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OPTICAL TOOLS COMPUTERIZED
DESIGN AND MANUFACTURE

by

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Clint Zimmerman

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Manufacturing Technology Directorate

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DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.
This report addresses the design, manufacture, and use of tooling used in the production of precision lenses. A computer program is presented which will provide tooling design based on lens specification input and from which a tape for NC manufacture of the tools can be produced. Economic data is presented on tooling made from the computer design using simulated NC methods.
TABLE OF CONTENTS

INTRODUCTION .......................................................... 1
UNIVERSAL TOOLING ...................................................... 3
COMPUTERIZED TOOL DESIGN ........................................ 3
TOOL MANUFACTURE AND USE ....................................... 8
METHOD A vs. METHOD B (COMPARISON) .............................. 15
RESULTS AND CONCLUSIONS ......................................... 22
DISTRIBUTION LIST ..................................................... 69
APPENDIX A - MATHEMATICS FOR TOOL DESIGN .................. 23
APPENDIX B - COMPUTER PROGRAM STBLK ......................... 43
APPENDIX C - COMPUTER OUTPUT - COST SAMPLE ............... 54
APPENDIX D - COMPUTER OUTPUT - SAMPLE SPOT BLOCKS ....... 59

CHARTS

I. TOOL DESIGN-MANUFACTURE PROCEDURE ...................... 18
II. LENS MANUFACTURE PROCEDURE ............................... 19
III. TOOL DESIGN-MANUFACTURE (COST) .......................... 20
IV. LENS MANUFACTURE (COST) ..................................... 21

List of Illustrations

Figure
1. Universal Spot Blocks, Variable Inserts ....................... 4
2. Distribution of Spots - Convex ................................ 5
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Distribution of Spots - Concave</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td>Limiting Angle Diagram</td>
<td>7</td>
</tr>
<tr>
<td>5.</td>
<td>Universal Adapters (Datum)</td>
<td>9</td>
</tr>
<tr>
<td>6.</td>
<td>CIM-X Geometry - Convex</td>
<td>10</td>
</tr>
<tr>
<td>7.</td>
<td>CIM-X Geometry - Concave</td>
<td>11</td>
</tr>
<tr>
<td>8.</td>
<td>Tool Clearance Geometry - Concave</td>
<td>12</td>
</tr>
<tr>
<td>10.</td>
<td>K &amp; T Geometry - Concave</td>
<td>14</td>
</tr>
<tr>
<td>11.</td>
<td>Sample Lens Tool Requirements</td>
<td>17</td>
</tr>
<tr>
<td>12.</td>
<td>Geometric Priorities (Computer Selected)</td>
<td>28</td>
</tr>
</tbody>
</table>
INTRODUCTION

The work covered by this report is a two part effort. The first part is devoted to establishing design standards for optical finishing tools, and part two is devoted to the manufacture of these tools and their use to make optical elements. The ultimate objectives are to reduce tool cost per optical element produced, and to reduce optical tool inventories so that less storage space is required.

The frequency of occurrence per 100 optical elements in fire control instruments is approximately 57 lenses, 16 prisms, 9 windows, 7 mirrors and 11 other. Tooling used in lens manufacture was therefore selected for study and improvement.

A review of lenses manufactured at the Frankford Arsenal optical facility between 1 January 1970 and 30 December 1973 showed that approximately 40,000 lenses were made in lot sizes varying from 10 to 1600 pcs. Most lot sizes were between 50 and 400 pcs (approximately 90%) and approximately 70% of the lenses had a finished diameter between 0.750 and 1.500 inches. All efforts in this study have been oriented toward the largest percentages cited above.

For clarity, the following GLOSSARY of terms is provided.

1. **Generate:** The act of forming a spherical surface on a lens blank.
2. **Generating Chuck:** Tool for holding a lens blank for generating.
3. **Pitch Block:** Block for holding lens blank in proper orientation for grinding and polishing operations using pitch buttons for retention.
4. **Pitch Buttons:** Pitch molded on the obverse side of lenses to hold them in place for finishing operations.
5. **Pitch Button Mold:** Tool for molding pitch buttons on lens blank.
6. **Blocker:** Spherical tool for precise positioning (curved radii) on pitch blocks.
7. **Spot Block:** Block with machined cavities for positioning and holding lens blank.
8. **Spot:** Machined cavity in spot block for retention and precise positioning of lens blank.
9. **Grinder:** Precision spherical lap for fine grinding lenses.
10. **Polisher:** Precision spherical lap for polishing lenses.

11. **Test Glasses:** Precise optical elements used for gaging optical work in progress.

Lens blanks are cored from plate or molded, individually generated, mounted on pitch blocks and "gang" finished. All lens surfaces are finished to within three Newton interference rings of the appropriate Test Glass. This tight tolerance is of particular significance in the case of couplets whereby two lenses are bonded together.

Test glasses, for a particular curve, are made in matching parts to within one Newton ring of each other.

Using existing practices, lens tooling design (including drawings) requires approximately two hours per tool per curve. Calculations are necessary to determine lens blank distribution on mounting blocks and pertinent dimensions of all tools.

Except for curve generation, lens tools are manufactured using conventional machine shop methods. After fabrication, the spherical surfaces of Grinders and Blockers require a "wearing in" process to obtain the necessary precision as indicated above. A Polisher consists of pitch or wax contained by a metal shell that is formed, while heated to its flow temperature, by the surface to be polished.

The operational advantages of using Spot Blocks is well known, however the cost of such tooling has previously been so high as to preclude their use except in large production quantities.

Initial efforts were directed toward making Spot Blocks more universal, i.e., capable of being used on a variety of lens radii. Though some advantages developed, it became apparent that the approach was not economically feasible. Efforts were then directed toward computerized design and N/C manufacture of lens tools.

**Note:** The use of Spot Blocks causes a change in the lens manufacturing procedure as is shown on Chart II. For the remainder of this report the "Spot Block Method" and the current or "Pitch Button Method" shall be referred to as Method A and Method B, respectively.
A universal spot block (Figure 1) was designed, fabricated and used under trial conditions. It utilized replaceable inserts that could be made to accommodate convex radii between 1.5 and 2 inches. Two sets of inserts were made to mount lens blanks whose radii were 1.688 and 1.994 inches respectively. Lenses were made following Method A procedures delineated on Chart II. The quality of the lenses produced was good in all respects.

A comparison of this method with the conventional Method B showed that the grinding and polishing times of the two methods was the same. Method A indicated advantages in the set up and curve generating times, and the elimination of tools such as: Blockers, Pitch Button Molds and Generating Chucks. However, major difficulties arose. Spot Blocks made with removable inserts have a fixed number of spots dictated by the lens outside diameter and the shortest radius that can be accommodated by that block. This results in a less than optimum use of the surface area developed by blanks with the same O.D. and longer radii. New inserts or new blocks must be made for each lens curve and diameter combination, and the result is additional design and fabrication times. In addition, the inventory and storage problems are increased. The benefits of lens fabrication using Method A are offset by the above problems, and the unit tool cost is increased rather than decreased. In order to take advantage of the benefits of Method A over Method B found in lens fabrication, another approach to reducing optical tool costs had to be found. It was determined that this reduction could be achieved with computerized tool design and N/C manufacture.

Mathematics (Appendix A) suitable for computerizing was developed to calculate design parameters for Spot Blocks, Grinders and Polishers. Application of the mathematics to lens drawing data, i.e., outside diameter, center thickness, and curve radii with a sign (±) convention to indicate form (convex, concave) results in all dimensions, including the precise distribution of spots on a block (Figures 2 and 3), required to fabricate tools for that lens.

A recently completed study, Project #6737062 F. A. report TR 75067 titled 'Radial Pressure Conversion of an Optical Polishing Machine" authored by Martin H. Horchler, showed that lenses block mounted beyond an 80° angle to the axis of the block measurably extended the grinding and polishing times for that block. Vertical forces (weights) are used in these operations, and the resultant normal forces on the surfaces being worked on falls below 20% of the total force applied (Figure 4). Hence, a limit of 160° included angle was accepted as a design constraint along with a limit of 10 inches in block diameter which is dictated by the geometry of most available optical fabrication equipment.
Figure 1. Universal Spot Blocks, Variable Inserts
Figure 2. Distribution of Spots - Convex
Figure 3. Distribution of Spots - Concave
Figure 4. Limiting Angle Diagram
The project was directed at developing N/C programs for a Wadell Lathe for turning and contour work and a Cincinnati Cim-X equipped with a programmable Walter universal rotary table with tilt capabilities for machining Spots. All lens tools were designed to be mounted on a common adapter (Figure 5) so that a datum could be established for both fixturing and calculating parameters.

The mathematics was further developed to compute position parameters for the above equipment such as: angular tilt increments, angular rotational increments, and Cartesian coordinates for tool to work piece orientation (Figures 6 and 7). In addition, lens blank dimensions are calculated to have excess material for finishing and sized so that standard sized end mills can be used for milling spots. Concave Spot Blocks presented a problem in that the criterion of a 160° included angle of the spherical sector could not be strictly adhered to because of the machine geometry (Figure 8). Hence, the mathematics was adjusted to find the best angle possible.

The mathematics was programmed (Appendix B) in Fortran IV language for a Control Data 6500 computer utilizing a Fortran compiler. Included in the program is a geometric priority selector (see Figure 12).

After debugging, sample computer runs were made (Appendix D), and spot checked for accuracy. The input consisted of lens data as described above and the output included the input data for identification plus all parameters necessary to program N/C equipment for the fabrication of Spot Blocks, Grinders and Polishers.

TOOL MANUFACTURE AND USE

Production time was not available on either the Wadell or the Cim-X (NC machine) when needed; therefore, rather than delay the project, simulated automation was decided on. The reasoning was that a programmed N/C machine can follow explicit instructions more efficiently than an operator; therefore, if an operator can successfully produce a spot block by carrying out indicated moves without recourse to intermittent measurements, success on N/C equipment is assured.

A Kearny and Trecker Milling Machine equipped with a Model H universal dividing head was selected for the milling work, and a Strasbaugh curve generator was selected for the contour work. Turning was done on an engine lathe. Since the geometry of the milling machine to be used in the simulation differs from that of the N/C equipment, it was necessary to include the proper mathematics for cutter to workpiece orientation in the computer program (Figures 9 and 10). This series of calculations has been left in the program and the results may be seen in the computer outputs shown in Appendices C and D.
Figure 5. Universal Adapters (Datum)
Figure 6. Cim-X Geometry - Convex
Figure 7. Cim-X Geometry - Concave
Figure 8. Tool Clearance Geometry - Concave
Figure 9. K & T Geometry - Convex
Figure 10. K & T Geometry - Concave
Computer runs were made for selected lenses and the output information was used to make optical tools. Since both Method A and Method B use the same basic grinder and polisher configuration, only spot blocks were actually made. All of the "spot" milling was done with two-lipped end mills. This type of cutter permits a straight in feed obviating the need for boring or drilling pilot holes, and results in a flat bottom shouldered cavity. After initial setup, all operations were carried out using manual adjustments as dictated by the computer output. No drawings were used.

A prototype lens production line was set up such that: lens blanks were cored out of glass plate, blanks were mounted on spot blocks using a temporary bonding cyanoacrylate adhesive, and curves were 'gang' generated on the blanks preparatory to the grinding and polishing operations. The grinding and polishing operations were carried out on a sufficient number of blocks to confirm design integrity and collect data.

Some blocks were successfully used by M. Horchler*, and will be reported on elsewhere.

METHOD A VS. METHOD B

This cost comparison of the two methods of lens manufacture is made on the basis of manhours, and is subject to the following assumptions:

1. The factors used for Method A shown on Charts I and II are derived from experience gained in this study; however, the set up and machine times for N/C equipment were extrapolated from actual set up and machine times recorded.

2. The criteria for corresponding data used for Method B was estimating charts prepared by the F. A. Production Engineering Section from historical data recorded over a long period.

3. An APT or UNI-APT N/C tape preparation system can be used to prepare N/C tapes from design parameters developed in Program STBLK Appendix B.

4. Costs for universally used tools for both methods such as: fixtures, adapters, pitch button molds, generating chucks, etc. have been omitted. These tools are permanent in nature, and their costs per lens produced approaches zero as usage increases.

---

*"High Speed Fabrication of Precision Optics" MM&T Project #6747463, by M. Horchler, August, 1976.
5. The comparison data shown on Tables 1 and 2 are complete in all essential details. Minor operations common to both methods have been omitted as irrelevant. Hence, the hours shown for each method should be considered as estimates of the two methods.

6. An achromatic couplet, as shown on Figure 11, was selected as a typical example for this comparison. The tool requirements shown are predicated on the results shown in Appendix C.

7. Application of the factors shown on Charts I and II, on the typical sample, results in Charts III and IV.
### TOOL REQUIREMENTS
(Lot Size 200)

<table>
<thead>
<tr>
<th>RADII</th>
<th>BLANKS/BLK.</th>
<th>BLOCKS</th>
<th>GRINDERS</th>
<th>POLISHERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_1$ (2.542)</td>
<td>25</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>$R_2$ (1.300)</td>
<td>6</td>
<td>12</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>$R_3$ (-1.300)</td>
<td>7</td>
<td>12</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>$R_4$ (3.350)</td>
<td>49</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>30</strong></td>
<td><strong>11</strong></td>
<td><strong>16</strong></td>
<td></td>
</tr>
</tbody>
</table>

### TOOL DESIGN REQUIREMENT

<table>
<thead>
<tr>
<th>METHOD A</th>
<th>METHOD B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ea. rad.</td>
<td>4 Spot Blocks</td>
</tr>
<tr>
<td>1 ea. rad.</td>
<td>4 Grinders</td>
</tr>
<tr>
<td>1 ea. rad.</td>
<td>4 Polishers</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

### TOOL MANUFACTURE REQUIREMENT

<table>
<thead>
<tr>
<th>METHOD A</th>
<th>METHOD B</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Spot Blocks</td>
<td>30 Pitch Blocks</td>
</tr>
<tr>
<td>11 Grinders</td>
<td>11 Grinders</td>
</tr>
<tr>
<td>16 Polishers</td>
<td>16 Polishers</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>57</strong></td>
</tr>
</tbody>
</table>

---

*Figure 11. Sample Lens Tool Requirements*
CHART I

TOOL DESIGN-MANUFACTURE PROCEDURE
TIME IN MAN HOURS

"METHOD A"

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>Spot Block Set up</th>
<th>Grinder Set up</th>
<th>Polisher Set up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepare(1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Computer Input</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Prepare(1)</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Design &amp; Design &amp;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare Dws</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Turn Taper &amp; the End</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face &amp; Bore for Adapter</td>
<td>1.0</td>
<td>0.5</td>
<td>Includes all tools</td>
</tr>
<tr>
<td>Assemble Adapter</td>
<td>0.5</td>
<td>0.5</td>
<td>Includes all tools</td>
</tr>
<tr>
<td>Turn &amp; Face(2)</td>
<td>1.0</td>
<td>0.5</td>
<td>Includes all tools</td>
</tr>
<tr>
<td>Generate(3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mill Spots(4)</td>
<td>1.0</td>
<td>0.33 Per individual spot</td>
<td></td>
</tr>
<tr>
<td>Break In</td>
<td>-</td>
<td>4.0</td>
<td>-</td>
</tr>
<tr>
<td>Form</td>
<td>-</td>
<td>-</td>
<td>1.0 1.0</td>
</tr>
</tbody>
</table>

"METHOD B"

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>Spot Block Set up</th>
<th>Grinder Set up</th>
<th>Polisher Set up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot Block</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pitch Button</td>
<td>2.0</td>
<td>1.5</td>
<td>Includes all tools</td>
</tr>
<tr>
<td>Tools</td>
<td>2.0</td>
<td>1.5</td>
<td>Includes all tools</td>
</tr>
<tr>
<td>Pitch Button</td>
<td>1.0</td>
<td>1.25</td>
<td>Includes all tools</td>
</tr>
<tr>
<td>Tools</td>
<td>1.0</td>
<td>1.25</td>
<td>Includes all tools</td>
</tr>
<tr>
<td>Mill Spots</td>
<td>1.0</td>
<td>4.0</td>
<td>1.0 1.0</td>
</tr>
</tbody>
</table>

Notes:
(1) The computer design time is a minimum. Tools for as many as ten different size lenses can be designed in the same time.
(2) Turn face and generate are done on the same set up in Method A. Add 0.5 hours set up time for each different size tool after initial set up.
(3) Add 0.5 hours set up time for each different size tool after initial set up in Method B.
(4) Add 0.5 hours set up time for each different size spot block after initial set up.
<table>
<thead>
<tr>
<th>Step</th>
<th>&quot;METHOD A&quot;</th>
<th></th>
<th>&quot;METHOD B&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Set up Unit Time</strong></td>
<td><strong>Time</strong></td>
<td><strong>Blanks per Block</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core Cut Blanks</td>
<td>1</td>
<td>1.0</td>
<td>0.05</td>
</tr>
<tr>
<td>Generate Curve 1</td>
<td>N.A.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Generate Curve 2</td>
<td>N.A.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Back up Blanks</td>
<td>N.A.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mount Blanks</td>
<td>2</td>
<td>0.25</td>
<td>-</td>
</tr>
<tr>
<td>Generate Block Curve 1</td>
<td>3</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Fine Grind Curve 1</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Finish Polish Curve 1</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Back up Blanks Curve 2</td>
<td>N.A.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mount Blanks Curve 2</td>
<td>6</td>
<td>0.25</td>
<td>-</td>
</tr>
<tr>
<td>Generate Block Curve 2</td>
<td>7</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Fine Grind Curve 2</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Finish Polish Curve 2</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
CHART III

TOOL DESIGN-MANUFACTURE (COST)
Couplet - 2 Lenses - 4 Radii - 57 Tools
Time in Man Hours

<table>
<thead>
<tr>
<th>Operation</th>
<th>&quot;Method A&quot;</th>
<th>&quot;Method B&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepare Computer input all tools</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Computer run all tools</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>Prepare tapes 4 Spot Blocks</td>
<td>4.0</td>
<td>-</td>
</tr>
<tr>
<td>Prepare tapes 4 Grinders</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Prepare tapes 4 Polishers</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Design &amp; Make Dwgs 12 tools</td>
<td>Note 1</td>
<td>24.0</td>
</tr>
<tr>
<td>Turn &amp; Thd. End 57 tools</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>Face &amp; Bore 57 tools</td>
<td>1.0</td>
<td>28.5</td>
</tr>
<tr>
<td>Assemble Adapter 57 tools</td>
<td>0.5</td>
<td>28.5</td>
</tr>
<tr>
<td>Turn &amp; Face 57 tools</td>
<td>6.5</td>
<td>Note 2</td>
</tr>
<tr>
<td>Generate 57 tools</td>
<td>Note 2</td>
<td>28.5</td>
</tr>
<tr>
<td>Mill Spots R₁ (25) 4 tools</td>
<td>1.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Mill Spots R₂ (6) 12 tools</td>
<td>0.5</td>
<td>2.38</td>
</tr>
<tr>
<td>Mill Spots R₃ (7) 17 tools</td>
<td>0.5</td>
<td>2.77</td>
</tr>
<tr>
<td>Mill Spots R₄ (49) 2 tools</td>
<td>0.5</td>
<td>3.37</td>
</tr>
<tr>
<td>Break in Grinders 11 tools</td>
<td>-</td>
<td>44.0</td>
</tr>
<tr>
<td>Form Polishers R₁ 2 tools</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Form Polishers R₂ 6 tools</td>
<td>1.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Form Polishers R₃ 6 tools</td>
<td>1.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Form Polishers R₄ 2 tools</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>TOTALS</td>
<td>24</td>
<td>157.32</td>
</tr>
</tbody>
</table>

NOTES:
(1) No drawing necessary in Method A
(2) See Note 2, Chart 1
# CHART IV
## LENS MANUFACTURING (COST)
### Couplet (200) - 400 Lenses
#### Time in Manhours

<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>No.</th>
<th>&quot;Method A&quot;</th>
<th></th>
<th>&quot;Method B&quot;</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Set up</td>
<td>Operation</td>
<td>Set up</td>
<td>Operation</td>
</tr>
<tr>
<td>Cut Blanks</td>
<td>400 pcs.</td>
<td>1.0</td>
<td>10.0</td>
<td>1.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Generate R₁</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Generate R₂</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Generate R₃</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Generate R₄</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Back up R₁</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Back up R₂</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Mount 25/block R₁</td>
<td>8 blks.</td>
<td>.25</td>
<td>1.04</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Mount 7/block R₃</td>
<td>29 blks.</td>
<td>.25</td>
<td>3.2</td>
<td>1.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Generate Block R₁</td>
<td>8 blks.</td>
<td>1.0</td>
<td>2.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Generate Block R₃</td>
<td>29 blks.</td>
<td>1.0</td>
<td>6.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fine Grind Block R₁</td>
<td>8 blks.</td>
<td>-</td>
<td>5.2</td>
<td>-</td>
<td>5.2</td>
</tr>
<tr>
<td>Fine Grind Block R₃</td>
<td>29 blks.</td>
<td>-</td>
<td>11.6</td>
<td>-</td>
<td>11.6</td>
</tr>
<tr>
<td>Polish Block R₁</td>
<td>8 blks.</td>
<td>-</td>
<td>10.4</td>
<td>-</td>
<td>10.4</td>
</tr>
<tr>
<td>Polish Block R₃</td>
<td>29 blks.</td>
<td>-</td>
<td>23.2</td>
<td>-</td>
<td>23.2</td>
</tr>
<tr>
<td>Back up R₂</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Back up R₄</td>
<td>200 pcs.</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Mount 6/block R₂</td>
<td>34 blks.</td>
<td>.25</td>
<td>2.72</td>
<td>1.0</td>
<td>2.72</td>
</tr>
<tr>
<td>Mount 49/block R₄</td>
<td>4 blks.</td>
<td>.25</td>
<td>0.8</td>
<td>1.0</td>
<td>4.00</td>
</tr>
<tr>
<td>Generate Block R₂</td>
<td>34 blks.</td>
<td>1.0</td>
<td>5.44</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Generate Block R₄</td>
<td>4 blks.</td>
<td>1.0</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fine Grind Block R₂</td>
<td>34 blks.</td>
<td>-</td>
<td>13.6</td>
<td>-</td>
<td>13.6</td>
</tr>
<tr>
<td>Fine Grind Block R₄</td>
<td>4 blks.</td>
<td>-</td>
<td>4.0</td>
<td>-</td>
<td>4.0</td>
</tr>
<tr>
<td>Polish Block R₂</td>
<td>34 blks.</td>
<td>-</td>
<td>27.2</td>
<td>-</td>
<td>27.2</td>
</tr>
<tr>
<td>Polish Block R₄</td>
<td>4 blks.</td>
<td>-</td>
<td>8.0</td>
<td>-</td>
<td>8.0</td>
</tr>
</tbody>
</table>

**TOTALS**                          |         | **6.0**    | **137.6**| **13.0**   | **167.12**|
RESULTS AND CONCLUSIONS

1. This study has provided basic mathematics and a computer design program for tooling required for lens manufacture using the spot block method. It is intended that the tooling be made on specific N/C equipment. Any 5-axis N/C machine can be used for milling, but its geometric constants must be inserted in the program. The same is true of a programmable lathe.

2. Charts III and IV indicate a savings, for the sample used, of 35% in tool manufacture, and 18% in lens fabrication. This conclusion presupposes a one time high cost of fixturing tools that have universal application, and whose unit cost per lens produced approaches zero as production of lenses increases.

3. The savings cited above will vary with lot sizes tending to increase with an increase in lot size and vice versa. They will also vary from lens to lens, since each lens has its unique set of parameters.

4. Spot blocks can be used only for specific lenses therefore the decision to store or scrap after use has to be made on a projection of future need and the cost of storage balanced against the cost of new tool manufacture if needed. Tool lead time is not a major consideration under Method A.

5. Grinders and polishers can (with small modifications) be used on a variety of lens sizes thereby reducing their unit tool cost. The probability of future use is sufficiently high to justify storage.

6. Tapes generated as a result of the computer design program described in the study should be stored. Having tapes available could reduce production lead time and the cost of storage is relatively small.

7. An APT or UNI-APT N/C tape preparation system can be used to prepare N/C tapes from design parameters developed in STBLK Appendix B.

8. STBLK output is programmable for an automatic drafting machine, if drawings are deemed necessary.
APPENDIX A
MATHEMATICS FOR TOOL DESIGN

I. MATHEMATICAL NOTATION

A. Variables

\begin{align*}
R_{L1} & = \text{Radius of first surface.} \\
R_{L2} & = \text{Radius of second surface.} \\
T_A & = \text{Axial thickness of lens.} \\
D_L & = \text{Finished Diameter of lens.} \\
D_M & = \text{Minimum diameter of lens blank.} \\
R_M & = \text{Minimum radius of lens blank.} \\
D_B & = \text{Actual blank diameter - End Mill Dia.} \\
R_B & = \text{Blank radius.} \\
R_{BC} & = \text{Blank radius plus clearance.} \\
D_C & = \text{Clearance hole diameter. - End Mill Dia.} \\
R_C & = \text{Clearance hole radius.} \\
H_1 & = \text{Height of first surface on blank.} \\
H_2 & = \text{Height of second surface on blank.} \\
H_C & = \text{Height of first surface from clearance hole.} \\
T_B & = \text{Actual blank thickness.} \\
T_{E1} & = \text{Edge thickness with first surface generated.} \\
T_{E2} & = \text{Edge thickness with both surfaces generated.} \\
R_{E1} & = \text{Perpendicular distance from center of spot block:} \\
& \quad (a) \text{ to blank seat (convex)} \\
& \quad (b) \text{ to top of blank (concave)}
\end{align*}
\[ R_{Ki} = \text{Spot block spherical radius.} \]
\[ R_{Si} = \text{Clearance radius for concave blocks.} \]
\[ D_{Ai} = \text{Chord across blocked lenses.} \]
\[ D_{AK} = \text{Chord across spot block (Convex) or Aperture of spot block (Concave)} \]
\[ D_{AS} = \text{Chord across spot block (Concave)} \]
\[ H_{Ki} = \text{Height of spot block curve.} \]
\[ H_{Bi} = \text{Spot block overall height.} \]
\[ H_{i} = \text{Distance from blank seat to spot block datum.} \]
\[ H_{D} = \text{See Figure 6.} \]
\[ R_{Gi} = \text{Grinder spherical radius.} \]
\[ D_{AGi} = \text{Chord across grinder (Convex)} \]
\[ D_{AGi} = \text{Aperture of grinder (Concave)} \]
\[ D_{Gi} = \text{Chord across grinder (Concave)} \]
\[ H_{Gi} = \text{Height of grinder curve.} \]
\[ G_{Hi} = \text{Grinder overall height.} \]
\[ R_{Pi} = \text{Polisher spherical radius.} \]
\[ D_{Api} = \text{Chord across polisher (Convex) or Aperture of polisher (Concave)} \]
\[ D_{Pi} = \text{Chord across polisher (Concave)} \]
\[ H_{Pi} = \text{Height of polisher curve.} \]
\[ P_{Hi} = \text{Polisher overall height.} \]
\[ \beta_{j} = \text{The angle subtended by a lens on the surface formed by its spherical radius.} \]
\[ \phi_j = \frac{1}{2} \text{ the angle subtended by a spot block.} \]
\[ \theta_j = \text{Tilt angles.} \]
\[ R_j = \text{Radii perpendicular to spot block axis through intersection of tilt angles at } R_E^i \]
\[ \alpha_j = \text{Angular divisions at radii } R. \]
\[ N_j = \text{Whole number of angular divisions.} \]
\[ N_{T} = \text{Number of spots on block.} \]
\[ \omega = \text{Test angle in search routine.} \]
\[ \omega' = \text{Test angle in search routine.} \]
\[ X_j = \text{See Figure 8.} \]
\[ Y_j = \text{See Figure 5.} \]
\[ Z_j = \text{See Figures 5 and 8.} \]

**NOTE:**
Subscript i refers to lens surface number, 1 or 2.
Subscript j refers to number of tilt angle, 1, 2, 3, \ldots

**B. Constants**

\[ \Delta D_L = \text{Factor to set minimum blank size (1.05)} \]
\[ \Delta D \text{ (R. O.)} = \text{Blank round off increment (0.125)} \]
\[ \Delta D_B = \text{Clearance used in calculations to prevent spots from overlapping (0.005)} \]
\[ \Delta D_C = \text{Difference between spot diameter and clearance hole diameter (0.125)} \]
\[ \Delta T_B = \text{Excess thickness in blank (0.010)} \]
\( \Delta R_K \) = Clearance in concave spot blocks (0.050)

\( \phi_T \) = Maximum value for \( \phi \) (80°)

\( R_T \) = Maximum tool radius.

\( H_{DT} \) = Minimum for \( H_D \) (0.250)

\( \Delta R_p \) = Difference between grinder and polisher radii (0.200)

\( \Delta D_T \) = Factor to determine concave tool O.D. (1.1)

\[ \begin{align*}
L_1 &= \text{Machine spindle extension} = 6.000 \\
L_2 &= \text{Tool holder extension} = 5.000 \\
L_3 &= \text{End mill extension} = 3.000 \\
W_1 &= \text{Spindle radius} = 2.875 \\
W_2 &= \text{Tool holder radius} = 2.000
\end{align*} \]

\[ \begin{align*}
C_1 &= \text{Distance from } \phi \text{ of rotary table to pivot point} = 3.3465 \\
C_2 &= \text{Distance from pivot point to top of table} = 3.8386 \\
C_3 &= \text{Distance from pivot point to machine table top} = 4.7236 \\
C_4 &= \text{Distance from Rotary Table Top to Datum} = 3
\end{align*} \]

\[ \begin{align*}
C_5 &= \text{Distance from Div. Hd Pivot Pt. to Datum} = 6.3125 \\
C_6 &= \text{Distance from Div. Hd Pivot Pt. to Table} = 4.6875 \\
C_7 &= \text{Distance from Div. Hd Pivot Pt. to axis of Hd.} = 0.375
\end{align*} \]
II. MATHEMATICS

SIGN CONVENTIONS

Convex Lens = (+) $R_L$
Concave Lens = (-) $R_L$
Plano Lens (+) $R_L$ = 10,000

GEOMETRIC PRIORITIES (Figure 12)

Case 1. Convex - Convex
$R_{L1}$ = Longest Radius
$R_{L2}$ = Shortest Radius

Case 2. Convex - Concave
$R_{L1}$ = Convex Radius
$R_{L2}$ = Concave Radius

Case 3. Concave - Concave
$R_{L1}$ = Longest Radius
$R_{L2}$ = Shortest Radius

Case 4. Plano - Convex
$R_{L1}$ = Plano
$R_{L2}$ = Convex Radius

Case 5. Plano - Concave
$R_{L1}$ = Plano (No tools designed for plano surfaces.)
$R_{L2}$ = Concave Radius

Note: In all subsequent calculations, when an either/or occurs, go to the next step or to the instruction; as dictated by the results.
Figure 12. Geometric Priorities (Computer Selected)
START ALL CASES:

\[ D_M = (\Delta D_L) D_L \]

\[ R_M = \frac{D_M}{2} \]

\[ D_B = D_M \text{ Rounded off upwards to nearest } 1/8 \text{ inch. Blank dia.} \]

\[ R_B = \frac{D_B}{2} \]

\[ R_{BC} = \frac{D_B + \Delta D_B}{2} \]

\[ D_C = D_B - \Delta D_C \]

\[ R_C = \frac{D_C}{2} \]

Go to para 1, 2, 3, 4 or 5 as determined by Geometric Priorities.

1. Convex - Convex

\[ H_1 = R_{L1} - \sqrt{R_{L1}^2 - R_B^2} \]

\[ H_2 = R_{L2} - \sqrt{R_{L2}^2 - R_B^2} \]

\[ T_B = T_A + \Delta T_B = \text{Blank Thk.} \]

\[ T_{E1} = T_B - H_1 \]

Go to 2A

2. Convex - Concave

\[ H_1 = R_{L1} - \sqrt{R_{L1}^2 - R_B^2} \]

\[ H_2 = R_{L2} - \sqrt{R_{L2}^2 - R_B^2} \]

\[ T_B = T_A + H_2 + \Delta T_B = \text{Blank thk.} \]

\[ T_{E1} = T_B - H_1 \]
2A. First Curve Convex

\[ H_C = R_{L1} - \sqrt{R_{L1}^2 - R_C^2} \]

\[ R_{E1} = R_{L1} - \left( T_B - \frac{\Delta T_B}{2} \right) \]

\[ R_{K1} = \sqrt{\left( R_{E1} + \frac{T_{E1}}{2} \right)^2 + R_B^2} \]

Second Curve Convex Go to 6

Second Curve Concave set \( H = 0 \), and go to 7

3. Concave - Concave

\[ H_1 = |R_{L1}| - \sqrt{R_{L1}^2 - R_M^2} \]

\[ H_2 = |R_{L2}| - \sqrt{R_{L2}^2 - R_M^2} \]

\[ H_C = 0 \]

\[ T_B = T_A + H_1 + H_2 + \Delta T_B = \text{Blank thk.} \]

\[ T_{E1} = T_B - 0.005 \]

\[ R_{E1} = |R_{L1}| + T_A + H_2 + \frac{T_B}{2} \]

\[ R_{K1} = \sqrt{\left( R_{E1} - \frac{T_{E1}}{2} \right)^2 + R_B^2} \]

\[ R_{S1} = \sqrt{\left( R_{E1} - \Delta R_K \right)^2 + R_B^2} \]

Go to 7
4. Plano - Convex

\[
\begin{align*}
H_1 &= 0 \\
H_2 &= R_{L2} - \sqrt{R_{L2}^2 - R_B^2} \\
H_C &= 0 \\
T_B &= T_A + \Delta T_B \\
\end{align*}
\]

Go to 6

5. Plano - Concave

\[
\begin{align*}
H_1 &= 0 \\
H_2 &= \left| R_{L2} \right| - \sqrt{R_{L2}^2 - R_B^2} \\
H_C &= 0 \\
T_B &= T_A + H_2 + \Delta T_B \\
T_E1 &= T_B - \frac{\Delta T_B}{2} \\
\end{align*}
\]

6. Curve 2 Convex

\[
\begin{align*}
T_{E2} &= T_A - H_1 - H_2 \\
R_{E1} &= R_{L2} - T_A + H_C \\
R_{K2} &= \sqrt{\left( R_{L2} - \frac{T_{E2}}{2} \right)^2 + R_B^2} \\
\end{align*}
\]

Go to 8A
7. Curve 2 - Concave

\[ T_{E2} = T_{E1} \]

\[ R_{E2} = \left| R_{L2} \right| + T_A + H_1 - H_C \]

\[ R_{K2} = \sqrt{\left( \left| R_{L2} \right| + \frac{T_{E2}}{2} \right)^2 + R_B^2} \]

\( R_{L1} \) Convex Go to 8A

\( R_{L1} \) Concave Go to 8B I or II

8A. \( R_{L1} \) Convex

\[ \phi_{TST} = 80^\circ \]

\[ R_{Ai} = R_{Li} \sin 80^\circ \]

\[ 0 < R_{Ai} - 5 \leq 0 \] then \( \phi = 80^\circ \)

\[ \phi = \sin^{-1} \frac{5}{R_{Li}} \]

\[ R_{Ai} = R_{Li} \sin \phi \]

\[ H_{Li} = R_{Li} - \sqrt{R_{Li}^2 - R_{Ai}^2} \]

\[ R_{AKi} = R_{Ki} \sin \phi \]

\[ D_{AKi} = 2R_{AKi} \text{ Spot block Dia.} \]

\[ H_{Ki} = R_{Ki} - \sqrt{R_{Ki}^2 - R_{AKi}^2} \text{ Spot block ht.} \]

\[ H'_{TST} = H_{Ki} - (R_{Ki} - R_{E1}) + H_D + H_C \]
\[ 0 \leq H_{TST}' - (1 + H_C) < 0 \]

\[ H' = H_{TST}' \quad \text{(Spot block fig. 5)} \]

and

\[ H_D = H_{DT} \quad \text{(Spot block fig. 5)} \]

\[ H' = 1 + H_C \quad \text{(Spot block fig. 5)} \]

and

\[ H_D = H' - H_Ki + (R_{Ki} - R_{Ei}) \quad \text{(Spot block fig. 5)} \]

\[ H_{Bi} = H_{Ki} + H_D \quad \text{Spot Block Ht.} \]

\[ R_{Gi} = R_{Li} \quad \text{Grinder sph. rad. (Concave)} \]

\[ D_{AGi} = 2 R_{Ai} \quad \text{Grinder Aperture} \]

\[ D_{Gi} = 1.1 D_{AGi} \quad \text{Grinder O.D.} \]

\[ H_{Gi} = \left| R_{Gi} \right| - \sqrt{R_{Gi}^2 - R_{AGi}^2} \]

\[ G_{Hi} = H_{Gi} + 1.00 \quad \text{Grinder Ht.} \]

\[ R_{Pi} = R_{Gi} - 0.200 \quad \text{Spherical radius polisher (Concave)} \]

\[ R_{API} = \left| R_{Pi} \right| \sin \phi \]

\[ D_{API} = 2 R_{API} \quad \text{Polisher Aperture} \]

\[ D_{Pi} = 1.1 D_{API} \quad \text{Polisher O.D.} \]

\[ H_{Pi} = \left| R_{Pi} \right| - \sqrt{R_{Pi}^2 - R_{API}^2} \]

\[ P_{Hi} = H_{Pi} + 1.000 \quad \text{Polisher Ht.} \]

\[ \frac{\beta}{2} = \tan^{-1} \frac{R_{BC}}{R_{Ei}}, \quad \text{Round off upward to nearest 1/2 degree} \]

\[ \beta = 2 \frac{\beta}{2}, \quad \text{R. O.} \]

Go to 9
8B. \( R_{Li} \) Concave

I Search Routine - CIM-X (Figure 7)

1 \[ 0 \leq R_{Ei} - L_2 < 0 \] Go to 6

2 \[ R_{A1} = R_{L1} \sin 80^\circ \]

3 \[ 0 \leq (R_{A1} - 5) < 0 \] Go to 5

4 \[ \phi = \sin^{-1} \frac{5}{R_{L1}} \] Go to para 8B III

5 \[ \phi = 80^\circ \] Go to para 8B III

6 \[ 0 \leq (R_{Ei} - L_3) < 0 \] Go to 12

7 \[ \omega = \cos^{-1} \frac{W_1}{R_{Ki}} \]

8 \[ \omega' = \sin^{-1} \frac{L_2 - R_{Ei}}{R_{Si}} \]

9 \[ 0 \leq (\omega - \omega') < 0 \] Go to 11

10 \[ \phi = \frac{\beta/2 + 90 + \omega}{2} \] Go to para 8B III

11 \[ \phi = \frac{\beta/2 + 90 + \omega'}{2} \] Go to para 8B III

12 \[ R_S \leq (L_2 - R_{Ei}) < R_S \] Go to 20

13 \[ R_S \leq (L_3 - R_{Ei}) < R_S \] Go to 15

14 \[ \phi = 80^\circ \] Go to para 8B III

15 \[ \omega = 70 - \beta/2 \]

16 \[ \omega' = \sin^{-1} \frac{L_3 - R_{Ei}}{R_S} \]

17 \[ 0 \leq (\omega - \omega') < 0 \] Go to 19
18 $\phi = \beta/2 + 90 + \omega'$

19 $\phi = 80'$

20 $\omega = \cos^{-1} \frac{W_2}{R_K}$

21 $\omega' = \sin^{-1} \frac{L_3 - R_{EI}}{R_{Si}}$

22 $0 \leq (\omega - \omega') < 0$

23 $\phi = \frac{\beta/2 + 90 + \omega}{2}$

24 $\phi = \frac{\beta/2 + 90 + \omega'}{2}$

II Search Routine K & T (Figure 7)

1 $0 \leq (R_{E1} - L_1) < 0$

2 $\phi_T = \frac{\cos^{-1} \left( \frac{R_{Ki} - L_1}{R_{Ki}} \right) + \frac{\beta}{2}}{2}$

3 $R_{AI} = R_{L1} \sin \phi_T$

4 $0 \leq (R_{AI} - 5) < 0$

5 $\phi = \sin^{-1} \frac{5}{R_{Li}}$

6 $\phi = \phi_T$

7 $0 \leq (R_{E1} - L_2) < 0$

8 $\omega = \sin^{-1} \frac{L_1 - R_{EI}}{R_{si}}$

9 $\phi_T = \frac{\beta/2 + 90 + \omega}{2}$
10 \( R_{Ai} = R_{Li} \sin \phi_T \)

11 \( 0 \leq R_{Ai} - 5 < 0 \)  
Go to 13

12 \( \phi = \sin^{-1} \frac{5}{R_{Li}} \)  
Go to para 8B III

13 \( \phi = \phi_T \)  
Go to para 8B III

14 \( 0 \leq (R_{Ei} - L_3) < 0 \)  
Go to 29

15 \( R_s \leq (L_1 - R_{Ei}) < R_{Si} \)  
Go to 21

16 \( \omega = \cos^{-1} \frac{W_2}{R_{Ki}} \)  

17 \( \omega' = \sin^{-1} \frac{L_2 - R_{Ei}}{R_{Si}} \)  

18 \( 0 \leq (\omega - \omega') < 0 \)  
Go to 20

19 \( \phi = \frac{\beta/2 + 90 + \omega}{2} \)  
Go to para 8B III

20 \( \phi = \frac{\beta/2 + 90 + \omega}{2} \)  
Go to para 8B III

21 \( \omega = \cos^{-1} \frac{W_1}{R_{Ki1}} \)  

22 \( \omega = \sin^{-1} \frac{L_1 - R_{Ei}}{R_{Si}} \)  

23 \( 0 \leq (\omega - \omega') < 0 \)  
Go to 25

24 \( \phi = \frac{\beta/2 + 90 + \omega'}{2} \)  
Go to para 8B III

25 \( \omega' = \sin^{-1} \frac{L_2 - R_{Ei}}{R_{Si}} \)  

26 \( 0 \leq (\omega - \omega) < 0 \)  
Go to 28
27 \[ \phi = \frac{\beta/2 + 90 + \omega}{2} \] Go to para 8B III

28 \[ \phi = \frac{\beta/2 + 90 + \omega'}{2} \] Go to para 8B III

29 \[ R_{Si} \leq (L_2 - R_{Ei}) < R_{Si} \] Go to 37

30 \[ R_{Si} \leq (L_3 - R_{Ei}) < R_{Si} \] Go to 32

31 \[ \phi = 80^\circ \] Go to para 8B III

32 \[ \omega = 70 - \beta/2 \] Go to para 8B III

33 \[ \omega' = \sin^{-1} \frac{L_3 - R_{Ei}}{R_{Si}} \] Go to para 8B III

34 \[ 0 \leq (\omega - \omega') < 0 \] Go to 36

35 \[ \phi = \frac{\beta/2 + 90 + \omega'}{2} \] Go to para 8B III

36 \[ \phi = 80^\circ \] Go to para 8B III

37 \[ \omega = \cos^{-1} \frac{W_2}{R_{Ki}} \] Go to para 8B III

38 \[ \omega' = \sin^{-1} \frac{L_3 - R_{Ei}}{R_{Si}} \] Go to 41

39 \[ 0 \leq (\omega - \omega') < 0 \] Go to 41

40 \[ \phi = \frac{\beta/2 + 90 + \omega}{2} \] Go to para 8B III

41 \[ \phi = \frac{\beta/2 + 90 + \omega'}{2} \] Go to para 8B III
\[ H' = 1 + H_C \]
\[ R_{AKi} = R_{Ki} \sin \phi \]
\[ D_{AKi} = 2 R_{AKi} \quad = \text{Spot Block Aperture} \]
\[ H_{Ki} = R_{Ki} - R_{Ki}^2 - R_{AKi}^2 \]
\[ H_{Bi} = H_i' + R_{Ei} - R_{Ki} + H_{Ki} \quad = \text{Spot Block Ht.} \]
\[ \text{Mult. } R_{Ki} \text{ by } (-1) \quad = \text{Spot Block Sph. Rad.} \]
\[ R_{AS} = R_{Si} \sin \phi \]  
\[ D_{AS} = 2 R_{AS} \quad = \text{Spot Block O. D.} \]
\[ R_{Gi} = R_{Li} \quad = \text{Grinder Sph. Rad} \]
\[ R_{AGi} = R_{Gi} \sin 0 \]
\[ D_{AGi} = 2 R_{AGi} \quad = \text{Grinder O. D.} \]
\[ H_{Gi} = R_{Gi} - \sqrt{R_{Gi}^2 - R_{AGi}^2} \]
\[ 0 \leq H_i' - H_{Gi} < 0 \]
\[ G_{Hi} = H_i' \quad = \text{Grinder Ht.} \]
\[ G_{Hi} = H_{Gi} \quad = \text{Grinder Ht.} \]
\[ R_{Pi} = R_{Gi} - 0.200 \quad = \text{Polisher Sph. Rad.} \]
\[ R_{API} = R_{Pi} \sin 0 \]
\[ D_{API} = 2 R_{API} \quad = \text{Polisher Dia.} \]
\[
H_{Pi} = R_{Pi} - \sqrt{R_{Pi}^2 - R_{Pi}^2}
\]

0 \leq H'_i - H_{Pi} < 0

\[
P_{Hi} = H'_i
\]

Polisher Ht.

\[
P'_{Hi} = H'_i
\]

Polisher Ht.

\[
\beta = \sin^{-1} \left( \frac{R_{BC}}{R_{Li}} \right), \text{ Round off to nearest 1/2 degree}
\]

\[
\beta = 2 \frac{\beta}{2} \text{ R.O.}
\]

Go to 9

9. Calculate \( \theta_j \), \( j = 1, 2, 3, \ldots \)

\[
\theta = \phi - \frac{\beta}{2}, \text{ where } j = 1
\]

\( 0_j < 0 \) Error stop

Start loop

\[
0 \leq (\theta_j - \frac{\beta}{2}) < 0, \theta_j = 0
\]

\[
0 \leq (\theta_j - \beta) < 0
\]

Tilt \( < = 90 - \theta \)

\[
\theta_j + 1 = \theta_j - \beta
\]

Center Lens

No Center Lens

End of loop

If \( R_{Li} \) convex Go to 10

If \( R_{Li} \) concave Go to 11
10 \( R_{Li} \) Convex

\[
R_j = R_{Ei} \sin \theta_j
\]

\[
R_{j+1} = R_{Ei} \sin \theta_{j+1}
\]

Continue for all values of \( \theta_j \) and go to 12

11 \( R_{Li} \) Concave

\[
R_j = (|R_{Li}| - H_i) \sin \theta_j
\]

Continue for all values of \( \theta_j \) and go to 12

12 Calculate no. of spot on block

\[
\frac{\alpha_j}{2} = \sin^{-1} \left( \frac{R_{BC}}{R_j} \right)
\]

\[
\alpha_j = 2 \sin^{-1} \left( \frac{R_{BC}}{R_j} \right)
\]

\[
N_j = \frac{360}{\alpha_j} \quad \text{Round off down to nearest integer}
\]

\[
\alpha_j = \frac{360}{N_j} \quad \text{(R.o.)}
\]

\[
\frac{\alpha_{j+1}}{2} = \sin^{-1} \left( \frac{R_{BC}}{R_j + 1} \right)
\]

\[
\alpha_{j+1} = 2 \sin^{-1} \left( \frac{R_{BC}}{R_j + 1} \right)
\]

Continue for all values of \( R_j \)

\[
N_T = \left\lfloor N_j \right\rfloor
\]

Go to coord. (Convex Concave) CIM-X

or

Go to (Convex Concave) K and T
13a. Calc. Coordinates CIM-X

Convex Block (Fig. 6)

\[ S_i = H'_i + C_4 \]

\[ K_i = S_i - R_{Ei} \]

Concave Block (Fig. 7)

\[ K_i = R_{Ei} + H'_i + C_4 \]

Change Sign of \( R_{Ei} \)

All Blocks

\[ Y_j = c_3 + c_2 \sin \theta_j + c_1 \cos \theta_j + k_i \sin \theta_j \]

\[ Y_j = (c_2 + k_i) \sin \theta_j + c_1 \cos \theta_j + c_3 \]

\[ Z_j = c_1 + c_2 \cos \theta_j - c_1 \sin \theta_j + k_i \cos \theta_j + R_{Ei} \]

\[ \Delta Z = H_{C_1} + .030 \]

13b. Calc. Coordinates K and T

Convex Block (Fig. 8A)

\[ S = H' + C_5 \]

\[ K_i = S - R_{Ei} \]

Concave Block (Fig. 8B)

\[ K_i = R_{Ei} + H'_i + C_5 \]

Change sign of \( R_{Ei} \) from (+) to (-)
All Blocks

\[ X_j = K_i \sin \theta_j + C_7 - C_7 \cos \theta_j \]

\[ X_j = K_i \sin \theta_j + C_7 (1 - \cos \theta_j) \]

\[ Z_j = K_i \cos \theta_j + C_7 \sin \theta_j + R_{E1} + C_6 \]

\[ \Delta Z = H_C + 0.030 \]
APPENDIX B

COMPUTER PROGRAM - STPBLK

INPUT, DATA
One Card Per Lens

Columns (1-9), Lens Radius
Columns (10-18), Lens Radius
Columns (19-27), Axial Thickness
Columns (28-36), Lens Diameter
Column 73, Indicator for Machine Geometry
   1 - K and T Dividing Head
   2 - Cim-X N/C

NOTE:

(+) Sign indicates Convex Lens
(-) Sign indicates Concave Lens
Radius of 10,000 indicates Plano
PROGRAM STPBLK
1
C-
C-
C-
C-
C-
5
DIMENSION A(B), REF(2), RTST(2), IND(2), RB(2)
C-
C-
C-
C-
C-
10
C-
C-
C-
C-
C-
15
DATA NREAD, NPRINT/5, 6/;
C-
C-
C-
C-
C-
DATA RTOD, PI/57, 29578, 3.14159265/;
C-
C-
C-
C-
C-
20
DATA DELX, DELZ/20, 0, 0300/;
C-
C-
C-
C-
C-
DATA TOLMR/5.00/;
DATA RF/6, 31250/;
C-
C-
C-
C-
C-
25
DATA HPIVOT/4.6875/;
C-
C-
C-
C-
C-
DATA AXDIS/0.3750/;
DATA DSUBP/5.00/;
C-
C-
C-
C-
C-
30
DATA DSS, DEHT, HC/3, 34645, 3.83858, 4.72360/;
C-
C-
C-
C-
C-
DATA CLR/0.1000/;
DATA W1, W2, W3/2.8750, 2.000, 0.010/;
C-
C-
C-
C-
C-
DATA ELL1, ELL2, ELL3/6.000, 5.000, 3.000/;
DATA PLANO/10000.0/;
C-
C-
C-
C-
C-
35
FORMAT (6F9.4, 2F9.5, 1I1)
4
FORMAT (14X, 13, 19H LENS ON BLOCK NO; I2 )
40
FORMAT (14H1 INPUT DATA = 4X, 4F11.4, 10X, I2/ 5X, 16HLENS BLANK DATA
10X, 10X, 17HBLANK DIAMETER =, F9.4, 10X, 18HLBLANK THICKNESS =
2, F9.4 )
10 FORMAT (4X, 32H CALCULATIONS FOR SPOT BLOCK NO. 12/ 10X, 19HSFERICAL
2RICAL DIAMETER, C112H =, F9.4, 1F1, 27HSFERICAL DIAMETER OF BLOCK =
3, F9.4 )
45
25 FORMAT (10X, 16HBLANK DIAMETER =, F9.4, 10X, 14HBLOCK HEIGHT =
1 F9.4 )
26 FORMAT (1H6, 10X, BHSIDE NO 12, 9H IS PLANO ///)
27 FORMAT (10X, 26HBLOCK APERTURE (CONCAVE) =, F9.4, 10X, 23HBLOCK O.D.
1D (CONCAVE) =, F9.4, 10X, 14HRLOCK HEIGH =, F9.4, 5H (H1 )
29 FORMAT (10X, 27HDIAMETER OF HOLES (SPOTS) =, F9.4, 10X, 29HDIAMETER
1ER OF CLEARANCE HOLES =, F9.4, 10X, 19HEFFECTIVE RADIUS =, F9.4, 10X,
2/ 10X, 6H PHI =, F7.2 / 10X, 7H BETA =, F6.2 )
55 FORMAT (10X, 4HRING, 5X, 4HILT, 5X, SHN, OF, 4X, 9HPOSITION, 10X,
1, 19HCX, T INDEXING HEAD, 11X, 3HNO, 5X, 5HANG, 4X, SHPOTS, 2,
5X, 5SHANGLE, 9X, 2H X, 8X, 2H Y, 9X, 7HDELTZ / )
36 FORMAT (19H, GRINDER DATA / 10X, 18HSPHERICAL RADIUS = , F9.4,
10X, 16HGRINDER DIAMETER = , F9.4, 10X, 18HGRINDER HEIGHT = , F9.4)
60 FORMAT (21H, POLISHER DATA / 10X, 18HSPHERICAL RADIUS = , F9.4,
1.4 / 10X, 19HPOLISH DIAMETER = , F9.4, 2 = , F9.4 / )
54 FORMAT (10X, 4HRING, 5X, 4HILT, 5X, SHN, OF, 4X, 9HPOSITION, 10X,
5X, 5HANG, 9X, 2H X, 8X, 2H Y, 9X, 7HDELTZ / )
136 FORMAT (19H, GRINDER DATA / 10X, 18HSPHERICAL RADIUS = , F9.4,
1.4 / 10X, 16HGRINDER APERTURE (CONCAVE) = , F9.4 / 10X, 16HGRINDER APERTURE (CONVEX) = , F9.4 / 10X, 16HGRINDER RADIUS = , F9.4 /
20.0 = , F9.4, 10X, 16HGRINDER HEIGHT = , F9.4 / )
137 FORMAT (21H, POLISHER DATA / 10X, 18HSPHERICAL RADIUS = , F9.4,
20.0 = , F9.4, 10X, 19HPOLISH HEIGHT = , F9.4 / )
167 FORMAT (1H, *TOLWR* = 2.00)
188 FORMAT (18H, "SPECIAL CASE"

C- A(1) OR A(2) CONTAINS RL1 AND RL2
C- A(3) = AXIAL THICKNESS
C- READ (NREAD, (A(I), I = 1, 8), LIMP
C- LAST DATA CARD HAS ALL ZEROS
C- MAKE RL=LONGEST RADIUS, CALCULATE FOR RL FIRST
C- SELECT CONCAVE OR CONVEX SIDES OF LENS AND CLASSIFY THE LENS
C- NOLT = 0
C- IND(1) = 1
C- IND(2) = 1
C- AA1 = ABS(A(1))
C- AA2 = ABS(A(2))
C- IF (A(1) .GT. 0.010 .AND. A(2) .GT. 0.010) NOLT = 11
C- IF (A(1) .LT. 0.000 .OR. A(2) .LT. 0.000) NOLT = 12
C- IF (A(1) .GT. 0.000 .AND. A(2) .LT. 0.000) NOLT = 22
C- IF (NOLT .GT. 10) Go TO 6
C- A(7) = AMIN(AA1, AA2) + 0.008
C- A(8) = AMIN1(A(1), A(2))
C- NOLT = 92
C- IF (A(7) .GT. AA1) AA1 = PLANO
C- IF (A(7) .GT. AA2) AA2 = PLANO
C- RTST(1) = PLANO
C- RTST(2) = AMIN1(AA1, AA2)
C- AA1 = PLANO
C- AA2 = RTST(2)
C- A(1) = PLANO
C- A(2) = A(8)
C- IF (A(8) .LT. 0.000) Go TO 6
C- NOLT = 91
C- A(2) = RTST(2)

THE FOLLOWING TESTS ESTABLISHES THE PRIORITY OF WHICH SIDE OF THE LENS TO
C- DO FIRST.
6 IF (NOLT .NE. 11) GO TO 7
C- DOUBLE CONVEX LENS
110 RTST(1) = AMAX1(AA,AA2)
RTST(2) = AMIN1(AA,A2A2)
IF (RTST(1) .GE. 9999.8) NOLT = 91
A11 = RTST(1)
A12 = RTST(2)
115 7 IF (NOLT .NE. 22) GO TO 8
C- DOUBLE CONCAVE LENS
120 RTST(1) = AMAX1(AA,AA2)
RTST(2) = AMIN1(AA,AA2)
IND(1) = 2
IND(2) = 2
IF (RTST(1) .GE. 9999.8) NOLT = 92
A11 = -1.0 * RTST(1)
A12 = -1.0 * RTST(2)
8 IF (NOLT .NE. 12) GO TO 9
125 C- CONVEX-CONCAVE LENS
RTST(1) = AMAX1(A11,A(1,2))
RTST(2) = AMIN1(A(1,2))
C- R-1 IS THE CONVEX AND R-2 IS THE CONCAVE SIDE
A11 = RTST(1)
A12 = RTST(2)
RTST(2) = ABS(A(1,2))
IND(2) = 2
IF (RTST(1) .GE. 9999.8) NOLT = 92
C- PLANO-CONVEX IS NOLT = 91
135 9 IF (NOLT .GE. 90) RTST(2) = AMIN1(AA1,AA2)
C- PLANO-CONCAVE IS NOLT = 92
IF (NOLT .NE. 92) GO TO 11
IND(2) = 2
11 CONTINUE
140 IF (A11 .LT. 0.000) IND(1) = 2
IF (A12 .LT. 0.000) IND(2) = 2
R1 = RTST(1)
R2 = RTST(2)
145 DEY(1) = DELY
DEY(2) = 0.000
DMLN1 = A4 * 1.5570
RMW = DMLN1 / 2.000
IDB = IFIX(DMLN1)
DPT = DMLN1-FLOAT(IDB)
150 C- THE FOLLOWING ROUTS BLANK DIAMETER UPWARDS TO THE NEAREST EIGHTH (1/8)
AN8TH = 0.1250
15 IF (AN8TH .GE. DPT) GO TO 20
AN8TH = AN8TH + 0.1250
GO TO 15
155 20 DPLANK = FLOAT(IDB) + AN8TH
RLANK = DPLANK / 2.000
RBC = (DPLANK + 0.005) / 2.000
C DPRING=DIAETER OF POSITION RING
DPRING = DPLANK - 0.1250
PROGRAM STPBLK

160 RPRING = DPRING / 2.0
H1 = R1 - SORT(R1**2 - RBLANK**2) * 2
IF (NOLT * EQ. 1) DEY(2) = H1
H2 = R2 - SORT(R2**2 - RBLANK**2) * 2
TSB = A(3) + CLR
IF (NOLT * EQ. 12) TSA = TSB + H2
HCLR = R1 - SORT(R1**2 - RPRING**2)
EFTHK(1) = A(3) - H1
REFF(1) = R1 - TSB + 0.0050
RBLK1 = SORT ( (REFF(1) + EFTHK(1) / 2.0)**2 + RBLANK**2)

170 IF (NOLT * EQ. 22) GO TO 22
H1 = R1 - SORT(R1**2 - RMM**2)
H2 = R2 - SORT(R2**2 - RMM**2)
TSB = TSB + H1 + H2
HCLR = 0.000
EFTHK(1) = TSB - 0.0050
REFF(1) = R1 - A(3) + 0.0050 + H1
RBLK1 = -1.00 * SORT((REFF(1) - EFTHK(1) / 2.0)**2 + RBLANK**2)
RS1 = SORT((REFF(1) + 0.0050)**2 + RBLANK**2)

22 CONTINUE
WRITE (NPRINT, 5) A(1), A(2), A(3), A(4), LIMP, DBLANK, TSB
C-
THE FOLLOWING IS CORRECTION FOR PLANO-XXX LENS
IF (NOLT * GT. 90) H1 = 0.000
IF (NOLT * GT. 90) HCLR = 0.000
IF (NOLT * GT. 90) H2 = R2 - SORT(R2**2 - RBLANK**2)
185 IF (NOLT * EQ. 92) TSB = A(3) + H2 + CLR
IF (NOLT * EQ. 92) EFTHK(1) = TSB - 0.0050
RBLK1 = ABS(RBLK1)
EFTHK(2) = A(3) - H1 - H2
REFF(2) = R2 - A(3) + HCLR - 0.0050
IF (IND(2) * EQ. 2) REFF(2) = R2 + A(3) + H1 + HCLR
C-
RBLK2 = SORT((REFF(2) + EFTHK(2)**2 / 2.0)**2 + RBLANK**2)
RBLK2 = SORT((R2 - HBLANK - EFTHK(2)**2 / 2.0)**2 + RBLANK**2)
195 IF (IND(2) * EQ. 2) RBLK2 = RBLK2 + EFTHK(2)**2 + RBLANK**2
RBLK2 = RBLK2 + RBLK2
C-
THE FOLLOWING LOOP CALCULATES BLOCK FOR R1, THEN RETURNS FOR R2.
DO 60 K = 1, 2
C-
INITIALIZE THE LENS PER BLOCK COUNT (LPB)
200 LPB = 0
IF (RTST(K), LT, 9999.8) GO TO 47
WRITE (NPRINT, 26) K
GO TO 60

47 CONTINUE
RDLUM = RTST(K)
KSIDE = K
IF (IND(K) * EQ. 2) RDLUM = -1.0**2 * RTST(K)
WRITE (NPRINT, 10) K, KSIDE, RDLUM, RB(K)
C-
THE FOLLOWING IS THE CONVERSION FROM RADIANS TO DEGREES
HRBETA = RTOD * ATAN(RBLK/RBLK(K))
IF (IND(K) * EQ. 2) HRBETA = ASIN(RBLK/RBLK(K)) * RTOD
C-
BETA IS THE ANGLE SUBTENDED BY A LENS ON THE SPOT BLOCK
CONCAVE
BETA = (HBETA + 0.5000) * 4.00
KDUM = IFFX(BETA) / ?
BETA = FLT(KDUM)
HBETA = BETA * 0.500

C- THE FOLLOWING ROUTINE IS ONLY USED WITH CONCAVE LENS -- WHERE A
C- DIFFERENT ANGLE (PHI) IS NEEDED DUE TO INTERFERENCE
C- PHI (PHI) IS ONE HALF (1/2) THE TOTAL ANGLE OF THE SPOT BLOCK

CHI = 80.00
CHIRAD = 80.00 / RTOD
RADUM = RTST(K) * SIN(CHI/RTOD)
IF (RADUM < LT; TOLMR) GO TO 33
CHI = ASIN (TOLMR/RTST(K)) / RTOD
IF (IND(K) = EQ. 2) CHI = CHI - 0.5000
ICH = CHI
XDUM = CHI - FLOAT(ICH)
CHI = FLOAT(ICH)
IF (XDUM = GE; 0.5000) CHI = CHI + 0.5000
CHIRAD = CHI / RTOD
RADUM = RTST(K) * SIN(CHIRAD)

33 CONTINUE
RASP = RBLOK(K) * SIN(CHIRAD)
RASP = RASP * 2.00
RGRIND = -1.00 * RBLOK
HGRIND = RTST(K) - SORT(RGRIND ** 2 - RADUM ** 2) + 1.00
POLR = -1.00 * (RTST(K) + 0.1500)
IF (IND(K) = EQ. 2) POLR = RTST(K) - 0.1500
DPOL = ABS(POLR * SIN(CHIRAD))
HTPOL = ABS(POLR) - SORT(POLR ** 2 - DPOL ** 2) + 1.00
IF (IND(K) = NE. 2) GO TO 63
HGRIND = ABS(RGRIND) - SORT(RGRIND**2 - RADUM**2)

C- WHERE H-PRIME = 1.0 + M-SUB-C
HPRIME = HCLR + 1.00
IF (HGRIND = LE. HPRIME) HGRIND = HPRIME
HTPOL = HTPOL - 1.000
IF (HTPOL = LE. HPRIME) HTPOL = HPRIME
63 CONTINUE
DPOL = DPOL * 2.0000
XP = CHI * 2.00 / BFTA
I2N = IFIX(X2N)
N = I2N / 2
DGND = 2.00 * RADUM
HKAY = RBLOK(K) - SORT(RBLOK(K)**2 - RASP**2)
HPRIME = HKAY - RBLOK(K) = REFF(K) + 0.2500 + HCLR
IF (HPRIME = LE. 1.000) HPRIME = 1.000 + HCLR
S = HPRIME + DSUBP
FLKAY = S - REFF(K)
FKC = HPRIME + 3.0000 - REFF(K)
HDEE = 1.000 - HKAY + RBLOK(K) - REFF(K)
IF (HPRIME = GE. 1.00) HDEE = 0.25000

C- FOR THE CONCAVE LENS, USE THE ROUTINE AFTER STATEMENT NO. 132
IF (IND(K) = EQ. 2) GO TO 132
HKAY = HKAY + HDEE
WRITE (NPRINT,25) OASP, HBA
WRITE (NPRINT,29) DRANK, DPRINT, REFF(K), CHI, BETA
TILT = CHI - HBA
I = 1
270 IF (LIMP *.NE. 2) GO TO 940
WRITE (NPRINT,54)
GO TO 950
940 WRITE (NPRINT,34)
950 CONTINUE
275 IF (TILT *.GE. 0.000) GO TO 41
WRITE (NPRINT,188)
GO TO 40
41 CONTINUE
IF (TILT *.GT. HBA) GO TO 44
LPA = LPA + 1
C- THE FOLLOWING ESTABLISHES THE PARAMETERS FOR A CENTER LENS
M = 1
POSANG = 0.000
TILT = 0.000
285 ALPHA = 0.000
X = 0.000
Y0L0 = REFF(K) + FLKAY * HPIVOT
IF (LIMP *.EQ. 1) GO TO 42
290 X = DSTT + HC
Y0LD = DSTT + ODE + FKC + REFF(K)
42 CONTINUE
WRITE (NPRINT,32) I, COTILT, M, POSANG, X, Y0L0, DEY(K)
GO TO 40
295 44 CONTINUE
ANGLE = TILT / RTOD
R = REFF(K) * SIN(ANGLF)
C- IF (IND(K) *.EQ. 2) R = SORT(RTST(K)**2 - RALANK**2) * SIN(ANGLF)
ALPHA = 2.00 * RTOD * ASIN(RBC/R)
300 XM = 360.0 / ALPHA
M = IFIX(XM)
C- M = NUMBER OF LENSES IN A GIVEN RING
LPA = LPA + M
POSANG = 360.0 / (FLOAT(M))
305 X = FLKAY * SIN(ANGLF) + AXDIS * (1.00 - COS(ANGLF))
Y0LD = REFF(K) + FLKAY * COS(ANGLF) + HPIVOT + AXDIS * SIN(ANGLF)
XNEW = (ODE + FKC) * SIN(ANGLF) + DSTT * COS(ANGLF) + HC
ZNEW = DSTT * (1.000 - SIN(ANGLF)) + (ODE + FKC) * COS(ANGLF)
1 + REFF(K)
310 COTILT = 90.00 - TILT
IF (LIMP *.NE. 2) GO TO 48
X = XNEW
Y0LO = ZNEW
48 CONTINUE
WRITE (NPRINT,32) I, COTILT, M, POSANG, X, Y0LD, DEY(K)
315 TILT = TILT - BETA
I = I + 1
IF (TILT *.GE. 0.000) GO TO 41
C- NO CENTER LENS
   (CENTER LENS CANNOT BE FITTED IN)
320 WRITE (NPRINT, 167)
   GO TO 40
C- 132 CONTINUE
C- CONCAVE LENS
325 I = 1
   LPL = 0
C- CINCINNATI N C. MILLING MACHINE SUPPLEMENT
   RSSKX = SQRT( (REFF(K) + 0.5000) ** 2 + RBLANK ** 2 )
330 W3 = RPRING
   PHI = 80.00
   IF (LIMP .NE. 2) GO TO 181
   IF (REFF(K) .LT. ELL2) GO TO 146
   CHIRAD = 90.00 / RTOD
   RADUM = RST(K) * SIN(CHIRAD)
   IF (RADUM .LT. TOLMR) GO TO 140
   PHI = ASIN(TOLMR/RST(K)) * RTOD
   GO TO 181
335 146 CONTINUE
    PHI = 80.00
    GO TO 181
340 146 CONTINUE
    PHI = 80.00
345 146 CONTINUE
    IF (REFF(K) .LT. ELL3) GO TO 161
    OMCA = ACOS(W1 / RBLOK(K)) * RTOD
    OMCAP = ASIN((ELL2 - REFF(K))/RSSKX) * RTOD
    PHI = (HBETA + 90.00 + OMCA) * 0.5000
    IF (OMCA .GT. OMCA) PHI = (HBETA + 90.00 + OMCA) * 0.5000
    GO TO 181
350 161 CONTINUE
   IF (ELL2 - REFF(K) .LT. RSSKX) GO TO 175
   IF (ELL3 - REFF(K) .LT. RSSKX) GO TO 164
   PHI = 80.00
   GO TO 181
355 164 CONTINUE
   OMCA = 70.00 - HBETA
   OMCAP = ASIN((ELL3 - REFF(K))/RSSKX) * RTOD
   PHI = 80.00
   IF (OMCA .LT. OMCA) GO TO 181
   PHI = (HBETA + 90.00 + OMCA) * 0.5000
   GO TO 181
360 175 CONTINUE
   OMCA = ACOS(W2/RBLOK(K)) * RTOD
   OMCAP = ASIN(ELL3 - REFF(K))/RSSKX) * RTOD
   OMDUM = AMAX1(OMCA,OMCAP)
   PHI = (HBETA + 90.00 + OMDUM) * 0.5000
181 CONTINUE
   CHI = PHI * 2.000
   KDOM = IFIX(CHI)
365 PHI = FLOAT(KDOM) * 0.50000
   IF (LIMP .NE. 1) GO TO 1190
C- CALCULATIONS FOR THE K+1 INDEXING HEAD

IF (REFF(K) .LT. ELL1) GO TO 1140
  CHI = (ACOS((REFF(K) - ELL1) / RBLK(K)) * RTOD + HBETA) * .5000
  RADUM = RTST(K) * SIN(CHI/RTOD)
  IF (RADUM .LT. TOLMR) GO TO 1181
  CHI = ASIN(TOLMR / RTST(K)) * RTOD
  GO TO 1181

1140 CONTINUE

IF (REFF(K) .LT. ELL2) GO TO 1150
  OMCA = ASIN((ELL1 - REFF(K)) / RSSXK) * RTOD
  CHI = (HBETA + 90.00 + OMCA) * .5000
  RADUM = RTST(K) * SIN(CHI/RTOD)
  IF (RADUM .LT. TOLMR) GO TO 1181
  CHI = ASIN(TOLMR/ELL1) * RTOD
  GO TO 1181

1150 CONTINUE

IF (REFF(K) .LT. ELL3) GO TO 1220
  IF ((ELL1 - REFF(K)) .LT. RSSXK) GO TO 1160
  OMCA = ACOS(W2 / RBLK(K)) * RTOD
  OMCAP = ASIN((ELL2 - REFF(K)) / RSSXK) * RTOD
  OMDUM = AMAX1(OMCA,OMCAP)
  CHI = (HBETA + 90.00 + OMDUM) * .5000
  GO TO 1181

1160 CONTINUE

OMCA = ACOS(W1 / RBLK(K)) * RTOD
OMCAP = ASIN((ELL1-REFF(K)) / RSSXK) * RTOD
IF (OMCA .LT. OMCA) GO TO 1170
  CHI = (HBETA + 90.00 + OMCA) * .5000
  GO TO 1181

1170 CONTINUE

OMCAP = ASIN((ELL2 - REFF(K)) / RSSXK) * RTOD
OMDUM = AMAX1(OMCA,OMCAP)
CHI = (HBETA + 90.00 + OMDUM) * .5000
  GO TO 1181

1220 CONTINUE

R SUB-E .LT. L-2,
IF (ELL2 - REFF(K)) .LT. RSSXK) GO TO 1250
IF (ELL3 - REFF(K)) .LT. RSSXK) GO TO 1230
  CHI = 80.00
  GO TO 1181

1230 CONTINUE

OMCA = 70.00 - HBETA
OMCAP = ASIN((ELL3 - REFF(K)) / RSSXK) * RTOD
CHI = 80.00
  IF (OMCA .GE. OMCA) CHI = (HBETA + 90.00 + OMCA) * .5000
  GO TO 1181

1250 CONTINUE

OMCA = ACOS(W2 / RBLK(K)) * RTOD
OMCAP = ASIN((ELL3 - REFF(K)) / RSSXK) * RTOD
OMDUM = AMAX1(OMCA,OMCAP)
CHI = (HBETA + 90.00 + OMDUM) * .5000
1181 CONTINUE

CHEX = CHI * 2.000
.425
KDUM = IFIX(CHEX)
CHI = FLOAT(KDUM) * 0.5000
1199 CONTINUE
C-
PRINT OUT PHI AND GO ON TO CALCULATE THETA OR TILT
XDUM = SORT((REFF(K) + 0.0500) * 2 + RBLANK**2)
430 IF (LIMP .EQ. 0.1) PHI = CHI
CONDB = 2.00 * XDUM * SIN(PHI/RTOD)
DASP = 2.00 * RBLOK(K) * SIN(PHI/RTOD)
HBKA = HKAY + HCLR + 1.00 + REFF(K) - RBLOK(K)
WRITE (NPRINT,29) DBLANK, DPRING, REFF(K), PHI, BETAN
435 WRITE (NPRINT,54)
197 WRITE (NPRINT, 34)
199 CONTINUE
C-
S = 8.250 HPIVOT + RBLK - REFF(K)
RF = REFF(K) + 6.000
FKC = REFF(K) + 4.000
C-
TILT IS FOR THE CIMA NC MACHINE AND/OR
C-
TILT2 WAS FOR THE K&T INDEXING HEAD (ONLY)
TILT = PHI - HBETA
TILT2 = CHI - HBETA
153 CONTINUE
450 IF (TILT .LT. 0.000) GO TO 144
IF (TILT .GT. HBETA) GO TO 142
LPB = LPB + 1
C-
THE FOLLOWING ESTABLISHES THE PARAMETERS FOR A CENTER LENS
M = 1
455 POSANG = 0.000
TILT = 0.000
ALPHA = 0.000
X = 0.000
YOLD = REFF(K) + FLKAY + HPIVOT
460 IF (LIMP .EQ. 0.1) GO TO 149
X = DSTT + HC
YOLD = DSTT + DEHT + FKC - REFF(K)
149 CONTINUE
C-
WRITE (NPRINT,32) I, TILT, M, POSANG, X, YOLD, DEY(K)
144 CONTINUE
C-
WRITE (NPRINT, 167)
142 CONTINUE
C-
WRITE (NPRINT, 167)
149 CONTINUE
C-
WRITE (NPRINT, 167)
142 CONTINUE
C-
WRITE (NPRINT, 167)
149 CONTINUE
C-
WRITE (NPRINT, 167)
149 CONTINUE
C-
WRITE (NPRINT, 167) (CENTER LENS CANNOT BE FITTED IN)
470 GO TO 89
475 ALPHA = 2.00 * RTOD * ASIN(RBC/R)
XM = 360.0 / ALPHA
M = IFIX(XM)
C-  M = NUMBER OF LENS IN A RING
    LPB = LPB + M
    POSANG = 360.0 / FLOAT(M)
    X = RF * SIN(ANG2) + AXDIS * (1.00 - COS(ANG2))
    YOLD = RF * COS(ANG2) + AXDIS * SIN(ANG2) + HPIVOT * REFF(K)
    C-  XNEW = SX * SIN(ANGLE)
              OPTIONAL
    XNEW = (DEHT + FK) * SIN(ANGLE) + DSTT * COS(ANGLE) + HC
    C-  ZNEW = DSTT * (1.000 - SIN(ANGLE))
              + (DEHT + FK) * COS(ANGLE)
    C-  YDUM = S - Y
    COTILT = 90.00 - TILT
    IF (LIMP .NE. 2) GO TO 404
    X = XNEW
    YOLD = ZNEW
    404 CONTINUE
       WRITE (NPRINT,32) I, COTILT, M, POSANG, X, YOLD, DEY(K)
    TILT = TILT - BETA
       I = I + 1
       GO TO 150
    495 CONTINUE
    490 CONTINUE
    485 CONTINUE
    480 CONTINUE
    470 CONTINUE
    460 CONTINUE
    450 CONTINUE
    440 CONTINUE
    430 CONTINUE
    420 CONTINUE
    410 CONTINUE
    400 CONTINUE
    390 CONTINUE
    380 CONTINUE
    370 CONTINUE
    360 CONTINUE
    350 CONTINUE
    340 CONTINUE
    330 CONTINUE
    320 CONTINUE
    310 CONTINUE
    300 CONTINUE
    290 CONTINUE
    280 CONTINUE
    270 CONTINUE
    260 CONTINUE
    250 CONTINUE
    240 CONTINUE
    230 CONTINUE
    220 CONTINUE
    210 CONTINUE
    200 CONTINUE
    190 CONTINUE
    180 CONTINUE
    170 CONTINUE
    160 CONTINUE
    150 CONTINUE
    140 CONTINUE
    130 CONTINUE
    120 CONTINUE
    110 CONTINUE
    100 CONTINUE
    90 CONTINUE
    80 CONTINUE
    70 CONTINUE
    60 CONTINUE
    50 CONTINUE
    40 CONTINUE
    30 CONTINUE
    20 CONTINUE
    10 CONTINUE
    END
APPENDIX C

COMPUTER OUTPUT - COST COMPARISON
### INPUT DATA =  
<table>
<thead>
<tr>
<th>Lens Blank Data</th>
<th>2.5420</th>
<th>1.3000</th>
<th>.2500</th>
<th>.8750</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank Diameter</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blank Thickness</td>
<td>.2600</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CALCULATIONS FOR SPOT BLOCK No. 1
- **Spherical Radius** C1 = 2.5420
- **Spherical Radius of Block** = 2.4390
- **Block Diameter** = 4.8438
- **Block Height** = 1.0000
- **Diameter of Clearance Holes (Spots)** = .8750
- **Effective Radius** = 2.2870
- **PHI** = 80.00
- **Beta** = 25.00

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Tilt Angle</th>
<th>No. of Spots</th>
<th>Position Angle</th>
<th>K+T Indexing Head X</th>
<th>Z</th>
<th>Delta Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.500°</td>
<td>13</td>
<td>27.6923°</td>
<td>4.7256°</td>
<td>9.1825°</td>
<td>.036°</td>
</tr>
<tr>
<td>2</td>
<td>47.500°</td>
<td>9</td>
<td>40.0000°</td>
<td>3.3849°</td>
<td>10.8143°</td>
<td>.036°</td>
</tr>
<tr>
<td>3</td>
<td>72.500°</td>
<td>3</td>
<td>120.0000°</td>
<td>1.4801°</td>
<td>11.7265°</td>
<td>.036°</td>
</tr>
</tbody>
</table>

No Center Lens

25 Lens on Block No. 1

### GRINDER DATA -
- **Spherical Radius** = -2.5420
- **Grinder Aperture (Concave)** = 5.0068
- **Grinder OD** = 5.5974
- **Grinder Height** = 3.1006

### POLISHER DATA -
- **Spherical Radius** = -2.6920
- **Polisher Aperture (Concave)** = 5.3622
- **Polisher OD** = 5.8324
- **Polisher Height** = 3.2245

### CALCULATIONS FOR SPOT BLOCK No. 2
- **Spherical Radius** C2 = 1.3000
- **Spherical Radius of Block** = 1.3461
- **Block Diameter** = 2.6514
- **Block Height** = 1.3624
- **Diameter of Holes (Spots)** = 1.0000
- **Diameter of Clearance Holes** = .8750
- **Effective Radius** = 1.0829
- **PHI** = 80.00
- **Beta** = 50.00

<table>
<thead>
<tr>
<th>Ring No.</th>
<th>Tilt Angle</th>
<th>No. of Spots</th>
<th>Position Angle</th>
<th>K+T Indexing Head X</th>
<th>Z</th>
<th>Delta Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>5</td>
<td>72.0000°</td>
<td>4.3000°</td>
<td>8.9766°</td>
<td>.0497</td>
</tr>
<tr>
<td>2</td>
<td>90.000°</td>
<td>1</td>
<td>0.0000°</td>
<td>0.0000°</td>
<td>10.8246°</td>
<td>.0497</td>
</tr>
</tbody>
</table>

6 Lens on Block No. 2

### GRINDER DATA -
- **Spherical Radius** = -1.3000
- **Grinder Aperture (Concave)** = 2.5665
- **Grinder OD** = 2.8166
- **Grinder Height** = 2.0743

### POLISHER DATA -
- **Spherical Radius** = -1.4506
- **Polisher Aperture (Concave)** = 2.8559
- **Polisher OD** = 3.1415
- **Polisher Height** = 2.1982
**CALCULATIONS FOR SPOT BLOCK NO. 1**

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<thead>
<tr>
<th>SPHERICAL RADIUS, C1</th>
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</tr>
</thead>
<tbody>
<tr>
<td>SPHERICAL RADIUS OF BLOCK</td>
<td>2.5430</td>
</tr>
<tr>
<td>BLOCK DIAMETER</td>
<td>4.8038</td>
</tr>
<tr>
<td>BLOCK HEIGHT</td>
<td>2.2654</td>
</tr>
<tr>
<td>DIAMETER OF HOLES (SPOTS)</td>
<td>1.0000</td>
</tr>
<tr>
<td>DIAMETER OF CLEARANCE HOLES</td>
<td>0.8750</td>
</tr>
<tr>
<td>EFFECTIVE RADIUS</td>
<td>2.2870</td>
</tr>
<tr>
<td>PHI</td>
<td>80.00</td>
</tr>
<tr>
<td>RING TILT NO. OF POSITION CIM-X N.C. EQUIPMENT</td>
<td></td>
</tr>
<tr>
<td>NO.</td>
<td>ANGLE</td>
</tr>
<tr>
<td>1</td>
<td>22.5000</td>
</tr>
<tr>
<td>2</td>
<td>47.5000</td>
</tr>
<tr>
<td>3</td>
<td>72.5000</td>
</tr>
</tbody>
</table>

**RING TILT NO. OF POSITION CIM-X N.C. EQUIPMENT**

| NO. | ANGLE | SPOTS | ANGLE | Y | Z | DELTA Z |
| 1 | 35.0000 | 5 | 72.0000 | 12.2893 | 5.6417 | .0497 |
| 2 | 90.0000 | 1 | 0.0000 | 8.0701 | 11.3221 | .0497 |

**RING TILT NO. OF POSITION CIM-X N.C. EQUIPMENT**

| NO. | ANGLE | SPOTS | ANGLE | Y | Z | DELTA Z |
| 6 | LENS ON BLOCK NO. 2 |

**GRINDER DATA-**

SPECIAL RADIUS = -2.5420
GRINDER APERTURE (CONCAVE) = 5.0068
GRINDER O.D, = 5.5074
GRINDER HEIGHT = 3.1006

**POLISHER DATA-**

SPECIAL RADIUS = -2.6920
POLISHER APERTURE (CONCAVE) = 5.3022
POLISHER O.D, = 5.8324
POLISHER HEIGHT = 3.2245

**GRINDER DATA-**

SPECIAL RADIUS = -1.3000
GRINDER APERTURE (CONCAVE) = 2.5685
GRINDER O.D, = 2.8166
GRINDER HEIGHT = 2.0743

**POLISHER DATA-**

SPECIAL RADIUS = -1.4500
POLISHER APERTURE (CONCAVE) = 2.8559
POLISHER O.D, = 3.1415
POLISHER HEIGHT = 2.1982
**INPUT DATA** =

| Lens Blank Data | 3.3500 | -1.3000 | .0460 | .8770 | 1 |

**Calculations for Spot Block No. 1**

<table>
<thead>
<tr>
<th>Spherical Radius, C1</th>
<th>3.3500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical Radius of Block</td>
<td>3.2400</td>
</tr>
<tr>
<td>Block Diameter</td>
<td>6.3555</td>
</tr>
<tr>
<td>Block Height</td>
<td>2.9291</td>
</tr>
<tr>
<td>Diameter of Holes (Spots)</td>
<td>1.0000</td>
</tr>
<tr>
<td>Diameter of Clearance Holes</td>
<td>.8750</td>
</tr>
<tr>
<td>Effective Radius</td>
<td>3.1990</td>
</tr>
<tr>
<td>Beta</td>
<td>18.00</td>
</tr>
<tr>
<td>Ring Tilt</td>
<td>No. Of Spots</td>
</tr>
<tr>
<td>1</td>
<td>19.0000</td>
</tr>
<tr>
<td>2</td>
<td>37.0000</td>
</tr>
<tr>
<td>3</td>
<td>55.0000</td>
</tr>
<tr>
<td>4</td>
<td>73.0000</td>
</tr>
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**Grinder Data**

<table>
<thead>
<tr>
<th>Spherical Radius</th>
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</thead>
<tbody>
<tr>
<td>Grinder Diameter (Concave)</td>
<td>6.5902</td>
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<tr>
<td>Grinder Height</td>
<td>3.7683</td>
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**Polisher Data**

<table>
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<tr>
<th>Spherical Radius</th>
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<tbody>
<tr>
<td>Polisher Diameter (Concave)</td>
<td>2.5605</td>
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<tr>
<td>Polisher Height</td>
<td>1.0743</td>
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**Calculations for Spot Block No. 2**

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<tr>
<th>Spherical Radius, C2</th>
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<tr>
<td>Spherical Radius of Block</td>
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<tr>
<td>Block Aperture (Concave)</td>
<td>2.5608</td>
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<tr>
<td>Block O.D. (Concave)</td>
<td>2.9370</td>
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<tr>
<td>Block Height</td>
<td>2.1570 (H1)</td>
</tr>
<tr>
<td>Diameter of Holes (Spots)</td>
<td>1.0000</td>
</tr>
<tr>
<td>Diameter of Clearance Holes</td>
<td>.8750</td>
</tr>
<tr>
<td>Effective Radius</td>
<td>1.3548</td>
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<tr>
<td>Beta</td>
<td>80.00</td>
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<tr>
<td>Ring Tilt</td>
<td>No. Of Spots</td>
</tr>
<tr>
<td>1</td>
<td>33.0000</td>
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<tr>
<td>2</td>
<td>90.0000</td>
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**Grinder Data**

<table>
<thead>
<tr>
<th>Spherical Radius</th>
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</thead>
<tbody>
<tr>
<td>Grinder Diameter</td>
<td>2.5605</td>
</tr>
<tr>
<td>Grinder Height</td>
<td>1.0743</td>
</tr>
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</table>

**Polisher Data**

<table>
<thead>
<tr>
<th>Spherical Radius</th>
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<tr>
<td>Polisher Diameter</td>
<td>2.2651</td>
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<tr>
<td>Polisher Height</td>
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</table>
**INPUT DATA** = 3.3500  -1.3000   0.0460  0.870

**LENS BLANK DATA**

BLANK DIAMETER = 1.0000
BLANK THICKNESS = 0.1560

**CALCULATIONS FOR SPOT BLOCK NO. 1**

SPHERICAL RADIUS, C1 = 3.3500
SPHERICAL RADIUS OF BLOCK = 3.2420
BLOCK DIAMETER = 6.3855
BLOCK HEIGHT = 2.9291
DIAMETER OF HOLES (SPOTS) = 1.0000
DIAMETER OF CLEARANCE HOLES = 0.8750
EFFECTIVE RADIUS = 3.1990

PHI = 80.00
BETA = 18.00

**RINTING TILT NO. OF POSITION CIN-X N.C. EQUIPMENT Z DELTA Z**

<table>
<thead>
<tr>
<th>NO.</th>
<th>ANGLE</th>
<th>SPOTS</th>
<th>ANGLE</th>
<th>Y</th>
<th>Z</th>
<th>DELTA Z</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>19.000</td>
<td>18</td>
<td>20.000</td>
<td>12.0103</td>
<td>5.5152</td>
<td>0.0365</td>
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<tr>
<td>2</td>
<td>37.000</td>
<td>15</td>
<td>24.000</td>
<td>11.9720</td>
<td>7.8173</td>
<td>0.0366</td>
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<tr>
<td>3</td>
<td>55.000</td>
<td>11</td>
<td>32.7273</td>
<td>11.2242</td>
<td>9.9950</td>
<td>0.0366</td>
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<tr>
<td>4</td>
<td>73.000</td>
<td>5</td>
<td>72.000</td>
<td>9.8401</td>
<td>11.8349</td>
<td>0.0360</td>
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</tbody>
</table>

NO CENTER LENS

49 LENS ON BLOCK NO. 1.

**GRINDER DATA**

SPHERICAL RADIUS = -3.3500
GRINDER APERTURE (CONCAVE) = 6.5982
GRINDER DIA. = 7.2580
GRINDER HEIGHT = 3.7683

**POLISHER DATA**

SPHERICAL RADIUS = -3.5000
POLISHER APERTURE (CONCAVE) = 6.8937
POLISHER DIA. = 7.5830
POLISHER HEIGHT = 3.8922

**CALCULATIONS FOR SPOT BLOCK NO. 2**

SPHERICAL RADIUS, C2 = -1.3000
SPHERICAL RADIUS OF BLOCK = 1.3042
BLOCK DIAMETER (CONCAVE) = 2.5688
BLOCK DIA. (CONCAVE) = 2.9370
BLOCK HEIGHT = 2.1570 (HI)
DIAMETER OF HOLES (SPOTS) = 1.0000
DIAMETER OF CLEARANCE HOLES = 0.8750
EFFECTIVE RADIUS = 1.3548

PHI = 80.00
BETA = 46.00

**RINTING TILT NO. OF POSITION CIN-X N.C. EQUIPMENT Z DELTA Z**

<table>
<thead>
<tr>
<th>NO.</th>
<th>ANGLE</th>
<th>SPOTS</th>
<th>ANGLE</th>
<th>Y</th>
<th>Z</th>
<th>DELTA Z</th>
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<tbody>
<tr>
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<td>4.1921</td>
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<td>0.0000</td>
<td>8.0701</td>
<td>11.1850</td>
<td>0.0375</td>
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7 LENS ON BLOCK NO. 2

**GRINDER DATA**

SPHERICAL RADIUS = 1.3000
GRINDER DIAMETER = 2.5605
GRINDER HEIGHT = 1.0743

**POLISHER DATA**

SPHERICAL RADIUS = 1.1500
POLISHER DIAMETER = 2.2651
POLISHER HEIGHT = 1.0287
APPENDIX D

COMPUTER OUTPUT - TEST SPOT BLOCKS
## INPUT DATA

| LENS BLANK DATA | 
|-----------------|--------------------------------------------------|
| BLANK DIAMETER  | 1.0000                                           |
| BLANK THICKNESS | 0.3636                                           |

## CALCULATIONS FOR SPOT BLOCK NO. 1

| SPHERICAL RADIUS: C1 | 2.5420 |
| BLOCK DIAMETER       | 2.3376 |
| BLOCK HEIGHT         | 2.1817 |
| DIAMETER OF HOLES (SPOTS) | 1.0000 |
| DIAMETER OF CLEARANCE HOLES | 0.8750 |
| EFFECTIVE RADIUS     | 2.1834 |
| PHI                  | 80.00  |
| BETA                 | 26.00  |

### RING TILT NO. OF POSITION K + T INDEXING HEAD

<table>
<thead>
<tr>
<th>NO.</th>
<th>ANGLE</th>
<th>SPOTS</th>
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<th>Z</th>
<th>DELTA Z</th>
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</thead>
<tbody>
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<td>30.000</td>
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<td>9.1236</td>
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<td>3.2949</td>
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## CALCULATIONS FOR SPOT BLOCK NO. 2

| SPHERICAL RADIUS: C2 | 1.2580 |
| BLOCK DIAMETER       | 1.3582 |
| BLOCK APERTURE (CONCAVE) | 2.6751 |
| BLOCK O.D. (CONCAVE)  | 3.2448 |
| DIAMETER OF HOLES (SPOTS) | 1.0000 |
| DIAMETER OF CLEARANCE HOLES | 0.8750 |
| EFFECTIVE RADIUS     | 1.5197 |
| PHI                  | 80.00  |
| BETA                 | 48.06  |

### RING TILT NO. OF POSITION K + T INDEXING HEAD

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<th>NO.</th>
<th>ANGLE</th>
<th>SPOTS</th>
<th>ANGLE</th>
<th>X</th>
<th>Z</th>
<th>DELTA Z</th>
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<td>11.2593</td>
<td>0.0497</td>
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## GRINDER DATA

| SPHERICAL RADIUS | -2.5420 |
| GRINDER DIAMETER | 2.4778  |
| GRINDER HEIGHT   | 1.0396  |

## POLISHER DATA

| SPHERICAL RADIUS | -1.1080 |
| POLISHER DIAMETER | 2.1823  |
| POLISHER HEIGHT  | 1.0379  |
INPUT DATA = 2.5420 1.2580 0.2500 0.8700

LENS BLANK DATA
BLANK DIAMETER = 1.0000
BLANK THICKNESS = 0.2600

CALCULATIONS FOR SPOT BLOCK NO. 1
SPHERICAL RADIUS = 2.5420
SPHERICAL RADIUS OF BLOCK = 2.4390
BLOCK DIAMETER = 4.8036
BLOCK HEIGHT = 2.2654
DIAMETER OF HOLES (SPOTS) = 1.0000
DIAMETER OF CLEARANCE HOLES = 0.8750
EFFECTIVE RADIUS = 2.2870
PHI = 80.00
BETA = 25.00

RING NO. TILT ANGLE NO. OF SPOTS POSITION K + T INDEXING HEAD
1 22.5000 13 27.6923 4.7256 9.1825 0.0300
2 47.5000 9 40.0000 3.3849 10.8143 0.0300
3 72.5000 3 120.0000 1.4801 11.7265 0.0300

NO CENTER LENS
25 LENS ON BLOCK NO. 1

GRINDER DATA
SPHERICAL RADIUS = 2.5420
GRINDER DIAMETER (CONCAVE) = 5.5074
GRINDER HEIGHT = 3.1006

POLISHER DATA
SPHERICAL RADIUS = -2.6920
POLISHER DIAMETER (CONCAVE) = 5.3224
POLISHER HEIGHT = 3.2245

CALCULATIONS FOR SPOT BLOCK NO. 2
SPHERICAL RADIUS = 1.2580
SPHERICAL RADIUS OF BLOCK = 1.3089
BLOCK DIAMETER = 2.5780
BLOCK HEIGHT = 1.3316
DIAMETER OF HOLES (SPOTS) = 1.0000
DIAMETER OF CLEARANCE HOLES = 0.8750
EFFECTIVE RADIUS = 1.0489
PHI = 80.00
BETA = 52.00

RING NO. TILT ANGLE NO. OF SPOTS POSITION K + T INDEXING HEAD
1 36.0000 4 90.0000 4.2487 9.0064 0.0497
2 90.0000 1 0.0000 0.0000 10.7891 0.0497

GRINDER DATA
SPHERICAL RADIUS = -1.2580
GRINDER DIAMETER (CONCAVE) = 2.4778
GRINDER HEIGHT = 2.0396

POLISHER DATA
SPHERICAL RADIUS = -1.4080
POLISHER DIAMETER (CONCAVE) = 2.7732
POLISHER HEIGHT = 2.1635
INPUT DATA =        1.9650    -2.1950      .1500      .9350      1

LENS BLANK DATA
BLANK DIAMETER =        1.0000
BLANK THICKNESS =      .2177

CALCULATIONS FOR SPOT BLOCK NO. 1
SPHERICAL RADIUS, C1 =    1.9650
SPHERICAL RADIUS OF BLOCK =    1.8633
BLOCK DIAMETER =        3.6700
BLOCK HEIGHT =        1.7897
DIAMETER OF HOLES (SPOTS) =    1.0000
DIAMETER OF CLEARANCE HOLES =    1.0000
EFFECTIVE RADIUS =        1.7523
PHI = 80.00
BETA = 33.00

RING NO.  TILT ANGLE SPOTS NO. OF POSITION ANGLE X Z INDEXING HEAD DELTA Z
1  26.5000  9  40.0000  4.6507  8.9956 .0300
2  59.5000  5  72.0000  2.5773 10.9174 .0300

NO CENTER LENS
14 LENS ON BLOCK NO. 1

GRINDER DATA-
SPHERICAL RADIUS =    -1.9650
GRINDER DIAMETER =    3.8703
GRINDER HEIGHT =        2.6238

POLISHER DATA-
SPHERICAL RADIUS =    -2.1150
POLISHER DIAMETER (CONCAVE) =    4.1657
POLISHER DIAMETER =        4.5823
POLISHER HEIGHT =    2.7477

CALCULATIONS FOR SPOT BLOCK NO. 2
SPHERICAL RADIUS, C2 =    -2.1950
SPHERICAL RADIUS OF BLOCK =    2.2377
BLOCK DIAMETER (CONCAVE) =    3.8361
BLOCK O.D. (CONCAVE) =    4.2201
BLOCK HEIGHT =    3.0211 (HI)
DIAMETER OF HOLES (SPOTS) =    1.0000
DIAMETER OF CLEARANCE HOLES =    1.0000
EFFECTIVE RADIUS =    2.3644
PHI = 59.00
BETA = 27.00

RING NO.  TILT ANGLE SPOTS NO. OF POSITION ANGLE X Z INDEXING HEAD DELTA Z
1  44.5000  9  40.0000  6.0752 13.1752 .0647
2  71.5000  3 120.0000  2.6722 15.0952 .0647

NO CENTER LENS
12 LENS ON BLOCK NO. 2

GRINDER DATA-
SPHERICAL RADIUS =    2.1950
GRINDER DIAMETER =    4.3233
GRINDER HEIGHT =    1.8138

POLISHER DATA-
SPHERICAL RADIUS =    2.0450
POLISHER DIAMETER =    4.0279
POLISHER HEIGHT =    1.6899

62
| INPUT DATA | 1.9650 | 1.0625 | .1500 | .9350 | 1 |
| LENS BLANK DATA | | | | |
| BLANK DIAMETER | 1.0000 | | | |
| BLANK THICKNESS | .1600 | | | |
| CALCULATIONS FOR SPOT BLOCK NO. 1 | | | | |
| SPHERICAL RADIUS, \( C1 \) | 1.9650 | | | |
| SPHERICAL RADIUS OF BLOCK | 1.9189 | | | |
| BLOCK DIAMETER | 3.7796 | | | |
| BLOCK HEIGHT | 1.8357 | | | |
| DIAMETER OF HOLES (SPOTS) | 1.0000 | | | |
| DIAMETER OF CLEARANCE HOLES | .8750 | | | |
| EFFECTIVE RADIUS | 1.8100 | | | |
| PHI | 80.00 | | | |
| BETA | 32.00 | | | |
| RING TILT | NO. OF SPOTS | POSITION | K. T INDEXING HEAD |
| NO. | ANGLE | | K | T | |
| 1 | 26.000 | 10 | 36.000 | 4.6741 | 9.0115 | .0368 |
| 2 | 58.000 | 5 | 72.000 | 2.6886 | 10.9077 | .0308 |
| 3 | 90.000 | 1 | 0.0000 | 0.0000 | 11.4636 | .0368 |
| 16 LENS ON BLOCK NO. 1 | | | | |
| 1 | 26.000 | 10 | 36.000 | 4.6741 | 9.0115 | .0368 |
| 2 | 58.000 | 5 | 72.000 | 2.6886 | 10.9077 | .0308 |
| 3 | 90.000 | 1 | 0.0000 | 0.0000 | 11.4636 | .0368 |
| GRINDER DATA | | | | |
| SPHERICAL RADIUS | -1.9650 | | | |
| GRINDER APERTURE (CONCAVE) | 3.8703 | | | |
| GRINDER O.D. | 4.2573 | | | |
| GRINDER HEIGHT | 2.6238 | | | |
| POLISHER DATA | | | | |
| SPHERICAL RADIUS | -2.1150 | | | |
| POLISHER APERTURE (CONCAVE) | 4.1657 | | | |
| POLISHER O.D. | 4.5823 | | | |
| POLISHER HEIGHT | 2.7477 | | | |
| CALCULATIONS FOR SPOT BLOCK NO. 2 | | | | |
| SPHERICAL RADIUS, \( C2 \) | 1.0625 | | | |
| SPHERICAL RADIUS OF BLOCK | 1.9222 | | | |
| BLOCK DIAMETER | 2.3483 | | | |
| BLOCK HEIGHT | 1.2352 | | | |
| DIAMETER OF HOLES (SPOTS) | 1.0000 | | | |
| DIAMETER OF CLEARANCE HOLES | .8750 | | | |
| EFFECTIVE RADIUS | .9568 | | | |
| PHI | 80.00 | | | |
| BETA | 56.00 | | | |
| RING TILT | NO. OF SPOTS | POSITION | K. T INDEXING HEAD |
| NO. | ANGLE | | K | T | |
| 1 | 38.000 | 4 | 90.000 | 4.1569 | 9.0750 | .0647 |
| 4 LENS ON BLOCK NO. 2 | | | | |

63
**INPUT DATA**

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SIDE NO. 1 IS PLANO

**CALCULATIONS FOR SPOT BLOCK NO. 2**

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<td>BLOCK HEIGHT</td>
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16 LENS ON BLOCK NO. 2

**GRINDER DATA**

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<tr>
<td>GRINDER O.D.</td>
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<td>GRINDER HEIGHT</td>
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**POLISHER DATA**

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<td>POLISHER HEIGHT</td>
<td>2.7477</td>
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**INPUT DATA**

- 10000.000
- 1.9650
- 0.150
- 0.9350
- 1

**LENS BLANK DATA**

- BLANK DIAMETER = 1.0000
- BLANK THICKNESS = 0.1600

**SIDE NO. 1 IS PLANO**

**CALCULATIONS FOR SPOT BLOCK NO. 2**

- SPHERICAL RADIUS, C2 = 1.9650
- SPHERICAL RADIUS OF BLOCK = 1.9863
- BLOCK DIAMETER = 3.9122
- BLOCK HEIGHT = 1.8914
- DIAMETER OF HOLES (SPOTS) = 1.0000
- DIAMETER OF CLEARANCE HOLES = 0.8750
- EFFECTIVE RADIUS = 1.8100
- PHI = 80.00
- BETA = 32.00

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<th>TILT ANGLE</th>
<th>NO. OF SPOTS</th>
<th>POSITION ANGLE</th>
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<th>Z</th>
<th>K + T INDEXING HEAD DELTA Z</th>
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<tr>
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**GRINDER DATA**

- SPHERICAL RADIUS = -1.9650
- GRINDER APERTURE (CONCAVE) = 3.8753
- GRINDER O.D. = -4.2573
- GRINDER HEIGHT = 2.6238

**POLISHER DATA**

- SPHERICAL RADIUS = -2.1150
- POLISHER APERTURE (CONCAVE) = 4.1657
- POLISHER O.D. = -4.5823
- POLISHER HEIGHT = 2.7477
INPUT DATA = 10000.0000 1.9650 .1500 .9350 2
LENS BLANK DATA
BLANK DIAMETER = 1.0000
BLANK THICKNESS = .1600
SIDE NO. 1 IS PLANO

CALCULATIONS FOR SPOT BLOCK NO. 2
SPHERICAL RADIUS, C2 = 1.9650
SPHERICAL RADIUS OF BLOCK = 1.9863
BLOCK DIAMETER = 3.9122
BLOCK HEIGHT = 1.8914
DIAMETER OF HOLES (SPOTS) = 1.0000
DIAMETER OF CLEARANCE HOLES = .8750
EFFECTIVE RADIUS = 1.8100
PHI = 80.00
BETA = 32.00
RING TILT NO. OF POSITION CIM-X N.C. EQUIPMENT
NO. ANGLE SPOTS ANGLE Y Z DELTA Z
1 26.0000 10 36.0000 12.2518 5.1049 .0000
2 58.0000 5 72.0000 11.1351 9.1021 .0000
3 90.0000 1 0.0000 8.0701 11.9001 .0000
16 LENS ON BLOCK NO. 2

GRINDER DATA-
SPHERICAL RADIUS = -1.9650
GRINDER APERTURE (CONCAVE) = 3.8733
GRINDER O.D. = 4.2573
GRINDER HEIGHT = 2.6238

POLISHER DATA-
SPHERICAL RADIUS = -2.1150
POLISHER APERTURE (CONCAVE) = 4.1657
POLISHER O.D. = 4.5823
POLISHER HEIGHT = 2.7477

ARGUMENT NEGATIVE
ERROR NUMBER 39 DETECTED BY SORT
INPUT DATA =  
LENSES BLANK DATA

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CALCULATIONS FOR SPOT BLOCK NO. 1

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<th>BLOCK DIAMETER</th>
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<th>DIAMETER OF HOLES (SPOTS)</th>
<th>DIAMETER OF CLEARANCE HOLES</th>
<th>EFFECTIVE RADIUS</th>
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53 LENSES ON BLOCK NO. 1

GRINDER DATA:

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POLISHER DATA:

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CALCULATIONS FOR SPOT BLOCK NO. 2

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<th>DIAMETER OF HOLES (SPOTS)</th>
<th>DIAMETER OF CLEARANCE HOLES</th>
<th>EFFECTIVE RADIUS</th>
<th>PHI</th>
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<th>NO. OF POSITION</th>
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<td></td>
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<tr>
<td>RING TILT NO. OF POSITION K + T INDEXING HEAD</td>
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<tr>
<td>1 22.000° 13 27.6923 4.6063 9.8229 0.0326</td>
<td></td>
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<tr>
<td>2 46.000° 10 35.0000 3.3806 11.3612 0.0326</td>
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<tr>
<td>3 70.000° 4 90.0000 1.6353 12.2679 0.0326</td>
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</tbody>
</table>

27 LENSES ON BLOCK NO. 2

GRINDER DATA:

<table>
<thead>
<tr>
<th>SPHERICAL RADIUS</th>
<th>GRINDER APERTURE (CONCAVE)</th>
<th>GRINDER O.D.</th>
<th>GRINDER HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.2500</td>
<td>6.4013</td>
<td>7.0414</td>
<td>3.6856</td>
</tr>
</tbody>
</table>

POLISHER DATA:

<table>
<thead>
<tr>
<th>SPHERICAL RADIUS</th>
<th>POLISHER APERTURE (CONCAVE)</th>
<th>POLISHER O.D.</th>
<th>POLISHER HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.4003</td>
<td>6.6967</td>
<td>7.3664</td>
<td>3.8096</td>
</tr>
</tbody>
</table>
**INPUT DATA** = 6.0000 3.2500 .2500 1.6900 2

**LENS BLANK DATA**
- BLANK DIAMETER = 1.2500
- BLANK THICKNESS = .2500

**CALCULATIONS FOR SPOT BLOCK NO. 1**
- SPHERICAL RADIUS, Cl = 6.0000
- SPHERICAL RADIUS OF BLOCK = 5.8870
- BLOCK DIAMETER = 2.8450
- DIAMETER OF HOLES (SPOTS) = 1.2500
- DIAMETER OF CLEARANCE HOLES = 1.1250
- EFFECTIVE RADIUS = 5.7450
- PHI = 56.00
- BETA = 13.00

<table>
<thead>
<tr>
<th>RING NO.</th>
<th>TILT ANGLE</th>
<th>NO. OF SPOTS</th>
<th>POSITION ANGLE</th>
<th>CIM-X N.C. EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.5000</td>
<td>21</td>
<td>17.1429</td>
<td>9.8040  9.0297</td>
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<tr>
<td>2</td>
<td>53.5000</td>
<td>17</td>
<td>21.1765</td>
<td>9.6877  10.1741</td>
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<tr>
<td>3</td>
<td>66.5000</td>
<td>11</td>
<td>32.7273</td>
<td>9.3169  11.2630</td>
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<tr>
<td>4</td>
<td>79.5000</td>
<td>4</td>
<td>90.0000</td>
<td>8.7107  12.2407</td>
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</tbody>
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**NO CENTER LENS**

53 LENS ON BLOCK NO. 1

**GRINDER DATA**
- SPHERICAL RADIUS = -6.0000
- GRINDER APERTURE (CONCAVE) = 9.9405
- GRINDER O.D. = 10.9433
- GRINDER HEIGHT = 3.6448

**POLISHER DATA**
- SPHERICAL RADIUS = -3.6856
- POLISHER APERTURE (CONCAVE) = 10.1972
- POLISHER O.D. = 7.3664
- POLISHER HEIGHT = 3.8096

**CALCULATIONS FOR SPOT BLOCK NO. 2**
- SPHERICAL RADIUS, C2 = 3.2500
- SPHERICAL RADIUS OF BLOCK = 3.2326
- BLOCK DIAMETER = 6.3671
- BLOCK HEIGHT = 2.9213
- DIAMETER OF HOLES (SPOTS) = 1.2500
- DIAMETER OF CLEARANCE HOLES = 1.1250
- EFFECTIVE RADIUS = 3.0214
- PHI = 80.00
- BETA = 24.00

<table>
<thead>
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<th>RING NO.</th>
<th>TILT ANGLE</th>
<th>NO. OF SPOTS</th>
<th>POSITION ANGLE</th>
<th>CIM-X N.C. EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.0000</td>
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<td>27.6923</td>
<td>12.0537  5.7201</td>
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<tr>
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<td>10</td>
<td>36.0000</td>
<td>11.6834  8.7575</td>
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<tr>
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<td>4</td>
<td>90.0000</td>
<td>10.1097  11.3818</td>
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</tbody>
</table>

**NO CENTER LENS**

27 LENS ON BLOCK NO. 2

**GRINDER DATA**
- SPHERICAL RADIUS = -3.2500
- GRINDER APERTURE (CONCAVE) = 6.4013
- GRINDER O.D. = 7.0413
- GRINDER HEIGHT = 3.6448

**POLISHER DATA**
- SPHERICAL RADIUS = -3.4000
- POLISHER APERTURE (CONCAVE) = 6.6967
- POLISHER O.D. = 7.3664
- POLISHER HEIGHT = 3.8096
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