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A PROGRAM FOR TESTING ASPHERIC SCHMIDT CORRECTOR PLATE

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ABSTRACT

A null test for testing aspheric Schmidt corrector plate has been described This paper gives a detailed procedure and a computer program for computing optimum test parameters A typical run of the program for testing a 450 mm corrector plate for f/3 00 Schmidt telescope is shown

Key words Schmidt corrector plates null test

1 Introduction

Accurate optical testing of an aspheric corrector plate for wide field Schmidt telescope generally requires auxiliary optics of good quality and large diameter A simple null test set up for testing such a corrector plate giving two alternative arrangements was described by Willstrop (1980) recently In these two types of arrangements no other auxiliary optics is required except the spherical mirror with which the corrector plate is to be used in the telescope Of the two methods the one adopted here is found to be more suitable for a wide range of f-ratios ($\geqslant$ 1 5) For determination of optimum test parameters following this method a computer program has been developed using a ray tracing procedure

Details of optical arrangements, the ray tracing procedure and computational method for the optical test parameter are described in this paper

2 Optical arrangement

In this arrangement (Fig 1) light from a small pin hole 10 20 μ in size, is made to fall on the spherical mirror, with the corrector plate located close to the focus near the pin hole The reflected beam from the spherical mirror after its passage through the corrector plate is focused at the longer conjugate focal point of the mirror Knife edge, a wire or wavefront shearing interferometer (Babinet compensator and polaroid combination), (Saxena, 1979) can be used for the evaluation of the wavefront departure

If the light source is positioned with an accuracy of .01% of the focal length of the sphere the second conjugate focus will fall within a couple of millimeters of the calculated value for a corrector plate which has been given roughly a close spherical profile. A similar accuracy for the centering of the light source with the optical axis has to be achieved for best results. The test probe kept at the best focus of the second conjugate point will not result in any significant wavefront errors.

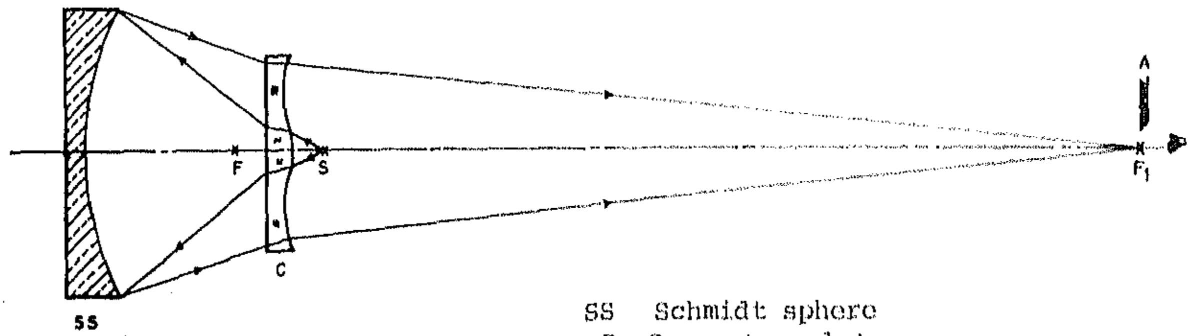


Fig.1 Test setup for the Schmidt Corrector Plate

3. The method and ray tracing procedure

For the optical arrangement shown in Fig. 1 there is always one pair of distance for which the higher order aberrations are well balanced. These conjugate focus points can be conveniently computed using ray tracing procedure (Kingslake, 1978). Optical ray diagram is shown in Fig. 2.

In general the corrector plate profile (Linfoot, 1955) can be expressed as

$$t_r = t_x + \frac{1}{(n_\lambda - 1)} \left\{ \frac{(r^2 - kr_o^2)\, r^2}{32F^3} + \frac{r^6}{256F^5} + \ldots\ldots \right\}$$

where t_r is the thickness at a radius r, t_x is the axial thickness, n_λ is the refractive index of the corrector plate material at wavelength λ and r_o is the maximum value of r.

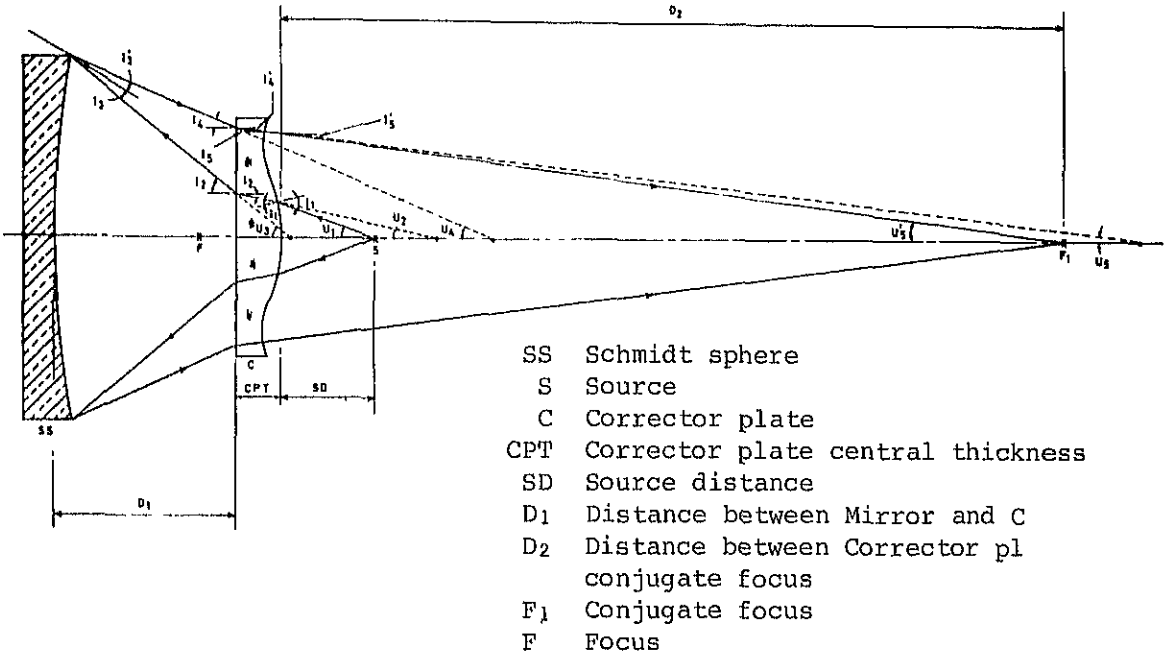
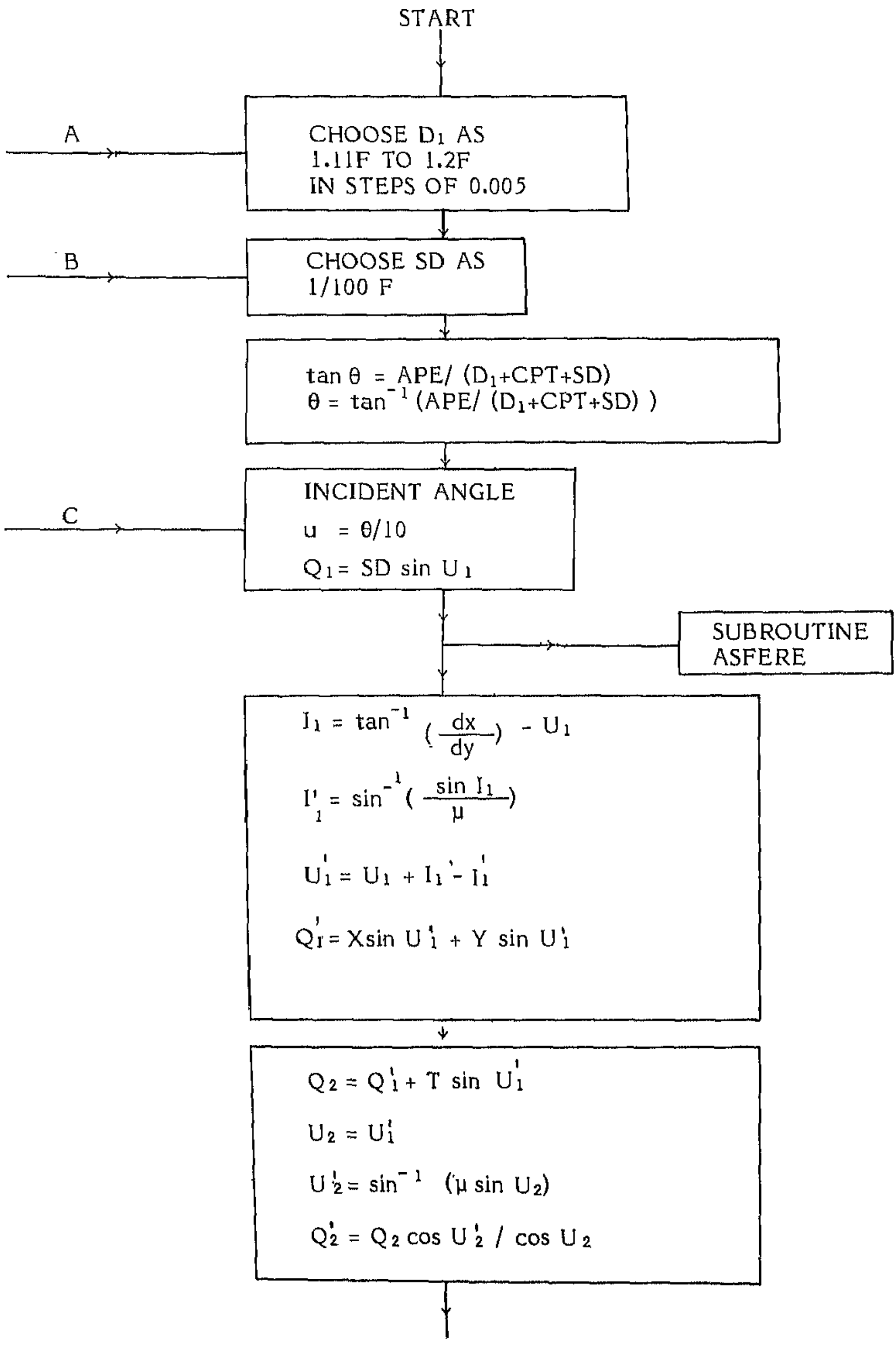


Fig.2 Ray Diagram for the test setup

The constant K=3/2 is chosen in order to minimise the effect of neglecting higher order terms. The aspheric profile of the corrector plate in the computation is taken with reference to the wavelength at which the camera or telescope system has to be used. This may be different for the wavelength at which testing is being performed.

Marginal rays are traced through aspheric face, the flat face of the corrector plate and finally on to the sphere. The return beam from the sphere after its passage through the corrector plate meets on the optical axis at the second conjugate focus F_1. The wavefront aberration is computed as the spread of the focus F_1 in the longitudinal direction. The flow chart and the computer program for the computation of test parameter is as follows.

FLOW CHART


START
A
CHOOSE D1 AS
1.11F TO 1.2F
IN STEPS OF 0.005
B
CHOOSE SD AS
1/100 F
tan θ = APE/ (D1+CPT+SD)
θ = tan⁻¹ (APE/ (D1+CPT+SD))
C
INCIDENT ANGLE
u = θ/10
Q1 = SD sin U1
SUBROUTINE
ASFERE
I1 = tan⁻¹ (dx/dy) - U1
I'1 = sin⁻¹ (sin I1/μ)
U'1 = U1 + I1' - I'1
Q'1 = Xsin U'1 + Y sin U'1
Q2 = Q'1 + T sin U'1
U2 = U'1
U'2 = sin⁻¹ (μ sin U2)
Q'2 = Q2 cos U'2 / cos U2

$$Q_3 = Q'_2 + D_1 \sin U'_2$$
$$U_3 = U'_2$$
$$I_3 = \sin^{-1} (Q_3/R - \sin U_3)$$
$$I'_3 = I_3$$
$$U_3 = U_3 + I_3 \quad I_3$$
$$G_3 = Q_3/(\cos U_3 + \cos I_3)$$
$$Q_3 = G_3 (\cos U'_3 + \cos I'_3)$$

$$Q_4 = Q'_3 - D_1 \sin U_3$$
$$U_4 = U'_3$$
$$U_4 = \sin^{-1} \left(\frac{\sin U_4}{\mu} \right)$$
$$Q_4 = \cos U_4 / \cos U_4$$
$$Q_5 = Q_4 - T \sin U_4$$

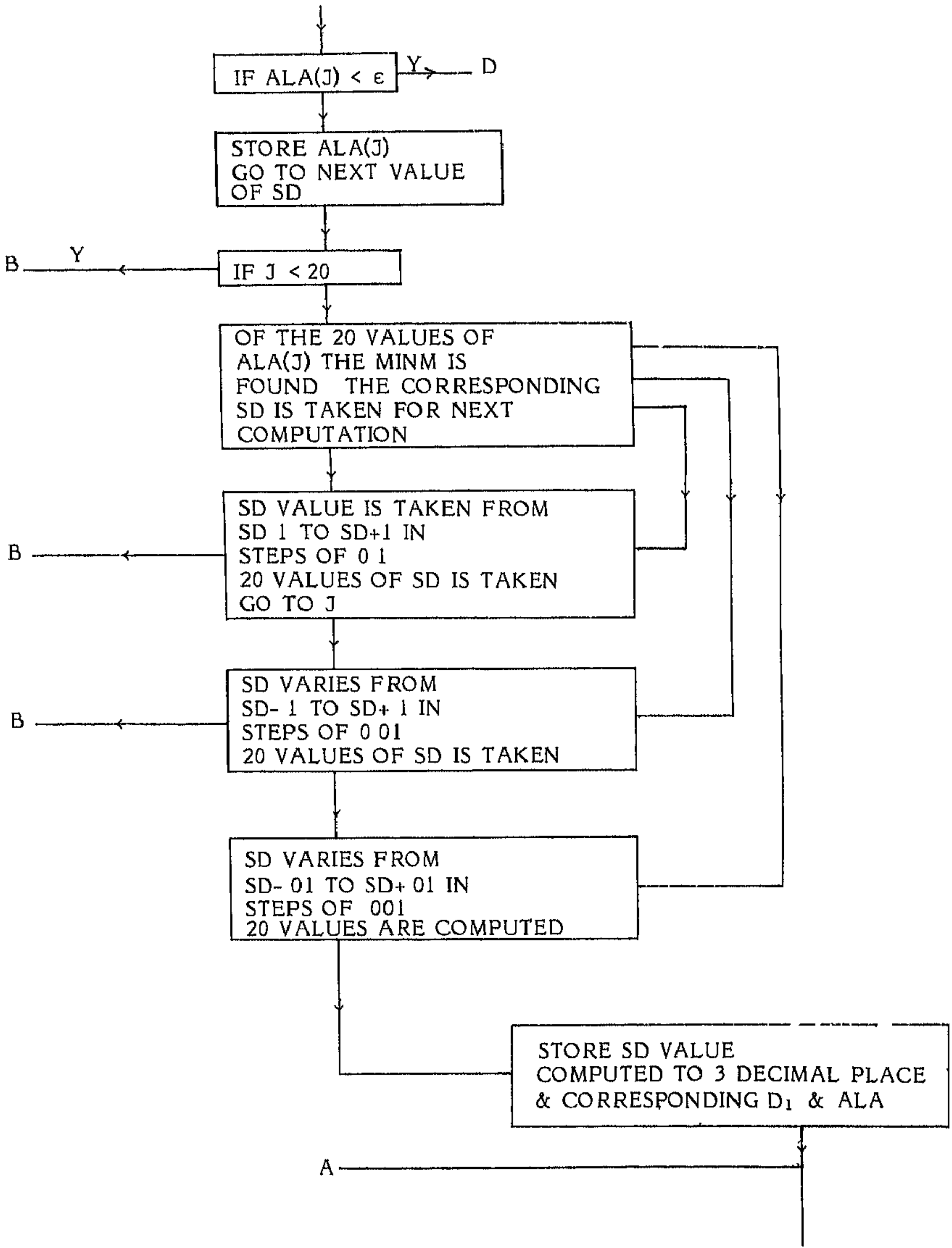
SUBROUTINE ASFERE

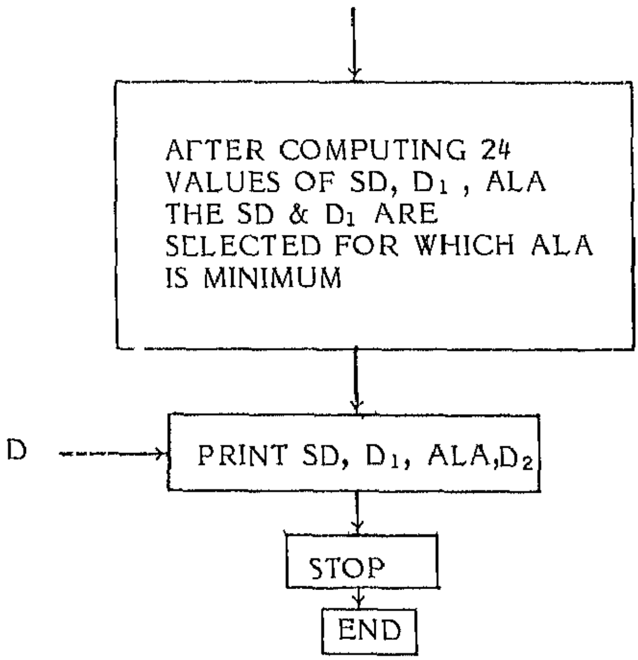
$$I_5 = \tan^{1}\left(\frac{dx}{dy}\right) \quad U_5$$
$$I_5 = \sin^{-1} ((\sin I_5)\ \mu)$$
$$U_5 = U_5 + I_5 - I_5$$
$$Q_5 = X_5 \sin U_5 + Y_5 \cos U_5$$
$$D_2 = Q_5 / \sin U_5$$
$$\Gamma_2(I) = D_2$$

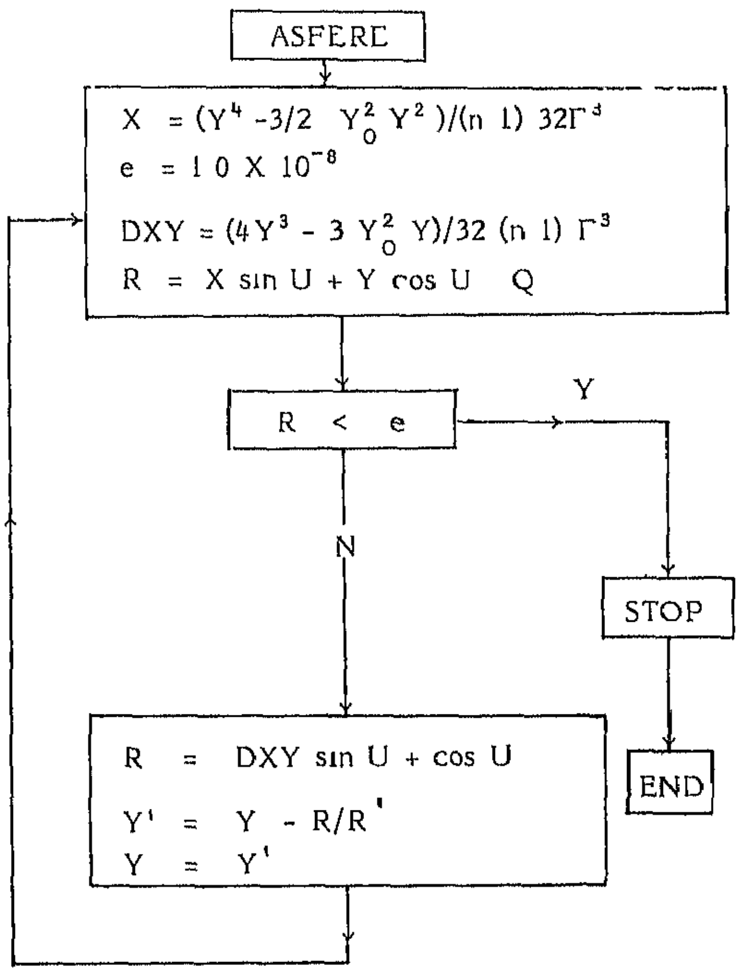
10 RAYS ARE TRACED WITH INCIDENT ANGLE VARYING FROM $\theta/10$ to θ

STORE $F_2(I)$
$I = 1,10$

OF THE 10 VALUES OF $F_2(I)$, FIND THE MAXM & MINM
MAX-MIN = ALA (J)


IF ALA(J) < ε
Y
D
STORE ALA(J)
GO TO NEXT VALUE
OF SD
B
Y
IF J < 20
OF THE 20 VALUES OF
ALA(J) THE MINM IS
FOUND THE CORRESPONDING
SD IS TAKEN FOR NEXT
COMPUTATION
B
SD VALUE IS TAKEN FROM
SD 1 TO SD+1 IN
STEPS OF 0 1
20 VALUES OF SD IS TAKEN
GO TO J
B
SD VARIES FROM
SD- 1 TO SD+ 1 IN
STEPS OF 0 01
20 VALUES OF SD IS TAKEN
SD VARIES FROM
SD- 01 TO SD+ 01 IN
STEPS OF 001
20 VALUES ARE COMPUTED
STORE SD VALUE
COMPUTED TO 3 DECIMAL PLACE
& CORRESPONDING D1 & ALA
A


AFTER COMPUTING 24 VALUES OF SD, D1 , ALA THE SD & D1 ARE SELECTED FOR WHICH ALA IS MINIMUM
D
PRINT SD, D1, ALA,D2
STOP
END


ASFERE
X = (Y4 -3/2 Y0 2 Y2)/(n 1) 32r3
e = 1 0 X 10-8
DXY = (4Y3 - 3 Y0 2 Y)/32 (n 1) r3
R = X sin U + Y cos U Q
R < e
Y
N
STOP
END
R = DXY sin U + cos U
Y' = Y - R/R'
Y = Y'

```
C             PROGRAMME SCHMID
C
C             CALCULATION OF TEST PARAMETERS FOR TESTING SCHMIDT
C             CORRECTOR PLATE
C
C             SYMBOLS USED:-
C             F-FOCAL LENGTH, R-RADIUS OF CURVATURE, YO-HALF APERTURE,
C             SD-SOURCE DISTANCE FROM CORRECTOR PLATE,
C             D1-DISTANCE BETWEEN SPHERE AND CORRECTOR PLATE,
C             D2-DISTANCE BETWEEN CORRECTOR PLATE AND FOCUS,
C             RI-REFRACTIVE INDEX OF THE PLATE
C             CPT-PLATE THICKNESS. SPE-SCHMIDT APERTURE.
C             COMMON F, YO, RI
              DIMENSION F2 (10), ALA (50), XNIM (50), AAMX (50), ADS (50),
              DONE (50), YC (50)
C
              DATA F, RI, R, YO, CPT, SPE/1347.5,1.5168,2695.0,224.0,12.04,592.0/
C
C             IN THE START AN APPROXIMATE VALUE OF SD IS CHOSEN AS 1/100TH
C             OF FOCAL LENGTH BY ITERATING THE CORRECT VALUE OF SD IS
C             COMPUTED. ALSO DI IS CHOSEN BETWEEN 1.11 AND 1.20 TIMES THE
C             FOCAL LENGTH OF THE CAMERA. THIS PROGRAMME COMPUTES
C             THE OPTIMUM VALUE OF SD AND D1 TO GIVE MINIMUM SPHERICAL
C             ABERRATIONS.
C
              EPS=0.01
              TC=0.0001
              APE=SPE/2.0
              CPA=2.0*YO
              FNO=F/CPA
              SPX=1.11
              DO 55 JS=1,24
              SP=SPX+FLOAT (JS)/200.0
              D1=F*SP
              SD=F/100.0
              ISD=INT(SD)
              M=ISD
              ISD=M-1
              SAD=FLOAT(ISD)
              B=1.0
C
C             RAY TRACING
C
     10       DO 30 J=1,20
              AC=FLOAT(J)*B
              SD=SAD+AC
              IL=0
              ANG=ATAN(APE/(D1+CPT+SD))/10.0
```

```
      DO 15 I=1,10
      U1=FLOAT(I)*ANG
      Q1=SD*SIN(U1)
      Y1=Q1
      CALL ASFERE(Y1,U1,X1,DXY1,Q1)
      AI=ATAN(DXY1)-U1
      AIP=ASIN(SIN(AI/RI)
      UP=U1+AI-AIP
      QP1=X1*SIN(UP)+Y1*COS(UP)
      Q2=QP1+CPT*SIN(UP)
      U2=UP
      UP2=ASIN(RI*SIN(U2))
      QP2=Q2*COS(UP2)/COS(U2)
      Q3=QP2+D1*SIN(UP2)
      U3=UP2
      AI3=ASIN(Q3/R-SIN(U3))
      AIP3=AI3
      UP3=U3+AI3-AIP3
      G3=Q3/(COS(U3)+COS(AI3))
      QP3=G3*(COS(UP3)+COS(AIP3))
      Q4=QP3-D1*SIN(UP3)
      U4=UP3
      UP4=ASIN(SIN(U4)/RI)
      QP4=Q4*COS(UP4)/COS(U4)
      Q5=QP4-CPT*SIN(UP4)
      Y5=Q5
      U5=UP4
      CALL ASFERE(Y5,U5,X5,DXY2,Q5)
      AI5 =ATAN(DXY2)-U5
      AIP5=ASIN(SIN(AI5)*RI)
      UP5=U5+AI5-AIP5
      QP5=X5*SIN(UP5)+Y5*COS(UP5)
      D2=QP5/SIN(UP5)
      F2(I)=D2
15    CONTINUE
      AMAX=F2(1)
      AMIN=F2(1)
      DO 20 K=2,10
      FA=F2(K)
      IF(FA.GT.AMAX)AMAX=FA
      IF(FA.LT.AMIN)AMIN=FA
20    CONTINUE
      ALA(J)=AMAX-AMIN
      IF(ALA(J).LT.EPS) GO TO 25
      GO TO 30
25    DAS=SD
      XMIN=ALA(J)
      IL=1
      Y5=Y5*2.0
      GO TO 35
```

```
30      CONTINUE
35      IF(IL.EQ.1) GO TO 75
        XMIN=ALA(1)
        DO 45 JP=2,20
        IF(ALA(JP).LT.XMIN) GO TO 40
        GO TO 45
40      XMIN=ALA(JP)
        IK=JP
45      CONTINUE
        IF(XMIN.EQ.ALA(1)) IK=1
        DAS=SAD+FLOAT(IK)*B
        SAD1=DAS-B
        SAD2=DAS+B
        SAD=SAD1
        BAC=B/10.0
        B=BAC
        IF(B.LE.TC) GO TO 50
        GO TO 10
50      ADS(JS)=DAS
        XNIM(JS)=XMIN
        AAMX(JS)=AMAX
        DONE(JS)=D1
        YC(JS)=Y5
55      CONTINUE
        IS=1
        XMIN=XNIM(1)
60      IS=IS+1
        IF(IS.GT.24) GO TO 70
        IF(XNIM(IS).LT.XMIN) GO TO 65
        GO TO 60
65      XMIN=XNIM(IS)
        IM=IS
        GO TO 60
70      IF(XMIN.EQ.XNIM(1)IM=1
        DAS=ADS(IM)
        AMAX=AAMX(IM)
        D1=DONE(IM)
        Y5=YC(IM)*2.0
75      WRITE(8,100)
        WRITE(8,150)SPE
        WRITE(8,200)F
        WRITE(8,250)CPA
        WRITE(8,300)FNO
        WRITE(8,350)RI
        WRITE(8,400)CPT
        WRITE(8,450)D1
        WRITE(8,500)DAS
        WRITE(8,550)AMAX
        WRITE(8,600)Y5
        WRITE(8,650)XMIN
```

```
      WRITE(8,700)
100   FORMAT(1H1////////40X,'SCHMIDT CORRECTOR PLATE
     1 OPTICAL TEST PARAMETERS.'/40X,48'*')
150   FORMAT(////40X,'SPHERE APERTURE'35X,F10.4)
200   FORMAT(/40X,'SPHERE FOCAL LENGTH'31X,F10.4)
250   FORMAT(/40X,'CORRECTOR PLATE APERTURE'26X,F10.4)
300   FORMAT(/40X,'SYSTEM FOCAL RATIO'32X,F10.4/42X,
     1 '(SPHERE FOCAL LENGTH/CORRECTOR PLATE DIA.)')
350   FORMAT(/40X,'REFRACTIVE INDEX OF CORRECTOR
     1 PLATE MATERIAL'6X,F10.4)
400   FORMAT(/40X,'CORRECTOR PLATE CENTRAL THICKNESS'
     1 17X,F10.4)
450   FORMAT(/40X,'DISTANCE BETWEEN SPHERE AND CORRECTOR
     1 PLATE-D1.'2X,F10.4)
500   FORMAT(/40.X, DISTANCE BETWEEN CORRECTOR PLATE
     1 AND SOURCE-SD.'3X,F10.4)
550   FORMAT(/40X,'CONJUGATE FOCUS DISTANCE FROM CORRECTOR
     1 PLATE-D2.'X,F10.4)
600   FORMAT(/40X,'MAXIMUM CORRECTOR APERTURE UNDER TEST'
     1 13X,F10.4)
650   FORMAT(/40X,'MAXIMUM LONGITUDINAL SPHERICAL ABERRATION
     1 AT'/50X,'CONJUGATE FOCUS'23X,F10.4)
700   FORMAT(/50X,'ALL UNITS ARE IN MM '///50X,30'-'/1H1)
      STOP
      END

      SUBROUTINE ASFERE(Y,U,X,DXY,Q)
      COMMON F,YO,RI
10    X=(Y**4-1.5*YO*YO*Y*Y)/(RI-1.0)*32.0*F**3)
      EPS=1.0E-08
      R=X*SIN(U)+Y*COS(U)-Q
      DXY=(4.0*Y*Y*Y-3.0*YO*YO*Y)/(32.0*(RI-1.0)*F**3)
      IF(R.LT.EPS) GO TO 20
      RP=DXY*SIN(U)+COS(U)
      YP=Y-(R/RP)
      Y=YP
      GO TO 10
20    RETURN
      END
```

TABLE 1. SCHMIDT CORRECTOR PLATE OPTICAL TEST PARAMETERS
(ALL UNITS ARE IN MM)

SPHERE APERTURE	592.0000
SPHERE FOCAL LENGTH	1347.4999
CORRECTOR PLATE APERTURE	440.0000
SYSTEM FOCAL RATIO (SPHERE FOCAL LENGTH/CORRECTOR PLATE DIA.)	3.0078
REFRACTIVE INDEX OF CORRECTOR PLATE MATERIAL	1.5168
CORRECTOR PLATE CENTRAL THICKNESS	12.0400
DISTANCE BETWEEN SPHERE AND CORRECTOR PLATE-D1	1630.4748
DISTANCE BETWEEN CORRECTOR PLATE AND SOURCE-SD	31.1260
CONJUGATE FOCUS DISTANCE FROM CORRECTOR PLATE - D2	5292.9062
MAXIMUM CORRECTOR APERTURE UNDER TEST	447.0261
MAXIMUM LONGITUDINAL SPHERICAL ABERRATION AT CONJUGATE FOCUS	.0234

4. Remarks

Table 1 gives the format of the optical test parameters obtained from this program. The test parameters of the 600/450 mm Schmidt telescope corrector plate are presented here. Using this set up 450 mm corrector plate was figured using its parent sphere Focault knife edge test and the shearing interferometer (Saxena, 1979) were employed for evaluating the wavefront errors during figuring process. Finally the optics including the field flattener was put into the telescope and was carefully aligned using the procedure given by Anderson & Clausen (1974). A laser beam in the place of a simple light source, provides an easy and a quick alignment of the system. The telescope was used for recording wide field pictures of Halley's comet. These pictures show that the quality (Bhattacharyya, 1986) of the telescope optics is quite satisfactory. It is therefore, felt that the above methods of testing and alignment can be conveniently used for any precise Schmidt optical system.

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