	(not used)	(not used)	Clear aperture tilt
CLTILTE	surf #	(not used)	(not used)	Clear aperture erase tilt
COTILT	surf #	(not used)	(not used)	Obscuration tilt
COTILTE	surf #	(not used)	(not used)	Obscuration erase tilt
CLAPX	surf #	(not used)	(not used)	Non-circular clear aperture X-dimension
CLAPY	surf #	(not used)	(not used)	Non-circular clear aperture Y-dimension
CLAPXE	surf #	(not used)	(not used)	Non-circular clear aperture erase X-dimension
CLAPYE	surf #	(not used)	(not used)	Non-circular clear aperture erase Y-dimension
COBSX	surf #	(not used)	(not used)	Non-circular obscuration X-dimension
COBSY	surf #	(not used)	(not used)	Non-circular obscuration Y-dimension
COBSXE	surf #	(not used)	(not used)	Non-circular obscuration erase X-dimension
COBSYE	surf #	(not used)	(not used)	Non-circular obscuration erase Y-dimension
XVERT	surf #	Global ref surf #	(not used)	Global X-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".
YVERT	surf #	Global ref surf #	(not used)	Global Y-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".
ZVERT	surf #	Global ref surf #	(not used)	Global Z-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".

LXVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
MXVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
NXVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
LYVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
MYVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
NYVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
LZVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
MZVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
NZVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
LENGTH or OAL	surf #	surf #	(not used)	Algebraic sum of axial thicknesses from surface "i" to surface "j"
MLENGTH or OPTLEN	surf #	surf #	(not used)	Physical length from surface "i" to surface "j" along a path connecting surface vertices and ignoring tilts and decentrations. This is the sum of the axial thickness multiplied by the refractive index in each space.
ET or ETY	surf #	(not used)	(not used)	Edge thickness from surface "i" to surface "i"+1. Surface tilts and decentrations are ignored. If clear apertures are assigned, they are assumed circular with the YZ-plane value being used. The larger of the values on surface "i" and "i"+1 is used. If no clear apertures are assigned, then the larger of the sums of PY+PCY on surfaces "i" and "i"+1 are used in the calculation. Clear aperture decentrations and tilts are ignored.
ETX	surf #	(not used)	(not used)	Edge thickness from surface "i" to surface "i"+1. Surface tilts and decentrations are ignored. If clear apertures are assigned, they are assumed circular with the XZ-plane value being used. The larger of the values on surface "i" and "i"+1 is used. If no clear apertures are assigned, then the larger of the sums of PX+PCX on surfaces "i" and "i"+1 are used in the calculation. Clear aperture decentrations and tilts are ignored.
ASI	surf #	(not used)	(not used)	Returns 0.0 if no alternate surface intersection was defined on the surface and returns 1.0 if there is an alternate surface intersection defined on the surface.
C1 through C96	surf #	(not used)	(not used)	This returns the value of any one of the 96 special surface coefficient values C1 THROUGH C96.

SHAPEFAC	surf #	(not used)	(not used)	This returns the shape factor for the lens element which begins at surface "i" and terminates at surface "i+1". The shape factor is defined by : $$SHAPEFAC = \frac{r_{i+1} + r_i}{r_{i+1} - r_i}$$ where: r is the radius of curvature
INR	surf #	(not used)	(not used)	Returns the current "inr" value associated with the specified surface.
SHRTWAVE	(not used)	(not used)	(not used)	Returns the wavelength, in current lens units, of the shortest wavelength whose spectral weight is non-zero.
SAY	(not used)	(not used)	(not used)	Returns the current "say" value
SAX	(not used)	(not used)	(not used)	Returns the current "sax" value
SCY	(not used)	(not used)	(not used)	Returns the current "scy" value
SCX	(not used)	(not used)	(not used)	Returns the current "scx" value
PIVX	surf #	(not used)	(not used)	X-alternate pivot point at surface "i"
PIVY	surf #	(not used)	(not used)	Y-alternate pivot point at surface "i"
PIVZ	surf #	(not used)	(not used)	Z-alternate pivot point at surface "I"
GRO	surf#	(not used)	(not used)	Linear diffraction grating order
GRS	surf#	(not used)	(not used)	Linear diffraction grating spacing in lens units
GRX	surf#	(not used)	(not used)	Linear diffraction grating x-direction number
GRY	surf#	(not used)	(not used)	Linear diffraction grating y-direction number
GRZ	surf#	(not used)	(not used)	Linear diffraction grating z- direction number
FLDSX	FOV #	(not used)	(not used)	X-value of the "i" th multiple field-of-view position.
FLDSY	FOV #	(not used)	(not used)	Y-value of the "i" th multiple field-of-view position.
WEIGHT	surf #	surf #	(not used)	MASS in Kgs of elements from surface "i" to surface "j". This calculation assumes spherical surfaces and ignores all decenters and tilts. It uses the specific gravity assigned to surfaces with the lens database command "SPGR".
ACT	surf #	actuator #	(not used)	Returns the actuator value between –1.0 and 1.0 for actuator "j" on surface "i" if surface "i" is defined as a deformable surface. If not gettable, 0.0 is returned.
ACTMAX	surf #	(not used)	(not used)	Returns the maximun actuator value on surface "i" if surface "i" is defined as a deformable surface. If not gettable, 0.0 is returned.
ACTMIN	surf #	(not used)	(not used)	Returns the minumum actuator value on surface "i" if surface "i" is defined as a deformable surface. If not gettable, 0.0 is returned.
ACTMEAN	surf #	(not used)	(not used)	Returns the average of all active actuator values on surface "i" if surface "i" is defined as a deformable surface. If not gettable, 0.0 is returned.
ACTSDEV	surf #	(not used)	(not used)	Returns the standard deviation from the mean of all active actuator values on surface "i" if surface "i" is defined as a deformable surface. If not gettable, 0.0 is returned.
ACTPTOV	surf #	(not used)	(not used)	Returns the peak to valley value for all active actuator values on surface "i" if surface "i" is defined as a deformable surface. If not gettable, 0.0 is returned.
SAG	surf#	x	y	Returns the surface SAG value for surface "i" at local surface coordinates "x" and "y". It also places the L, M and N surface normal direction cosines at "x" and "y" into the Y, Z and T stack registers.

GETABLE PROGRAM OPERATING CONDITION PARAMETERS

DATABASE ITEM NAME	"i"	"j"	"k"	DESCRIPTION
ONTOL	(not used)	(not used)	(not used)	Operand dependence test value.
ORTOL	(not used)	(not used)	(not used)	SVD zero level for W matrix.
OPTOL	(not used)	(not used)	(not used)	Operand to target tolerance value.
SURTOL	(not used)	(not used)	(not used)	Aspheric/ray intersection tolerance.
AIMTOL	(not used)	(not used)	(not used)	Iterative ray aim to reference surface tolerance.
CAIMTOL	(not used)	(not used)	(not used)	Iterative ray aim to image surface tolerance.
NRAITR	(not used)	(not used)	(not used)	Maximum number of ray iterations for aspheric intersection and reference surface ray aiming.
DELSUR	(not used)	(not used)	(not used)	Derivative increment used for surface normal calculations for non-flat, non-spherical and non-conic surfaces.
PFAC	(not used)	(not used)	(not used)	Current value of PFAC
DINMUL	(not used)	(not used)	(not used)	Current value of DINMUL
DIFTOL	(not used)	(not used)	(not used)	Current value of DIFTOL
MRAYS	(not used)	(not used)	(not used)	Current value of MRAYS

GETABLE GRAPHICS PARAMETERS				
DATABASE ITEM NAME	"i"	"j"	"k"	DESCRIPTION
XPEN	(not used)	(not used)	(not used)	Current X-coordinate of the pen
YPEN	(not used)	(not used)	(not used)	Current Y-coordinate of the pen
XPENOL	(not used)	(not used)	(not used)	Previous X-coordinate of the pen
YPENOL	(not used)	(not used)	(not used)	Previous Y-coordinate of the pen
PENSTA	(not used)	(not used)	(not used)	0 = pen "UP", 1 = pen "DOWN"

GETABLE REAL RAY PARAMETERS				
DATABASE ITEM NAME	"i"	"j"	"k"	DESCRIPTION
X	surf #	(not used)	(not used)	X-local coordinate at surface "i" of last ray traced
Y	surf #	(not used)	(not used)	Y-local coordinate at surface "i" of last ray traced
Z	surf #	(not used)	(not used)	Z-local coordinate at surface "i" of last ray traced
DX	surf #	(not used)	(not used)	DX at surface "i" of last ray traced
DY	surf #	(not used)	(not used)	DY at surface "i" of last ray traced
DR	surf #	(not used)	(not used)	DR at surface "i" of last ray traced
DRA	surf #	(not used)	(not used)	DRA at surface "i" of last ray traced
XANG	surf #	(not used)	(not used)	XZ-plane slope angle at surface "i" of the last ray traced (radians)
YANG	surf #	(not used)	(not used)	YZ-plane slope angle at surface "i" of the last ray traced (radians)
DCL or K	surf #	(not used)	(not used)	X-direction cosine at surface "i" of the last ray traced (after refraction, reflection or diffraction)
DCM or L	surf #	(not used)	(not used)	Y-direction cosine at surface "i" of the last ray traced (after refraction, reflection or diffraction)
DCN or M	surf #	(not used)	(not used)	Z-direction cosine at surface "i" of the last ray traced (after refraction, reflection or diffraction)
LOLD	surf #	(not used)	(not used)	X-direction cosine at surface "i" of the last ray traced (before refraction, reflection or diffraction)
MOLD	surf #	(not used)	(not used)	Y-direction cosine at surface "i" of the last ray traced (before refraction, reflection or diffraction)
NOLD	surf #	(not used)	(not used)	Z-direction cosine at surface "i" of the last ray traced (before refraction, reflection or diffraction)
LEN	surf #	(not used)	(not used)	Physical length along the current ray from surface "i-1" to surface "i"
AII	surf #	(not used)	(not used)	Cosine of the angle of incidence of current ray at surface "i"

AIP	surf #	(not used)	(not used)	Cosine of the angle of refraction, reflection or diffraction of current ray at surface "i"
LN	surf #	(not used)	(not used)	Local surface coordinate system X-direction cosine of the surface normal at surface "i" where the current ray intersects surface "i"
MN	surf #	(not used)	(not used)	Local surface coordinate system Y-direction cosine of the surface normal at surface "i" where the current ray intersects surface "i"
NN	surf #	(not used)	(not used)	Local surface coordinate system Z-direction cosine of the surface normal at surface "i" where the current ray intersects surface "i"
PXPX	surf #	(not used)	(not used)	Derivative, at surface "i", of the X-coordinate of the last chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PXPY	surf #	(not used)	(not used)	Derivative, at surface "i", of the X-coordinate of the last chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PYPX	surf #	(not used)	(not used)	Derivative, at surface "i", of the Y-coordinate of the last chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PYPY	surf #	(not used)	(not used)	Derivative, at surface "i", of the Y-coordinate of the last chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PXAPX	surf #	(not used)	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the last chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PXAPY	surf #	(not used)	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the last chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PYAPX	surf #	(not used)	(not used)	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the last chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PYAPY	surf #	(not used)	(not used)	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the last chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
DXDX	surf #	(not used)	(not used)	Derivative, at surface "i", of the X-coordinate of the last ray traced with respect to a change in that ray's X-coordinate at the current reference surface.
DXDY	surf #	(not used)	(not used)	Derivative, at surface "i", of the X-coordinate of the last ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
DYDX	surf #	(not used)	(not used)	Derivative, at surface "i", of the Y-coordinate of the last ray traced with respect to a change in that ray's X-coordinate at the current reference surface.
DYDY	surf #	(not used)	(not used)	Derivative, at surface "i", of the Y-coordinate of the last ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.

DXADX	surf #	(not used)	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the last ray traced with respect to a change in that chief ray's X-coordinate at the current reference surface.
DXADY	surf #	(not used)	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the last ray traced with respect to a change in that chief ray's Y-coordinate at the current reference surface.
DYADX	surf #	(not used)	(not used)	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the last ray traced with respect to a change in that chief ray's X-coordinate at the current reference surface.
DYADY	surf #	(not used)	(not used)	Derivative, at surface "i", of the YZ-plane slope angle of the last ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
XREF	surf #	(not used)	(not used)	X-coordinate of the current reference ray at surface "i"
YREF	surf #	(not used)	(not used)	Y-coordinate of the current reference ray at surface "i"
ZREF	surf #	(not used)	(not used)	Z-coordinate of the current reference ray at surface "i"
LREF	surf #	(not used)	(not used)	X-direction cosine of the current reference ray at surface "i" after refraction, reflection or diffraction
MREF	surf #	(not used)	(not used)	Y-direction cosine of the current reference ray at surface "i" after refraction, reflection or diffraction
NREF	surf #	(not used)	(not used)	Z-direction cosine of the current reference ray at surface "i" after refraction, reflection or diffraction
LREFOL	surf #	(not used)	(not used)	X-direction cosine of the current reference ray at surface "i" before refraction, reflection or diffraction
MREFOL	surf #	(not used)	(not used)	Y-direction cosine of the current reference ray at surface "i" before refraction, reflection or diffraction
NREFOL	surf #	(not used)	(not used)	Z-direction cosine of the current reference ray at surface "i" before refraction, reflection or diffraction
LENREF	surf #	(not used)	(not used)	Physical length along the current reference ray from surface "i-1" to surface "i"
OPLREF	surf #	(not used)	(not used)	Optical path length along the current reference ray from surface "i-1" to surface "i"
IREF	surf #	(not used)	(not used)	Cosine of the angle of incidence of the current reference ray at surface "i"
IPREF	surf #	(not used)	(not used)	Cosine of the angle of refraction, reflection or diffraction of the current reference ray at surface "i"
XAREF	surf #	(not used)	(not used)	XZ-plane slope angle of the current reference ray at surface "i", measured in radians
YAREF	surf #	(not used)	(not used)	YZ-plane slope angle of the current reference ray at surface "i", measured in radians
LNREF	surf #	(not used)	(not used)	X-direction cosine of the surface normal at surface "i" where the current reference ray intersects surface "i"
MNREF	surf #	(not used)	(not used)	Y-direction cosine of the surface normal at surface "i" where the current reference ray intersects surface "i"
NNREF	surf #	(not used)	(not used)	Z-direction cosine of the surface normal at surface "i" where the current reference ray intersects surface "i"

GLX	surf #	(not used)	(not used)	Global X-coordinate of the last ray traced at surface "i"
GLY	surf #	(not used)	(not used)	Global Y-coordinate of the last ray traced at surface "i"
GLZ	surf #	(not used)	(not used)	Global Z-coordinate of the last ray traced at surface "i"
GLL	surf #	(not used)	(not used)	Global X-direction cosine of the last ray traced at surface "i" after refraction, reflection or diffraction
GLM	surf #	(not used)	(not used)	Global Y-direction cosine of the last ray traced at surface "i" after refraction, reflection or diffraction
GLN	surf #	(not used)	(not used)	Global Z-direction cosine of the last ray traced at surface "i" after refraction, reflection or diffraction
GLLOLD	surf #	(not used)	(not used)	Global X-direction cosine of the last ray traced at surface "i" before refraction, reflection or diffraction
GLMOLD	surf #	(not used)	(not used)	Global Y-direction cosine of the last ray traced at surface "i" before refraction, reflection or diffraction
GLNOLD	surf #	(not used)	(not used)	Global Z-direction cosine of the last ray traced at surface "i" before refraction, reflection or diffraction
GLLN	surf #	(not used)	(not used)	Global surface normal X-direction cosine at the last ray intersection at surface "i"
GLMN	surf #	(not used)	(not used)	Global surface normal Y-direction cosine at the last ray intersection at surface "i"
GLNN	surf #	(not used)	(not used)	Global surface normal Z-direction cosine at the last ray intersection at surface "i"
VIGY	n	(not used)	(not used)	Upper and lower Y-vignetting factors. These are the largest positive and negative Y values used in "RAY" commands which will not result in a ray blockage by mechanisms other than obscuration. 2n+1 points from 1.0 to -1.0 will be searched in a Y-fan to determine the returned results. The largest positive value is placed in the X-register. The largest negative value is placed in the IX-register. The default for "n" is 10.
VIGX	n	(not used)	(not used)	Same as VIGY except in the XZ-plane or the reference surface.
VIGSY	n	(not used)	(not used)	The value which would have been placed in the X-register by previously described "GET VIGY" command is "gotten" and is subtracted from 1.0 and is then placed in the X-register by the "GET VIGSY" command. The value which would have been placed in the IX-register by the previously described "GET VIGY" command is "gotten" and is added to 1.0 and then is placed in the IX-register.
VIGSX	n	(not used)	(not used)	Same as VIGSY except in the YZ-plane of the reference surface.
RENERGY	surf#	(not used)	(not used)	Ray energy at surface "i" after all coating losses, if coating losses are being taken into account.
NUMHITS	surf #	(not used)	(not used)	The number of times the last ray intersects the designated surface. Used for non-sequential surface groups. For sequential surfaces, 1 is always returned.

GETABLE SPOT DIAGRAM, COMPLEX APERTURE FUNCTION (CAPFN) AND PSF PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**

CENTX	(not used)	(not used)	(not used)	X- centroid location in the current image surface of the current spot diagram centroid. A spot diagram must exist or an error message will be displayed.
CENTY	(not used)	(not used)	(not used)	Y- centroid location in the current image surface of the current spot diagram centroid. A spot diagram must exist or an error message will be displayed.
RMS	(not used)	(not used)	(not used)	Root Mean Square spot size. In modes FOCAL and UFOCAL units are lens units. In modes AFOCAL and UAFOCAL, units are RADIANS. Calculated about the spot centroid. A spot diagram must exist or an error message will be displayed.
RMSX	(not used)	(not used)	(not used)	Same as RMS, except it considers the X-components of rays in the spot diagram.
RMSY	(not used)	(not used)	(not used)	Same as RMS, except it considers the Y-components of rays in the spot diagram.
RMSASPECT	(not used)	(not used)	(not used)	Returns the ratio of the Y to the X-RMS spot values.
RSS	(not used)	(not used)	(not used)	Root Sum Square spot size. In modes FOCAL and UFOCAL, units are lens units. In modes AFOCAL and UAFOCAL, units are RADIANS. Calculated about the chief ray position. A spot diagram must exist or an error message will be displayed.
RSSX	(not used)	(not used)	(not used)	Same as RSS, except it considers the X-components of rays in the spot diagram.
RSSY	(not used)	(not used)	(not used)	Same as RSS, except it considers the Y-components of rays in the spot diagram.
FCSFT	(not used)	(not used)	(not used)	Spot diagram recommended distance to best spot focus. Full statistics must be "on" and the lens must be in the FOCAL or UFOCAL mode.
FCSFTX	(not used)	(not used)	(not used)	Spot diagram recommended distance to best spot focus (X-components only). Full statistics must be "on" and the lens must be in the FOCAL or UFOCAL mode.
FCSFTY	(not used)	(not used)	(not used)	Spot diagram recommended distance to best spot focus (Y-components only). Full statistics must be "on" and the lens must be in the FOCAL or UFOCAL mode.
RMSOPD	wavelength # (optional)	(not used)	(not used)	RMSOPD for the current complex aperture function in waves at the control wavelength. A CAPFN must exist or an error message will be displayed. If no wavelength number is issued, the max RMSOPD for all wavelengths is returned. If a wavelength number is issued, only the RMSOPD value for that wavelength is returned.
PTOVOPD	wavelength # (optional)	(not used)	(not used)	Peak to valley OPD for the current complex aperture function in waves at the control wavelength. A CAPFN must exist or an error message will be displayed. If no wavelength number is issued, the max PTOVOPD for all wavelengths is returned. If a wavelength number is issued, only the PTOVOPD value for that wavelength is returned.
ZERN37	coef#	(not used)	(not used)	If a complex aperture function (CAPFN) exists and if a fitted wavefront map has been generated via the "FITZERN" command, then the value of the specified coefficient will be returned. The 37 term "Fringe" Zernike polynomial is used for the fit. (See the description of the "FITZERN" command in the FOE section.)

PSF	i	j	(not used)	Places the "i , j " element of the current diffraction Point Spread Function into the accumulator. This is a "power" value. The PSF is normalized so that the peak value is always 32676.0. "i" counts columns from -x to +x and "j" counts rows from -y to +y in the coordinate system of the reference surface.
RSPHX	(not used)	(not used	(not used)	Returns the X-coordinate of the center of the reference sphere used in CAPFN opd calculations.
RSPHY	(not used)	(not used	(not used)	Returns the Y-coordinate of the center of the reference sphere used in CAPFN opd calculations.
RSPHZ	(not used)	(not used	(not used)	Returns the Z-coordinate of the center of the reference sphere used in CAPFN opd calculations.
SPDTRANS	(not used)	(not used)	(not used)	% optical transmission for the existing spot diagram.
TRANS	(not used)	(not used)	(not used)	% optical transmission for the existing complex aperture function.
PSFSUM	(not used)	(not used)	(not used)	If a PSF exists, the value returned is the summation or integration of the current Point Spread Function lying inside the currently defined "prg"x"prg" grid.
PSFFWHMX	(not used)	(not used)	(not used)	If a PSF exists, the value returned is the "full width half max" x-dimension of the Spread Function lying inside the currently defined "prg"x"prg" grid.
PSFFWHMY	(not used)	(not used)	(not used)	Same as PSFFWHMX except in the y-dimention of the PSF.

GETABLE PARAXIAL RAY PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
PWRX	surf #	surf #	(not used)	XZ-plane paraxial, optical power of optical system from surface "i" to surface "j"
PWRY	surf #	surf #	(not used)	Same as PWRX except in the YZ-plane.
FLCLTHX	surf #	surf #	(not used)	XZ-plane, paraxial, effective focal length at the control wavelength of optical system from surface "i" to surface "j"
FLCLTH or FLCLTHY	surf #	surf #	(not used)	Same as FLCLTHY except in the YZ plane.
PX	surf #	wavelength #	(not used)	XZ-plane, marginal paraxial ray height at surface "i" and at wavelength "j"
PY	surf #	wavelength #	(not used)	Same as PX except in the YZ-plane.
PCX	surf #	wavelength #	(not used)	XZ-plane, chief paraxial ray height at surface "i" and at wavelength "j"
PCY	surf #	wavelength #	(not used)	Same as PCX except in the YZ-plane.
PUX	surf #	wavelength #	(not used)	XZ-plane, marginal paraxial ray tangent at surface "i" and at wavelength "j" after refraction or reflection.
PUY	surf #	wavelength #	(not used)	Same as PUX except in the YZ-plane.
PUCX	surf #	wavelength #	(not used)	XZ-plane, chief paraxial ray tangent at surface "i" and at wavelength "j" after refraction or reflection.
PUCY	surf #	wavelength #	(not used)	Same as PUCX except in the YZ-plane.
PIX	surf #	wavelength #	(not used)	XZ-plane, marginal paraxial ray incident angle tangent at surface "i" and at wavelength "j"
PIY	surf #	wavelength #	(not used)	Same as PIX except in the YZ-plane.
PICX	surf #	wavelength #	(not used)	XZ-plane, chief paraxial ray incident angle tangent at surface "i" and at wavelength "j" before refraction or reflection.
PICY	surf #	wavelength #	(not used)	Same as PICX except in the YZ-plane.
PIXP	surf #	wavelength #	(not used)	XZ-plane, marginal paraxial ray angle of refraction or reflection (tangent) at surface "i" and at wavelength "j"

PIYP	surf #	wavelength #	(not used)	Same as PIXP except in the YZ-plane.
PICXP	surf #	wavelength #	(not used)	XZ-plane, chief paraxial ray angle of refraction or reflection (tangent) at surface "i" and at wavelength "j"
PICYP	surf #	wavelength #	(not used)	Same as PICXP except in the YZ-plane.
PACX	(not used)	(not used)	(not used)	XZ-plane, primary axial chromatic aberration at the final surface.
PACY	(not used)	(not used)	(not used)	Same as PACX except in the YZ-plane.
PLCX	(not used)	(not used)	(not used)	XZ-plane, primary lateral chromatic aberration at the final surface.
PLCY	(not used)	(not used)	(not used)	Same as PLCX except in the YZ-plane.
SACX	(not used)	(not used)	(not used)	XZ-plane, secondary axial chromatic aberration at the final surface.
SACY	(not used)	(not used)	(not used)	Same as SACX except in the YZ-plane.
SLCX	(not used)	(not used)	(not used)	XZ-plane, secondary lateral chromatic aberration at the final surface.
SLCY	(not used)	(not used)	(not used)	Same as SLCX except in the YZ-plane.
MAGX	(not used)	(not used)	(not used)	XZ-plane magnification. Uses ratio of slope of paraxial chief ray at object surface to slope of paraxial chief ray at image surface if no differential chief ray was traced. If real differential chief ray was traced, uses ratio of slope of differential chief ray at object surface to slope of differential chief ray at image surface.
MAGY	(not used)	(not used)	(not used)	Same as MAGX except in the YZ-plane.
MAGXOR	(not used)	(not used)	(not used)	XZ-plane reference magnification. Uses ratio of slope of paraxial chief ray at object surface to slope of paraxial chief ray at reference surface if no differential chief ray was traced. If real differential chief ray was traced, uses ratio of slope of differential chief ray at object surface to slope of differential chief ray at reference surface.
MAGYOR	(not used)	(not used)	(not used)	Same as MAGXOR except in the YZ-plane.

GETABLE SPECIAL REAL RAY/PARAXIAL RAY PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
FFLX	(not used)	(not used)	(not used)	XZ-plane front focal length. Based upon the paraxial ray trace if no differential chief ray was traced. If real differential chief ray was traced, uses differential ray data.
FFLY	(not used)	(not used)	(not used)	Same as FFLX except in the YZ-plane.
BFLX	(not used)	(not used)	(not used)	XZ-plane back focal length. Based upon the paraxial ray trace if no differential chief ray was traced. If real differential chief ray was traced, uses differential ray data.
BFLY	(not used)	(not used)	(not used)	Same as BFLX except in the YZ-plane.
FFNX	(not used)	(not used)	(not used)	XZ-plane front F-number. Uses the reciprocal of -2 times the slope of paraxial marginal ray at object surface if no differential chief ray was traced. If real differential chief ray was traced, uses the reciprocal of -2 times the slope of differential marginal ray at object surface.
FFNY	(not used)	(not used)	(not used)	Same as FFNX except in the YZ-plane.
EFLX	(not used)	(not used)	(not used)	XZ-plane effective focal length. Based upon the paraxial ray trace if no differential chief ray was traced. If real differential chief ray was traced, uses differential ray data.
EFLY	(not used)	(not used)	(not used)	Same as EFLX except in the YZ-plane.

BFNX	(not used)	(not used)	(not used)	XZ-plane back F-number. Uses the reciprocal of -2 times the slope of paraxial marginal ray at image surface if no differential chief ray was traced. If real differential chief ray was traced, uses the reciprocal of -2 times the slope of differential marginal ray at image surface.
BFNY	(not used)	(not used)	(not used)	Same as BFNX except in the YZ-plane.
ENDIAX	(not used)	(not used)	(not used)	XZ-plane entrance pupil diameter. If no real differential chief rays exists, the value is based upon paraxial ray data. If differential ray data exists, it is used for the calculation.
ENDIAY	(not used)	(not used)	(not used)	Same as ENDIAX except in the YZ-plane.
EXDIAX	(not used)	(not used)	(not used)	XZ-plane exit pupil diameter. If no real differential chief rays exists, the value is based upon paraxial ray data. If differential ray data exists, it is used for the calculation.
EXDIAY	(not used)	(not used)	(not used)	Same as EXDIAX except in the YZ-plane.
ENPOSX	(not used)	(not used)	(not used)	X-coordinate of the center of the entrance pupil. If no real differential ray data exists, value is based upon paraxial ray data and is represented in the coordinate system of surface #1. If differential ray data exists, that data is used in the calculation and the value is represented in the coordinate system of the NEWOBJ+1 surface.
ENPOSY	(not used)	(not used)	(not used)	Same as ENPOSX except the Y-coordinate.
ENPOSZ	(not used)	(not used)	(not used)	Same as ENPOSX except the Z-coordinate.
EXPOSX	(not used)	(not used)	(not used)	X-coordinate of the center of the exit pupil. If no real differential ray data exists, value is based upon paraxial ray data and is represented in the coordinate system of the last surface. If differential ray data exists, that data is used in the calculation and the value is represented in the coordinate system of the NEWIMG surface.
EXPOSY	(not used)	(not used)	(not used)	Same as EXPOSX except the Y-coordinate.
EXPOSZ	(not used)	(not used)	(not used)	Same as EXPOSX except the Z-coordinate.
FNUMX	(not used)	(not used)	(not used)	Image space F-number. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
FNUMY	(not used)	(not used)	(not used)	Same as FNUMX except in the YZ-plane.
OBFNUMX	(not used)	(not used)	(not used)	Object space F-number. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
OBFNUMY	(not used)	(not used)	(not used)	Same as OBFUMBX except in the YX-plane.
ENPDIAX	(not used)	(not used)	(not used)	Entrance pupil diameter. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
ENPDIAY	(not used)	(not used)	(not used)	Same as ENPDIAX except in the YZ-plane.
EXPDIAX	(not used)	(not used)	(not used)	Exit pupil diameter. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
EXPDIAY	(not used)	(not used)	(not used)	Same as EXPDIAX except in the YZ-plane.

PUPDIAX	surf #	(not used)	(not used)	XZ-plane. This is 2.0 times the height of the paraxial marginal ray at the position relative to surface "i" at which the paraxial chief ray has zero height.
PUPDIAY	surf #	(not used)	(not used)	Same as PUPDIAX except in the YZ-plane.
PUPDISX	surf #	(not used)	(not used)	XZ-plane. This is the position at which the paraxial chief, in the space folloing surface "i", ray has zero height. It is represented in the coordinate system of surface "i".
PUPDISY	surf #	(not used)	(not used)	Same as PUPDISX except in the YZ-plane.
CHFIMX	surf #	(not used)	(not used)	XZ-plane. This is the height of the paraxial chief ray at the position relative to surface "i" at which the paraxial marginal ray has zero height.
CHFIMY	surf #	(not used)	(not used)	Same as CHFIMX except in the YZ-plane.
GPX	surf #	(optional) y-fob value	(optional) x-fob value	XZ-plane generalized paraxial marginal ray height (at the control wavelength). If no differential ray can be traced, an error message is issued.
GPY	surf #	(optional) y-fob value	(optional) x-fob value	Same as GPUX except in the YZ-plane.
GPUX	surf #	(optional) y-fob value	(optional) x-fob value	XZ-plane generalized paraxial marginal ray slope (at the control wavelength). If no differential ray can be traced, an error message is issued.
GPUY	surf #	(optional) y-fob value	(optional) x-fob value	Same as GPUX except in the YZ-plane.
GPCX	surf #	(optional) y-fob value	(optional) x-fob value	XZ-plane generalized paraxial chief ray height (at the control wavelength). If no differential ray can be traced, an error message is issued.
GPCY	surf #	(optional) y-fob value	(optional) x-fob value	Same as GPCX except in the YZ-plane.
GPUCX	surf #	(optional) y-fob value	(optional) x-fob value	XZ-plane generalized paraxial chief ray slope (at the control wavelength). If no differential ray can be traced, an error message is issued.
GPUCY	surf #	(optional) y-fob value	(optional) x-fob value	Same as GPUCX except in the YZ-plane.
DIST	Y-FOB	X-FOB	(not used)	Uses real chief and real chief differential ray traces (at the control wavelength) to calculate percent distortion at the field point designated by the Y and X-FOB input values. Calculation is performed at the control wavelength for the current lens configuration. Value is valid for tilted and decentered systems. All surface types including special surfaces are recognized. See the "DIST" command for a full description of the nature of this calculation.
FISHDIST	Y-FOB	X-FOB	(not used)	This is similar to DIST but does its calculation with the slope angles in radians rather than with the slope tangents. See the "FISHDIST" command for a full description.
XFOC	Y-FOB	X-FOB	(not used)	XFOC returns the distance from the current image surface to the focus position of close XZ-plane marginal differential rays traced about the chief ray specified by the X and Y-FOB values (at the control wavelength). This distance is measured along the local Z-axis of the current image surface in the coordinate system of the current image surface. **This is the X-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**

YFOC	Y-FOB	X-FOB	(not used)	Same as XFOC but in the YZ-plane. **This is the Y-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**
AST	Y-FOB	X-FOB	(not used)	AST returns the the astigmatism along the chief ray specified by the X and Y-FOB values (at the control wavelength). It is just the YFOC value minus the XFOC value. **In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the astigmatism is too large to represent, it will be set to 1.0D20.**
IMDISX	surf #	(not used)	(not used)	XZ-plane. This is the position at which the paraxial marginal ray, in the space following surface "i", has zero height. It is represented in the coordinate system of surface "i".
IMDISY	surf #	(not used)	(not used)	YZ-plane. This is the position at which the paraxial marginal ray, in the space following surface "i", has zero height. It is represented in the coordinate system of surface "i".

GETABLE 3RD, 5TH and 7TH ORDER ABERRATION PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
SA3	surf #	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XSA3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3	surf #	(not used)	(not used)	YZ-plane, 3rd order COMA at surface "i" and at the control wavelength.
XCMA3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST3	surf #	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM at surface "i" and at the control wavelength.
XAST3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3	surf #	(not used)	(not used)	YZ-plane, 3rd order DISTORTION at surface "i" and at the control wavelength.
XDIS3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3	surf #	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE at surface "i" and at the control wavelength.
XPTZ3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA5	surf #	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XSA5	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5	surf #	(not used)	(not used)	YZ-plane, 5th order COMA at surface "i" and at the control wavelength.
XCMA5	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST5	surf #	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM at surface "i" and at the control wavelength.
XAST5	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5	surf #	(not used)	(not used)	YZ-plane, 5th order DISTORTION at surface "i" and at the control wavelength.
XDIS5	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5	surf #	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE at surface "i" and at the control wavelength.
XPTZ5	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSA	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength.

XTOBSA	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSA	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XSOBSA	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMA	surf #	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA at surface "i" and at the control wavelength.
XELCMA	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TAS	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM at surface "i" and at the control wavelength.
XTAS	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SAS	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM at surface "i" and at the control wavelength.
XSAS	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA7	surf #	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XSA7	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA3P	surf #	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSA3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3P	surf #	(not used)	(not used)	YZ-plane, 3rd order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XCMA3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST3P	surf #	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XAST3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3P	surf #	(not used)	(not used)	YZ-plane, 3rd order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XDIS3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3P	surf #	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XPTZ3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA5P	surf #	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSA5P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5P	surf #	(not used)	(not used)	YZ-plane, 5th order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XCMA5P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST5P	surf #	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XAST5P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5P	surf #	(not used)	(not used)	YZ-plane, 5th order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.

XDIS5P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5P	surf #	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XPTZ5P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAP	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XTOBSAP	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAP	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSOBSAP	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAP	surf #	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the .
XELCMAP	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TASP	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XTASP	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SASP	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSASP	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA7P	surf #	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSA7P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA3S	surf #	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSA3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3S	surf #	(not used)	(not used)	YZ-plane, 3rd order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XCMA3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST3S	surf #	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XAST3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3S	surf #	(not used)	(not used)	YZ-plane, 3rd order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XDIS3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3S	surf #	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XPTZ3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.

SA5S	surf #	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSA5S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5S	surf #	(not used)	(not used)	YZ-plane, 5th order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XCMA5S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST5S	surf #	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XAST5S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5S	surf #	(not used)	(not used)	YZ-plane, 5th order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XDIS5S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5S	surf #	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XPTZ5S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAS	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XTOBSAS	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAS	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSOBSAS	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAS	surf #	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XELCMAS	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TASS	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XTASS	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SASS	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSASS	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA7S	surf #	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength.
XSA7S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XSA5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.

CMA5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order COMA at surface "i" and at the control wavelength.
XCMA5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order ASTIGMATISM at surface "i" and at the control wavelength.
XAST5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order DISTORTION at surface "i" and at the control wavelength.
XDIS5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order PETZVAL CURVATURE at surface "i" and at he control wavelength.
XPTZ5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAI	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XTOBSAI	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAI	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XSOBSAI	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAI	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order ELLIPTICAL COMA at surface "i" and at the control wavelength.
XELCMAI	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TASI	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order TANGENTIAL ASTIGMATISM at surface "i" and at the control wavelength.
XTASI	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SASI	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SAGITTAL ASTIGMATISM at surface "i" and at the control wavelength.
XSASI	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA7I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 7th order SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XSA7I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION at surface "i" and at the control wavelength.
XPSA3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA at surface "i" and at the control wavelength.
PXCMA3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM at surface "i" and at the control wavelength.
XPAST3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION at surface "i" and at the control wavelength.
XPDIS3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.

PPTZ3	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE at surface "i" and at the control wavelength.
XPPTZ3	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3P	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i".
XPSA3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3P	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i".
XPCMA3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3P	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPAST3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3P	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i".
XPDIS3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PPTZ3P	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i".
XPPTZ3P	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3S	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i".
PXSA3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3S	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i".
XPCMA3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3S	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i".
XPAST3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3S	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i".
XPDIS3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
PPTZ3S	surf #	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i".
XPPTZ3S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.

PTZCV	surf#	(not used)	(not used)	This is the YZ-plane, third order Petzval curvature. Its value is independent of lens mode.
XPTZCV	surf#	(not used)	(not used)	Same as above except in the XZ-plane.

GETABLE OPTIMIZATION PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
DERIV or MATRIX	variable #	operand #	(not used)	This returns the value of the derivative matrix for variable "i" and operand "j".
OPWT or WT	operand #	(not used)	(not used)	This returns the value of the weighting factor for operand "i".
VARWT or WVFC	variable #	(not used)	(not used)	This returns the value of the weighting factor for variable "i".
VARDNC	variable #	(not used)	(not used)	This returns the "dincr" value used for variable "i".
OPTYPE	operand #	(not used)	(not used)	This returns a code which designates the operand type for operand "i": 1 = COR 2 = BYP 3 = HLD 4 = BLO or GTE 5 = BHI or LTE
VB	variable #	(not used)	(not used)	The value of the variable "i" is returned.
VBT	variable #	(not used)	(not used)	The value of the tolerance variable "i" is returned.
LCV	(not used)	(not used)	(not used)	The length of the last change vector is returned.
TV	operand #	(not used)	(not used)	The target value of operand "i" is returned.
OPRD	operand #	(not used)	(not used)	The current value of operand "i" is returned.
FOCRIT	operand #	(not used)	(not used)	The value of focus criteria operand "i" is returned.
KDWA	(not used)	(not used)	(not used)	The number of operands is returned.
NVAR	(not used)	(not used)	(not used)	The number of variables is returned.

GETABLE GAUSSIAN BEAM PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
GBRADX	surf #	z-position default = 0.0	(not used)	This returns the value of the XZ-plane $1/e^2$ semi-diameter of the gaussian beam at a Z-distance "j" from surface "i". The last "FOB" command is used to specify object point and wavelength used. If no "FOB" command was issued, then an on-axis point at the control wavelength is assumed.
GBRADY	surf #	z-position default = 0.0	(not used)	This is the same as GBRADX except that it works in the YZ-plane.
GBDISX	surf #	(not used)	(not used)	This returns the distance from surface "i" to the next XZ-plane beam waist in the image space of surface "i". The last "FOB" command is used to specify object point and wavelength used. If no "FOB" command was issued, then an on-axis point at the control wavelength is assumed.
GBDISY	surf #	(not used)	(not used)	This is the same as GBDISX except that it works in the YZ-plane.
GBRCVX	surf #	z-position default = 0.0	(not used)	This returns the XZ-plane wavefront radius of curvature at a Z-distance "j" from surface "i". in the image space of surface "i". The last "FOB" command is used to specify object point and wavelength used. If no "FOB" command was issued, then an on-axis point at the control wavelength is assumed.
GBRCVY	surf #	z-position default = 0.0	(not used)	This is the same as GBRCVX except that it works in the YZ-plane.

GBWAISTX	surf #	(not used)	(not used)	This returns the XZ-plane $1/e^2$ semi-diameter of the beam waist in the image space of surface "i". The last "FOB" command is used to specify object point and wavelength used. If no "FOB" command was issued, then an on-axis point at the control wavelength is assumed.
GBWAISTY	surf #	(not used)	(not used)	This is the same as GBWAISTX except that it works in the YZ-plane.
WRY	(not used)	(not used)	(not used)	Returns the current "wry" value, the starting YZ-plane beam waist semi-diameter.
WRX	(not used)	(not used)	(not used)	Returns the current "wrx" value, the starting XZ-plane beam waist semi-diameter.
BDY	(not used)	(not used)	(not used)	Returns the current "bdy" value, the starting YZ-plane beam divergence half-angle.
BDX	(not used)	(not used)	(not used)	Returns the current "bdx" value, the starting XZ-plane beam divergence half-angle.

GETABLE MISCELLANEOUS PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
GLASSWV1 or GLASSWV2 or GLASSWV3 or GLASSWV4 or GLASSWV5	(not used)	(not used)	(not used)	The first, second, third, fourth or fifth lens independent wavelength used in the glass catalog refractive index calculation when not connected with the "current" lens. Value is in mcron units.
MINREG	(MINREG #)	(not used)	(not used)	The value currently in the MINREG register designated by (MINREG#). Valid inputs are 1 to 100. Default value is 1.
MAXREG	(MAXREG #)	(not used)	(not used)	The value currently in the MAXREG register designated by (MAXREG#). Valid inputs are 1 to 100. Default value is 1.

GETABLE NSS DATABASE PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
NSSMEANX	(not used)	(not used)	(not used)	X - mean value of the last NSS spot diagram
NSSMEANY	(not used)	(not used)	(not used)	Y - mean value of the last NSS spot diagram
NSSMEANR	(not used)	(not used)	(not used)	Radial - mean value of the last NSS spot diagram
NSSRMSX	(not used)	(not used)	(not used)	X - RMS value of the last NSS spot diagram
NSSRMSY	(not used)	(not used)	(not used)	Y - RMS value of the last NSS spot diagram
NSSRMSR	(not used)	(not used)	(not used)	Radial - RMD value of the last NSS spot diagram

GETTING RMS SPOT SIZE - The RMS (Root Mean Square) spot diameter and the X and Y-widths of the spot are automatically placed into the X, Y and Z-general purpose storage registers whenever a spot diagram is generated with one of the "SPD" commands. These values are useful in optimization and are just some of the data items which do not need to be explicitly "gotten" with the "GET" command.

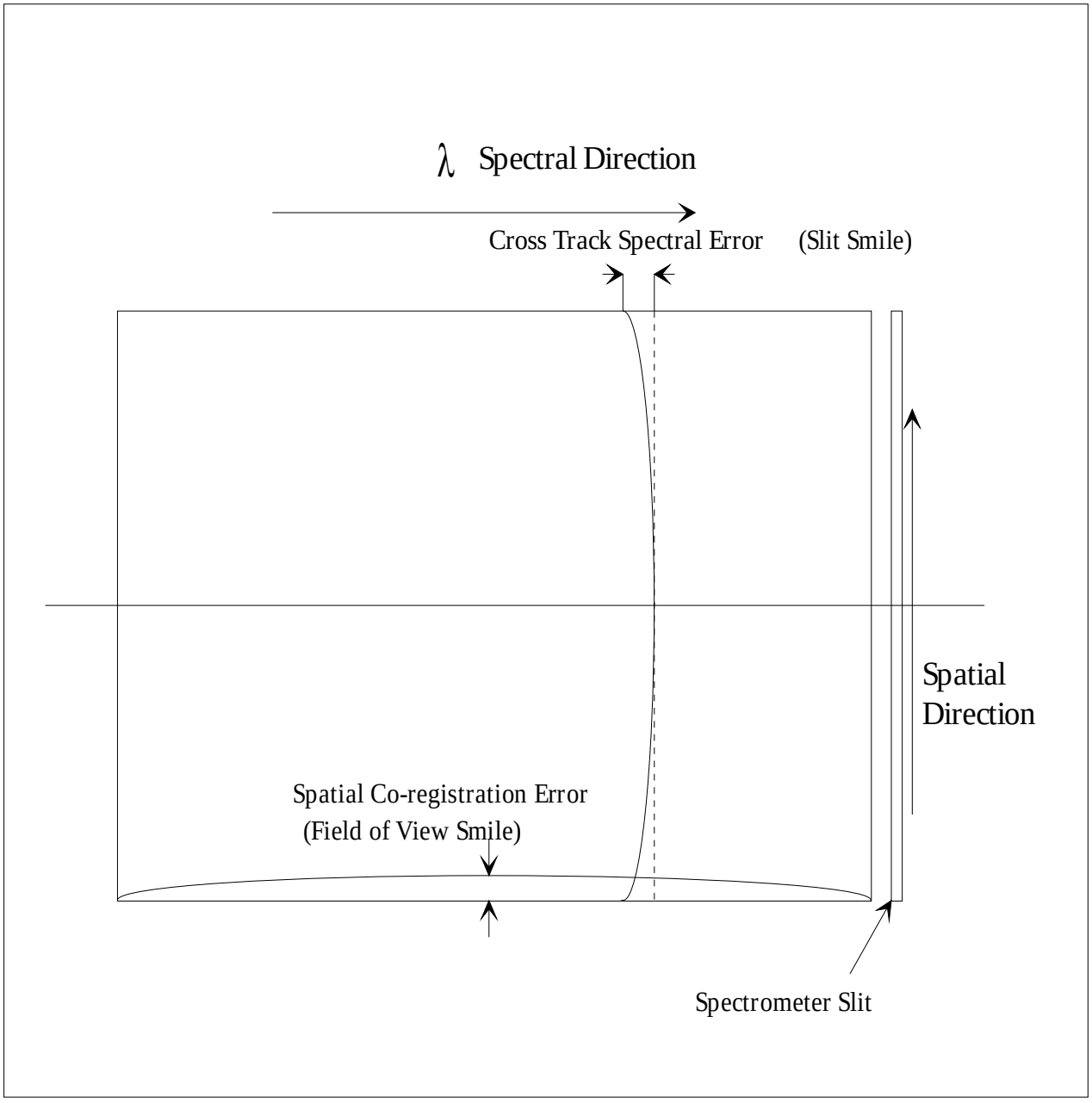
OPTIMIZATION SPECIFIC PARAMETERS - Any "gettable" parameters may be used as part of a user-defined merit function during the optimization process. Construction of this user-defined merit function is described in the "OPTIMIZATION" section of this manual.

SPECTROMETER CHARACTERISTICS

GETABLE REAL RAY SPECTROMETER CHARACTERISTICS (See explanation below)				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
CTSX and CTSY	wavelength #	pixel size (optional)	(not used)	Cross-track Spectral Co-registration Error at wavelength number "i".
SCEX and SCEY	pixel size (optional)	(not used)	(not used)	Spatial Co-registration Error for all defined wavelengths.

The REAL RAY SPECTROMETER CHARACTERISTICS are intended for use in the analysis of imaging spectrometers. These values are only valid for FOCAL or UFOCAL systems. "CTSX" and "CTSY" are measures of a characteristic known as Cross Track Spectral Co-registration Error measured either in the XZ or the YZ-plane of the image surface. "CTSX" is the appropriate choice if the spectral direction at the focal plane lies in the YZ-plane and the spatial direction lies in the XZ-plane. "CTSY" is the appropriate choice if the spectral direction at the focal plane lies in the XZ-plane and the spatial direction lies in the YZ-plane. They are calculated at a specified wavelength. For "CTSX", chief rays are traced at the specified wavelength at the top, middle and bottom of the XZ-plane field of view. CTSX is then the absolute value of the maximum spread of the YZ-plane components of these three rays. For "CTSY", chief rays are traced at the specified wavelength at the top, middle and bottom of the YZ-

plane field of view. CTSY is then the absolute value of the maximum spread of the XZ-plane components of these three rays. "SCEX" and "SCEY" are measures of a characteristic known as Spatial co-registration error measured either in the XZ or the YZ-plane of the image surface. They are calculated at every non-zero wavelength. For "SCEX", chief rays are traced at each non-zero wavelength at the top, middle and bottom of the XZ-plane field of view. Three preliminary values (one for each of the three field positions) of SCEX are calculated. Each preliminary value is equal to the maximum spread of the XZ-plane coordinates of the rays traced at the different wavelengths. The preliminary SCEX value with the largest absolute value becomes the final SCEX value. For "SCEY", chief rays are traced at each non-zero wavelength at the top, middle and bottom of the YZ-plane field of view. Three preliminary values (one for each of the three field positions) of SCEY are calculated. Each preliminary value is equal to the maximum spread of the YZ-plane coordinates of the rays traced at the different wavelengths. The preliminary SCEY value with the largest absolute value becomes the final SCEX value. If a square pixel size (in lens units) is input, then CTSX, CTSY, SCEX and SCEY are represented as a percentage of that pixel size. If no pixel size is input, then CTSX, CTSY, SCEX and SCEY will be in lens units. The next page contains a figure which graphically illustrates these spectrometer characteristics.



Spectrometer Characteristics

RETRIEVAL OF ALPHANUMERIC VALUES (THE "AGET" COMMAND) - Using the "AGET" command, many alphanumeric database items can be quickly retrieved into any one of the MAXREG alphanumeric storage registers. These retrieved values may then be displayed, manipulated interactively at the CMD level or manipulated from within a user-written macro or macro function.

AGET (database item name) , i , j , k „ r or
ASHOW (database item name) , i , j , k „ r - The "AGET" command retrieves into the alphanumeric storage register designated by "r", the program database item with name = "database item name". The numeric input values "i", "j" and "k" are not always required, and their use will be

made clear by referring to the "AGET" table starting on the next page. The default value for "r" is 1 and refers to the "A1" alphanumeric storage register. The "ASHOW" command, when used with a qualifier word, acts exactly as the "AGET" command does except that it also displays the retrieved data to the screen.

GETABLE ALPHANUMERIC PARAMETERS				
DATABASE ITEM NAME	**"i"**	**"j"**	**"k"**	**DESCRIPTION**
LI	(not used)	(not used)	(not used)	Returns the current Lens Identifier
LIC1	(not used)	(not used)	(not used)	Returns the current first Lens Identifier continuation line
LIC2	(not used)	(not used)	(not used)	Returns the current second Lens Identifier continuation line
LIC3	(not used)	(not used)	(not used)	Returns the current third Lens Identifier continuation line
LIC4	(not used)	(not used)	(not used)	Returns the current fourth Lens Identifier continuation line
CATNAME	surf#	(not used)	(not used)	Glass catalog name at surface "i".
GLANAME	surf#	(not used)	(not used)	Glass name at surface "i"
SURFLBL	surf#	(not used)	(not used)	Surface label at surface "i"

PART III - GENERAL OPTICAL ENGINEERING UTILITIES - The following section contains CMD level commands which can best be described as general optical engineering utilities. They are listed here in the order in which they were added to the program.

THIN LENS RELATIONSHIPS

OIF (P) , o , i , f - The "OIF" command calculates either the object distance "o", the image distance "i" or the focal length "f" given any of the other two values. The resultant value will be placed in the X-register and the LASTX register will be updated. If the optional qualifier word "P" is included, output will be displayed at the current output device. The quantities are related by the following equation:

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

Two of the three values must be entered with the third represented by default numerical input delimiting commas as appropriate. This command does not refer in any way to the "current" lens in the lens database. Zero input values are disallowed.

XXF (P) , x , x' , f - The "XXF" command calculates either the Newtonian object distance "x", the Newtonian image distance "x'" or the focal length "f" given any of the other two values. The resultant value will be placed in the X-register and the LASTX register will be updated. If the optional qualifier word "P" is included, output will be displayed at the current output device. The quantities are related by the following equation:

$$f^2 = -xx'$$

Two of the three values must be entered with the third represented by default numerical input delimiting commas as appropriate. This command does not refer in any way to the "current" lens in the lens database. Zero input values are disallowed.

XXFF (P) , x , x' , f , f' - The "XXFF" command calculates either the Newtonian object distance "x", the Newtonian image distance "x'" or the first focal length "f" or the second focal length "f'" given any of the other three values. The resultant value will be placed in the X-register and the LASTX register will be updated. If the optional qualifier word "P" is included, output will be displayed at the current output device. The quantities are related by the following equation:

$$ff' = -xx'$$

Three of the four values must be entered with the fourth represented by default numerical input delimiting commas as appropriate. This command does not refer in any way to the "current" lens in the lens database. Zero input values are disallowed.

RADIOMETRIC RELATIONSHIPS

RADUNITS (qualifier word) - The "RADUNITS" command sets the type of radiometric units used for all CMD level radiometric calculations. The "qualifier word" may be either "WATTS" or "PHOTONS". "WATTS" sets radiometric units to WATTS, (CENTIMETERS) ^{2} and DEGREES KELVIN. "PHOTONS" sets the radiometric units to PHOTONS, SECONDS, (CENTIMETERS) ^{2} and DEGREES KELVIN. The radiometric units remain set until changed by the user or until the program stops. The default value assumed for the "qualifier word" when the program starts is "WATTS". Issuing the "RADUNITS" command with no qualifier or with the special interrogator "?" causes the current radiometric units type to be displayed.

WIEN (P) , T - The "WIEN" command calculates either the wavelength of maximum radiant emittance or the wavelength of maximum radiant photon emittance depending on whether the current radiometric units are set to "WATTS" or "PHOTONS". The resultant wavelength value (in micron units) will be placed in the X-register and the LASTX register will be updated. If the optional qualifier word "P" is included, output will be displayed at the current output device. Wien's displacement law in terms of radiant emittance is:

$$\lambda_m T = 2897.8 \mu\text{-}^{\circ}K$$

Wien's displacement law in terms of radiant photon emittance is:

$$\lambda_m T = 3669.73 \mu\text{-}^{\circ}K$$

STEFBOLT (P) , T , λupper , λlower - "STEFBOLT" command calculates either the total radiant emittance or the total radiant photon emittance between "λlower" and "λupper". The value calculated depends on whether the current radiometric units are set to "WATTS" or "PHOTONS". "T" must be in degrees Kelvin and "λlower" and "λupper", if entered, must be in micron units. The resultant value will be placed in the X-register and

the LASTX register will be updated. If the optional qualifier word "P" is included, output will be displayed at the current output device. The default value for "λlower" is 0.0 microns. The default value for "λupper" is ∞. The units of total radiant emittance are WATTS-CM^{2}. The units of total radiant photon emittance are PHOTONS-SEC^{-1}-CM^{-2}. The total radiant emittance between "λlower" and "λupper" is:

$$W(T) = \int_{\lambda_{lower}}^{\lambda_{upper}} \frac{c_1}{\lambda^5} \frac{d\lambda}{e^{\frac{c_2}{\lambda T}} - 1}$$

The total radiant photon emittance between "λlower" and "λupper" is:

$$Q(T) = \int_{\lambda_{lower}}^{\lambda_{upper}} \frac{c_1'}{\lambda^4} \frac{d\lambda}{e^{\frac{c_2}{\lambda T}} - 1}$$

c1 = 37415.0 WATT-CM^{-2}-MICRON^{4}
c1' = 1.88365X10^{23} PHOTON-SEC^{-1}-CM^{-2}-MICRON^{3}
c2 = 1.4387.9 MICRON-DEG K

PLANK (P) , T , λ - The "PLANK" command calculates either the radiant emittance or the radiant photon emittance depending on whether the current radiometric units are set to "WATTS" or "PHOTONS". "T" must be in degrees Kelvin and λ must be in microns. The resultant value will be placed in the X-register and the LASTX register will be updated. If the optional qualifier word "P" is included, output will be displayed at the current output device. The units of radiant emittance are WATTS-CM^{2}-MICRON^{-1}. The units of total radiant photon emittance are PHOTONS-SEC^{-1}-CM^{-2}-MICRON^{-1}. Plank's law in terms of radiant emittance is:

$$W(\lambda, T) = \frac{c_1}{\lambda^5 \left[e^{\frac{c_2}{\lambda T}} - 1 \right]}$$

Plank's law in terms of radiant photon emittance is:

$$Q(\lambda, T) = \frac{c_1'}{\lambda^4 \left[e^{\frac{c_2}{\lambda T}} - 1 \right]}$$

c1 = 37415.0 WATT-CM^{-2}-MICRON^{4}
c1' = 1.88365X10^{23} PHOTON-SEC^{-1}-CM^{-2}-MICRON^{3}
c2 = 1.4387.9 MICRON-DEG K

GAUSSIAN BEAM RELATIONSHIPS

RAYLEIGH (w_o) , (λ)- he Rayleigh Range is the distance from a gaussian beam's beam waist to a region which can be considered to be in the "far field" of the beam. The equation used here was taken from "Lasers" by Siegman. The "RAYLEIGH" command calculates the rayleigh range (b) in current lens units for a gaussian beam which has a beam waist diameter "w_0" at the 1/e^{2} point. The wavelength for the calculation is λ. By default, the value of w_0 is 2 times the current "wry" value assigned to the current lens database. The default value for λ is the control wavelength assigned for the current lens database. The value for the Rayleigh Range is displayed and also placed into the X-register. If the optional qualifier word "ACC" is issued, the value display is suppressed.

$$b = \frac{2\pi w_0^2}{\lambda}$$

GRAZING INCIDENCE OPTICS

K0 , cv , κ , Zo - The "K0" command calculates and displays the value of the "K_0" term used in the apo-vertex equations described in "Reflective Optics" by Dietrich Korsch, Academic Press, Inc., 1991. The input values are the base curvature "cv"; which is just the reciprocal of the base radius of curvature "rd", "κ", the conic constant and "Z_0", the distance from the surface vertex to the center of the section of the surface used. A figure illustrating "Z_0" is included as part of the description of the TYPE 18 special surface in the SPECIAL SURFACE section of this manual. The relationship of "K_0" to "cv" , "κ" and "Z_0" is given in the following equation:

$$K_0 = \frac{1}{cv} + \left[(1 + \kappa) \times Z_0 \right]$$

The resultant K_0 value is left in the X-register.

CVG, K_0 , κ , Z_0 - The "CVG" command calculates and displays the value of the surface curvature "cv" term. The input values are the term "K_0", "κ", the conic constant and "Z_0", the distance from the surface vertex to the center of the section of the surface used. The relationship of " cv" to " K_0 " , "κ" and "Z_0" is given in the following equation:

$$cv = \frac{1}{K_0 + \left[(1 + \kappa) \times Z_0 \right]}$$

The resultant curvature value is left in the X-register.

FOCI (R or C) , nw1 , κ - The "FOCI" command calculates and displays the position or positions of the focus or foci of parabolic, hyperbolic and prolate spheroidal shaped optical surfaces relative to the surface's vertex. "nw1" is either the radius of curvature or the curvature depending upon whether the "R" or "C" qualifier word is used. "κ" is the conic constant. "κ" is -1.0 for a parabola, is between -1.0 and 0.0 for a prolate spheroid and is less than -1.0 for a hyperbola. The units are understood to be the units of the radius of curvature as used in the calculation. Negative distances are understood to lie to the left of the surface vertex while positive distances are understood to lie to the right. Surfaces with negative curvatures or radii have their centers of curvature to the left of the surface vertex. Surfaces with positive curvatures or radii have their centers of curvature to the right of the surface vertex. The default qualifier is understood to be "R" for radius of curvature input. The resultant focus or focii location(s) are left in the X or the X and Y-registers.

RHO (R or C) , nw1 , κ , Z - The "RHO" command calculates and displays the distance from the local Z-axis, measured perpendicular to the local Z-axis, of a point which lies a distance "Z" from the surface vertex of a conic surface. "nw1" is either the radius of curvature or the curvature depending upon whether the "R" or "C" qualifier word is used. "κ" is the conic constant. "κ". "Z" is a distance measured from the surface vertex along the local Z-axis. The units are understood to be the units of the radius of curvature and Z-position as used in the calculation. Negative Z-distances are understood to lie to the left of the surface vertex while positive Z-distances are understood to lie to the right. Surfaces with negative curvatures or radii have their centers of curvature to the left of the surface vertex. Surfaces with positive curvatures or radii have their centers of curvature to the right of the surface vertex. The default qualifier is understood to be "R" for radius of curvature input. The resultant RHO value is left in the X-register.

Z0 (R or C) , nw1 , κ , RHO - The "Z0" command calculates and displays the Z-position(s) along a conic's local Z-axis which are also a distance "RHO" from the conic's local Z-axis. "RHO" is measured perpendicular to the conic's local Z-axis. "nw1" is either the radius of curvature or the curvature depending upon whether the "R" or "C" qualifier word is used. "κ" is the conic constant. "κ". "RHO" is the distance measured from the local Z-axis, perpendicular to the local Z-axis, to a point of intersection with the conic. The units are understood to be the units of the radius of curvature and "RHO". Negative Z-distances are understood to lie to the left of the surface vertex while positive Z-distances are understood to lie to the right. Surfaces with negative curvatures or radii have their centers of curvature to the left of the surface vertex. Surfaces with positive curvatures or radii have their centers of curvature to the right of the surface vertex. The default qualifier is understood to be "R" for radius of curvature input. The resultant value(s) are left in the X or the X and Y-registers.

RTOD , r , e - The "RTOD" command calculates and displays "d", the distance from a conic's focus to the nearest direxrtix line measured along the conic's local Z-axis. "r" is the base radius of curvature of the conic and "e" is the conic's eccentricity. Only conics with real eccentricities are supported by this command. A positive "r" value yields a negative "d" value and vice versa. "d" is just "r" divied by "e". "e" must be non-zero.The resultant value is left in the X-register.

DTOR , r , e - The "DTOR" command calculates and displays the conic base radius of curvature "r". "d" is the distance from a conic's focus to the nearest direxrtix line measured along the conic's local Z-axis and "e" is the conic's eccentricity. Only conics with real eccentricities are supported by this command. A positive "d" value yields a negative "r" value and vice versa. "r" is just "d" multiplied by "e". "e" must be non-zero.The resultant value is left in the X-register.

ETOCC , e , iflag - The "ETOCC" command calculates and displays the conic constant "cc",given the conic's eccentricity "e". If "iflag" is set to -1.0, the eccentricity is understood to be imaginary. The conic constant "cc" is just equal to $-e^2$ .The resultant value is left in the X-register.

CCTOE , cc - The "CCTOE" command calculates and displays the conic eccentricity "e",given the conic constant "cc". The conic's eccentricity "e" is just equal to $\sqrt{-cc}$. The resultant value is left in the X-register.

PART IV - GENERAL PURPOSE COMMANDS - The commands described in PART IV have their greatest usage inside Macros but may be used from the CMD level in an interactive way as well.

INDIRECT ADDRESSING OF COMMANDS

W1 (qualifier or numeric word #1) through **W5 (qualifier or numeric word #1)** - The "W1" through "W5" commands are special purpose commands which provide a form of indirect addressing for all other program commands that accept numeric input. They act in the following way: If commands "W1" through "W5" are entered with no "qualifier word" and no "numeric word #1", then the current value stored in the "X" or accumulator register will be used as the numeric word #1, #2, #3, #4 or #5, respectively, for the next program command (excluding other "W1" through "W5" commands). If commands "W1" through "W5" are entered with a qualifier word equal to the name of any named storage register, then the current value stored in that named register will be used as the numeric word #1, #2, #3, #4 or #5, respectively, for the next program command (excluding other "W1" through "W5" commands). If commands "W1" through "W5" are entered with numeric word #1 in the range 1 to MAXREG, then the current value stored in the general purpose storage register designated by that numeric word #1 entry will be used as the numeric word #1, #2, #3, #4 or #5, respectively, for the next program command (excluding other "W1" through "W5" commands). The following example will set the new "WV" values to be equal to the old "WV" values divided by 1.5. These are all CMD level command issued one after another from the command line. The "W1" through "W5" commands act like CMD level "NSUB" commands.

```
GET WV 1
STO 1
GET WV 2
STO 2
GET WV 3
STO 3
GET WV 4
STO 4
GET WV 5
STO 5
SET X 1.5
STO DIV 1
STO DIV 2
```

STO DIV 3
STO DIV 4
STO DIV 5
U L
W1 1
W2 2
W3 3
W4 4
W5 5
WV
EOS

PROMPTED INPUT - The program prompt has been discussed in the INTRO section of this manual. In general, the user issues a command from that prompt and the program does something. The next three commands allow the user to cause input to be prompted for. They are CMD level commands but they only have value when issued from within a macro.

PROMPT (character string of up to 20 characters) - The "PROMPT" command allows the user to set up a character string of up to 20 characters which will be used as part of the prompting string for a subsequent issuance of a "PREAD" command. This string will be appended to the string "INPUT ". The default prompt is a single blank space. Once set, the prompt remains set until changed or until the program ends. This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

PREAD The "PREAD" command causes a prompted read from the keyboard to be performed. The prompt "INPUT " followed by the last user defined prompt string will be displayed. The program will pause until input has been issued via the keyboard and the ENTER key has been pressed. The program will wait forever for the press of the ENTER key or until the computer power is interrupted. The input may be anything usable from the keyboard. It will be treated as a character value by the program. Up to 80 characters may be input. From within macros, if string comparisons are made, the lengths of those comparisons will be set by the length of the comparison test string. If, for example, the comparison test string is "END", then only the first three characters of the input string read by the last "PREAD" command will be compared. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5". This command is not supported in the "THE PROGRAM AS A SUBROUTINE" mode.

ATON The "ATON" command causes the first 23 characters of the last value read by the "PREAD" command to be converted to a numeric value. If this conversion process is successful, the numeric value will be stored in the X-register which will be described in the next section. If it can not be converted, a message to that effect will be displayed, the X-register will be left unchanged and an error flag will be set in the program which may be tested using the "BRERR" or "Branch on Read ERRor" command which is described in the MACRO section of this manual.. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

STOAX , i - The "STOAX" command causes the last string value read by the "PREAD" command to be stored in alphanumeric storage register "i". The alphanumeric storage registers are discussed later in the CMD section. Valid values for "i" range from 1 to MAXREG. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

ARCL , i - The "ARCL" command causes the string value stored in alphanumeric storage register "i" to be recalled so that it may be operated upon by an "ATON" command or so that it may be used in a macro with the "QRSUB" or "CRSUB" commands. The alphanumeric storage registers are discussed later in the CMD section. Valid values for "i" range from 1 to MAXREG. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

ARITHMETIC PROCESSING COMMANDS - There is a set of eight symbolic storage registers available for direct calculation and for calculations within a macro. These registers are named "A", "B", "C", "D", "E", "F", "G" and "H". These registers, along with an accumulator register also called the "X"-register, are known as the primary named registers. There also exists a number of secondary named registers. These secondary registers are used to form the real and imaginary stacks. The secondary named registers are named "Y", "Z", "T", "IX", "IY", "IZ" and "IT". There are also two other special tertiary named registers which keep track of the previous values of the "X" and "IX" registers. They are the "LASTX" and "LASTIX" registers. There also exists a set of MAXREG general purpose registers with their own separate set of manipulation commands. Only the primary and secondary named registers are saved and reloaded by the "SAVE" and "RELOAD" macro processing commands discussed in the MACRO section. When the program begins execution, all registers are initialized to zero. They are **not** automatically re-initialized again at any time during program execution. In the commands which follow, blank entry for "register name" indicates that the register to be used is the accumulator. The accumulator may, however, be called by name if so desired. Its names are "X" or "ACC". "register name" means "X", "Y", "Z", "T", "IX", "IY", "IZ", "IT", "A", "B", "C", "D", "E", "F", "G" and "H". It never refers to the numbered, general purpose registers.

SET (target register name) , (i or source register name) - The "SET" command places either the number "i" into the named target register or it places the value contained in the named source register into the named target register. This command is valid for both the primary and secondary named registers. There is a short cut to setting these registers as well. Enter the target register name with an equal sign appended then a space or comma (necessary) and finally either the numerical value to which the target register is to be set to, or the name of the source register which contains the value which is to be moved to the target register. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

SET C 25.67
(or)
C= 25.67
(or)
SET A 25.67
(then)
SET C A
(or)
C= A

PI (register name) - The "PI" command places the value of π in double precision (3.141592653589793D0) into the named register. This command is valid for both the primary and secondary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

MOVE register name - The "MOVE" command moves the number stored in the named register to the accumulator. This command is valid for both the primary and secondary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

LASTX - The "LASTX" command moves the contents of the "LASTX" register into the accumulator. The previous accumulator value is moved to the "LASTX" register. This is a swap operation. This is similar to the "LASTX" key on some calculators. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

LASTIXThe "LASTIX" command moves the contents of the imaginary "LASTIX" register into the "IX" register. The previous "IX" register is moved to the "LASTIX" register. This is a swap operation analogous to "LASTX". This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

INCR (register name) , i - The "INCR" command adds the number "i" to the number in the named register, and the result is placed in the named register, i.e. the named register is incremented by "i". If "i" is not specified, the default value is taken as 1.0. The accumulator is unaffected unless no entry is made for the register name or unless the register "X" or "ACC" is named. This command is valid for both the primary and secondary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

PLUS (register name) - The "PLUS" command adds the number in the named register to the accumulator, and the result is left in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

MINUS (register name) - The "MINUS" command subtracts the number in the named register from the number in the accumulator, and the result is left in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

MPY (register name) - The "MPY" command multiplies the number in the accumulator by the number in the named register, and the result is left in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

DIV (register name) - The "DIV" command divides the number in the accumulator by the number in the named register, and the result is left in the accumulator. This command is only valid for the primary named registers. If the divisor is zero, the accumulator is set to zero. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

SQRT (register name) - The "SQRT" command causes the square root of the number in the named register to be placed in the accumulator. If the argument is zero, the accumulator is set to zero. If the argument is negative, an error message is printed and the accumulator is unchanged. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

SIN (register name) - The "SIN" command causes the sine of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The value is assumed to be in radian measure. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

COS (register name) - The "COS" command causes the cosine of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The value is assumed to be in radian measure. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

TAN (register name) - The "TAN" command causes the tangent of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The value is assumed to be in radian measure. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

SINH (register name) - The "SINH" command causes the hyperbolic sine of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The value is assumed to be in radian measure. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

COSH (register name) - The "COSH" command causes the hyperbolic cosine of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The value is assumed to be in radian measure. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

TANH (register name) - The "TANH" command causes the hyperbolic tangent of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The value is assumed to be in radian measure. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

ASIN (register name) - The "ASIN" command causes the arc-sine (in radians) of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

ACOS (register name) - The "ACOS" command causes the arc-cosine (in radians) of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

ATAN (register name) - The "ATAN" command causes the arc-tangent (in radians) of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

ABS (register name) - The "ABS" command causes the absolute value of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

EXP (register name) - The "EXP" command causes the exponential (e^X) of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The maximum allowable value for the register value is 88.0. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

LN (register name) - The "LN" command causes the natural logarithm of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. If the register value is less than or equal to 0.0, the accumulator is set to 0.0. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
LOG10 (register name) - The "LOG10" command causes the base 10 logarithm of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. If the register value is less than or equal to 0.0, the accumulator is set to 0.0. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
FACT (register name) - The "FACT" command causes the factorial of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. The argument must be positive and must have a zero fractional part. Arguments larger than 33 are not allowed. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
SGN (register name) - The "SGN" command causes the SIGNUM function of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

Sgn(x) Values		
0	IF	x=0
+1	IF	x>0
-1	IF	x<0

RECIP (register name) The "RECIP" command causes the reciprocal of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. If the argument is zero, the accumulator is set to zero. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
INTGR (register name) - The "INTGR" command causes the integer portion of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. This is truncation and not rounding. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
FRAC (register name) - The "FRAC" command causes the fractional portion of the number in the named register to be placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
POW (register name) - The "POW" command causes the number in the accumulator to be raised to the power of the number in the named register, and the result is left in the accumulator. This command is only valid for the primary named registers. If the number in the accumulator and the number in the named register are both zero, the result of this operation is 1.0. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
STORE (register name) - The "STORE" command causes the number in the accumulator to be placed in the named register. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
RAND - The "RAND" command returns a uniform random deviate (uniformly distributed random value) in the range 0.0 to 1.0 to the X-register and a gaussian normally distributed deviate with mean value 0.0 and unit variance 1.0 (normally distributed value with mean 0.0 and one sigma value 1.0) to the Y-register. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
NEWSEED - The random number generator used for all program random number calculations is automatically initialized each time the program starts. The "NEWSEED" command is used to re-initialize this random number generator at any time during program operation.
SEED , (seed value) - The random number generator used for all program random number calculations is automatically initialized each time the program starts and each time the "NEWSEED" command is issued. The "SEED" command is used to re-specify a "user-provided" seed value. The user-supplied "seed" must not be less than 0.001 and not greater than 1.0. The program uses the frist 5 significant figures of the input seed, thus and input seed of 0.1234567 would cause the new seed to be 0.12345. Issued with the interrogator "?", "SEED" displays the new seed value.
MOD , i , j - The "MOD" command causes the MODULO function of the arguments "i" and "j" to be calculated and returned to the accumulator. "i" and "j" are assumed to be floating point numbers. No other registers are involved. If "j" is equal to zero, the modulo is not defined and 0.0 is returned to the accumulator. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
ATAN2, i , j - The "ATAN2" command causes the FORTRAN "ATAN2" function of the arguments "i" and "j" to be calculated and returned (in radians) to the accumulator. No other registers are involved. "i" and "j" are assumed to be floating point numbers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
DTR (register name) - The "DTR" command causes the number in the named register (assumed to be an angular value in decimal degrees) to be converted to radian measure and placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
RTD (register name) - The "RTD" command causes the number in the named register (assumed to be an angular value in radians) to be converted to decimal degree measure and placed in the accumulator. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
CHS (register name) - The "CHS" command causes the number in the named register to be moved to the accumulator where its sign is changed. This command is only valid for the primary named registers. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".
J1 , x - The "J1" command causes the value of the Bessel function $J_1(x)$, for any real "x" from -1.0D+15 to +1.0D+15, to be calculated and placed in the X-register. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5". Whenever the value of the "X" or "IX" registers are changed, the previous values are placed in the "LASTX" or "LASTIX" registers. This behavior is true program wide.

GENERAL PURPOSE REGISTERS - The following commands work only upon the MAXREG general purpose storage registers. These registers are initially set to zero and only changed by the user and by certain commands where specifically documented.

RCL , i - The "RCL" command causes the number stored in register "i" to be recalled into the accumulator. "i" is a positive integer in the range 1 to MAXREG. The register value remains unchanged.

STO , i , (optional value) - If the "(optional value)" is not included, the "STO" command causes the number in the accumulator to be stored into register "i". "i" is a positive integer in the range 1 to MAXREG. If the "(optional vale)" is included, it is stored in the specified register. The accumulator remains unchanged in either case. Qualifier words may also be specified with the "RCL" and "STO" commands. These qualifier words modify the value to be transferred according to the rules below. This is storage register arithmetic similar to that found on some calculators. For division, if the accumulator (X-register) is zero, zero is stored or recalled. The "RCL" and "STO" commands are also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

Qualifier Word	Value Stored or Recalled
PLUS	Register "i" + "ACC"
MINUS	Register "i" - "ACC"
MPY	Register "i" * "ACC"
DIV	Register "i" / "ACC"

MAXVAL - The "MAXVAL" command stores the maximum of all values in the general purpose registers into the "X" register. It also stores the general purpose register number containing this maximum value into the "Y" register. The old "Y" register is copied into the "T" register and the old "X" register is copied into the "Z" register. The value of the "LASTX" register is updated. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

MINVAL - The "MINVAL" command stores the minimum of all values in the general purpose registers into the "X" register. It also stores the general purpose register number containing this minimum value into the "Y" register. The old "Y" register is copied into the "T" register and the old "X" register is copied into the "Z" register. The value of the "LASTX" register is updated. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

SHOW i , j - The "SHOW" command, when issued with no qualifier word input, is used to display the contents of one or more of the general purpose storage registers. If only the first numeric word is input, then the contents of general purpose storage register "i" will be displayed. If "i" and "j" are both input, the contents of registers "i" through "j" will be displayed. This is the first usage of the "SHOW" command. The second usage is described in connection with the "GET" command later in this manual section. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

SAVEREG i , j - The "SAVEREG" command outputs the values of general purpose storage registers "i" through "j" in a format which is readable by the program. Using this command in conjunction with "OUT" and "IN" provides the user with a way of saving and reloading all of the general purpose numeric storage registers from one program session to the next. This is advantageous in cases wherein the general purpose registers are being used as optimization variables or operands or as definition parameters from within the USERSURF.FOR or GOES.FOR subroutines.

CLEARREG i , j - The "CLEARREG" command resets the values of general purpose storage registers "i" through "j" to zero.

USER DEFINED FUNCTIONS

USERFUNC , x , y , z , t , i - The "USERFUNC" command causes the value of a user defined function, defined in the subroutine USERFUNC.FOR to be returned either to general purpose storage register "i", if "i" is explicitly entered or to the accumulator (x-register) is "i" is not explicitly entered. The values "x", "y", "z" and "t" are passed to the function. If these values are not explicitly entered, then the current values in the stack registers "X", "Y", "Z" and "T" will be passed to the function. The user of this command requires access to the program source code and access to the current compiler and graphics package software used to build this program.

USER DEFINED SUBROUTINE

USERSUBR - The "USERSUBR" command causes the user-written subroutine USERSUBR.FOR to be called. Anything may be included in this subroutine. The routine can take numeric, qualifier and string input. The user is 100% responsible for what this routine does.

ALPHANUMERIC REGISTERS - There are MAXREG alphanumeric storage registers. The following commands work only upon these MAXREG alphanumeric storage registers. These registers are initially set to blank and only changed by the user. Within a macro, the QSUB command may be used to modify these commands.

ASTO (qualifier word) (alphanumeric string) - The "ASTO" command causes the full alphanumeric string (up to 80 characters) to be stored in the alphanumeric storage register designated by the qualifier word. The string is later used by other program options, such as optimization and tolerancing, to clarify and annotate output. The valid qualifier words range from "A1" through "A(MAXREG)" and designate alphanumeric registers 1 through MAXREG. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

CLASTO - The "CLASTO" command causes the contents of the MAXREG alphanumeric storage registers to be set to blank character values. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

STOAX , i - The "STOAX" command causes the last string value read by the "PREAD" command to be stored in alphanumeric storage register "i". This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

ARCL , i The "ARCL" command causes the string value stored in alphanumeric storage register "i" to be recalled so that it may be operated upon by an "ATON" command or so that it may be used in a macro with the "QRSUB" or "CRSUB" commands. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

AWRITE , i - The "AWRITE" command causes the string value stored in alphanumeric storage register "i" to be displayed on the current output device. This command is also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

THE STACK REGISTERS - Unlike RPN calculators, there is no automatic stack push in this program. The only way the stack gets "pushed" is if the "ENT", "ENTI" or "ENTC" commands are issued. The secondary and tertiary named registers are used to provide a 4-level complex arithmetic

RPN (Reverse Polish Notation) stack made up of the real stack ("X", "Y", "Z" and "T") and the imaginary stack ("IX", "IY", "IZ" and "IT"). The "LASTX" and "LASTIX" registers are provided to track the "X" and "IX" register previous values. All stack register commands are also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5". Values may be entered into these stack registers directly through the "SET" command or the values may be entered into the registers "X" and "IX" and then manipulated using the following commands:

ENT - Each time the "ENT" command is issued, the "Z" register is copied into the "T" register, then the "Y" register is copied into the "Z" register, then the "X" register is copied into the "Y" register. The value of the accumulator ("X" register) is left unchanged. This command pushes the real stack.

ENTI - Each time the "ENTI" command is issued, the "IZ" register is copied into the "IT" register, then the "IY" register is copied into the "IZ" register, then the "IX" register is copied into the "IY" register. The value of the "IX" register is left unchanged. This command pushes the imaginary stack.

ENTC The "ENTC" command is a combination of the "ENT" command and the "ENTI" command. This command pushes the complex stack.

PULL - The "PULL" command is the inverse of the "ENT" command. The "Y" register is copied into the "X" register, then the "Z" register is copied into the "Y" register, then the "T" register is copied into the "Z" register. The "T" register is left unchanged. The "LASTX" register is updated.

IPULL - The "IPULL" command is the inverse of the "ENTI" command. The "IY" register is copied into the "IX" register, then the "IZ" register is copied into the "IY" register, then the "IT" register is copied into the "IZ" register. The "IT" register is left unchanged. The "LASTIX" register is updated.

CPULL - The "CPULL" command is a combination of "PULL" and "IPULL". It operates on the complex stack.

RUP - The "RUP" command rolls up the values in the real stack registers. Each time it is issued, the value in the "X" register moves into the "Y" register, the value in the "Y" register moves to the "Z" register, the value in the "Z" register moves to the "T" register, and the value in the "T" register moves to the "X" register. The "LASTX" register is updated each time.

IRUP - The "IRUP" command rolls up the values in the imaginary stack registers "IX", "IY", "IZ" and "IT" in the same way that "RUP" rolled up the values in the real stack registers. The "LASTIX" register is updated each time.

CRUP - The "CRUP" command rolls up the values in the complex stack registers. It is a combination of the "RUP" and "IRUP" commands.

RDN - The "RDN" command rolls down the values in the real stack registers "X", "Y", "Z" and "T". Each time it is issued, the value in the "X" register moves into the "T" register, the value in the "Y" register moves into the "X" register, the value in the "Z" register moves into the "Y" register and the value in the "T" register moves into the "Z" register. The "LAST" register is updated each time.

IRDN - The "IRDN" command rolls down the values in the imaginary stack registers "IX", "IY", "IZ" and "IT". Each time it is issued, the value in the "IX" register moves into the "IT" register, the value in the "IY" register moves into the "IX" register, the value in the "IZ" register moves into the "IY" register and the value in the "IT" register moves into the "IZ" register. The "LASTIX" register is updated each time.

CRDN - The "CRDN" command is a combination of the "RDN" and "IRDN" commands.

CLSTK - The "CLSTK" command clears the real stack registers "X", "Y", "Z" and "T" to zero. The "LASTX" register is updated.

CLSTKI - The "CLSTKI" command clears the imaginary stack registers "IX", "IY", "IZ" and "IT" to zero. The "LASTIX" register is updated.

CLSTKC - The "CLSTKC" command clears the complex stack registers. It is a combination of the "CLSTK" and "CLSTKI" commands.

CLREG - The "CLREG" command clears to zero all the primary, secondary and tertiary named registers. It also clears the index and test registers which are described in detail in the MACRO section of this manual. Use it carefully!

CLGREG - The "CLGREG" command clears to zero all numeric and alpha-numeric general purpose storage registers. Use it carefully!

CLX and CLIX - The "CLX" and "CLIX" commands clear the "X" and "IX" registers respectively. The "LASTX" and "LASTIX" registers are updated.

X-Y - The "X-Y" command exchanges the values in the "X" and "Y" register. The "LASTX" register is updated.

IX-IY - The "IX-IY" command exchanges values in the "IX" and "IY" registers. The "LASTIX" register is updated.

+ - The "+" command causes the values in the "X" and "Y" registers to be added together with the result left in the "X" register. The "LASTX" register is updated, and the real stack is "pulled" down.

- - The "-" command causes the value in the "X" register to be subtracted from the value in the "Y" stack register with the result left in the "X" register. The "LASTX" register is updated, and the real stack is "pulled" down.

***** - The "*" command causes the values in the "X" and "Y" stack registers to be multiplied together with the result left in the "X" register. The "LASTX" register is updated, and the real stack is "pulled" down.

/ - The "/ " command causes the value in the "Y" register to be divided by the value in the "X" register with the result left in the "X" register. The "LASTX" register is updated, and the real stack is "pulled" down. If the contents of the "X" register are equal to 0.0, then no division is performed, a warning is printed and the real stack is left unchanged).

I+ - The "I+" command causes the values in the "IX" and "IY" stack registers to be added together with the result left in the "IX" register. The "LASTIX" register is updated, and the imaginary stack is "pulled" down.

I- The "I-" command causes the value in the "IX" register to be subtracted from the value in the "IY" register with the result left in the "IX" register. The "LASTIX" register is updated and the imaginary stack is "pulled" down.

I* - The "I*" command causes the values in the "IX" and "IY" registers to be multiplied together with the result left in the "IX" register. The "LASTIX" register is updated, and the imaginary stack is "pulled" down.

I/ - The "I/" command causes the value in the "IY" register to be divided by the value in the "IX" stack register with the result left in the "IX" register. The "LASTIX" register is updated, and the imaginary stack is "pulleddown. If the contents of the "IX" register are equal to 0.0, then no division is performed, a warning is printed and the imaginary stack is left unchanged).

C+ - The "C+" command is a combination of ("+") and ("I+").

C- - The "C-" command is a combination of ("-") and ("I-").

C* - The "C*" command is a combination of ("*") and ("I*").

C/ - The "C/" command is a combination of ("/") and ("I/").

YX** - The "Y**X" command causes the value in the "Y" register to be raised to the power of the value in the "X" register. The result is left in the "X" register, and the real stack is "pulled" down.

IYIX** - The "IY**X" command causes the value in the "IY" register to be raised to the power of the value in the "IX" register. The result is left in the "IX" register, and the imaginary stack is "pulled" down.
CYCX** - The "CY**CX" command is a combination of the "Y**X" and the "IY**IX" commands.
P-R - The "P-R" command converts the R(radius) and Ø (angular) values stored in the "X" and "Y" registers from polar to rectangular coordinates. The results are stored in the "X" and "Y" registers, the X-result stored in the "X" register and the Y-result stored in the "Y" register. Ø is assumed to be in decimal degrees.
R-P - The "R-P" command converts the X and Y values stored in the "X" and "Y" registers from rectangular to polar coordinates. The results are stored in the "X" and "Y" registers, the R(radius)-result stored in the "X" register and the Ø (angular)-result stored in the "Y" register. Ø is represented in decimal degrees.
CYL-R - The "CYL-R" command converts the R, Ø and Z values stored in the "X", "Y" and "Z" registers from right-handed cylindrical to rectangular coordinates. The results are stored in the "X", "Y" and "Z" registers, the X-result stored in the "X" register, the Y-result stored in the "Y" register and the Z-result stored in the "Z" register. Ø is assumed to be in decimal degrees.
R-CYL - The "R-CYL" command converts the X, Y and Z values stored in the "X", "Y" and "Z" registers from rectangular to right-handed cylindrical coordinates. The results are stored in the "X", "Y" and "Z" registers, the R-result stored in the "X" register, the Ø-result stored in the "Y" register and the Z-result stored in the "Z" register. Ø is represented in decimal degrees.
SP-R - The "SP-R" command converts the R, Ø and PHI values stored in the "X", "Y" and "Z" registers from right-handed spherical to rectangular coordinates. The results are stored in the "X", "Y" and "Z" registers, the X-result stored in the "X" register, the Y-result stored in the "Y" register and the Z-result stored in the "Z" register. Ø and PHI are assumed to be in decimal degrees.
R-SP - The "R-SP" command converts the X, Y and Z values stored in the "X", "Y" and "Z" registers from rectangular to right-handed spherical coordinates. The results are stored in the "X", "Y" and "Z" registers, the R-result stored in the "X" register, the Ø-result stored in the "Y" register and the PHI-result stored in the "Z" register. Ø and PHI are represented in decimal degrees.
RE-IM - The "RE-IM" command exchanges the real and imaginary stacks. The "LASTX" and "LASTIX" registers are updated. This is an expanded version of the "X-Y" command.
H-HMS - The "H-HMS" command converts the value in the "X" register (assumed to be a value in decimal hours or decimal degrees) to hours-minutes-seconds or degrees-minutes-seconds format. The "LASTX" register is updated.
HMS-H - The "HMS-H" command converts the value in the "X" register (assumed to be a value in hours-minutes-seconds or degrees-minutes-seconds) to decimal hours or decimal degrees format. The "LASTX" register is updated.

VECTOR OPERATIONS - The following commands allow for the input of two, three component vectors and allow for DOT and CROSS products to be formed from them
AVEC , x , y ,z - The "AVEC command is used to set the A-vector's components to "x", "y" and "z" Default values are assumed to be zero as long as at least one explicit value is input. Issued with the "?" operator or with no input, the current values of "x", "y" and "z" are displayed.
BVEC , x , y , z - The "BVEC command is used to set the B-vector's components to "x", "y" and "z" Default values are assumed to be zero as long as at least one explicit value is input. Issued with the "?" operator or with no input, the current values of "x", "y" and "z" are displayed.
DOT (N) - The "DOT command causes the vector DOT product of A and B to be computed, placed in the X-register and displayed to the current output device. If the qualifier word "N" is included, the display is suppressed.
CROSS (N) - The "CROSS command causes the vector CROSS product of A and B to be computed. The x-component is placed in the x-register, the y-component is placed in the y-register and the z-component is placed in the z-register. The values are displayed to the current output device. If the qualifier word "N" is included, the display is suppressed.

THE MIN/MAX REGISTERS - Many times it is of use to find the maximum or minimum value of a set of values. The MIN/MAX registers serve this purpose. There are 100 MIN registers and 100 MAX registers (1 to 100). These registers may be reset to any starting value using the commands "RESETMIN" and "RESETMAX"
RESETMIN , n , v - The "RESETMIN command is used to reset the MIN register designated by the integer "n" to value "v". If "n" is not explicitly entered, all 100 MIN registers will be reset. The default value for "v" is +1.0D+300.
RESETMAX , n , v - The "RESETMAX command is used to reset the MAX register designated by the integer "n" to value "v". If "n" is not explicitly entered, all 100 MAX registers will be reset. The default value for "v" is -1.0D+300. Any numeric value in the x-register (or accumulator) may be "tested" against a current value in a NIM or MAX register. If the value in the x-register is tested against a MIN register value and the value in the x-register is numerically less than the value in that MIN register, then the value in the accumulator is copied into that MIN register and becomes the new minimum value. Likewise, if the value in the x-register is tested against a MAX register value and the value in the x-register is numerically greater than the value in that MAX register, then the value in the accumulator is copied into that MAX register and becomes the new maximum value.
STOREMIN , n - The "STOREMIN command is used to test if the current value in the x-register is less than the value in the MIN register designated by "n". The default for "n" is 1, for the first MIN register. If the value in the x-register is less than the value in the referenced MIN register, then the value in the x-register is copied into that MIN register and becomes the new minimum vale.
STOREMAX , n - The "STOREMAX command is used to test if the current value in the x-register is greater than the value in the MAX register designated by "n". The default for "n" is 1, for the first MAX register. If the value in the x-register is greater than the value in the referenced MAX register, then the value in the x-register is copied into that MAX register and becomes the new maximum value. Values in MIN and MAX registers may be copied back into the x-register at any time using the "GET MINREG" and "GET MAXREG" commands described in the "GET" section of this manual section.

UNITS CONVERSIONS - The following commands assume that the value in the X-register is representative of a quantity in "from units". The commands convert this value to specific "to units". These commands ar also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5".

From Units	To Units	Command Name
in	mm	IN-MM

in	cm	**IN-CM**
in	m	**IN-M**
mm	in	**MM-IN**
cm	in	**CM-IN**
m	in	**M-IN**

LINEAR, PARABOLIC AND CUBIC INTERPOLATION - The following seven commands give the program the ability to do linear 2-point, parabolic 3-point and cubic 4-point interpolation of data:
X1Y1= , i , j and
X2Y2= , i , j and
X3Y3= , i , j and
X4Y4= , i , j
The "X1Y1=", X2Y2=", "X3Y3=" and "X4Y4=" commands provide for the input of up to four x, y data pairs. These data pairs are remembered until they are changed or until program termination.
INTERP LIN , x - The "INTERP LIN" command causes a linear interpolation between the x1, y1 and x2, y2 data pairs. A new value y is calculated for the value of "x". The new y-value is displayed and also stored in the accumulator. The "LASTX" register is updated.
INTERP LAG , x or INTERP PAR , x - The "INTERP LAG" or "INTERP PAR" command causes a 3-point parabolic Lagrangian interpolation among the x1, y1, x2, y2 and x3, y3 data pairs. A new value y is calculated for the value of "x". The new y-value is displayed and also stored in the accumulator. The "LASTX" register is updated.
INTERP CUBIC , x - The "INTERP CUBIC" command causes a 4-point cubic interpolation among the x1,y1, x2,y2, x3,y3 and x4,y4 data pairs. A new value y is calculated for the value of "x". The new y-value is displayed and also stored in the accumulator. The "LASTX" register is updated.

FLAG CONTROLS - The program has 20 user flags which may be set and tested by the user. They are global and are available at the CMD level or from any macro nesting level.
FLAG , f1, f2, f3, f4 , f5 - The "FLAG" command may be used to turn "on" or "off" up to five flags at a time. The absolute value of each flag f_i specifies the flag to be set. If f_i is positive, the flag is set "on". If fi is negative, the flag is set "off". NSUB commands (described in the MACRO section) may be used to modify the "FLAG" command from within a macro. If the "FLAG" command is issued without numeric input (just "FLAG"), then the setting of each flag is printed to the current output device. Output appears as either a "+ 1" for true or "- 1" for false with the status of flags f1 to f5 in the first row, f6 to f10 in the second row, etc. In order to set flags numbers 3, 5 and 6 to on and 17 and 19 to off, issue the command: "FLAG ,3, 5, 6, -17, -19" In order to display the current status of all flags, issue the command: "FLAG" which will yield output of the following form:

-1	**-2**	**3**	**-4**	**5**
6	**-7**	**-8**	**-9**	**-10**
-11	**-12**	**-13**	**-14**	**-15**
-16	**17**	**-18**	**19**	**-20**

The output shown on the previous page indicates that flags 3, 5 and 6 are the only flags currently set to on. All 20 user flags are initially set off when the program is started.

STATISTICAL COMMANDS - The program has statistical functions similar to some popular hand calculators. All statistical register commands are also operational at all the program sub-levels in order to support the indirect addressing commands "W1" through "W5". The general purpose registers 151 to 200 are used for these calculations. The following commands are available for statistical calculations:
CLSTREG - The "CLSTREG" command clears to zero the general purpose registers 150 to 200.
STADD - The "STADD" command adds the current values in the "X" and "Y" registers to the statistical accumulations being formed in the statistical registers. It also increments the statistical counter by 1.0.
STSUB - The "STSUB" command subtracts the current values in the "X" and "Y" stack registers from the statistical accumulations being formed in the statistical registers and also decrements the statistical counter by 1.0.
MEAN - The "MEAN" command calculates the X-mean value and the Y-mean value of the data in the statistical accumulation registers and leaves the X-mean and the Y-mean values in the "X" and "Y" registers, respectively. The "LASTX" register is updated.
STDEV - The "STDEV" command calculates the X-standard deviation and the Y-standard deviation of the data in the statistical accumulation registers, placing the X-standard deviation value in the "X" register and the Y-standard deviation value in the "Y" register. The "LASTX" register is updated.

REGISTER	151	NUMBER OF DATA POINTS ACCUMULATED
REGISTER	152	SUMMATION OF X-VALUES
REGISTER	153	SUMMATION OF SQUARES OF X-VALUES
REGISTER	154	SUMMATION OF Y-VALUES
REGISTER	155	SUMMATION OF SQUARES OF Y-VALUES
REGISTER	156	SUMMATION OF PRODUCT X*Y
REGISTER	157	SUMMATION OF PRODUCT (X**2)*Y
REGISTER	158	SUMMATION OF PRODUCT X*(Y**2)
REGISTER	159	SUMMATION OF CUBES OF X-VALUES
REGISTER	160	SUMMATION OF CUBES OF Y-VALUES
REGISTERS	161-200	(RESERVED FOR EXPANSION)

DATA OUTPUT COMMANDS

FORMAT (format string) - The "FORMAT" command is used to set up the output format for the "WRITE", "SHOW", "PRIREG", "PSTK", "PSTKI", "PSTKC", "PLSTX" and "PLSTIX" commands. The "format string" can any valid FORTRAN format specification. The program default format is "D23.15". Only output to the screen, to the spool file and to the printer are modified by the "FORMAT" command. Output to all other devices and files is done in a D23.15 format. EXAMPLE: **"FORMAT F11.2"** would cause all output generated by the "WRITE", "SHOW", "PRIREG" and stack output commands to be displayed in an F11.2 format.

WRITE (register name) , (optional alphanumeric label up to 40 characters) - The "WRITE" command generates a line of output which looks like:

label = value stored in the named register

The "WRITE" command is valid for the primary and secondary named registers only. If no register name is given, then the value in the accumulator ("X" register) is printed. If no label is entered and if the output device is the screen or the file PRINTER.DAT, then the register name will be printed in front of the numeric value. Output to the file PRINTER.DAT is specified using the command "OUTPUT LP". For other file output, such as to the file CARDTEXT.DAT using "OUTPUT CP", the labels and/or register names are not printed before the numeric values of the register contents. If the qualifier word "ALL" is used, then the contents of all primary and secondary registers are printed. In the "ALL" option, labels are not available for use. If the "label" is explicitly entered, then the first forty (40) non-blank characters of "label" will be used for the label.

PRIREG - The "PRIREG" command performs the same function as "WRITE ALL" in the foregoing discussion of output using "WRITE".

PRSTK - The "PRSTK" command causes the values in the real stack registers "X", "Y" ,"Z" and "T" to be output. If output goes to the screen or to LP, program supplied labels are used. For other output devices, only the numerical values stored in the real stack registers are printed.

PRSTKI - The "PRSTKI" command causes the values in the imaginary stack registers "IX", "IY", "IZ" and "IT" to be output. If output goes to the screen or to LP, program supplied labels are used. For other output devices, only the numerical values stored in the imaginary stack registers are printed.

PRSTKC - The "PRSTKC" command is a combination of the "PRSTK" and "PRSTKI" commands.

PRLSTX and

PRLSTIX - The "PRLSTX" and "PRLSTIX" commands cause the "LASTX" and "LASTIX" registers to be output. If output is to the terminal or to LP, then a program supplied label is used. For other output devices, only the numerical value stored in the "LASTX" or "LASTIX" register is printed.

LFORMAT (format string) - The line formatting "LFORMAT" command is used to set up the output format for the "LWRITE" command. The "format string" can be any valid FORTRAN format specification which will output up to five numerical values. If the "format string" conflicts with the number of output values listed in the "LWRITE" command, a warning message is issued and no action is taken. This is a very powerful command. All "LWRITE" output is modified by the "LFORMAT" command. There is no default value for the "format string". EXAMPLE: **LFORMAT F11.2,1x,G23.15** would cause all output generated by the "LWRITE 3, 5" command to be output with the (F11.2,2x,G23.15) format. For those not familiar with FORTRAN formatting, see a basic FORTRAN reference text.

LWRITE (A1 through A(MAXREG)) , i1, i2, i3, i4, i5 - The line writing "LWRITE" command generates a line of output of up to five numerical values formatted by the current "LFORMAT" format specification. The values "i1", "i2", "i3", "i4" and "i5" are the numbers of general purpose numerical storage registers. In the example above, the contents of the #3 and #5 general purpose numerical storage registers would be written to the current output device. "LWRITE" also accepts optional qualifier words "A1" through "A(MAXREG)". If one of these qualifier words is issued with the "LWRITE" command, then the numeric output generated by the "LWRITE" command will be preceded by an alphanumeric label which will consist of the current contents of the alphanumeric storage register designated by the qualifier word. If the content of the designated alphanumeric storage register is all blank then no label will be displayed. If, for example, alphanumeric storage register #50 had stored in it the string value "DATA" and general purpose storage registers 1, 2, 3 and 4 had the values 10, 20, 30 and 60 stored in them, then the command "LWRITE A50 , 1 , 2 , 3 , 4" using a previously issued "LFORMAT" statement of

"LFORMAT F6.2,1x,F6.2,1x,F6.2,1x,F6.2

would generate the output:

DATA 10.00 20.00 30.00 60.00

The use of the optional label is a good way to generate new program input commands in an output text file which will later be read into back into the program and executed.

OUTPUT FORMATS - The "FORMAT" and "LFORMAT" commands refer to Fortran format specifications. This next section explains these format specifications for users not familiar with the Fortran language. The "FORMAT" and "LFORMAT" commands can take any of the many format specifications available in Fortran. Only a few of these format specifiers are really needed in order to control output using the "WRITE" and "LWRITE" commands. The "X", "F", "I" and "D" specifiers will be described here. Should the user wish to use other Fortran format specifies, the user should refer to one of the many good Fortran 77 or Fortran 90 reference books available at any good technical bookstore or library. The "X" format specifier is used to add a blank or blanks to output. 5X would generate five blank spaces in the output. This format specifier is only useful with "LWRITE" and "LFORMAT". The "F" format specifier is used to output "fixed" format, non-integer data. The syntax is F#.d where "#" is an integer which specifies the total number of spaces used for the number (including the sign) and "d" is an integer which specifies the number of digits to the right of the decimal point. The value of -π output in F7.4 format would be -3.1416. The "I#" format specifier is used to output "integer" format, integer data. "#" specifies the number of spaces used. To output the value 345 in 5 spaces, use the format specifier I5. The output would contain two spaces preceding 345. The "D#.d" format specifier is used to output floating point data in exponential, double precision form. "#" specifies the total number of spaces used, "d" specifies the number of digits to the right of the decimal. If 234.5675431 was output with D10.5 format, the result would be 0.23457D+3.

THE TABLE WRITER - The TABLE WRITER provides the capability for conveniently generating tabulated output of user data. Tables can have up to100 rows and 9 columns. The following commands are used to construct, manipulate and display data tables:

TABLE SETUP - The "TABLE SETUP" command sets the numeric storage area of the current table to 0.0. This is required before table input.

TABLE CLEAR - The "TABLE CLEAR" command sets the numeric storage area of the current table to 0.0. Any existing row and column headings are preserved.

ROWHD (row name), : (row label) and

COLHD (column name), : (row label) and

ROWHD2 (row name), (row label) and

COLHD2 (column name), (row label) - The "ROWHD" and "ROWHD2" commands expect to be given "row names" which range from "R1" through "R100". The "COLHD" and "COLHD2" commands expect to be given column names "C1" through "C9". Each of these commands also expect a 1 to 12-character string input designating the particular "row label" or "column label". "ROWHD" or "COLHD" is used for the first 12-character line of a row or column label. "ROWHD2" or "COLHD2" is used if a second 12-character line is needed for a row or column label.
TABLE PUT , i , j , (numeric value) - The "TABLE PUT" command copies the contents of the accumulator (X-register) to row "i", column "j" of the current table if no numeric value is supplied. If a numeric value is supplied as numeric word #3, that value is loaded into the designated table position.
TABLE GET , i , j - he "TABLE GET" command copies the contents of row "i", column "j" of the current table into the accumulator (X-register). The stack and the LASTX register are updated.
TABLE PRINT1 and
TABLE PRINT2 and
TABLE PRINT3 - The "TABLE PRINT1", "TABLE PRINT2" and "TABLE PRINT3" commands cause the contents of the current table to be displayed on the current output device or to be written to a file.
"TABLE PRINT1" displays the table in a space delimited, 80-column format to the current output device.
"TABLE PRINT2" is used to write the table to a disk file when OUT is not TP or LP (terminal or printer)..
"TABLE PRINT3" outputs the table, without column and row headings, in a comma delimited, D23.15 format when the output file was previously specified with an "OUT FILE (file name)" type of output redirection.
TABLE SAVE and
TABLE RELOAD - The "TABLE SAVE" and "TABLE RELOAD" commands cause the contents of the table to be written to and read from a direct access, unformatted binary file named TAB.DAT.