TES-Test Plate Fitting

TES, by automatically driving the AUTOMATIC DESIGN option, fits surfaces sequentially to a specified test plate list, within defined limits on performance loss.

When to Use the Test Plate Fitting (TES) Option

In preparing a new design for manufacture, either new tooling (including testplates for measuring optical surface curvatures) will have to be created or you will need to fit the design to existing tooling of the chosen fabricator. The former (new tooling) is less desirable because:

- It is more expensive
- Allows an extra error (error in test plate radius) to come into tolerances, which will consume some of the error budget if you will not get the chance to adjust the design after the tooling is finished. (This error does not disappear if surface quality testing will be done by interferometer.)

It is desirable, therefore, to fit as many surfaces to existing test plates as possible, after the fabricator is known. The TESTPLATE fitting option is very effective in the iterative substitution and re-optimization of the lens; typically, 85-95% of the surfaces can be fit with almost no quality loss, if the test plate list is reasonably complete. Since the re-optimization is done for each surface that is fit, the runs can take considerable time.

Default Operation

None. The list of plates (PLA command) must be provided, plus whatever AUTO commands are required. With these, unfrozen surfaces are selected, one by one, according to an optimum fitting strategy; each fit is optimized and accepted or rejected according to whether it results in error function degradation within allowable limits, both on any single fit or the total effect of all fits since the start of the run. With a reasonably complete test plate list, more than 90% of all surfaces are typically fit.

The lens system must be one that has been previously optimized in CODE V and stored with the error function value recorded. If this has not been done, optimize and save it first, with the same error function definition as is to be used in fitting.

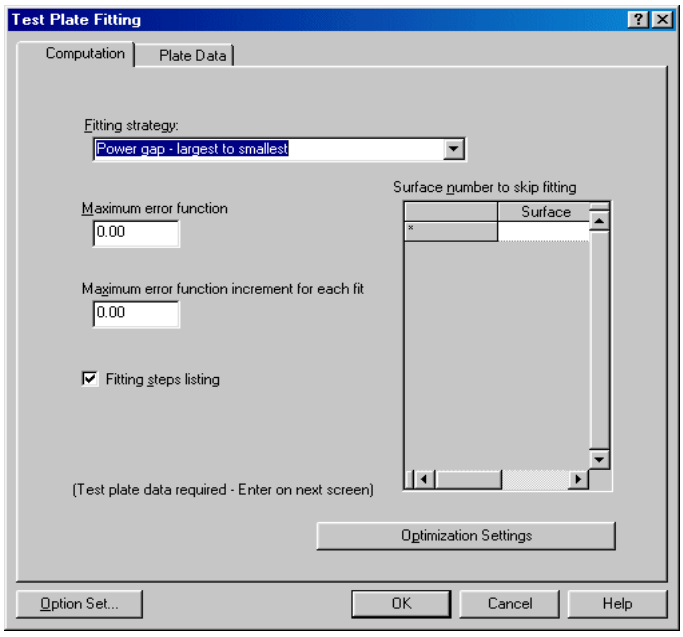
The AUTO commands can be interspersed between TESTPLATE commands or follow immediately after, either by direct entry or from a file; do not include the AUT command itself. The AUT commands will not be tested immediately, so errors will not be detected until the run is started. Note that TES will delete all curvature solves and make those curvatures variables, thus extra constraints may be needed.

Command Mnemonics
(alphabetical)

END	ERI	ERM	FUL	FUR	GAP
LIS	NEA	PLA	POW	SKI	STC

Defining Computational Controls

To define computational controls, select the **Optimization** > **Test Plate Fitting** menu. The **Diagnostic Option TES** dialog box is displayed, with the **Computation** tab in the foreground.

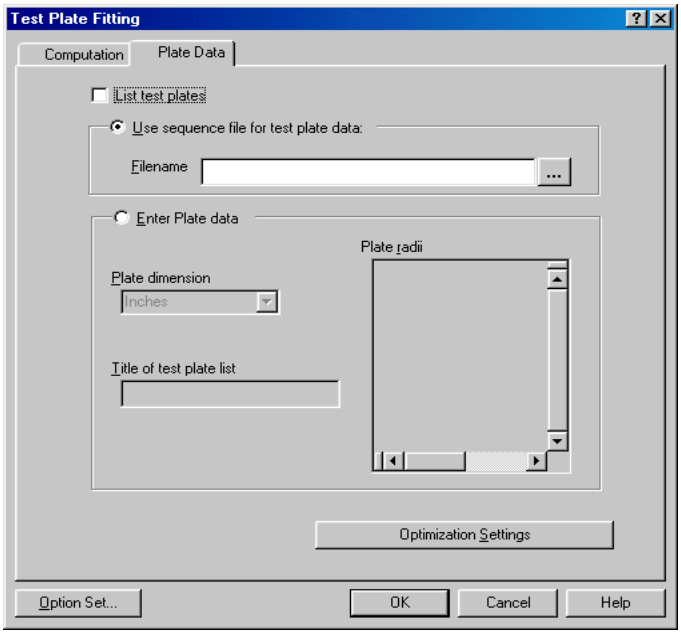


Command Syntax		
Screen Control	**Explanation**	**Default**
GAP | POW | STC | FYR | NEA		
Fitting strategy	Fitting strategy: GAP – largest (gap in list) * (index difference integrated over wavelength) first POW – strongest surface power first STC – strongest curvature first FUR – curvature furthest from test plate first NEA – curvature nearest to test plate first	GAP. It tends to fit the most plates with the least degradation.
ERM reject_fit_above_erf_max		
Maximum error function	Maximum error function value that will be allowed before an attempted fit on a surface is rejected. Rejected fits will not be reattempted during the current run.	5% larger than the starting design error function.
ERI reject_fit_above_erf_increment		
Maximum error function increment for each fit	Maximum error function increase over prior fit that will be allowed before an attempted fit on a surface is rejected. Avoids loss of total ERM allowance in a single fit. Rejected fits will not be reattempted during the current run.	Half of starting difference from ERM.

Command Syntax		
Screen Control	**Explanation**	**Default**
FUL Yes | No		
Fitting steps listing	Include listing of all AUTO operations. No will cause listing of only the successful and rejected fits and their error function values.	Yes.
SKI Sk | Si..j		
Surface number to skip fitting	Skip the fitting of these surface(s). Use to avoid retrying rejected fits of a prior run, etc. Enter as many SKI commands as are needed.	Try to fit all variable surfaces.

Defining Test Plate Data

To define test plate data, select the **Optimization** > **Test Plate Fitting** menu. The **Diagnostic Option TES** dialog box is displayed. Select the **Plate Data** tab to bring it to the foreground.



Command Syntax		
Screen Control	**Explanation**	**Default**
LIS Yes | No		
List test plates	List the test plate radii and curvature at the beginning of the run, sorted in ascending order of radii. Listing appears before the first fit is attempted.	No.
PLA I | C | M 'plate_list_name'(80) 1st_plate_radius 2nd_plate_radius : last_plate_radius END		
Use sequence file for test plate data **or** **Enter plate data**	Key in sequence file for test plate data. or List of test plates. Select inches, centimeters, millimeters for plate dimensions. 'plate_list_name' allows 80 characters of identification; not otherwise functional. Order of radii is unimportant; the program will sort them. The number of plates that can be entered is unlimited. **Recommendation**: Enter plates once in a PLATES.SEQ file, then use with an IN PLATES command; start file with PLA command; if you wish to turn off the echoing of each line, precede and follow this file with OUT No and OUT Yes, respectively.	REQUIRED. No default.
END		
	Terminate list of test plates, started by PLA.	

Discussion of Input and Computations

What to Include in the LDM

No additional data is required in the LDM, but the lens must have been optimized on CODE V (so the optimization is aiming at the same goal during the fitting). You will also need to designate as variables the parameters you will allow to be used in the fitting. These typically are:

- All of the radii you want fitted
- Any other variables (usually airspaces and possibly thicknesses) that you will allow to be changed to compensate the small radii changes being generated.

As the fitting proceeds, the program will fit and freeze radii in a particular order, so that the end result will be a lens with all of the successfully fit surfaces frozen and the other variables slightly different from their starting values. As free variables are used up, you may find it necessary to restart the process, with some carefully chosen constraints removed to allow it to proceed further; you can bypass unsuccessful prior fits with the **SKI** command on the re-try and still leave them as variables, knowing that you will need new tooling for them.

Usage

By using TES, you are invoking optimization which requires all applicable input that would be used with the AUTOMATIC DESIGN option, plus any of the required data entries described below.

The lens system must be one which has been previously optimized and stored with the error function recorded.

Using the test plate list entered, the program fits a curvature (or curvatures if coupled) to a test plate, freezes the curvature, and then calls the AUTOMATIC DESIGN option. The system is then optimized in the conventional manner of AUTO after which control is returned to the test plate fitting program. If the error function is acceptable (see **ERM** and **ERI** commands below) the system is accepted. If the error function is unacceptable, the previous system is restored. The process continues until a fit has been attempted on all of the surfaces. AUTO commands can be interspersed among TES commands, but do not include the AUT command itself.

Note that TES deletes all curvature solves and makes those curvatures variables. You must enter constraints to perform the actions of the solves. Thickness solves are retained.

Test Plate Data

Within TES, only the plates entry (**PLA**) *must* be used, followed immediately by the test plate list. It is recommended that before invoking the TES option, you create a PLATES.SEQ file, with the first line containing **PLA** and either I,C, or M to designate dimensional units (inches, centimeters, millimeters) of the plates. You may optionally include on the first line up to 80 characters of a 'plate_list_name' for identification purposes. On lines 2 through n of the file, enter the test plate radii. Upon invoking TES on your optimized lens, perform an IN PLATES (or any other desired sequence name) to load your file. Note that each line is echoed as an input line; if you wish to suppress this echoing, precede the **PLA** command with OUT NO, and follow the END command with OUT YES to restore echoing. See the example in the Description of Output section.

Testplate Lists Supplied with CODE V

Several lists of optical manufacturers' testplates are supplied with CODE V. These are all stored in sequence form and are formatted for direct use with **TES**. The sequences are all stored in the directory CV_PLATE. Table 1 lists the testplates supplied with CODE V. Note that these lists are supplied as a convenience to CODE V users; ORA has no direct relationship with any of these companies, and does not endorse any of them nor guarantee the accuracy of the data or availability of the testplates. Contact the vendors directly for more information on the testplates.

Table 1. Testplates Supplied with CODE V

Manufacturer	Sequence	Update Date
Brighten Optics	BRIGHTEN1.SEQ	February 1999
Brighten Optics	BRIGHTEN2.SEQ	February 1999
Brighten Optics	BRIGHTEN3.SEQ	February 1999
Ferson Optics, Inc.	FERSON.SEQ	January 1988
Harold Johnson Optical Labs	HJOL.SEQ	February 1993
J. L. Wood Optical Systems	JLWOOD.SEQ	March 1991
JML Optical Industries	JML.SEQ	July 1999
Kreischer Optics Ltd	KREISCHR.SEQ	October 1996
MediVision Optics	MDVISION.SEQ	March 1998
Melles Griot Optical Systems	MGOS.SEQ	July 1988
Model, Inc.	MODEL.SEQ	August 1994
OCA Applied Optics	OCA.SEQ	January 1995
Optical Components, Inc.	OCI.SEQ	August 1999
Optical Instrumentation Corp.	OIC.SEQ	October 1993
Optico Glass Fabrication	OPTICO.SEQ	August 1994
Optimax Systems, Inc.	OPTIMAX.SEQ	February 1999
Optimum Optical Systems, Inc.	OOS.SEQ	July 1994
PFG Precision Optics	PFG.SEQ	January 1995
Precision Applied Products	PAP.SEQ	April 1995
Rodenstock Precision Optics	RSTOCK.SEQ	March 1998
Special Optics	SPECOPT.SEQ	February 1996
Tropel Corp.	TROPEL.SEQ	June 1996
Tucson Optical Research Co.	TORC.SEQ	March 2009

To use the testplates for a given manufacturer, use the sequence directly in **TES**. For example, to use the testplates from Harold Johnson Optical Labs, give the following commands:

```
TES
IN CV_PLATE:HJOL
(rest of your TES commands)
GO
```

Fitting Strategies

Any one of five different strategies may be selected. In the default mode, it is ordered from the largest power gap in the list to the smallest (**GAP**). The criterion is |δC (n-n')| where δC is the gap in the list within which the curvature lies, (n-n') is the index difference across the surface, integrated over the wavelength band. The **GAP** mode tends to fit the most plates with the least degradation. However, you may select other strategies, such as strongest surface power to weakest (**POW**), strongest lens curvature to weakest (**STC**) (which is similar to **POW** except the index differences are excluded). You can also order the test plate fitting beginning with the curvature that is furthest from a test plate (**FUR**), or nearest (**NEA**).

Computational Controls

By default, an increase of up to 5% in the starting design error function is allowed, cumulative throughout all the testplate fitting attempts. This error function maximum can be adjusted (**ERM**). The maximum error function *increment* that will be allowed between individual fitting attempts on a surface (before the fit attempt is rejected and the surface is "released") is one-half of the **ERM** and can also be adjusted (**ERI**). Any number of surfaces can be omitted from fitting attempts using the skip command (**SKI**).

Description of Output

The test plate radii and curvature can be listed at the beginning of the run if desired (**LIS**). All of the fitting steps including the AUTO cycles will be listed as well, unless suppressed (**FUL** N), in which case only the successful and rejected fits ("releases") and their error function values are listed.

Examples

Example 1. Test plate file

The following is a sample test plate list file (DUMPLATES.SEQ). This is typically prepared once (new testplates may later be added of course), then inserted into the TES input with the IN command. A typical actual test plate list would contain many more radii than this example:

```
PLA M 'Dummy Test Plate List (DUMPLATES.SEQ) (radii in mm)'
10.5
12.7
16.8
17.5
19.2
21.6
22.3
50.5
73.2
125.0
160.3
211.4
330.0
END
```

Example 2. Test plate fitting

The following input sequence starts with the standard f/4.5 Cooke Triplet (COOKE1.LEN), optimizes it with focus only (THC Si 0), then saves it as TESCOOKE.LEN to be sure of having a starting error function stored with the lens. Variables for testplate fitting are defined before saving the lens.

The TES input example which follows is nearly a default run. Only EFL is constrained (in practice, other constraints such as ET, OAL, etc., might also be needed). The **GAP** command defines the fitting strategy.

The testplate list (shown above) is DUMPLATES.SEQ. The output consists mostly of normal AUTO interaction. TES also reports which curvatures were replaced with testplates. The output below is for **FUL** NO, so AUTO output is suppressed. In this artificial example with a limited testplate list, 4 of the 6 curvatures were fit (the list contains few long-radius plates, so the nearly-flat surfaces 1 and 3 were "released" and not substituted with testplates). Even with real and extensive lists, a small number of surfaces will often require "designer attention," i.e., some other parameters will need adjustment, or new testplates will need to be made to match the design values.

Be certain to save your testplate-fit lens after running TES, before exiting from CODE V, using the LDM Command SAV (lens_file_name). Internally, the option saves the retained configuration in the file TEShhmmss.LEN, where hhmmss are the hours, minutes, and seconds of the beginning of the TES run; this will also be the final system at the end of the run. Thus, if you run more than one lens at a time you will have a unique file for each run.

```
Command inputs:
   RES   CV_LENS:COOKE1
   ! Prepare the lens for testplate fitting
   FRZ   SA
   THC   Si   0                              !  Defocus only variable
   AUTO
   GO
   DEF   VAR   SA                            !  Default variables on all surfaces
   !  Add lens thicknesses as variables
   THC  S1  0;  THC  S3  0; THC  S5  0
   SAV   TESCOOKE                            !  To save lens with a starting error function
            !  Initial error function in this example =156.71847148
            !  From AUTO run above
   !  Do testplate fitting:
   RES   TESCOOKE                                  !  Load newly optimized triplet

   TES
   EFL  =  50
   IN   DUMPLATES                                  !  Load testplate list
   GAP                                             !  Use same as default fitting strategy
   FUL   NO                                        !  Suppress AUTO output listing
   GO
   SAV   FITCOOKE                                  !  Save testplate-fit lens
```

```
ERR. F.=156.71847148   ! Starting error function of lens
        ! produced by AUTO prior to using TES.
        ! (Not a well optimized lens - see
        ! how TES actually improves it in the
        ! reduced error functions below)
TES
------------------------------------------------------------------------
        PASS NUMBER  1

               SURFACES FIT
            NUMBER     TEST PLATE
               6    -0.05952381    ! Attempt to fit surface
                                   ! # 6 to a testplate:
AUTO
                (... AUTO output not shown .....)

TES
        ERROR FUNCTION =          99.31935154      ! Successful fitting
                                                   ! of surface # 6
(Pass 2 not shown)
------------------------------------------------------------------------

        PASS NUMBER  3


                    SURFACES FIT
                 NUMBER     TEST PLATE
                    1     0.05208333    ! Attempt to fit surface
                                        ! # 1 to a testplate
AUTO
                (... AUTO output not shown .....)
TES

       ERROR FUNCTION =           103.40964094     ! Error increment limit
                                                   ! (ERI) exceeded,
                                                   ! so surface #1 will be
                                                   ! "released", i.e. not
                                                   ! fit to a testplate in
                                                   ! this run:

                 SURFACES RELEASED
                             1              ! Surface #1 is "released"
        (Succeeding passes not shown)
```

(Although AUTO is called at each fitting attempt, its output is not shown here. Only passes 1 and 3 of TES are shown as examples of successful and unsuccessful fittings of surfaces to supplied testplate radii.)