Appendix 1

Suggested method for preparation of standard specimens

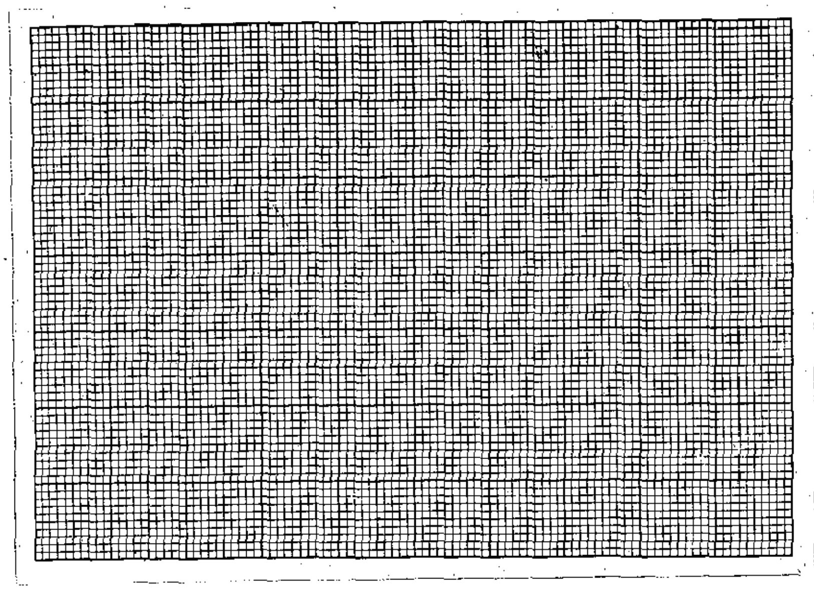
Typical microscopical fields are selected using a magnification at which the counts are to be determined. These fields should contain the type and size (severity) of inclusions of interest, e.g. a field similar to JK grading 2 or 3 (Fig.3). Each field is identified with micro-hardness indentations to correspond to the blank frame edge. Photographs are then taken of each of these fields by removing the binocular head and replacing it with a 35-mm camera and attachment (obtainable from Vickers Instrument Company, Ltd.). The negative is processed and an enlargement made of standard field. When enlarging the photomicrograph of the standard field a grid negative is used in conjunction with the photomicrograph negative. The photographic exposure and processing are adjusted to give a good contrast without distorting the image. Prints are made by exposing the bromide paper to the photomicrograph negative and grid negative separately, and then developing the latent images simultaneously. This maintains the clarity and definition of the two negatives.

A grid negative can be made by contact printing a piece of tracing graph paper on to a photographic plate or film. Photographs of two such grid negatives are shown below.

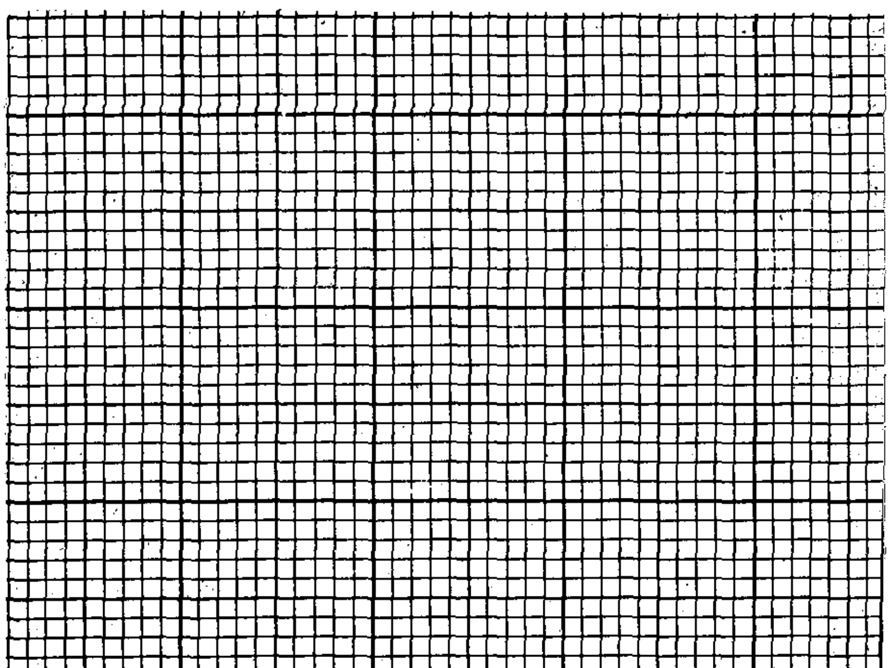
To assess the area occupied by inclusions, the number of small squares+ occupied by the inclusions or features of interest is counted and compared with the total number of such squares within the area of interest (field) on the specimen, i.e. the area corresponding to the blank frame. This gives the proportion by area of that inclusion or feature in the field. This value is then used as a standard area

\+ Special note: Features less than 1 square are counted as $\frac{1}{2}$ a unit.

for that field of view. In practice, the operator sets up the instrument so that the standard field of interest is projected on the TV screen, focuses the microscope to give a sharp image and sets the threshold level to correspond to the standard area measurement.



Photograph of grid used for preparing standard specimens containing relatively small features



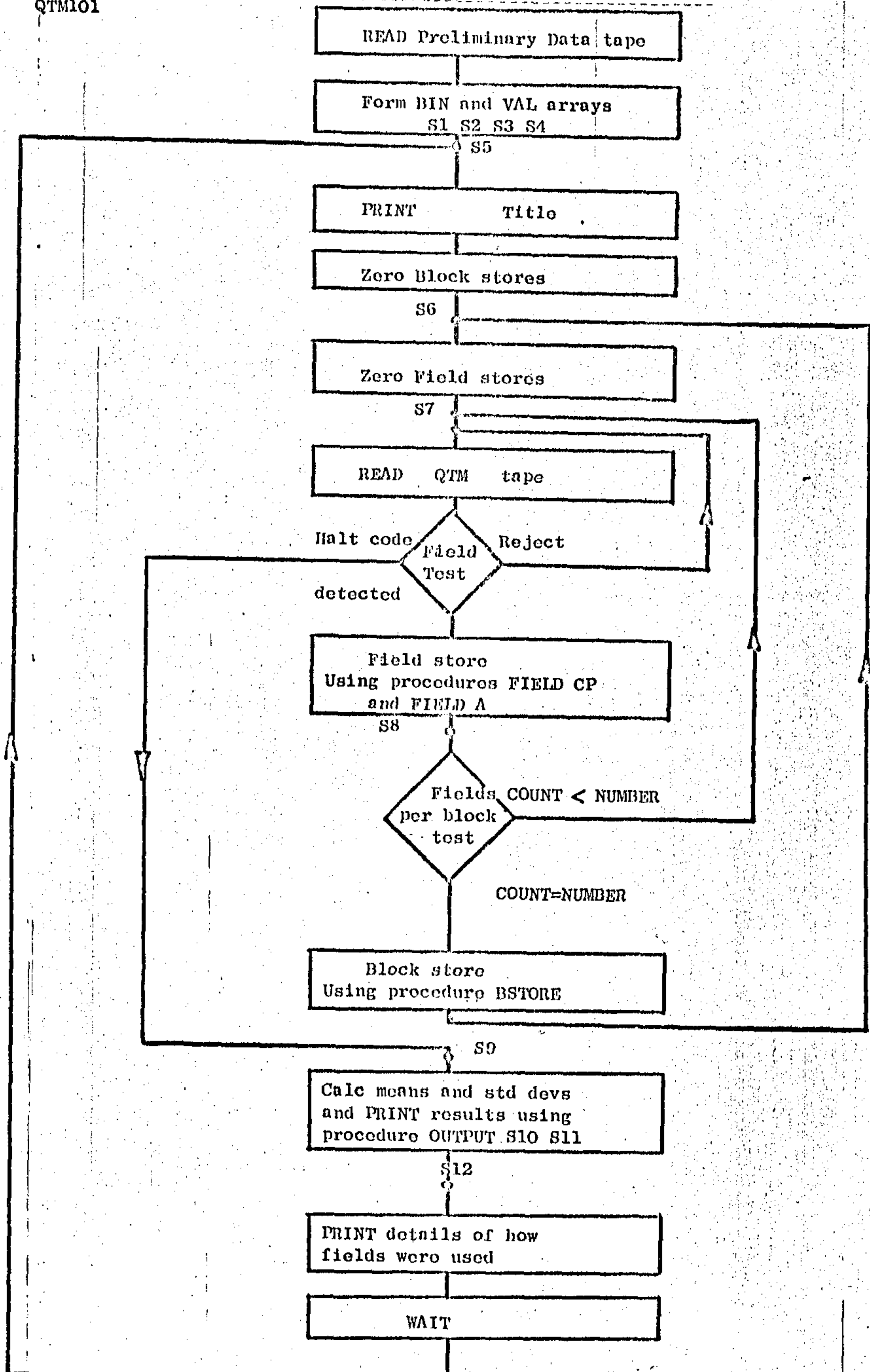
Photograph of grid used for preparing standard specimens containing relatively large features

Appendix 2

FLOW DIAGRAM AND DETAILS OF COMPUTER PROGRAMME QTM101

```
QTM 101
+ WARNING
Y
P FIELDC       ADR     35
E              ADR     54
P FIELDA       ADR     56
E              ADR    103
P BSTORE       ADR    105
E              ADR    137
P OUTPUT       ADR    139
L H            ADR    176
E              ADR    240
E              ADR    240
L SI           ADR    380
E              ADR    412
E              ADR    435
L S2           ADR    435
E              ADR    511
E              ADR    545
E              ADR    572
L S3           ADR    573
L S4           ADR    602
L S5           ADR    631
E              ADR    705
E              ADR    737
L S6           ADR    738
E              ADR    774
L S7           ADR    775
E              ADR    809
E              ADR    850
L S8           ADR    876
E              ADR    929
L S9           ADR    950
E              ADR   1005
L S10          ADR   1006
E              ADR   1060
L S11          ADR   1061
L S12          ADR   1092
E              ADR   1162
 PROGRAM    1204
 SCALARS      65
```

QTM101



READ Preliminary Data tape
Form BIN and VAL arrays
S1 S2 S3 S4
S5
PRINT Title
Zero Block stores
S6
Zero Field stores
S7
READ QTM tape
Halt code detected
Field Test
Reject
Field store
Using procedures FIELD CP and FIELD A
S8
Fields per block test
COUNT < NUMBER
COUNT=NUMBER
Block store
Using procedure BSTORE
S9
Calc means and std devs and PRINT results using procedure OUTPUT S10 S11
S12
PRINT details of how fields were used
WAIT

QTM 101;

```
"BEGIN" "REAL" FH, FW, AR, Y, FAR, SDEV, DATE;
        "INTEGER"CN, PN, I, J, X, W, AREA, BLOCK, SCANNED, COUNT,
                 NUMBER, REJECT;
        "INTEGER""ARRAY" A[0:75], TITLE[0:15];
        "ARRAY"CS, PS[1:8], BIN, VAL, CSUM, PSUM, SSOC, SSOP, C, P[1:16],
               RR, TT, ARE, ARSUM, FARSUM, ARSTOR, SSOAR[0:1];
        "SWITCH" SW:=S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12;
        "CODE" "PROCEDURE" LININ(Y);
               "INTEGER""ARRAY"Y;
        "ALGOL";


        "PROCEDURE" FIELDCP(AA, BB);
                    "ARRAY" AA;
                    "INTEGER""ARRAY" BB;
        "BEGIN" AA[X]:=BB[4*X-1]+AA[X];
        "END";


        "PROCEDURE" FIELDA(BB, CC, DD, EE, NUMBER);
                    "ARRAY" CC, DD, EE;
                    "INTEGER""ARRAY" BB;
                    "INTEGER" NUMBER;
        "BEGIN" CC[W]:=BB[4*X-1]/100;
                DD[W]:=CC[W]/NUMBER+DD[W];
                EE[W]:=CC[W]/NUMBER+EE[W];
        "END";


        "PROCEDURE" BSTORE(FF, GG, SUM1, SUM2, SSQ);
                    "ARRAY"FF, GG, SUM1, SUM2, SSQ;
        "BEGIN" SUM1[X]:=FF[X]+SUM2[X];
                SSQ[X]:=GG[X]*GG[X]+SSQ[X];
        "END";


        "PROCEDURE" OUTPUT(TT, SUM, SSQ, BLOCK);
                    "ARRAY" TT, SUM, SSQ;
                    "INTEGER" BLOCK;
        "BEGIN" "SWITCH" SW:=H;
                "PRINT" ''L'';
                "IF" TT[X]=-1 "THEN""GOTO" H;
                "PRINT" SAMELINE, ALIGNED(5, 1), TT[X], ''S2'';
            H:  "PRINT" SAMELINE, ALIGNED(3, 4), SUM[X]/BLOCK;
                "IF" BLOCK "GE" 2 "THEN"
                "BEGIN"
                   Y:=(SSQ[X]-((SUM[X]*SUM[X])/BLOCK))/(BLOCK-1);
                   "IF" Y "LE" 0 "THEN" SDEV:=0
                                 "ELSE" SDEV:=SQRT (Y);
                   "PRINT" SAMELINE, ''S3'', ALIGNED(3, 4), SDEV;
                "END";
        "END";
```

```
"READ" DATE,FH,FW,AR,CN;
"FOR" I:=1 "STEP" 1 "UNTIL" CN "DO" "READ" CS[I];
"READ" PN;
"FOR" J:=1 "STEP" 1 "UNTIL" PN "DO" "READ" PS[J];
"READ" AREA;
FAR:=FH*FW;
NUMBER:=AR/FAR;
"PRINT"''L'DATE',SAMELINE,ALIGNED(6,0),DATE,
        ''L'FIELD WIDTH & HEIGHT',ALIGNED(1,2),FW,FH,' MMS',
        ''L'EXAMINED AREA',ALIGNED(1,2),AR,' SQ MMS',
        ''L'ONE DETECTION LEVEL ONLY';
WAIT;


    I:=J:=0;
S1: "IF" I+J=CN+PN "THEN" "GOTO" S5;
    "IF" CN=0 "THEN""BEGIN" J:=J+1; BIN[J]:=0;
                            VAL[J]:=PS[J]; "GOTO" S1;
                     "END";
    "IF" PN=0 "THEN""BEGIN" I:=I+1; BIN[I]:=1;
                            VAL[I]:=CS[I]; "GOTO" S1;
                     "END";


S2: "IF" I+J=CN+PN "THEN" "GOTO" S5;
    "IF" I=CN "THEN" "GOTO" S3;
    "IF" J=PN "THEN" "GOTO" S4;
    I:=I+1; J:=J+1;
    "IF" CS[I]=PS[J] "THEN""BEGIN" BIN[I+J-1]:=1; BIN[I+J]:=0;
                                   VAL[I+J-1]:=CS[I];
                                   VAL[I+J]:=PS[J];
                                   "GOTO" S2;
                            "END";


    "IF" CS[I]<PS[J] "THEN""BEGIN" BIN[I+J-1]:=1;
                                   VAL[I+J-1]:=CS[I];
                                   J:=J-1;
                            "END"
                      "ELSE""BEGIN" BIN[I+J-1]:=0;
                                   VAL[I+J-1]:=PS[J];
                                   I:=I-1;
                            "END";
    "GOTO" S2;


S3: J:=J+1;
    BIN[I+J]:=0;  VAL[I+J]:=PS[J];
    "IF" J=PN "THEN" "GOTO" S5 "ELSE" "GOTO" S3;
```

```
S4:    I:=I+1;
       BIN[I+J]:=1;   VAL[I+J]:=CS[I];
       "IF" I=CN "THEN" "GOTO" S5 "ELSE" "GOTO" S4;

S5:    "PRINT"''L6'';
       J:=0;
       INSTRING(TITLE,J);
       J:=0;
       OUTSTRING(TITLE,J);
       WAIT;

       SCANNED:=REJECT:=BLOCK:=0;
       RR[0]:=RR[1]:=0;  TT[0]:=TT[1]:=-1;
       "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
                "BEGIN" ARSUM[X]:=FARSUM[X]:=SSQAR[X]:=0;
                "END";
       "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
                "BEGIN" CSUM[X]:=PSUM[X]:=SSQC[X]:=SSQP[X]:=0;
                "END";

S6:    ARSTOR[0]:=ARSTOR[1]:=0;   COUNT:=0;
       "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
                "BEGIN" C[X]:=P[X]:=0;
                "END";

S7:    LININ(A);

       "IF" A[0]=1 "THEN" "GOTO"S9;
       "IF" A[0]>1 "OR" A[1] "NE" PN+CN+AREA+1
                "THEN" "BEGIN" REJECT:=REJECT+1;
                                "GOTO" S7;
                          "END";
       COUNT:=COUNT+1;
       SCANNED:=SCANNED+1;

       "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
       "BEGIN"
             "IF"BIN[X]=1 "THEN" FIELDCP(C,A)
                          "ELSE" FIELDCP(P,A);
       "END";

       "IF" AREA=0 "THEN" "GOTO" S8;
       W:=0; X:=PN+CN+AREA;
       FIELDA(A,ARE,FARSUM,ARSTOR,NUMBER);
```

```
S8:  "IF" COUNT<NUMBER "THEN" "GOTO" S7;
     BLOCK:=BLOCK+1;
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
     "BEGIN"
     "IF"BIN[X]=1 "THEN" BSTORE(C,C,CSUM,CSUM,SSQC)
                   "ELSE" BSTORE(P,P,PSUM,PSUM,SSQP);
     "END";
     "IF" AREA=0 "THEN" "GOTO" S9;
     X:=W;
     BSTORE(RR,ARSTOR,ARSUM,FARSUM,SSQAR);
     "GOTO" S6;


S9:  "IF" BLOCK=0 "THEN" "GOTO" S12;
     "IF" CN=0 "THEN""GOTO" S10;
     "PRINT"'L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR" X:=1"STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=1 "THEN" OUTPUT(VAL,CSUM,SSQC,BLOCK);
     "END";

S10: "IF" PN=0 "THEN""GOTO" S11;
     "PRINT"'L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR"X:=1 "STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=0 "THEN" OUTPUT(VAL,PSUM,SSQP,BLOCK);
     "END";

S11: "IF" AREA=0 "THEN""GOTO" S12;
     "PRINT"'L4'%AREA'LS4'MEAN'S6'STD DEV';
     X:=W;
     OUTPUT(TT,ARSUM,SSQAR,BLOCK);


S12: "PRINT"
     ''L2'NUMBER OF FIELDS SCANNED',SAMELINE,DIGITS(3),SCANNED,
     ''L'NUMBER OF FIELDS REJECTED',SAMELINE,DIGITS(3),REJECT,
     ''L'FIELDS WERE USED IN',SAMELINE,DIGITS(3),BLOCK,
     ' BLOCKS OF',NUMBER,''R100'';


     WAIT;
     "GOTO" S5;

"END";
```

<u>Appendix 3</u>

DETAILS OF COMPUTER PROGRAMME QTM201

```
QTM 201
+ WARNING
Y
P FIELDC    ADR     35
E           ADR     54
P FIELDA    ADR     56
E           ADR    103
P BSTORE    ADR    105
E           ADR    137
P OUTPUT    ADR    139
L H         ADR    176
E           ADR    240
E           ADR    240
L S1        ADR    386
E           ADR    430
E           ADR    465
L S2        ADR    465
E           ADR    577
E           ADR    631
E           ADR    678
L S3        ADR    679
L S4        ADR    724
L S5        ADR    769
E           ADR    843
E           ADR    877
L S6        ADR    878
E           ADR    916
L S7        ADR    917
E           ADR    949
E           ADR   1005
E           ADR   1005
E           ADR   1058
L S8        ADR   1098
E           ADR   1162
L S9        ADR   1197
L S10       ADR   1228
L S11       ADR   1257
E           ADR   1305
L S12       ADR   1306
E           ADR   1358
L S13       ADR   1359
L S14       ADR   1390
E           ADR   1469
  PROGRAM 1515
  SCALARS   68
```

QTM2O1;

```
"BEGIN" "REAL" FH,FW,AR,Y,FAR,SDEV,DATE;
     "INTEGER"CN,PN,F,G,I,J,X,Z,W,AREA,BLOCK,SCANNED,COUNT,
            NUMBER,REJECT;
     "INTEGER""ARRAY" A[0:150],TITLE[0:15];
     "ARRAY"CS,PS[1:8],BIN,VAL,CSUM,PSUM,SSOC,SSOP,C,P[1:33],
           RR,TT,ARE,ARSUM,FARSUM,ARSTUR,SSOAR[0:1];
     "SWITCH" SW:=S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,S11,S12,S13,
              S14;
     "CODE" "PROCEDURE" LININ(Y);
           "INTEGER""ARRAY"Y;
     "ALGOL";


     "PROCEDURE" FIELDCP(AA,BB);
               "ARRAY" AA;
               "INTEGER""ARRAY" BB;
     "BEGIN" AA[X]:=BB[4*X-1]+AA[X];
     "END";


     "PROCEDURE" FIELDA(BB,CC,DD,EE,NUMBER);
               "ARRAY" CC,DD,EE;
               "INTEGER""ARRAY" BB;
               "INTEGER" NUMBER;
     "BEGIN" CC[W]:=BB[4*X-1]/100;
             DD[W]:=CC[W]/NUMBER+DD[W];
             EE[W]:=CC[W]/NUMBER+EE[W];
     "END";


     "PROCEDURE" BSTURE(FF,GG,SUM1,SUM2,SSQ);
               "ARRAY"FF,GG,SUM1,SUM2,SSQ;
     "BEGIN" SUM1[X]:=FF[X]+SUM2[X];
             SSQ[X]:=GG[X]*GG[X]+SSQ[X];
     "END";


     "PROCEDURE" OUTPUT(TT,SUM,SSQ,BLOCK);
               "ARRAY" TT,SUM,SSQ;
               "INTEGER" BLOCK;
     "BEGIN" "SWITCH" SW:=H;
             "PRINT" ''L'';
             "IF" TT[X]=-1 "THEN""GOTO" H;
             "PRINT" SAMELINE,ALIGNED(5,1),TT[X],''S2'';
         H:  "PRINT" SAMELINE,ALIGNED(3,4),SUM[X]/BLOCK;
             "IF" BLOCK "GE" 2 "THEN"
             "BEGIN"
                Y:=(SSQ[X]-((SUM[X]*SUM[X])/BLOCK))/(BLOCK-1);
                "IF" Y "LE" 0 "THEN" SDEV:=0
                             "ELSE" SDEV:=SQRT (Y);
                "PRINT" SAMELINE,''S3'',ALIGNED(3,4),SDEV;
             "END";
     "END";
```

```
"READ" DATE,FH,FW,AR,CN;
"FOR" I:=1 "STEP" 1 "UNTIL" CN "DO" "READ" CS[I];
"READ" PN;
"FOR" J:=1 "STEP" 1 "UNTIL" PN "DO" "READ" PS[J];
"READ" AREA;
FAR:=FH*FW;
NUMBER:=AR/FAR;
"PRINT"'L'DATE',SAMELINE,ALIGNED(6,0),DATE,
       'L'FIELD WIDTH & HEIGHT',ALIGNED(1,2),FW,FH,' MMS',
       'L'EXAMINED AREA',ALIGNED(1,2),AR,' SQ MMS',
       'L'TWO DETECTION LEVELS';
WAIT;


Z:=CN+PN+AREA;
I:=J:=0;
S1: "IF" I+J=CN+PN "THEN" "GOTO" S5;
"IF" CN=0 "THEN""BEGIN" J:=J+1; BIN[J]:=BIN[J+Z]:=0;
                                VAL[J]:=VAL[J+Z]:=PS[J];
                                "GOTO" S1;
                  "END";
"IF" PN=0 "THEN""BEGIN" I:=I+1; BIN[I]:=BIN[I+Z]:=1;
                                VAL[I]:=VAL[I+Z]:=CS[I];
                                "GOTO" S1;
                  "END";


S2: "IF" I+J=CN+PN "THEN" "GOTO" S5;
"IF" I=CN "THEN" "GOTO" S3;
"IF" J=PN "THEN" "GOTO" S4;
I:=I+1; J:=J+1;
"IF" CS[I]=PS[J]"THEN"
                "BEGIN"BIN[I+J-1]:=BIN[I+J-1+Z]:=1;
                       BIN[I+J]:=BIN[I+J+Z]:=0;
                       VAL[I+J-1]:=VAL[I+J-1+Z]:=CS[I];
                       VAL[I+J]:=VAL[I+J+Z]:=PS[J];
                       "GOTO" S2;
                "END";


"IF" CS[I]<PS[J]"THEN"
                "BEGIN"BIN[I+J-1]:=BIN[I+J-1+Z]:=1;
                       VAL[I+J-1]:=VAL[I+J-1+Z]:=CS[I];
                       J:=J-1;
                "END"
              "ELSE"
                "BEGIN" BIN[I+J-1]:=BIN[I+J-1+Z]:=0;
                        VAL[I+J-1]:=VAL[I+J-1+Z]:=PS[J];
                        I:=I-1;
                "END";
"GOTO" S2;
```

```
S 3:  J:=J+1;
      BIN[I+J]:=BIN[I+J+Z]:=0;
        VAL[I+J]:=VAL[I+J+Z]:=PS[J];
      "IF" J=PN "THEN" "GOTO" S5 "ELSE" "GOTO" S3;

S4:   I:=I+1;
      BIN[I+J]:=BIN[I+J+Z]:=1;
      VAL[I+J]:=VAL[I+J+Z]:=CS[I];
      "IF" I=CN "THEN" "GOTO" S5 "ELSE" "GOTO" S4;

S5:   "PRINT"''L6'';
      J:=0;
      INSTRING(TITLE,J);
      J:=0;
      OUTSTRING(TITLE,J);
      WAIT;


      SCANNED:=REJECT:=BLOCK:=0;
      RR[0]:=RR[1]:=0;  TT[0]:=TT[1]:=-1;
      "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
                "BEGIN" ARSUM[X]:=FARSUM[X]:=SSQAR[X]:=0;
                "END";
      "FOR" X:=1 "STEP" 1 "UNTIL" (2*Z)-1 "DO"
                "BEGIN" CSUM[X]:=PSUM[X]:=SSQC[X]:=SSQP[X]:=0;
                "END";

S6:   ARSTOR[0]:=ARSTOR[1]:=0;   COUNT:=0;
      "FOR" X:=1 "STEP" 1 "UNTIL" (2*Z)-1 "DO"
                "BEGIN" C[X]:=P[X]:=0;
                "END";


S7:   LININ(A);

      "IF" A[0]=1 "THEN" "GOTO"S9;
      "IF" A[0]>1 "OR" A[1] "NE" (2*Z)+1
                 "THEN" "BEGIN" REJECT:=REJECT+1;
                                "GOTO" S7;
                        "END";
      "FOR" X:=Z+1 "STEP" 1 "UNTIL" 2*Z "DO"
      "BEGIN" A[4*X-1]:=A[4*X-1]-A[4*(X-Z)-1];
              "IF" A[4*X-1]<0 "THEN"
              "BEGIN" REJECT:=REJECT+1;
                      "GOTO" S7;
              "END";
      "END";

      COUNT:=COUNT+1;
      SCANNED:=SCANNED+1;
```

```
        "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN,
                Z+1"STEP" 1 "UNTIL" Z+PN+CN "DO"
        "BEGIN"
             "IF"BIN[X]=1 "THEN" FIELDCP(C,A)
                              "ELSE" FIELDCP(P,A);
        "END";

        "IF" AREA=0 "THEN" "GOTO" S8;
        W:=0; X:=Z;
        FIELDA(A,ARE,FARSUM,ARSTOR,NUMBER);


        W:=1; X:=2*Z;
        FIELDA(A,ARE,FARSUM,ARSTOR,NUMBER);


S8:     "IF" COUNT<NUMBER "THEN" "GOTO" S7;
        BLOCK:=BLOCK+1;
        "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN,
                Z+1"STEP" 1 "UNTIL" Z+PN+CN "DO"
        "BEGIN" "IF" BIN[X]=1
             "THEN" BSTORE(C,C,CSUM,CSUM,SSQC)
             "ELSE" BSTORE(P,P,PSUM,PSUM,SSQP);
        "END";

        "IF" AREA=0 "THEN" "GOTO" S6;
        W:=0;
        "FOR" X:=W "STEP" 1 "UNTIL" W+1 "DO"
        BSTORE(RR,ARSTOR,ARSUM,FARSUM,SSQAR);
        "GOTO" S6;


S9:     "IF" BLOCK=0 "THEN" "GOTO" S14;
        W:=0;  F:=1;  G:=PN+CN;
        "PRINT"''L4'FIRST DETECTION LEVEL';
        "GOTO" S11;


S10:    W:=1;  F:=Z+1;  G:=Z+PN+CN;
        "PRINT"''L4'SECOND DETECTION LEVEL';


S11:    "IF" CN=0 "THEN" "GOTO" S12;
        "PRINT"''L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
        "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
        "BEGIN" "IF" BIN[X]=1 "THEN" OUTPUT(VAL,CSUM,SSQC,BLOCK);
        "END";


S12:    "IF" PN=0 "THEN" "GOTO" S13;
        "PRINT"''L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
        "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
        "BEGIN" "IF" BIN[X]=0 "THEN" OUTPUT(VAL,PSUM,SSQP,BLOCK);
        "END";
```

```
S13: "IF" AREA=0 "THEN" "GOTO" S14;
     "PRINT" ''L4'%AREA'LS4'MEAN'S6'STD DEV';
     X:=W;
     OUTPUT(TT,ARSUM,SSQAR,BLOCK);

S14: "IF" W=0 "AND" BLOCK>0 "THEN" "GOTO" S10;
     "PRINT"
     ''L2'NUMBER OF FIELDS SCANNED',SAMELINE,DIGITS(3),SCANNED,
     ''L'NUMBER OF FIELDS REJECTED',SAMELINE,DIGITS(3),REJECT,
     ''L'FIELDS WERE USED IN',SAMELINE,DIGITS(3),BLOCK,
     ' BLOCKS OF',NUMBER,''R100'';

     WAIT;
     "GOTO" S5;

"END";
```

Appendix 4

DETAILS OF COMPUTER PROGRAMME QTM301

```
QTM 301
+ WARNING
Y
P FIELDC     ADR    39
E            ADR    58
P FIELDA     ADR    60
E            ADR   107
P BSTORE     ADR   109
E            ADR   141
P OUTPUT     ADR   143
L H          ADR   180
E            ADR   244
E            ADR   244
L S1         ADR   407
E            ADR   439
E            ADR   462
L S2         ADR   462
E            ADR   538
E            ADR   572
E            ADR   599
L S3         ADR   600
L S4         ADR   629
L S5         ADR   658
E            ADR   722
E            ADR   754
L S6         ADR   755
E            ADR   809
E            ADR   841
L S7         ADR   842
E            ADR   878
L S8         ADR   879
E            ADR   913
E            ADR   954
L S9         ADR   980
E            ADR  1033
L S10        ADR  1053
E            ADR  1101
L S11        ADR  1122
E            ADR  1177
L S12        ADR  1178
E            ADR  1232
L S13        ADR  1233
L S14        ADR  1264
E            ADR  1338
E            ADR  1410
L S15        ADR  1411
E            ADR  1465
L S16        ADR  1466
L S17        ADR  1497
E            ADR  1506
  PROGRAM  1559
  SCALARS    83
```

QTM 301;

```
"BEGIN" "REAL" FH, FW, AR, Y, FAR, SDEV, DATE;
      "INTEGER"CN, PN, I, J, K, X, W, AREA, BLOCK, GBLOCK, SCANNED,
              COUNT, NUMBER, REJECT, SET, COUNTER;
      "INTEGER""ARRAY" A[0:75], TITLE[0:15], NAME[0:50];
      "ARRAY"CS, PS[1:8], BIN, VAL, CSUM, GCSUM, PSUM, GPSUM, SSQC,
             GSSQC, SSQP, GSSOP, C, P[1:16], RR, TT, ARE, ARSUM, GARSUM,
             FARSUM, ARSTOR, SSQAR, GSSQAR[0:1];
      "SWITCH" SW:=S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12,
                S13, S14, S15, S16, S17;
      "CODE" "PROCEDURE" LININ(Y);
             "INTEGER""ARRAY"Y;
      "ALGOL";


      "PROCEDURE" FIELDCP(AA, BB);
                  "ARRAY" AA;
                  "INTEGER""ARRAY" BB;
      "BEGIN" AA[X]:=BB[4*X-1]+AA[X];
      "END";


      "PROCEDURE" FIELDA(BB, CC, DD, EE, NUMBER);
                  "ARRAY" CC, DD, EE;
                  "INTEGER""ARRAY" BB;
                  "INTEGER" NUMBER;
      "BEGIN" CC[W]:=BB[4*X-1]/100;
              DD[W]:=CC[W]/NUMBER+DD[W];
              EE[W]:=CC[W]/NUMBER+EE[W];
      "END";


      "PROCEDURE" BSTORE(FF, GG, SUM1, SUM2, SSQ);
                  "ARRAY"FF, GG, SUM1, SUM2, SSQ;
      "BEGIN" SUM1[X]:=FF[X]+SUM2[X];
              SSQ[X]:=GG[X]*GG[X]+SSQ[X];
      "END";


      "PROCEDURE" OUTPUT(TT, SUM, SSQ, BLOCK);
                  "ARRAY" TT, SUM, SSQ;
                  "INTEGER" BLOCK;
      "BEGIN" "SWITCH" SW:=H;
              "PRINT" ''L'';
              "IF" TT[X]=-1 "THEN""GOTO" H;
              "PRINT" SAMELINE, ALIGNED(5, 1), TT[X], ''S2'';
          H:  "PRINT" SAMELINE, ALIGNED(3, 4), SUM[X]/BLOCK;
              "IF" BLOCK "GE" 2 "THEN"
              "BEGIN"
                 Y:=(SSQ[X]-((SUM[X]*SUM[X])/BLOCK))/(BLOCK-1);
                 "IF" Y "LE" 0 "THEN" SDEV:=0
                                "ELSE" SDEV:=SQRT (Y);
                 "PRINT" SAMELINE, ''S3'', ALIGNED(3, 4), SDEV;
              "END";
      "END";
```

```
"READ" DATE,FH,FW,AR,CN;
"FOR" I:=1 "STEP" 1 "UNTIL" CN "DO" "READ" CS[I];
"READ" PN;
"FOR" J:=1 "STEP" 1 "UNTIL" PN "DO" "READ" PS[J];
"READ" AREA,SET;
K:=1;
"FOR" X:=1 "STEP" 1 "UNTIL" SET+1 "DO"
INSTRING(NAME,K);
FAR:=FH*FW;
NUMBER:=AR/FAR;
"PRINT"''L'DATE',SAMELINE,ALIGNED(6,0),DATE,
        ''L'FIELD WIDTH & HEIGHT',ALIGNED(1,2),FW,FH,' MMS',
        ''L'EXAMINED AREA',ALIGNED(1,2),AR,' SQ MMS',
        ''L'ONE DETECTION LEVEL ONLY';
WAIT;


     I:=J:=0;
S1:  "IF" I+J=CN+PN "THEN" "GOTO" S5;
     "IF" CN=0 "THEN""BEGIN" J:=J+1; BIN[J]:=0;
                             VAL[J]:=PS[J]; "GOTO" S1;
                     "END";
     "IF" PN=0 "THEN""BEGIN" I:=I+1; BIN[I]:=1;
                             VAL[I]:=CS[I]; "GOTO" S1;
                     "END";


S2:  "IF" I+J=CN+PN "THEN" "GOTO" S5;
     "IF" I=CN "THEN" "GOTO" S3;
     "IF" J=PN "THEN" "GOTO" S4;
     I:=I+1; J:=J+1;
     "IF" CS[I]=PS[J] "THEN""BEGIN" BIN[I+J-1]:=1; BIN[I+J]:=0;
                                   VAL[I+J-1]:=CS[I];
                                   VAL[I+J]:=PS[J];
                                   "GOTO" S2;
                           "END";


     "IF" CS[I]<PS[J] "THEN""BEGIN" BIN[I+J-1]:=1;
                                   VAL[I+J-1]:=CS[I];
                                   J:=J-1;
                           "END"
                     "ELSE""BEGIN" BIN[I+J-1]:=0;
                                   VAL[I+J-1]:=PS[J];
                                   I:=I-1;
                           "END";
     "GOTO" S2;


S3:  J:=J+1;
     BIN[I+J]:=0;  VAL[I+J]:=PS[J];
     "IF" J=PN "THEN" "GOTO" S5 "ELSE" "GOTO" S3;
```

```
S4:  I:=I+1;
     BIN[I+J]:=1;   VAL[I+J]:=CS[I];
     "IF" I=CN "THEN" "GOTO" S5 "ELSE" "GOTO" S4;

S5:  "PRINT"''L6'';
     J:=0;   K:=1;
     INSTRING(TITLE,J);
     WAIT;

     COUNTER:=GBLOCK:=0;
     RR[0]:=RR[1]:=0;  TT[0]:=TT[1]:=-1;
     "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
               "BEGIN"
                    GARSUM[X]:=GSSQAR[X]:=0;
               "END";
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
               "BEGIN"
                    GCSUM[X]:=GPSUM[X]:=GSSQC[X]:=GSSQP[X]:=0;
               "END";

S6:  J:=0;
     OUTSTRING(TITLE,J);
     "PRINT"''L'';
     OUTSTRING(NAME,K);

     SCANNED:=REJECT:=BLOCK:=0;
     COUNTER:=COUNTER+1;
     "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
               "BEGIN" ARSUM[X]:=FARSUM[X]:=SSQAR[X]:=0;
               "END";
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
               "BEGIN" CSUM[X]:=PSUM[X]:=SSQC[X]:=SSQP[X]:=0;
               "END";

S7:  ARSTOR[0]:=ARSTOR[1]:=0;   COUNT:=0;
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
               "BEGIN" C[X]:=P[X]:=0;
               "END";


S8:  LININ(A);

     "IF" A[0]=1 "THEN" "GOTO"S11;
     "IF" A[0]>1 "OR" A[1] "NE" PN+CN+AREA+1
               "THEN" "BEGIN" REJECT:=REJECT+1;
                              "GOTO" S8;
                      "END";
     COUNT:=COUNT+1;
     SCANNED:=SCANNED+1;


     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
     "BEGIN"
          "IF"BIN[X]=1 "THEN" FIELDCP(C,A)
                         "ELSE" FIELDCP(P,A);
     "END";
```

```
     "IF" AREA=0 "THEN" "GOTO" S9;
     W:=0;   X:=PN+CN+AREA;

     FIELDA(A,ARE,FARSUM,ARSTOR,NUMBER);


S9:  "IF" COUNT<NUMBER "THEN" "GOTO" S8;
     BLOCK:=BLOCK+1;
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
     "BEGIN"
     "IF"BIN[X]=1 "THEN" BSTORE(C,C,CSUM,CSUM,SSQC)
                    "ELSE" BSTORE(P,P,PSUM,PSUM,SSQP);
     "END";
     "IF" AREA=0 "THEN" "GOTO" S10;
     X:=W;
     BSTORE(RR,ARSTOR,ARSUM,FARSUM,SSQAR);


S10: GBLOCK:=GBLOCK+1;
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
     "BEGIN"
     "IF" BIN[X]=1 "THEN" BSTORE(C,C,GCSUM,GCSUM,GSSQC)
                    "ELSE" BSTORE(P,P,GPSUM,GPSUM,GSSQP);
     "END";
     "IF" AREA=0 "THEN" "GOTO" S7;
     X:=W;
     BSTORE(GARSUM,ARSTOR,GARSUM,ARSTOR,GSSQAR);
     "GOTO" S7;

S11: "IF" BLOCK=0 "THEN" "GOTO" S14;
     "IF" CN=0 "THEN""GOTO" S12;
     "PRINT"''L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR" X:=1"STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=1 "THEN" OUTPUT(VAL,CSUM,SSQC,BLOCK);
     "END";


S12: "IF" PN=0 "THEN""GOTO" S13;
     "PRINT"''L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR"X:=1 "STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=0 "THEN" OUTPUT(VAL,PSUM,SSQP,BLOCK);
     "END";

S13: "IF" AREA=0 "THEN""GOTO" S14;
     "PRINT"''L4'%AREA'LS4'MEAN'S6'STD DEV';
     X:=W;
     OUTPUT(TT,ARSUM,SSQAR,BLOCK);
```

```
S14: "PRINT"
     ''L2'NUMBER OF FIELDS SCANNED',SAMELINE,DIGITS(3),SCANNED,
     ''L'NUMBER OF FIELDS REJECTED',SAMELINE,DIGITS(3),REJECT,
     ''L'FIELDS WERE USED IN',SAMELINE,DIGITS(3),BLOCK,
     ' BLOCKS OF',NUMBER,''L6R75'';
     "IF" COUNTER "NE" SET
     "THEN" "BEGIN" WAIT; "GOTO" S6;
            "END";


     "IF" BLOCK=0 "THEN" "GOTO" S17;
     J:=0;
     OUTSTRING(TITLE,J);
     "PRINT"''L'';
     OUTSTRING(NAME,K);
     "IF" CN=0 "THEN" "GOTO" S15;
     "PRINT"''L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR" X:=1 "STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=1
        "THEN" OUTPUT(VAL,GCSUM,GSSQC,GBLOCK);
     "END";

S15: "IF" PN=0 "THEN" "GOTO" S16;
     "PRINT"''L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR" X:=1 "STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=0
        "THEN" OUTPUT(VAL,GPSUM,GSSQP,GBLOCK);
     "END";

S16: "IF" AREA =0 "THEN" "GOTO" S17;
     "PRINT" ''L4'%AREA'LS4'MEAN'S6'STD DEV';
     X:=W;
     OUTPUT(TT,GARSUM,GSSQAR,GBLOCK);

S17: "PRINT" ''R100'';

     WAIT;
     "GOTO" S5;

"END";
```

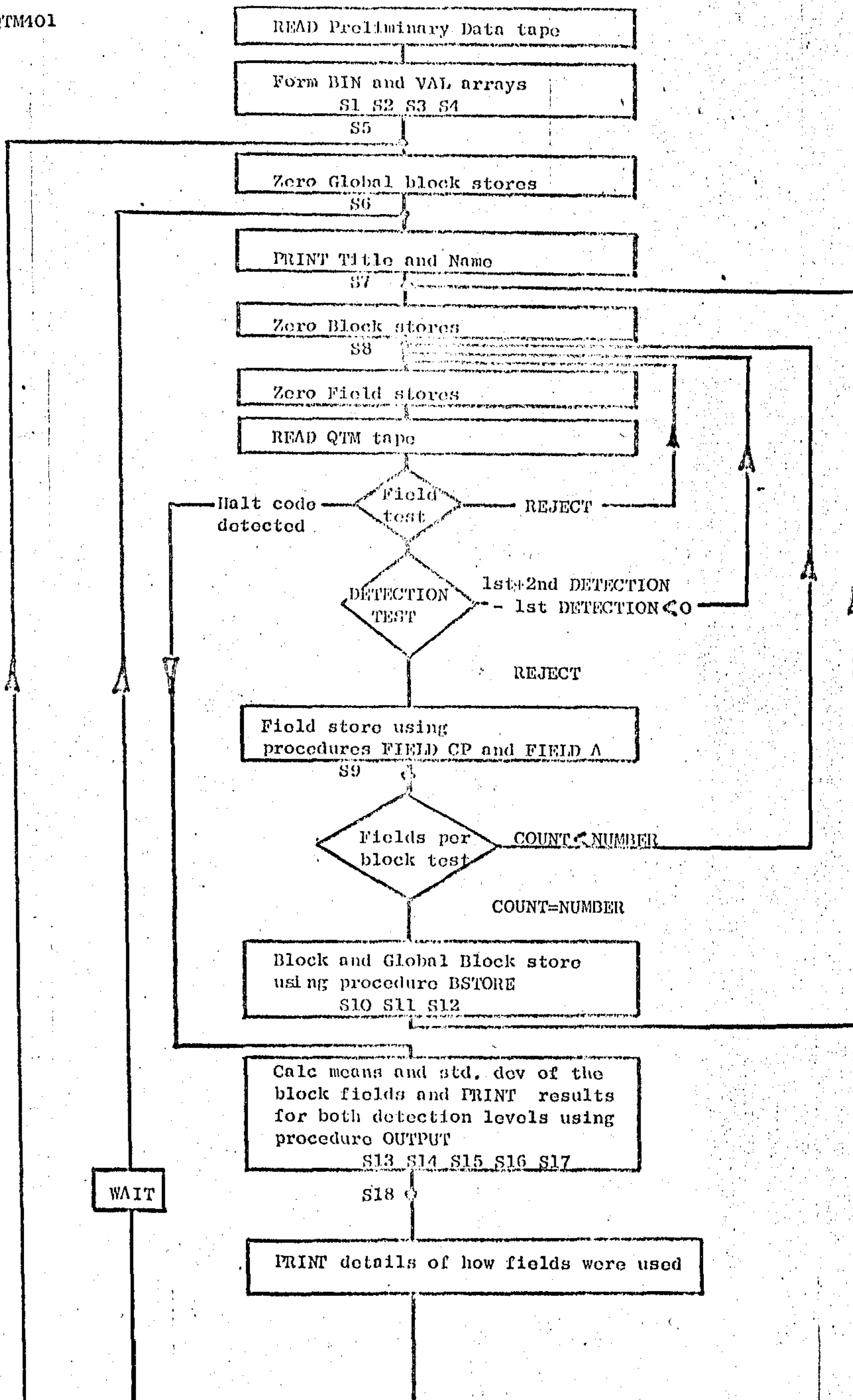
Appendix 5

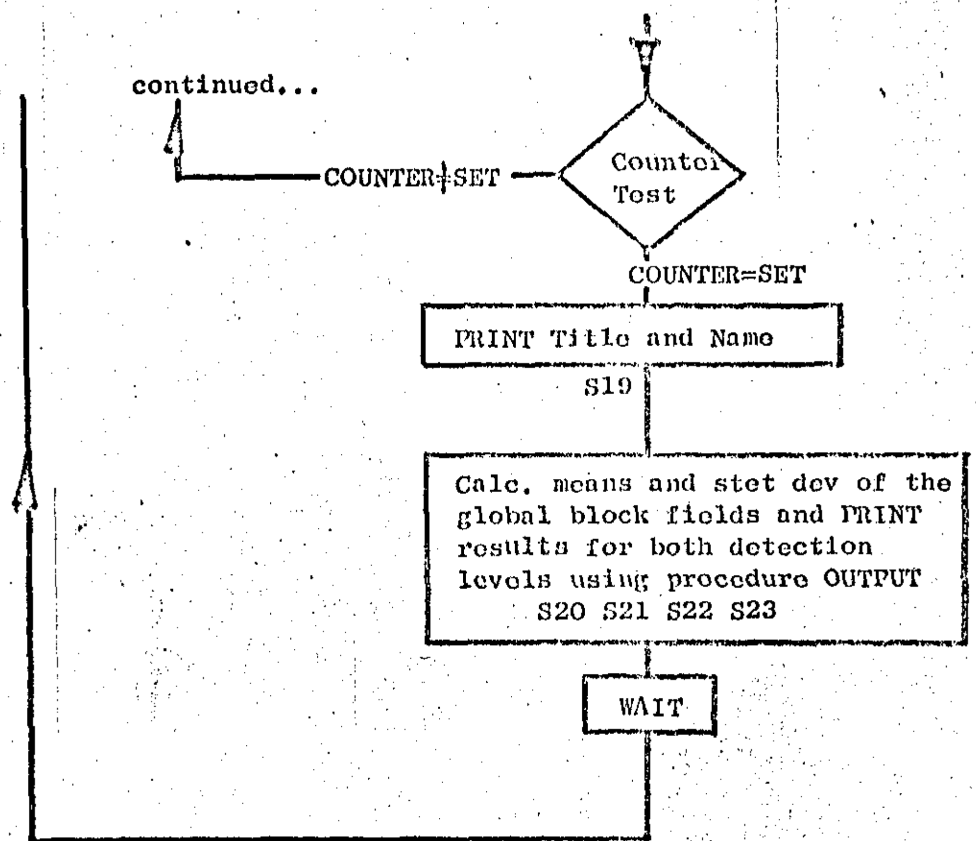
FLOW DIAGRAM AND DETAILS OF COMPUTER PROGRAMME QTM401

QTM 401
+ WARNING
Y

P FIELDC	ADR 39		E	ADR	1834
E	ADR 58		L S21	ADR	1835
P FIELDA	ADR 60		E	ADR	1889
E	ADR 107		L S22	ADR	1890
P BSTORE	ADR 109		L S23	ADR	1921
E	ADR 141		E	ADR	1939
P OUTPUT	ADR 143		PROGRAM	2004	
L H	ADR 180		SCALARS	88	
E	ADR 244				
E	ADR 244				
L S1	ADR 413				
E	ADR 457				
E	ADR 492				
L S2	ADR 492				
E	ADR 604				
E	ADR 658				
E	ADR 705				
L S3	ADR 706				
L S4	ADR 751				
L S5	ADR 796				
E	ADR 860				
E	ADR 894				
L S6	ADR 895				
E	ADR 949				
E	ADR 983				
L S7	ADR 984				
E	ADR 1022				
L S8	ADR 1023				
E	ADR 1055				
E	ADR 1111				
E	ADR 1111				
E	ADR 1164				
L S9	ADR 1204				
E	ADR 1268				
L S10	ADR 1302				
L S11	ADR 1317				
E	ADR 1360				
L S12	ADR 1384				
L S13	ADR 1415				
L S14	ADR 1447				
L S15	ADR 1478				
E	ADR 1528				
L S16	ADR 1529				
E	ADR 1583				
L S17	ADR 1584				
L S18	ADR 1615				
E	ADR 1698				
L S19	ADR 1753				
L S20	ADR 1784				

QTM401


READ Preliminary Data tape
Form BIN and VAL arrays
S1 S2 S3 S4
S5
Zero Global block stores
S6
PRINT Title and Name
S7
Zero Block stores
S8
Zero Field stores
READ QTM tape
Halt code detected
Field test
REJECT
DETECTION TEST
1st+2nd DETECTION - 1st DETECTION ≤0
REJECT
Field store using procedures FIELD CP and FIELD A
S9
Fields per block test
COUNT<NUMBER
COUNT=NUMBER
Block and Global Block store using procedure BSTORE
S10 S11 S12
Calc means and std. dev of the block fields and PRINT results for both detection levels using procedure OUTPUT
S13 S14 S15 S16 S17
WAIT
S18
PRINT details of how fields were used


continued...
COUNTER≠SET
Counter Test
COUNTER=SET
PRINT Title and Name
S19
Calc. means and stet dev of the global block fields and PRINT results for both detection levels using procedure OUTPUT
S20 S21 S22 S23
WAIT

QTM401;

```
"BEGIN" "REAL" FH,FW,AR,F,G,Y,FAR,SDEV,DATE;
        "INTEGER"CN,PN,I,J,K,X,Z,W,AREA,BLOCK,GBLOCK,SCANNED,
               COUNT,NUMBER,REJECT,SET,COUNTER;
        "INTEGER""ARRAY" A[0:150];TITLE[0:15],NAME[0:50];
        "ARRAY"CS,PS[1:8],BIN,VAL,CSUM,GCSUM,PSUM,GPSUM,SSQC,
               GSSQC,SSQP,GSSQP,C,P[1:33],RR,TT,ARE,ARSUM,GARSUM,
               FARSUM,ARSTOR,SSQAR,GSSQAR[0:1];
        "SWITCH" SW:=S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,S11,S12,
                 S13,S14,S15,S16,S17,S18,S19,S20,S21,S22,
                 S23;
        "CODE" "PROCEDURE" LININ(Y);
               "INTEGER""ARRAY"Y;
        "ALGOL";


        "PROCEDURE" FIELDCP(AA,BB);
                  "ARRAY" AA;
                  "INTEGER""ARRAY" BB;
        "BEGIN" AA[X]:=BB[4*X-1]+AA[X];
        "END";


        "PROCEDURE" FIELDA(BB,CC,DD,EE,NUMBER);
                  "ARRAY" CC,DD,EE;
                  "INTEGER""ARRAY" BB;
                  "INTEGER" NUMBER;
        "BEGIN" CC[W]:=BB[4*X-1]/100;
                DD[W]:=CC[W]/NUMBER+DD[W];
                EE[W]:=CC[W]/NUMBER+EE[W];
        "END";


        "PROCEDURE" BSTORE(FF,GG,SUM1,SUM2,SSQ);
                  "ARRAY"FF,GG,SUM1,SUM2,SSQ;
        "BEGIN" SUM1[X]:=FF[X]+SUM2[X];
                SSQ[X]:=GG[X]*GG[X]+SSQ[X];
        "END";


        "PROCEDURE" OUTPUT(TT,SUM,SSQ,BLOCK);
                  "ARRAY" TT,SUM,SSQ;
                  "INTEGER" BLOCK;
        "BEGIN" "SWITCH" SW:=H;
                "PRINT" ''L'';
                "IF" TT[X]=-1 "THEN""GOTO" H;
                "PRINT" SAMELINE,ALIGNED(5,1),TT[X],''S2'';
           H:   "PRINT" SAMELINE,ALIGNED(3,4),SUM[X]/BLOCK;
                "IF" BLOCK "GE" 2 "THEN"
                "BEGIN"
                   Y:=(SSQ[X]-((SUM[X]*SUM[X])/BLOCK))/(BLOCK-1);
                   "IF" Y "LE" 0 "THEN" SDEV:=0
                                 "ELSE" SDEV:=SQRT (Y);
                   "PRINT" SAMELINE,''S3'',ALIGNED(3,4),SDEV;
                "END";
        "END";
```

```
"READ" DATE, FH, FW, AR, CN;
"FOR" I:=1 "STEP" 1 "UNTIL" CN "DO" "READ" CS[I];
"READ" PN;
"FOR" J:=1 "STEP" 1 "UNTIL" PN "DO" "READ" PS[J];
"READ" AREA, SET;
K:=1;
"FOR" X:=1 "STEP" 1 "UNTIL" SET+1 "DO"
INSTRING(NAME,K);
FAR:=FH*FW;
NUMBER:=AR/FAR;
"PRINT"''L'DATE',SAMELINE,ALIGNED(6,0),DATE,
        ''L'FIELD WIDTH & HEIGHT',ALIGNED(1,2),FW,FH,' MMS',
        ''L'EXAMINED AREA',ALIGNED(1,2),AR,' SQ MMS',
        ''L'TWO DETECTION LEVELS';
WAIT;

Z:=CN+PN+AREA;
I:=J:=0;
S1: "IF" I+J=CN+PN "THEN" "GOTO" S5;
"IF" CN=0 "THEN""BEGIN" J:=J+1; BIN[J]:=BIN[J+Z]:=0;
                         VAL[J]:=VAL[J+Z]:=PS[J];
                                  "GOTO" S1;
                  "END";
"IF" PN=0 "THEN""BEGIN" I:=I+1; BIN[I]:=BIN[I+Z]:=1;
                         VAL[I]:=VAL[I+Z]:=CS[I];
                                  "GOTO" S1;
                  "END";


S2: "IF" I+J=CN+PN "THEN" "GOTO" S5;
"IF" I=CN "THEN" "GOTO" S3;
"IF" J=PN "THEN" "GOTO" S4;
I:=I+1; J:=J+1;
"IF" CS[I]=PS[J] "THEN"
                  "BEGIN"BIN[I+J-1]:=BIN[I+J-1+Z]:=1;
                         BIN[I+J]:=BIN[I+J+Z]:=0;
                         VAL[I+J-1]:=VAL[I+J-1+Z]:=CS[I];
                         VAL[I+J]:=VAL[I+J+Z]:=PS[J];
                         "GOTO" S2;
                  "END";

"IF" CS[I]<PS[J] "THEN"
                  "BEGIN"BIN[I+J-1]:=BIN[I+J-1+Z]:=1;
                         VAL[I+J-1]:=VAL[I+J-1+Z]:=CS[I];
                         J:=J-1;
                  "END"
                  "ELSE"
                  "BEGIN"BIN[I+J-1]:=BIN[I+J-1+Z]:=0;
                         VAL[I+J-1]:=VAL[I+J-1+Z]:=PS[J];
                         I:=I-1;
                  "END";
"GOTO" S2;
```

```
S3:  J:=J+1;
     BIN[I+J]:=BIN[I+J+Z]:=0;
     VAL[I+J]:=VAL[I+J+Z]:=PS[J];
     "IF" J=PN "THEN" "GOTO" S5 "ELSE" "GOTO" S3;

S4:  I:=I+1;
     BIN[I+J]:=BIN[I+J+Z]:=1;
     VAL[I+J]:=VAL[I+J+Z]:=CS[I];
     "IF" I=CN "THEN" "GOTO" S5 "ELSE" "GOTO" S4;

S5:  "PRINT"''L6'';
     J:=0;   K:=1;
     INSTRING(TITLE,J);
     WAIT;

     COUNTER:=GBLOCK:=0;
     RR[0]:=RR[1]:=0;    TT[0]:=TT[1]:=-1;
     "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
                "BEGIN"
                     GARSUM[X]:=GSSQAR[X]:=0;
                "END";
     "FOR" X:=1 "STEP" 1 "UNTIL" (2*Z)-1 "DO"
                "BEGIN"
                     GCSUM[X]:=GPSUM[X]:=GSSQC[X]:=GSSQP[X]:=0;

                "END";

S6:  J:=0;
     OUTSTRING(TITLE,J);
     "PRINT"''L'';
     OUTSTRING(NAME,K);

     SCANNED:=REJECT:=BLOCK:=0;
     COUNTER:=COUNTER+1;
     "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
                "BEGIN" FARSUM[X]:=ARSUM[X]:=SSQAR[X]:=0;
                "END";
     "FOR" X:=1 "STEP" 1 "UNTIL" (2*Z)-1 "DO"
                "BEGIN" CSUM[X]:=PSUM[X]:=SSQC[X]:=SSQP[X]:=0;
                "END";

S7:  ARSTOR[0]:=ARSTOR[1]:=0;   COUNT:=0;
     "FOR" X:=1 "STEP" 1 "UNTIL" (2*Z)-1 "DO"
                "BEGIN" C[X]:=P[X]:=0;
                "END";
```

```
S 8:  LININ(A);

      "IF" A[0]=1 "THEN" "GOTO"S13;
      "IF" A[0]>1 "OR" A[1] "NE" (2*Z)+1
                  "THEN" "BEGIN" REJECT:=REJECT+1;
                                 "GOTO" S8;
                         "END";

      "FOR" X:=Z+1 "STEP" 1 "UNTIL" 2*Z "DO"
      "BEGIN" A[4*X-1]:=A[4*X-1]-A[4*(X-Z)-1];
              "IF" A[4*X-1]<0 "THEN"
              "BEGIN" REJECT:=REJECT+1;
                      "GOTO" S8;
              "END";
      "END";

      COUNT:=COUNT+1;
      SCANNED:=SCANNED+1;

      "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN,
              Z+1 "STEP" 1 "UNTIL" Z+PN+CN "DO"
      "BEGIN"
          "IF"BIN[X]=1 "THEN" FIELDCP(C,A)
                       "ELSE" FIELDCP(P,A);
      "END";

      "IF" AREA=0 "THEN" "GOTO" S9;
      W:=0;   X:=Z;
      FIELDA(A,ARE,FARSUM,ARSTOR,NUMBER);

      W:=1;   X:=2*Z;
      FIELDA(A,ARE,FARSUM,ARSTOR,NUMBER);

S9: "IF" COUNT<NUMBER "THEN" "GOTO" S8;
      BLOCK:=BLOCK+1;
      "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN,
              Z+1 "STEP" 1 "UNTIL" Z+PN+CN "DO"
      "BEGIN" "IF"BIN[X]=1
          "THEN" BSTORE(C,C,CSUM,CSUM,SSQC)
          "ELSE" BSTORE(P,P,PSUM,PSUM,SSQP);
      "END";
      "IF" AREA=0 "THEN" "GOTO" S10;
      W:=0;
      "FOR" X:=W "STEP" 1 "UNTIL" W+1 "DO"
      BSTORE(RR,ARSTOR,ARSUM,FARSUM,SSQAR);
```

```
S10: GBLOCK:=GBLOCK+1;
     F:=1; G:=PN+CN;
S11: "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
     "BEGIN"
      "IF" BIN[X]=1 "THEN" BSTORE(C,C,GCSUM,GCSUM,GSSQC)
                    "ELSE" BSTORE(P,P,GPSUM,GPSUM,GSSQP);
     "END";
     "IF" F=Z+1 "THEN" "GOTO" S12;
     F:=Z+1; G:=Z+PN+CN;
     "GOTO" S11;

S12: "IF" AREA=0 "THEN" "GOTO" S7;
     "FOR" X:=W "STEP" 1 "UNTIL" W+1 "DO"
     BSTORE(GARSUM,ARSTOR,GARSUM,ARSTOR,GSSQAR);
     "GOTO" S7;

S13: "IF" BLOCK=0 "THEN" "GOTO" S18;
     W:=0; F:=1; G:=PN+CN;
     "PRINT"''L4'FIRST DETECTION LEVEL';
     "GOTO" S15;

S14: W:=1; F:=Z+1; G:=Z+PN+CN;
     "PRINT"''L4'SECOND DETECTION LEVEL';

S15: "IF" CN=0 "THEN""GOTO" S16;
     "PRINT"''L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
     "BEGIN" "IF" BIN[X]=1 "THEN" OUTPUT(VAL,CSUM,SSQC,BLOCK);
     "END";

S16: "IF" PN=0 "THEN""GOTO" S17;
     "PRINT"''L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR"X:=F "STEP" 1 "UNTIL" G "DO"
     "BEGIN" "IF" BIN[X]=0 "THEN" OUTPUT(VAL,PSUM,SSQP,BLOCK);
     "END";

S17: "IF" AREA=0 "THEN""GOTO" S18;
     "PRINT"''L4'%AREA'LS4'MEAN'S6'STD DEV';
     X:=W;
     OUTPUT(TT,ARSUM,SSQAR,BLOCK);

S18: "IF" W=0 "AND" BLOCK>0 "THEN" "GOTO" S14;
     "PRINT"
     ''L2'NUMBER OF FIELDS SCANNED',SAMELINE,DIGITS(3),SCANNED,
     ''L'NUMBER OF FIELDS REJECTED',SAMELINE,DIGITS(3),REJECT,
     ''L'FIELDS WERE USED IN',SAMELINE,DIGITS(3),BLOCK,
     ' BLOCKS OF',NUMBER,''L6R75'';
     "IF" COUNTER "NE" SET
     "THEN" "BEGIN" WAIT; "GOTO" S6;
            "END";
```

```
        "PRINT"''L'';
        J:=0;
        OUTSTRING(TITLE,J);
        "PRINT"''L'';
        OUTSTRING(NAME,K);
        "IF" BLOCK=0 "THEN" "GOTO" S23;
        W:=0; F:=1; G:=PN+CN;
        "PRINT"''L4'FIRST DETECTION LEVEL';
        "GOTO" S20;

S19:    W:=1; F:=Z+1; G:=Z+PN+CN;
        "PRINT"''L4'SECOND DETECTION LEVEL';

S20:    "IF" CN=0 "THEN" "GOTO" S21;
        "PRINT"''L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
        "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
        "BEGIN" "IF" BIN[X]=1
                "THEN" OUTPUT(VAL,GCSUM,GSSQC,GBLOCK);
        "END";

S21:    "IF" PN=0 "THEN" "GOTO" S22;
        "PRINT"''L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
        "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
        "BEGIN" "IF" BIN[X]=0
                "THEN" OUTPUT(VAL,GPSUM,GSSQP,GBLOCK);
        "END";

S22:    "IF" AREA =0 "THEN" "GOTO" S23;
        "PRINT"''L4'%AREA'LS4'MEAN'S6'STD DEV';
        X:=W;
        OUTPUT(TT,GARSUM,GSSOAR,GBLOCK);

S23:    "IF" W=0 "AND" BLOCK>0 "THEN" "GOTO" S19;
        "PRINT" ''R100'';

        WAIT;
        "GOTO" S5;

"END";
```

Appendix 6

DETAILS OF COMPUTER PROGRAMME QTM102 AND 202

```
QTM 102
+ WARNING
Y
P FIELDC    ADR     43
E           ADR     62
P FIELDA    ADR     64
E           ADR    111
P GRADER    ADR    113
E           ADR    143
P BSTORE    ADR    145
E           ADR    177
P OUTPUT    ADR    179
L H         ADR    216
E           ADR    280
E           ADR    280
E           ADR    470
L S1        ADR    477
E           ADR    509
E           ADR    532
L S2        ADR    532
E           ADR    608
E           ADR    642
E           ADR    669
L S3        ADR    670
L S4        ADR    699
L S5        ADR    728
E           ADR    819
E           ADR    851
L S6        ADR    852
E           ADR    888
L S7        ADR    889
E           ADR    923
E           ADR    964
L S8        ADR   1011
E           ADR   1064
L S9        ADR   1085
E           ADR   1140
L S10       ADR   1141
E           ADR   1195
L S11       ADR   1196
L S12       ADR   1227
E           ADR   1398
  PROGRAM  1440
  SCALARS    73
```

QTM102

```
QTM102;
"BEGIN" "REAL" FH,FW,AR,Y,FAR,SDEV,DATE;
      "INTEGER"CN,PN,I,J,X,W,AREA,BLOCK,SCANNED,COUNT,
            NUMBER,REJECT;
      "INTEGER""ARRAY" A[0:75],TITLE[0:15],GRADE[0:5];
      "ARRAY"CS,PS[1:8],BIN,VAL,CSUM,PSUM,SSOC,SSOP,C,P[1:16],
            RR,TT,ARE,ARSUM,FARSUM,ARSTOR,SSOAR[0:1],UL,LL,
            LIMITS[0:5];
      "SWITCH" SW:=S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,S11,S12;
      "CODE" "PROCEDURE" LININ(Y);
            "INTEGER""ARRAY"Y;
      "ALGOL";


      "PROCEDURE" FIELDCP(AA,BB);
                  "ARRAY" AA;
                  "INTEGER""ARRAY" BB;
      "BEGIN" AA[X]:=BB[4*X-1]+AA[X];
      "END";


      "PROCEDURE" FIELDA(BB,CC,DD,EE,NUMBER);
                  "ARRAY" CC,DD,EE;
                  "INTEGER""ARRAY" BB;
                  "INTEGER" NUMBER;
      "BEGIN" CC[W]:=BB[4*X-1]/100;
              DD[W]:=CC[W]/NUMBER+DD[W];
              EE[W]:=CC[W]/NUMBER+EE[W];
      "END";


      "PROCEDURE" GRADER(CC,HH,II,JJ);
                  "ARRAY" CC,II,JJ;
                  "INTEGER""ARRAY" HH;
      "BEGIN"
          "IF" CC[W] "GE" JJ[X] "AND"
               CC[W] < II[X] "THEN" HH[X]:=HH[X]+1;
      "END";


      "PROCEDURE" BSTORE(FF,GG,SUM1,SUM2,SSQ);
                  "ARRAY"FF,GG,SUM1,SUM2,SSQ;
      "BEGIN" SUM1[X]:=FF[X]+SUM2[X];
              SSQ[X]:=GG[X]*GG[X]+SSQ[X];
      "END";


      "PROCEDURE" OUTPUT(TT,SUM,SSQ,BLOCK);
                  "ARRAY" TT,SUM,SSQ;
                  "INTEGER" BLOCK;
```

```
"BEGIN" "SWITCH" SW:=H;
        "PRINT" ''L'';
        "IF" TT[X]=-1 "THEN""GOTO" H;
        "PRINT" SAMELINE,ALIGNED(5,1),TT[X],''S2'';
   H:   "PRINT" SAMELINE,ALIGNED(3,4),SUM[X]/BLOCK;
        "IF" BLOCK "GE" 2 "THEN"
        "BEGIN"
           Y:=(SSQ[X]-((SUM[X]*SUM[X])/BLOCK))/(BLOCK-1);
           "IF" Y "LE" 0 "THEN" SDEV:=0
                          "ELSE" SDEV:=SQRT (Y);
           "PRINT" SAMELINE,''S3'',ALIGNED(3,4),SDEV;
        "END";
"END";


"READ" DATE,FH,FW,AR,CN;
"FOR" I:=1 "STEP" 1 "UNTIL" CN "DO" "READ" CS[I];
"READ" PN;
"FOR" J:=1 "STEP" 1 "UNTIL" PN "DO" "READ" PS[J];
"READ" AREA;
FAR:=FH*FW;
NUMBER:=AR/FAR;
"PRINT"''L'DATE',SAMELINE,ALIGNED(6,0),DATE,
       ''L'FIELD WIDTH & HEIGHT',ALIGNED(1,2),FW,FH,' MMS',
       ''L'EXAMINED AREA',ALIGNED(1,2),AR,' SQ MMS',
       ''L'ONE DETECTION LEVEL ONLY';
WAIT;


"FOR" X:=1 "STEP" 1 "UNTIL" 5 "DO" "READ" LIMITS[X];
LL[0]:=0;    UL[5]:=100;
"FOR" X:= 0 "STEP" 1 "UNTIL" 4 "DO"
"BEGIN" UL[X]:=LL[X+1]:=LIMITS[X+1];
"END";
WAIT;


    I:=J:=0;
S1: "IF" I+J=CN+PN "THEN" "GOTO" S5;
    "IF" CN=0 "THEN""BEGIN" J:=J+1; BIN[J]:=0;
                            VAL[J]:=PS[J]; "GOTO" S1;
                    "END";
    "IF" PN=0 "THEN""BEGIN" I:=I+1; BIN[I]:=1;
                            VAL[I]:=CS[I]; "GOTO" S1;
                    "END";


S2: "IF" I+J=CN+PN "THEN" "GOTO" S5;
    "IF" I=CN "THEN" "GOTO" S3;
    "IF" J=PN "THEN" "GOTO" S4;
    I:=I+1; J:=J+1;
```

```
"IF" CS[I]=PS[J] "THEN""BEGIN" BIN[I+J-1]:=1; BIN[I+J]:=0;
                               VAL[I+J-1]:=CS[I];
                               VAL[I+J]:=PS[J];
                               "GOTO" S2;
                          "END";


"IF" CS[I]<PS[J] "THEN""BEGIN" BIN[I+J-1]:=1;
                               VAL[I+J-1]:=CS[I];
                               J:=J-1;
                          "END"
                   "ELSE""BEGIN" BIN[I+J-1]:=0;
                               VAL[I+J-1]:=PS[J];
                               I:=I-1;
                          "END";
"GOTO" S2;


S3:  J:=J+1;
     BIN[I+J]:=0;  VAL[I+J]:=PS[J];
     "IF" J=PN "THEN" "GOTO" S5 "ELSE" "GOTO" S3;

S4:  I:=I+1;
     BIN[I+J]:=1;  VAL[I+J]:=CS[I];
     "IF" I=CN "THEN" "GOTO" S5 "ELSE" "GOTO" S4;

S5:  "PRINT""L6"";
     J:=0;
     INSTRING(TITLE,J);
     J:=0;
     OUTSTRING(TITLE,J);
     WAIT;


     SCANNED:=REJECT:=BLOCK:=0;
     RR[0]:=RR[1]:=0;  TT[0]:=TT[1]:=-1;
     "FOR" X:=0 "STEP" 1 "UNTIL" 5 "DO"  GRADE[X]:=0;
     "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
               "BEGIN" ARSUM[X]:=FARSUM[X]:=SSQAR[X]:=0;
               "END";
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
               "BEGIN" CSUM[X]:=PSUM[X]:=SSQC[X]:=SSQP[X]:=0;
               "END";

S6:  ARSTOR[0]:=ARSTOR[1]:=0;  COUNT:=0;
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
               "BEGIN" C[X]:=P[X]:=0;
               "END";
```

```
S7:  LININ(A);

     "IF" A[0]=1 "THEN" "GOTO"S9;
     "IF" A[0]>1 "OR" A[1] "NE" PN+CN+AREA+1
               "THEN" "BEGIN" REJECT:=REJECT+1;
                              "GOTO" S7;
                        "END";
     COUNT:=COUNT+1;
     SCANNED:=SCANNED+1;


     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
     "BEGIN"
          "IF"BIN[X]=1 "THEN" FIELDCP(C,A)
                       "ELSE" FIELDCP(P,A);
     "END";


     "IF" AREA=0 "THEN" "GOTO" S8;
     W:=0; X:=PN+CN+AREA;
     FIELDA(A,ARE,FARSUM,ARSTOR,NUMBER);
     "FOR" X:=0 "STEP" 1 "UNTIL" 5 "DO"
     GRADER(ARE,GRADE,UL,LL);


S8:  "IF" COUNT<NUMBER "THEN" "GOTO" S7;
     BLOCK:=BLOCK+1;
     "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN "DO"
     "BEGIN"
     "IF"BIN[X]=1 "THEN" BSTORE(C,C,CSUM,CSUM,SSQC)
                  "ELSE" BSTORE(P,P,PSUM,PSUM,SSQP);
     "END";
     "IF" AREA=0 "THEN" "GOTO" S9;
     X:=W;
     BSTORE(RR,ARSTOR,ARSUM,FARSUM,SSQAR);
     "GOTO" S6;


S9:  "IF" BLOCK=0 "THEN" "GOTO" S12;
     "IF" CN=0 "THEN""GOTO" S10;
     "PRINT"''L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR" X:=1"STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=1 "THEN" OUTPUT(VAL,CSUM,SSQC,BLOCK);
     "END";

S10: "IF" PN=0 "THEN""GOTO" S11;
     "PRINT"''L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
     "FOR"X:=1 "STEP" 1 "UNTIL" CN+PN "DO"
     "BEGIN" "IF" BIN[X]=0 "THEN" OUTPUT(VAL,PSUM,SSQP,BLOCK);
     "END";
```

```
S11:  "IF" AREA=0 "THEN""GOTO" S12;
      "PRINT"''L4'%AREA'LS4'MEAN'S6'STD DEV';
      X:=W;
      OUTPUT(TT,ARSUM,SSQAR,BLOCK);

S12:  "PRINT"
      ''L2'NUMBER OF FIELDS SCANNED',SAMELINE,DIGITS(3),SCANNED,
      ''L'NUMBER OF FIELDS REJECTED',SAMELINE,DIGITS(3),REJECT,
      ''L'FIELDS WERE USED IN',SAMELINE,DIGITS(3),BLOCK,
      ' BLOCKS OF',NUMBER,

      ''L5'NUMBER OF FIELDS',
      ''L'GRADE 0 ',SAMELINE,DIGITS(3),GRADE[0],
      ''L'GRADE 1 ',SAMELINE,DIGITS(3),GRADE[1],
      ''L'GRADE 2 ',SAMELINE,DIGITS(3),GRADE[2],
      ''L'GRADE 3 ',SAMELINE,DIGITS(3),GRADE[3],
      ''L'GRADE 4 ',SAMELINE,DIGITS(3),GRADE[4],
      ''L'GRADE 5 ',SAMELINE,DIGITS(3),GRADE[5],
      ''R100'';

      WAIT;
      "GOTO" S5;

'END";
```

```
QTM 202
+ WARNING
Y
P FIELDC    ADR     43
E           ADR     62
P FIELDA    ADR     64
E           ADR    111
P GRADER    ADR    113
E           ADR    143
P BSTORE    ADR    145
E           ADR    177
P OUTPUT    ADR    179
L H         ADR    216
E           ADR    280
E           ADR    280
L           ADR    477
E           ADR    502
L S1        ADR    516
E           ADR    560
E           ADR    595
L S2        ADR    595
E           ADR    707
E           ADR    761
E           ADR    808
L S3        ADR    809
L S4        ADR    854
L S5        ADR    899
E           ADR    990
E           ADR   1024
L S6        ADR   1025
E           ADR   1063
L S7        ADR   1064
E           ADR   1096
E           ADR   1152
E           ADR   1152
E           ADR   1205
L S8        ADR   1287
F           ADR   1351
L S9        ADR   1386
L S10       ADR   1416
L S11       ADR   1445
E           ADR   1493
L S12       ADR   1494
E           ADR   1546
L S13       ADR   1547
L S14       ADR   1578
E           ADR   1804
F           ADR   1814
  PROGRAM  1862
  SCALARS    76
```

QTM 202;

```
"BEGIN" "REAL" FH, FW, AR, Y, FAR, SDEV, DATE;
      "INTEGER"CN, PN, F, G, I, J, X, Z, W, AREA, BLOCK, SCANNED, COUNT,
            NUMBER, REJECT;
      "INTEGER""ARRAY" A[0:150], TITLE[0:15], GRADE[0:11];
      "ARRAY"CS, PS[1:8], BIN, VAL, CSUM, PSUM, SSOC, SSOP, C, P[1:33],
            RR, TT, ARE, ARSUM, FARSUM, ARSTUR, SSOAR[0:1], LIMITS,
            UL, LL[0:11];
      "SWITCH" SW:=S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13,
                  S14;
      "CODE" "PROCEDURE" LININ(Y);
            "INTEGER""ARRAY"Y;
      "ALGOL";


      "PROCEDURE" FIELDCP(AA, BB);
                  "ARRAY" AA;
                  "INTEGER""ARRAY" BB;
      "BEGIN" AA[X]:=BB[4*X-1]+AA[X];
      "END";


      "PROCEDURE" FIELDA(BB, CC, DD, EE, NUMBER);
                  "ARRAY" CC, DD, EE;
                  "INTEGER""ARRAY" BB;
                  "INTEGER" NUMBER;
      "BEGIN" CC[W]:=BB[4*X-1]/100;
              DD[W]:=CC[W]/NUMBER+DD[W];
              EE[W]:=CC[W]/NUMBER+EE[W];
      "END";


      "PROCEDURE" GRADER(CC, HH, II, JJ);
                  "ARRAY" CC, II, JJ;
                  "INTEGER""ARRAY" HH;
      "BEGIN"
        "IF" CC[W] "GE" JJ[X] "AND"
             CC[W]  <   II[X] "THEN" HH[X]:=HH[X]+1;
      "END";


      "PROCEDURE" BSTURE(FF, GG, SUM1, SUM2, SSQ);
                  "ARRAY"FF, GG, SUM1, SUM2, SSQ;
      "BEGIN" SUM1[X]:=FF[X]+SUM2[X];
              SSQ[X]:=GG[X]*GG[X]+SSQ[X];
      "END";


      "PROCEDURE" OUTPUT(TT, SUM, SSQ, BLOCK);
                  "ARRAY" TT, SUM, SSQ;
                  "INTEGER" BLOCK;
```

```
"BEGIN" "SWITCH" SW:=H;
        "PRINT" ''L'';
        "IF" TT[X]=-1 "THEN""GOTO" H;
        "PRINT" SAMELINE,ALIGNED(5,1),TT[X], ''S2'';
   H:   "PRINT" SAMELINE,ALIGNED(3,4),SUM[X]/BLOCK;
        "IF" BLOCK "GE" 2 "THEN"
        "BEGIN"
           Y:=(SSQ[X]-((SUM[X]*SUM[X])/BLOCK))/(BLOCK-1);
           "IF" Y "LE" 0 "THEN" SDEV:=0
                            "ELSE" SDEV:=SQRT (Y);
           "PRINT" SAMELINE, ''S3'',ALIGNED(3,4),SDEV;
        "END";
"END";




"READ" DATE,FH,FW,AR,CN;
"FOR" I:=1 "STEP" 1 "UNTIL" CN "DO" "READ" CS[I];
"READ" PN;
"FOR" J:=1 "STEP" 1 "UNTIL" PN "DO" "READ" PS[J];
"READ" AREA;
FAR:=FH*FW;
NUMBER:=AR/FAR;
"PRINT"''L'DATE',SAMELINE,ALIGNED(6,0),DATE,
        ''L'FIELD WIDTH & HEIGHT',ALIGNED(1,2),FW,FH,' MMS',
        ''L'EXAMINED AREA',ALIGNED(1,2),AR,' SQ MMS',
        ''L'TWO DETECTION LEVELS';
WAIT;


"FOR" X:=1 "STEP" 1 "UNTIL" 10 "DO" "READ" LIMITS[X];
LL[0]:=LL[6]:=0;
UL[5]:=UL[11]:=100;
"FOR" X:=0 "STEP" 1 "UNTIL" 4 "DO"
           "BEGIN" UL[X]:=LL[X+1]:=LIMITS[X+1];
           "END";
"FOR" X:=6 "STEP" 1 "UNTIL" 10 "DO"
           "BEGIN" UL[X]:=LL[X+1]:=LIMITS[X];
           "END";
WAIT;


Z:=CN+PN+AREA;
I:=J:=0;
S1: "IF" I+J=CN+PN "THEN" "GOTO" S5;
"IF" CN=0 "THEN""BEGIN" J:=J+1; BIN[J]:=BIN[J+Z]:=0;
                                VAL[J]:=VAL[J+Z]:=PS[J];
                                "GOTO" S1;
                  "END";
"IF" PN=0 "THEN""BEGIN" I:=I+1; BIN[I]:=BIN[I+Z]:=1;
                                VAL[I]:=VAL[I+Z]:=CS[I];
                                "GOTO" S1;
                  "END";
```

```
S2: "IF" I+J=CN+PN "THEN" "GOTO" S5;
    "IF" I=CN "THEN" "GOTO" S3;
    "IF" J=PN "THEN" "GOTO" S4;
    I:=I+1; J:=J+1;
    "IF" CS[I]=PS[J]"THEN"
                        "BEGIN"BIN[I+J-1]:=BIN[I+J-1+Z]:=1;
                               BIN[I+J]:=BIN[I+J+Z]:=0;
                               VAL[I+J-1]:=VAL[I+J-1+Z]:=CS[I];
                               VAL[I+J]:=VAL[I+J+Z]:=PS[J];
                               "GOTO" S2;
                        "END";


    "IF" CS[I]<PS[J]"THEN"
                        "BEGIN"BIN[I+J-1]:=BIN[I+J-1+Z]:=1;
                               VAL[I+J-1]:=VAL[I+J-1+Z]:=CS[I];
                               J:=J-1;
                        "END"
                      "ELSE"
                        "BEGIN" BIN[I+J-1]:=BIN[I+J-1+Z]:=0;
                                VAL[I+J-1]:=VAL[I+J-1+Z]:=PS[J];
                                I:=I-1;
                        "END";
    "GOTO" S2;


S3: J:=J+1;
    BIN[I+J]:=BIN[I+J+Z]:=0;
      VAL[I+J]:=VAL[I+J+Z]:=PS[J];
    "IF" J=PN "THEN" "GOTO" S5 "ELSE" "GOTO" S3;

S4: I:=I+1;
    BIN[I+J]:=BIN[I+J+Z]:=1;
    VAL[I+J]:=VAL[I+J+Z]:=CS[I];
    "IF" I=CN "THEN" "GOTO" S5 "ELSE" "GOTO" S4;

S5: "PRINT"''L6'';
    J:=0;
    INSTRING(TITLE,J);
    J:=0;
    OUTSTRING(TITLE,J);
    WAIT;

    SCANNED:=REJECT:=BLOCK:=0;
    RR[0]:=RR[1]:=0; TT[0]:=TT[1]:=-1;
    "FOR" X:=0 "STEP" 1 "UNTIL" 11 "DO" GRADE[X]:=0;
    "FOR" X:=0 "STEP" 1 "UNTIL" 1 "DO"
              "BEGIN" ARSUM[X]:=FARSUM[X]:=SSQAR[X]:=0;
              "END";
    "FOR" X:=1 "STEP" 1 "UNTIL" (2*Z)-1 "DO"
              "BEGIN" CSUM[X]:=PSUM[X]:=SSOC[X]:=SSQP[X]:=0;
              "END";
```

```
S6: ARSTUR[0]:=ARSTUR[1]:=0;  COUNT:=0;
    "FOR" X:=1 "STEP" 1 "UNTIL" (2*Z)-1 "DO"
              "BEGIN" C[X]:=P[X]:=0;
              "END";

S7: LININ(A);

    "IF" A[0]=1 "THEN" "GOTO"S9;
    "IF" A[0]>1 "OR" A[1] "NE" (2*Z)+1
               "THEN" "BEGIN" REJECT:=REJECT+1;
                              "GOTO" S7;
                      "END";
    "FOR" X:=Z+1 "STEP" 1 "UNTIL" 2*Z "DO"
    "BEGIN" A[4*X-1]:=A[4*X-1]-A[4*(X-Z)-1];
            "IF" A[4*X-1]<0 "THEN"
            "BEGIN" REJECT:=REJECT+1;
                    "GOTO" S7;
            "END";
    "END";

    COUNT:=COUNT+1;
    SCANNED:=SCANNED+1;

    "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN,
            Z+1"STEP" 1 "UNTIL" Z+PN+CN "DO"
    "BEGIN"
         "IF"BIN[X]=1 "THEN" FIELDCP(C,A)
                         "ELSE" FIELDCP(P,A);
    "END";

    "IF" AREA=0 "THEN" "GOTO" S8;
    W:=0; X:=Z;
    FIELDA(A,ARE,FARSUM,ARSTUR,NUMBER);
    "FOR" X:=0 "STEP" 1 "UNTIL" 5 "DO"
    GRADER(ARE,GRADE,UL,LL);


    W:=1; X:=2*Z;
    FIELDA(A,ARE,FARSUM,ARSTUR,NUMBER);
    "FOR" X:=6 "STEP" 1 "UNTIL" 11 "DO"
    GRADER(ARE,GRADE,UL,LL);


S8: "IF" COUNT<NUMBER "THEN" "GOTO" S7;
    BLOCK:=BLOCK+1;
    "FOR" X:=1 "STEP" 1 "UNTIL" PN+CN,
            Z+1"STEP" 1 "UNTIL" Z+PN+CN "DO"
    "BEGIN" "IF" BIN[X]=1
         "THEN" BSTORE(C,C,CSUM,CSUM,SSQC)
         "ELSE" BSTORE(P,P,PSUM,PSUM,SSQP);
    "END";
```

```
    "IF" AREA=0 "THEN" "GOTO" S6;
    W:=0;
    "FOR" X:=W "STEP" 1 "UNTIL" W+1 "DO"
    BSTORE(RR,ARSTOR,ARSUM,FARSUM,SSQAR);
    "GOTO" S6;

S9: "IF" BLOCK=0 "THEN" "GOTO" S14;
    W:=0;   F:=1;   G:=PN+CN;
    "PRINT"''L4'FIRST DETECTION LEVEL';
    "GOTO" S11;

S10: W:=1;   F:=Z+1;   G:=Z+PN+CN;
    "PRINT"''L4'SECOND DETECTION LEVEL';

S11: "IF" CN=0 "THEN" "GOTO" S12;
    "PRINT"''L4'COUNT'LS4'SIZE'S6'MEAN'S6'STD DEV';
    "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
    "BEGIN" "IF" BIN[X]=1 "THEN" OUTPUT(VAL,CSUM,SSQC,BLOCK);
    "END";

S12: "IF" PN=0 "THEN" "GOTO" S13;
    "PRINT"''L4'PROJECTED LENGTH'LS4'SIZE'S6'MEAN'S6'STD DEV';
    "FOR" X:=F "STEP" 1 "UNTIL" G "DO"
    "BEGIN" "IF" BIN[X]=0 "THEN" OUTPUT(VAL,PSUM,SSQP,BLOCK);
    "END";

S13: "IF" AREA=0 "THEN" "GOTO" S14;
    "PRINT"''L4'%AREA'LS4'MEAN'S6'STD DEV';
    X:=W;
    OUTPUT(TT,ARSUM,SSQAR,BLOCK);

S14: "IF" W=0 "AND" BLOCK>0 "THEN" "GOTO" S10;
    "PRINT"
    ''L2'NUMBER OF FIELDS SCANNED',SAMELINE,DIGITS(3),SCANNED,
    ''L'NUMBER OF FIELDS REJECTED',SAMELINE,DIGITS(3),REJECT,
    ''L'FIELDS WERE USED IN',SAMELINE,DIGITS(3),BLOCK,
    ''BLOCKS OF',NUMBER;

    "FOR" X:=0 "STEP" 6 "UNTIL" 6 "DO"
    "BEGIN"
    "IF" X=0 "THEN" "PRINT" ''L3'FIRST DETECTION LEVEL'
             "ELSE" "PRINT" ''L3'SECOND DETECTION LEVEL';
```

```
    "PRINT"
            ''L2'NUMBER OF FIELDS',
            ''L'GRADE 0 ',SAMELINE,DIGITS(3),GRADE[X],
            ''L'GRADE 1 ',SAMELINE,DIGITS(3),GRADE[X+1],
            ''L'GRADE 2 ',SAMELINE,DIGITS(3),GRADE[X+2],
            ''L'GRADE 3 ',SAMELINE,DIGITS(3),GRADE[X+3],
            ''L'GRADE 4 ',SAMELINE,DIGITS(3),GRADE[X+4],
            ''L'GRADE 5 ',SAMELINE,DIGITS(3),GRADE[X+5];
    "END";

    "PRINT"''R100'';

    WAIT;
    "GOTO" S5;

'END";
```

APPENDIX 7

QUANTIMET DATA FORM

QTM 101 Single data tape: one detection level	1	0	1	1	1	0	1	1	0	0	0	1	0
QTM201 Single data tape: two detection level..............	1	1	0	0	0	1	0	0	1	1	0	1	1
QTM301 Set of data tapes: one detection level..............	1	1	0	0	0	1	1	0	1	0	1	1	1
QTM401 Set of data tapes: two detection level..............	1	1	0	1	0	1	0	0	1	1	0	0	1
QTM102 Same as QTM101 but with frequency grading of percent area	1	1	0	0	0	0	1	0	1	0	1	1	0
QTM202 Same as QTM201 but with frequency grading of percent area	1	1	0	0	1	1	1	1	1	1	1	1	1

Method

Enter QTM programme at 8; at first stop, re-enter at 11; at second stop re-enter at the Re-entry Number given in the table above.
First data tape is entered at 10 and consists of:-

1. Date [ ] Numbers only

2. Field height [ ]

3. Field width [ ]

4. Area to be examined [ ]

5. No. of counts [ ] 5

6. Count sizes
   Use a 6 for C_0
   Example... 0 2 5 10 100
   Leave blank if there are no counts

7. No. of projected counts [ ]

8. Proj. sizes
   Use a 0 for P_0
   Leave blank if there are no projection counts.

9. percent area [ ]
   1 if areas are present;
   0 if areas are absent.

QTM101
QTM201

10. Two spaces to end tape.

QTM301
QTM401

10. No. of tapes that make up a set. ....

11. Title of each tape making up the set.
12&11 together can take up to about 140 characters and spaces.

12. Title of the set

13 Two spaces to end tape

QTM102
QTM202
Re-enter at 9

10. First detection level grading limits*

11. QTM202 only. Second detection level grading limits.

12. Two spaces to end tape. See below for explanation.

Second data tape is entered at 9.

1. Title of QTM data tape

Up to 46 characters and spaces etc.

2. Two spaces to end tape.

QTM data tape follows and must have a halt code (TC3 on ICT 1905) at the end of each tape and is entered at 9.

For subsequent QTM data tapes, it is only necessary to re-enter a second data tape at 9, unless the preliminary data in the first data tape needs revising.

* Grading

Grade 0.......... $< a$

Grade 1...... $\geq a$ $< b$

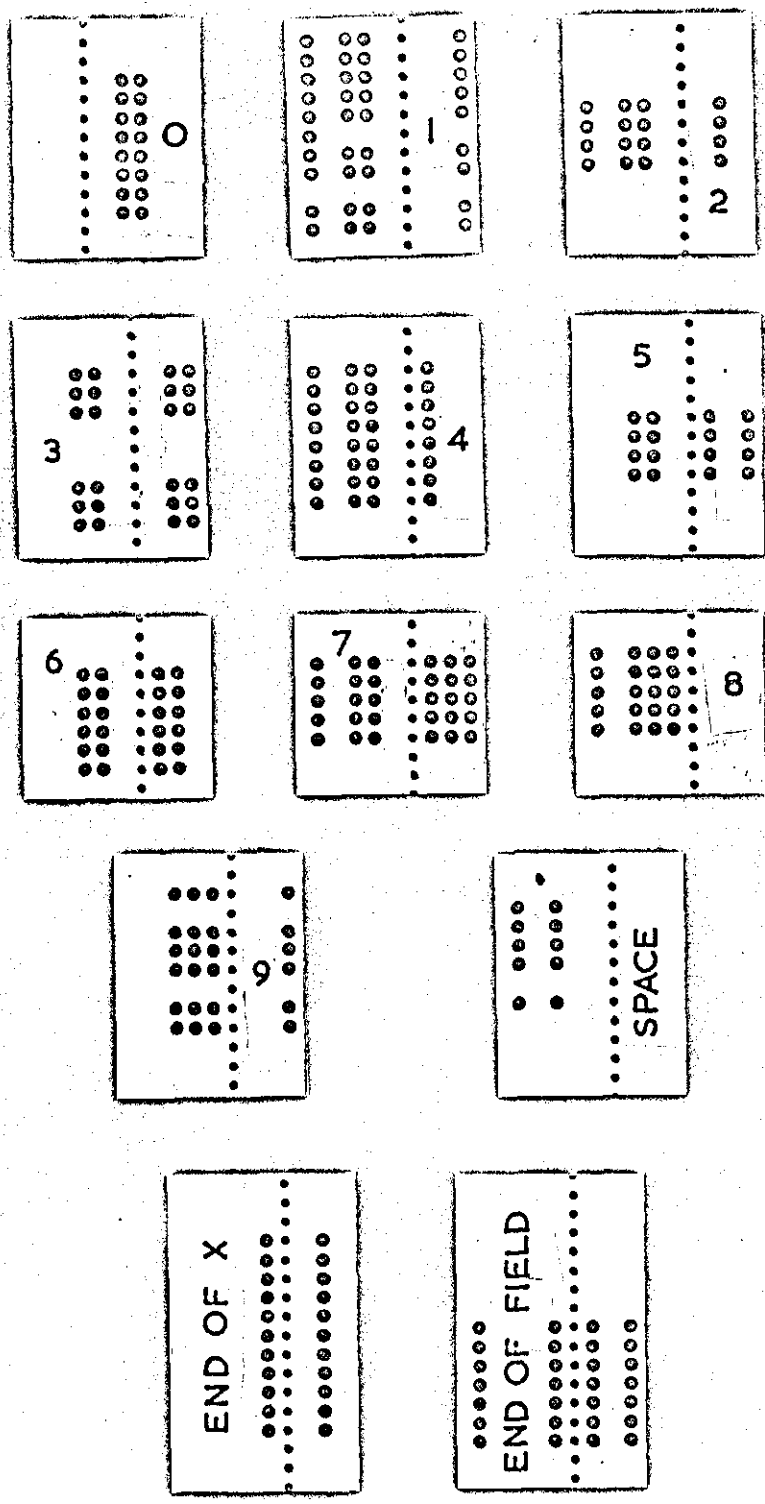
Grade 2...... $\geq b$ $< c$

Grade 3...... $\geq c$ $< d$

Grade 4...... $\geq d$ $< e$

Grade 5........... $\geq e$

a	b	c	d	e



APPENDIX 8 SYSTEM OF CODING USED

Variation in Oxide counts on same surface of sample from a steel with low oxide content.

Sample*	Percentage area.							Count.			
	Frequency per 100 fields.						Mean ($X10^{-4}$)	Mean: No > than ($X10^{-2}$)			
	< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%		1.8 µm.	3.0 µm	10.0 µm.	20.0. µm.
1	96	4	•	•	•	•	116	76	8	•	•
2	96	4	•	•	•	•	124	108	4	•	•
3	80	16	4	•	•	•	320	160	20	•	•
4	88	12	•	•	•	•	168	108	40	•	•
5	97	3	•	•	•	•	80	108	•	•	•
6	100	•	•	•	•	•	32	100	•	•	•
7	96	4	•	•	•	•	64	112	•	•	•
8	100	•	•	•	•	•	44	80	•	•	•
9	92	8	•	•	•	•	76	104	•	•	•
10	92	8	•	•	•	•	64	76	4	•	•
11	92	8	•	•	•	•	56	76	4	•	•
12	100	•	•	•	•	•	24	76	•	•	•
13	80	20	•	•	•	•	172	80	4	•	•
14	92	8	•	•	•	•	72	92	•	•	•
15	100	•	•	•	•	•	40	92	•	•	•
16	92	8	•	•	•	•	100	100	8	•	•
17	88	12	•	•	•	•	100	112	8	•	•
18	92	8	•	•	•	•	60	88	4	•	•
19	80	20	•	•	•	•	128	92	8	•	•
20	92	8	•	•	•	•	76	84	8	•	•
21	92	8	•	•	•	•	72	124	4	•	•
22	80	20	•	•	•	•	108	112	4	•	•
23	96	4	•	•	•	•	48	88	•	•	•
24	96	4	•	•	•	•	56	92	•	•	•
25	100	0	•	•	•	•	24	40	•	•	•
26	92	8	•	•	•	•	48	68	•	•	•
27	92	8	•	•	•	•	64	88	•	•	•
28	96	4	•	•	•	•	32	84	•	•	•
29	84	16	•	•	•	•	196	92	•	•	•
30	88	12	•	•	•	•	116	64	16	•	•
31	84	16	•	•	•	•	92	88	•	•	•
32	88	12	•	•	•	•	132	76	8	4	•
33	80	20	•	•	•	•	108	152	4	•	•
34	96	4	•	•	•	•	76	84	8	•	•
35	96	4	•	•	•	•	60	108	4	•	•
36	92	8	•	•	•	•	52	108	•	•	•
37	92	8	•	•	•	•	52	64	•	•	•
38	96	1	•	•	•	•	32	68	•	•	•
39	88	8	4	•	•	•	168	116	16	•	•
40	92	8	•	•	•	•	108	92	4	•	•

* each sample made up of 25 fields, each 0.25 sq.mm. selected randomly from edge to centre of billets on same polished surface.

APPENDIX 10

Variation on oxide counts on same surface of sample from a steel with average oxide content.

Sample*	Percentage area.							Count.			
	Frequency per 100 fields.							Mean: No than ($X10^{-2}$)			
	< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	Mean ($X10^{-4}$)	1.8. µm.	3.0 µm.	10.0. µm.	20.0. µm.
1.	80	20	•	•	•	•	84	156	4	•	•
2.	88	12	•	•	•	•	92	132	•	•	•
3.	100	0	•	•	•	•	56	96	•	•	•
4.	100	0	•	•	•	•	64	116	•	•	•
5.	96	4	•	•	•	•	100	136	4	•	•
6.	100	0	•	•	•	•	56	100	1	•	•
7.	92	8	•	•	•	•	96	132	•	•	•
8.	96	4	•	•	•	•	96	128	•	•	•
9.	92	8	•	•	•	•	92	164	•	•	•
10	88	12	•	•	•	•	120	124	•	•	•
11.	92	8	•	•	•	•	120	128	8	•	•
12.	92	8	•	•	•	•	72	124	•	•	•
13.	80	20	•	•	•	•	148	100	•	•	•
14.	88	12	•	•	•	•	68	136	•	•	•
15.	88	12	•	•	•	•	116	124	4	•	•
16.	96	4	•	•	•	•	56	116	4	•	•
17.	96	4	•	•	•	•	80	96	4	•	•
18.	92	8	•	•	•	•	48	100	•	•	•
19.	84	16	•	•	•	•	104	112	4	•	•
20.	92	8	•	•	•	•	68	100	4	•	•
21.	92	8	•	•	•	•	92	108	4	•	•
22.	92	8	•	•	•	•	68	116	4	•	•
23.	96	4	•	•	•	•	60	96	8	•	•
24.	84	16	•	•	•	•	136	176	4	•	•
25.	84	4	•	•	•	•	96	116	4	•	•
26.	84	16	•	•	•	•	108	100	4	•	•
27.	84	16	•	•	•	•	192	140	8	•	•
28.	84	16	•	•	•	•	96	168	•	•	•
29.	88	12	•	•	•	•	100	176	•	•	•
30.	84	12	4	•	•	•	128	112	4	•	•
31.	88	12	•	•	•	•	100	148	•	•	•
32.	88	12	•	•	•	•	72	188	•	•	•
33.	92	8	•	•	•	•	100	108	16	•	•
34.	88	12	•	•	•	•	112	116	4	•	•
35.	88	3	•	•	•	•	80	136	•	•	•
36.	88	12	•	•	•	•	72	136	•	•	•
37.	84	16	•	•	•	•	88	128	8	•	•
38.	84	16	•	•	•	•	104	128	8	•	•
39.	92	8	•	•	•	•	96	124	4	•	•
40.	92	8	•	•	•	•	96	132	4	•	•

* each sample made up of 24 fields, each 0.25 sq.mm. selected randomly from edge to centre of billets on same polished surface.

APPENDIX II

Variation in oxide counts on same surface of sample from a steel with high oxide content.

Sample*	Percentage Area.							Count.			
	Frequency per 100 fields.							Mean: No than ($X10^{-2}$)			
	<0 03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%.	Mean. ($X10^{-4}$)	1.8. µm.	3.0. µm.	10.0. µm.	20.0. µm.
1.	88	8	0	4	•	•	364	184	8	•	•
2.	72	24	4	•	•	•	316	156	12	4	•
3.	72	24	0	4	•	•	392	176	8	4	•
4.	76	24	•	•	•	•	240	168	4	•	•
5.	84	12	0	4	•	•	336	192	8	•	•
6.	72	28	•	•	•	•	216	168	12	•	•
7.	76	16	8	•	•	•	336	144	24	4	•
8.	72	28	•	•	•	•	192	128	12	•	•
9.	72	28	•	•	•	•	236	168	12	•	•
10.	72	20	8	•	•	•	408	180	20	•	•
11.	80	20	•	•	•	•	204	116	8	4	•
12	72	24	0	4	•	•	492	256	24	4	•
13.	72	24	4	•	•	•	300	164	8	4	•
14.	80	12	8	•	•	•	372	252	16	•	•
15.	76	24	•	•	•	•	284	148	12	•	•
16.	88	8	4	•	•	•	268	156	12	•	•
17.	76	24	•	•	•	•	188	188	•	•	•
18.	76	24	•	•	•	•	200	188	•	•	•
19.	68	28	0	4	•	•	444	176	28	•	•
20.	72	28	•	•	•	•	268	212	20	•	•
21.	72	28	•	•	•	•	260	212	20	•	•
22.	60	36	4	•	•	•	372	280	16	•	•
23.	76	20	0	0	4	•	720	184	20	8	•
24.	76	24	•	•	•	•	256	164	12	4	•
25.	72	28	•	•	•	•	236	144	8	•	•
26.	68	28	4	•	•	•	372	240	16	•	•
27.	80	8	12	•	•	•	384	172	28	•	•
28.	84	12	4	•	•	•	248	156	20	•	•
29.	80	16	4	•	•	•	288	168	16	•	•
30.	68	32	•	•	•	•	236	180	8	•	•
31.	68	32	•	•	•	•	220	164	8	•	•
32.	84	12	0	4	•	•	560	196	28	•	•
33.	72	24	0	0	1	•	712	116	20	8	•
34.	76	24	•	•	•	•	208	168	16	•	•
35.	68	24	8	•	•	•	568	228	24	•	•
36.	84	12	0	4	•	•	396	208	12	•	•
37.	64	32	4	•	•	•	444	196	12	4	•
38.	80	20	•	•	•	•	232	244	8	•	•
39.	68	28	4	•	•	•	412	204	28	•	•
40.	72	24	4	•	•	•	394	200	16	•	•

* each sample made up of 25 fields, each 0.25 sq.mm. selected randomly from edge to centre of billet on same polished surface.

Appendix 12

MEAN PROJECTION COUNTS OBTAINED ON SAMPLES FROM "CLEAN" BILLET P587

Samples & position in billet inches	Projection (Total length, μm) Mean	Std. dev.	Samples & position in billet inches	Projection (Total length, μm) Mean	Std. dev.	Samples & position in billet, inches	Projection (Total length, μm) Mean	Std. dev.
0(top)	44	52	41	56	32	82	24	24
1	20	28	42	44	46	83	32	28
2	16	28	43	32	24	84	40	44
3	16	24	44	48	36	85	32	32
4	32	56	45	52	80	86	36	60
5	52	224	46	40	44	87	16	24
6	20	32	47	56	40	88	24	20
7	32	48	48	44	64	89	24	32
8	20	28	49	40	40	90	24	36
9	28	36	50	24	28	91	24	96
10	24	32	51	36	32	92	20	28
11	36	48	52	64	40	93	12	20
12	24	44	53	60	204	94	20	36
13	32	64	54	40	52	95	12	20
14	12	20	55	76	48	96	16	16
15	32	52	56	52	60	97	28	28
16	20	48	57	60	64	98	20	44
17	24	44	58	24	48	99	28	84
18	28	32	59			100	24	60
19	60	76	60	32	28	101	36	56
20	32	64	61	68	132	102	24	32
21	48	88	62	56	68	103	16	16
22	32	48	63	44	72	104	28	24
23	16	24	64	36	36	105	32	36
24	16	28	65	48	52	106	72	56
25	12	24	66	56	52	107	68	60
26	28	40	67	44	116	108	40	40
27	48	120	68	32	48	109	20	20
28	20	28	69	56	44	110	92	52
29	16	24	70	64	48	111	56	48
30	48	48	71	56	36	112	48	44
31	32	44	72	60	48	113	32	44
32	40	64	73	76	52	114	44	36
33	24	24	74	44	32	115	40	32
34	40	40	75	48	64	116	24	36
35	32	48	76	48	40	117	20	28
36	28	40	77	12	24	118	28	28
37	32	56	78	28	32	119	20	24
38	48	44	79	16	32	120	28	56
39	20	20	80	52	44	121	40	52
40	28	36	81	24	32	122	28	40

continued.......

Appendix 12 (Contd.)

Sample & position in billet inches	Projection (Total length, μm) Mean	Std. dev.	Sample & position in billet inches	Projection (Total length, μm) Mean	Std. dev.
123	28	36	168	24	24
124	24	28	165	24	32
125	20	24	166	52	44
126	24	32	167	44	40
127	16	20	168	32	64
128	24	64	169	48	36
129	32	28	170	32	32
130	24	24	171	48	48
131	28	28	172	56	44
132	20	36	173	52	64
133	20	36	174	48	56
134	16	20	175	36	32
135	12	48	176	140	300
136	12	28	177	84	116
137	16	28	178	52	44
138	12	28	179	48	40
139	28	48	(bottom)		
140	24	24			
141	24	24			
142	28	32			
143	28	24			
144	36	40			
145	52	60			
146	36	52			
147	36	32			
148	32	32			
149	28	28			
150	40	44			
151	24	20			
152	44	32			
153	16	24			
154	32	32			
155	28	28			
156	36	52			
157	24	20			
158	20	20			
159	20	24			
160	28	28			
161	36	32			
162	52	40			
163	44	124			

Appendix 13

MEAN PROJECTION COUNTS OBTAINED ON SAMPLES FROM "DIRTY" BILLET T369

Sample & position in billet, inches	Projection (Total lgth, μm) Mean	Std. dev.	Sample & position in billet, inches	Projection (Total lgth, μm) Mean	Std. dev.	Sample & position in billet, inches	Projection (Total lgth, μm) Mean	Std. dev.
0	36	112	41	60	68	82	40	32
1	32	92	42	72	52	83	60	40
2	32	60	43	80	52	84	44	32
3	32	84	44	36	40	85	52	40
4	40	60	45	88	72	86	84	76
5	64	120	46	100	56	87	40	40
6	40	60	47	92	92	88	64	108
7	84	164	48	56	44	89	76	44
8	32	44	49	60	124	90	44	32
9	20	24	50	56	56	91	44	32
10	60	96	51	80	48	92	64	88
11	44	40	52	60	148	93	-132	88
12	36	52	53	68	144	94	188	104
13	48	36	54	108	72	95	72	52
14	60	116	55	76	116	96	124	52
15	40	44	56	64	40	97	100	68
16	40	32	57	52	44	98	88	60
17	88	76	58	120	76	99	160	96
18	40	60	59	56	40	100	76	52
19	28	28	60	28	28	101	56	36
20	32	56	61	28	24	102	36	36
21	32	56	62	64	44	103	172	80
22	28	36	63	88	44	104	52	32
23	48	84	64	76	56	105	28	24
24	40	32	65	56	96	106	36	52
25	24	36	66	88	56	107	72	72
26	28	24	67	104	60	108	64	152
27	20	20	68	36	32	109	60	56
28	36	28	69	88	76	110	44	36
29	84	148	70	40	32	111	80	68
30	36	28	71	72	72	112	72	96
31	36	68	72	116	72	113	40	40
32	44	44	73	44	48	114	132	292
33	20	20	74	80	44	115	36	32
34	44	44	75	40	32	116	52	40
35	120	92	76	116	120	117	44	40
36	84	56	77	48	44	118	52	40
37	52	40	78	76	60	119	72	48
38	80	72	79	40	44	120	60	44
39	64	68	80	60	52	121	44	28
40	96	52	81	52	44	122	56	88

continued........

Appendix 13 (Contd.)

Sample & position in billet, inches	Projection (Total length, μm) Mean	Std.dev.	Sample & position in billet inches	Projection (Total length, μm) Mean	Std.dev.
123	64	40	164	84	52
124	44	44	165	76	84
125	88	60	166	84	120
126	44	104	167	88	64
127	24	32	168	60	56
128	20	44	169	104	192
129	60	44	170	64	48
130	116	68	171	72	52
131	40	40	172	56	48
132	44	44	173	40	40
133	92	120	174	40	44
134	132	84	175	100	132
135	52	48	176	48	36
136	64	132	177	68	68
137	56	112	178	104	64
138	104	68	179	52	44
139	40	40			
140	44	36			
141	96	120			
142	64	88			
143	28	44			
144	72	88			
145	48	76			
146	32	56			
147	44	52			
148	56	44			
149	40	48			
150	52	56			
151	64	48			
152	80	72			
153	44	36			
154	60	40			
155	44	52			
156	44	64			
157	100	204			
158	112	76			
159	60	40			
160	100	60			
161	52	52			
162	60	48			
163	84	200			

Appendix 14

MEAN SIZE DISTRIBUTION COUNTS OBTAINED ON SAMPLES FROM "CLEAN" BILLET P587

Sample and position in billet, inches	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
0	3.44	0.40	0.20	0.10	0.05
1	2.24	0.13	0.02		
2	1.52	0.01	0.01	0.01	
3	1.52	0.08	0.02		
4	2.67	0.29	0.12	0.06	0.02
5	2.11	0.51	0.32	0.24	0.18
6	2.15	0.07	0.02	0.02	
7	2.90	0.21	0.05	0.02	
8	2.00	0.05			
9	2.38	0.08	0.03		
10	2.35	0.10	0.02	0.01	
11	2.80	0.23	0.10	0.05	0.02
12	2.28	0.12	0.02	0.01	0.01
13	2.14	0.18	0.10	0.05	0.02
14	1.60	0.03	0.01		
15	2.63	0.11	0.01	0.01	
16	1.96	0.07	0.01		
17	2.70	0.15	0.01		
18	2.90	0.12	0.02	0.01	
19	3.83	0.60	0.31	0.10	0.04
20	2.57	0.19	0.02		
21	3.75	0.28	0.20	0.07	0.04
22	2.62	0.24	0.05	0.03	0.01
23	1.35	0.03			
24	1.54	0.12	0.04	0.04	0.03
25	1.10	0.09	0.04	0.02	
26	2.76	0.10	0.04	0.04	0.01
27	2.72	0.30	0.06	0.03	
28	1.94	0.03			
29	1.22	0.06	0.01		
30	3.60	0.23	0.04	0.02	0.02
31	2.74	0.09			
32	3.12	0.15	0.04	0.01	
33	2.49	0.04			
34	3.50	0.23	0.05		
35	2.52	0.16	0.04	0.01	0.01
36	2.32	0.18	0.10	0.04	0.02
37	2.82	0.08			
38	4.67	0.36	0.11	0.04	0.01
39	2.27	0.16	0.08	0.04	0.01

continued.......

Appendix 14 (contd.)

Sample and position in billet. inches	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
40	2.47	0.11	0.02		
41	5.57	0.59	0.13	0.05	0.01
42	3.74	0.29	0.06		
43	3.33	0.17	0.07	0.01	
44	4.84	0.26	0.06	0.01	
45	4.23	0.37	0.14	0.06	0.01
46	3.75	0.16	0.05	0.03	0.01
47	5.09	0.36	0.03		
48	3.78	0.09	0.01		
49	3.52	0.10	0.01	0.01	
50	2.55	0.10	0.01	0.01	
51	3.13	0.19	0.05	0.01	0.01
52	6.13	0.36	0.08	0.04	0.01
53	3.38	0.55	0.31	0.09	0.08
54	3.44	0.26	0.07	0.01	
55	6.40	0.37	0.05	0.01	
56	4.63	0.15	0.02	0.01	0.01
57	4.81	0.22	0.08	0.02	
58	2.02	0.14	0.05	0.03	0.01
59					
60	2.64	0.30	0.08	0.02	0.02
61	4.76	0.50	0.22	0.10	0.03
62	3.88	0.47	0.10	0.04	0.02
63	2.83	0.16	0.10	0.03	0.02
64	3.27	0.10	0.01		
65	3.76	0.23	0.04	0.01	
66	3.74	0.49	0.19	0.09	0.02
67	3.01	0.37	0.16	0.07	0.04
68	2.85	0.12	0.05	0.02	0.01
69	5.13	0.28	0.07	0.02	
70	5.28	0.13	0.03	0.01	
71	4.92	0.19	0.01		

continued.......

Appendix 14 (contd.)

Sample and position in billet, inches	Mean number/field(0.5 sq.mm)greater than:				
	3.6μm	10μm	15μm	20μm	25μm
72	4.73	0.26	0.03		
73	6.96	0.39	0.08	0.02	0.01
74	4.66	0.16	0.06	0.02	
75	3.78	0.15	0.04	0.03	0.03
76	4.40	0.15	0.07	0.03	0.02
77	1.28	0.06	0.01	0.01	0.01
78	2.90	0.25	0.07	0.05	0.02
79	1.40	0.90	0.06	0.01	0.01
80	3.59	0.54	0.24	0.11	0.07
81	2.13	0.21	0.03	0.02	0.01
82	2.12	0.25	0.06	0.05	0.01
83	2.49	0.20	0.04	0.02	0.01
84	2.54	0.25	0.05	0.03	0.03
85	2.29	0.13	0.03	0.02	
86	2.26	0.41	0.16	0.11	0.03
87	1.22	0.12	0.04		
88	1.60	0.20	0.04	0.03	0.02
89	1.78	0.14	0.05	0.01	0.01
90	1.65	0.12	0.06	0.01	
91	1.06	0.17	0.10	0.06	0.02
92	1.43	0.07	0.04	0.01	
93	1.15	0.03	0.01		
94	1.71	0.11	0.04	0.02	0.01
95	1.01	0.04	0.04		
96	1.39	0.09	0.03	0.01	
97	2.27	0.22	0.06	0.02	
98	1.36	0.11	0.06	0.02	0.01
99	1.36	0.15	0.01		
100	1.19	0.21	0.08	0.03	
101	2.42	0.38	0.14	0.04	0.01
102	1.74	0.23	0.08	0.03	0.03
103	1.57	0.08	0.04	0.01	

continued......

Appendix 14 (contd.)

Sample and position in billet, inches	Mean number/field(0.5sq.mm.)greater than:				
	3.6 µm	10 µm	15 µm	20 µm	25 µm
104	2.69	0.24	0.06	0.03	0.03
105	2.98	0.13	0.04		
106	6.73	0.35	0.12	0.02	0.01
107	5.33	0.41	0.20	0.03	0.02
108	3.30	0.14	0.04	0.03	0.01
109	2.04	0.10	0.01	0.01	
110	6.63	0.83	0.30	0.13	0.08
111	6.22	0.25	0.06	0.02	0.02
112	4.37	0.45	0.12	0.05	0.04
113	3.10	0.14	0.05	0.01	0.01
114	5.66	0.14	0.04	0.03	0.02
115	3.58	0.28	0.06	0.01	
116	1.91	0.10	0.02		
117	1.81	0.09			
118	2.36	0.25	0.08	0.02	0.01
119	2.02	0.12	0.03		
120	2.38	0.16	0.04	0.01	
121	2.81	0.15	0.03	0.02	
122	2.54	0.06	0.02		
123	2.74	0.15	0.04	0.02	0.01
124	2.62	0.07	0.01	0.01	
125	2.60	0.06	0.03	0.01	
126	2.81	0.06	0.01		
127	1.71	0.09	0.03	0.01	
128	2.41	0.08	0.02		
129	3.11	0.28	0.09	0.05	0.02
130	2.16	0.10	0.02		
131	2.51	0.03			
132	1.39	0.11	0.03		
133	1.76	0.12	0.02	0.01	
134	1.36	0.03	0.02		
135	0.99	0.08	0.01	0.01	0.01
136	0.98	0.01			

continued.........

Appendix 14 (contd.)

Sample and position in billet, inches	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
137	1.32	0.04	0.01		
138	1.26	0.06	0.03		
139	2.39	0.19	0.06	0.05	0.01
140	3.07	0.02	0.02	0.01	0.01
141	2.21	0.09	0.01		
142	2.80	0.06	0.02	0.01	0.01
143	3.00	0.09	0.02	0.01	0.01
144	3.61	0.13	0.02		
145	4.66	0.11			
146	2.90	0.18	0.05	0.03	
147	3.51	0.27	0.08	0.02	0.01
148	3.09	0.15	0.08		
149	3.31	0.15	0.04		
150	4.12	0.20	0.07	0.02	0.01
151	2.60	0.06			
152	4.02	0.20	0.08	0.03	
153	1.62	0.08	0.03	0.01	0.01
154	3.07	0.24	0.15	0.06	0.01
155	2.76	0.18	0.04	0.02	
156	2.56	0.15	0.06	0.02	
157	2.54	0.11	0.01		
158	2.32	0.08	0.01		
159	2.48	0.02	0.01	0.01	
160	2.87	0.14			
161	3.70	0.09	0.01		
162	4.72	0.09	0.01		
163	3.92	0.31	0.13	0.06	0.02
164	2.69	0.11	0.03	0.02	
165	2.50	0.04	0.02	0.01	
166	4.43	0.19	0.06	0.04	0.01
167	3.72	0.04	0.01	0.01	
168	3.01	0.17	0.09	0.05	0.02
169	4.14	0.30	0.11	0.01	0.01

continued........

Appendix 14 (contd.)

Sample and position in billet, inches	Mean number/field(0.5 sq.mm.) greater than:				
	3.6μm	10μm	15μm	20μm	25μm
170	3.45	0.07	0.01	0.01	
171	4.77	0.13	0.01	0.01	
172	5.43	0.40	0.07	0.01	0.01
173	4.10	0.12	0.03	0.01	
174	4.06	0.14	0.02	0.01	
175	3.71	0.05	0.02	0.02	0.01
176	8.79	0.84	0.40	0.23	0.17
177	6.65	0.33	0.03	0.01	
178	5.34	0.13	0.06	0.02	0.02
179	3.07	0.34	0.09	0.03	0.01

Appendix 15

MEAN SIZE DISTRIBUTION COUNTS OBTAINED ON SAMPLES FROM "DIRTY" BILLET T369

Sample and position in billet, inches	Mean number/field(0.5 sq.mm.) greater than				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
0	2.55	0.17	0.03	0.01	
1	3.19	0.11	0.03		
2	2.78	0.24	0.07	0.01	
3	3.21	0.19	0.03		
4	4.89	0.10	0.01		
5	6.39	0.33	0.07	0.04	
6	3.66	0.12	0.05		
7	6.69	0.30	0.09	0.01	0.01
8	4.08	0.08	0.02	0.01	
9	1.95	0.09	0.03	0.01	0.01
10	4.39	0.47	0.08	0.04	
11	3.89	0.28	0.05		
12	3.54	0.13	0.03		
13	5.16	0.17	0.05	0.03	0.01
14	5.38	0.29	0.05	0.02	
15	3.78	0.18	0.04	0.01	
16	4.29	0.32	0.05	0.03	
17	8.86	0.49	0.12	0.04	0.02
18	3.58	0.25	0.12	0.06	0.04
19	2.91	0.10	0.05	0.04	0.02
20	4.83	0.33	0.08		
21	3.01	0.31	0.13	0.08	0.04
22	2.63	0.22	0.09	0.02	
23	5.65	0.11	0.05	0.03	0.02
24	4.97	0.22	0.04	0.01	
25	2.71	0.05	0.01		
26	3.51	0.22	0.08	0.05	0.08
27	2.49	0.19	0.07	0.03	0.01
28	4.42	0.46	0.22	0.09	0.05
29	9.76	0.25	0.11	0.05	0.01
30	4.81	0.31	0.08	0.02	0.02

continued.......

Appendix 15 (contd.)

Sample and position in billet, inches	Mean number/field (0.5 sq.mm.)greater than:				
	3.6 µm	10 µm	15 µm	20 µm	25 µm
31	4.32	0.05	0.01	0.02	0.01
32	4.92	0.42	0.16	0.10	0.05
33	2.55	0.13	0.03	0.02	0.01
34	4.92	0.42	0.16	0.10	0.05
35	15.82	1.33	0.51	0.28	0.21
36	11.41	0.42	0.14	0.07	0.01
37	6.38	0.38	0.09	0.02	
38	8.78	1.06	0.30	0.12	0.06
39	6.57	0.37	0.09	0.04	0.02
40	10.64	0.97	0.31	0.13	0.05
41	6.23	0.52	0.14	0.09	0.05
42	8.25	0.37	0.11	0.04	0.01
43	8.23	0.48	0.16	0.07	0.04
44	3.99	0.17	0.07	0.04	0.04
45	9.75	0.40	0.07	0.03	0.02
46	11.60	0.53	0.17	0.07	0.02
47	8.61	1.15	0.42	0.23	0.11
48	6.18	0.28	0.10	0.04	0.03
49	5.52	0.52	0.20	0.08	0.04
50	5.50	0.16	0.07	0.03	0.02
51	8.32	0.59	0.22	0.12	0.05
52	5.84	0.18	0.09	0.05	0.02
53	6.89	0.45	0.13	0.04	0.03
54	11.24	1.34	0.44	0.22	0.08
55	7.28	0.61	0.13	0.04	0.01
56	7.14	0.62	0.21	0.14	0.08
57	5.57	0.16	0.06	0.04	0.04
58	10.86	0.72	0.33	0.15	0.10
59	5.62	0.40	0.19	0.11	0.05
60	2.98	1.00	0.46	0.23	0.15
61	2.86	1.09	0.46	0.26	0.15
62	7.37	2.34	1.07	0.46	0.26

continued.........

Appendix 15 (contd.)

Sample and position in billet, inches	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
63	10.18	3.63	1.79	0.92	0.64
54	9.00	1.81	0.79	0.49	0.28
65	4.97	0.63	0.36	0.18	0.09
66	7.22	0.81	0.33	0.18	0.16
67	12.52	0.24	0.05		
68	4.29	1.01	0.32	0.16	0.06
69	8.71	0.93	0.34	0.14	0.10
70	4.99	1.14	0.45	0.26	0.17
71	6.81	0.86	0.32	0.19	0.08
72	9.38	1.79	0.76	0.37	0.27
73	4.77	0.41	0.11	0.04	0.02
74	8.66	0.56	0.17	0.06	0.02
75	4.59	0.44	0.19	0.07	0.05
76	9.73	1.63	0.91	0.46	0.35
77	5.01	0.38	0.20	0.07	0.04
78	7.80	1.15	0.58	0.26	0.14
79	4.35	0.45	0.23	0.16	0.11
80	5.14	0.85	0.50	0.24	0.09
81	4.76	0.62	0.31	0.11	0.06
82	3.52	0.99	0.40	0.17	0.05
83	7.73	0.26	0.07	0.02	0.01
84	5.20	0.27	0.05	0.01	
85	7.34	0.17	0.04	0.01	0.01
86	9.15	0.69	0.30	0.16	0.07
87	4.31	0.54	0.28	0.22	0.16
88	6.28	0.24	0.08	0.03	0.02
89	6.58	1.19	0.38	0.19	0.10
90	5.64	0.46	0.14	0.07	0.06
91	5.66	0.49	0.13	0.06	0.03
92	5.56	0.60	0.22	0.07	0.03
93	13.84	1.65	0.52	0.26	0.13
94	19.57	2.94	1.15	0.67	0.39
95	8.32	1.22	0.47	0.23	0.09

continued.........

Appendix 15 (contd.)

Sample and position in billet, inches	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 µm	10 µm	15 µm	20 µm	25 µm
96	15.27	1.46	0.52	0.18	0.09
97	8.72	1.36	0.53	0.31	0.21
98	10.32	0.66	0.25	0.14	0.09
99	17.39	1.37	0.35	0.11	0.07
100	9.16	0.41	0.19	0.04	0.02
101	7.41	0.27	0.12	0.02	0.01
102	4.55	0.22	0.07	0.05	
103	23.75	0.96	0.23	0.08	0.02
104	5.09	0.86	0.43	0.23	0.11
105	3.16	0.18	0.07	0.04	0.03
106	4.05	0.18	0.03	0.02	0.02
107	10.06	0.50	0.15	0.04	0.03
108	5.24	0.59	0.17	0.07	0.06
109	7.41	0.30	0.10	0.05	0.01
110	5.56	0.23	0.11	0.02	0.01
111	10.93	0.36	0.15	0.06	0.02
112	8.09	0.38	0.15	0.09	0.07
113	5.77	0.18	0.03	0.01	
114	11.55	0.78	0.29	0.27	0.14
115	4.23	0.18	0.08	0.03	0.01
116	6.36	0.37	0.14	0.03	0.01
117	4.33	0.33	0.17	0.05	0.01
118	4.92	0.70	0.30	0.14	0.09
119	10.22	0.24	0.06	0.02	0.01
120	6.18	0.49	0.18	0.09	0.04
121	5.48	0.24	0.07	0.02	0.01
122	6.89	0.20	0.12	0.05	0.03
123	6.69	0.55	0.18	0.09	0.02
124	5.21	0.33	0.09	0.05	0.02
125	10.52	0.33	0.13	0.05	0.03
126	3.76	0.30	0.26	0.06	0.05
127	2.78	0.22	0.11	0.07	0.04
128	2.12	0.06	0.04	0.01	

continued.........

Appendix 15 (contd.)

Sample and position in billet, inches	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
129	6.84	0.28	0.16	0.13	0.11
130	9.18	2.17	1.04	0.53	0.28
131	4.14	0.35	0.17	0.11	0.07
132	2.76	0.51	0.29	0.11	0.06
133	6.74	1.24	0.52	0.28	0.15
134	13.57	1.15	0.40	0.18	0.07
135	3.61	0.71	0.40	0.25	0.12
136	6.01	0.36	0.10	0.05	0.01
137	5.26	0.47	0.24	0.11	0.03
138	12.14	0.80	0.22	0.07	0.06
139	4.62	0.40	0.15	0.08	0.05
140	4.37	0.37	0.11	0.06	0.05
141	8.37	0.49	0.14	0.08	0.06
142	7.69	0.24	0.03	0.02	0.01
143	3.21	0.31	0.05	0.02	0.01
144	8.57	0.54	0.15	0.05	0.03
145	6.32	0.22	0.06	0.02	0.01
146	3.42	0.10	0.07	0.03	0.02
147	4.83	0.24	0.03	0.01	0.01
148	5.69	0.35	0.13	0.06	0.02
149	4.10	0.31	0.10	0.04	0.01
150	6.53	0.27	0.12	0.04	0.01
151	5.76	0.86	0.30	0.14	0.12
152	6.42	1.22	0.61	0.41	0.25
153	4.03	0.45	0.12	0.07	0.04
154	4.81	0.89	0.42	0.20	0.16
155	5.13	0.18	0.04		
156	5.71	0.27	0.11	0.06	0.04
157	9.84	0.33	0.11	0.05	0.04
158	15.73	0.30	0.19	0.07	0.04
159	8.34	0.28	0.09	0.02	
160	14.46	0.64	0.14	0.04	0.01

continued.........

Appendix 15 (contd.)

Sample and position in billet, inches	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
161	6.79	0.66	0.15	0.03	
162	8.89	0.28	0.10	0.03	0.03
163	8.62	0.21	0.06	0.04	0.02
164	13.10	0.33	0.15	0.01	0.01
165	9.46	0.53	0.23	0.13	0.09
166	11.20	0.37	0.06	0.05	0.04
167	18.08	0.48	0.13	0.06	
168	12.25	1.33	0.36	0.09	0.04
169	17.53	4.17	3.14	2.58	1.47
170	8.43	0.53	0.15	0.08	0.06
171	8.40	0.32	0.16	0.03	0.02
172	6.37	0.12	0.04	0.02	0.02
173	6.72	0.27	0.14	0.05	0.03
174	9.28	0.32	0.08	0.03	0.01
175	12.41	0.41	0.12	0.05	0.02
176	5.98	0.24	0.09	0.06	0.02
177	9.06	0.41	0.10	0.04	0.01
178	13.51	0.58	0.14	0.02	0.02
179	5.93	0.32	0.15	0.05	0.01

<u>Appendix 16</u>

OXIDE SIZE DISTRIBUTION RESULTS ON SAMPLE P587-53 AFTER THIRTY REPOLISHES

Repolish	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
1	5.22	1.11	0.31	0.09	0.04
2	5.64	0.98	0.33	0.05	0.02
3	4.02	0.28	0.05		
4	2.26	0.09			
5	2.75	0.13	0.04	0.01	
6	2.27	0.16	0.02	0.01	
7	2.48	0.30	0.08	0.05	0.03
8	1.80	0.78	0.44	0.30	1.85
9	2.12	1.36	0.74	0.70	0.44
10	1.74	0.72	0.52	0.46	0.34
11	1.54	0.67	0.32	0.28	0.24
12	1.69	0.48	0.33	0.22	0.22
13	0.89	0.27	0.12	0.12	0.04
14	0.53	0.18	0.08		
15	0.91	0.37	0.21	0.10	0.06
16	1.32	0.71	0.55	0.37	0.31
17	0.75	0.18	0.08	0.04	0.01
18	0.63	0.06	0.01		
19	0.99	0.32	0.09	0.02	0.01
20	0.39	0.06	0.01	0.01	
21	0.60	0.08	0.01	0.01	
22	0.78	0.15	0.05	0.03	0.02
23	0.52	0.05			
24	1.17	0.27	0.05	0.03	
25	0.90	0.25	0.17	0.14	0.11
26	0.63	0.05	0.03	0.02	0.01
27	1.57	0.20	0.05	0.02	0.02
28	0.66	0.23	0.08	0.02	
29	2.09	0.53	0.16	0.06	0.02
30	0.79	0.12	0.02		
Mean	1.66	0.38	0.17	0.16	0.13

Appendix 17

OXIDE SIZE DISTRIBUTION RESULTS ON SAMPLE P587-1 AFTER 30 REPOLISHES

Repolish	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
1	5.75	0.24	0.05		
2	4.19	0.21	0.10	0.04	0.02
3	3.13	0.09	0.02	0.02	0.02
4	2.52	0.06	0.03	0.02	
5	3.39	0.11	0.02		
6	1.22	0.06			
7	1.74	0.11	0.02	0.01	
8	0.51	0.03			
9	0.58	0.11	0.02	0.01	
10	1.65	0.27	0.02		
11	2.24	0.84	0.66	0.35	0.23
12	1.59	0.34	0.11	0.04	0.01
13	1.05	0.26	0.11	0.04	0.02
14	0.71	0.08	0.02	0.01	
15	0.34	0.13	0.06	0.03	
16	0.41	0.05	0.03	0.02	0.01
17	0.77	0.18	0.10	0.05	0.03
18	0.71	0.16	0.07	0.03	0.01
19	1.23	0.13	0.03	0.01	
20	2.31	0.74	0.37	0.18	0.08
21	1.07	0.11	0.02		
22	1.66	0.26	0.10	0.01	0.01
23	1.31	0.20	0.05	0.03	
24	0.61	0.22	0.01		
25	1.17	0.22	0.07	0.07	0.01
26	1.21	0.23	0.04	0.02	
27	1.30	0.21	0.05	0.03	
28	0.89	0.19	0.07	0.03	0.01
29	1.03	0.17	0.02	0.01	
30	0.59	0.09	0.02	0.01	
Mean	1.56	0.21	0.08	0.04	0.04

Appendix 18

OXIDE SIZE DISTRIBUTION RESULTS ON SAMPLE P587-126 AFTER 30 REPOLISHES

Repolish	Mean number/field (0.5 sq.mm.) greater than:				
	3.6 μm	10 μm	15 μm	20 μm	25 μm
1	3.17	0.11	0.07	0.02	0.01
2	3.47	0.19	0.01		
3	2.49	0.08	0.01	0.01	
4	2.00	0.10	0.04	0.02	0.01
5	1.83	0.08	0.03	0;01	0.01
6	1.34	0.10	0.02	0.01	
7	2.08	0.14	0.08		
8	0.70	0.09	0.05	0.01	
9	0.36	0.10	0.04		
10	0.92	0.18	0.06	0.02	0.02
11	0.80	0.16	0.04	0.03	
12	0.76	0.09	0.02	0.02	0.01
13	0.45	0.11	0.03	0.02	
14	0.76	0.15	0.06	0.03	0.02
15	0.59	0.18	0.03	0.01	0.01
16	0.95	0.19	0.07	0.03	0.02
17	0.86	0.21	0.08	0.04	0.01
18	0.68	0.13	0.04	0.01	0.01
19	0.90	0.26	0.19	0.13	0.07
20	0.53	0.10	0.02	0.01	0.01
21	0.78	0.11	0.04	0.01	
22	1.35	0.39	0.20	0.09	0.03
23	0.85	0.16	0.04	0.01	0.01
24	0.77	0.14	0.01	0.01	0.01
25	0.58	0.13	0.02		
26	1.27	0.19	0.06	0.02	
27	0.75	0.18	0.05	0.02	
28	0.58	0.07	0.03	0.01	
29	1.04	0.24	0.05	0.02	0.01
30	0.56	0.12	0.03	0.01	0.01
Mean	1.00	0.12	0.03	0.01	0.009

<u>Appendix 19</u>

Calculation of correlation coefficient - Quantimet oxygen versus neutron activation oxygen (n=59 determinations)

x = Quantimet (wt.% O_2) x 10^{-2}

	Σ	3	5	7	5	12	16	3	3	5	59
12	10.0 - 10.8				1	1	1			1	4
11	9.2 - 10.0					1		1			2
10	8.4 - 9.2				1						1
9	7.6 - 8.4						3				3
8	6.8 - 7.6						1		1	1	3
7	6.0 - 6.8	1			1		1	1			4
6	5.2 - 6.0			2	1	1	1		1	1	7
5	4.4 - 5.2		1			3	1		1	2	8
4	3.6 - 4.4	1		2	1	1	3				8
3	2.8 - 3.6		2	1		2	3	1			9
2	2.0 - 2.8		1	2		2	3				3
1	1.2 - 2.0	1	1			1					3
	Value	2.6	3.0	3.4	3.8	4.2	4.6	5.0	5.4	5.8	
		3.0	3.4	3.8	4.2	4.6	5.0	5.4	5.8	6.2	
GROUP		1	2	3	4	5	6	7	8	9	Σ

y = Neutron activation (wt.% O_2) x 10^{-2}

$\Sigma y = 3 + 10 + 21 + 20 + 60 + 96 + 21 + 24 + 45 = 300$

$\Sigma y^2 = 3 + 20 + 63 + 80 + 300 + 576 + 147 + 192 + 405 = 1766$

Correlation due to mean $= \frac{300^2}{59} = 1525$

Sum of squares abt. mean = 1766 - 1525 = 241

$\therefore$ variance of $y = \frac{241}{58} = \underline{4.138}$

$\Sigma x = 3 + 16 + 27 + 32 + 40 + 42 + 21 + 24 + 27 + 10 + 22 + 48 = 319$

$\Sigma x^2 = 3 + 24 + 81 + 128 + 200 + 252 + 147 + 192 + 243 + 100 + 242$

$+ 576 = 2188$

Correlation due to mean $= \frac{319^2}{59} = 1725$

Sum of squares abt. mean = 2188 - 1725 = 463

$\therefore$ variance of $x = \frac{463}{58} = 7.984$

Appendix 19 (contd.)

Sum of products $\sum xy$ Calculate $x\sum y$	$\sum y$	x	$x\sum y$
col. 1 (x=1) = 1 + 4 + 7 =	12	1	12
2 = 1 + 2 + 6 + 5 =	14	2	28
3 = 4 + 3 + 8 + 12 =	27	3	81
4 = 4 + 6 + 7 + 10 + 12 =	39	4	156
5 = 1 + 2 + 6 + 4 + 15 + 6 + 11 + 12 =	59	5	295
6 = 6 + 9 + 12 + 5 + 6 + 7 + 8			
+ 27 + 12 =	92	6	552
7 = 3 + 7 + 11 =	21	7	147
8 = 5 + 6 + 8 =	19	8	152
9 = 10 + 6 + 8 + 12 =	36	9	324
Total ($\sum$)	319		1747

Correlation due to mean $= \dfrac{\sum x . \sum y}{n} = \dfrac{300 \times 319}{59}$

sum of products = 1747 - 1622 = 125

covariancy of x, y = $\dfrac{125}{58} = 2.155$

correlation coefficient, r, = $\dfrac{125}{\sqrt{241 \times 463}} = 0.3742$

significance levels for 58 degrees of freedom

10%	5%	1%	0.1%	r
0.215	0.255	0.331	0.415	0.374

∴ r is significant to better than 1%, i.e. the correlation is highly significant.

Quantimet percent area measurements were converted to volume percent oxygen using the formula:

$$\text{Oxygen, wt.\%} = \frac{\text{Percentage area oxide (Quantimet)}}{K}$$

with a knowledge of the composition and density of the oxides, the K factor can be calculated from the formula:

$$K = \frac{100 . \gamma_{Fe}}{p . \gamma_{inc.}}$$

where p = weight percent of oxygen in inclusion

γ_{Fe} = density of steel

γ_{inc} = density of inclusion

The values of p and γ_{inc}, and the corresponding K values for some of the oxides commonly found in steel are given in Appendix 20. In the work described, K was taken as 5.

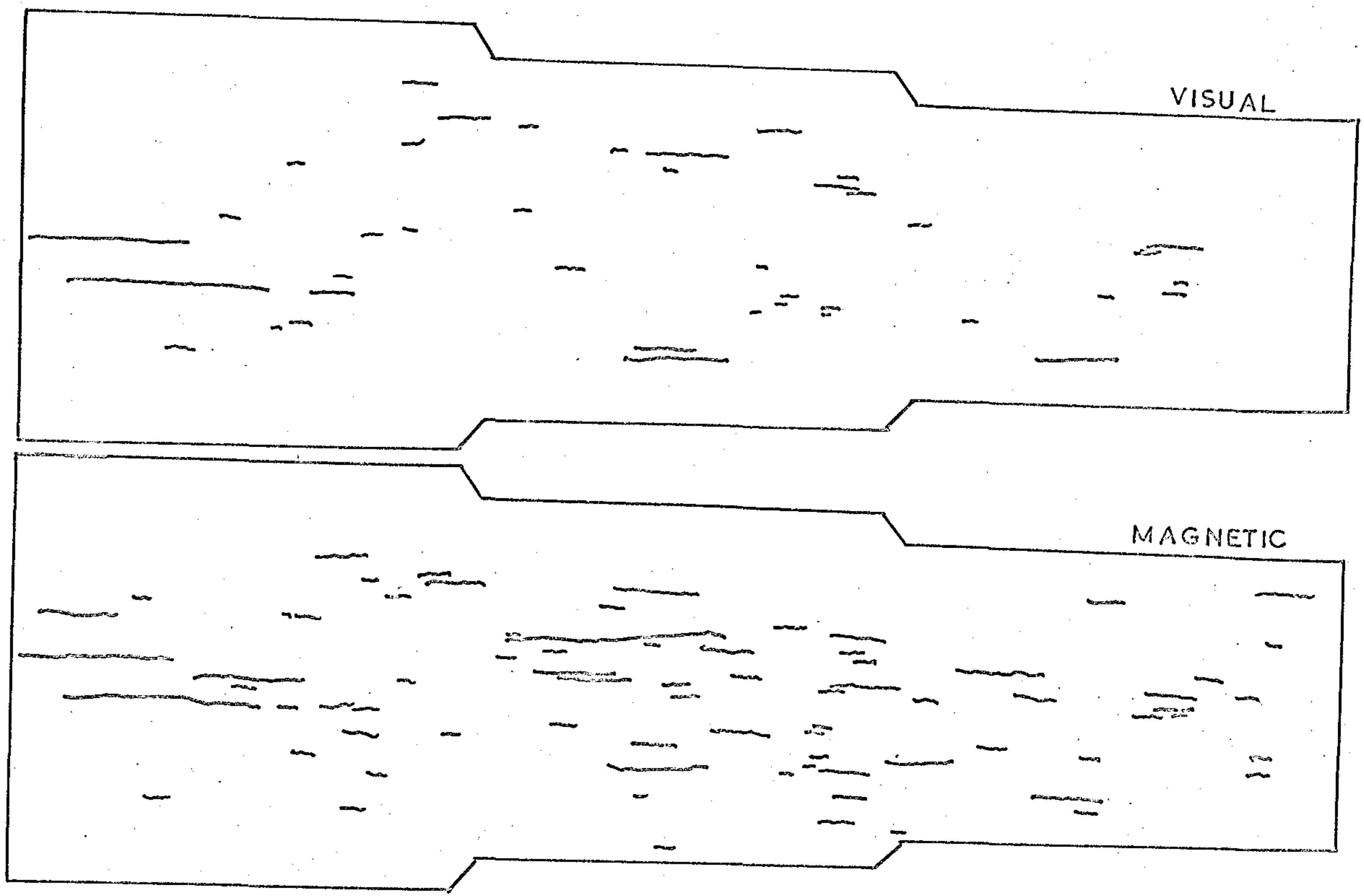
Appendix 20

DENSITY, OXYGEN CONTENT AND K VALUES FOR SOME COMMONLY OCCURRING INCLUSIONS IN STEEL[103]

Formula	Type	Density g/cm^3	Oxygen %	Calculated K values
FeO	Wüstite	5.7	22.3	6.1
MnO	Manganosite	5.4	22.5	6.5
SiO_2	Cristobalite	2.3	53.3	6.4
SiO_2	Quartz	2.6	53.3	5.7
Al_2O_3	Corundum	4.0	47.1	4.2
Cr_2O_3	Chromium oxide (escolaite)	5.2	31.6	4.7
$MnO.SiO_2$	Rhodonite	3.7	36.6	5.7
$2MnO.SiO_2$	Tephroite	4.0	31.7	6.1
$2FeO.SiO_2$	Fayalite	4.3	31.4	5.8
$FeO.Al_2O_3$	Hercynite	4.1	36.8	5.2
$FeO.Cr_2O_3$	Chromite	5.1	28.6	5.3
$MnO.Al_2O_3$	Galaxite	4.2	37.0	5.0
$3Al_2O_3.2SiO_2$	Mullite	3.2	44.5	5.6

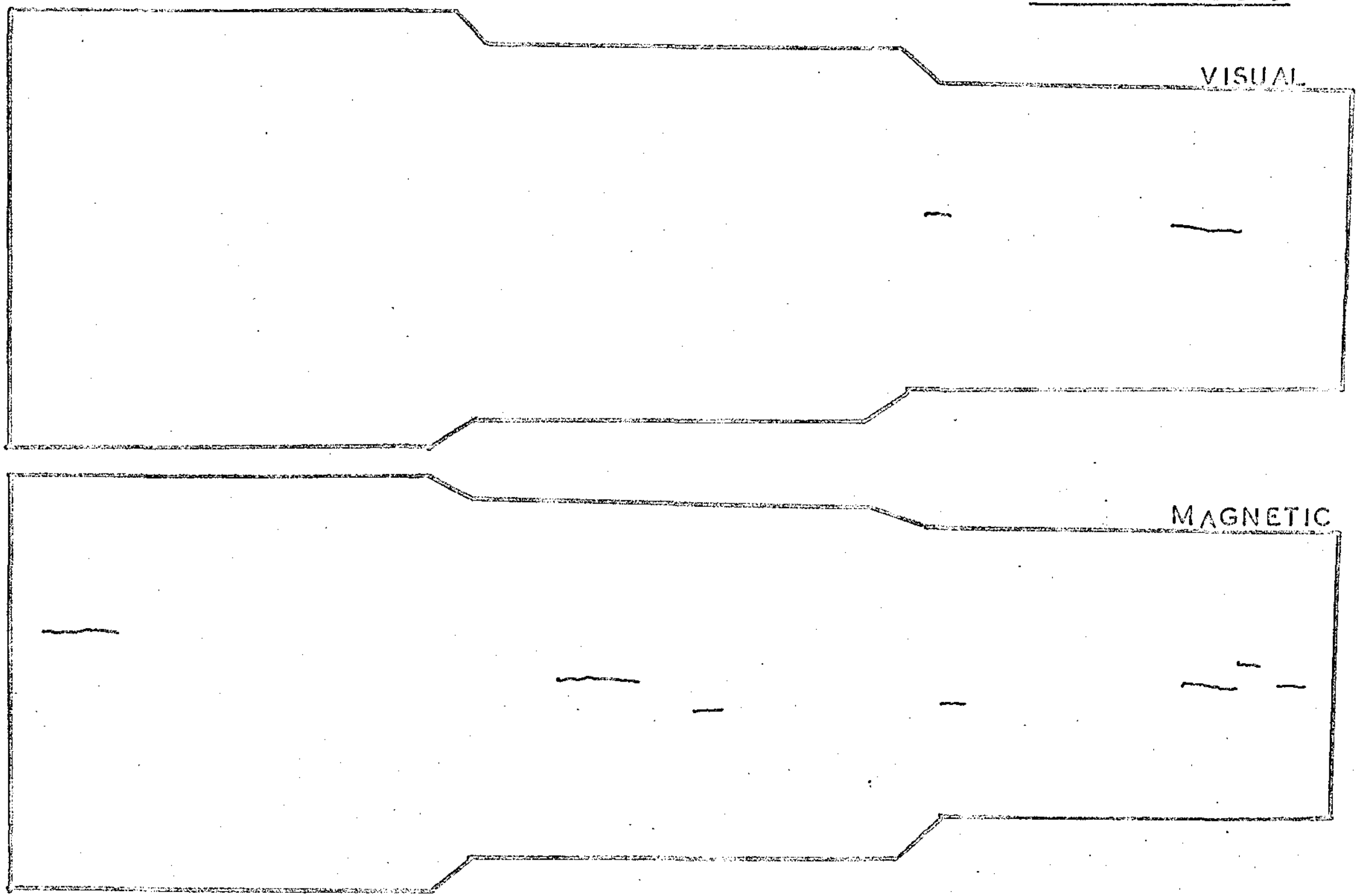
APPENDIX 21

RESULT OBTAINED ON 66 TEST PIECES



Appendix 21 CONTD.

SAMPLE 61 D 6
SAMPLE 63 B 6



APPENDIX 21 contd.

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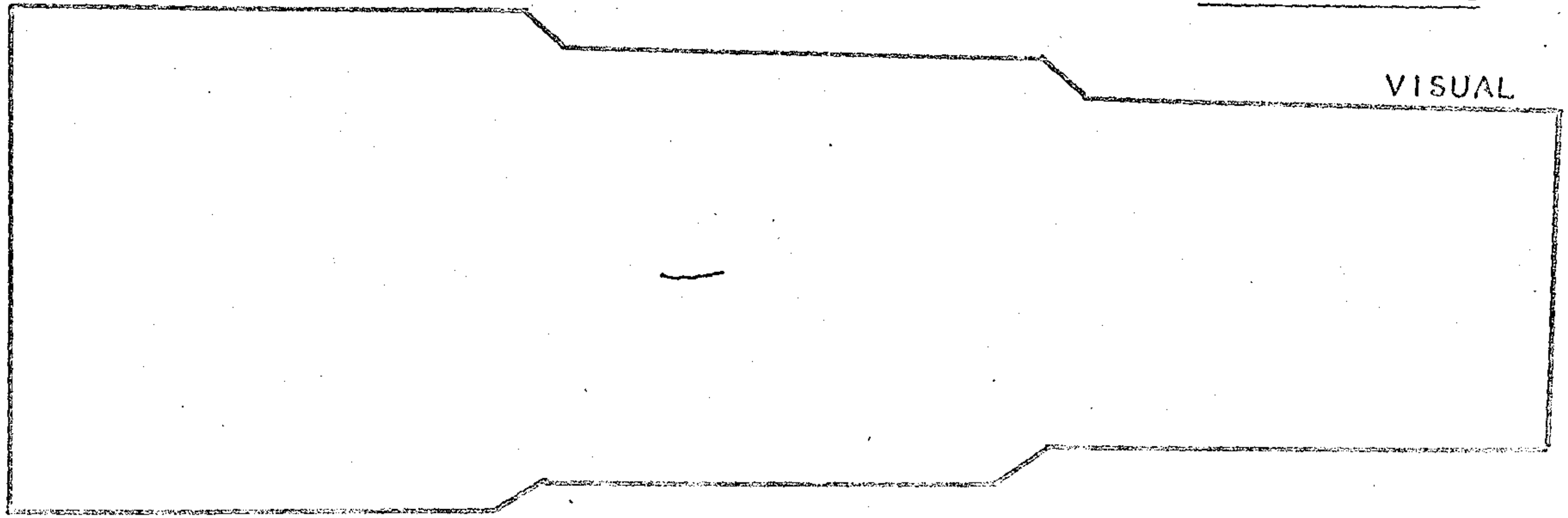
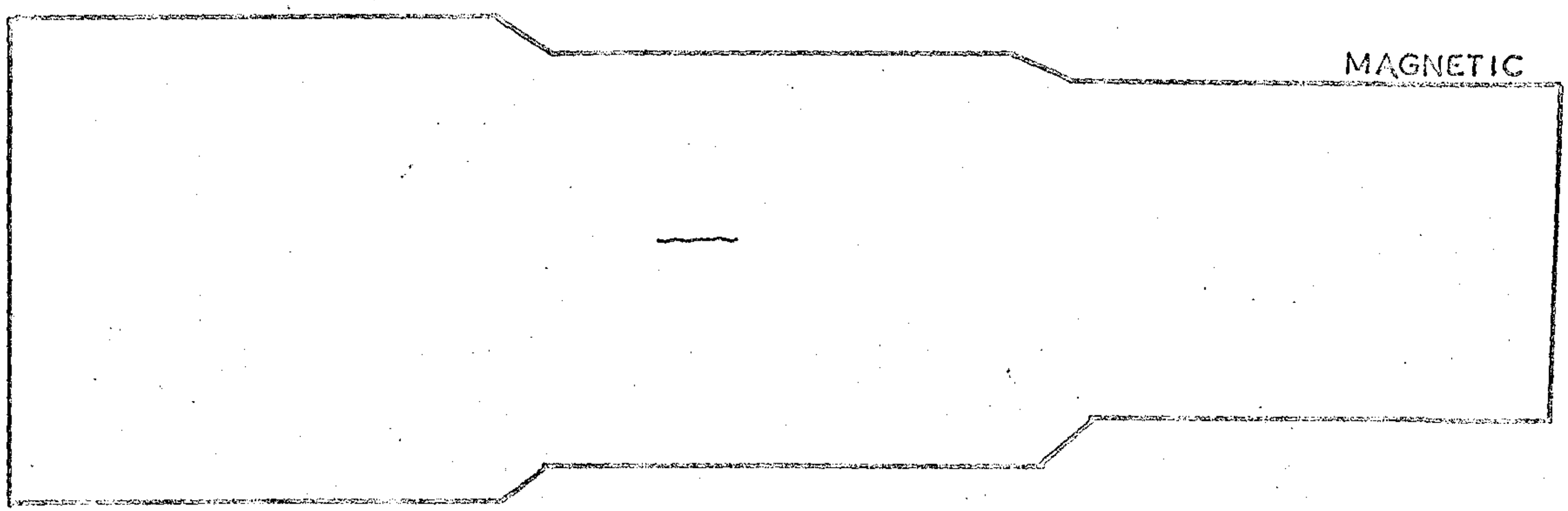
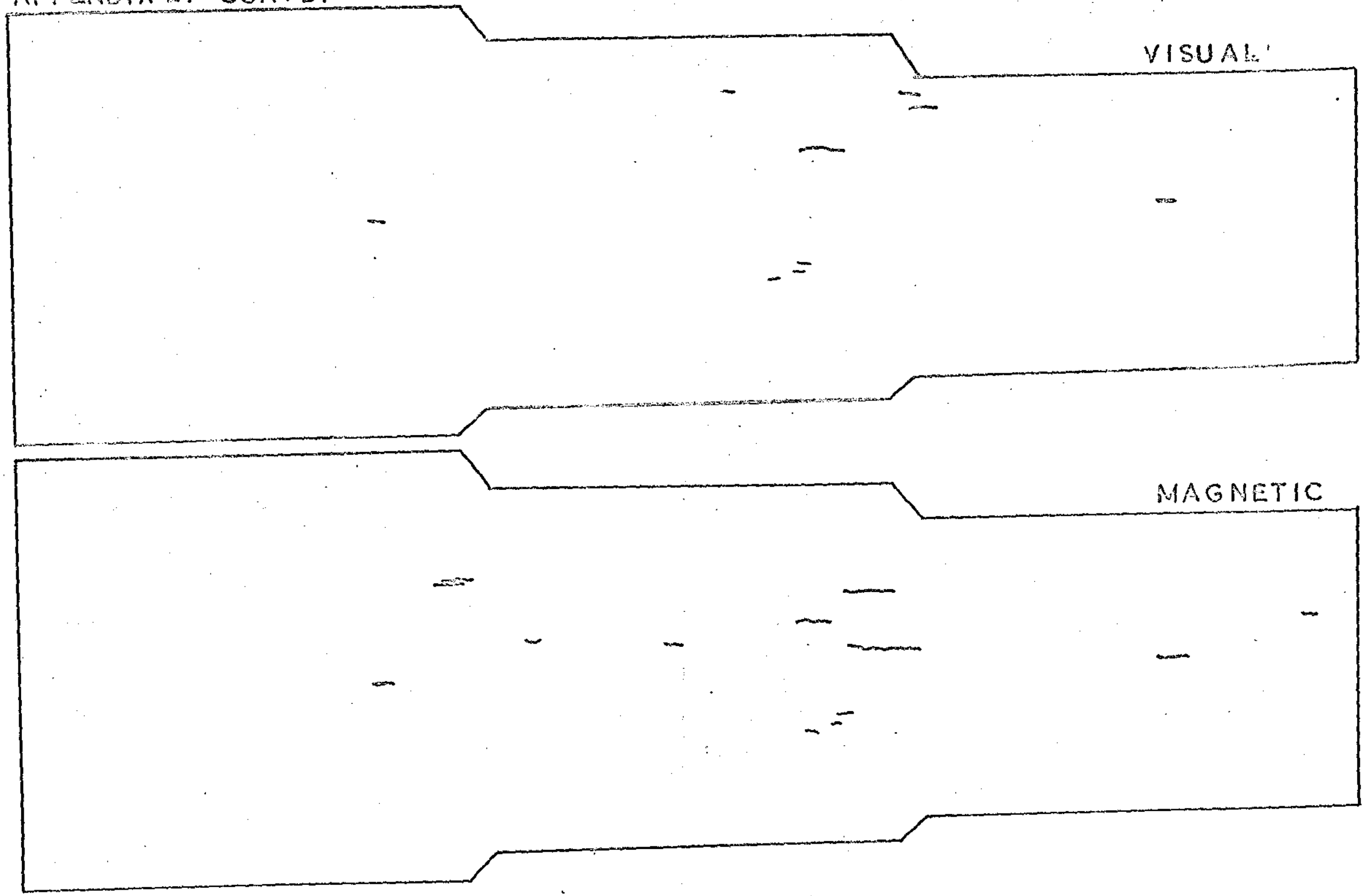
SAMPLE 63 B 5





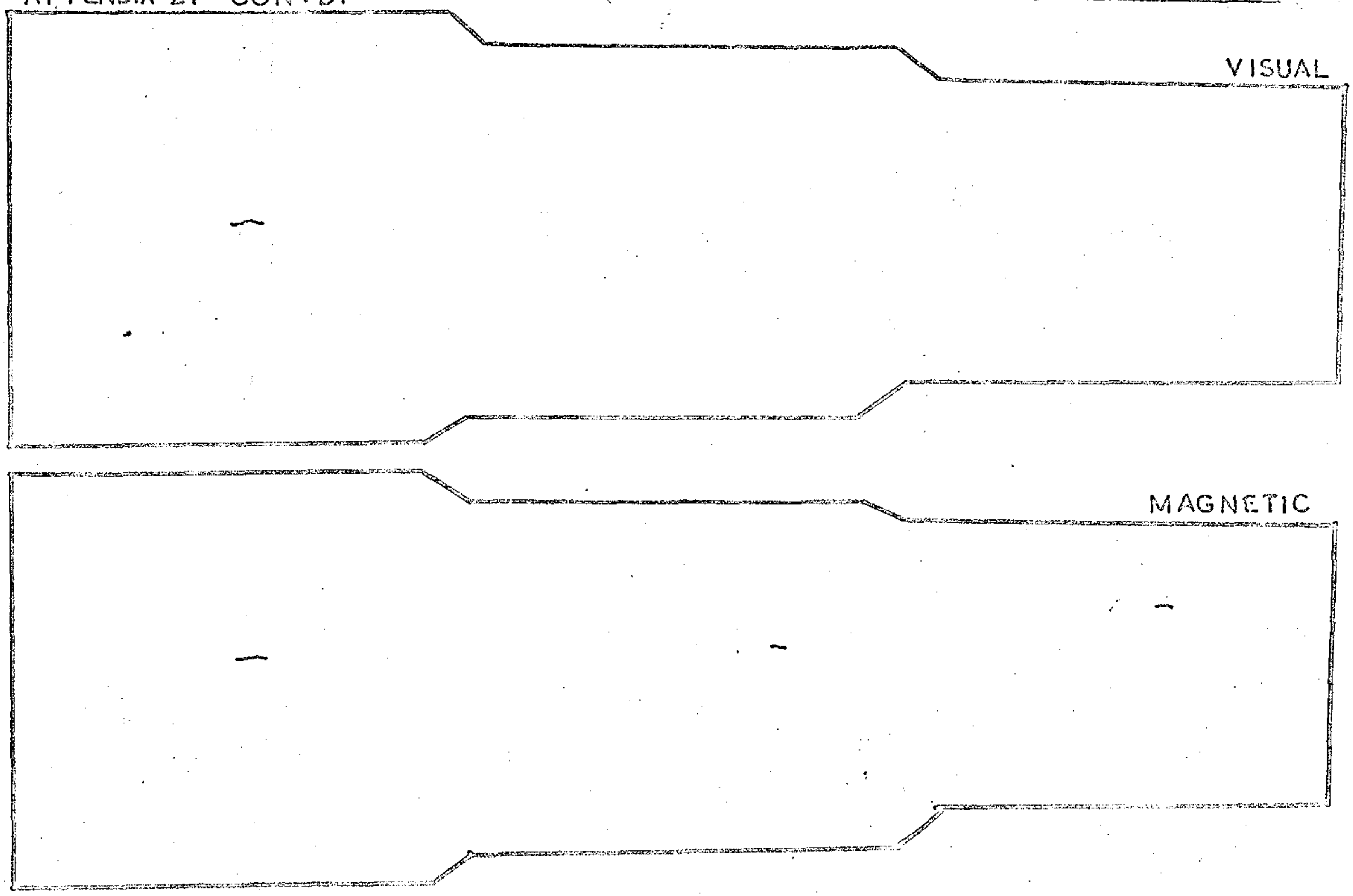
SAMPLE 63 B 4

APPENDIX 21 CONTD.



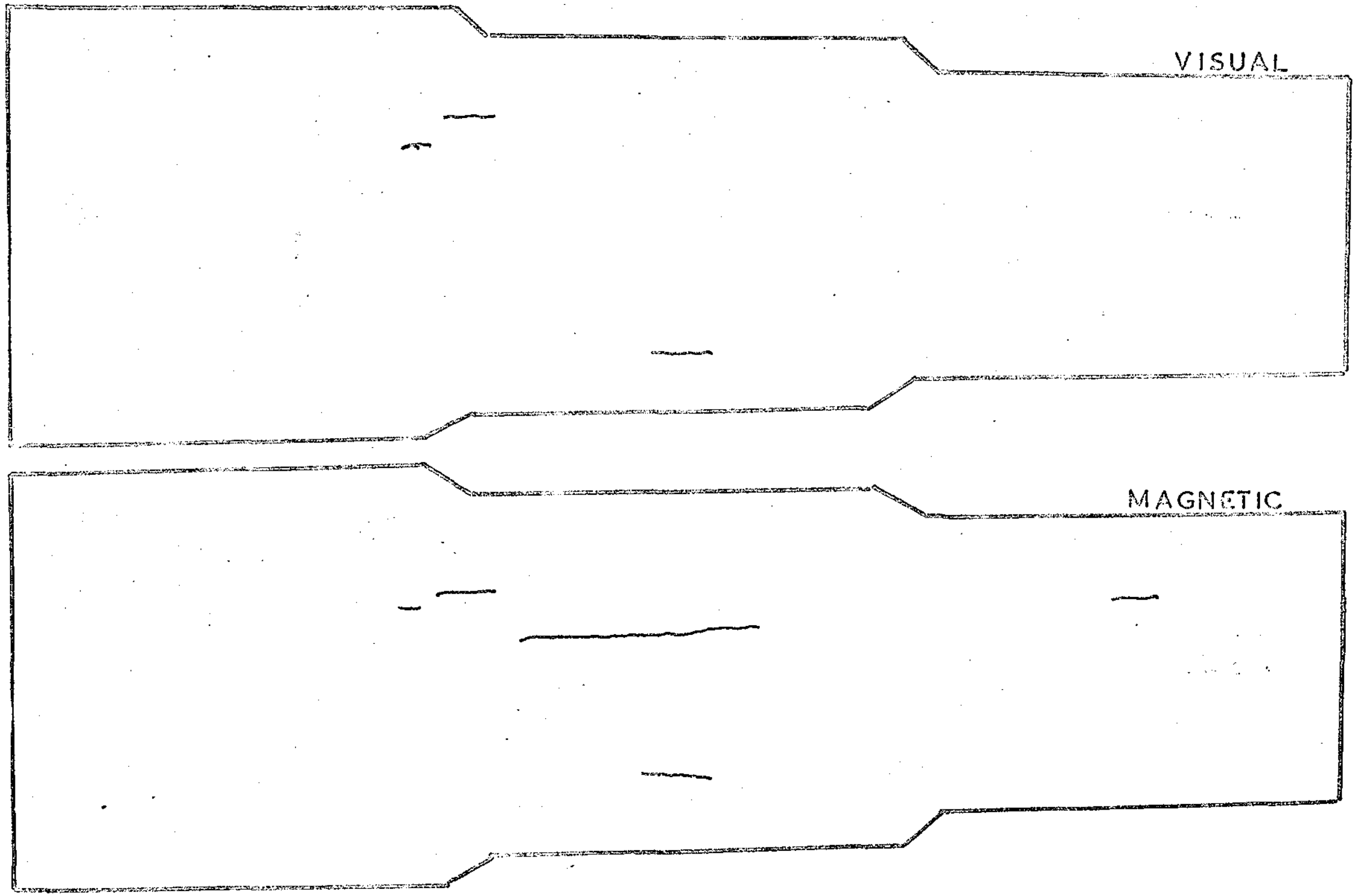
SAMPLE 61 B 3
SAMPLE 63 B 3

APPENDIX 21 CONTD.



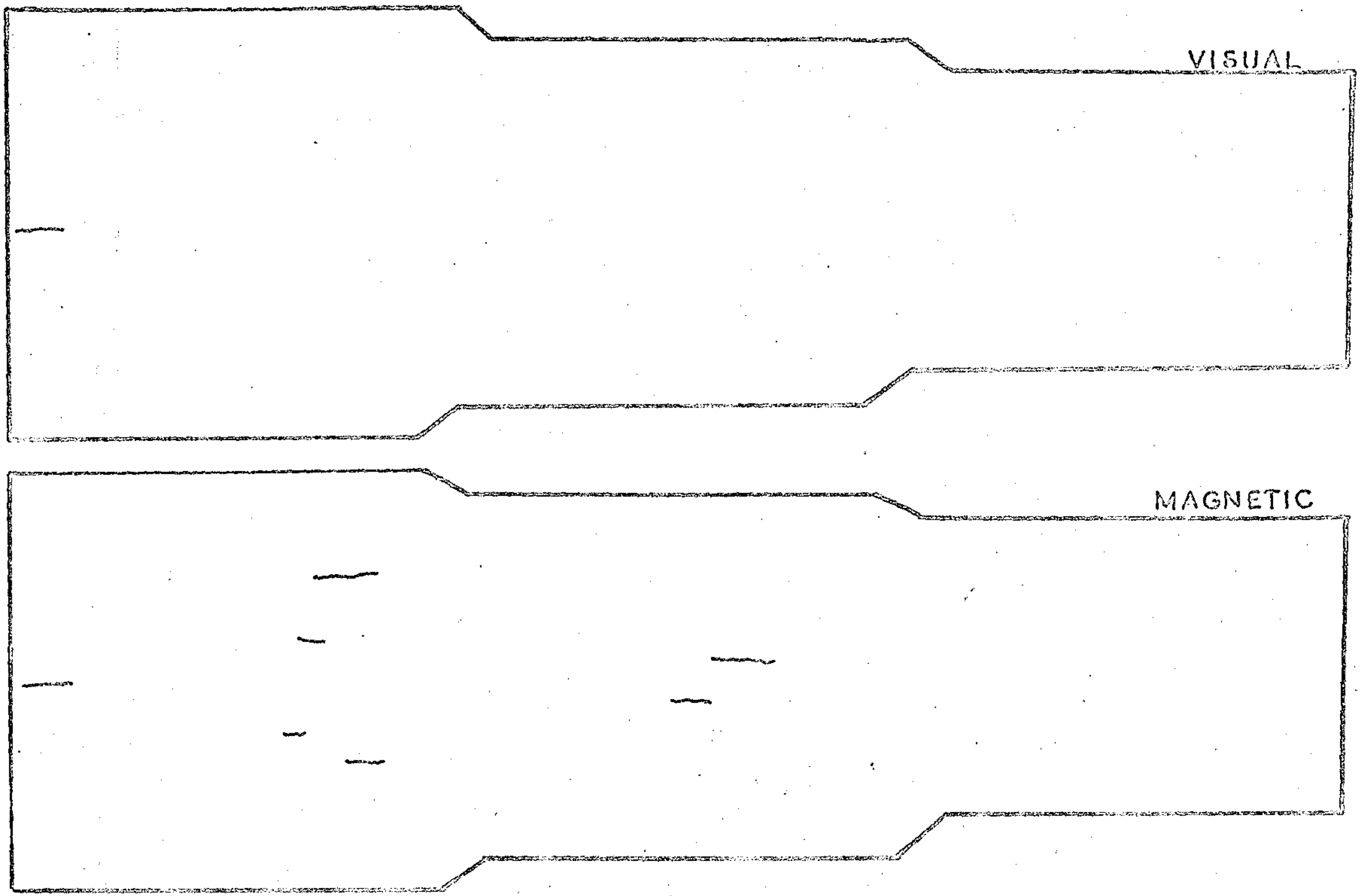
APPENDIX 21 CONTD.

SAMPLE 61 B 2
SAMPLE 63 B 2



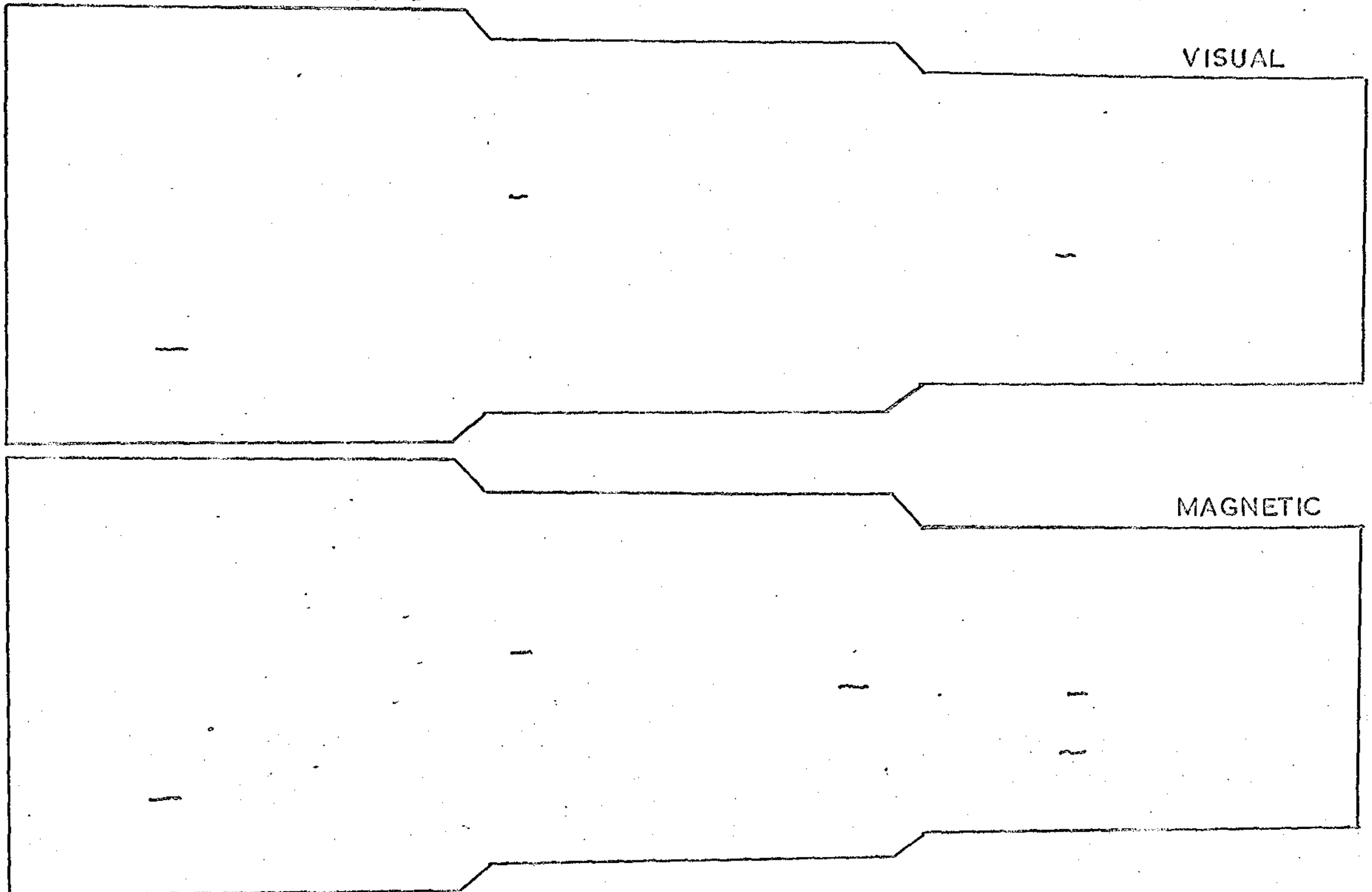
SAMPLE 63 B I
SAMPLE 61 B I

APPENDIX 21 CONTD.



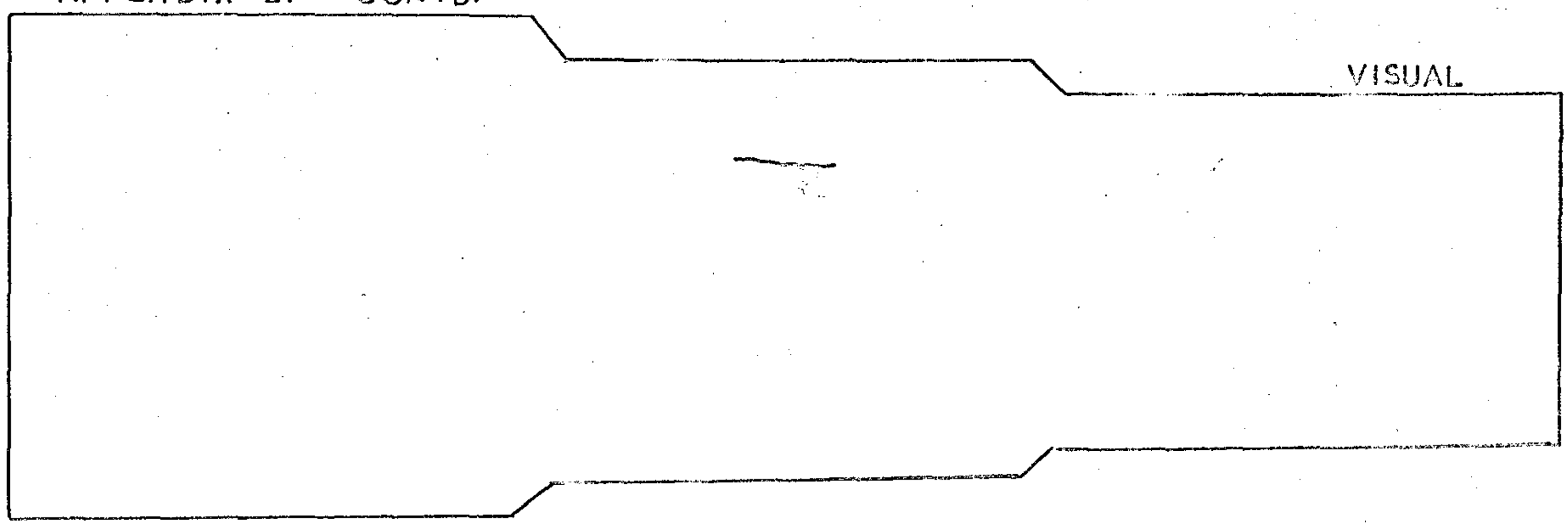
SAMPLE 61 B
SAMPLE 63 B

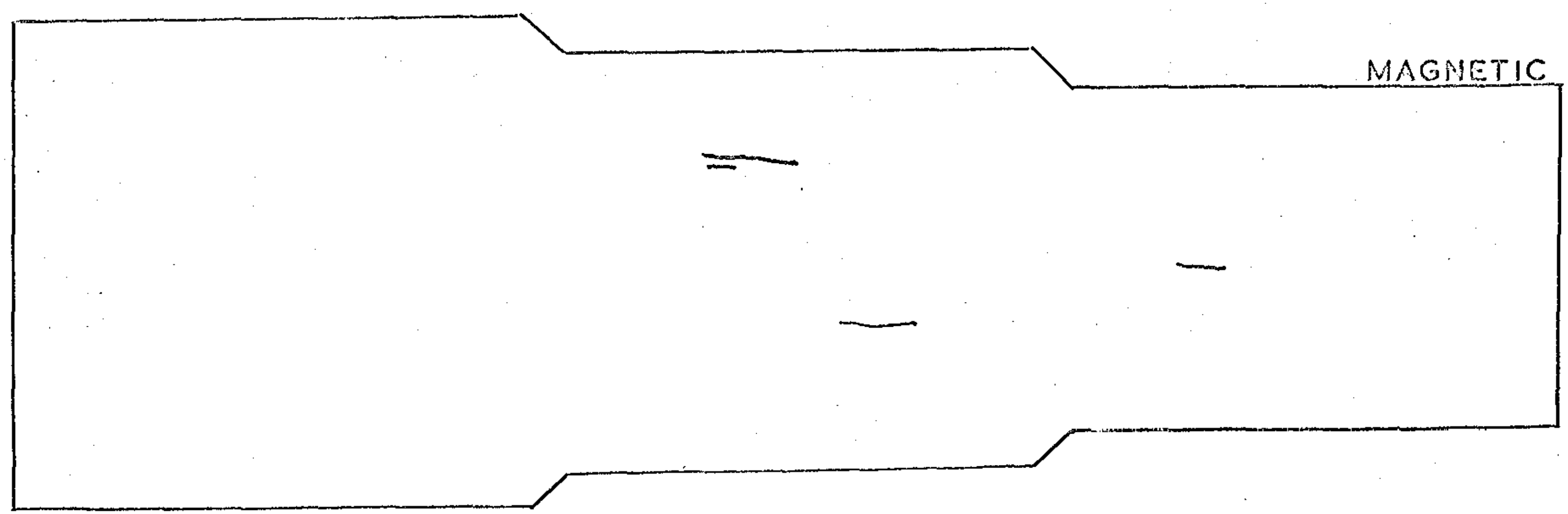
APPENDIX 21 CONTD.



SAMPLE 63
SAMPLE 61

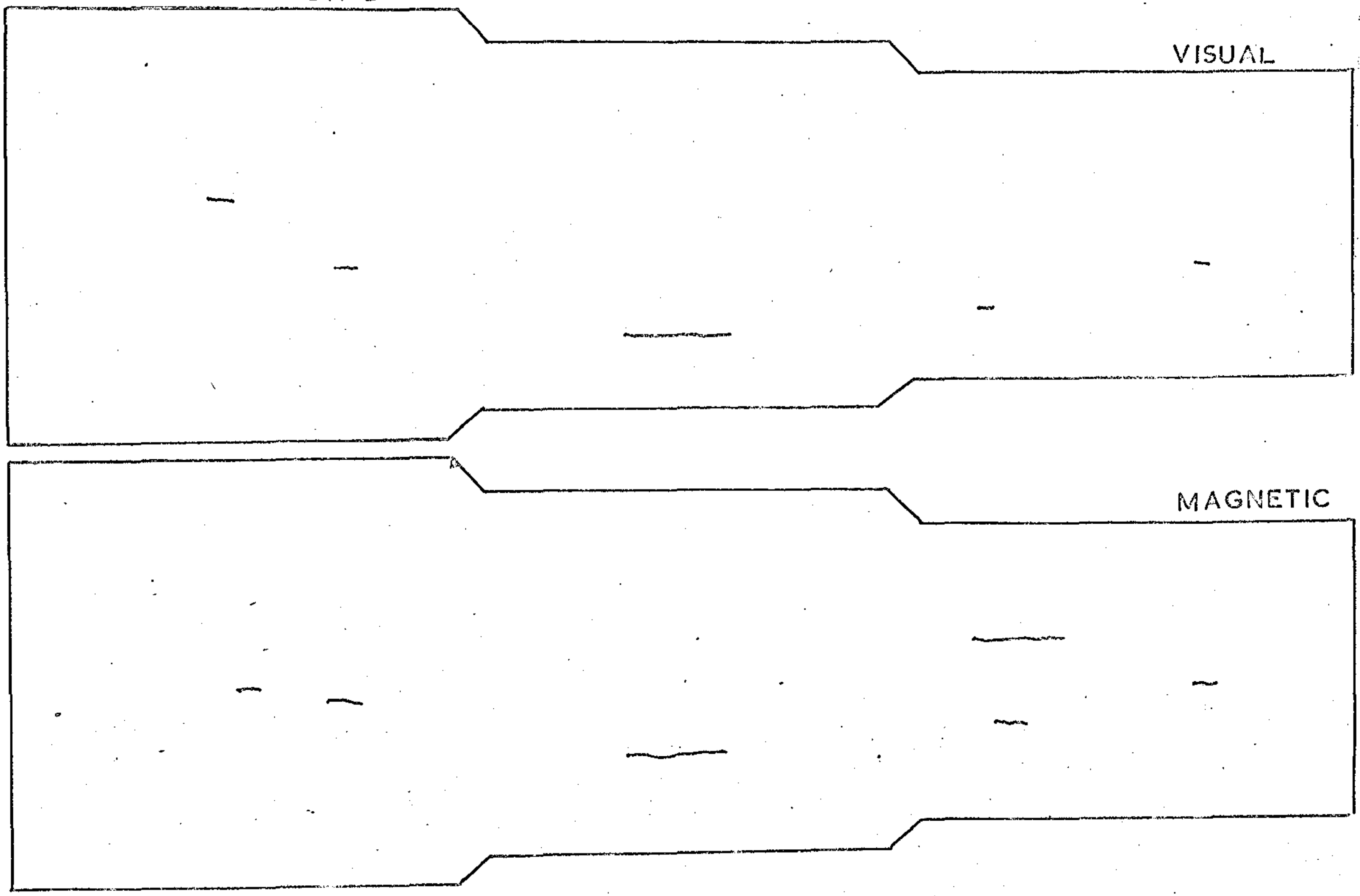
APPENDIX 21 CONTD.





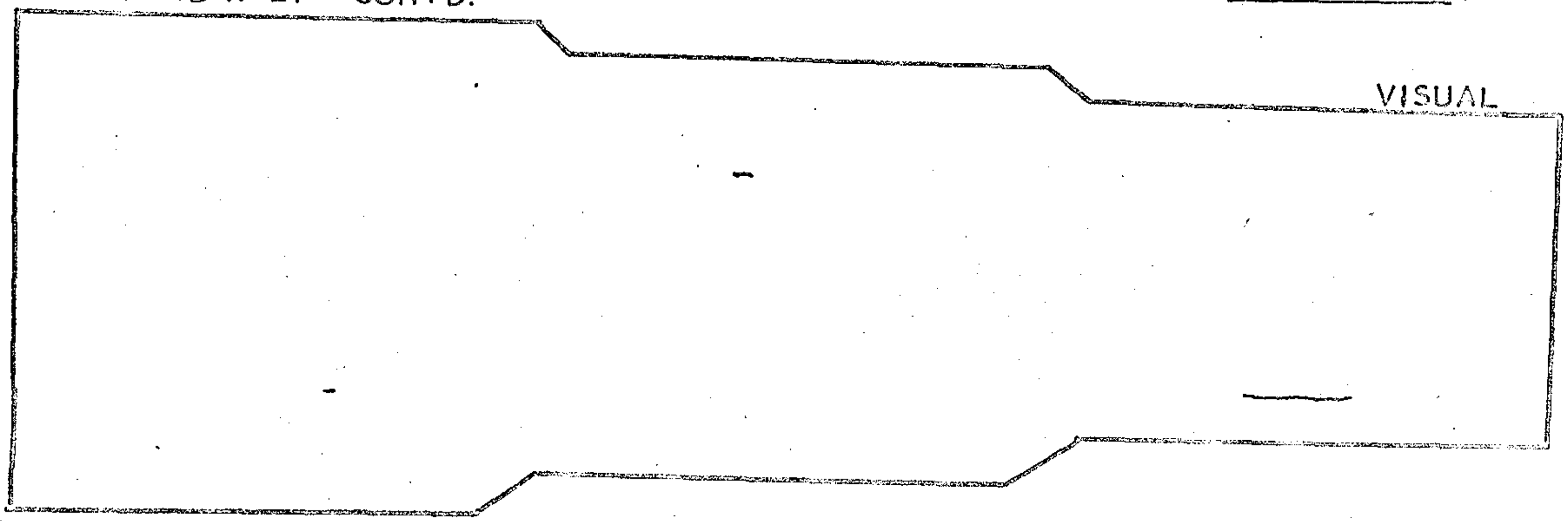
SAMPLE 61
SAMPLE 63

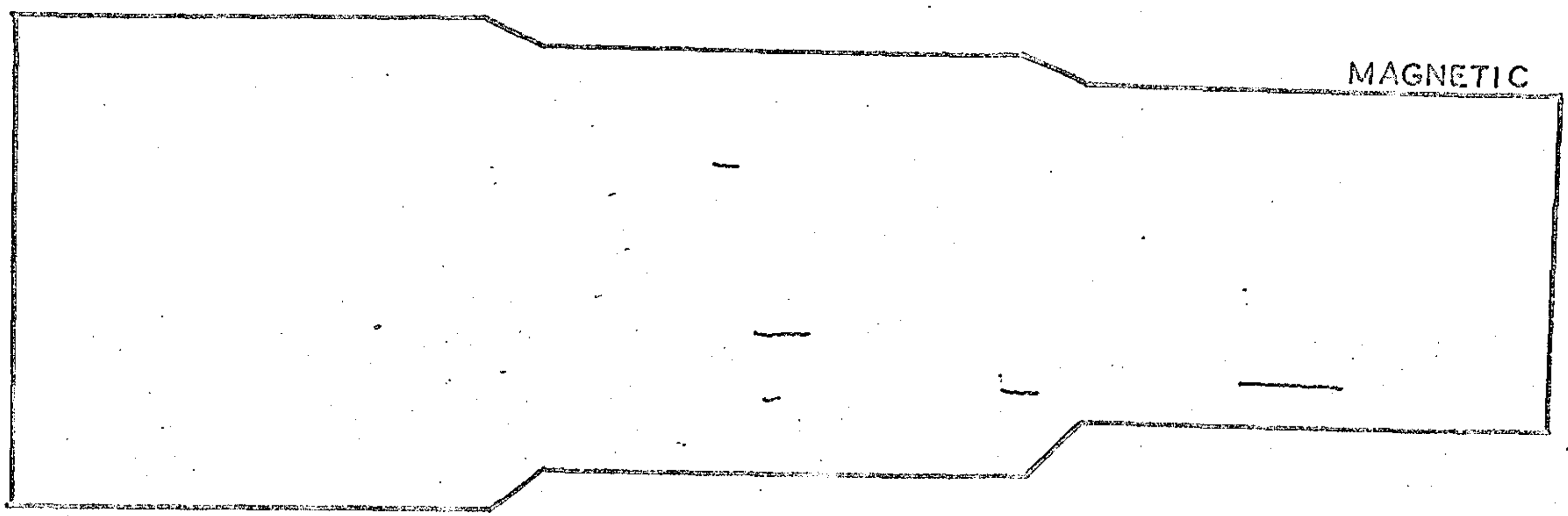
APPENDIX 21 CONTD.



APPENDIX 21 CONTD.

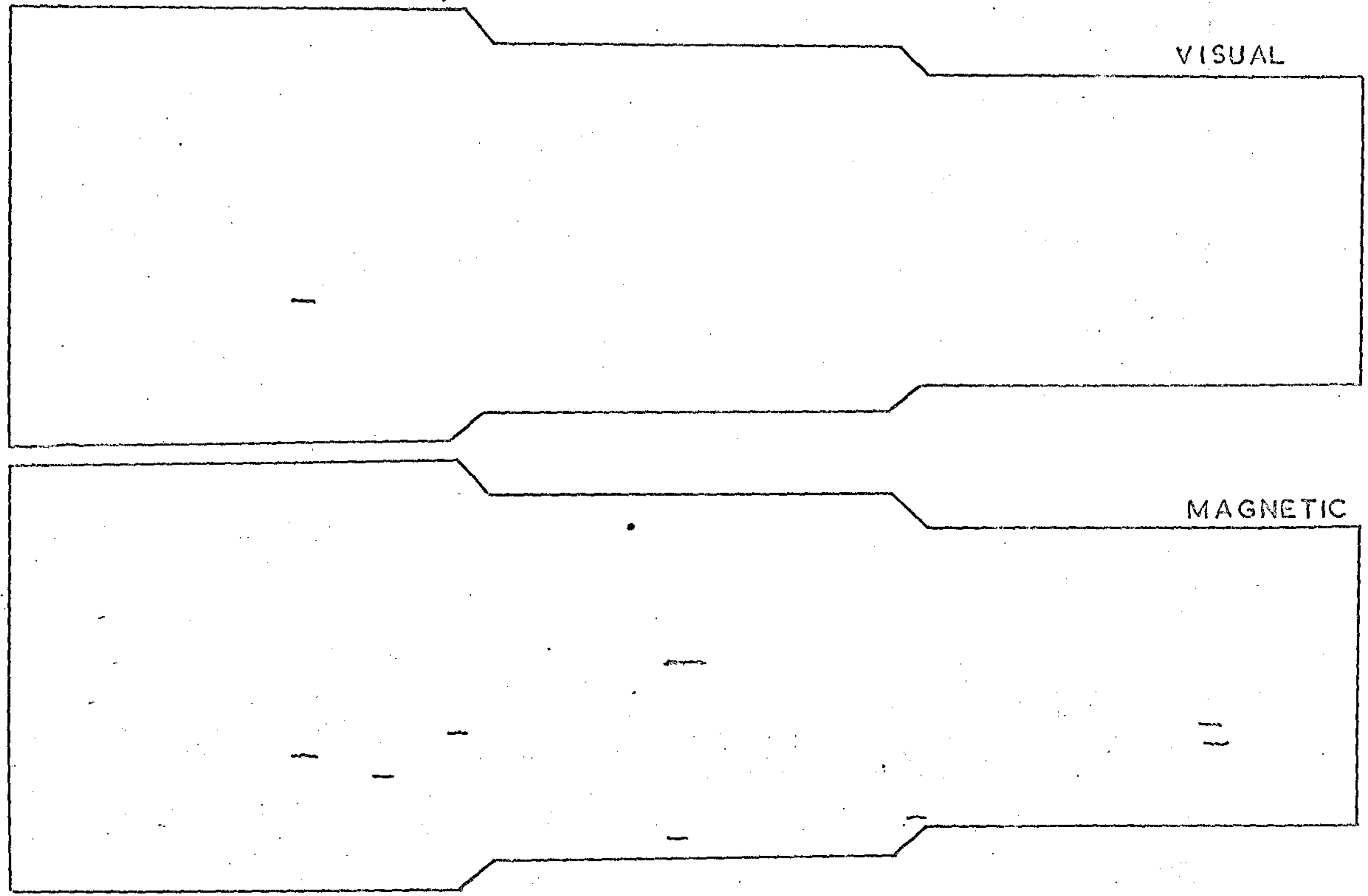
SAMPLE 61 T
SAMPLE 63 T





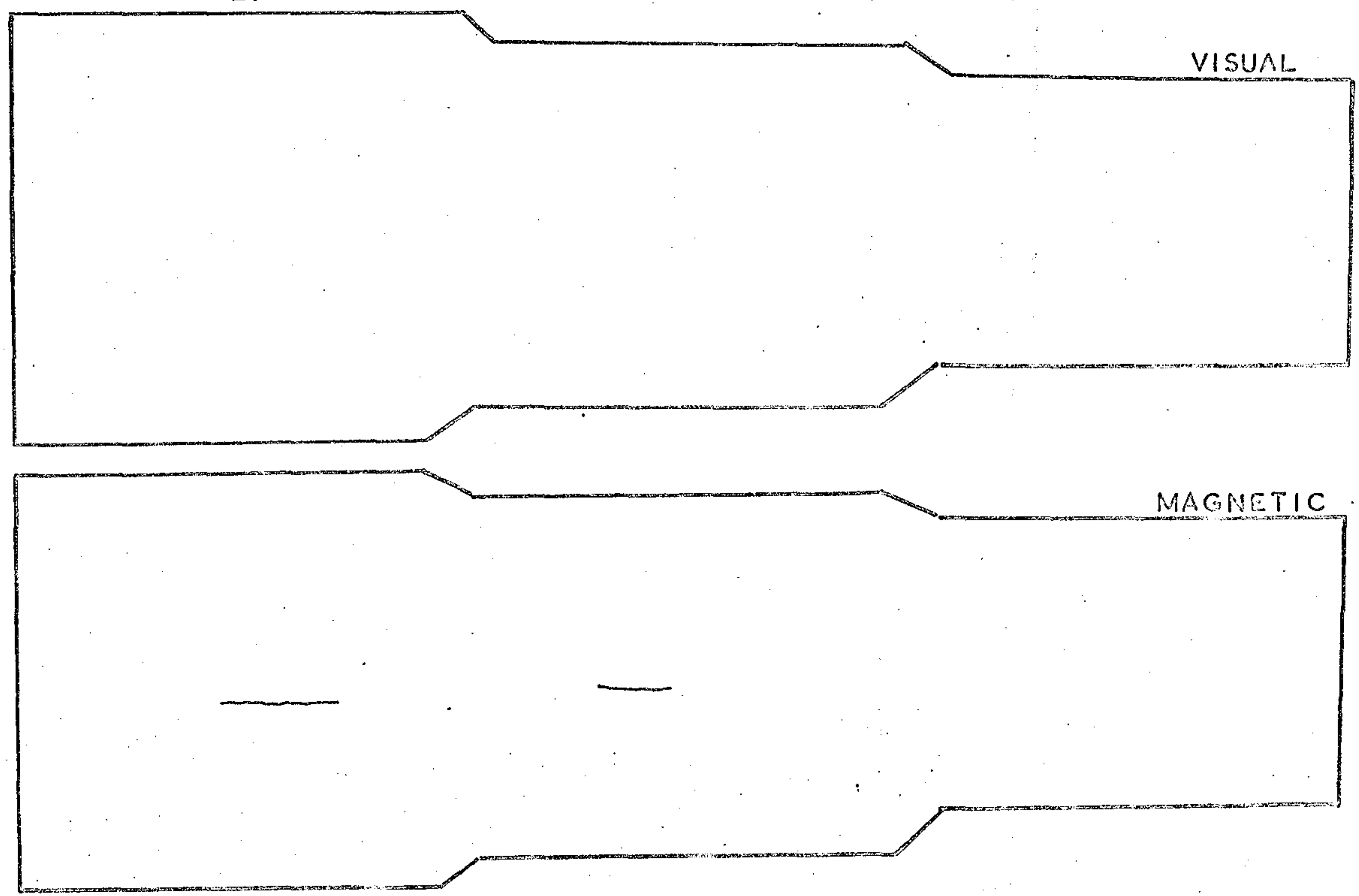
SAMPLE 61TT
SAMPLE 63TT

APPENDIX 21 CONTD.



APPENDIX 21 CONTD.

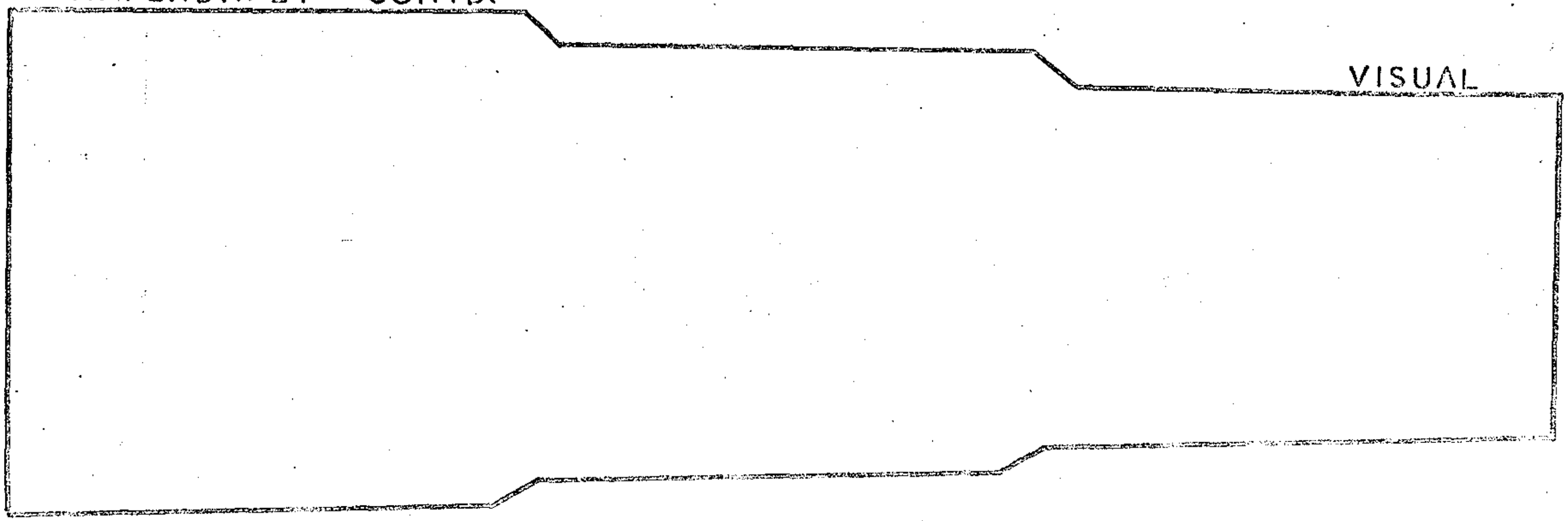
SAMPLE 62 B
SAMPLE 64 B



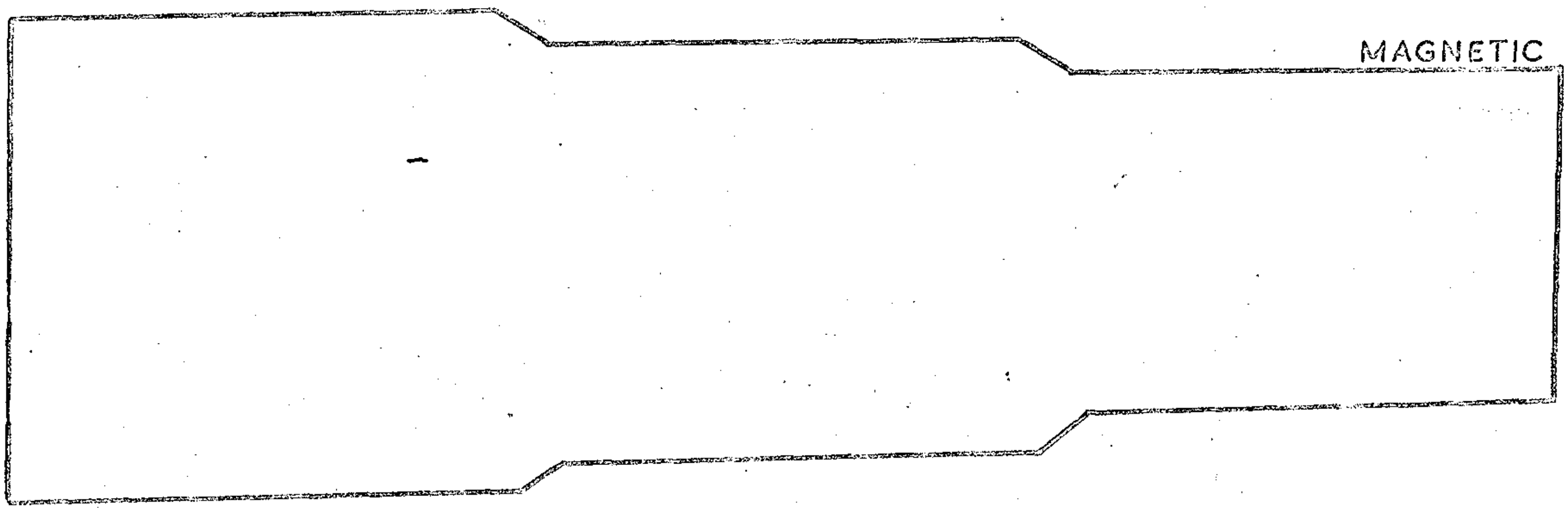
APPENDIX 21 CONTD.

SAMPLE 62
SAMPLE 64

VISUAL

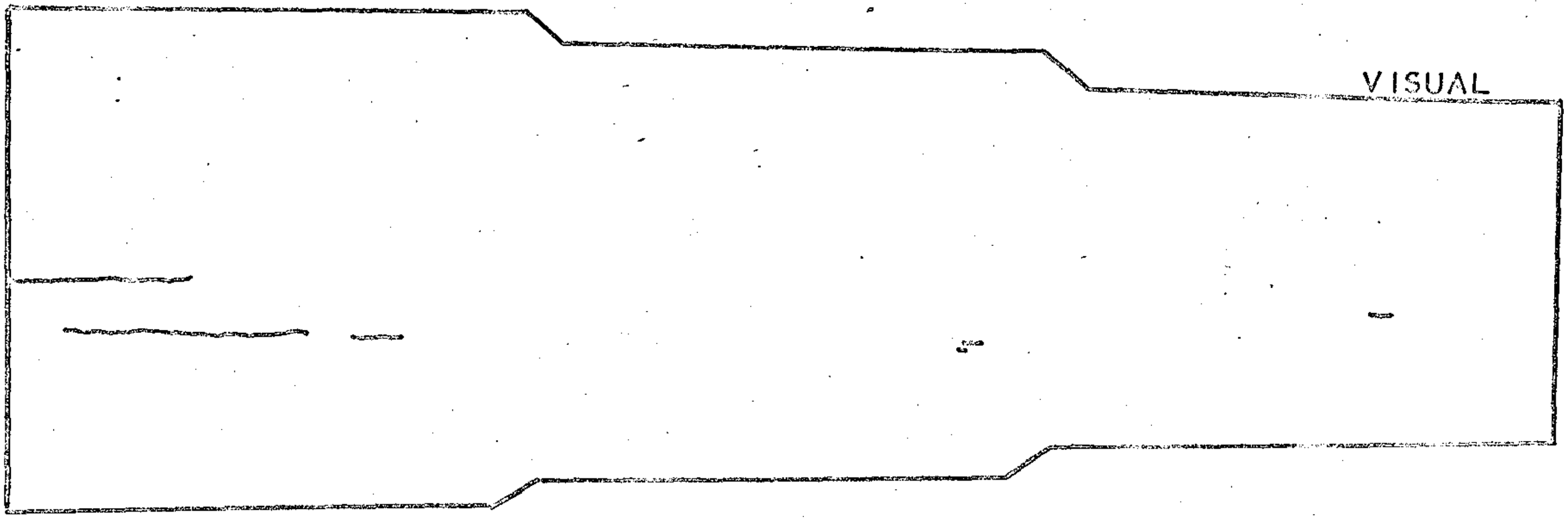


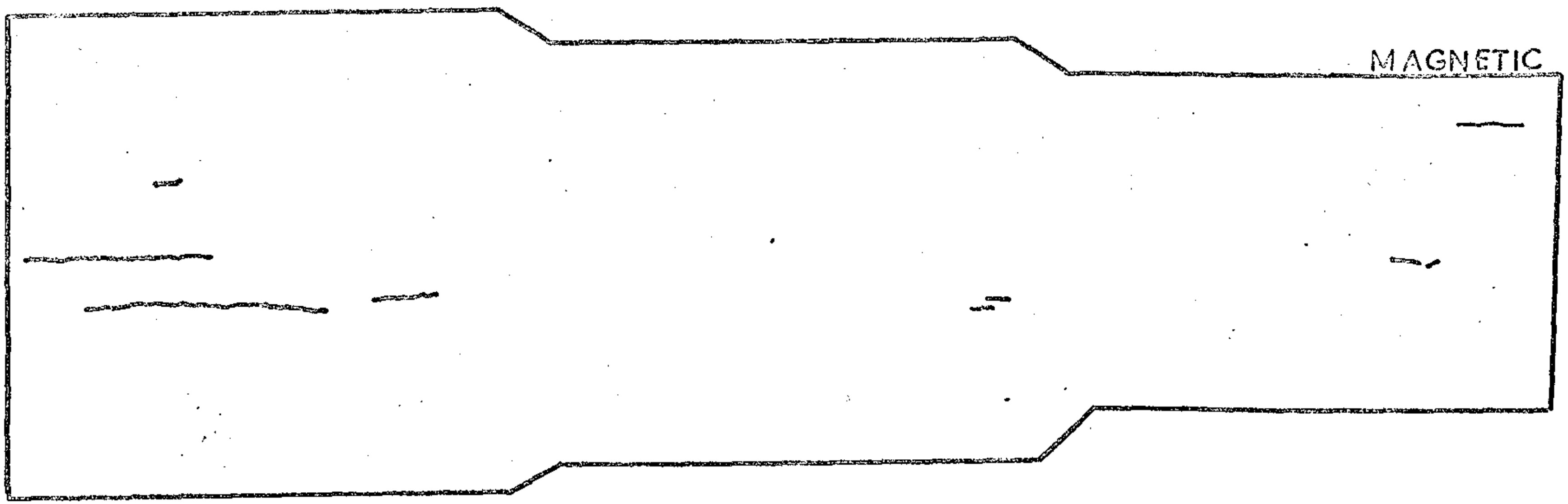
MAGNETIC



APPENDIX 21 CONTD.

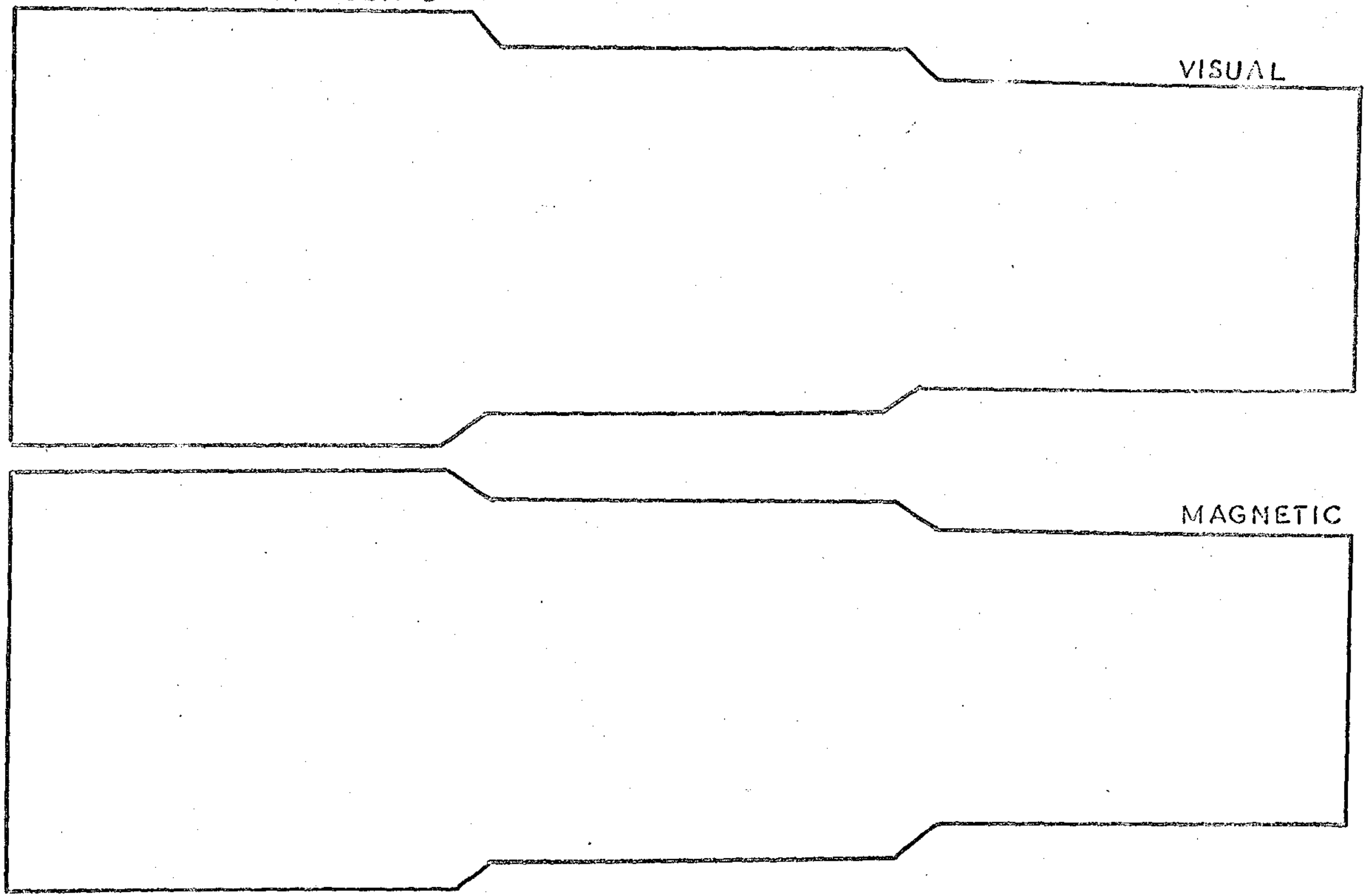
SAMPLE 64
SAMPLE 62





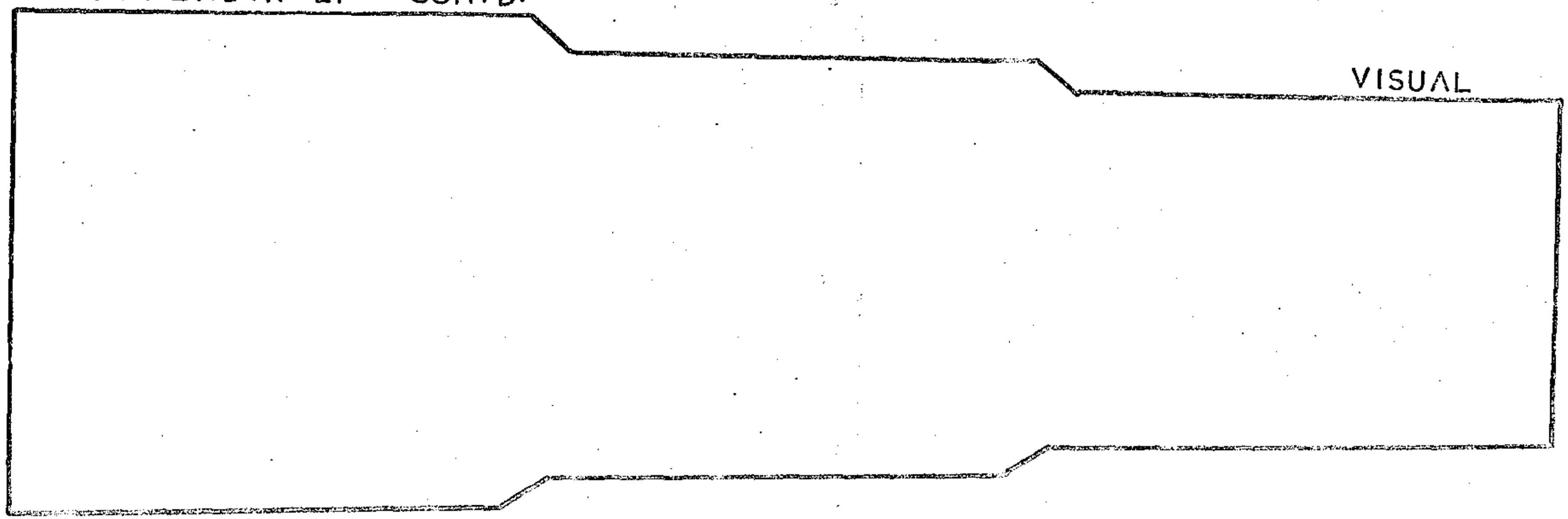
APPENDIX 21 CONTD.

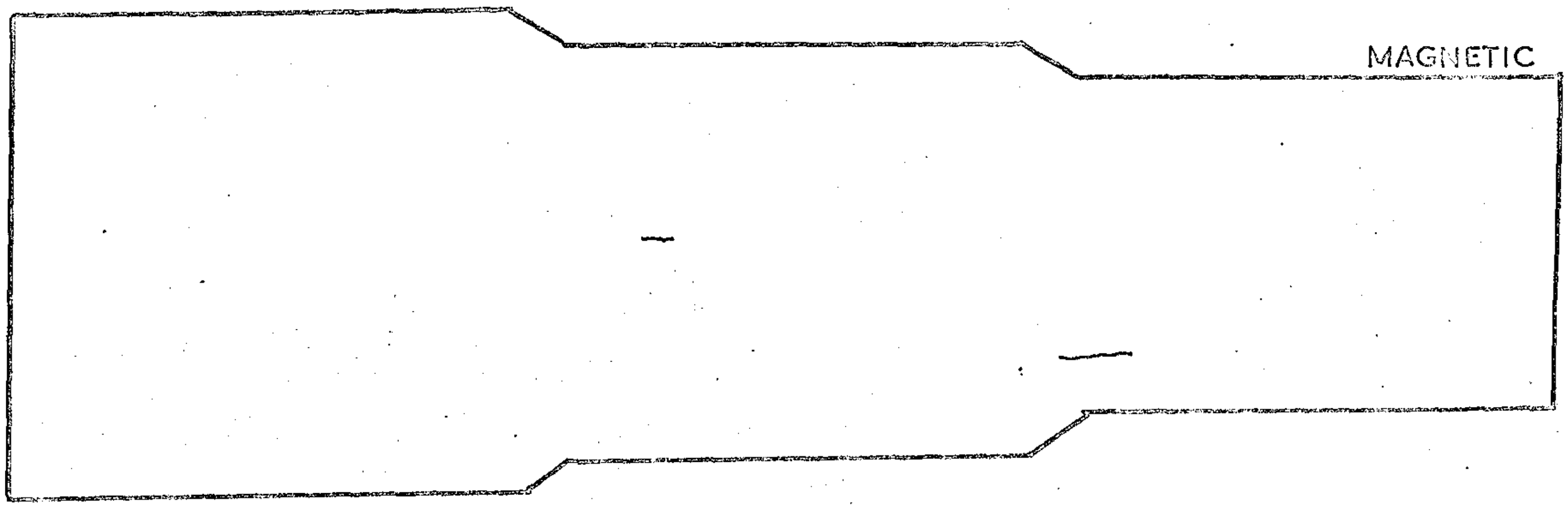
SAMPLE 62 T
SAMPLE 64T



SAMPLE 62TT

APPENDIX 21 CONTD.





APPENDIX 22

Mean oxide percentage area and projection counts for samples from top of ingot.

Spec. No.	Cast No.	Percentage field. Frequency per 100 fields. < 0.03	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%.	Mean. ($X10^{-4}$)	Std. Dev. ($X10^{-4}$)	Projection (total leng) mm. Mean.	Std. Dev'n.
1	3224	44	53	3	.	.	.	731	1004	60	64.
2	"	62	36	2	.	.	.	434	509	40	40.
3	"	48	50	2	.	.	.	490	453	68	60.
4	"	48	49	2	1	.	.	621	779	68	68.
5	2958	78	22	.	.	.	.	171	319	16	32.
6	"	64	36	.	.	.	.	478	563	56	52.
7	"	44	56	.	.	.	.	209	261	20	24.
8	"	64	32	2	.	.	.	438	428	44	36.
9	"	86	14	.	.	.	.	122	202	8	12.
10	P683	73	27	.	.	.	.	256	346	28	36.
11	"	80	20	.	.	.	.	294	573	24	36.
12	2969	62	35	3	.	.	.	408	675	40	64.
13	"	88	12	.	.	.	.	144	206	12	16.
14	"	62	37	1	.	.	.	368	404	40	44.
15	"	79	21	.	.	.	.	253	288	24	28.
16	P917	32	48	.	.	.	.	499	470	48	40.
17	"	81	18	1	.	.	.	257	453	24	44.
18	"	75	25	.	.	.	.	256	287	28	28.
19	"	84	16	.	.	.	.	189	209	20	20.
20	"	93	7	.	.	.	.	129	208	12	20.
21	"	94	6	.	.	.	.	136	146	16	20.
22	P792	98	2	.	.	.	.	71	103	8	12.
23	"	72	26	2	.	.	.	347	589	28	28.
24	"	76	24	.	.	.	.	273	308	24	28.
25	"	92	8	.	.	.	.	147	197	40	20.
26	3225	64	34	.	.	.	.	393	395	40	36.
27	"	57	39	3	1	.	.	367	425	40	36.
28	"	38	56	5	1	.	.	745	937	76	80.
29	"	65	35	.	.	.	.	318	347	28	28.
30	P902	50	46	4	.	.	.	511	527	44	44.
31	"	60	39	1	.	.	.	442	474	44	36.
32	T113	73	27	.	.	.	.	345	342	40	36.
33	"	64	35	1	.	.	.	383	443	40	40.
34	P894	68	31	1	.	.	.	345	339	44	40.
35	"	34	64	2	.	.	.	648	558	72	56.
36	"	63	36	1	.	.	.	392	388	40	36.
37	"	39	51	2	.	.	.	560	464	64	48.
38	3391	53	41	6	.	.	.	616	713	60	64.
39	"	62	38	.	.	.	.	362	347	36	32.
40	"	41	47	9	2	1	.	1064	1939	100	148.
41	"	64	36	.	.	.	.	372	358	44	40.
42	"	55	41	4	.	.	.	533	631	64	64.
43	P445	58	41	1	.	.	.	383	447	40	36.
44	"	71	28	1	.	.	.	327	572	32	40.
45	2387	86	14	.	.	.	.	135	234	13	20.
46	"	92	8	.	.	.	.	116	143	12	12.
47	"	59	40	1	.	.	.	317	387	36	36.
48	P200	80	19	1	.	.	.	200	478	12	40.
49	"	44	55	1	.	.	.	406	431	48	44.
50	"	51	47	2	.	.	.	371	450	40	44.
51	.	.	.	.	.	.	.	.	.	.	.
52	"	61	29	.	.	.	.	192	189	20	24.
53	"	81	19	.	.	.	.	177	312	16	28.

* Field size = 0.5 sq.mm.

APPENDIX 23

Mean oxide percentage area and projection counts for samples from middle of ingot.

Specimen No.	Cast No.	Percentage fields.								Projection (total leng)	
		Frequency per 100 fields *								mm.	
		< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	Mean. $(X10^{-4})$	Std.Dev. $(X10^{-4})$	Mean.	Std. Dev.
1	3224	30	59	10	1	.	.	929	1028	88	92.
2	"	33	54	12	1	.	.	946	1116	68	72.
3	"	55	44	1	.	.	.	431	408	56	48.
4	"	42	51	6	1	.	.	686	885	68	76.
5	2958	85	15	.	.	.	.	230	276	24	28.
6	"	48	49	2	.	.	.	545	583	60	60.
7	"	74	26	.	.	.	.	298	388	32	44.
8	"	84	16	.	.	.	.	204	284	20	28.
9	"	38	60	2	.	.	.	418	355	52	44.
10	P683	88	12	.	.	.	.	164	191	20	20.
11	"	75	24	1	.	.	.	254	602	20	40.
12	2969	41	54	5	.	.	.	639	534	68	44.
13	"	92	8	.	.	.	.	108	170	12	16.
14	"	78	21	1	.	.	.	237	318	24	28.
15	"	68	30	2	.	.	.	357	423	36	44.
16	P917	61	38	1	.	.	.	450	526	44	44.
17	"	88	12	.	.	.	.	198	317	20	32.
18	"	77	23	.	.	.	.	278	343	36	44.
19	"	67	32	1	.	.	.	336	387	.	.
20	"	87	12	1	.	.	.	177	320	20	20.
21	"	90	9	1	.	.	.	155	404	.	.
22	P.792	93	7	.	.	.	.	104	140	8	16.
23	"	68	28	4	.	.	.	295	466	32	40.
24	"	66	32	1	1	.	.	348	364	36	36.
25	"	87	13	.	.	.	.	166	209	20	28.
26	3225	18	64	17	1	.	.	1208	1159	120.	100.
27	"	56	40	4	.	.	.	504	608	52	52.
28	"	53	38	9	.	.	.	647	766	72	76.
29	"	56	42	2	.	.	.	712	746	.	.
30	P902	74	24	2	.	.	.	386	707	36	68.
31	"	41	52	7	.	.	.	757	825	76	84.
32	T113	54	39	6	1	.	.	695	1074	64	92.
33	"	54	44	3	.	.	.	525	571	44	52.
34	P.894	54	45	1	.	.	.	418	364	44	36.
35	"	51	48	1	.	.	.	406	411	40	40.
36	"	68	31	1	.	.	.	352	387	28	28.
37	"	29	70	1	.	.	.	663	452	68	40.
38	3391	62	34	4	.	.	.	517	694	48	64.
39	"	31	54	11	2	2	.	1356	2946	140	212.
40	"	55	36	7	2	.	.	684	1172	68	100.
41	"	51	31	17	1	.	.	952	1186	92	100.
42	"	41	50	9	.	.	.	737	786	72	68.
43	P.445	46	46	8	.	.	.	694	844	60	72.
44	"	58	26	10	2	1	.	1053	2537	80	136.
45	2387	69	31	.	.	.	.	196	191	20	24.
46	"	66	34	.	.	.	.	285	329	32	40.
47	"	75	23	2	.	.	.	265	417	24	40.
48	P200	80	20	.	.	.	.	172	258	16	28.
49	"	67	32	1	.	.	.	261	303	24	24.
50	"	40	59	1	.	.	.	425	408	40	36.
51		.	.	.	.	.	.	.	.	.	.
52	"	77	21	2	.	.	.	263	612	20	40.
53	"	82	18	.	.	.	.	147	200	12	20.

* Field area = 0.5 Sq.mm.

Mean oxide percentage area and projection counts for samples from one billet length from bottom.

Specimen No.	Cast No.	Percentage fields								Projection (total leng)	
		Frequency per 100 fields *								mm.	
		< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	mean ($X10^{-4}$)	Std. Dev ($X10^{-4}$)	Mean.	Std. Dev'n
1	3224	47	40	11	2	.	.	941	1420	92	124.
2	"	59	36	4	1	.	.	627	1165	56	92.
3	"	59	40	.	.	1	.	578	2159	56	88.
4	"	58	38	3	1	.	.	612	1162	56	92.
5	2958	47	48	5	.	.	.	378	446	44	48.
6	"	73	26	1	.	.	.	404	540	44	52.
7	"	70	30	.	.	.	.	273	317	28	32.
8	"	77	22	1	.	.	.	286	336	32	40.
9	"	28	64	7	1	.	.	750	722	68	52.
10	P683	61	32	6	1	.	.	.	.	60	124.
11	"	83	14	2	1	.	.	.	.	.	.
12	2969	63	33	4	.	.	.	418	610	52	84.
13	"	83	16	1	.	.	.	216	245	20	24.
14	"	72	28	.	.	.	.	333	368	32	32.
15	"	84	16	.	.	.	.	253	326	32	40.
16	P917	81	17	2	.	.	.	269	526	32	32.
17	"	86	12	2	.	.	.	236	382	32	52.
18	"	73	27	.	.	.	.	286	293	36	32.
19	"	83	16	.	1	.	.	330	1305	28	44.
20	"	79	20	1	.	.	.	334	473	44	36.
21	"	73	17	9	1	.	.	530	1120	48	60.
22	P792	85	13	1	1	.	.	318	1289	24	64.
23	"	77	22	1	.	.	.	281	349	24	24.
24	"	58	42	.	.	.	.	447	461	32	28.
25	"	83	15	2	.	.	.	265	601	24	52.
26	3225	31	59	5	3	2	.	1257	2456	104	144.
27	"	58	36	5	1	.	.	693	1388	64	88.
28	"	43	54	3	.	.	.	576	663	52	56.
29	"	79	19	2	.	.	.	291	571	28	56.
30	P902	76	23	1	.	.	.	268	388	24	36.
31	"	72	22	2	4	.	.	630	587	56	164.
32	T113	81	17	2	.	.	.	300	459	28	44.
33	"	77	22	1	.	.	.	301	532	28	36.
34	P894	69	30	1	.	.	.	387	590	44	52.
35	"	50	47	2	.	11	.	684	1502	56	76.
36	"	70	30	.	.	.	.	310	328	28	28.
37	"	51	49	.	.	.	.	434	308	44	32.
38	3391	44	46	9	2	.	.	1128	1807	104	124.
39	"	49	43	6	1	1	.	812	1736	72	112.
40	"	68	26	4	2	.	.	549	1104	56	80.
41	"	40	45	10	3	2	.	1274	2455	124	176.
42	"	29	59	9	3	.	.	1195	1650	104	124.
43	P445	74	20	5	1	.	.	518	1262	48	100.
44	"	49	44	3	3	1	.	887	1941	84	144.
45	2387	41	50	5	3	1	.	1049	2374	88	188.
46	"	34	59	7	.	.	.	779	901	44	56.
47	"	28	67	4	.	.	.	605	612	68	60.
48	P200	67	32	1	.	.	.	314	560	24	40.
49	"	50	50	.	.	.	.	491	1652	32	100.
50	"	61	36	2	.	1	.	478	1590	36	68.
51	"	28	68	3	1	.	.	561	863	52	64.
52	"	70	26	3	1	.	.	396	1091	32	72.
53	"	82	17	1	.	.	.	160	328	16	24.

* Field area = 0.5 Sq.mm.

APPENDIX 25

Mean oxide percentage area and projection counts for samples from bottom of ingot.

Specimen Coding	Cast No.	Percentage fields. Frequency per 100 fields* < 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	mean ($\times 10^{-4}$)	Std. Dev ($\times 10^{-4}$)	Projection. (total leng) mm. Mean	Std. Dev'n.
1	3224	43	47	8	2	.	.	794	3775	44	108.
2	"	63	34	3	.	.	.	568	697	60	56.
3	"	62	38	..	.	.	.	494	475	56	44.
4	"	53	45	2	.	.	.	477	643	48	64.
5	2958	58	39	2	1	.	.	195	529	20	40.
6	"	85	15	.	.	.	.	202	214	24	28.
7	"	81	19	.	.	.	.	234	639	24	52.
8	"	81	16	3	.	.	.	387	295	52	36.
9	"	61	38	1	.	.	.	369	335	40	32.
10	P.683	79	20	1	.	.	.	328	440	28	36.
11	"	64	36	.	.	.	.	354	361	12	16.
12	2969	72	28	.	.	.	.	303	355	36	44.
13	"	67	32	1	.	.	.	310	418	32	36.
14	"	61	36	2	1	.	.	433	733	44	68.
15	"	82	13	2	1	2	.	719	3229	52	168.
16	P917	87	12	.	.	.	.	409	2257	20	44.
17	"	55	45	.	.	.	.	406	338	60	48.
18	"	72	22	2	1	3	.	1120	3584	72	152.
19	"	65	23	4	2	4	2	2408	8840	128	308.
20	"	68	28	1	.	3	.	777	2501	60	120.
21	"	83	9	3	2	1	2	1169	4341	72	268.
22	P792	92	7	.	.	.	.	114	156	40	28.
23	"	80	20	.	.	.	.	227	311	24	32.
24	"	85	15	.	.	.	.	178	234	20	24.
25	"	72	27	1	.	.	.	344	428	28	24.
26	3225	69	30	1	.	.	.	301	294	36	28.
27	"	48	47	3	.	.	.	456	522	.	.
28	"	71	25	2	1	.	1	803	1067	68	68.
29	"	73	26	1	.	.	.	336	306	48	40.
30	P902	51	40	5	1	3	.	1138	3090	104	252.
31	"	76	18	4	.	2	.	612	1927	60	180.
32	T113	18	70	11	.	.	.	1083	846	124	80.
33	"	62	38	.	.	.	.	323	286	40	32.
34	P894	74	26	.	.	.	.	355	346	36	32.
35	"	60	39	1	.	.	.	187	252	20	28.
36	"	61	37	2	.	.	.	424	1301	44	100.
37	"	14	82	4	.	.	.	498	1354	60	136.
38	3391	31	65	4	.	.	.	796	738	84	72.
39	"	52	40	4	4	.	.	898	1804	88	156.
40	"	50	47	.	2	1	.	688	1758	76	124.
41	"	32	59	8	1	.	.	902	1033	96	80.
42	"	48	44	6	2	.	.	765	1390	72	80.
43	P445	68	25	5	1	1	.	713	575	84	64.
44	"	28	70	2	.	.	.	735	1988	52	92.
45	2387	48	51	1	.	.	.	402	490	44	48.
46	"	78	20	..	.	.	.	424	461	48	44.
47	"	64	29	5	2	.	.	944	600	92	48.
48	P200	69	29	1	1	.	.	367	882	32	56.
49	"	77	22	.	1	.	.	239	577	20	28.
50	"	76	22	.	.	.	.	435	1546	32	92.
51	"	81	19	.	.	.	.	233	239	24	28.
52	"	61	35	1	1	1	.	692	2640	40	94.
53	"	90	10	.	.	.	.	177	164	20	20.

APPENDIX 26

Mean oxide size distribution counts for samples from top of ingot.

Specimen Coding	Cast No.	Mean number/field(0.5 sq.mm) ≥ than				
		3.6 µm	10 µm	15 µm.	20 µm.	25 µm.
1	3224	3.46	0.77	0.21	0.08	0.06.
2	"	2.45	0.33	0.10	0.03	0.03.
3	"	3.98	0.13	0.02	0.01	0.01.
4	"	4.94	0.39	0.09	0.05	0.01.
5	2958	1.12	0.03	0.02	•	•
6	"	5.24	0.17	0.04	0.01	•
7	"	1.62	0.12	0.05	0.02	0.01.
8	"	3.30	0.22	0.01	•	•
9	"	0.93	0.05	0.03	•	•
10	P683	1.67	0.10	0.05	0.03	0.01.
11	"	1.24	0.02	•	•	•
12	2969	2.50	0.20	0.02	•	•
13	"	0.95	0.08	0.01	•	•
14	"	2.95	0.08	0.01	•	•
15	"	2.62	0.14	0.02	0.01	0.01.
16	P.917	3.62	0.43	0.15	0.04	0.01.
17	"	1.96	0.16	0.06	•	•
18	"	2.19	0.18	0.05	0.01	•
19	"	1.96	0.13	0.03	0.02	0.01.
20	"	1.59	0.04	0.02	0.01	0.01.
21	"	1.79	0.01	•	•	•
22	P792	0.67	0.01	•	•	•
23	"	2.19	0.22	0.10	0.07	0.06.
24	"	2.05	0.23	0.06	0.03	0.02.
25	"	1.43	0.07	0.01	•	•
26	3225	3.82	0.27	0.09	0.02	•
27	"	4.03	0.19	0.10	0:03	•
28	"	4.93	0.54	0.08	0.02	•
29	"	2.27	0.21	0.04	0.02.	0.01.
30	P.902	3.40	0.55	0.17	0.03	•
31	"	3.56	0.29	0.09	0.06	0.01.
32	T113	3.27	0.19	0.05	0.03	0.02.
33	"	3.62	0.29	0.09	0.01	0.01.
34	P.894	4.33	0.13	0.02	0.01	0.01.
35	"	5.23	0.49	0.12	0.05	0.01.
36	"	3.88	0.40	0.08	0.05	0.03.
37	"	5.76	0.41	0.05	•	•
38	3391	3.40	0.30	0.07	0.02	0.01.
39	"	3.97	0.48	0.16	0.03	0.02.
40	"	5.66	0.72	0.23	0.09	0.09.
41	"	3.81	0.18	0.06	•	•
42	"	4.83	0.32	0.08	0.04	0.02.
43	P.445	2.50	0.21	0.07	0.04	•
44	"	2.35	0.16	0.06	0.02	•
45	2387	1.14	0.14	0.05	0.01	•
46	"	1.28	0.07	0.02	•	•
47	"	3.14	0.30	0.09	0.05	0.01.
48	P200	0.88	0.27	0.05	•	•
49	"	4.26	0.34	0.08	0.02	0.01.
50	"	3.13	0.39	0.04	0.02	•
51	"	•	•	•	•	•
52	"	2.06	0.13	0.01	•	•
53	"	1.16	0.14	0.05	0.01	•

APPENDIX 27

Mean oxide dize distribution counts for samples from middle of ingot.

Specimen Coding.	Cast No.	Mean number /field(0.5 sq.mm) > than				
		3. 6µm.	10µm.	15µm.	20µm.	25µm.
1	3224	6.75	0.85	0.22	0.06	0.02.
2	"	4.86	1.41	0.47	0.18	0.08.
3	"	3.91	0.15	0.07	0.02	•
4	"	4.87	0.44	0.06	0.04	•
5	2958	2.17	0.07	0.01	•	•
6	"	4.24	0.24	0.04	•	•
7	"	2.30	0.07	0.01	0.01	0.01.
8	"	1.71	0.06	0.01	0.01	0.01.
9	"	5.29	0.21	0.04	0.01	•
10	P683	1.69	0.02	0.02	•	•
11	"	0.89	0.04	0.02	0.01	•
12	2969	4.41	0.57	0.14	0.05	0.01.
13	"	1.02	0.05	•	•	•
14	"	1.59	0.09	•	•	•
15	"	3.46	0.15	0.05	0.03	0.03.
16	P917	3.61	0.41	0.16	0.02	0.01.
17	"	1.98	0.09	0.01	0.01	0.01.
18	"	3.12	0.06	•	•	•
19	"	4.10	0.16	0.04	0.02	•
20	"	1.63	0.06	0.03	0.02	0.02.
21	"	1.26	0.12	0.01	•	•
22	P.792	0.86	0.03	•	•	•
23	"	2.72	0.22	0.06	•	•
24	"	2.99	0.23	0.03	•	•
25	"	1.70	0.06	•	•	•
26	3225	9.09	1.01	0.34	0.07	0.06.
27	"	4.16	0.37	0.11	0.03	0.02.
28	"	4.37	0.26	0.03	0.01	0.01.
29	"	3.16	0.07	0.04	0.01	•
30	P.902	2.76	0.27	0.04	0.02	•
31	"	5.91	0.51	0.15	0.07	0.01.
32	T113	4.66	0.52	0.19	0.14	0.09.
33	"	3.18	0.51	0.19	0.08	0.05.
34	P894	4.41	0.23	0.07	0.04	0.02.
35	"	2.46	0.25	0.07	0.02	•
36	"	2.10	0.28	0.10	0.04	0.04.
37	"	6.40	0.55	0.12	0.05	0.02.
38	3391	3.77	0.37	0.06	0.03	0.01.
39	"	9.10	0.61	0.22	0.09	0.06.
40	"	2.97	0.37	0.06	0.02	•
41	"	5.32	0.89	0.21	0.07	0.01.
42	"	4.56	0.49	0.09	0.04	0.01.
43	P445	4.36	0.50	0.06	0.03	•
44	"	4.30	0.82	0.35	0.21	0.12.
45	2387	2.16	0.0[illegible]	0.01	•	•
46	"	2.63	0.15	0.06	•	•
47	"	2.31	0.29	0.15	0.03	0.01.
48	P200	1.66	0.13	0.05	•	•
49	"	2.49	0.21	0.03	0.01	•
50	"	4.49	0.62	0.14	0.02	0.01.
51	"	•	•	•	•	•
52	"	1.39	0.28	0.14	0.03	0.01.
53	"	1.16	0.10	0.06	0.02	•

Mean oxide size distribution counts for samples from one billet length from bottom of ingot.

Specimen Coding.	Cast No.	Mean number /field(0.5 sq.mm) > than				
		3.6 μm.	10 μm.	15 μm.	20. μm.	25. μm.
*1	3224	5.14	0.80	0.19	0.05	0.01.
2	"	3.50	0.48	0.14	0.04	0.01.
3	"	2.96	0.21	0.13	0.10	0.04.
4	"	3.77	0.40	0.11	0.04	.
5	2958	2.59	0.08	0.02	0.02	.
6	"	2.71	0.09	0.01	0.01	0.01.
7	"	2.63	0.14	0.03	0.03	.
8	"	2.32	0.07	0.01	.	.
9	"	6.24	0.65	0.20	0.09	0.05.
10	P683	4.69	0.29	0.04	0.01	0.01.
11	"	.	.	.	.	.
12	2969	4.11	0.10	0.01	0.01	.
13	"	1.97	0.07	0.03	0.01	0.01.
14	"	2.61	0.23	0.05	0.02	.
15	"	1.91	0.09	0.04	.	.
16	P917	1.31	0.29	0.02	0.02	0.01.
17	"	3.15	0.05	0.01	.	.
18	"	3.25	0.09	0.01	.	.
19	"	2.46	0.07	0.02	0.01	0.01.
20	"	6.17	0.12	0.05	0.03	0.03.
21	"	5.02	0.31	0.17	0.14	0.09.
22	P792	1.65	0.19	0.05	0.02	0.01.
23	"	2.10	0.24	0.07	0.03	0.03.
24	"	1.99	0.40	0.11	0.04	0.02.
25	"	2.12	0.13	0.03	.	.
26	3225	6.95	0.63	0.20	0.06	0.03.
27	"	4.87	0.48	0.13	0.08	0.03.
28	"	3.68	0.49	0.10	0.02	0.01.
29	"	1.83	0.20	0.04	0.01	.
30	P902	2.07	0.23	0.07	0.03	0.01.
31	"	3.97	0.48	0.13	0.04	0.01.
32	T113	2.55	0.17	0.03	.	.
33	"	2.36	0.20	0.07	0.02	0.02.
34	P.894	4.81	0.27	0.07	0.01	0.02.
35	"	4.28	0.51	0.21	0.05	0.02.
36	"	2.58	0.20	0.09	0.07	0.03.
37	"	4.98	0.33	0.07	0.01	.
38	3391	8.25	0.70	0.34	0.16	0.09.
39	"	5.37	0.61	0.15	0.05	0.02.
40	"	2.83	0.34	0.18	0.04	0.03.
41	"	8.73	0.82	0.22	0.11	0.07.
42	"	6.38	0.97	0.34	0.16	0.07.
43	P445	2.43	0.[illegible]2	0.09	0.03	.
44	"	4.69	0.53	0.13	0.02	0.01.
45	2387	6.01	1.47	0.50	0.15	0.03.
46	"	3.33	1.30	0.93	0.40	0.15.
47	"	6.93	0.62	0.18	0.02	.
48	P200	1.79	0.35	0.08	0.01	.
49	"	1.22	0.37	0.06	0.05	0.02.
50	"	2.10	0.32	0.11	0.05	0.02.
51	"	5.44	0.65	0.18	0.04	0.01.
52	"	1.82	0.27	0.13	0.06	0.03.
53	"	1.16	0.09	0.04	.	.

Mean oxide size distribution counts for sample from bottom of ingot.

Specimen Coding.	Cast No.	Mean number/field(o.5.sq.mm.) > than				
		3.6 μm.	10. μm.	15 μm.	20. μm.	25. μm.
1	3224	2.73	0.46	0.11	0.07	0.07.
2	"	5.45	0.29	0.06	0.02	0.01.
3	"	4.68	0.27	0.07	0.01	.
4	"	3.61	0.25	0.08	0.01	.
5	2958	1.23	0.06	0.02	0.01	.
6	"	2.09	0.06	0.01	.	.
7	"	1.54	0.08	0.01	.	.
8	"	4.44	0.06	.	.	.
9	"	3.73	0.24	0.03	0.01	.
10	P683	2.51	0.24	0.09	0.02	.
11	"	1.23	0.05	0.02	0.01	.
12	2969	3.12	0.11	0.03	.	.
13	"	2.49	0.15	0.01	0.01	.
14	"	2.91	0.25	0.04	.	.
15	"	2.72	0.29	0.06	0.06	0.04.
16	P917	1.81	0.15	0.07	0.01	0.01.
17	"	4.29	0.07	0.01	.	.
18	"	4.82	0.47	0.26	0.15	0.08.
19	"	5.58	1.28	0.92	0.64	0.60.
20	"	4.25	0.34	0.17	0.11	0.04.
21	"	2.82	0.82	0.37	0.17	0.13.
22	P792	4.36	0.19	0.06	0.03	.
23	"	1.84	0.12	0.01	0.01	.
24	"	1.56	0.08	.	.	.
25	"	2.45	0.34	0.17	0.06	0.04.
26	3225	3.64	0.08	0.01	0.01	.
27	"	3.21	0.39	0.15	0.02	0.01.
28	"	4.28	0.54	0.25	0.13	0.08.
29	"	3.31	0.11	0.02	0.02	0.01.
30	P902	6.16	1.00	0.36	0.08	0.04.
31	"	4.09	0.48	0.08	0.02	0.01.
32	T113	7.04	0.57	0.19	0.10	0.06.
33	"	3.43	0.14	0.04	0.02	.
34	P894	3.24	0.55	0.14	.	.
35	"	2.03	0.19	0.05	0.02	.
36	"	2.97	0.15	0.08	0.02	0.02.
37	"	4.97	0.51	0.19	0.06	0.01.
38	3391	5.45	0.40	0.19	0.08	0.03.
39	"	4.56	0.49	0.09	0.02	0.01.
40	"	5.51	0.29	0.09	0.05	0.03.
41	"	6.97	0.48	0.19	0.10	0.02.
42	"	5.08	0.48	0.13	0.09	0.05.
43	P445	8.41	0.32	0.04	0.02	0.01.
44	"	2.94	0.31	0.14	0.06	0.03.
45	2387	4.06	0.25	0.02	0.02	0.01.
46	"	4.04	0.22	0.04	0.03	0.01.
47	"	8.66	0.95	0.21	0.08	0.03.
48	P200	2.25	0.39	0.17	0.04	0.01.
49	"	1.66	0.17	0.06	0.04	.
50	"	1.05	0.16	0.09	0.04	0.02.
51	"	2.41	0.21	0.06	0.01	.
52	"	2.69	0.87	0.23	0.09	0.02.
53	"	1.65	0.04	0.02	0.01.	.

Table 1

Summary of Inclusion Types and their Effects

Type	Origin	Nature at working temperatures	Final shape	Distribution	Effects	
					Good	Adverse
Sulphides	Reaction with Mn with S in solution	Plastic	Smooth, elongated	Fairly uniform	Greatly improved machinability	Hot-shortness. Bursting in forging. Reduced ductility. Fatigue properties unaffected.
Refractory inclusions (e.g. high melting point silicates)	Exogenous and/or indigenous	Brittle	Spherical or broken up	Largely unpredictable	None	Stress raisers, especially in fatigue. Cause tool chipping. Lower machinability.
Plastic inclusions (e.g. low melting-point silicates)	"	Mainly plastic	Stringers	"	"	Stress raisers, surface defects, lower machinability.
Fine inclusions (e.g. oxides)	Deoxidation or grain size control	Non-plastic	Angular to spherical	Frequently as clusters	"	No major mechanical effects. Abrasive toolwear. Reduced cutting speeds.
None	e.g. vacuum melted & cast	-	-	-	Max. mechanical properties, especially ductility and fatigue	Tool welding, poor machinability.

Table 2

Commercial Instruments for Inclusion Assessment

Manufacturer and country of origin	Instrument	Remarks
Rank Cintel Ltd. U.K.	Flying-spot Particle Resolver	Uses transmitted light, therefore necessary to first record inclusions on 35 mm film. Semi-automatic. Image inspected line by line.
	Flying-spot microscope	Transmission version adapted for reflected light and used in conjunction with Vickers' projection microscope. Semi-automatic. Not under commercial development.
Image Analysing Computers Ltd. (A subsidiary of Metals Research Ltd.) U.K.	Quantitative TV Microscope - Model A	Uses TV technique. Image inspected line by line. Two monitors, one for displaying image to be analysed; other for displaying detected image being measured. Now obsolete. Semi-automatic.
	Quantimet - Model B	Improved version of Model A. Semi-automatic, fields selected manually and results recorded by operator. Commercially available from 1964.
	Quantimet - Model B	Fully automatic with usual computer peripherals. Manufactured from 1967.
	Quantimet-720	Improved version of Model B. Better resolution detection, counting circuits and computer peripherals. Commercially available from 1969.
Leitz Instruments, Ltd. East Germany.	Integramat	First displayed at Labex Exhibition 1969. Uses TV technique similar to Quantimet Model B.
Carl Zeiss Ltd. West Germany.	Micro-Videomat	Details first released in 1970. Uses TV technique similar to Quantimet and Integramat.
Union Optical Co. of Japan.	Scanning Microscope Model ASM-1	Details first released in 1966-67. Uses photomultiplier. Specimen scans, fixed optics.

continued....

Table 2 [contd.]

Manufacturer and country of origin	Instrument	Remarks
Hilger and Watts. U.K.	TI-Hilger Automatic Inclusion Counter	Introduced in 1966-67. Fixed optics. Specimen scans using photomultiplier.
FERCO U.S.A.	Ameda	Used mainly for counting volume fraction of phases in minerals. Used for counting inclusions but not very satisfactory. Fixed optics, specimen scans.
Tube Investments Research Laboratories, U.K.	Automatic Inclusion counter, sizer and identifier	Based on the electron micro-probe analyser. Fully automatic. Not under commercial development.
Vickers Instrument Company, Ltd. U.K.	Automatic Inclusion Classifier	An electron optical counter without X-ray indentification. Uses back scatter of electrons to form image which is then classified into grades and types of inclusions.
"	Coulter Counter	Used for counting particles of inclusions in steel residue. Not used generally for inclusion assessment.

Table 3

Reproducibility attained over four and half hours when measuring oxide inclusions in same field of view

PARAMETER	Mean and standard deviation			
	11.50 to 12.20 hrs.	13.10 to 13.40 hrs.	15.05 to 15.35 hrs.	16.50 to 17.20 hrs.
Percentage area	0.175 $\pm$ 0.004	0.176 $\pm$ 0.005	0.167 $\pm$ 0.006	0.165 $\pm$ 0.006
Total count	11 $\pm$ 0.33	12 $\pm$ 0.40	11 $\pm$ 0.036	10 $\pm$ 0.50
No. of determinations	200	200	200	200

Table 4

Reproducibility attained at the beginning of the eight month test period when counting oxide inclusions in same field of view

Parameter	Oxide		Oxide		Manganese sulphide		Standard specimen (Black spheres)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Percent area	1.40	0.014	0.77	0.026	2.97	0.036	19.25	0.089
Total number	54	2.400	25	0.520	111	2.470	48	0
Size distribution (No.> than)								
5 μm	27	0.830	5	0	111	2.660	48	0
10 μm	2	0	4	0	111	1.900	48	0
15 μm	1	0	1.9	0	10	1.000	48	0
20 μm	1	0	0	0	9	0	48	0
Total projection (No. of lines)	226	3.800	137	1.610	405	3.500	746	1.670
Size of Features on TV Monitor	1 to 4 mm		1 to 4 mm		1 to 15 mm		10 mm	

Table 5

Reproducibility attained at the end of the eight month test period when counting oxide inclusions in the same field of view

Parameter	Oxide (field 1)		Oxide (field 2)		Manganese sulphide		Standard specimen (Black spheres)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Percent area	1.48	0.016	0.81	0.020	2.60	0.031	19.30	0.09
Total number	58	2.7	30	0.500	90	2.100	48	0
Size distribution (No. > than)								
5 μm	20	0.600	3	0	80	2.000	48	0
10 μm	1	0	1	0	71	1.600	48	0
15 μm	0	0	0	0	0	0	48	0
20 μm	0	0	0	0	0	0	48	0
Total projection (No. of lines)	206	3.00	142	1.800	396	3.800	745	1.680
Size of features on TV monitor	1 to 4 mm		1 to 4 mm		1 to 17 mm		10 mm	

Table 6

Typical errors in using both detection systems simultaneously

Description of image analysed	Detection	Percent area	Parameter: Total number	Parameter: Number larger than 15 μm
Oxide inclusions No sulphide	1 (oxide)	0.75	9	2
	2* (sulphide)	0.81	9	2
Difference as percent		8.6	0	0
Oxide inclusions No sulphide	1 (oxide)	1.00	2	1
	2* (sulphide)	1.18	2	1
Difference as percent		18.0	0	0
Oxide inclusions No sulphide	1 (oxide)	0.22	3	2
	2* (sulphide)	0.26	3	2
Difference as percent		18.4	0	0
Oxide inclusions No sulphide	1 (oxide)	0.01	2	0
	2 (sulphide)	0.02	2	0
Difference as percent		100.0	0	0

*No sulphides in fields measured but detection 2 set to correspond to sulphide contrast.

Table 7

Reproducibility attained by two operators when setting the focus of the same image (inclusions) by two methods, microscope and TV monitor

Method of focusing	Operator	Field 1 (MnS)			Field 2 (Al_2O_3)			Field 3 (Al_2O_3+MnS)			Field 4 (MnS Free-cutting steel)		
		Mean area	Std. devn.	Coeff. of var.	Mean area	Std. devn.	Coeff. of var.	Mean area	Std. devn.	Coeff. of var.	Mean area	Std. devn.	Coeff. of var.
TV Monitor	1	0.28	0.016	5.7	0.068	0.004	5.9	0.702	0.037	5.3	1.11	0.009	0.9
	2	0.29	0.009	3.1	0.073	0.008	10.9	0.720	0.014	2.0	1.10	0.008	0.8
Microscope	1	0.29	0.007	0.007	0.076	0.003	4.0	0.730	0.016	2.2	1.10	0.008	0.8
	2	0.31	2.4	2.3	0.079	0.003	3.8	0.700	0.028	4.0	1.10	0.008	0.8

Grand summary

Method of focusing	Operator	Mean	Standard deviation	Coefficient of variation
TV Monitor	1	0.540	0.0165	4.45
	2	0.546	0.0093	4.20
Microscope	1	0.549	0.0085	2.35
	2	0.550	0.0115	2.73

Table 8

Reproducibility attained by three operators when adjusting the threshold level on the same inclusions using three different methods, A, B and C

Method	Statistic	Operator						Mean of operators 1, 2 and 3	
		1		2		3			
		Threshold setting	Volume fraction	Threshold setting	Volume fraction	Threshold setting	Volume fraction	Threshold setting	Volume fraction
A	Mean	6.47	1.14	6.64	1.46	6.67	1.47	6.66	1.36
	Std. deviation	0.130	0.173	0.105	0.174	0.104	0.184	0.113	0.18
	Coeff. of variation as percent of mean	2.01	15.17	1.59	11.90	1.56	12.50	1.72	13.17
B	Mean	6.60	1.56	6.71	1.80	6.75	1.60	6.69	1.65
	Std. deviation	0.09	0.14	0.09	0.15	0.05	0.15	0.08	0.15
	Coeff. of variation as percent of mean	1.37	9.30	1.41	8.34	0.72	9.40	1.17	9.01
C	Mean	6.77	1.30	6.84	1.57	6.76	0.98	6.79	1.28
	Std. deviation	0.09	0.13	0.07	0.15	0.06	0.05	0.07	0.11
	Coeff. of variation as percent of mean	1.30	10.00	1.03	9.86	0.89	5.10	1.07	12.32

Number of determinations made by each operator for each method = 30.

Table 9

Reproducibility attained by three operators using Method C* and standard single field method for adjusting threshold level

Specimen 1A

Percentage area range	Frequency per 100 fields: Method C, Oper. 1	2	3	Standard field method, Oper. 1	2	3
< 0.03	68	60	56	62	61	62
0.03 - 0.20	25	37	40	35	36	34
0.20 - 0.55	5	2	3	2	2	3
0.55 - 1.20	1	1	0	.	.	.
1.20 - 2.70	1	1	1	1	1	1
> 2.70	.	.	.	.	.	.
Mean area %	0.071	0.066	0.083	0.067	0.068	0.066

Specimen 1B

Percentage area range	Method C, Oper. 1	2	3	Standard field method, Oper. 1	2	3
< 0.03	67	78	74	71	63	69
0.03 - 0.20	31	19	26	28	36	30
0.20 - 0.55	2	3	0	1	1	1
0.55 - 1.20	.	.	.	.	.	.
1.20 - 2.70	.	.	.	.	.	.
> 2.70	.	.	.	.	.	.
Mean area %	0.038	0.030	0.027	0.030	0.032	0.030

* Method C as described in section 4.60

Table 10

Numerical Ratings for SAE-ASTM chart (long axes of inclusions 90 degrees from scan line)

Chart grading	Percent area		Total projected length, mm.		Total count	
	Silicate	Oxide	Silicate	Oxide	Silicate	Oxide
1	0.10	0.39	0.06	0.04	1 (1)	2 (2)
2	0.17	0.56	0.09	0.11	3 (3)	8 (8)
3	0.38	0.46	0.12	0.09	4 (4)	11 (11)
4	0.90	0.54	0.28	0.10	9 (9)	14 (14)
5	1.45	2.66	0.44	0.18	12 (13)	15 (16)
6	1.94	2.22	0.68	0.33	16 (15)	43 (42)
7	4.00	5.45	1.02	0.82	4 (2)	54 (98)
8	8.30	8.86	1.07	1.16	7 (3)	49 (64)

Apparent field size 107 x 80 mm = 8560 mm^2

True field size 1.07 x 0.8 mm = 0.86 mm^2

Numbers in brackets are actual numbers on chart.

Table 11

Numerical Ratings for JK-ASTM charts (long axes of inclusions 90 degrees from scan line)

Chart grading	Percent area		Total projected length, mm.		Total count	
	Thin	Thick	Thin	Thick	Thin	Thick
Type A: Manganese sulphide						
1	0.08	0.12	0.10	0.10	3	3 (3)
2	0.18	0.29	0.34	0.34	9	9 (9)
3	0.50	0.89	7.95	0.85	17	16 (16)
4	1.04	1.74	1.46	1.63	26	26 (26)
5	1.60	2.64	2.60	2.79	47	43 (43)
Type B: Alumina						
1	0.03	0.07	0.04	0.05	3	3 (4)
2	0.09	0.33	0.13	0.22	15	15 (14)
3	0.20	0.95	0.27	0.60	30	31 (42)
4	0.43	1.56	0.57	1.00	60	66 (92)
5	1.10	3.58	1.43	2.30	157	140 (166)
Type C: Silicate						
1	0.06	0.09	0.10	0.11	3	2 (2)
2	0.18	0.23	0.25	0.25	6	4 (5)
3	0.29	0.40	0.47	0.48	7	5 (6)
4	0.48	0.70	0.80	0.81	11	8 (9)
5	0.80	1.41	1.44	1.67	12	15 (11)
Type D: Globular oxide						
1	0.04	0.10	0.04	0.06	3	3 (3)
2	0.13	0.32	0.17	0.23	16	14 (14)
3	0.20	0.56	0.27	0.41	25	26 (26)
4	0.33	0.91	0.45	0.72	47	44 (43)
5	0.46	1.46	0.66	1.10	71	69 (68)

Apparent field size = 80 square mm = 6400 mm^2

True field size = 0.80 x 0.625 mm = 0.5 mm^2

Numbers in brackets are actual numbers on chart.

Table 12

Numerical Ratings for Diergarten chart (long axes of inclusions 90 degrees to scan line)

Chart grading	Percent area		Total projected length, mm.		Total count	
	Thin	Thick	Thin	Thick	Thin	Thick
Form M						
1	0.13	0.14	0.09	0.09	4 (4)	4 (4)
2	0.40	0.31	0.19	0.19	8 (8)	4 (3)
3	0.46	0.55	0.36	0.33	13 (12)	6 (5)
4	0.64	0.77	0.57	0.54	21 (21)	16 (17)
5	1.80	2.40	1.17	1.34	45 (46)	28 (30)
6	2.87	2.87	1.93	1.69	47 (55)	18 (19)
7	5.99	6.66	3.50	2.68		
8	8.99	11.36	6.60	4.05		
Form T						
1	0.05	0.07	0.08	0.08	8 (8)	8 (8)
2	0.13	0.27	0.16	0.23	16 (16)	17 (18)
3	0.34	0.34	0.19	0.22	16 (16)	16 (16)
4	0.49	0.69	0.35	0.42	24 (26)	26 (31)
5	1.09	0.92	0.55	0.67	24 (30)	20 (24)
6	1.46	2.03	1.11	1.04	34 (37)	39 (41)
7	5.59	3.36	1.99	2.90		
8	6.71	4.32	3.30	4.15		
Kugelform K						
1	0.06		0.02		I (I)	
2	0.10		0.03		2 (I)	
3	0.18		0.04		2 (I)	
4	0.30		0.06		I (I)	
5	0.71		0.09		2 (I)	
6	1.11		0.I2		6 (I)	
7	2.83		-		-	
8	5.10		-		-	

- denotes not determined

continued....

Table 12 [Contd.]

Strichform S			
1	0.07	0.06	1 (1)
2	0.26	0.12	1 (1)
3	0.29	0.15	1 (1)
4	0.39	0.21	1 (1)
5	0.74	0.30	1 (1)
6	1.49	0.32	1 (1)
7	2.97		1 (1)
8	4.35		1 (1)
Doppelzeilenform Z			
1	0.11	0.09	3 (2)
2	0.17	0.12	4 (4)
3	0.41	0.21	2 (3)
4	0.80	0.39	6 (6)
5	1.13	0.60	4 (4)
6	1.57	0.68	6 (6)
7	2.96		
8	3.91		
Vielpunkform P			
1	0.05	0.03	1 (2)
2	0.27	0.10	3 (6)
3	0.19	0.12	3 (5)
4	0.41	0.14	5 (6)
5	0.56	0.16	6 (6)
6	0.82	0.18	4 (4)
7	1.81		
8	3.17		

Apparent field size 80 mm square = 6400 mm^2

True field size = 0.80 x 0.625 mm = 0.5 mm^2

Numbers in brackets are actual numbers on chart.

Table 13

Distribution of percentage area determinations made on a hundred randomly selected fields of view

Percentage area	Specimen No.		
	1	2	3
0.10 - 0.20	2	3	2
0.20 - 0.40	10	9	8
0.40 - 0.60	13	16	18
0.60 - 0.80	23	24	30
0.80 - 1.00	14	19	18
1.00 - 1.20	16	8	9
1.20 - 1.40	13	6	6
1.40 - 1.60	6	8	6
1.60 - 1.80	2	4	2
1.80 - 2.00	1	3	1

Table 14

Comparison between JK ratings obtained by Quantimet and two operators*
for same fields of view

Sample	Method	JK Rating: Frequency per 100 fields					
		Grade 0	1	2	3	4	5
1	Quantimet	82	15	3	.	.	.
	Manual Optr.1	78	17	3	2	.	.
	Manual Optr.2	91	6	3	.	.	.
2	Quantimet	81	11	5	3	.	.
	Manual Optr.1	70	23	5	2	.	.
	Manual Optr.2	92	6	2	.	.	.
3	Quantimet	97	3	.	.	.	.
	Manual Optr.1	98	2	.	.	.	.
	Manual Optr.2	100	.	.	.	.	.
4	Quantimet	20	70	6	2	1	1
	Manual Optr.1	40	54	3	1	1	1
	Manual Optr.2	33	60	4	2	1	.

* Experienced operators

Table 15

Percentage area counts determined on adjacent samples step-forged to different size sections

Section size	Frequency of fields, %						Percent area	
% area range	<0.03	0.03-0.20	0.20-0.55	0.55-1.20	1.20-2.70	>2.70	Mean	Std.devn.
Steel 1								
15 cm x 15 cm	86	11	2	.	1	.	0.05	0.23
10 cm x 10 cm	87	11	2	.	.	.	0.03	0.03
7.5 cm x 7.5 cm	71	29	.	.	.	.	0.03	0.03
5 cm x 5 cm	86	14	.	.	.	.	0.02	0.03
2.5 cm dia.	91	9	.	.	.	.	0.01	0.02
Steel 2								
15 cm x 15 cm	64	35	1	.	.	.	0.04	0.04
10 cm x 10 cm	88	11	1	.	.	.	0.02	0.02
7.5 cm x 7.5 cm	91	8	1	.	.	.	0.02	0.02
5 cm x 5 cm	81	19	.	.	.	.	0.02	0.03
2.5 cm dia.	93	7	.	.	.	.	0.01	0.02

Table 16

Total length counts determined on adjacent samples step-forged to different size sections

Section Size	Total length, µm.	
	Mean	Std. devn.
Steel 1		
15 cm x 15 cm	19	68
10 cm x 10 cm	12	16
7.5 cm x 7.5 cm	16	20
5 cm x 5 cm	16	20
2.5 cm dia.	6	9
Steel 2		
15 cm x 15 cm	36	36
10 cm x 10 cm	12	12
7.5 cm x 7.5 cm	20	28
5 cm x 5 cm	23	32
2.5 cm dia.	8	16

Table 17

Size distribution counts determined on adjacent samples step-forged to different size sections

Section Size	Total number (Mean/field)	Mean number/field (0.5 sq.mm) greater than:			
		10 μm	15 μm	20 μm	25 μm
Steel 1					
15 cm x 15 cm	1.51	0.30	0.12	0.08	0.05
10 cm x 10 cm	1.01	0.17	0.06	0.04	0.02
7.5 cm x 7.5 cm	1.37	0.35	0.10	0.04	•
5 cm x 5 cm	1.51	0.23	0.01	•	•
2.5 cm dia.	0.81	0.19	•	•	•
Steel 2					
15 cm x 15 cm	3.63	0.13	0.03	0.02	0.01
10 cm x 10 cm	2.66	0.04	0.01	0.01	0.01
7.5 cm x 7.5 cm	2.17	0.05	0.03	0.01	•
5 cm x 5 cm	2.80	0.05	0.03	•	•
2.5 cm dia.	1.27	0.06	0.01	•	•

Table 18

Size distribution results for manganese sulphide inclusions in same sample but different planar sections

Planar Section*	Size distribution: Number greater than stated size per 100 fields (16 mm^2)				
	Total	>10 μm	20 μm	50 μm	100 μm
Forging steel					
A	604	70	18	1	•
B	797	112	32	1	•
C	1900	85	9	•	•
High sulphur free-cutting steel					
A	2398	513	211	24	•
B	2008	511	216	22	•
C	3700	459	112	•	•

* See Figs. 34 and 35.

Table 19

Size distribution results for oxide (alumina) inclusions in same sample but different planar sections

Planar section×	Size distribution: Number greater than stated size per 100 fields (16 mm^2)				
	Total	>10 μm	20 μm	50 μm	100 μm
Forging steel					
A	115	3	•	•	•
B	140	4	•	•	•
C	190	0	•	•	•
High sulphur free-cutting steel					
A	252	2	•	•	•
B	219	2	•	•	•
C	437	0	•	•	•

× See Figs. 34 and 35.

Table 20

Grand summary of results obtained on "dirty", "clean" and "very clean" specimens, numbers 1, 2 and 3 respectively

Specimen Number	Percentage area Frequency per 1000 fields							
	< 0.03%	0.03–0.20%	0.20–0.55%	0.55–1.20%	1.20–2.70%	> 2.70%	Mean	Std. devn.
1 "dirty"	742	228	17	I	[illegible]	[illegible]	0.032	0.093
2 "clean"	890	102	8	•	•	•	0.009	0.020
3 "very clean"	900	80	20	•	•	•	0.009	0.023

Specimen Number	Count: Mean number per field (0.25 mm^2) > than:			
	1.8 μm (Total count)	3.0 μm	10.0 μm	20.0 μm
1 "dirty"	1.8967	0.1500	0.0125	•
2 "clean"	1.2500	0.0350	•	•
3 "very clean"	0.9600	0.0400	•	•

Table 21

Summary showing distribution of fields with various numbers of oxide inclusions for "dirty", "clean" and "very clean" specimens, numbers 1, 2 and 3 respectively

Number of inclusions per field	Specimen number 1 "dirty"	2 "clean"	3 "very clean"
0	320	370	630
1	250	290	200
2	170	170	60
3	90	100	30
4	50	40	30
5	20	20	20
6	20	10	10
7	20	..	.
8	10	.	10
9	10	.	.
10 and more	40	.	10
	Statistics		
Mean	1.89	1.25	0.96
Std. devn.	2.45	1.43	1.50

Table 22

Details of steels used in investigation on billet sampling

Billet	Composition, wt. percent									
	C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Sn
P587	0.42	1.35	0.27	0.034	0.042	0.39	0.29	0.10	0.16	0.025
T369	0.13	0.50	0.27	0.032	0.026	1.50	1.50	0.05	0.12	0.015

Manufacturing details of cast	P587	T369
Quality	JDM 1041 F. Equiv. British spec. En 15	15 NiCrMo6
Deoxidation	SiMn/Al	SiMn/Al
Single or double slag	Single	Single
Vacuum degassed	Yes	No
Grain size controlled	No	No
Tapping temp. of cast	1700°C	1625°C
Teeming temp. of cast	1700°C before degas. 1570°C after	1585°C
Number of groups in cast	2	2
Total number of ingots	13	13
Ingot weight, cwt.	34.5	37
Length of billet examined	15' approx. (4.7 metres approx.)	15' approx. (4.7 metres approx.)

Table 23

(P587)

Mean oxide percentage area counts on adjacent samples from 'clean' billet

Position in billet, inches.	Frequency per 100 fields.						Area %	
	< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%.	Mean	Std. Dev.
0	59	36	2	1	.	.	0.05	0.09.
1	84	16	.	.	.	.	0.02	0.02.
2	88	12	.	.	.	.	0.01	0.02.
3	93	7	.	.	.	.	0.02	0.02.
4	74	25	.	1	.	.	0.04	0.12.
5	80	17	.	1	.	2	0.09	0.45.
6	89	11	.	.	.	.	0.02	0.03.
7	72	26	2	.	.	.	0.03	0.05.
8	84	14	.	.	.	.	0.02	0.02.
9	80	20	.	.	.	.	0.02	0.03.
10	82	18	.	.	.	.	0.02	0.02.
11	71	26	3	.	.	.	0.04	0.06.
12	89	8	3	.	.	.	0.02	0.04.
13	83	15	1	1	.	.	0.03	0.08.
14	92	8	.	.	.	.	0.01	0.02.
15	79	20	1	.	.	.	0.03	0.04.
16	90	9	1	.	.	.	0.02	0.04.
17	82	18	.	.	.	.	0.02	0.03.
18	79	20	1	.	.	.	0.02	0.03.
19	42	51	5	2	.	.	0.07	0.01.
20	81	18	.	1	.	.	0.03	0.07.
21	69	26	4	1	.	.	0.05	0.13.
22	73	25	1	1	.	.	0.04	0.07.
23	92	8	.	.	.	.	0.01	0.02.
24	88	11	1	.	.	.	0.02	0.05.
25	90	8	1	.	.	.	0.02	0.04.
26	82	17	1	.	.	.	0.03	0.05.
27	79	17	2	1	1	.	0.05	0.16.
28	83	17	.	.	.	.	0.02	0.02.
29	92	8	.	.	.	.	0.02	0.02.
30	53	43	3	1	.	.	0.05	0.07.
31	75	24	1	.	.	.	0.03	0.04.
32	76	24	.	.	.	.	0.03	0.03.
33	90	10	.	.	.	.	0.02	0.02.
34	58	42	.	.	.	.	0.03	0.03.
35	81	16	3	.	.	.	0.03	0.06.
36	76	21	3	.	.	.	0.03	0.03.
37	85	14	1	.	.	.	0.03	0.05.
38	55	44	1	.	.	.	0.05	0.05.
39	71	29	.	.	.	.	0.03	0.03.
40	78	22	.	.	.	.	0.03	0.03.
41	35	65	.	.	.	.	0.06	0.04.
42	54	46	.	.	.	.	0.04	0.04.
43	71	29	.	.	.	.	0.03	0.03.
44	62	38	.	.	.	.	0.04	0.06.
45	66	32	.	1	.	.	0.05	0.12.
46	63	36	1	.	.	.	0.03	0.04.
47	52	48	.	.	.	.	0.05	0.04.
48	69	30	1	.	.	.	0.04	0.06.
49	64	35	1	.	.	.	0.03	0.03.
50	87	13	.	.	.	.	0.02	0.02.

continued.....

Table 23 continued

Position in billet.	Frequency per 100 fields. < 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	Area % Mean	Std. Dev.
51	67	33	.	.	.	.	0.03	0.02.
52	29	56	5	5	3	2	0.06	0.05.
53	38	61	2	.	.	.	0.02	0.03.
54	64	33	1	.	1	1	0.06	0.06.
55	70	28	1	.	.	.	0.02	0.04.
56	23	77	.	.	.	.	0.03	0.04.
57	65	34	1	.	.	.	0.03	0.03.
58	47	51	1	1	.	.	0.05	0.05.
59	89	10	.	1	.	.	0.04	0.03.
60	63	37	.	.	.	.	0.02	0.02.
61	46	50	3	.	.	1	0.08	0.28.
62	50	47	2	1	.	.	0.06	0.08.
63	68	30	.	2	.	.	0.05	0.03.
64	71	29	.	.	.	.	0.02	0.03.
65	60	39	1	.	.	.	0.03	0.05.
66	39	58	1	1	.	.	0.06	0.09.
67	67	31	1	.	1	.	0.05	0.18.
68	17	22	1	.	.	.	0.03	0.04.
69	47	51	2	.	.	.	0.05	0.04.
70	48	51	1	.	.	.	0.05	0.04.
71	48	52	.	.	.	.	0.04	0.03.
72	48	51	.	.	.	.	0.05	0.04.
73	35	62	3	.	.	.	0.06	0.05.
74	68	31	1	.	.	.	0.04	0.04.
75	64	35	.	.	1	.	0.05	0.14.
76	57	42	.	1	.	.	0.04	0.08.
77	92	7	1	.	.	.	0.01	0.05.
78	71	28	1	.	.	.	0.03	0.06.
79	88	11	1	.	.	.	0.02	0.04.
80	42	51	6	1	.	.	0.07	0.08.
81	78	21	1	.	.	.	0.03	0.04.
82	73	27	.	.	.	.	0.03	0.03.
83	63	36	1	.	.	.	0.03	0.03.
84	63	34	2	1	.	.	0.05	0.08.
85	74	26	.	.	.	.	0.03	0.03.
86	65	31	3	1	.	.	0.05	0.09.
87	82	18	.	.	.	.	0.02	0.03.
88	77	23	.	.	.	.	0.02	0.03.
89	83	16	1	.	.	.	0.03	0.04.
90	85	14	1	.	.	.	0.02	0.04.
91	91	7	1	.	1	.	0.02	0.17.
92	83	17	.	.	.	.	0.02	0.02.
93	91	9	.	.	.	.	0.02	0.02.
94	85	14	1	.	.	.	0.02	0.03.
95	91	9	.	.	.	.	0.01	0.02.
96	86	14	.	.	.	.	0.02	0.02.
97	69	31	.	.	.	.	0.03	0.03.
98	78	21	.	1	.	.	0.03	0.08.
99	83	15	1	.	.	.	0.03	0.13.
100	82	16	.	2	.	.	0.03	0.09.

continued....

TABLE 23 continued.

Position in billet.	Frequency per 100 fields.						Area %	
	< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%.	Mean	Std. Dev
101	63	34	3	.	.	.	0.05	0.06.
102	76	23	1	.	.	.	0.03	0.06.
103	88	12	.	.	.	.	0.02	0.02.
104	66	34	.	.	.	.	0.03	0.03.
105	68	31	.	.	.	.	0.03	0.03.
106	36	60	4	.	.	.	0.06	0.05.
107	42	54	4	.	.	.	0.06	0.07.
108	73	25	2	.	.	.	0.04	0.05.
109	90	10	.	.	.	.	0.02	0.02.
110	11	78	11	.	.	.	0.10	0.07.
111	58	41	1	.	.	.	0.04	0.04.
112	52	46	2	.	.	.	0.05	0.06.
113	78	21	1	.	.	.	0.03	0.05.
114	69	31	.	.	.	.	0.04	0.03.
115	58	42	.	.	.	.	0.04	0.03.
116	76	24	.	.	.	.	0.02	0.03.
117	86	14	.	.	.	.	0.02	0.02.
118	63	37	.	.	.	.	0.03	0.03.
119	82	18	.	.	.	.	0.02	0.03.
120	80	18	1	1	.	.	0.03	0.07.
121	75	24	1	.	.	.	0.03	0.06.
122	81	18	1	.	.	.	0.03	0.05.
123	72	28	.	.	.	.	0.03	0.03.
124	86	14	.	.	.	.	0.02	0.02.
125	86	14	.	.	.	.	0.02	0.02.
126	87	13	.	.	.	.	0.02	0.02.
127	86	14	.	.	.	.	0.02	0.02.
128	90	9	.	1	.	.	0.02	0.06.
129	60	40	.	.	.	.	0.03	0.03.
130	75	25	.	.	.	.	0.03	0.03.
131	82	18	.	.	.	.	0.02	0.02.
132	86	13	1	.	.	.	0.02	0.04.
133	85	14	1	.	.	.	0.02	0.03.
134	91	9	.	.	.	.	0.01	0.02.
135	92	7	.	1	.	.	0.02	0.06.
136	94	6	.	.	.	.	0.01	0.02.
137	91	8	1	.	.	.	0.01	0.03.
138	92	8	.	.	.	.	0.02	0.03.
139	85	14	1	.	.	.	0.03	0.05.
140	87	13	.	.	.	.	0.02	0.02.
141	85	15	.	.	.	.	0.02	0.03.
142	77	23	.	.	.	.	0.02	0.02.
143	84	16	.	.	.	.	0.02	0.03.
144	75	24	1	.	.	.	0.03	0.04.
145	68	31	.	1	.	.	0.04	0.06.
146	78	20	2	.	.	.	0.03	0.06.
147	62	38	.	.	.	.	0.04	0.04.
148	76	24	.	.	.	.	0.03	0.03.
149	76	24	.	.	.	.	0.03	0.02.
150	70	29	1	.	.	.	0.04	0.05.

continued......

Table 23 continued

Position in billet.	Frequency per 100 fields.						Area %	
	< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	Mean	Std. Dev.
151	84	16	.	.	.	.	0.02	0.02.
152	55	44	1	.	.	.	0.04	0.04.
153	86	13	1	.	.	.	0.02	0.04.
154	63	35	2	.	.	.	0.04	0.05.
155	75	25	.	.	.	.	0.03	0.03.
156	79	19	2	.	.	.	0.03	0.06.
157	84	16	.	.	.	.	0.02	0.02.
158	82	18	.	.	.	.	0.02	0.02.
159	88	12	.	.	.	.	0.02	0.02.
160	83	17	.	.	.	.	0.02	0.03.
161	72	28	.	.	.	.	0.03	0.03.
162	63	37	.	.	.	.	0.04	0.03.
163	73	25	1	.	1	.	0.05	0.19.
164	83	17	.	.	.	.	0.02	0.03.
165	84	16	.	.	.	.	0.02	0.02.
166	62	35	3	.	.	.	0.04	0.05.
167	65	34	1	.	.	.	0.03	0.03.
168	79	20	.	1	.	.	0.04	0.11.
169	51	49	.	.	.	.	0.05	0.04.
170	77	22	1	.	.	.	0.03	0.03.
171	68	31	1	.	.	.	0.04	0.05.
172	46	52	2	.	.	.	0.05	0.05.
173	62	36	1	1	.	.	0.04	0.08.
174	65	34	.	1	.	.	0.04	0.06.
175	77	22	1	.	.	.	0.03	0.03.
176	38	56	1	1	2	2	0.16	0.49.
177	50	47	1	2	.	.	0.07	0.04.
178	64	34	2	.	.	.	0.04	0.04.
179	48	51	1	.	.	.	0.05	0.05.

Table 24

Mean oxide percentage area counts on adjacent samples from 'dirty' billets. (T 369)

Position in billet inches.	Frequency per 100 fields.						Area %	
	<0.03%.	0.03-0.20%.	0.20-0.55%.	0.55-1.20%.	1.20-2.70%.	>2.70%.	Mean	Std. Dev.
0	86	12	1	.	1	.	0.03	0.13.
1	85	13	1	1	.	.	0.03	0.08.
2	80	17	1	2	.	.	0.04	0.09.
3	85	14	1	.	.	.	0.03	0.09.
4	81	17	2	.	.	.	0.03	0.05.
5	65	31	3	.	.	.	0.06	0.14.
6.	75	22	3	.	.	.	0.03	0.05.
7.	64	27	7	2	.	.	0.07	0.12.
8	87	11	2	.	.	.	0.02	0.04.
9	83	17	.	.	.	.	0.02	0.02.
10	47	49	3	1	.	.	0.06	0.09.
11	57	43	.	.	.	.	0.04	0.04.
12	74	24	2	.	.	.	0.03	0.04.
13	64	36	.	.	.	.	0.04	0.03.
14	69	24	5	2	.	.	0.05	0.10.
15	73	24	3	.	.	.	0.04	0.05.
16	54	46	.	.	.	.	0.04	0.03.
17	34	59	7	.	.	.	0.08	0.07.
18	71	25	4	.	.	.	0.04	0.07.
19	80	19	1	.	.	.	0.03	0.04.

continued.......

Table 24 continued

Position in billet inches.	Frequency per 100 fields.						Area %	
	< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	Mean	Std. Dev.
20	50	49	1	.	.	.	0.03.	0.06.
21	73	25	2	.	.	.	0.03.	0.06.
22	79	20	1	.	.	.	0.03	0.04.
23	81	17	2	.	.	.	0.03	0.05.
24	64	35	1	.	.	.	0.04	0.03.
25	89	11	.	.	.	.	0.02	0.02.
26	82	17	1	.	.	.	0.03	0.03.
27	83	17	.	.	.	.	0.02	0.02.
28	62	38	.	.	.	.	0.04	0.03.
29	65	29	6	.	.	.	0.05	0.07.
30	57	43	.	.	.	.	0.04	0.03.
31	80	19	1	.	.	.	0.03	0.04.
32	61	36	3	.	.	.	0.04	0.05.
33	88	12	.	.	.	.	0.02	0.02.
34	26	69	5	.	.	.	0.04	0.05.
35	9	81	10	.	.	.	0.10	0.07.
36	36	64	.	.	.	.	0.06	0.04.
37	55	45	.	.	.	.	0.04	0.03.
38	31	63	5	1	.	.	0.08	0.08.
39	54	41	5	.	.	.	0.05	0.06.

continued.......

Table 24 continued

Position in billet inches.	Frequency per 100 fields.						Area %	
	<0.03%.	0.03–0.20%.	0.20–0.55%.	0.55–1.20%.	1.20–2.70%.	>2.70%.	Mean	Std. Dev.
40	10	83	7	.	.	.	0.09	0.06.
41	53	44	3	.	.	.	0.05	0.06.
42	37	62	1	.	.	.	0.06	0.04.
43	27	69	4	.	.	.	0.07	0.06.
44	77	19	2	2	.	.	0.03	0.06.
45	36	62	2	.	.	.	0.07	0.07.
46	12	82	6	.	.	.	0.08	0.05.
47	26	65	7	2	.	.	0.10	0.12.
48	60	38	2	.	.	.	0.04	0.04.
49	66	28	2	4	.	.	0.05	0.12.
50	60	38	2	.	.	.	0.04	0.05.
51	23	75	2	.	.	.	0.07	0.05.
52	73	22	4	1	.	.	0.04	0.08.
53	75	18	6	1	.	.	0.06	0.12.
54	17	77	6	.	.	.	0.11	0.09.
55	55	40	4	1	.	.	0.06	0.11.
56	39	55	5	1	.	.	0.06	0.09.
57	59	39	2	.	.	.	0.04	0.06.
58	12	78	10	.	.	.	0.10	0.08.
59	46	51	3	.	.	.	0.05	0.05.
60	50	48	2	.	.	.	0.06	0.06.
61	47	47	6	.	.	.	0.06	0.06.
62	15	71	14	.	.	.	0.11	0.08.
63	7	69	24	.	.	.	0.16	0.10.
64	13	74	12	1	.	.	0.11	0.11.
65	32	58	9	1	.	.	0.07	0.10.
66	41	59	.	.	.	.	0.09	0.08.

continued.....

Table 24 continued

Position in billet inches.	Frequency per 100 fields.						Area %	
	<0.03%.	0.03-0.20%.	0.20-0.55%.	0.55-1.20%	1.20-2.70%.	>2.70%	Mean	Std. Dev.
67	25	73	2	.	.	.	0.06	0.03.
68	21	71	8	.	.	.	0.06	0.05.
69	65	23	12	.	.	.	0.09	0.10.
70	44	51	5	.	.	.	0.06	0.06.
71	30	61	9	.	.	.	0.08	0.08.
72	9	72	18	1	.	.	0.15	0.12.
73	61	36	3	.	.	.	0.04	0.04.
74	33	64	2	1	.	.	0.07	0.08.
75	57	42	1	.	.	.	0.04	0.05.
76	28	54	10	7	1	.	0.14	0.20.
77	52	44	4	.	.	.	0.05	0.05.
78	26	60	14	.	.	.	0.09	0.08.
79	55	36	9	.	.	.	0.05	0.07.
80	33	55	.	.	.	.	0.07	0.07.
81	49	47	4	.	.	.	0.06	0.06.
82	48	47	5	.	.	.	0.06	0.06.
83	57	41	2	.	.	.	0.04	0.03.
84	58	42	.	.	.	.	0.04	0.03.
85	65	35	.	.	.	.	0.03	0.03.
86	28	66	5	1	.	.	0.08	0.09.
87	50	44	6	.	.	.	0.06	0.12.
88	66	30	3	1	.	.	0.05	0.08.
89	22	70	8	.	.	.	0.09	0.09.
90	51	48	1	.	.	.	0.05	0.04.
91	47	51	1	1	.	.	0.05	0.07.
92	39	57	3	.	1	.	0.07	0.14.
93	5	80	14	1	.	.	0.14	0.11.
94	0	61	32	7	.	.	0.23	0.17.
95	21	75	4	.	.	.	0.08	0.07.
96	0	87	13	.	.	.	0.13	0.08.
97	14	71	15	.	.	.	0.12	0.11.
98	18	76	6	.	.	.	0.08	0.07.
99	3	83	13	1	.	.	0.14	0.08.
100	35	63	2	.	.	.	0.06	0.05.

continued........

Table 24 continued

Position in billet inches.	Frequency per 100 fields.						Area %	
	<0.03%.	0.03-0.20%.	0.20-0.55%.	0.55-1.20%.	1.20-2.70%.	>2. 70%.	Mean	Std. Dev.
101	51	42	7	•	•	•	0.04	0.03.
102	68	27	5	•	•	•	0.04	0.05.
103	•	86	14	•	•	•	0.13	0.06.
104	27	70	3	•	•	•	0.07	0.06.
105	79	19	2	•	•	•	0.03	0.06.
106	77	22	1	•	•	•	0.03	0.03.
107	48	49	3	•	•	•	0.06	0.05.
108	65	31	2	1	1	•	0.06	0.16.
109	49	50	1	•	•	•	0.05	0.05.
110	66	34	•	•	•	•	0.03	0.03.
111	47	50	3	•	•	•	0.06	0.05.
112	61	34	4	1	•	•	0.06	0.09.
1[illegible]	71	27	2	•	•	•	0.03	0.03.
114	48	41	6	3	1	1	0.15	0.50.
115	75	25	•	•	•	•	0.03	0.03.
116	55	42	3	•	•	•	0.04	0.04.
117	60	37	3	•	•	•	0.04	0.05.
118	41	57	2	•	•	•	0.06	0.07.
119	44	55	1	•	•	•	0.05	0.04.
120	38	58	4	•	•	•	0.06	0.05.
121	58	42	•	•	•	•	0.04	0.03.
122	68	31	1	•	•	•	0.04	0.06.
123	34	65	1	•	•	•	0.06	0.04.
124	63	35	2	•	•	•	0.04	0.05.
125	36	62	2	•	•	•	0.06	0.05.
126	71	21	1	•	1	•	0.06	0.21.
127	75	25	•	•	•	•	0.03	0.04.
128	86	12	2	•	•	•	0.02	0.03.
129	48	48	4	•	•	•	0.06	0.06.
130	7	63	30	•	•	•	0.15	0.11.
131	63	34	3	•	•	•	0.05	0.06.
132	53	44	3	•	•	•	0.05	0.06.
133	27	59	12	2	•	•	0.11	0.14.
134	38	50	11	1	•	•	0.12	0.07.

continued..........

Table 24 continued

Position in billet inches.	Frequency per 100 fields.						Area %	
	<0 0.03%.	0.03-0.20%.	0.20-0.55%.	0.55-1.20%.	1.20-2.70%.	>2.70%.	Mean	Std. Dev.
135	5	86	9	.	.	.	0.09	0.12.
136	74	20	5	1	.	.	0.06	0.13.
137	62	35	1	2	.	.	0.05	0.09.
138	14	81	4	1	.	.	0.09	0.11.
139	61	36	3	.	.	.	0.04	0.05.
140	60	38	2	.	.	.	0.04	0.05.
141	33	57	10	.	.	.	0.08	0.09.
142	56	41	3	.	.	.	0.05	0.06.
14.	71	26	3	.	.	.	0.03	0.05.
144	59	35	6	.	.	.	0.06	0.07.
145	73	21	6	.	.	.	0.04	0.05.
146	78	20	2	.	.	.	0.03	0.04.
147	69	31	.	.	.	.	0.03	0.04.
148	51	45	4	.	.	.	0.05	0.05.
149	66	32	2	.	.	.	0.04	0.04.
150	52	44	4	.	.	.	0.04	0.04.
151	30	65	5	.	.	.	0.08	0.07.
152	34	48	18	.	.	.	0.11	0.11.
153	48	59	3	.	.	.	0.05	0.05.
154	30	64	6	.	.	.	0.08	0.07.
155	71	29	.	.	.	.	0.03	0.03.
156	67	29	4	.	.	.	0.04	0.05.
157	71	16	10	3	.	.	0.07	0.15.
158	32	63	5	.	.	.	0.07	0.06.
159	57	43	.	.	.	.	0.04	0.03.
160	11	87	2	.	.	.	0.08	0.05.
161	50	48	2	.	.	.	0.05	0.06.
162	58	41	1	.	.	.	0.04	0.04.
163	73	20	5	2	.	.	0.06	0.13.
164	25	73	2	.	.	.	0.07	0.04.
165	51	40	7	2	.	.	0.07	0.11.
166	55	39	6	.	.	.	0.06	0.08.
167	42	54	4	.	.	.	0.06	0.05.
168	41	57	2	.	.	.	0.06	0.06.
169	49	46	.	2	2	1	0.15	0.52.
170	39	60	1	.	.	.	0.06	0.05.
171	43	57	.	.	.	.	0.05	0.04.
172	60	40	.	.	.	.	0.04	0.03.
173	71	27	2	.	.	.	0.03	0.04.
174	68	32	.	.	.	.	0.03	0.03.
175	38	55	6	1	.	.	0.07	0.13.
176	59	40	1	.	.	.	0.04	0.04.
177	44	55	1	.	.	.	0.05	0.05.
178	21	78	1	.	.	.	0.08	0.05.
179	56	44	.	.	.	.	0.04	0.04.

TABLE 25

Oxide percentage area and projection counts on specimen No. P.587 - 53. after thirty repolishes.

Repolish. +	Percentage area. Frequency per 100 Fields* <.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20%-2.70%	>2.70%	Mean ($X10^{-4}$)	Std. Dev ($X10^{-4}$)	Projection. (Total length mm.) Mean.	Std. Dev.
Original.	29	56	5	5	3	2	564	458	64	40
1	48	36	4	9	3	1	1712	3422	136	228
2	42	50	2	2	4	.	1387	3569	120	272
3	61	35	2	2	.	.	614	1439	64	112
4	84	15	1	.	.	.	223	313	24	36
5	81	16	3	.	.	.	314	587	36	56
6	81	19	.	.	.	.	223	254	20	28
7	86	9	4	.	1	.	459	1851	40	280
8	82	10	2	2	3	1	1377	5478	56	184
9	82	11	1	2	2	2	1393	5832	56	228
10	81	14	.	3	.	2	1289	6489	52	212
11	82	12	4	.	.	2	1567	9287	44	200
12	76	19	2	.	.	3	1431	6851	52	204
13	94	5	.	.	1	.	271	1828	12	76
14	93	4	1	1	.	.	148	715	12	44
15	89	7	2	1	1	.	466	2472	20	96
16	92	3	.	1	1	3	1559	7602	48	204
17	93	6	1	.	.	.	126	318	8	12
18	94	6	.	.	.	.	92	187	8	12
19	82	17	1	.	.	.	207	390	12	16
20	95	5	.	.	.	.	56	113	4	8
21	91	9	.	.	.	.	114	239	8	16
22	92	7	1	.	.	.	148	395	8	24
23	96	4	.	.	.	.	57	108	4	8
24	87	12	1	.	.	.	199	513	12	28
25	86	12	.	2	.	.	330	1418	12	44
26	95	5	.	.	.	.	94	187	4	12
27	74	26	.	.	.	.	231	280	16	20
28	85	15	.	.	.	.	154	283	8	16
29	64	36	.	.	.	.	305	291	20	16
30	91	8	1	.	.	.	120	342	8	24

* Area of each field = 0.5 sq.mm.

\+ Specimen reground and polished, approximately 0.5mm.of surface removed each time.

TABLE. 26

Oxide percentage area and projection counts on specimen No.P587-1 after thirty repolishes.

Repolish+	Percentage Area.								Projection. (total length) mm.	
	Frequency per 100 fields*									
	< .03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20%-2.70%	> 2.70%	Mean (X10^{-4})	Std. Dev. (X10^{-4})	Mean.	Std. Dev.
Original	59	36	2	1	.	.	484	881	44	52
1	61	37	2	.	.	.	402	427	48	44
2	69	26	3	2	.	.	525	1088	60	84
3	83	16	1	.	.	.	270	542	32	40
4	85	14	1	.	.	.	239	452	28	44
5	72	26	1	1	.	.	340	769	48	84
6	90	10	.	.	.	.	129	166	12	20
7	88	11	1	.	.	.	203	492	24	36
8	95	5	.	.	.	.	56	136	4	12
9	88	12	.	.	.	.	119	227	8	16
10	73	27	.	.	.	.	249	281	20	20
11	73	24	1	3	2	.	913	3295	44	120
12	78	20	1	1	.	.	327	1125	20	52
13	86	12	.	1	.	1	503	3134	24	100
14	95	5	.	.	.	.	94	148	8	12
15	89	11	.	.	.	.	107	249	4	12
16	94	6	.	.	.	.	77	175	4	8
17	88	11	1	.	.	.	156	479	8	24
18	89	10	1	.	.	.	141	338	8	16
19	82	17	1	.	.	.	202	349	16	28
20	75	21	1	1	1	1	822	3519	44	156
21	84	16	.	.	.	.	176	292	12	20
22	69	28	3	.	.	.	327	544	20	32
23	79	20	1	.	.	.	213	400	16	24
24	92	8	.	.	.	.	88	192	4	12
25	86	13	.	1	.	.	222	901	12	36
26	79	19	2	.	.	.	254	435	16	42
27	78	21	1	.	.	.	256	519	16	32
28	86	13	.	1	.	.	254	1056	12	28
29	87	13	.	.	.	.	145	208	8	12
30	89	11	.	.	.	.	105	256	8	16

* Area of each field = 0.5sq.mm.

\+ Specimen reground and polished, approximately 0.5mm of surface removed each time.

TABLE 27

Oxide percentage area and projection counts on Specimen No.P587-126 after thirty repolishes.

Repolish +	Percentage area.								Projection. (total length) mm.	
	Frequency per 100 fields*						Mean. (X10^{-4})	Std. Dev. (X10^{-4})	Mean.	Std. Dev.
	<0.03%	0.03-0.20%	0.20-1.20%	0.55-1.20%	1.20%-2.70%	>2.70%.				
Original.	86.	14.	.	.	.	.	202.	222.	20.	24.
1.	72.	27.	1.	.	.	.	288.	333.	32.	28.
2.	67.	33.	.	.	.	.	320.	292.	40.	32.
3.	77.	22.	1.	.	.	.	261.	316.	32.	40.
4.	88.	11.	1.	.	.	.	198.	302.	20.	24.
5.	87.	12.	11.	.	.	.	210.	456.	20.	28.
6.	87.	13.	.	.	.	.	171.	320.	16.	32.
7.	73.	26.	1.	.	.	.	312.	409.	28.	36.
8.	92.	8.	.	.	.	.	102.	191.	8.	12.
9.	92.	7.	1.	.	.	.	111.	485.	8.	28.
10.	90.	9.	.	1.	.	.	230.	948.	12.	36.
11.	92.	7.	1.	.	.	.	144.	378.	8.	20.
12.	90.	10.	.	.	.	.	116.	214.	8.	16.
13.	94.	6.	.	.	.	.	82.	206.	4.	12.
14.	90.	10.	.	.	.	.	132.	245.	8.	12.
15.	89.	11.	.	.	.	.	119.	242.	8.	12.
16.	85.	15.	.	.	.	.	174.	295.	12.	16.
17.	81.	19.	.	.	.	.	169.	258.	8.	16.
18.	89.	11.	.	.	.	.	125.	220.	8.	16.
19.	87.	10.	1.	.	2.	.	515.	2556.	20.	88.
20.	92.	8.	.	.	.	.	90.	202.	4.	12.
21.	86.	14.	.	.	.	.	159.	315.	12.	20.
22.	64.	35.	1.	.	.	.	340.	520.	20.	24.
23.	86.	14.	.	.	.	.	142.	200.	8.	12.
24.	90.	9.	1.	.	.	.	149.	323.	8.	20.
25.	91.	9.	.	.	.	.	112.	286.	8.	20.
26.	80.	19.	1.	.	.	.	228.	313.	16.	20.
27.	84.	16.	.	.	.	.	153.	262.	8.	16.
28.	92.	8.	.	.	.	.	100.	175.	4.	8.
29.	82.	18.	.	.	.	.	168.	230.	12.	16.
30.	91.	9.	.	.	.	.	100.	232.	8.	12.

* Area of each field = 0.5 sq.mm.

\+ Specimen re-ground and polished, approximately 0.5.mm. of surface removed each time.

Table 28

Details of two ingots used in inclusion distribution study

Cast no.	5485
Pit	A
No. of ingots in cast	32
No. of groups	5
Weight of ingot	36 cwt.

No. of ingots in each group:

Group 1	Group 2	Group 3	Group 4	Group 5
8	8	8	6	2

Method of teeming	bottom
Teeming temperature	1560°C
Nozzle size	$1^{7}/8$ dia. Magnesite (47 mm)

Group	Teeming time	Feeding time
1	3'55"	1'20"
2	4'40"	1'30"
3	4'55"	1'40"
4	5'20"	1'50"
5	2'35"	0.40"

Deoxidation:	Si Mn in furnace, $\frac{1}{2}$ lb/ton (0.22 kg/tonne) Al to ladle
Billet size	$2^{7}/8$" (73 mm) sq. section
Length of billet	12'11" to 13'1" (3940-3980 mm) approx.

	Composition: Wt. %									
	C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Sn
Pit analysis	0.375	1.51	0.30	0.031	0.023	0.25	0.13	0.22	0.16	0.023
Specification limits	0.35- 0.40	1.40- 1.60	0.25- 0.30	0.030- 0.040	0.025 Max.	.	.	0.20- 0.30	.	.

Table 29

Details of samples used from two adjacent ingots of low alloy steel

Sample no.	Position in ingot, % from top	Specimen/billet: coding		Remarks
		Ingot 1	Ingot 2	
1	6	62TT	64TT	Extreme top next to discard
2	17	62T	64T	
3	26	62	64	
4	35	62	64	
5	44	62B	64B	
6	54	61TT	63TT	Middle
7	63	61T	63T	
8	72	61	63	
9	81	61	63	
10	90	61B	63B	One billet length from bottom
11	99	61B7	63B7	Bottom next to discard
1	90	61B	63B	One billet length from bottom (top)
2	91.2	61B1	63B1	
3	92.5	61B2	63B2	
4	93.8	61B3	63B3	
5	95.1	61B4	63B4	
6	96.4	61B5	63B5	
7	97.7	61B6	63B6	
8	99.0	61B7	63B7	Bottom next to discard

Note: Adjacent samples from the above positions were selected for Quantimet, sulphur printing, total oxygen and step testing.

Table 30

Composition of typical oxide inclusions determined by electron probe micro-analyser

Metallographic description of inclusion	Inclusion No.	Mean composition, %			
		MnO[x]	SiO_2[x]	Al_2O_3	CaO[x]
Stringer type with second phase	1	28	34	20	4
	2	31	32	22	3
	3	26	34	25	4
Stringer type with no second phase	4	•	•	94	3
	5	•	•	96	2
	6	•	•	98	<2
Discrete particles	7	•	•	93	4
	8	•	•	94	4
	9	•	•	94	3

[x]Found in matrix in two-phase inclusions.

Table 31

Oxide percentage area counts on billet samples from Ingot 1.

Position in sample	Position in ingot.	Frequency per 100 fields.						Mean percent area.
		< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	
A	1 top.	97	3	.	.	.	.	0.01.
	2.	87	12	1	.	.	.	0.02.
	3	91	8	1	.	.	.	0.01.
	4	85	14	1	.	.	.	0.02.
	5	91	8	1	.	.	.	0.02.
	6	92	6	1	.	.	.	0.01.
	7	92	8	.	.	.	.	0.01.
	8	92	6	2	1	.	.	0.01.
	9	94	5	1	.	.	.	0.01.
	10	89	10	1	.	.	.	0.01.
	11 bottom.	89	10	1	.	.	.	0.01.
B	1 top.	92	6	1	.	.	.	0.01.
	2	93	6	1	.	.	.	0.01.
	3	92	7	1	.	.	.	0.01.
	4	88	11	1	.	.	.	0.02.
	5	88	11	1	.	.	.	0.01.
	6	87	8	3	.	1	1	0.04.
	7	90	8	1	1	.	.	0.02.
	8	94	4	2	.	.	.	0.01.
	9	93	4	2	1	.	.	0.02.
	10	88	10	2	.	.	.	0.01.
	11 bottom.	87	10	1	1	.	1	0.04.

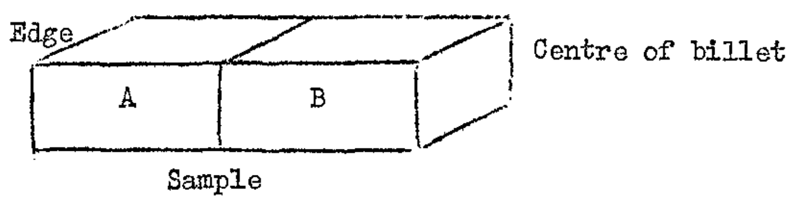


Table 32

Oxide percentage area counts on billet samples from ingot 2.

Position in sample	Position in ingot.	Frequency per 100 fields.						Mean per cent area.
		< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	
A	1	.	.	.	.	.	.	.
	2	90	10	.	.	.	.	0.01.
	3	91	8	1	.	.	.	0.01.
	4	92	6	1	1	.	.	0.02.
	5	95	5	.	.	.	.	0.01.
	6	88	10	1	.	.	.	0.02.
	7	93	7	.	.	.	.	0.01.
	8	93	6	1	.	.	.	0.01.
	9	91	7	1	.	.	.	0.02.
	10	90	8	1	1	.	.	0.02.
	11	93	5	1	1	.	.	0.01.
B	1	.	.	.	.	.	.	.
	2	97	3	.	.	.	.	0.02.
	3	91	8	1	.	.	.	0.01.
	4	92	8	.	.	.	.	0.01.
	5	87	11	2	.	.	.	0.01.
	6	93	6	1	.	.	.	0.01.
	7	86	12	2	.	.	.	0.02.
	8	92	7	1	.	.	.	0.02.
	9	87	9	3	.	.	.	0.02.
	10	94	4	1	1	.	.	0.01.
	11	89	10	1	1	.	.	0.01.

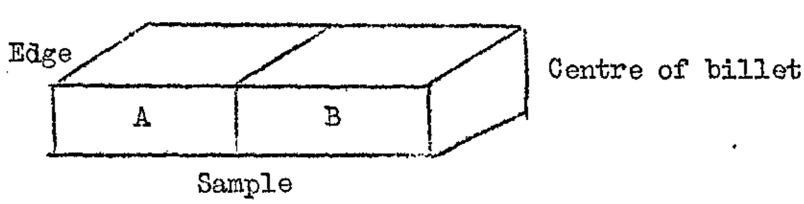


Table 33

Oxide size distribution counts on billet samples from Ingot 1.

Position in sample.	Position in ingot.	number per sq.cm.in each size range μm					
		1.8-3.0	3.0-10.0.	10.0-20.0	20.0-50.0	50.0-100.0	$>$ 100.0.
A	1 top.	502	67	4.	.	.	.
	2	741	304	12	18	.	.
	3	817	168	40	3	3	.
	4	1777	278	88	3	.	.
	5	948	138	21	.	.	.
	6	419	90	37	20	.	.
	7	700	111	15	2	.	.
	8	676	198	77	2	2	.
	9	443	126	30	1	.	.
	10	624	140	18	.	.	.
	11 bottom.	1413	257	12	3	.	.
B	1	643	110	27	.	.	.
	2	431	104	30	2	.	.
	3	405	317	10	4	.	.
	4	887	85	11	.	.	.
	5	1288	37	97	6	.	.
	6	744	309	89	41	14	.
	7	718	194	67	1	30	.
	8	730	227	27	4	.	.
	9	577	202	20	2	.	.
	10	505	105	19	.	.	.
	11						

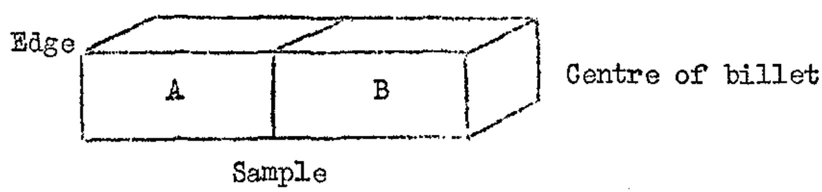


Table 34

Oxide size distribution counts on billet samples from ingot 2.

Position in Sample.	Position in ingot.	Number per sq.cm.in each size range μm. 1.8-3.0.	3.0-10.0.	10.0-20.0.	20.0-50.0	50.0-100.0.	> 100.
	1	.	.	.	.	.	.
	2	717	117	14	.	.	.
	3	341	119	.	.	.	.
	4	342	114	.	.	.	.
	5	344	165	18	2	.	.
	6	805	138	3	.	.	4
A	7	622	88	.	.	.	.
	8	636	124	.	.	.	.
	9	698	110	.	.	.	.
	10	735	152	8	7	.	.
	11	473	81	9	2	.	.
	1	.	.	.	.	.	.
	2	179	72	3	.	.	.
	3	376	87	10	6	.	.
	4	384	77	5	.	.	.
	5	485	135	48	6	.	.
	6	901	172	98	15	33	.
B	7	977	261	30	2	.	51.
	8	830	261	52	2	.	.
	9	621	149	42	13	.	.
	10	601	324	39	21	.	.
	11	984	117	23	.	.	.

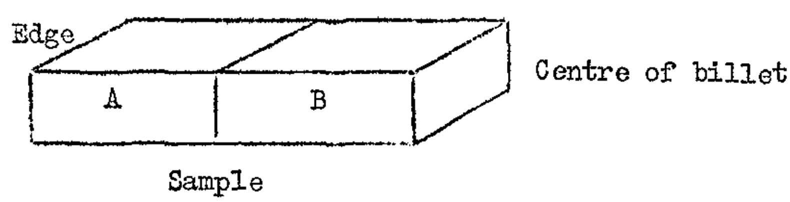


Table 35

Oxide percentage area counts on samples from bottom billet of ingot 1.

Position in sample.	Position in billet.	Frequency per 100 fields						Mean percent area.
		< 0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	
A	1 top	89	10	1	.	.	.	0.01.
	2	93	7	.	.	.	.	0.01.
	3	84	15	1	.	.	.	0.01.
	4	87	12	1	.	.	.	0.02.
	5	91	6	1	1	1	.	0.04.
	6	90	9	1	.	.	.	0.01.
	7	94	4	1	1	.	.	0.01.
	8 bottom	89	10	1	.	.	.	0.01.
B	1 top	88	10	2	.	.	.	0.01.
	2	87	11	1	1	.	.	0.02.
	3	90	8	1	1	.	.	0.02.
	4	92	8	.	.	.	.	0.01.
	5	82	18	.	.	.	.	0.02.
	6	93	6	1	.	.	.	0.01.
	7	88	11	1	.	.	.	0.02.
	8 bottom	87	10	1	1	.	1	0.04.

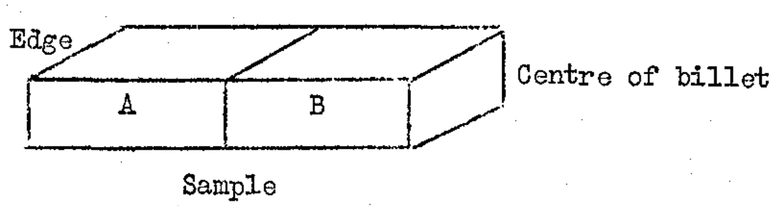


Table 36

Oxide percentage area counts on samples from bottom billet of ingot 2.

Position in sample.	Position in billet.	Frequency per 100 fields. <0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	Mean percent area.
A	1 top.	90	8	1	1	.	.	0.02.
	2	93	6	1	1	.	.	C.01.
	3	86	12	1	1	.	.	0.02.
	4	94	5	1	.	.	.	0.01.
	5	94	5	1	.	.	.	0.01.
	6	90	9	1	.	.	.	0.02.
	7	92	7	1	.	.	.	0.01.
	8bottom.	93	5	1	1	.	.	0.01.
B	1 top	94	4	1	1	.	.	0.01.
	2	85	12	2	1	.	.	0.02.
	3	88	9	3	.	.	.	0.02.
	4	88	11	1	.	.	.	0.02.
	5	94	5	1	.	.	.	0.01.
	6	80	15	3	1	1	.	0.04.
	7	94	5	1	.	.	.	0.01.
	8 bottom.	89	10	1	.	.	.	0.01.

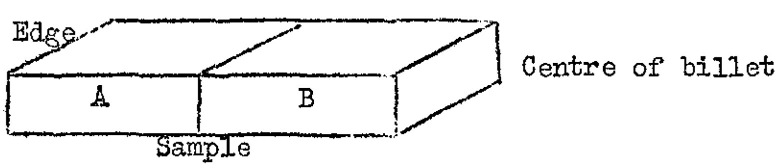


Table 37

Oxide size distribution counts on samples from bottom billet of ingot 1.

Position in sample.	Position in billet.	Number per sq.c.m.in each size range μm.					
		1.8-3.0.	3.0-10.0.	10.0-20.0.	20.0-50.0.	50.0-100.0.	$>$ 100.0.
	1	624	140	18	.	.	.
	2	662	96	19	.	.	.
	3	720	173	17	.	.	.
A	4	1153	67	13	2	.	.
	5	635	156	22	16	2	.
	6	1076	227	16	1	.	.
	7	1212	195	15	.	.	.
	8	1413	257	12	3	.	.
	1	505	105	19	.	.	.
	2	917	169	28	4	2	.
	3	807	244	28	.	.	.
B	4	567	104	11	2	.	.
	5	1592	184	45	33	.	.
	6	394	194	63	3	.	.
	7	1371	184	31	6	.	.
	8	593	275	16	50	20	20.

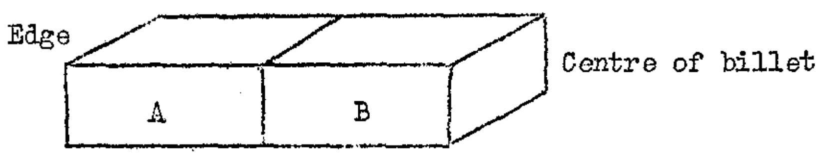


Table 38

Oxide size distribution counts on samples from bottom billet of ingot 2.

Position in sample.	Position in billet.	Number per sq.cm.in each size range μm.					
		1.8-3.0.	3.0-10.0.	10.0-20.0.	20.0-50.0.	50.0-100.0.	> 100.0.
A	1	735	152	13	3	7	.
	2	819	142	73	3	.	.
	3	890	205	19	2	.	.
	4	754	91	18	.	.	.
	5	777	122	9	.	.	.
	6	1052	194	33	.	.	.
	7	736	150	9	.	.	.
	8	473	81	9	2	.	.
B	1	601	324	39	21	.	.
	2	1021	294	26	5	.	.
	3	764	290	34	.	.	.
	4	742	204	28	1	.	.
	5	563	152	14	.	.	.
	6	866	281	50	23	.	.
	7	541	132	21	1	1	.
	8	984	117	23	.	.	.

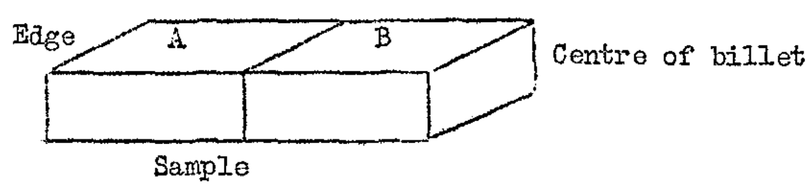


Table 39

Total oxygen content on adjacent billet samples from two ingots used.

Position in ingot.	Oxygen , weight per cent.($X10^{-4}$)	
	Ingot 1.	Ingot 2.
1. top.	56	.
2	.	38.
3	36	42.
4	38	50.
5	62	60.
6	47	70.
7	81	71.
8	47	43.
9	62	44.
10	53	80.
11 bottom.	50	62.

Bottom billets.

Position in billet.	Oxygen, weight percent ($X10^{-4}$)	
	Ingot. 1.	Ingot 2.
1 Top	53	80.
2	71	67.
3	62	55.
4	59	67.
5	56	65.
6	62	84.
7	51	60.
8 bottom.	50.	62.

Table 40

Assessment of inclusion content of billet samples from two adjacent ingots by sulphur printing

Position in ingot	Classification of samples	
	Ingot 31	Ingot 32
1	Clear	-
2	Clear	Clear
3	Clear	Clear
4	Clear	Clear
5	Clear	Spotty
6	Spotty	Spotty
7	Spotty	Spotty
8	Spotty	Clear
9	Spotty	Clear
10	Spotty	Clear
11	Clear	Spotty
Bottom billets		
1	Spotty	Clear
2	Clear	Spotty
3	Clear	Clear
4	Clear	Clear
5	Clear	Clear
6	Clear	Clear
7	Clear	Spotty
8	Clear	Spotty

Table 41

Step down visual and magnetic crack detection test results on samples from Ingot 1

Position in ingot	No. of inclusions/step						Aggregate inclusion length (mm)/step					
	Visual			Magnetic			Visual			Magnetic		
	1*	2*	3*	1	2	3	1	2	3	1	2	3
1 Top	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	2	.	.	.	.	.	10	.
4	.	2	.	2	2	1	.	20	.	71	26	6
5	1	.	.	2	1	1	9	.	.	12	16	12
6	.	3	2	3	7	10	.	31	18	15	105	105
7	.	1	.	1	.	.	.	8	.	12	.	.
8	.	.	.	.	3	2	.	.	.	.	75	55
9	1	.	.	1	4	4	10	.	.	18	57	39
10	1	.	.	1	2	38	10	.	.	15	8	61
11 Bottom	.	1	.	3	3	3	.	1	.	13	23	20
	Bottom billet											
1	1	.	.	1	2	38	10	.	.	15	8	61
2	.	.	.	.	2	1	.	.	.	.	25	20
3	1	.	.	.	1	1	14	.	.	.	25	35
4	2	.	3	3	2	3	16	.	21	43	17	18
5	.	.	1	.	.	2	.	.	8	.	.	30
6	.	.	.	3	1	4	.	.	.	41	14	25
7	1	1	.	1	1	3	1	1	.	43	17	35
8	.	1	.	3	3	3	.	1	.	13	23	20

*Steps on test piece, see Fig.50.

Table 42

Step down visual and magnetic crack detection test results on samples from Ingot 2

Position in ingot	No. of inclusions/step						Aggregate inclusion length (mm)/step					
	Visual			Magnetic			Visual			Magnetic		
	1*	2*	3*	1	2	3	1	2	3	1	2	3
1+												
2	.	.	.	3	2	4	.	.	.	21	29	46
3	.	2	.	3	12	12	.	86	.	24	35	12
4	.	1	.	4	14	2	.	9	.	28	100	65
5	.	.	1	1	1	1	.	.	13	10	15	35
6	1	.	.	1	.	.	6	.	.	20	.	.
7	.	1	.	2	2	3	.	10	.	65	25	30
8	3	1	.	4	4	1	29	7	.	83	123	10
9	.	2	1	.	1	2	.	22	8	.	50	16
10	3	1	1	7	4	6	19	4	6	63	57	53
11	.	1	.	3	3	3	.	11	.	13	25	20
Bottom billet												
1	3	1	1	7	4	6	19	4	6	63	57	53
2	.	.	.	.	2	1	.	.	.	.	11	10
3	.	.	.	2	1	4	.	.	.	15	5	65
4	.	2	1	1	1	5	.	6	12	6	7	31
5	.	1	1	2	3	2	.	9	8	31	28	31
6	.	.	.	.	1	2	.	.	.	.	5	12
7	2	1	3	1	2	2	12	6	17	8	16	24
8	.	1	.	3	3	3	.	11	.	13	25	20

+ Sample inadvertently lost

* Steps on test piece, see Fig. 50.

Table 43

Specifications of steels used

Specification	Composition, wt, %							
	C	Mn	Si	S	P	Ni	Cr	Mo
SAE8620	0.18-0.21	0.70-0.80	0.20-0.25	0.030-0.040	0.025 Max	0.45-0.55	0.45-0.55	0.18-0.23
En16	0.35-0.38	1.40-1.60	0.25-0.30	0.030-0.040	0.025	-	-	0.20-0.30
CK35 (German) (En8)	0.34-0.37	0.58-0.68	0.25-0.30	0.025-0.035	0.030	-	0.10-0.15	0.03-0.04
En15A	0.35-0.40	1.40-1.60	0.25-0.30	0.30-0.04	0.025	-	-	-
JDM1041 F (En 15)	0.36-0.44	1.40-1.60	0.25-0.30	0.025-0.035	0.030	-	0.20-0.25	0.09-0.10

Table 44

Pit-side chemical analysis of casts of steel used

Cast No.	Quality	Pit-side analysis, wt. %									
		C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Sn
P200	SAE 8620	0.19	0.71	0.25	0.033	0.032	0.49	0.51	0.18	0.14	0.017
P445	" "	0.195	0.82	0.23	0.036	0.019	0.48	0.53	0.19	0.155	0.020
P917	" "	0.185	0.80	0.24	0.035	0.024	0.48	0.52	0.19	0.160	0.022
P894	" "	0.180	0.76	0.23	0.035	0.029	0.55	0.53	0.19	0.160	0.020
2969	" "	0.220	0.81	0.26	0.037	0.016	0.50	0.44	0.20	0.17	0.021
P792	" "	0.210	0.83	0.30	0.026	0.021	0.54	0.52	0.21	0.17	0.023
P902	" "	0.220	0.79	0.25	0.034	0.018	0.51	0.49	0.20	0.135	0.019
2387	" "	0.230	0.78	0.27	0.034	0.025	0.46	0.50	0.22	0.15	0.020
3225	En16	0.360	1.49	0.31	0.034	0.024	0.34	0.19	0.22	0.180	0.024
3391	En15A	0.390	1.49	0.28	0.032	0.030	0.15	0.130	0.04	0.100	0.014
3224	En16	0.350	1.46	0.30	0.036	0.034	0.34	0.225	0.22	0.17	0.022
P603	SAE8620	0.205	0.76	0.27	0.043	0.023	0.55	0.47	0.19	0.16	0.019
2958	" "	0.230	0.86	0.25	0.034	0.027	0.50	0.54	0.20	0.19	0.021
T113	CK35	0.355	0.59	0.31	0.035	0.018	0.05	0.12	0.03	0.08	0.012
P587	JDM1041	0.420	1.35	0.27	0.034	0.042	0.39	0.29	0.10	0.16	0.025

Table 45

Details of casts of steel used

Cast no.	Quality	Tapping temp., $^{o}C.$	Teeming temp., $^{o}C.$	No. of groups	No. of ingots	Ingot size, cwt.	No. of samples taken	Remarks
P200	SAE8620	1710	$1670^{\times}$ 1580^{+}	2	13	37	20	Single slag, vacuum degassed, grain refined
P445	"	1700	$1650^{\times}$ 1575^{+}	2	13	37	8	
P917	"	1690	$1650^{\times}$ 1575^{+}	2	13	$34\frac{1}{2}$	24	
P894	"	1700	$1670^{\times}$ 1580^{+}	2	13	37	16	
2969	SAE8620	1610	1580	5	31	37	16	Single slag, grain refined
P792	"	1630	1575	3	9	31	16	
P902	"	1610	1580	2	13	$34\frac{1}{2}$	8	
2387	"	1615	1575	4	31	37	12	
T369	15NiCr Mo6	1625	1585	2	13	37	180	Single slag
3225	En16	1600	1575	5	34	37	16	
3391	En15A	1605	1570	5	35	$34\frac{1}{2}$	20	
[illegible]224	En16	1600	1575	5	34	37	16	
P683	"	1620	1580	2	12	37	6	Double slag, grain refined
2958	"	1600	1570	5	35	34	20	
T113	CK35	1710	$1660^{\times}$ 1570^{+}	2	13	37	8	Single slag, vacuum degassed
P587	JDM1041 F	1700	$1700^{\times}$ 1570^{+}	2	13	$34\frac{1}{2}$	180	

$^{\times}$ Before degassing

+ After degassing

Table 46

Conditions under which samples were examined on the Quantimet

Details	Condition	
	A	B
Objective	X10	X5
Magnification to TV screen	X537	X270
Resolution (optical)	1.8 μm	3.6 μm
Field area	0.25 mm^2	0.5 mm^2
Optical resolution	1.8 μm	3.6 μm
Electronic resolution setting	Max.	Max.
Light source and setting	W/8	W/8
No. of fields per zone	100	100
Parameters measured on each field		
Percentage area A_o		
Total projection P_o		
Total count (No > than)	1.8	3.6
Size distribution:		
No. > than	3	5
" " "	10	10
" " "	20	15
" " "	50	20
" " "	100	25
Calibration	By std. sample before each specimen	By std. sample before each specimen

Table 47

Summary of data on oxide inclusions in four zones, 1, 2, 3 and 4, extending from edge to centre of billet

Percentage area count

Position in billet sample	Frequency of fields						Percentage area	
	<0.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	>2.70%	Mean	Std. devn.
Zone 1	3618	1775	100	5	1	1	0.05	0.04
Zone 2	3696	1904	90	14	.	.	0.05	0.04
Zone 3	3791	1809	100	20	1	.	0.05	0.04
Zone 4	3856	1744	120	23	6	3	0.06	0.05

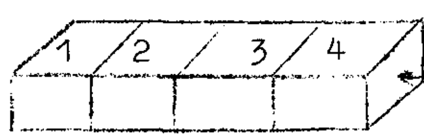
Size distribution count

Position in billet sample	Mean count: No of oxides greater than:				
	1.8 μm	10 μm	20 μm	50 μm	10 μm
Zone 1	10.68	1.56	0.28	0.08	0.020
Zone 2	9.35	1.44	0.25	0.04	0.016
Zone 3	9.58	2.18	0.39	0.03	0.010
Zone 4	7.93	1.11	0.21	0.07	0.030

Projection count:

Position in billet sample	Total length, μm.	
	Mean	Std. devn.
Zone 1	67	39
Zone 2	64	43
Zone 3	65	40
Zone 4	57	45

Edge



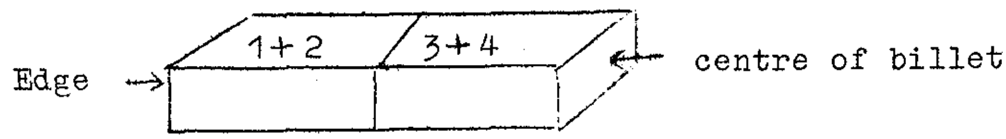
centre of billet

Note: The mean estimates are for 1 field 0.25 mm^2

Table 48

Summary of data on oxide inclusions in two zones (1+2) and (3+4), of the billet

Position in billet sample	Frequency of fields						Percentage area	
	< 0.03	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	> 2.70%	Mean.	Std. dev.
Zone 1 + 2	3625	1427	46	2	.	.	0.03	0.04
Zone 3 + 4	3750	1267	49	18	4	4	0.04	0.05



Note: The mean estimates are for 1 field 0.5 mm^2

Table 49

Percentage area, size distribution and projection measurements for oxide inclusions in samples drawn from 45 ingots representing different groups in cast of steel

Position of samples in cast	Frequency of fields^{x}						Percentage area	
	< .03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	>2.70%	Mean	Std. devn.
Group 1	2264	1122	99	14	2	.	0.04	0.079
Group 2	2253	1251	80	12	4	.	0.05	0.055
Group 3	2261	1262	58	11	3	1	0.05	0.027
Group 4	2307	1199	92	12	8	2	0.05	0.092

Position of samples in cast	Size distribution: No greater than (mean no/field^{x})				
	> 3.6 µm (total)	>10 µm	>15 µm	20 µm	25 µm
Group 1	3.47	0.32	0.10	0.04	0.01
Group 2	3.31	0.30	0.09	0.03	0.01
Group 3	3.09	0.27	0.07	0.03	0.01
Group 4	3.71	0.31	0.10	0.04	0.01

Position of samples in cast	Projection (total length, µm) per field^{x}	
	Mean	Std. devn.
Group 1	47.31	55.78
Group 2	43.66	55.09
Group 3	45.00	58.33
Group 4	48.85	64.36

^{x} Field area = 0.5 mm^2

Table 50

Percentage area counts for oxide inclusions in 14 casts of steel made by different finishing processes

Cast no.	Finishing process	Frequency of fields* percentage						Percentage area	
		<.03%	0.03-0.20%	0.20-0.55%	0.55-1.20%	1.20-2.70%	>2.70%	Mean	Std. Devn.
P200	Single slag,	67.57	31.20	0.91	0.23	0.09	.	0.037	0.079
P445	vacuum degassed,	56.85	37.55	4.39	0.88	0.38	.	0.067	0.115
P917	grain refined	77.40	20.50	1.21	0.26	0.46	0.17	0.047	0.125
P894		53.25	45.34	1.25	.	0.06	.	0.044	0.052
2969	Single slag,	72.00	26.30	1.34	0.15	0.13	.	0.034	0.058
P792	grain refined	80.60	18.60	0.77	0.13	.	.	0.024	0.039
P902		62.50	33.00	3.24	0.63	0.63	.	0.065	0.045
2387		62.00	35.42	2.08	0.42	0.08	.	0.046	0.059
3225	Single slag	55.00	40.45	3.90	0.50	0.10	0.05	0.060	0.079
3391		50.00	42.00	6.30	1.35	0.35	.	0.079	0.128
3224		50.50	44.50	4.30	0.64	0.06	.	0.065	0.110
P683	Double slag,	75.00	23.50	1.25	0.25	.	.	0.024	0.036
2958	grain refined	66.30	32.30	1.30	0.10	.	.	0.033	0.040
T113	Single slag, vacuum degassed	60.4	36.50	3.00	0.13	.	.	0.049	0.057

* Field area = 0.5 mm^2

Table 51

Size distribution counts for oxide inclusions in 14 casts of steel made by different finishing processes

Cast no.	Finishing process	Size distribution: no greater than (Mean no./field*)				
		3.6 μm	10 μm	15 μm	20 μm	25 μm
P200	Single slag, vacuum degassed, grain refined	2.18	0.66	0.08	0.03	0.01
P445		4.00	0.40	0.12	0.05	0.02
P917		3.08	0.24	0.11	0.06	0.04
P894		2.68	0.23	0.06	0.02	0.01
2969	Single slag, grain refined	2.58	0.25	0.03	0.01	0.01
P792		2.04	0.17	0.05	0.02	0.01
P902		3.99	0.48	0.14	0.04	0.02
2387		3.81	0.49	0.20	0.07	0.02
3225	Single slag	4.16	0.37	0.11	0.04	0.02
3391		9.25	0.52	0.16	0.06	0.03
3224		4.22	0.41	0.13	0.05	0.02
P683	Double slag, grain refined	2.00	0.11	0.03	0.01	0.002
2958		2.86	0.11	0.03	0.01	0.005
T113	Single slag, vacuum degassed	3.76	0.32	0.10	0.05	0.03

*Field area = 0.5 mm^2

<u>Table 52</u>

<u>Total projection (total length) counts for oxide inclusions in 14 casts of steel made by different finishing processes</u>

Cast no.	Finishing process	Projection (total length μm)/field	
		Mean	Std. devn.
P200	Single slag, vacuum degassed grain refined	32	51
P445		60	86
P917		41	68
P894		47	45
2969	Single slag, grain refined	37	52
P792		26	30
P902		55	96
2337			
3225	Single slag	43	51
3391		77	101
3224		49	59
P683	Double slag, grain refined	28	39
2958		36	39
T113	Single slag, vacuum degassed	51	52

Table 53

Percentage area data for oxide inclusions in 14 casts of steel made by different finishing processes

Cast no.	No. of determinations	Percentage area count				Remarks
		Mean	Std. dev.	Std. error	Largest possible error	
P200	20	0.04	0.015	0.0034	0.0068	Single slag, vacuum degassed, grain refined
P445	8	0.07	0.030	0.0106	0.0212	
P917	24	0.05	0.050	0.0102	0.0204	
P894	16	0.04	0.015	0.0038	0.0076	
T113	8	0.05	0.026	0.0090	0.0180	Single slag, vacuum degassed
P683	6	0.02	0.007	0.0029	0.0098	Double slag, grain refined
2958	20	0.03	0.016	0.0036	0.0072	
3225	16	0.06	0.031	0.0078	0.0156	Single slag
3391	20	0.08	0.030	0.0067	0.0134	
3224	16	0.07	0.016	0.0040	0.0080	
2969	16	0.03	0.017	0.0044	0.0088	Single slag, grain refined
P792	16	0.02	0.014	0.0035	0.0070	
P902	8	0.07	0.026	0.0090	0.0180	
2387	12	0.05	0.031	0.0090	0.0180	

Fig.1. Reactions taking place inside the neutron generator

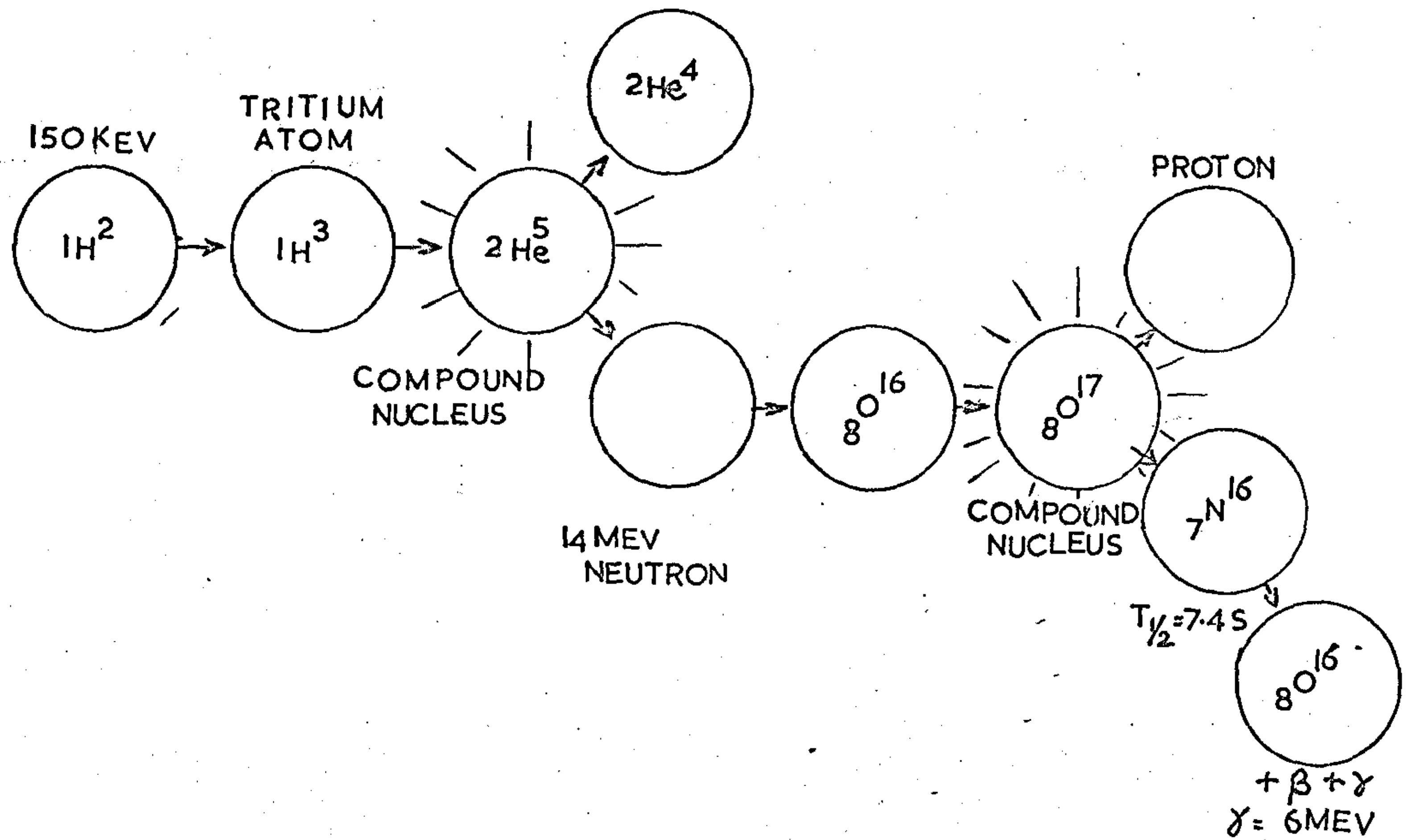


FIG. 2

THE "FOX" INCLUSION CHART

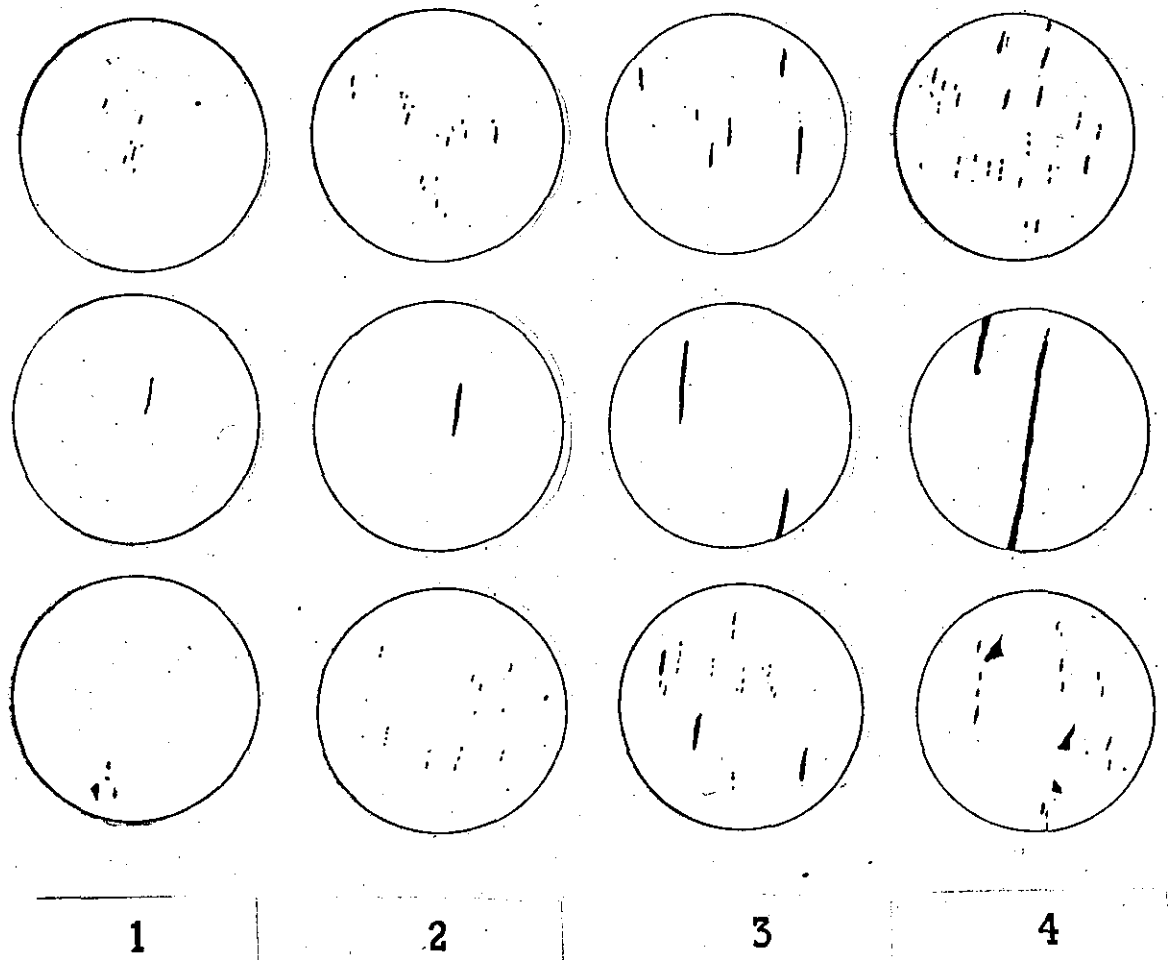


Fig. 3 The JK Inclusion Chart

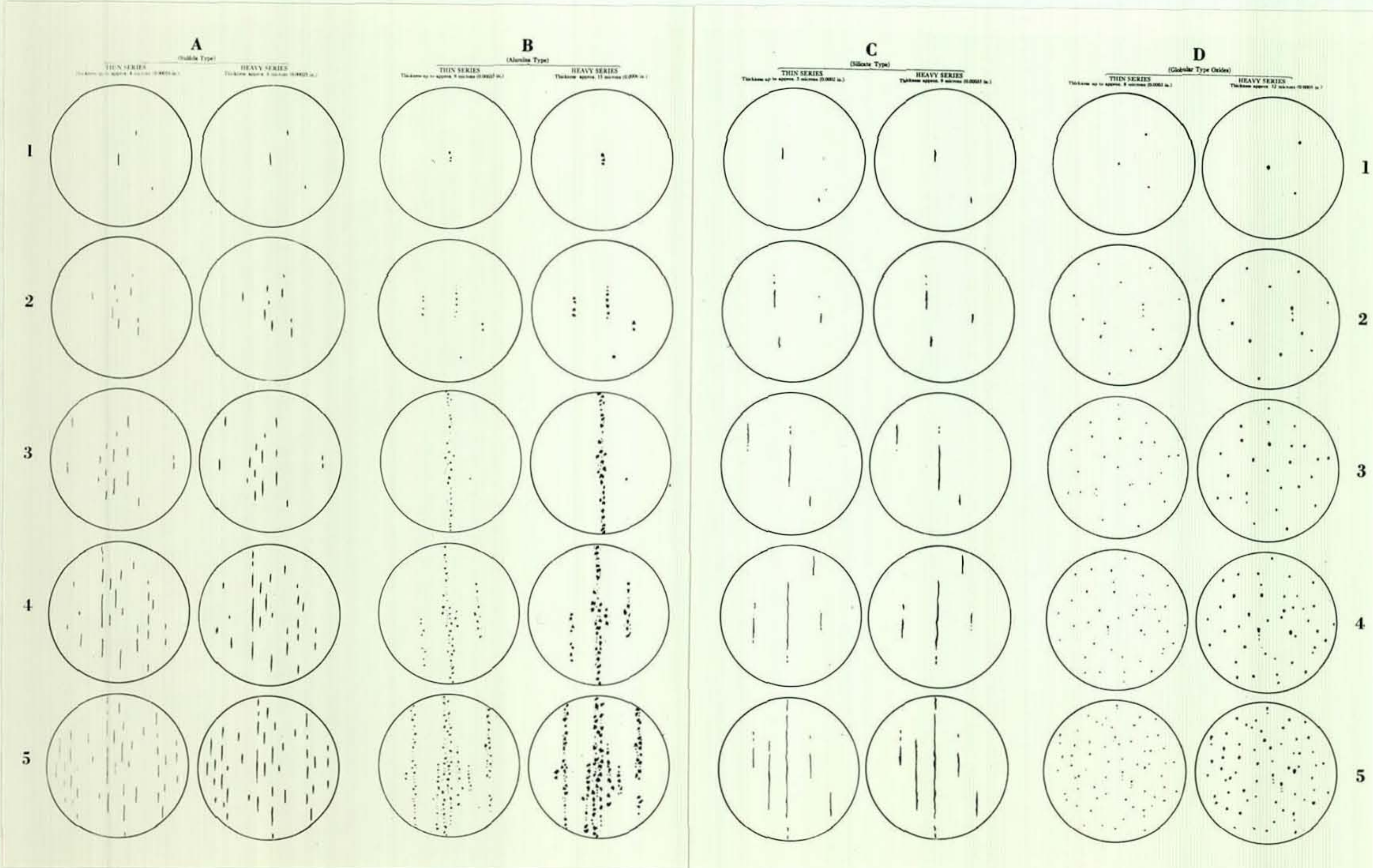


Fig. 4 The Diergarten Inclusion Chart
(REduced 33:1; original 100:1)

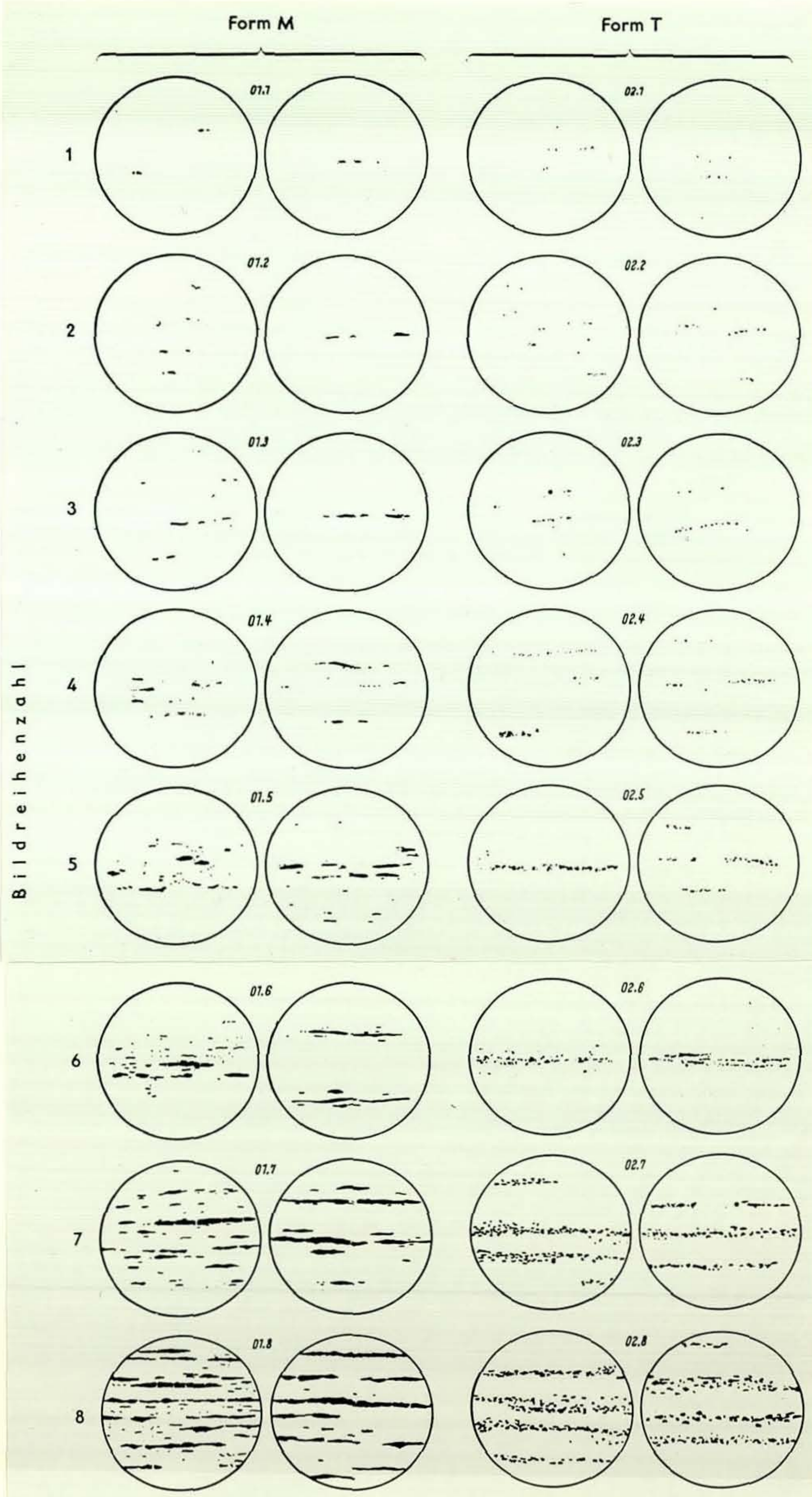


Fig. 4 continued

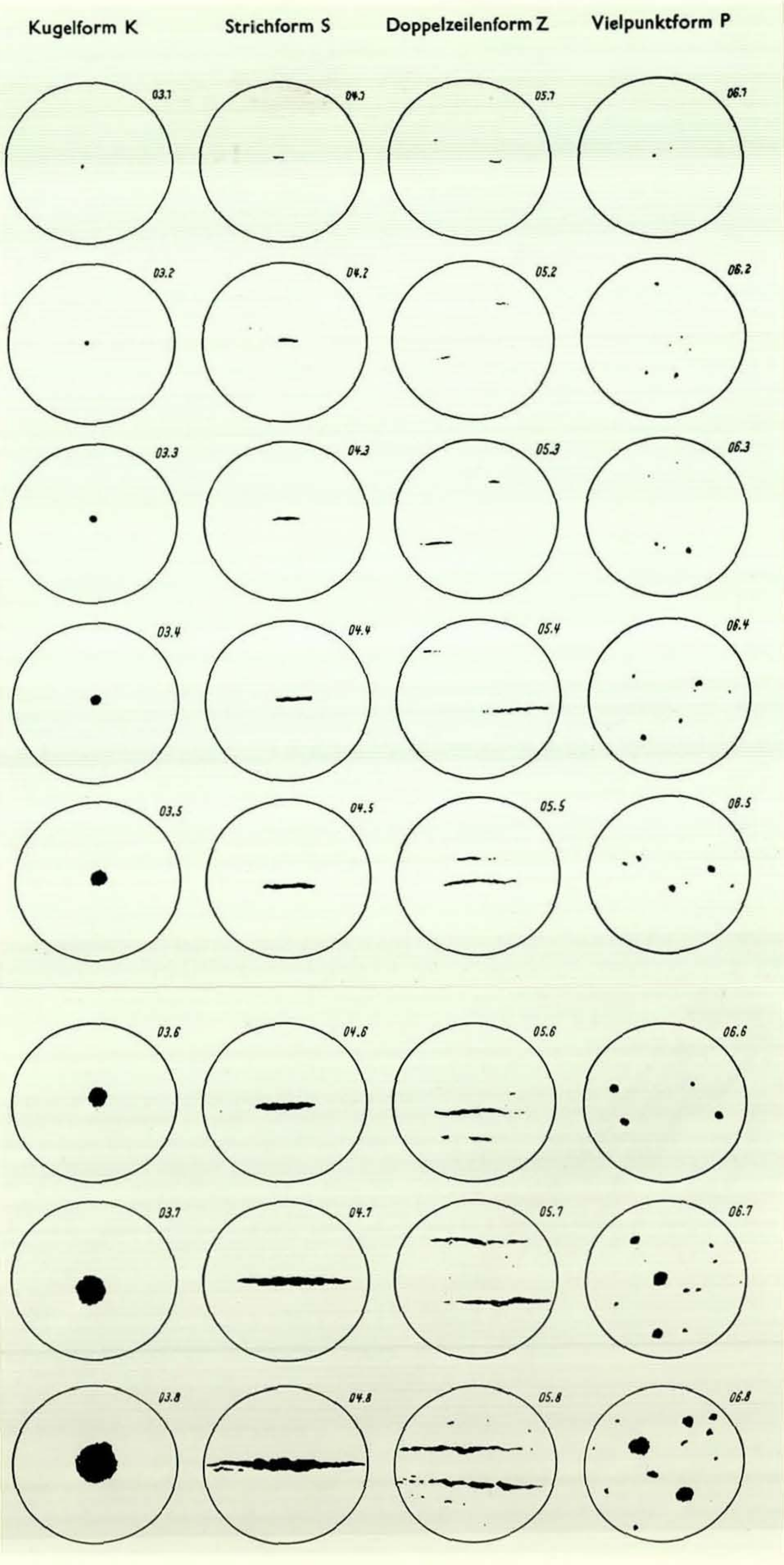
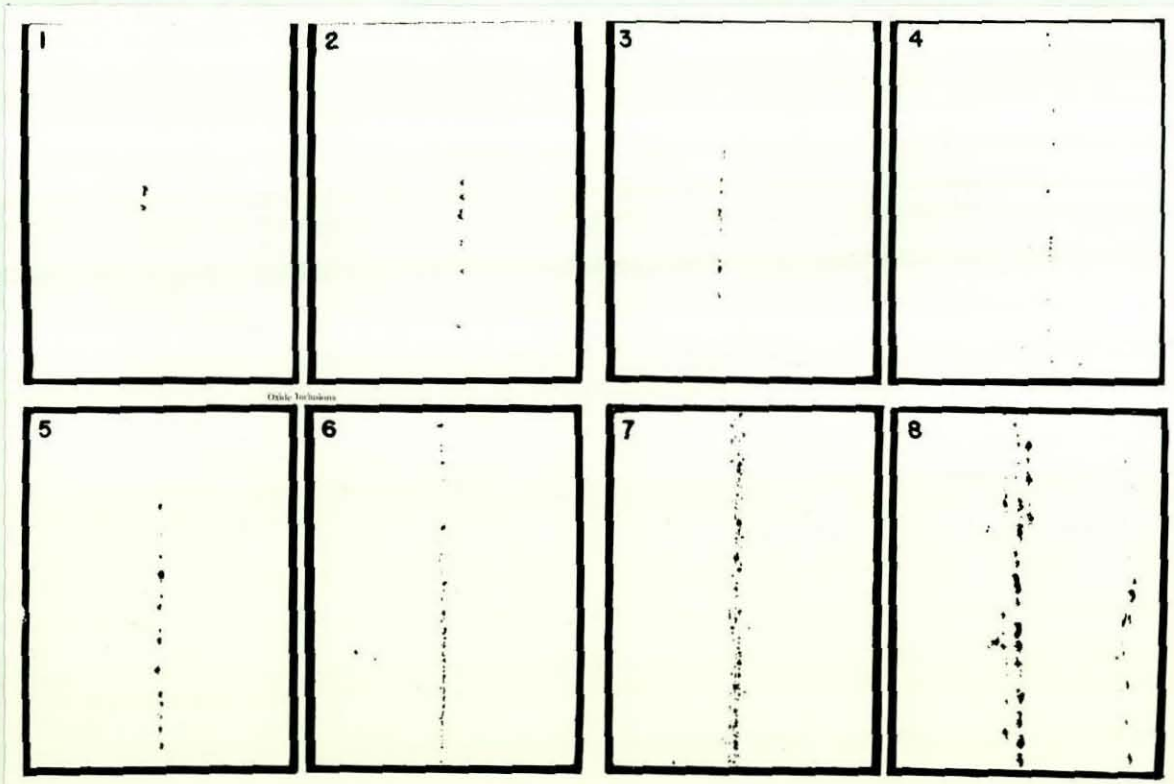
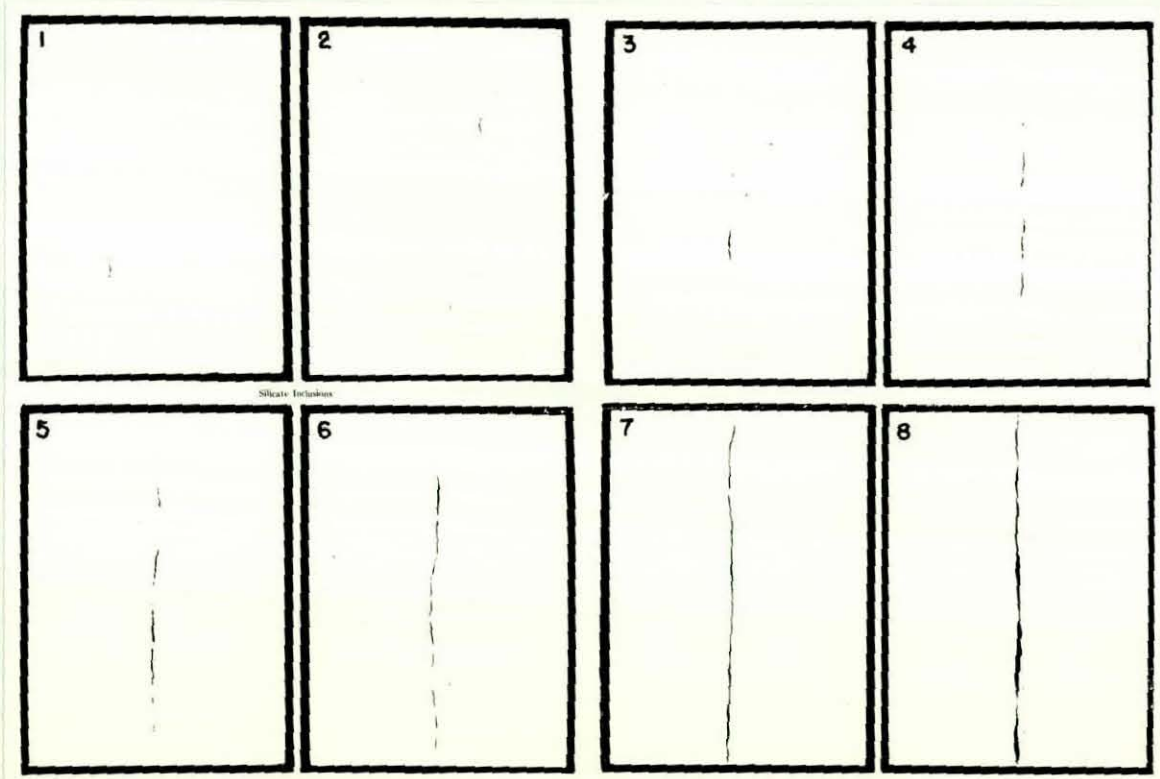


Fig. 5 The Chevrolet Inclusion Chart (SAE-ASTM method)



Oxides

Fig. 5 continued



Silicates

Fig. 6

Lineal traverse inclusion count in which a measured distance is traversed under the microscope and only inclusions intercepted by the intersection of the cross-wires, such as A, B , and C, are counted.

Fig. 6 Illustrating principle of counting inclusions by the LT method

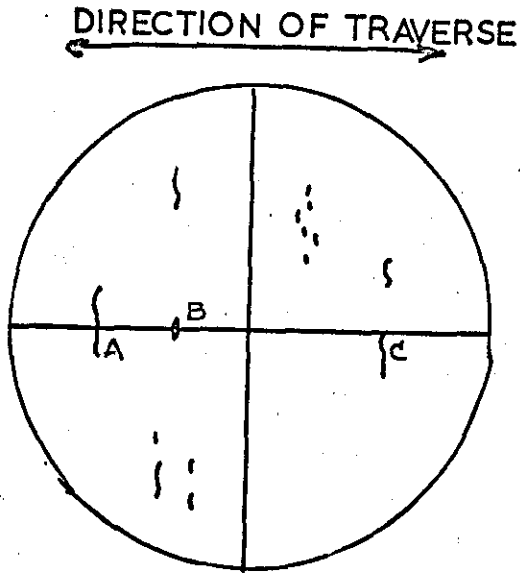


Fig. 7

Modified lineal traverse method. A measured distance is traversed under the microscope and only inclusions intercepted by both cross-wires, such as I, 5, and 7, are counted. Inclusions, such as 2,3,4,6 and 8 , are not counted.

e f is a movable cross-wire pre-set a certain distance from a b.

Fig. 7 Illustrating principle of counting inclusions by the modified LT method

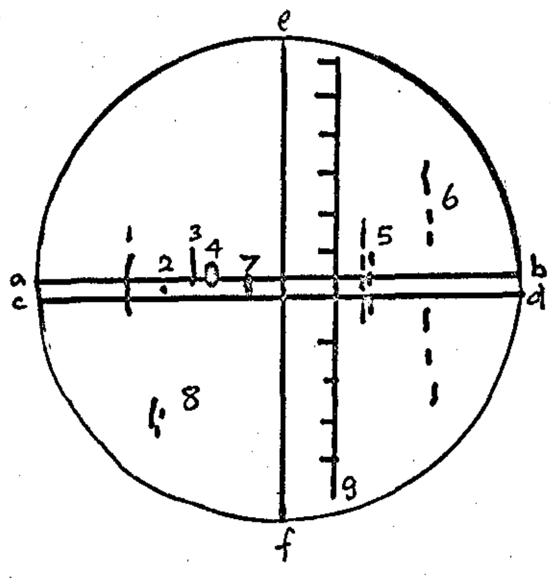


Fig. 8

Baynes' Intercept Count Method. The inclusion to be counted in Fig. 8 a is at point A. The inclusion at point B on the lower cross-wire is not to be counted in this field. The next field to be counted after that shown in (a) is shown in Fig.8 b. The inclusion at point B in (a) is now available for counting at point B_I on the counting cross-wire in Fig. 8 b. As a chech on the position of this field to be assessed, the inclusion at point A in Fig. 8 a is now on the upper cross-wire of point A_I in Fig. 8 b. The index of the inclusion count is the number of fields observed to count IOO inclusions.

Fig. 8 Illustrating principle of counting inclusions by Baynes' intercept method

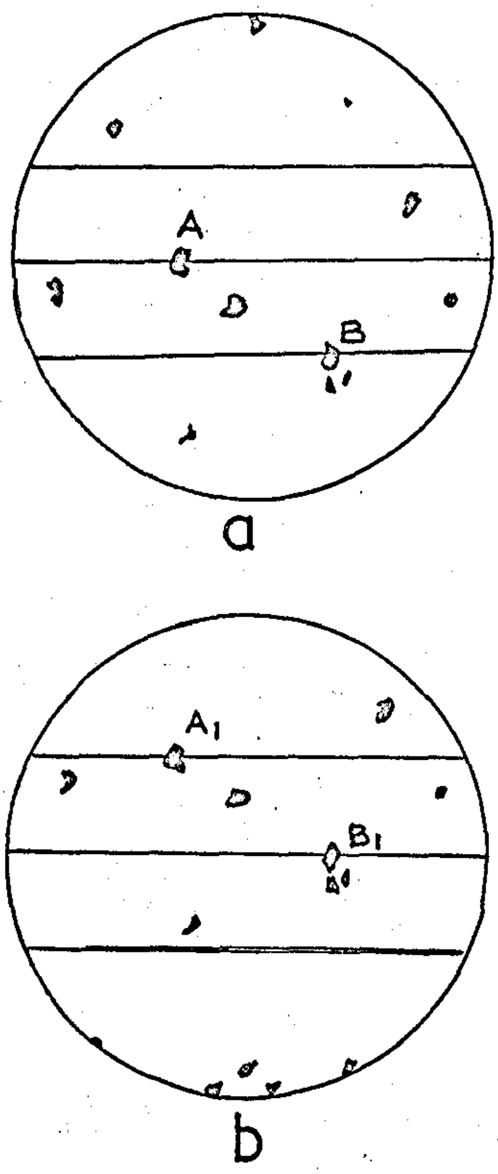


Fig. 9 Illustrating principle of Rosiwal's method for determining volume fraction of phases

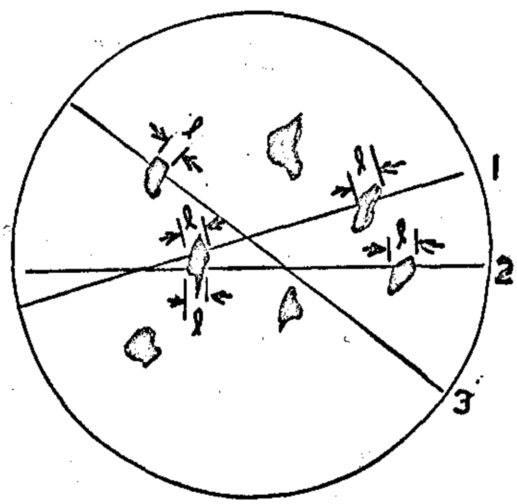


Fig.10 Point-counting reticules for use in a focusing eyepiece

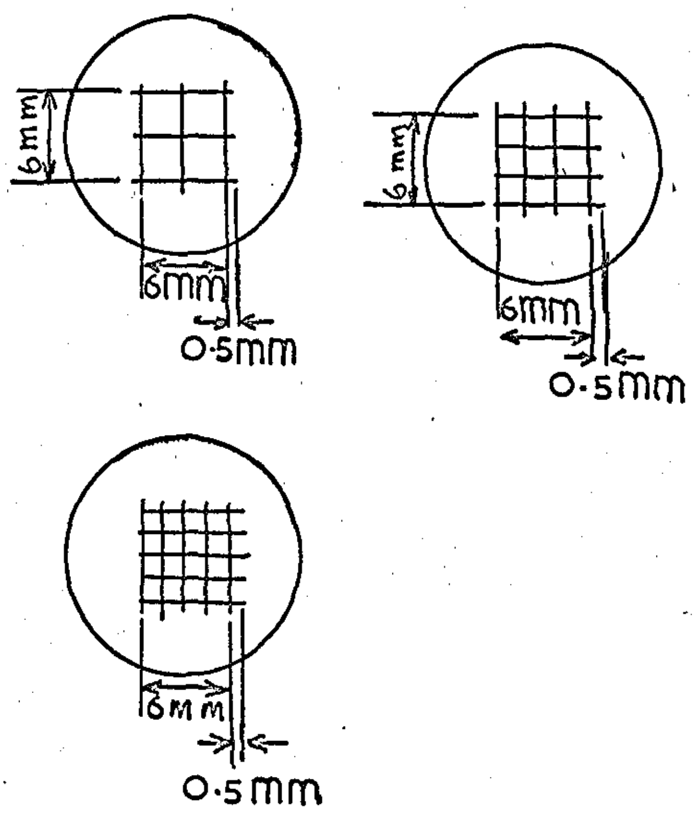


Fig. II

Examples of assessment of some typical inclusions. Note that the inclusion length , L, is indicated as a if $a < L < (a + I)$. I: length = 4 units, 2 crosses over inclusions. 2, 3, 4, and 5: according to the rules in the test these are two stringers; 2 and 3 are one stringer with L = I unit, 0 cross, and 4 and 5 are one stringer with L = I unit, 0 cross. 6 inclusion with L less than I unit not counted. 7 and 8, one stringer because the space between them is shorter than the length of the shorter inclusion with L = 3 units, I cross. 9, inclusion partially falling outside the grid, number 0.5, L = 3 units, I cross. Special types of inclusions, e.g. alumina; inclusion assessed as a stringer of $L \geq 4$ units.

Fig. 11 Illustrating principle of counting inclusions by Bergh's method

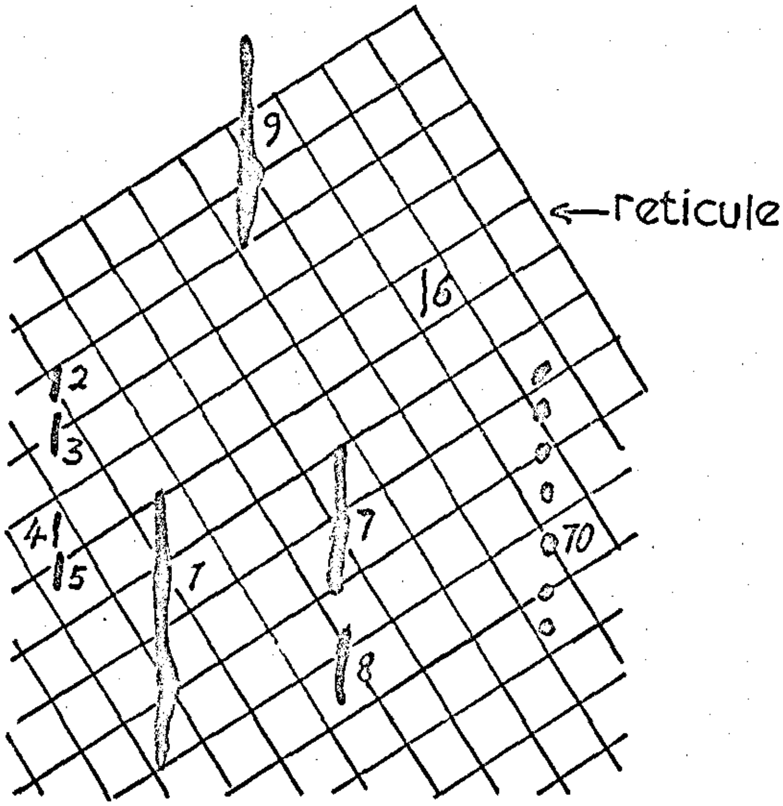


Fig.12 Example of chart suggested by Jernkontoret

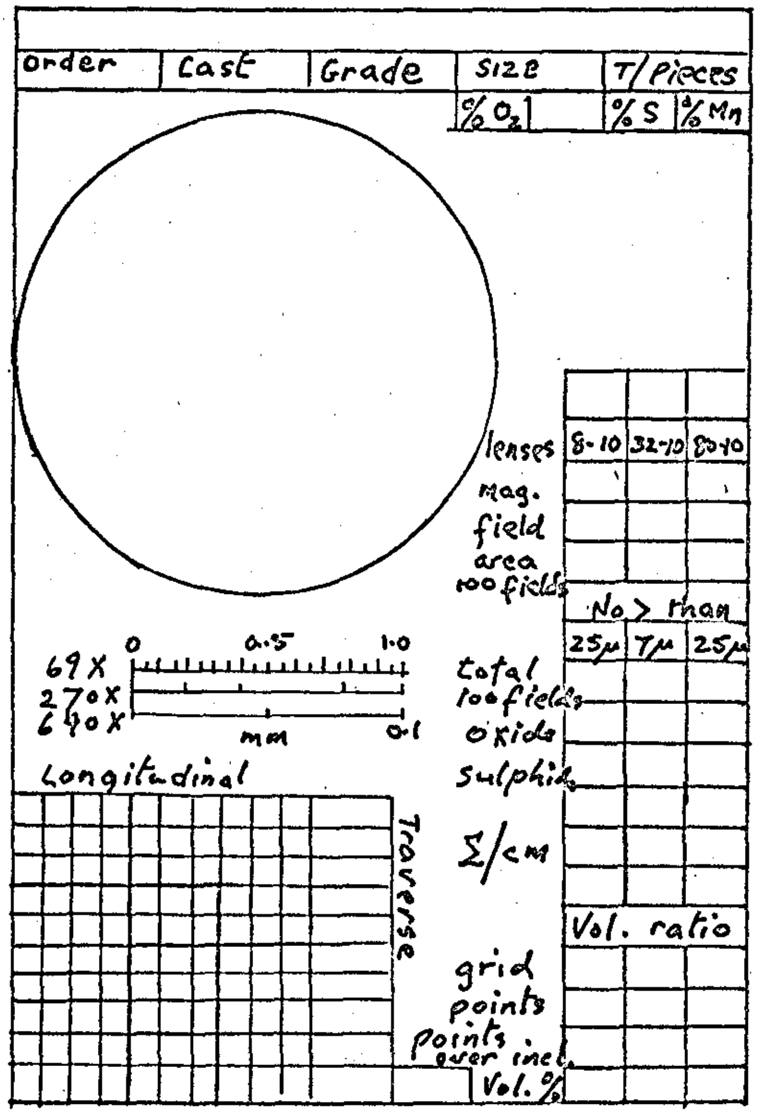


Fig.13 Schematic ray and block diagram of flying-spot microscope for metallurgy

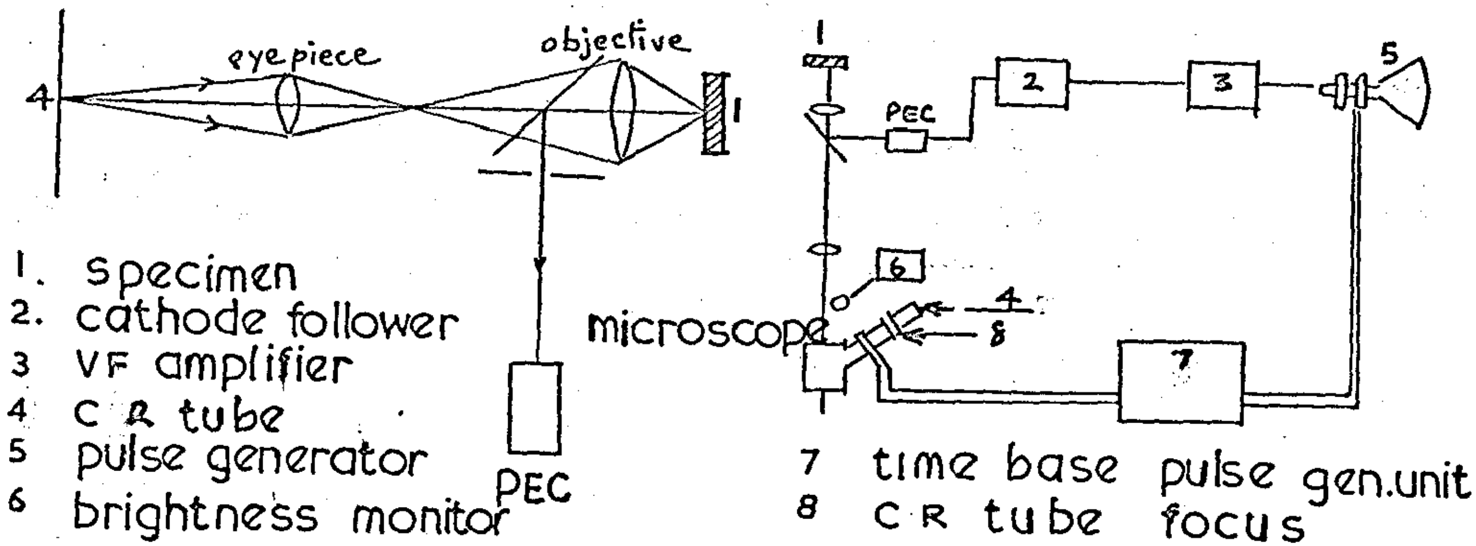
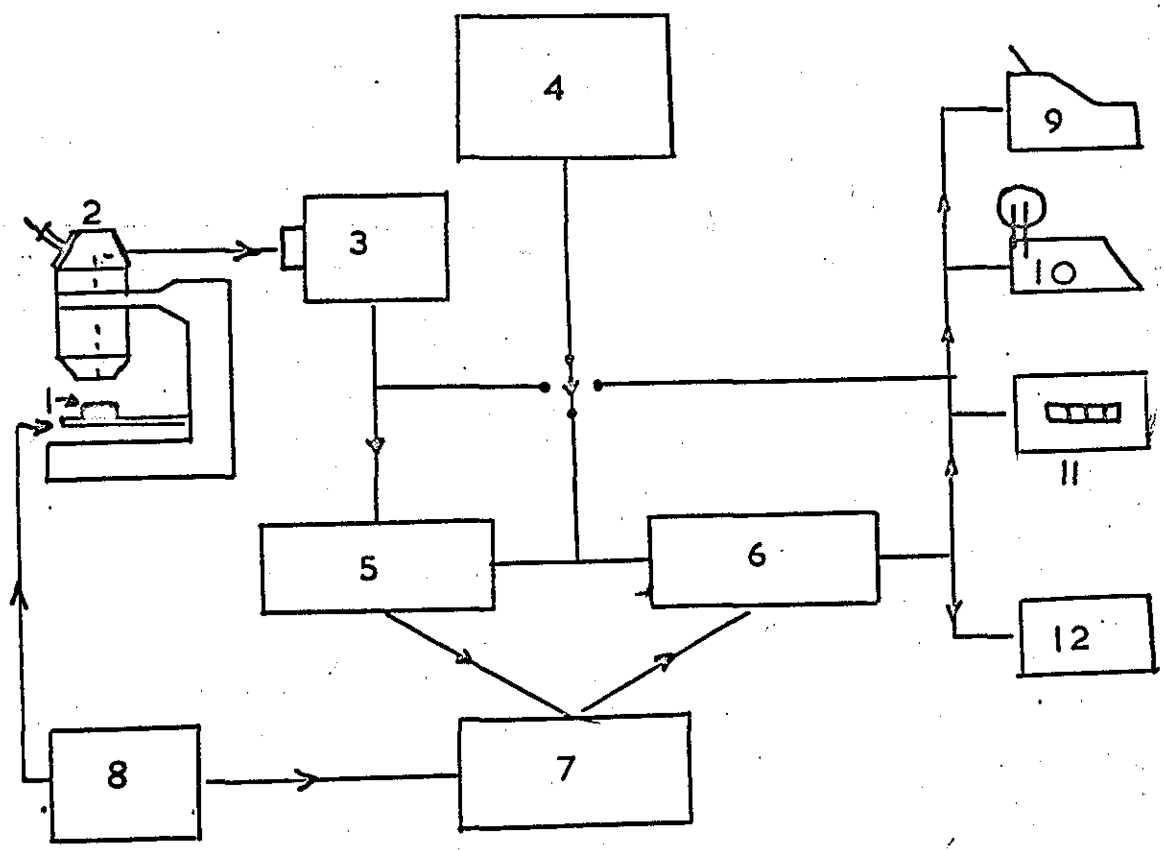


Fig 14 Simplified block diagram of Quantimet image analysing computer



1 specimen
2 microscope
3 camera
4 monitor
5 detector
6 computer
7 programme selector
8 sequence control
9 print out
10 punch
11 digital display
12 special output monitors

Fig. 15 Schematic diagram of Coulter particle size counter

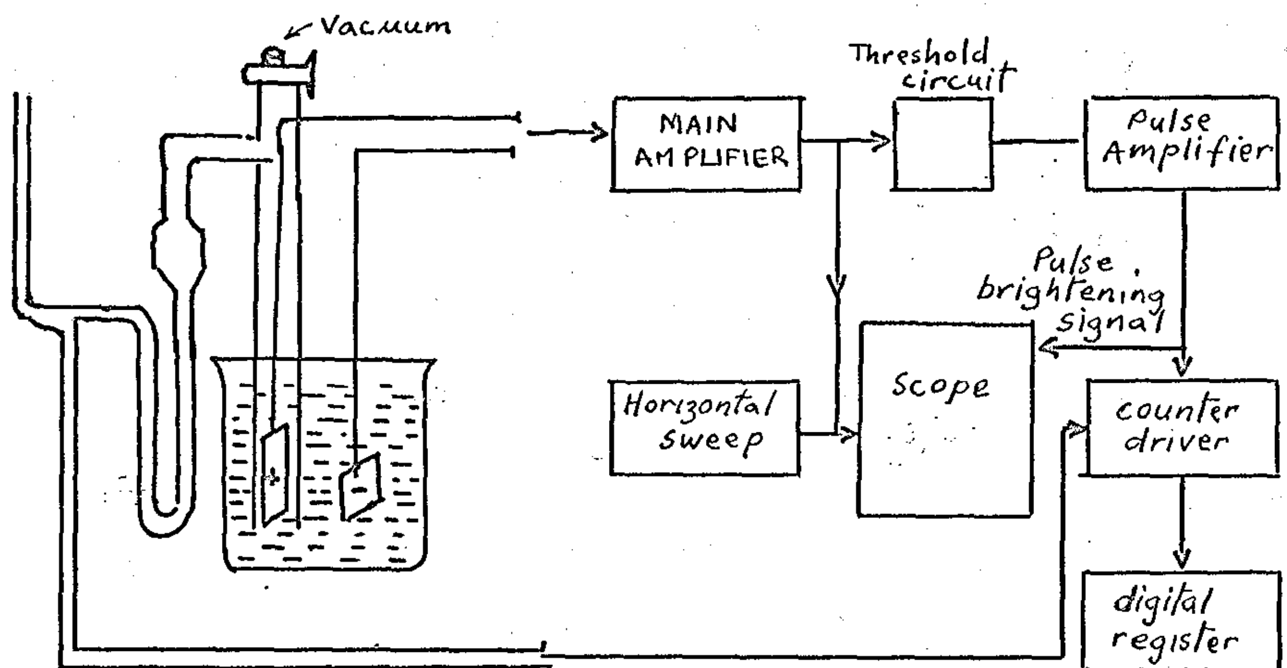
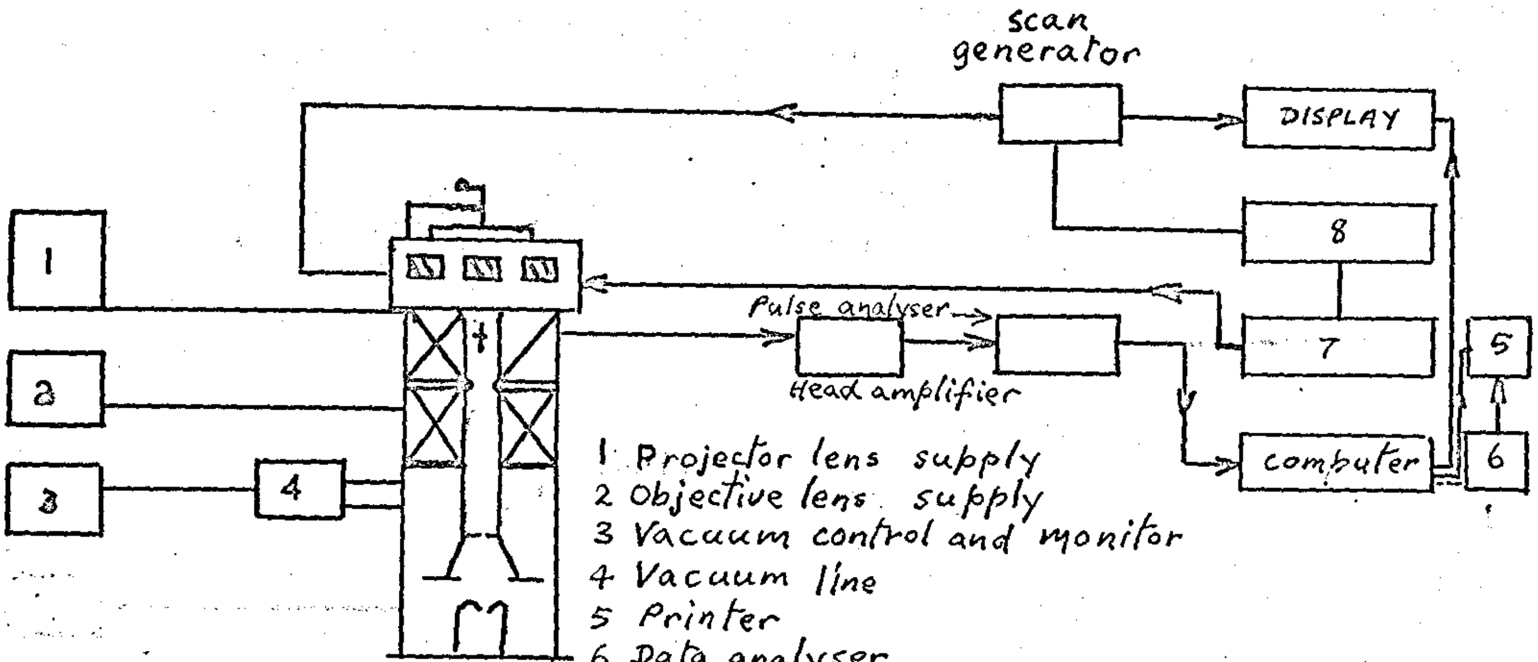


Fig. 16 Schematic layout of the Vickers Automatic Inclusion Counter



1 Projector lens supply
2 Objective lens supply
3 Vacuum control and monitor
4 Vacuum line
5 Printer
6 Data analyser
7 Specimen stage drive
8 Programme unit

Fig. 17 A general view of the automatic Quantimet Image Analysing Computer

FIG. 18.

OUTPUT SIGNAL FROM A SINGLE LINE SCAN OF A SAMPLE CONTAINING THREE INCLUSIONS OF DIFFERENT SIZES & CONTRAST

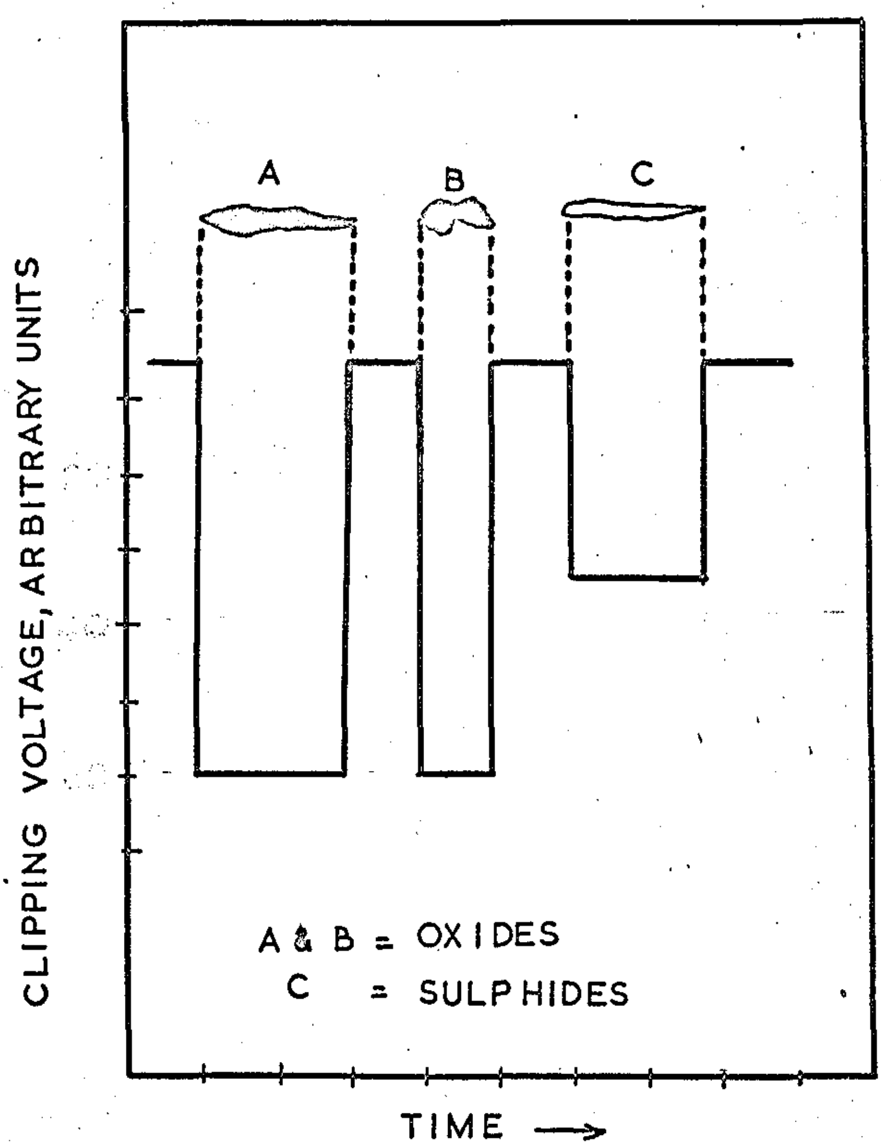


FIG. 19

VARIATION IN BLANK FRAME SETTING

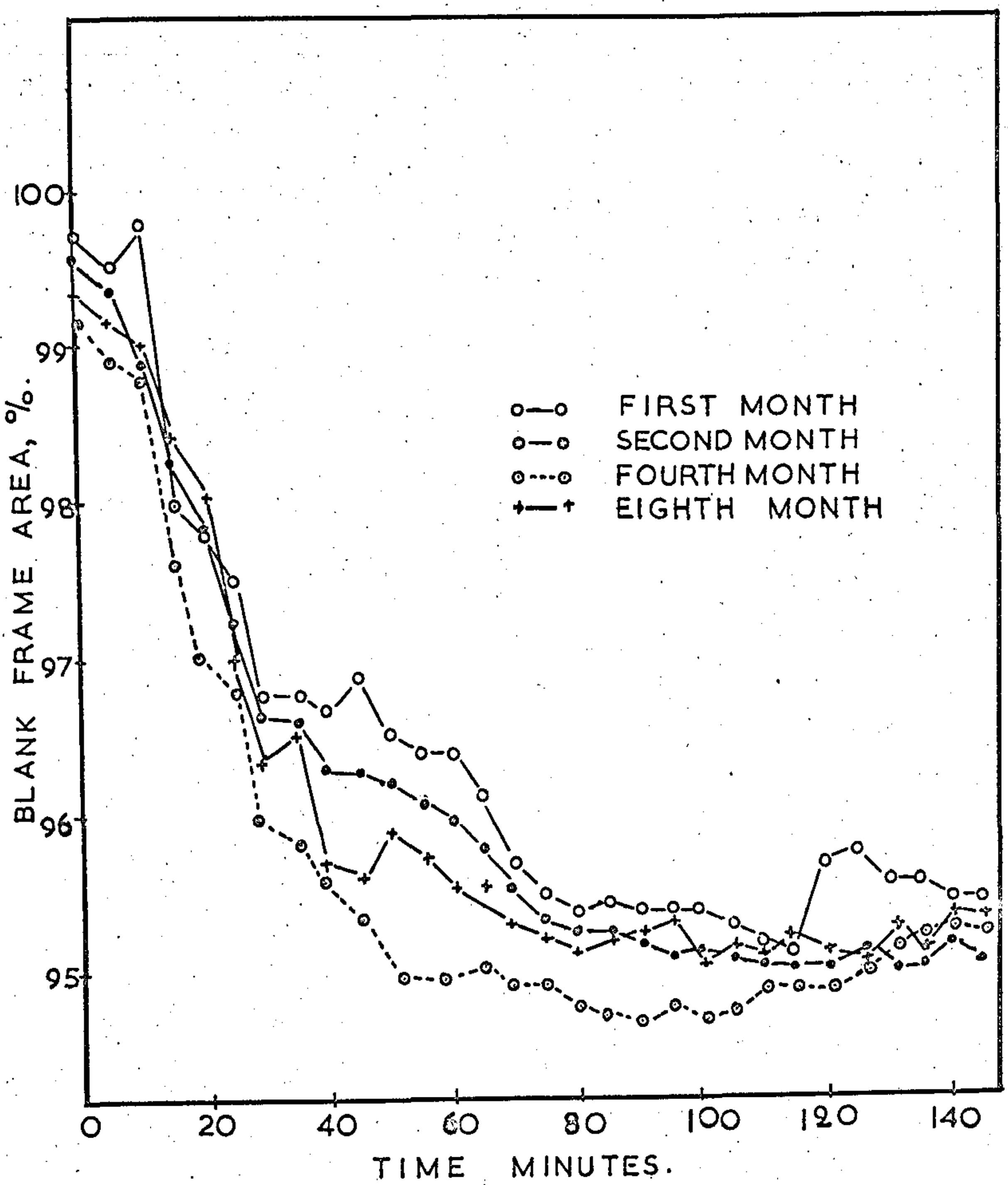


FIG. 20.

VARIATIONS IN CAMERA SENSITIVITY

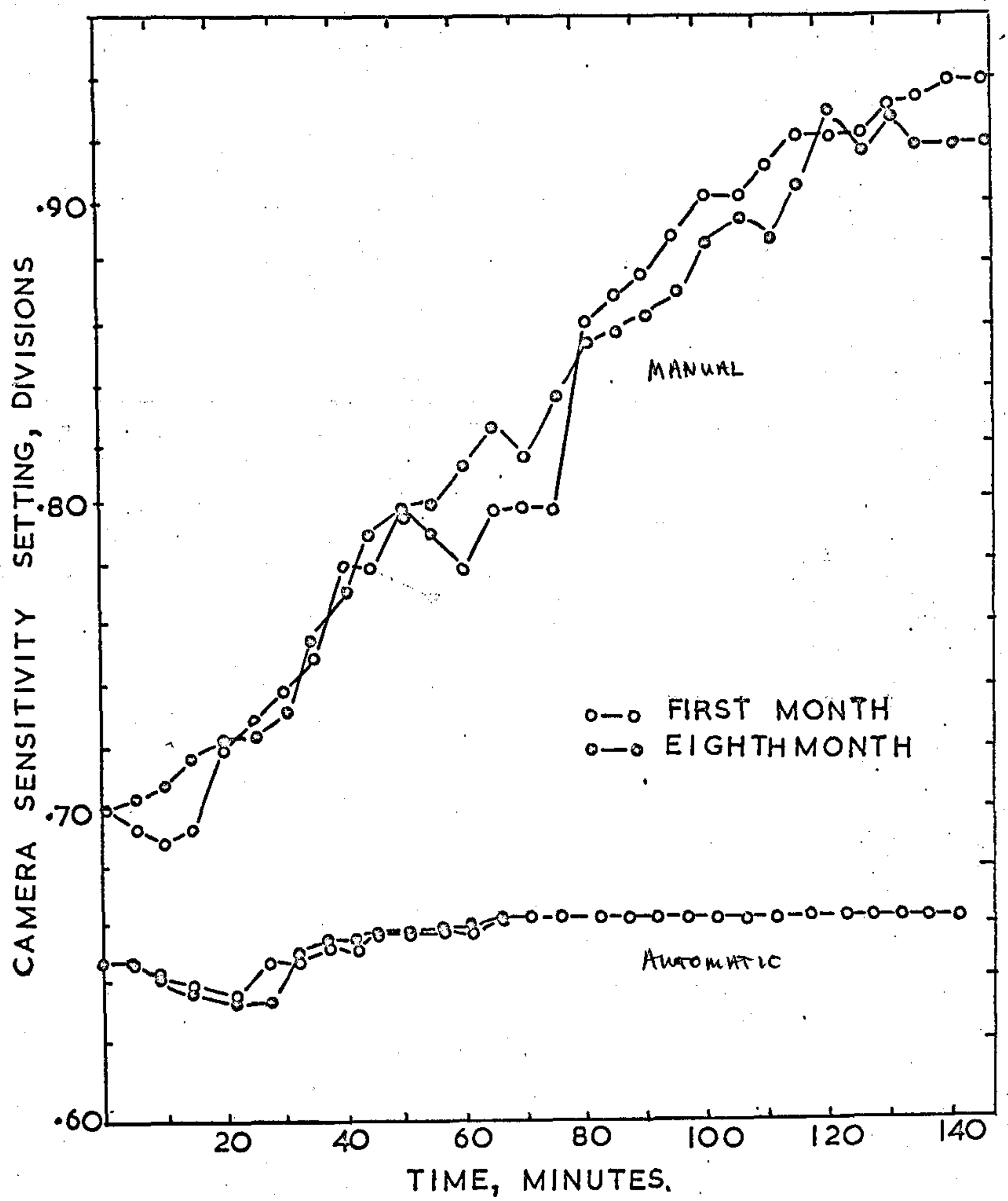


FIG. 21

EFFECT OF FILTERS AND LIGHT SETTINGS ON OXIDE CONTENT MEASURED

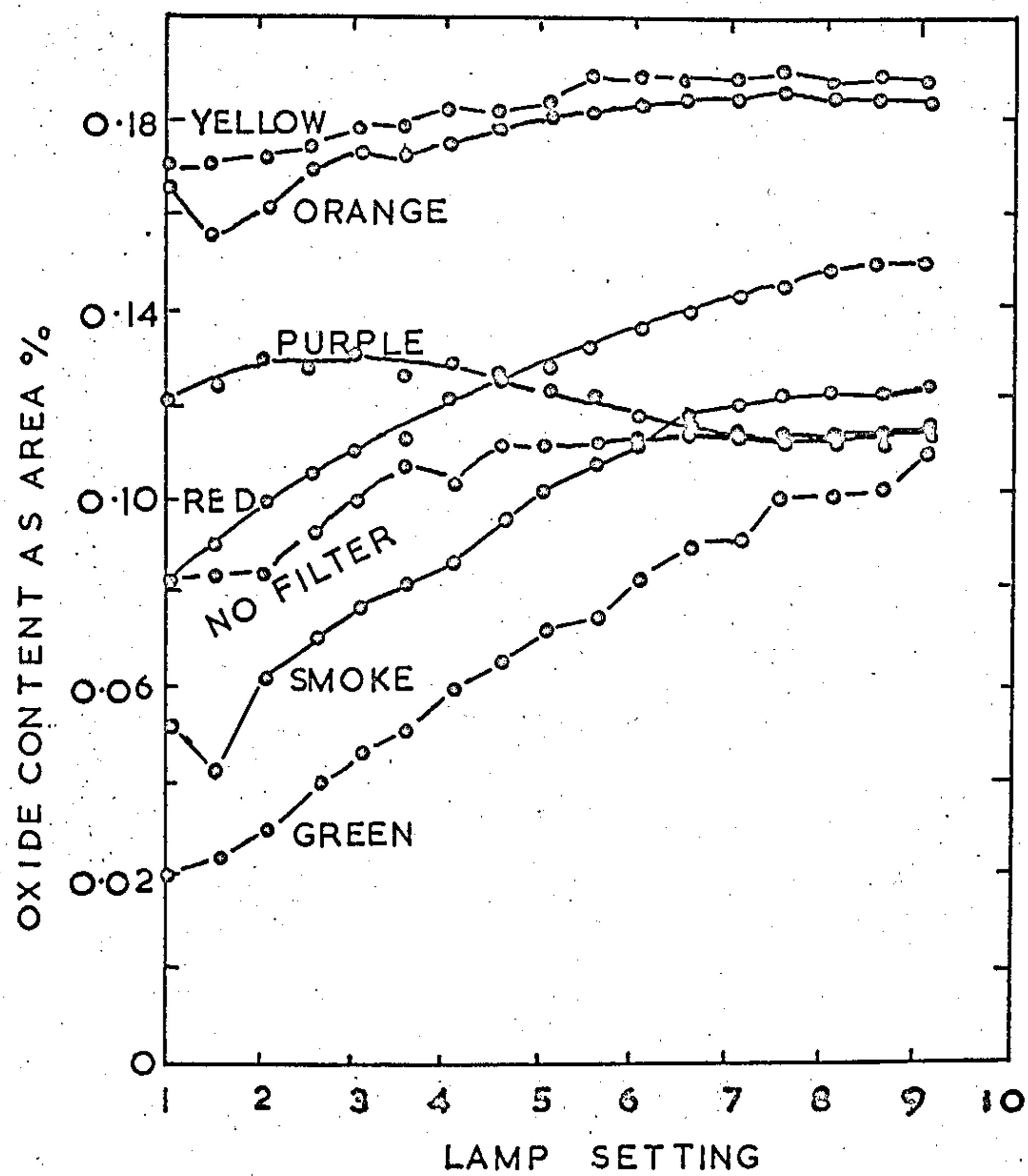
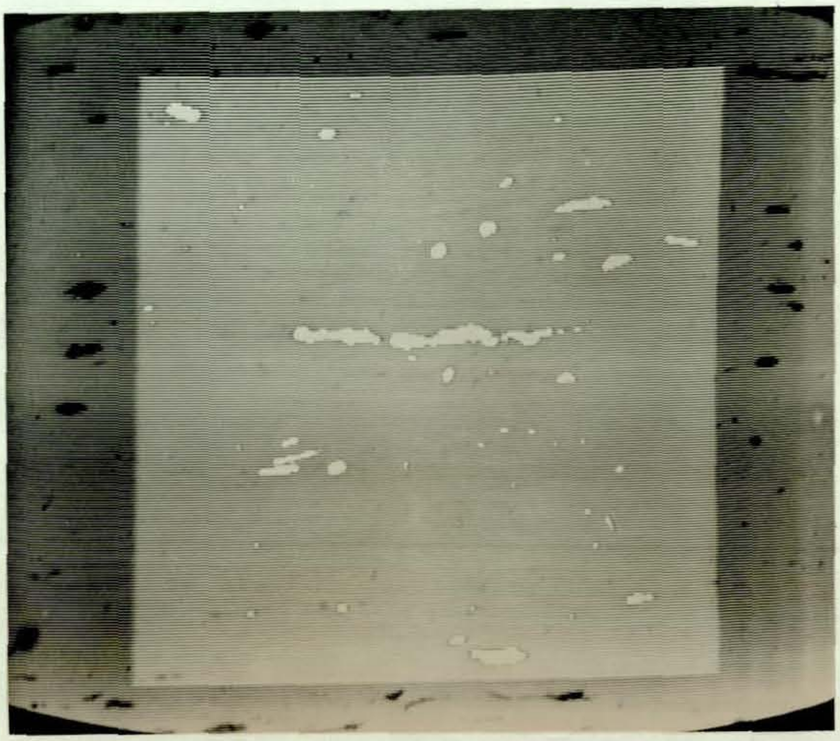


Fig. 22 View of image to be analysed
(a) before detection (filling-in) and
(b) after detection

(a)



(b)

FIG. 23.

DISTRIBUTION OF THRESHOLD SETTINGS FOR THREE METHODS, A, B & C

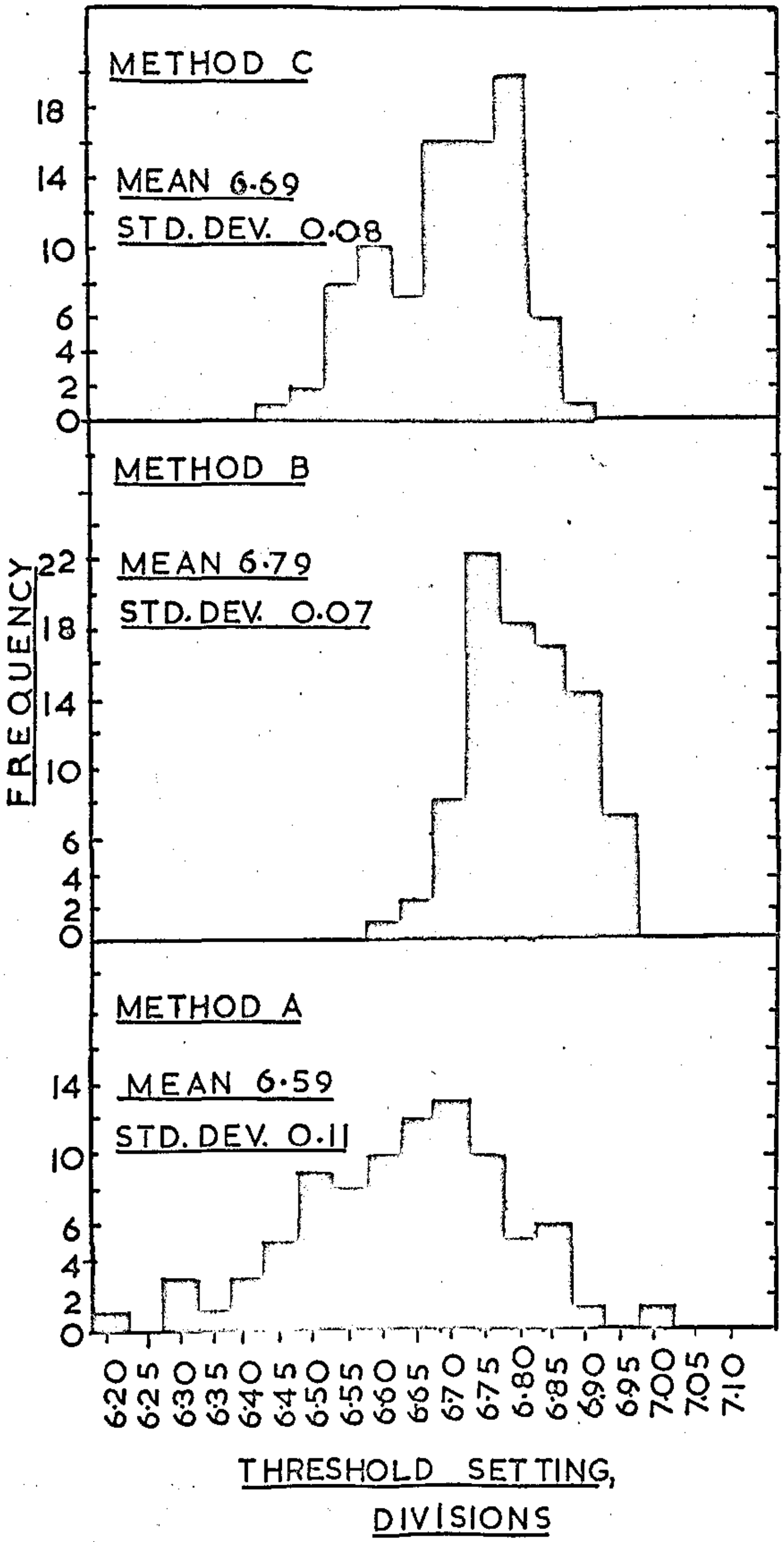


FIG 24

MEAN AND STANDARD DEVIATION REPORTED BY THREE OPERATORS EXAMINING THE SAME INCLUSIONS BY THREE METHODS

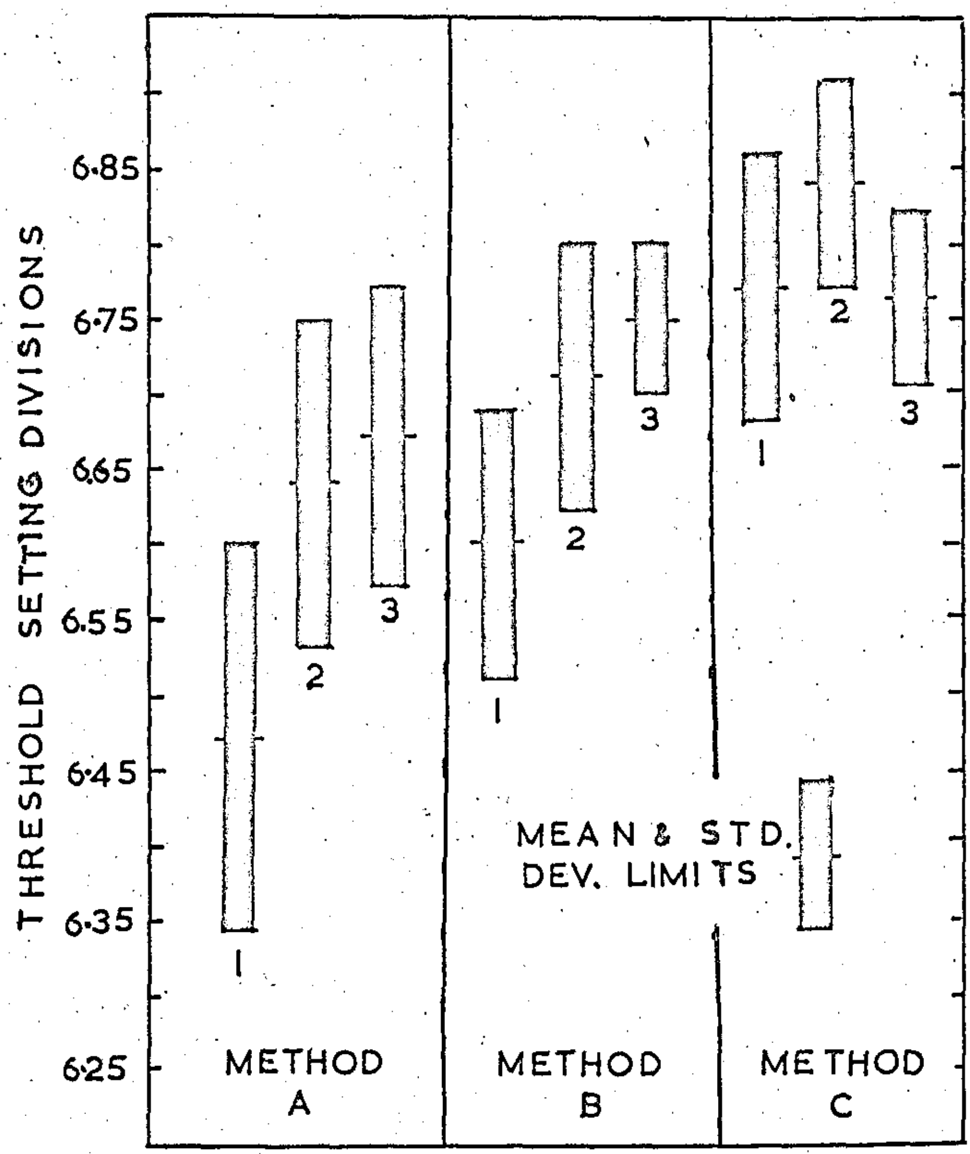


FIG. 25.

SHOWING RELATIONSHIP BETWEEN CAMERA SENSITIVITY SETTING AND THRESHOLD SETTING

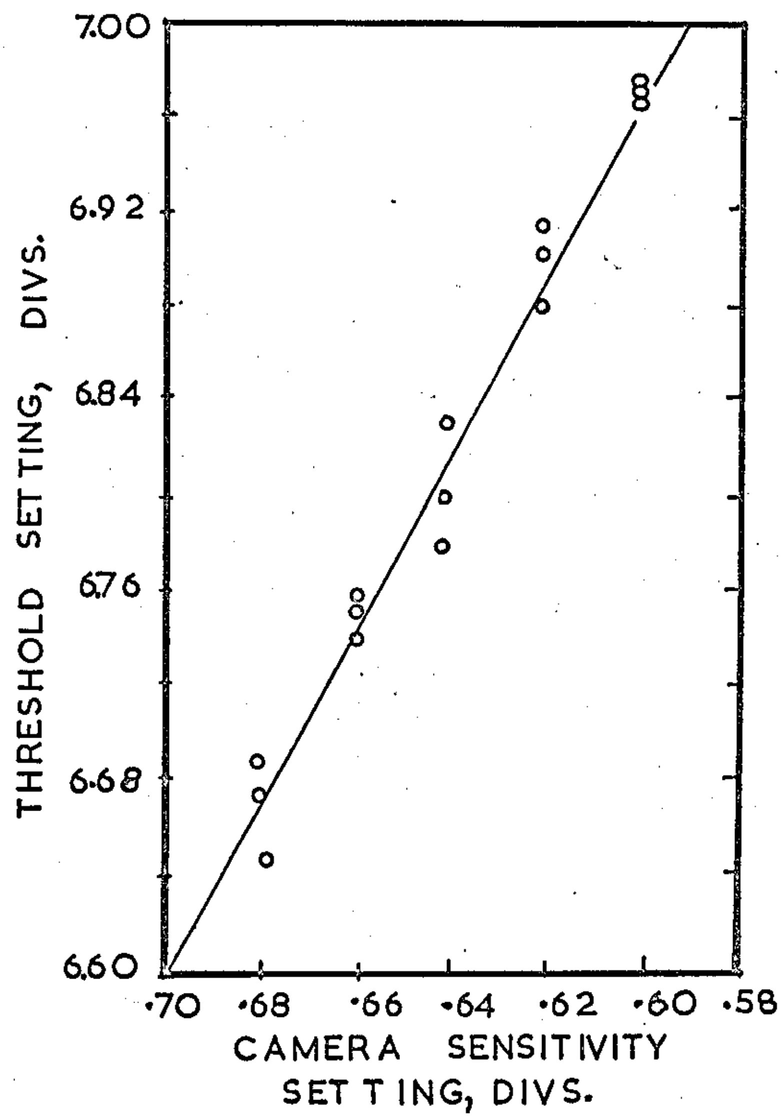


FIG. 26

EFFECT OF VARIATIONS IN THRESHOLD SETTING ON INCLUSION AREA MEASUREMENTS

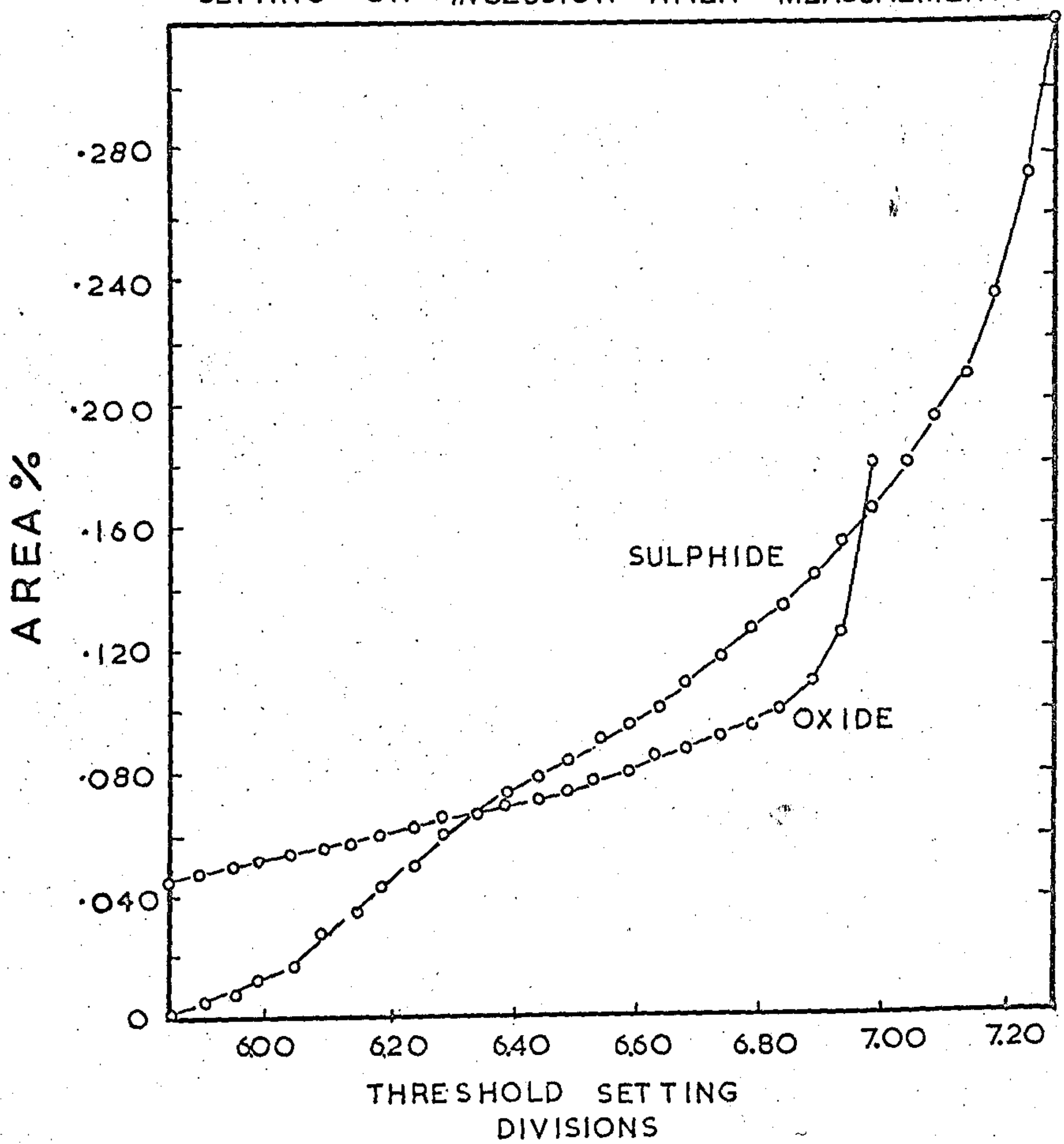


FIG. 27

COMPARISON OF PERCENT AREA MEASUREMENTS DETERMINED VISUALLY AND WITH QUANTIMET

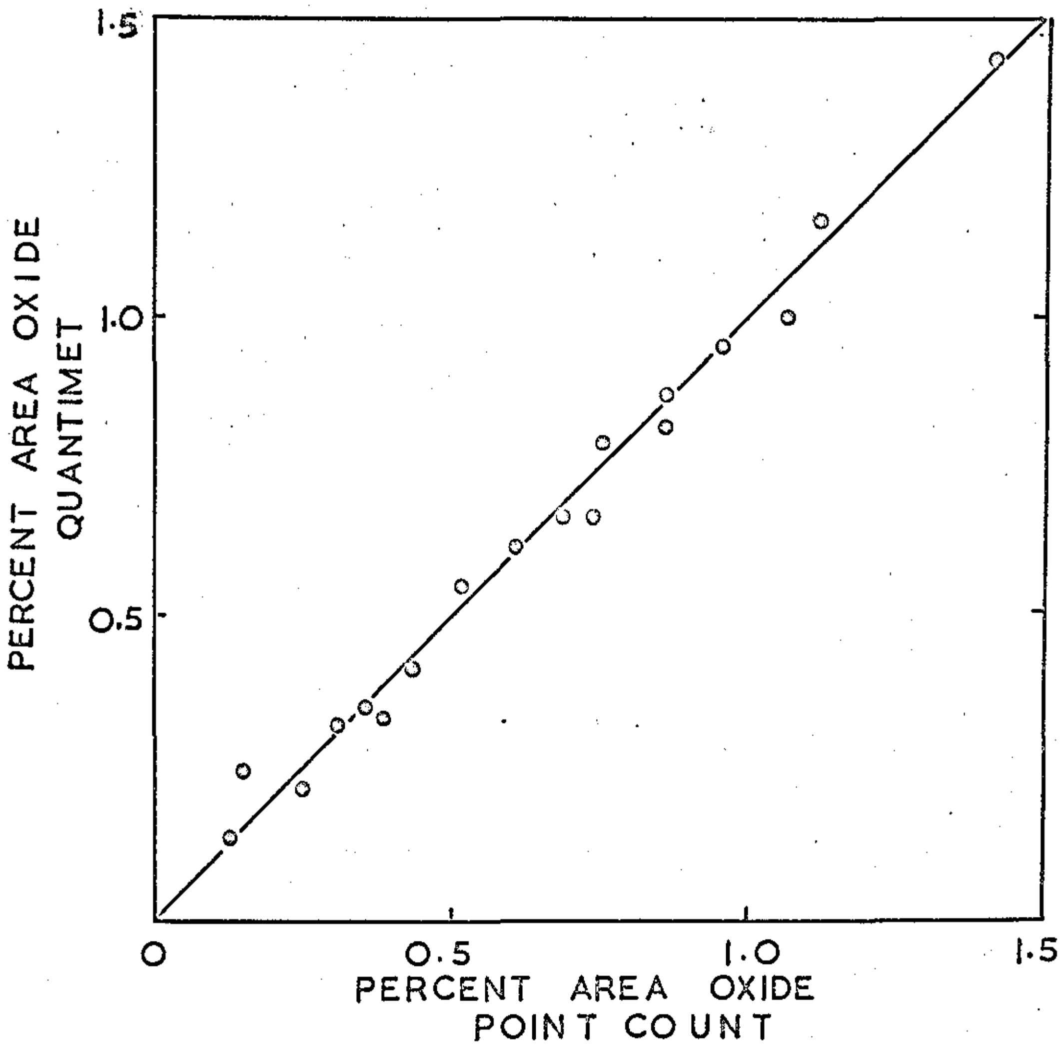


FIG 28

COMPARISON OF TOTAL NUMBER OF OXIDES DETERMINED VISUALLY AND WITH QUANTIMET

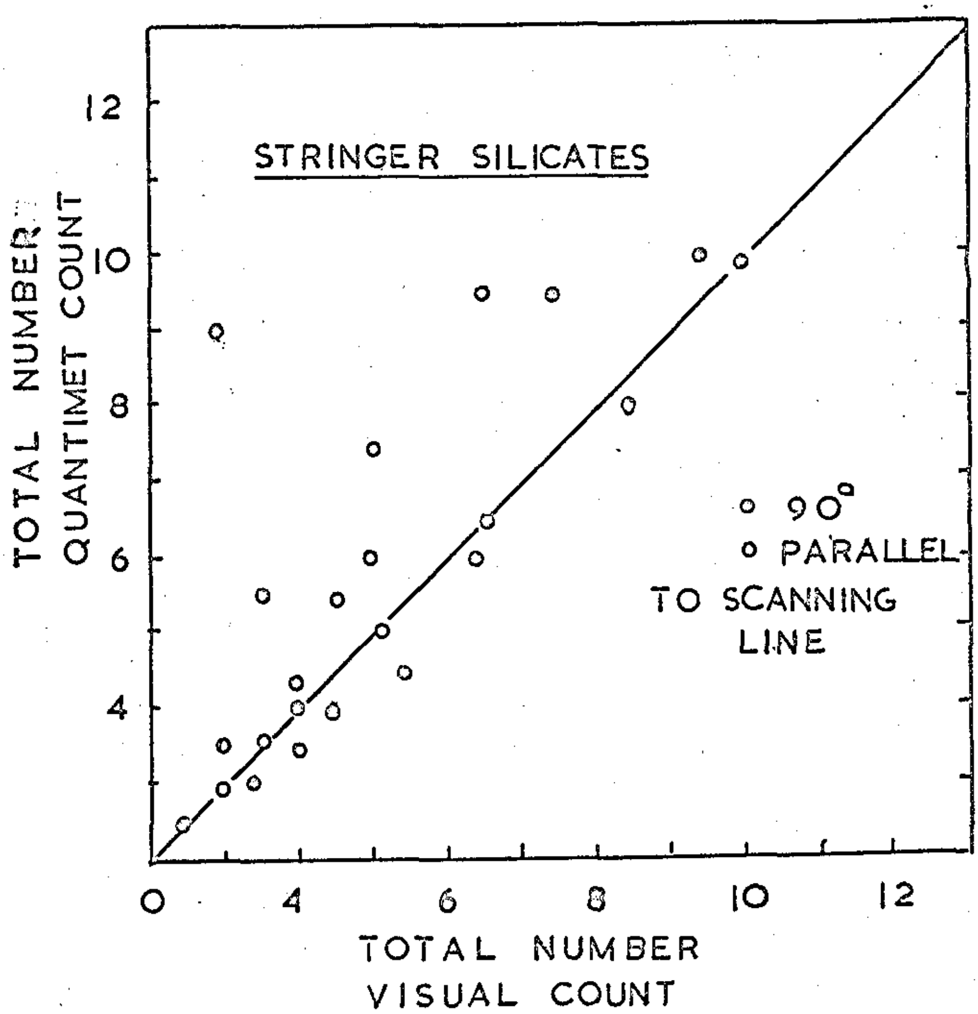


FIG 29

COMPARISON OF TOTAL NUMBER OF OXIDES DETERMINED VISUALLY AND WITH QUANTIMET

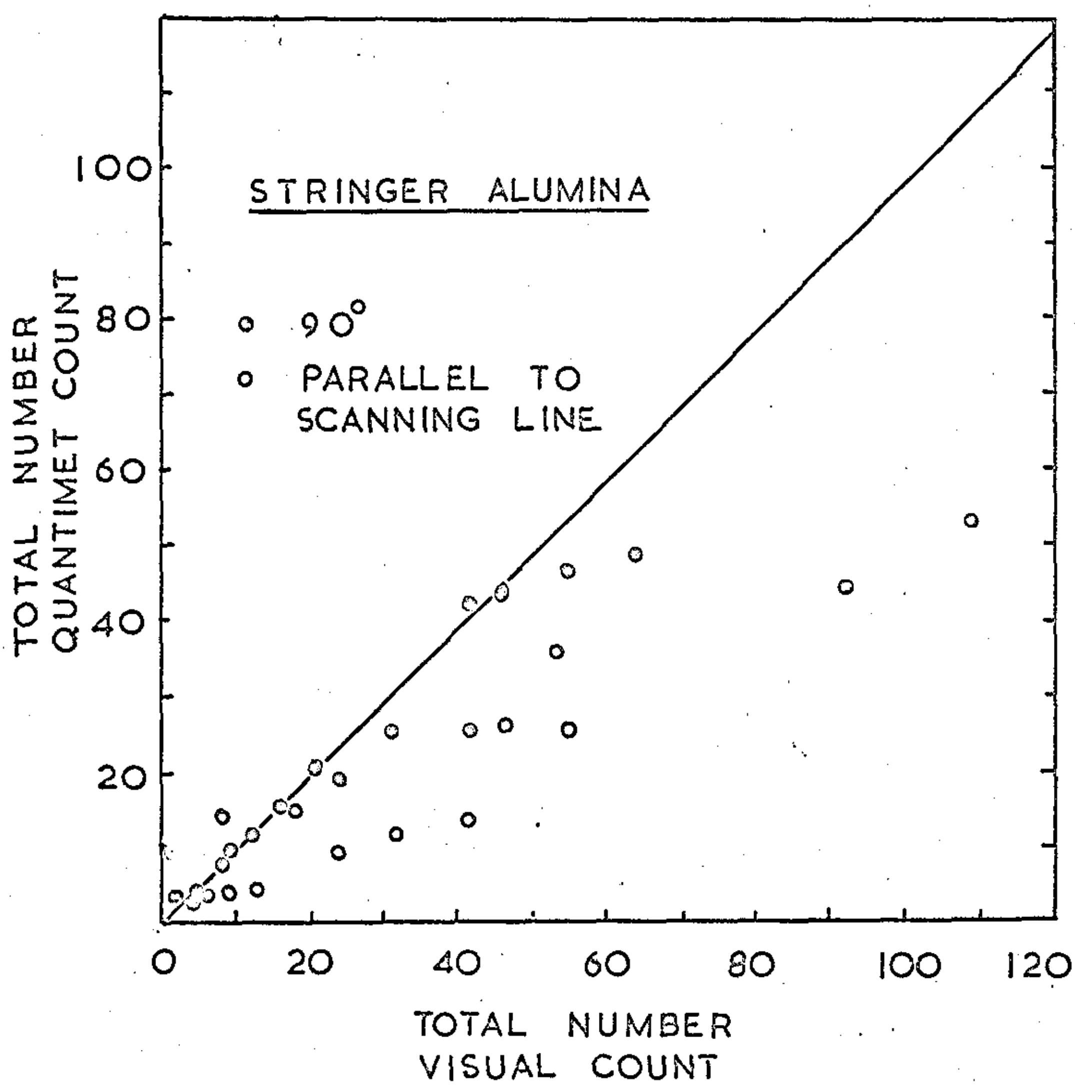


FIG. 30

COMPARISON OF TOTAL NUMBER OF OXIDES DETERMINED VISUALLY AND WITH QUANTIMET

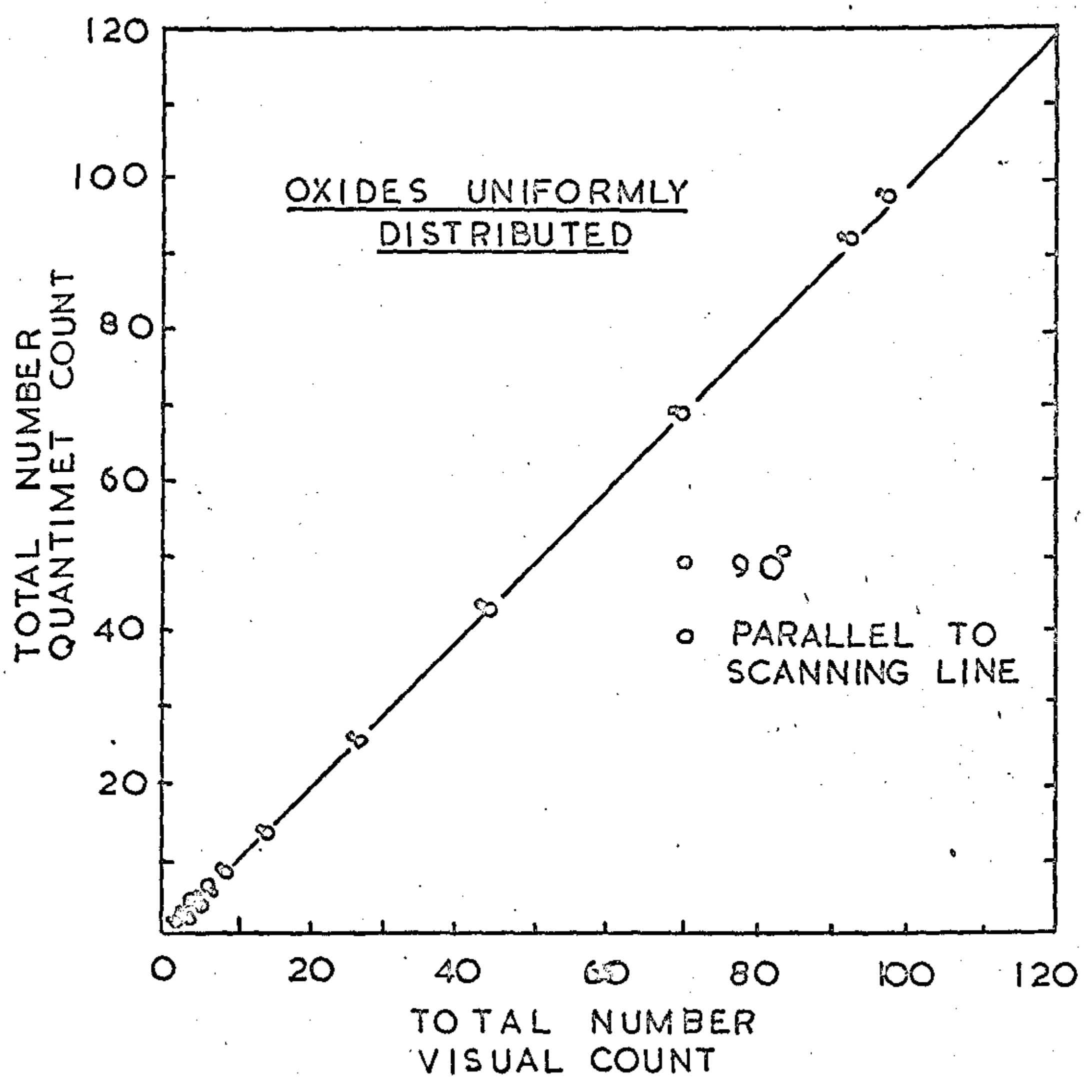


FIG. 31

COMPARISON OF TOTAL LENGTH MEASUREMENTS DETERMINED VISUALLY AND WITH QUANTIMET

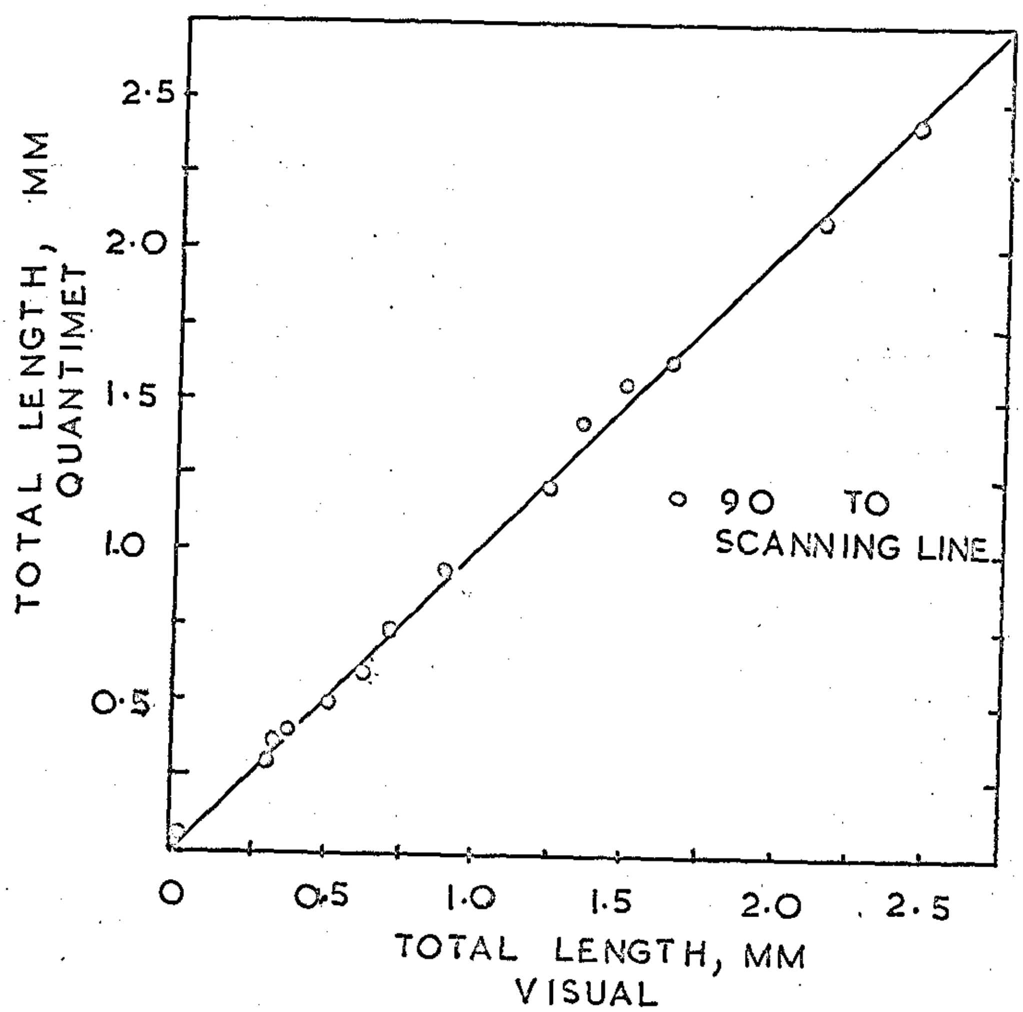
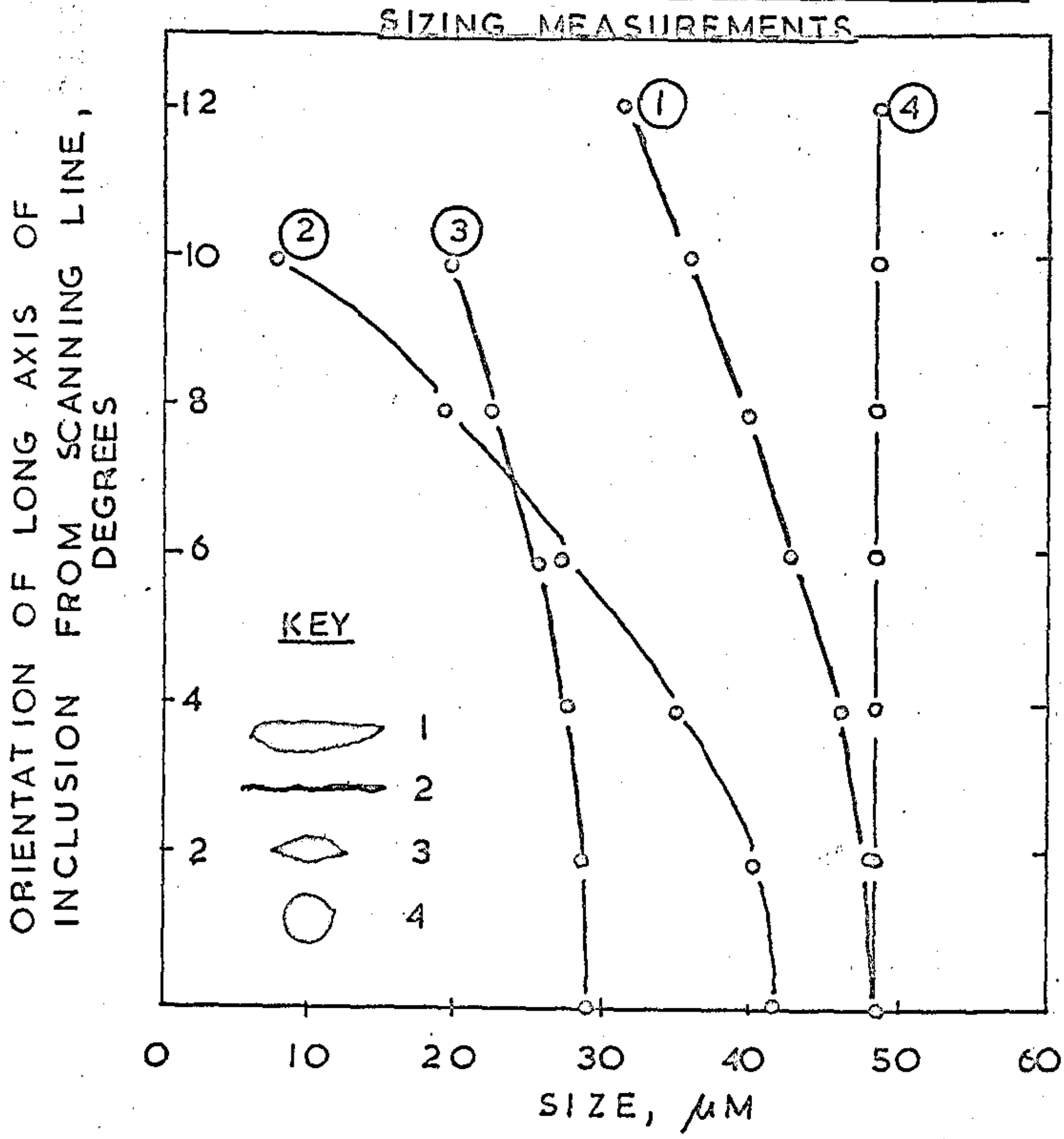


FIG. 32

EFFECT OF ORIENTATION OF LONG AXIS OF INCLUSION FROM SCANNING LINE SIZING MEASUREMENTS



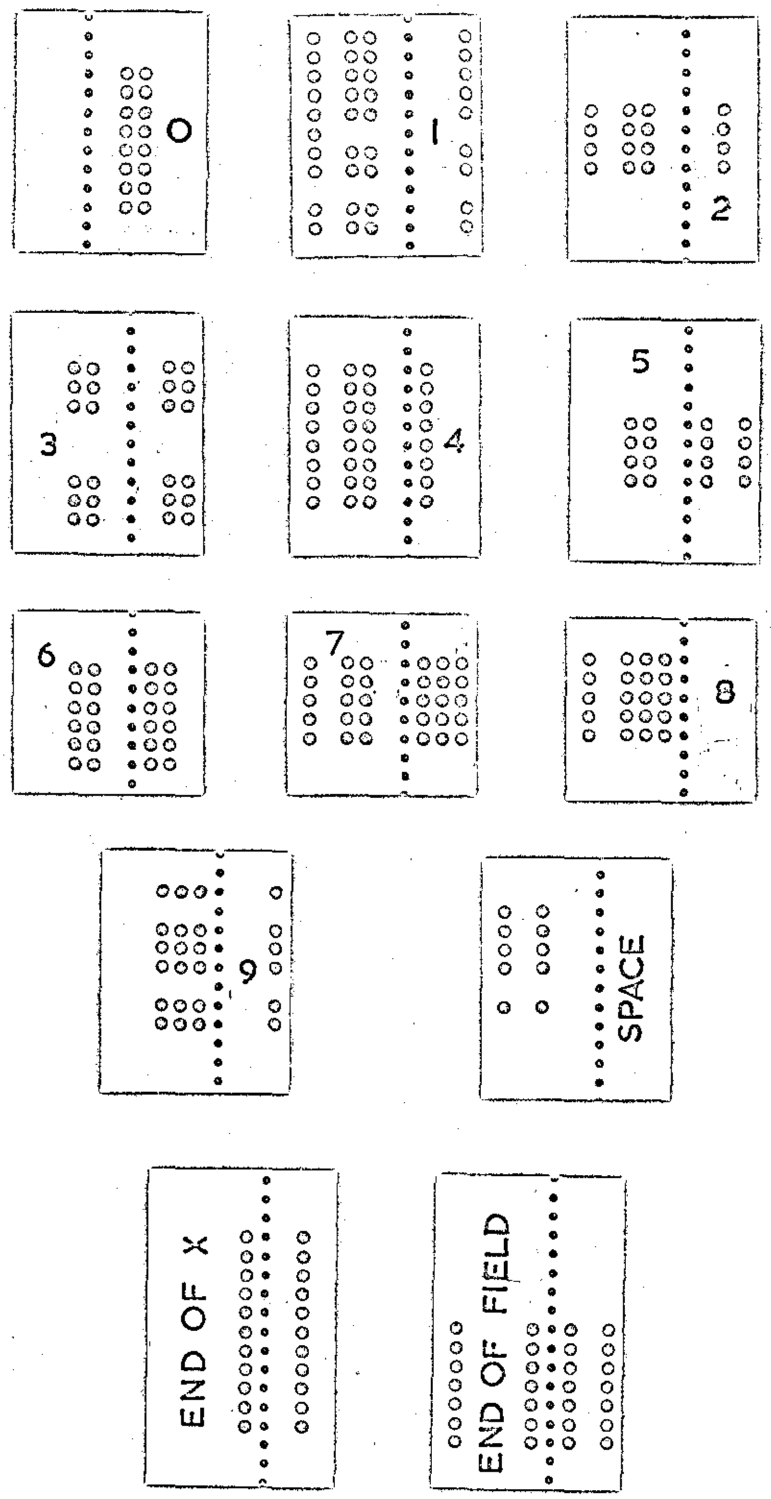
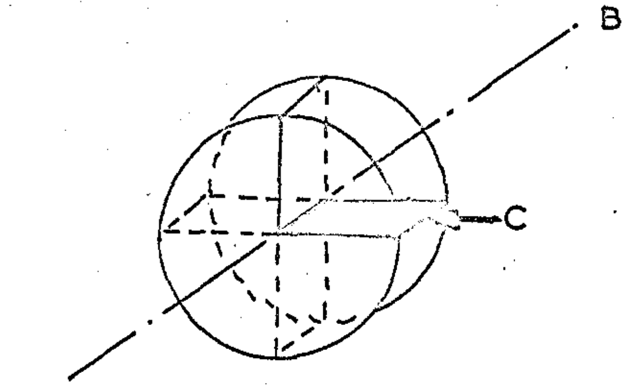
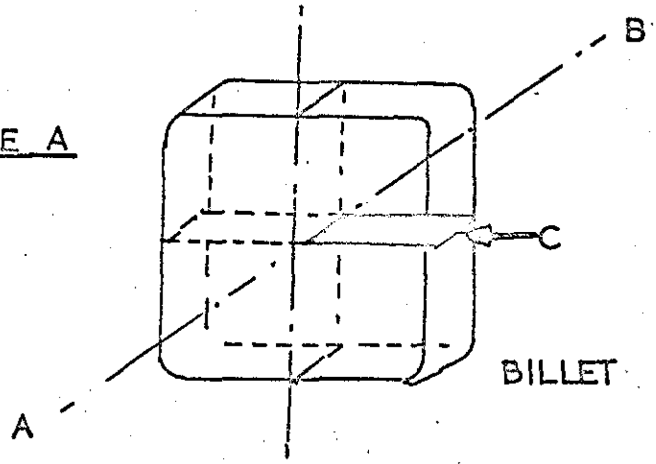


FIG. 33 SYSTEM OF CODING USED

Fig.34 Showing planes normally examined



BAR



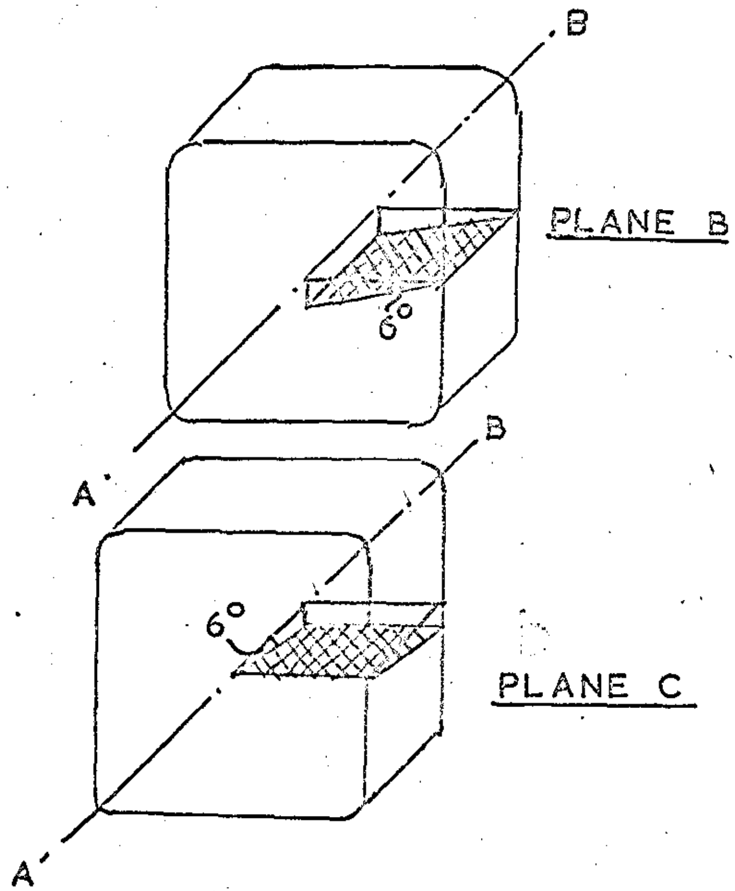
PLANE A

BILLET

AB ROLLING DIRECTION
C PLANE EXAMINED

FIG. 35

Showing planes that could be examined



AB ROLLING DIRECTION
OF BILLET AND AXIS

FIG 36
TOTAL NUMBER OF INCLUSIONS COUNTED ON SAME SAMPLE BUT DIFFERENT SECTIONS

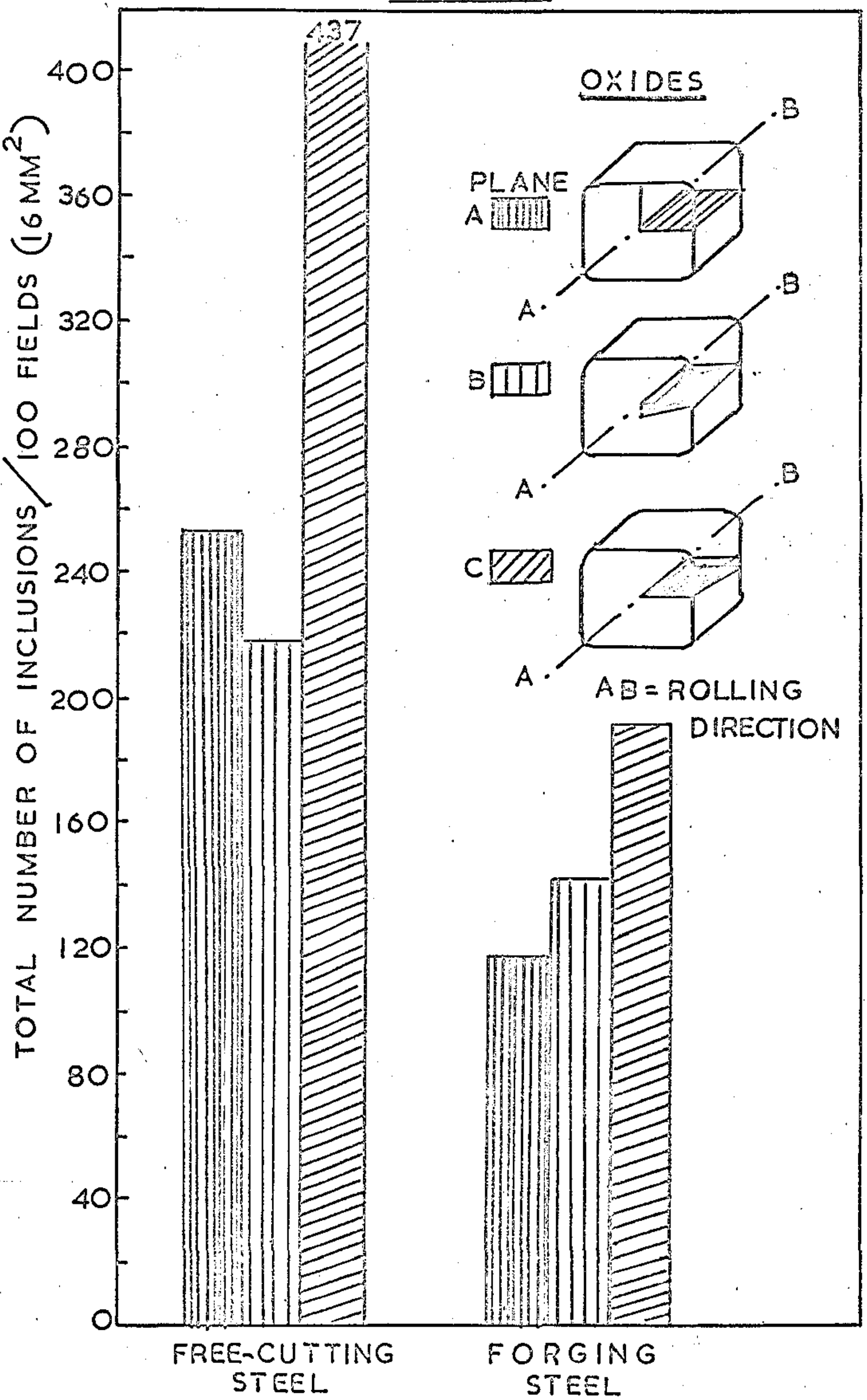


FIG 37

TOTAL NUMBER OF INCLUSIONS COUNTED ON SAME SAMPLE BUT DIFFERENT SECTIONS

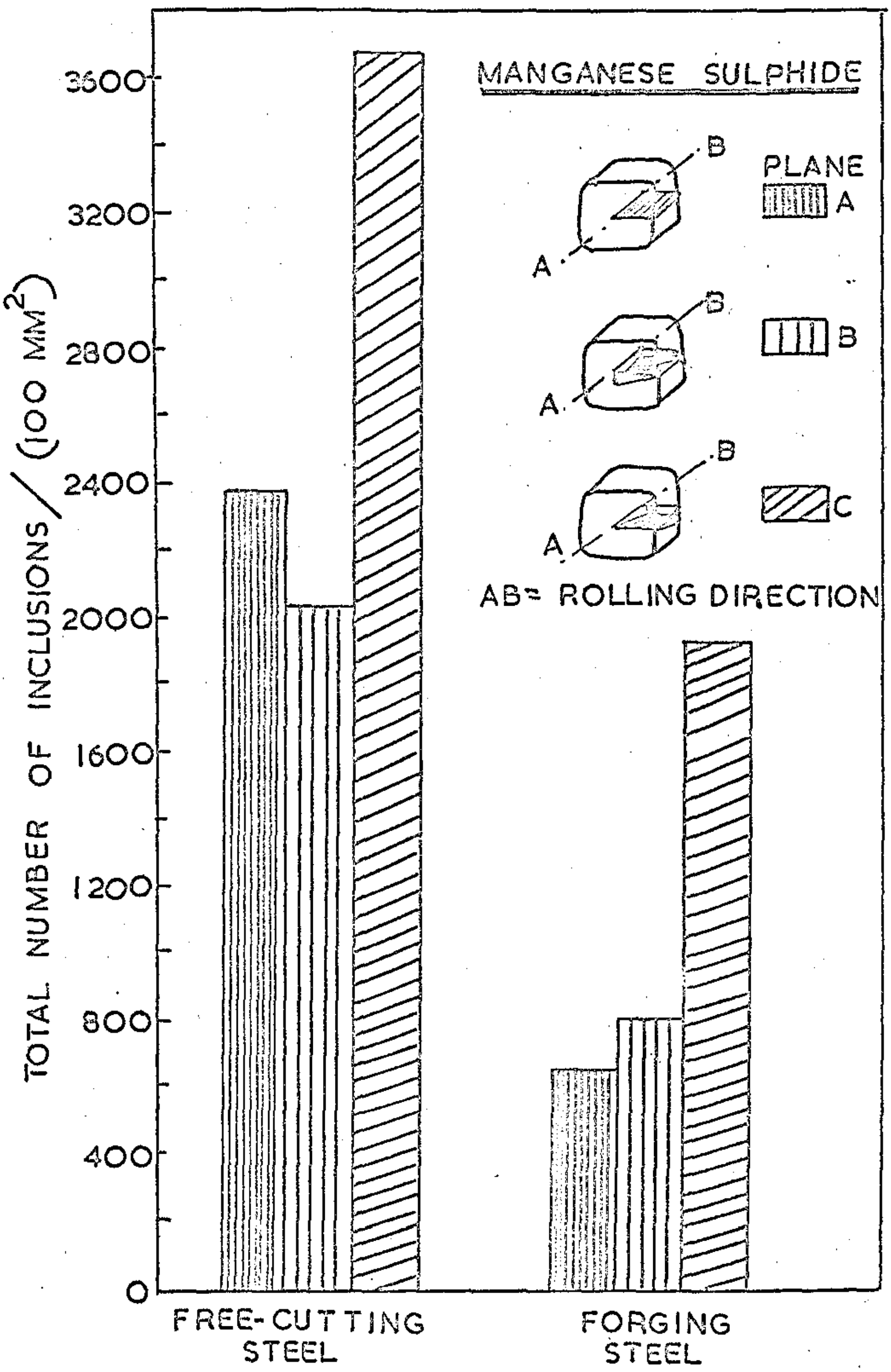


FIG 38

DISTRIBUTION OF SEVERITY RATINGS ON SAME SAMPLE BUT DIFFERENT PLANAR SECTIONS

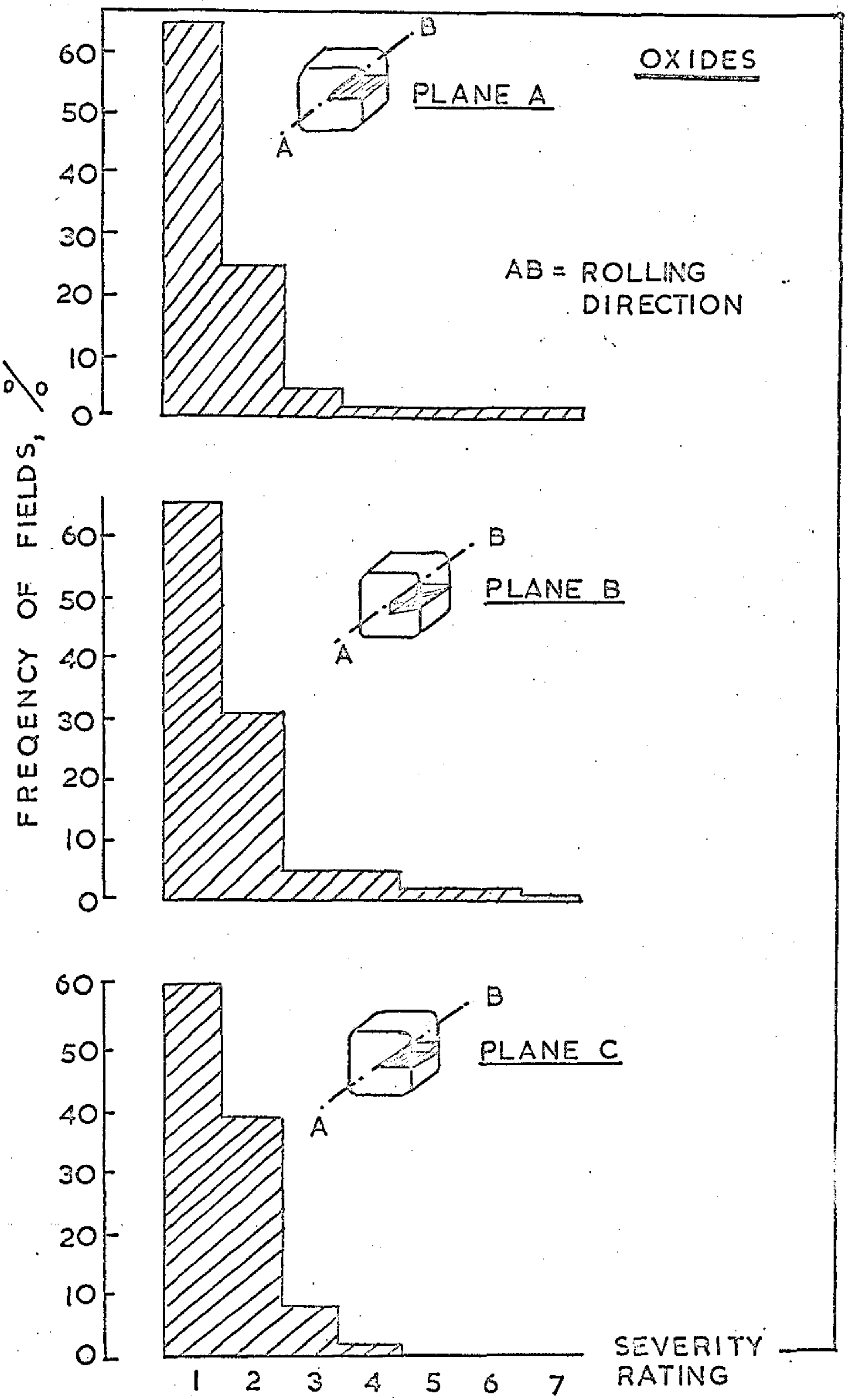


FIG 39

DISTRIBUTION OF SEVERITY RATINGS ON SAME SAMPLE BUT DIFFERENT PLANAR SECTIONS

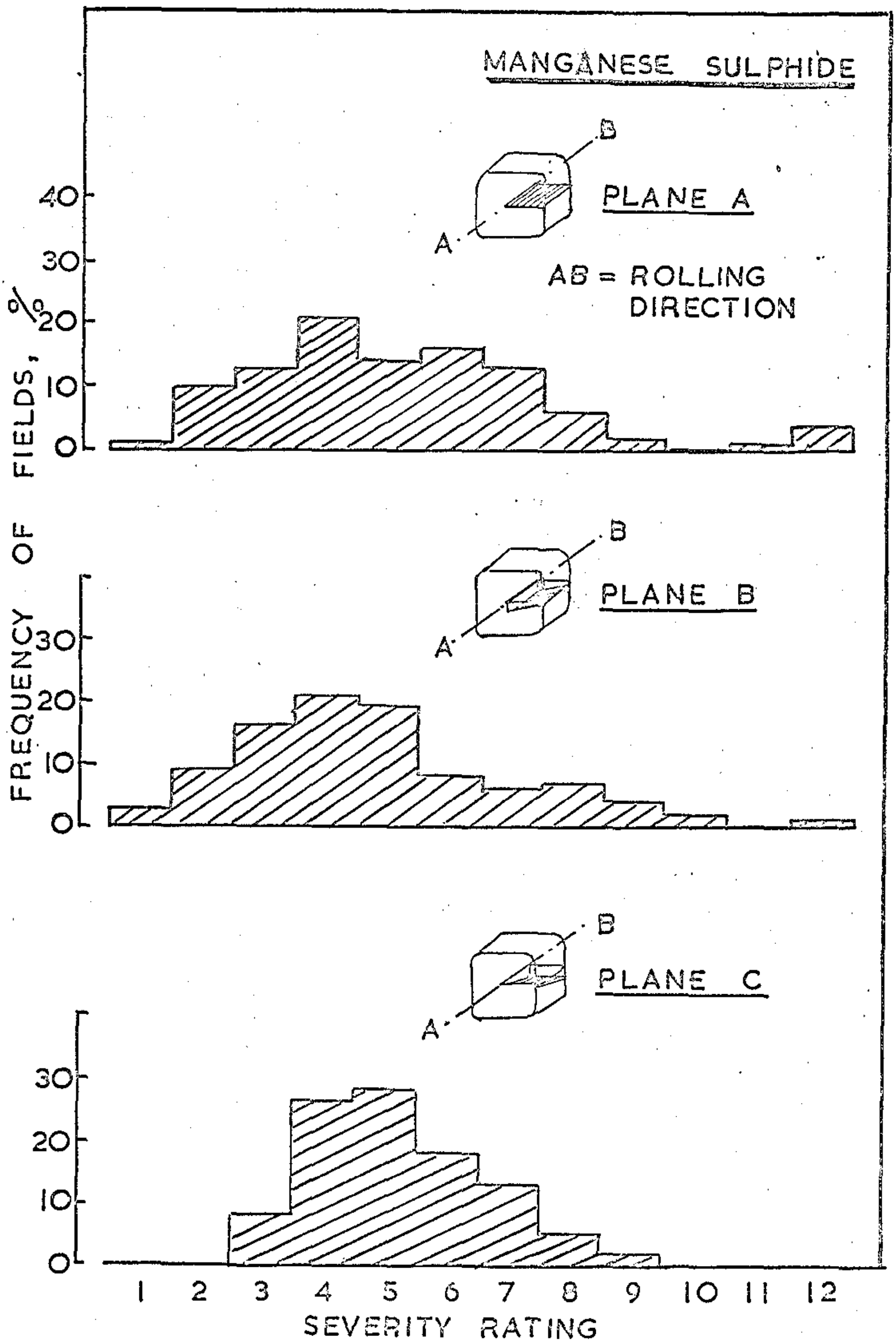


FIG. 40

MEAN PERCENTAGE AREA DETERMINATIONS MADE ON SAME SAMPLES BUT DIFFERENT SECTIONS

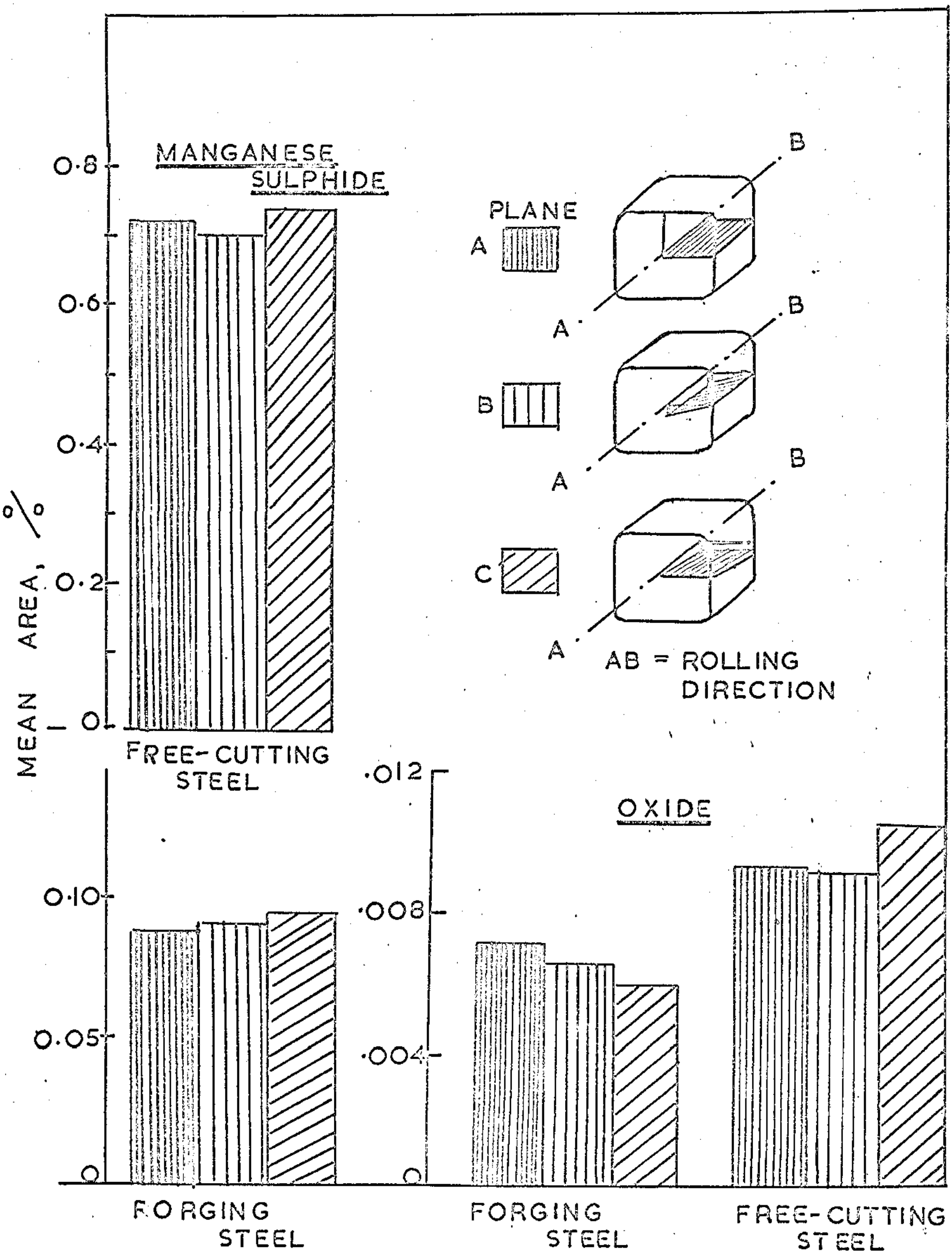


FIG. 41

OXIDE COUNTS OBTAINED ON SAME SURFACE BUT DIFFERENT SAMPLES OF 100 FIELDS

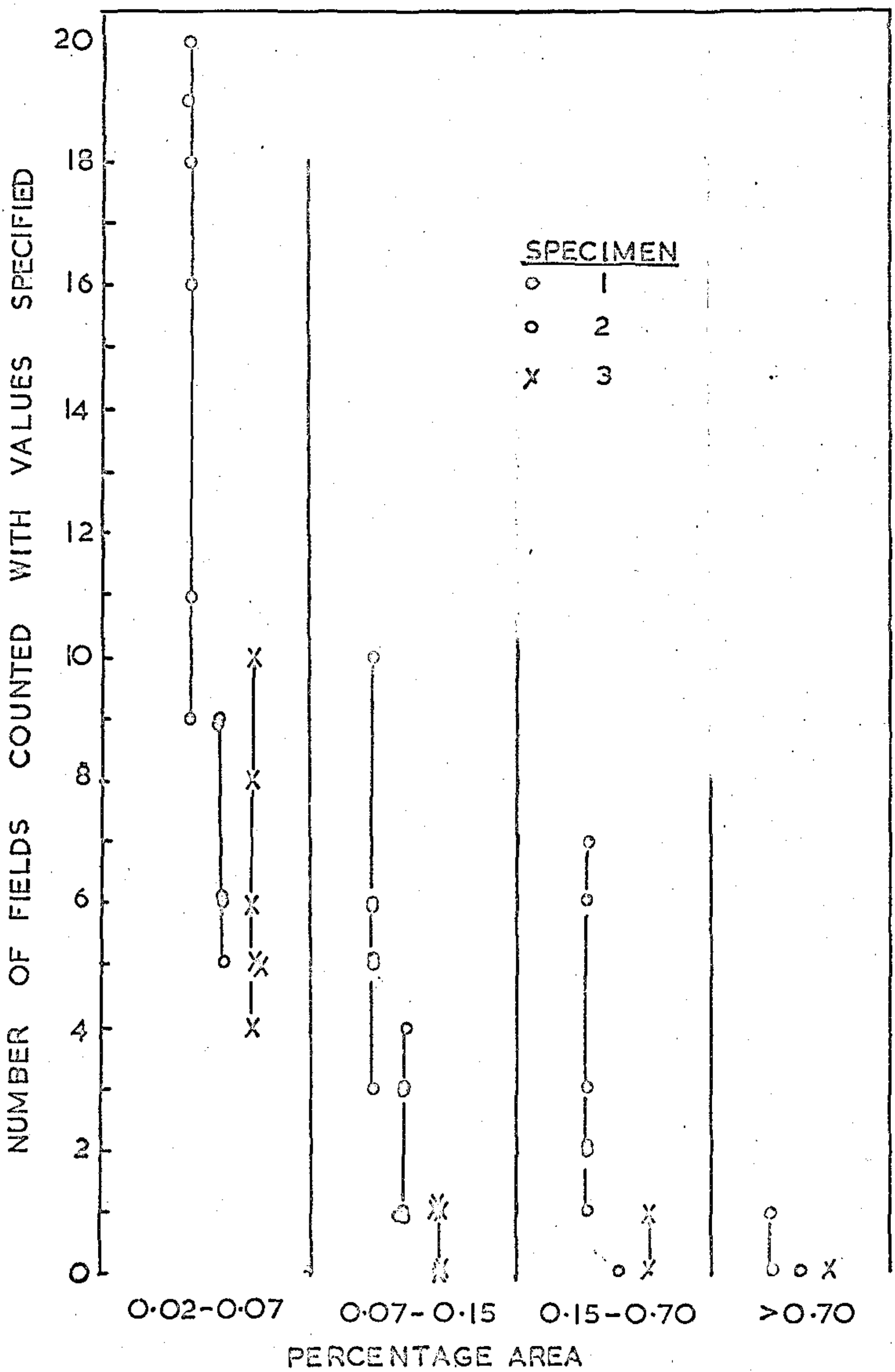


FIG. 42

RESULTS OF OXIDE PERCENTAGE AREA COUNTS SHOWING VARIATIONS BETWEEN DETERMINATIONS

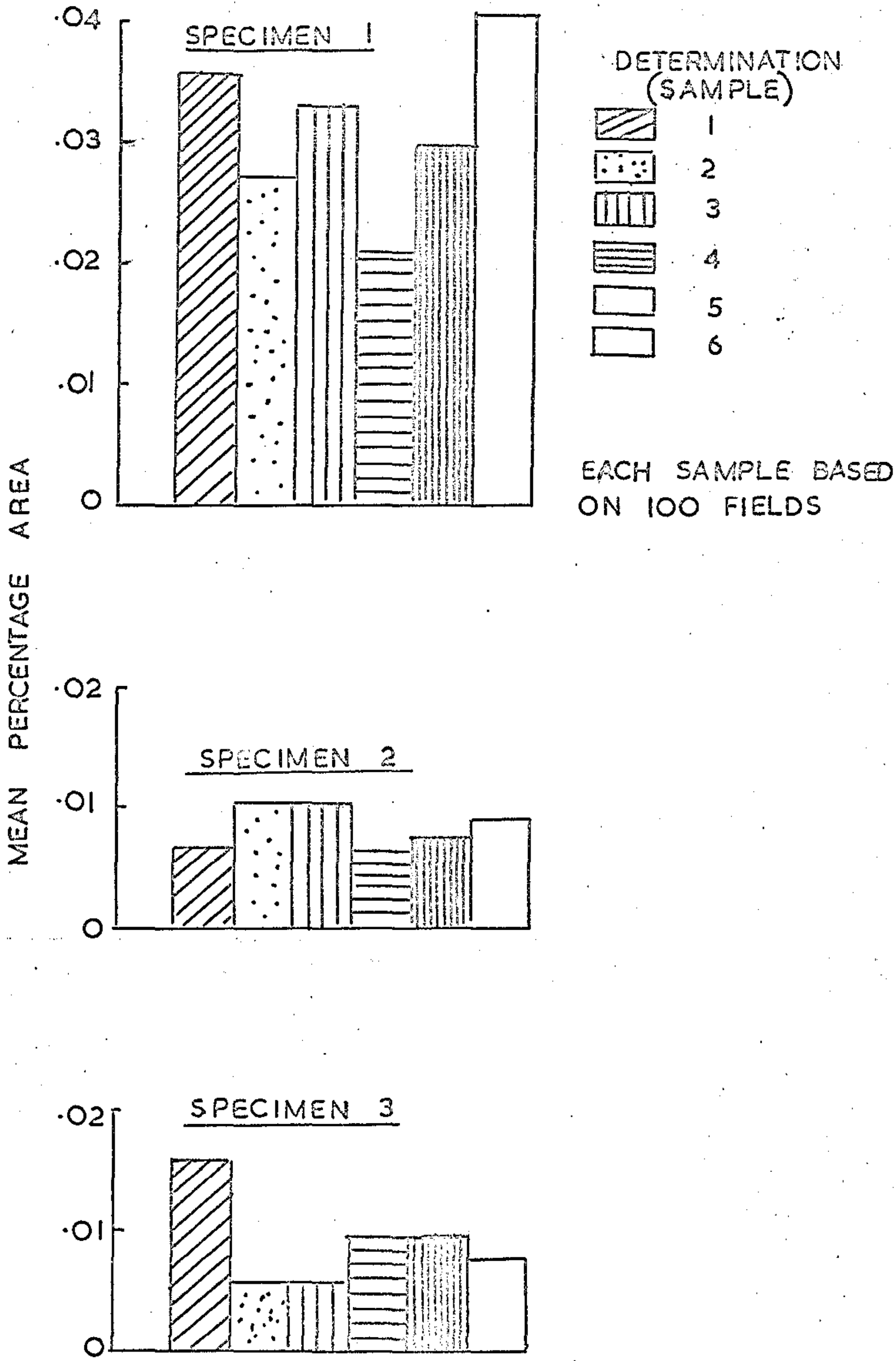


FIG. 43

RESULTS OF TOTAL OXIDE COUNTS SHOWING VARIATION BETWEEN DETERMINATIONS

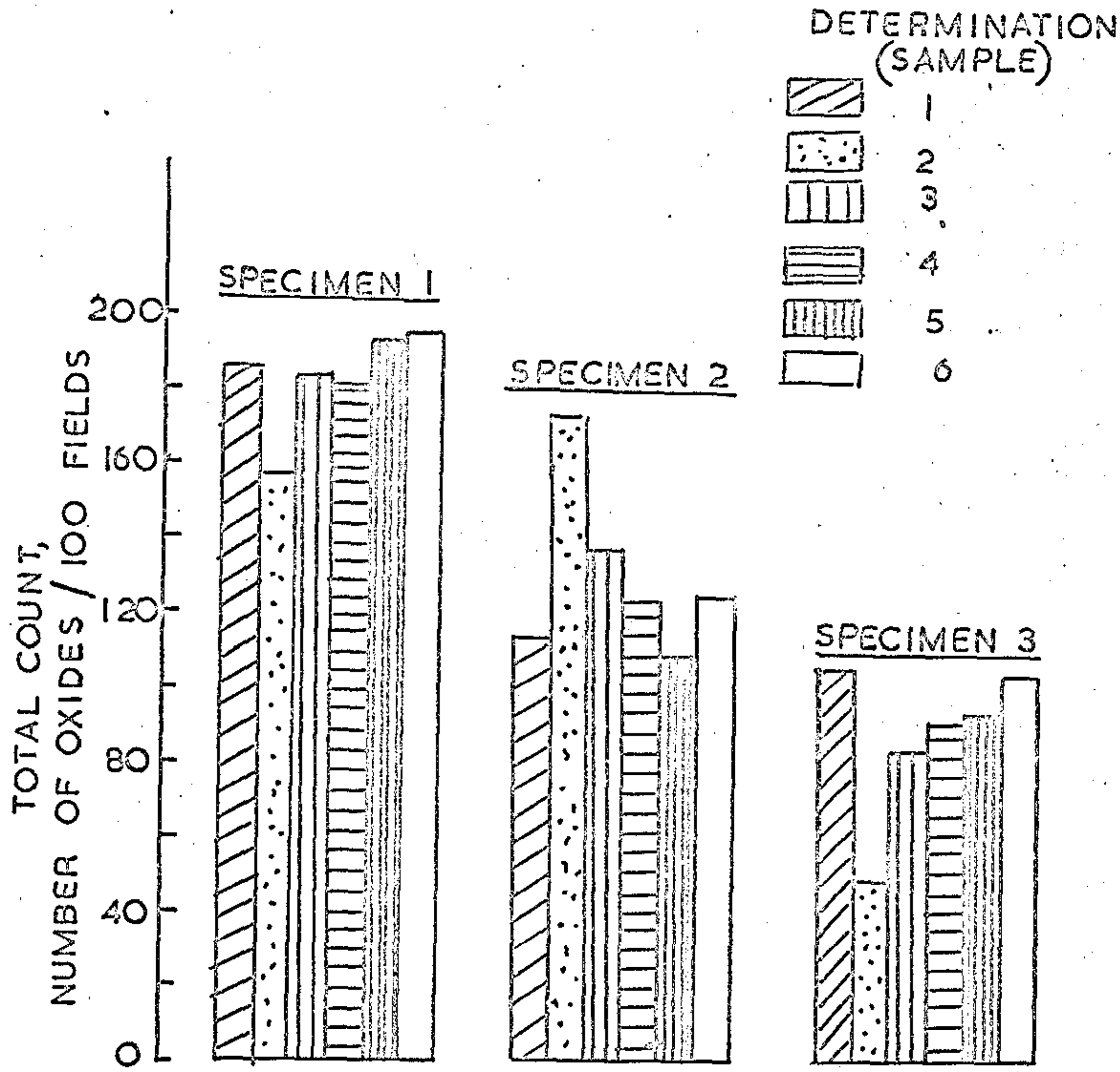


FIG. 44

RESULTS OF OXIDE SIZE DISTRIBUTION COUNTS SHOWING VARIATION BETWEEN DETERMINATIONS

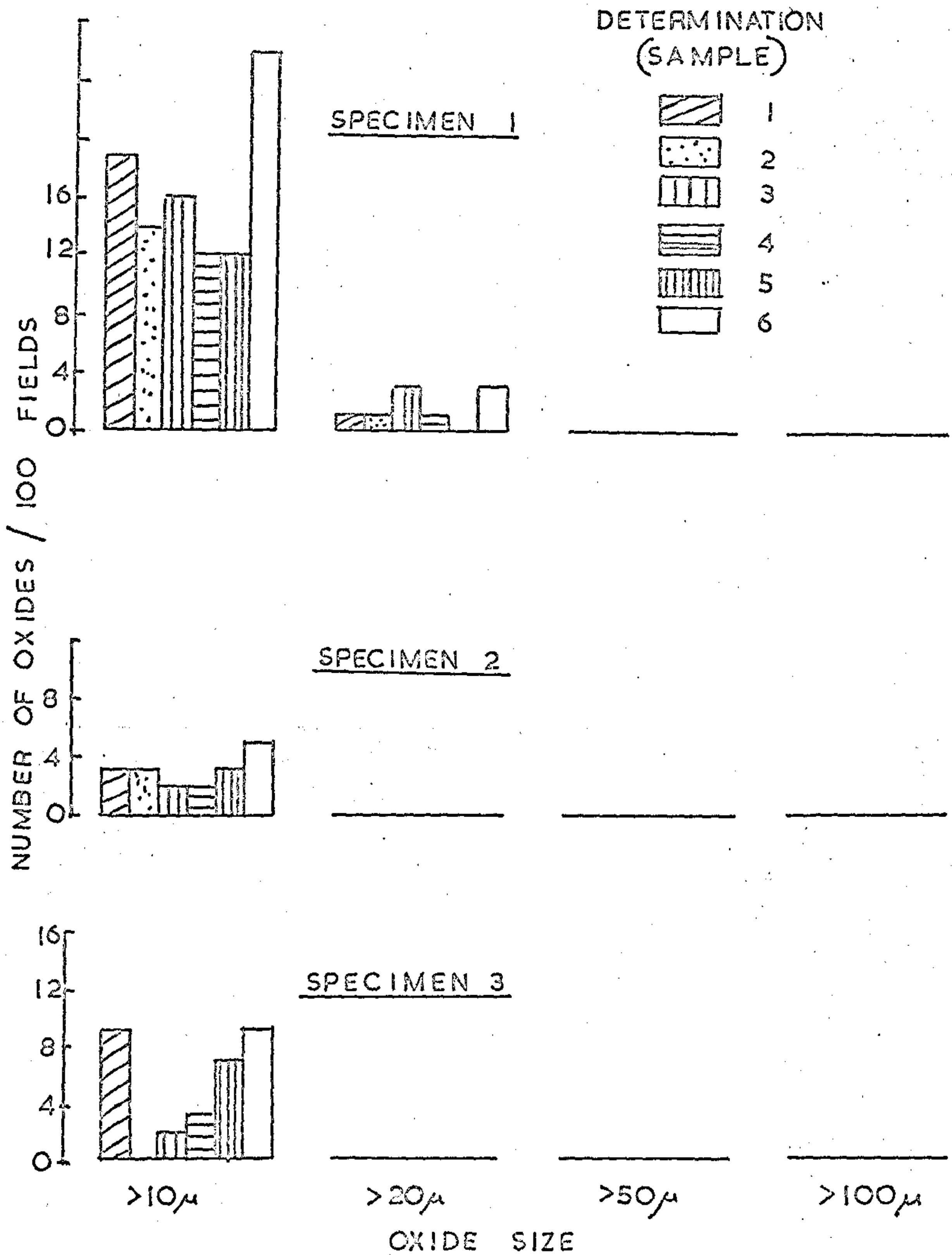
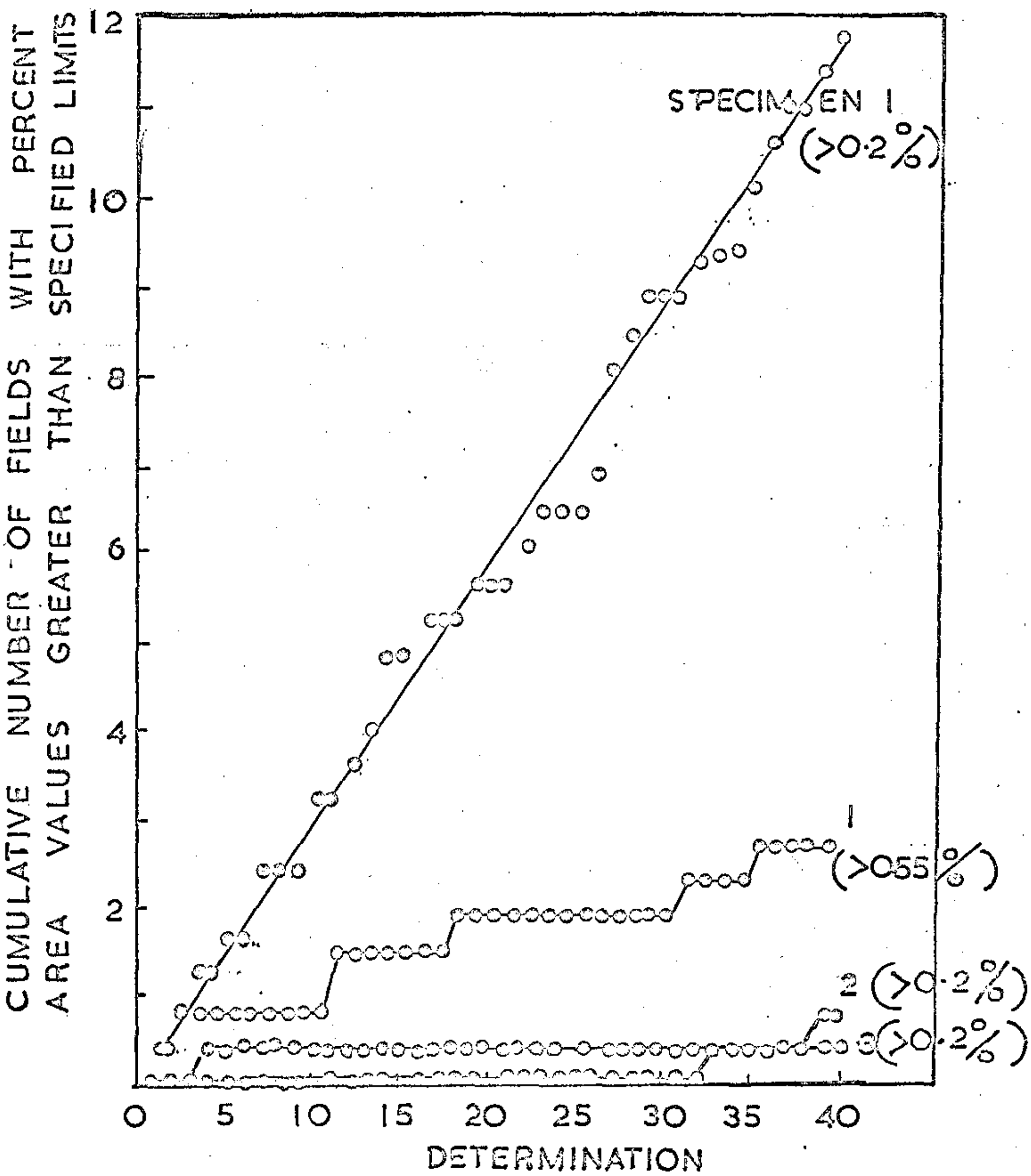


FIG. [illegible]45



CUMULATIVE NUMBER OF FIELDS WITH PERCENT AREA VALUES GREATER THAN SPECIFIED LIMITS
DETERMINATION
0
5
10
15
20
25
30
35
40
2
4
6
8
10
12
SPECIMEN 1
(>0.2%)
1
(>0.55%)
2 (>0.2%)
3 (>0.2%)

FIG. 46

RESULTS OF OXIDE PERCENTAGE AREA COUNTS FROM EDGE TO CENTRE OF BILLET

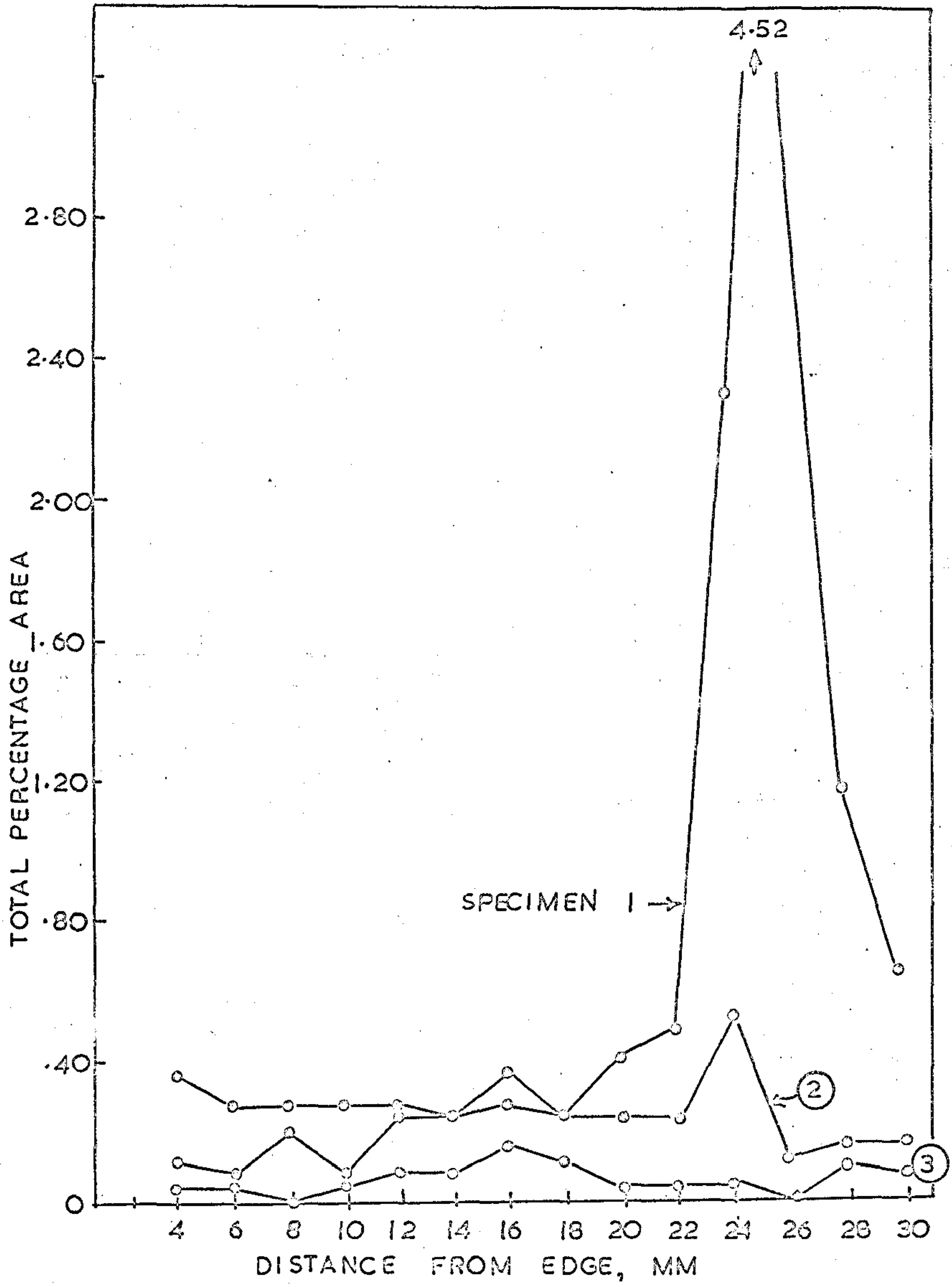


FIG. 47

RELATIONSHIP BETWEEN NUMBER OF FIELDS AND MEAN PERCENT AREA MEASUREMENTS

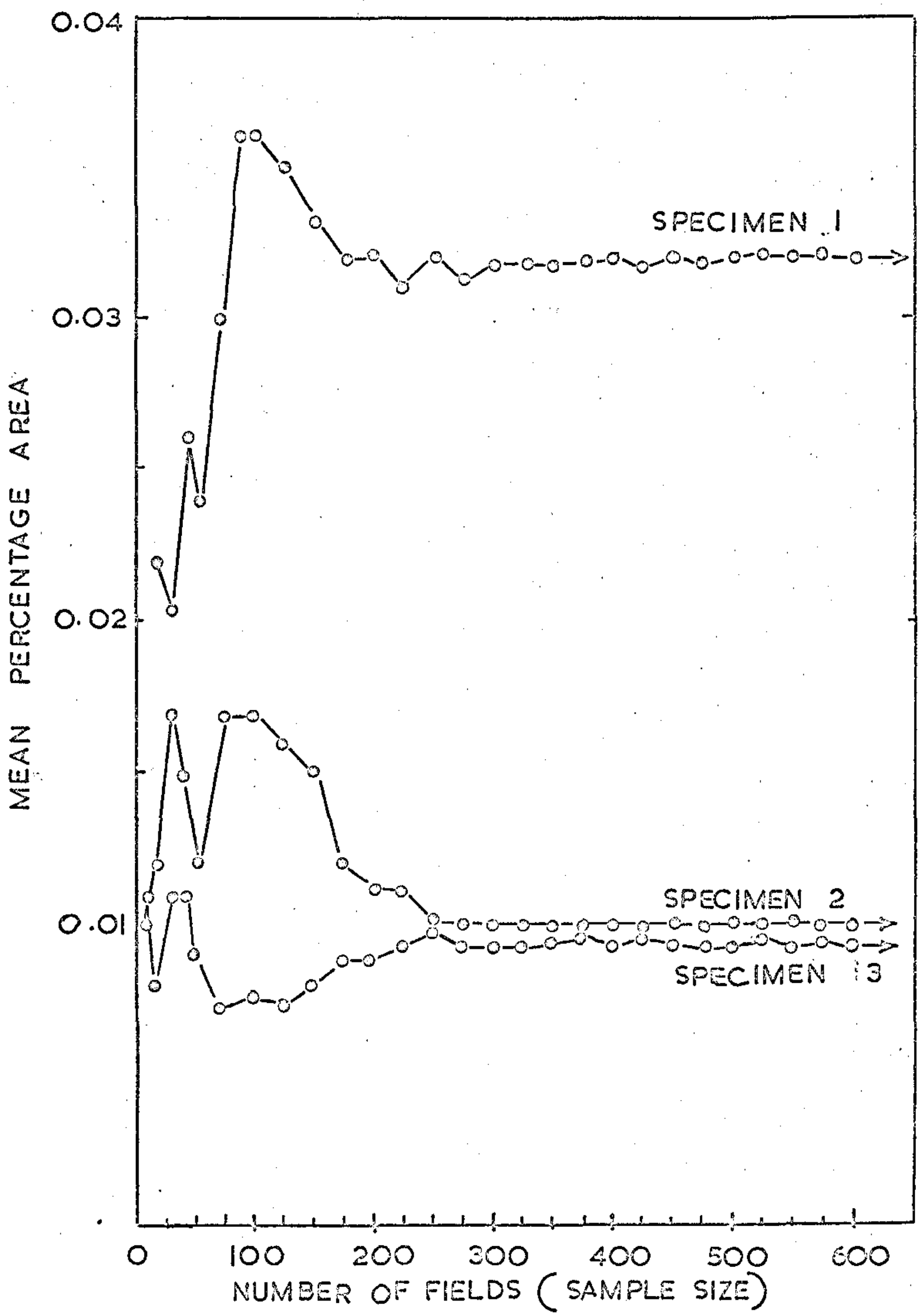


FIG. 48

SUMMARY OF MEAN PERCENTAGE AREA MEASUREMENTS

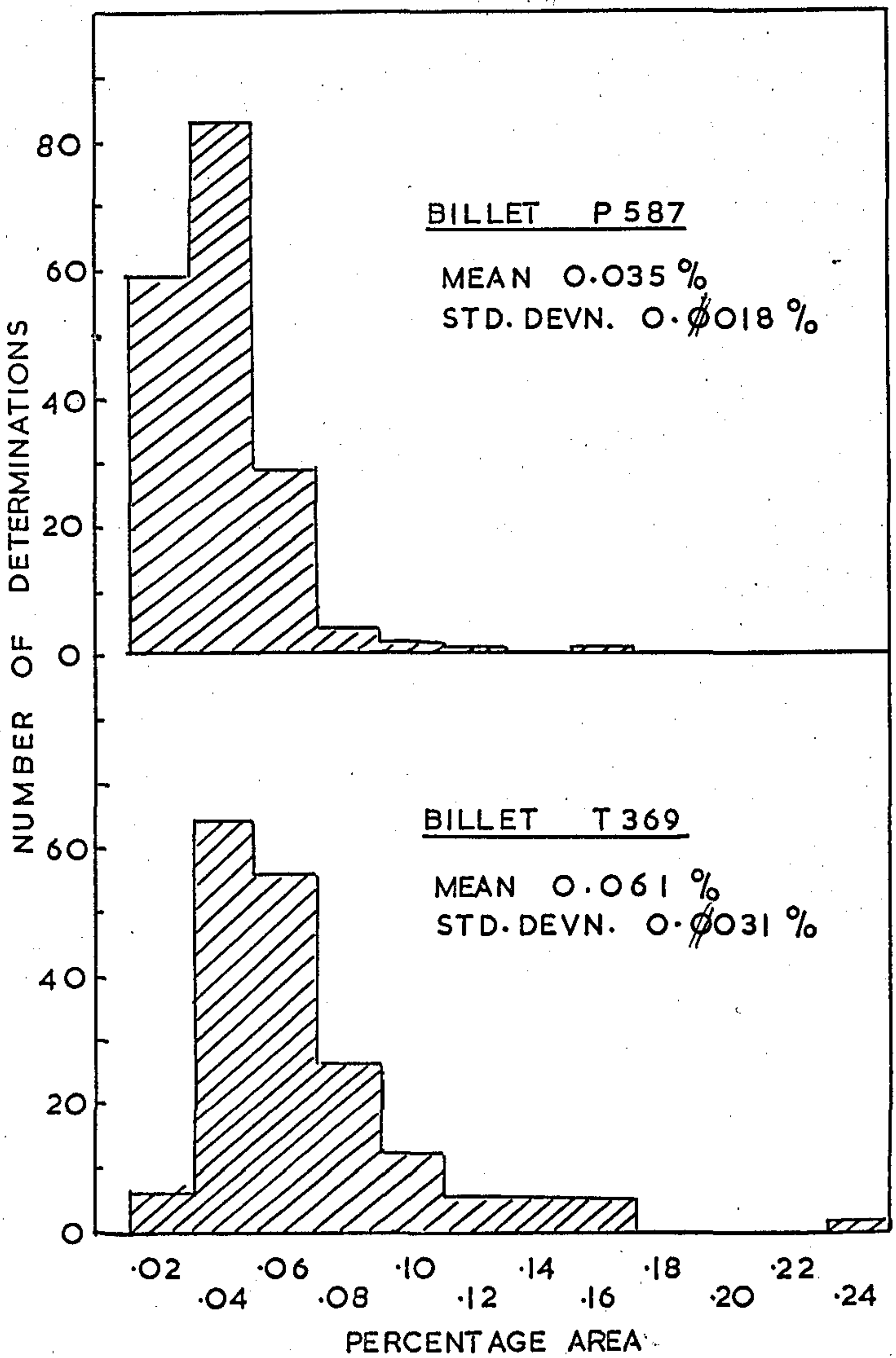


FIG 49

DETAILS OF SAMPLING AND SAMPLE PREPARATION

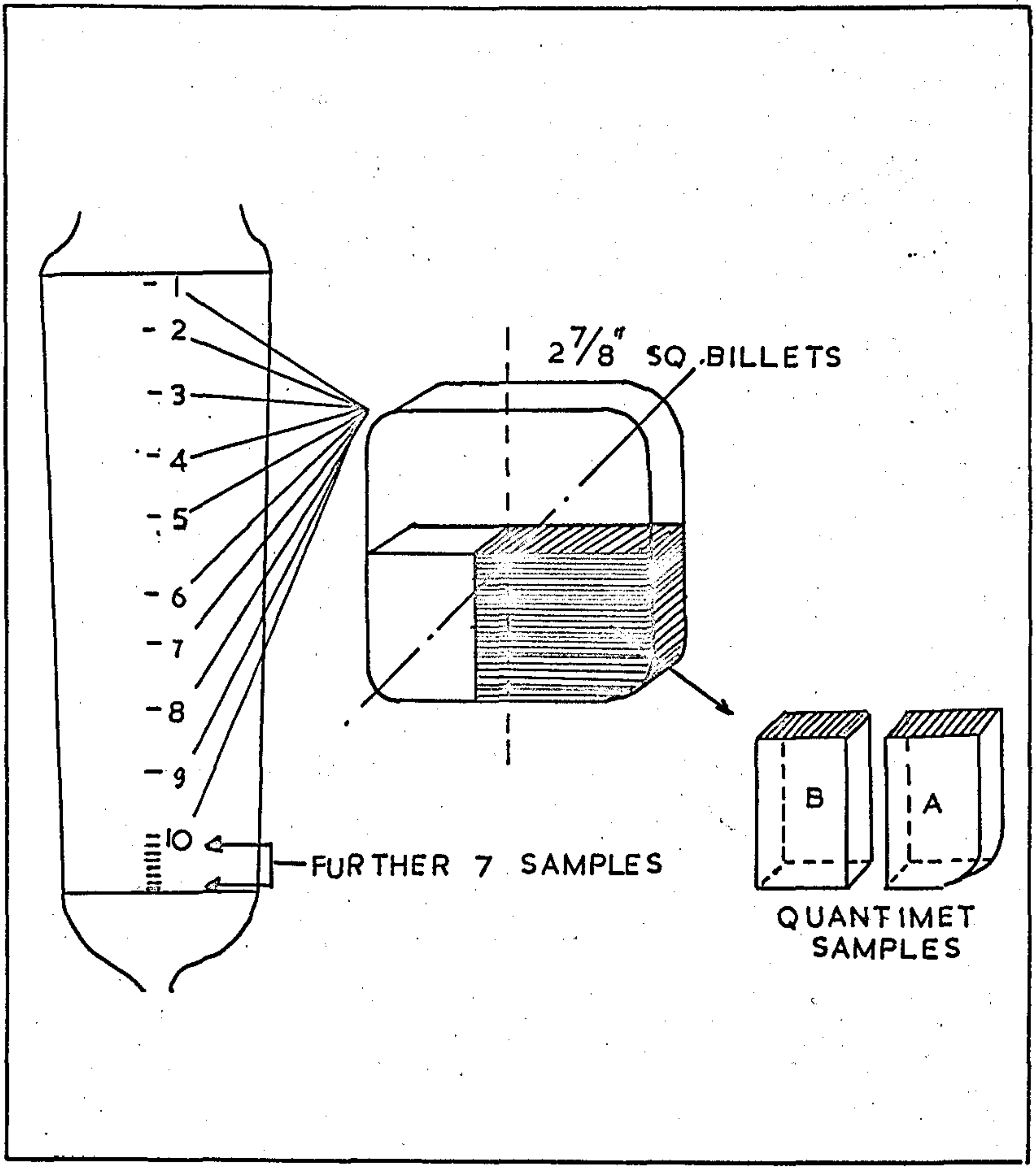


FIG 50
DETAILS OF STEP DOWN
TEST PIECE

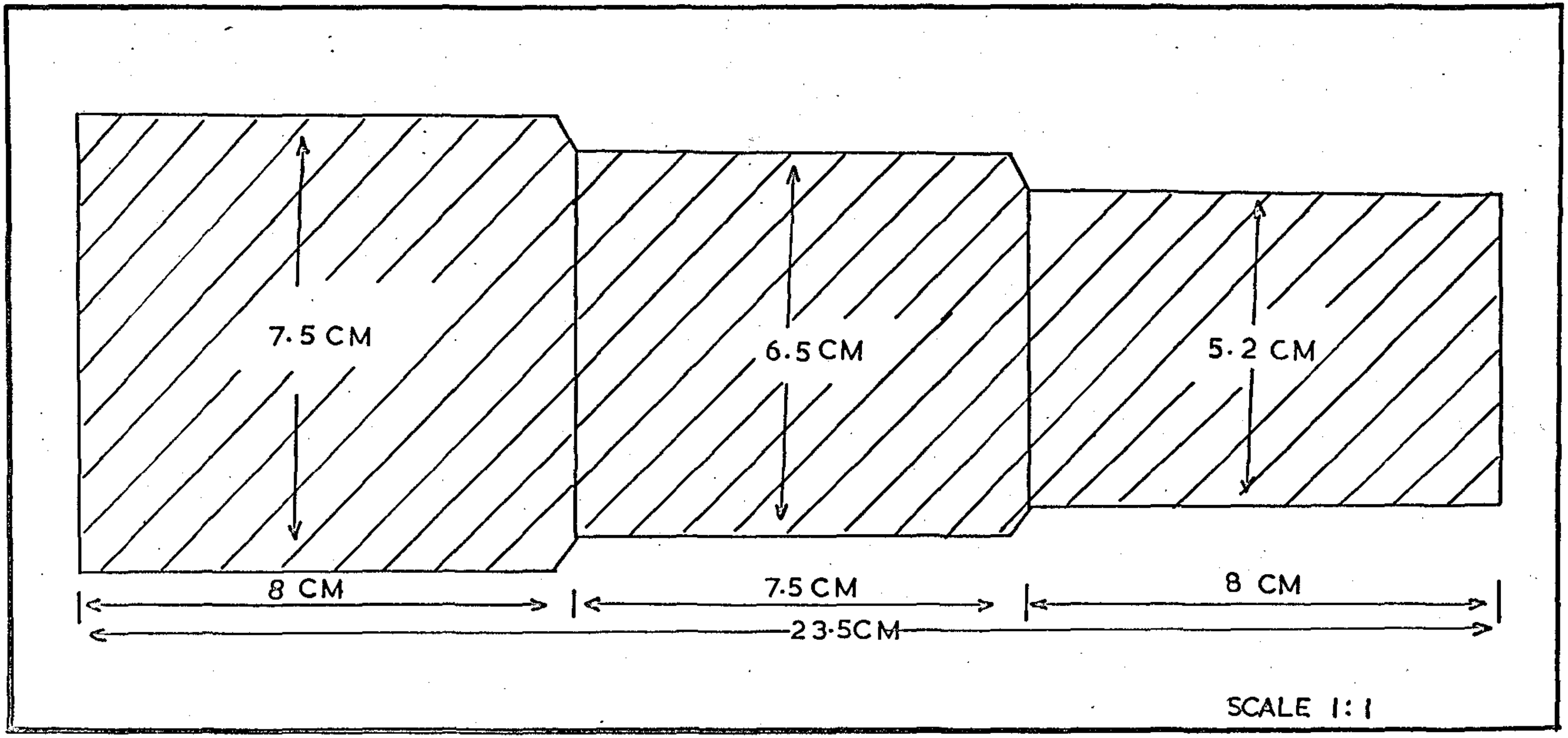


FIG. 51

DISTRIBUTION OF PERCENTAGE AREA COUNTS GREATER THAN 0·2 PERCENT IN FOUR REGIONS OF SAMPLE

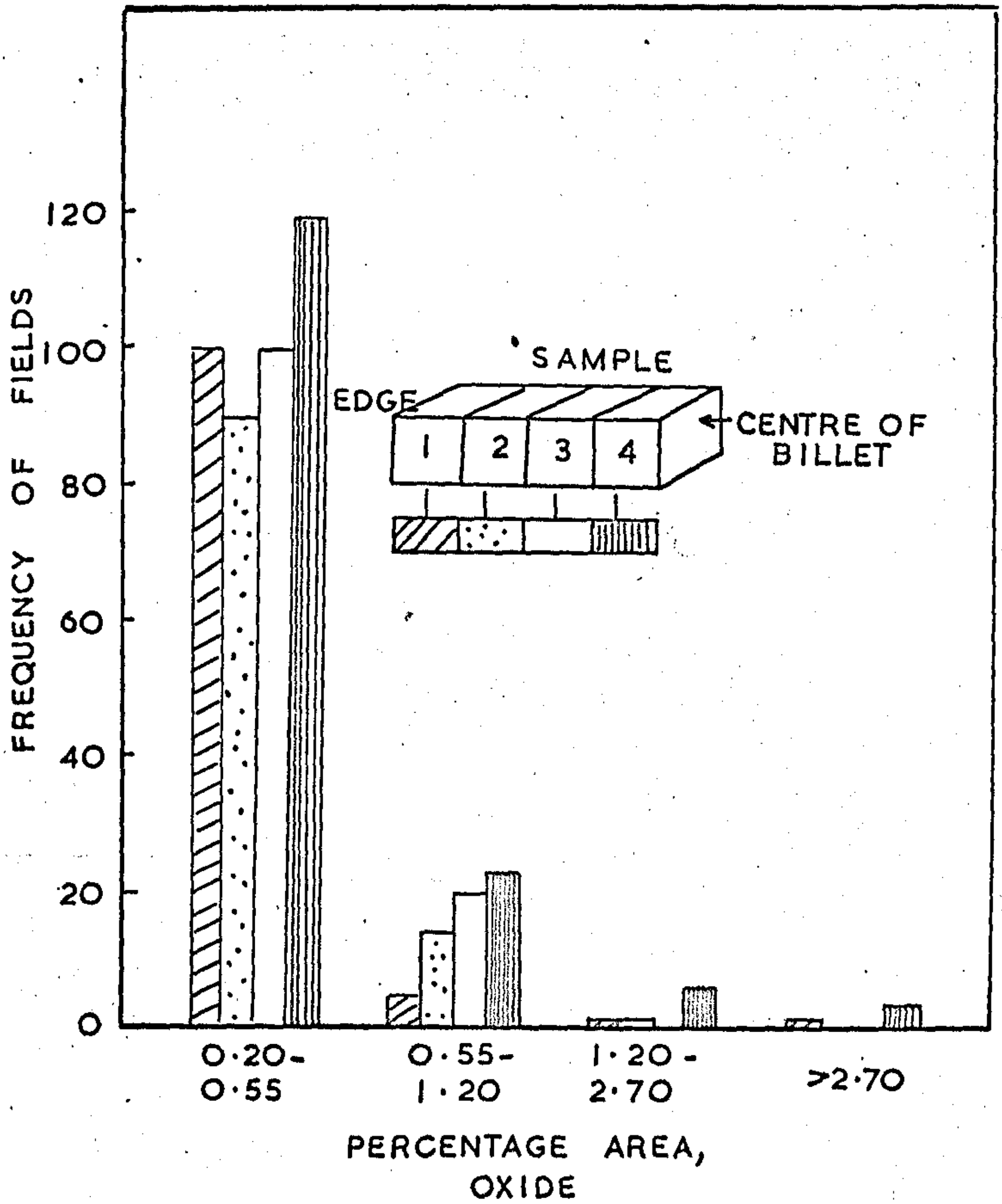


FIG. 52 - DISTRIBUTION OF MEAN PERCENTAGE AREA COUNTS IN FOUR ZONES OF 56 SAMPLES

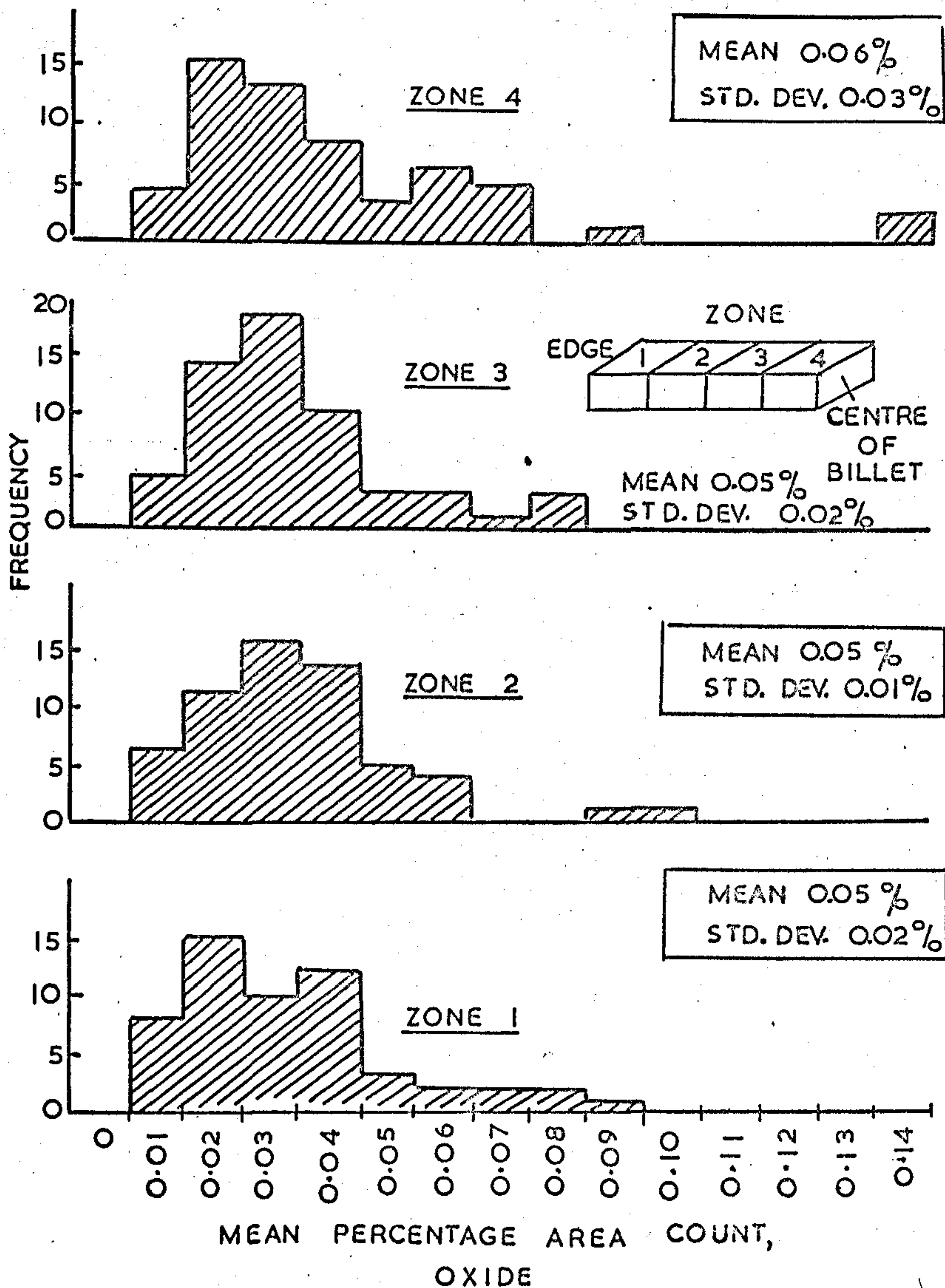


FIG. 53

DISTRIBUTION OF PERCENTAGE AREA COUNTS GREATER THAN 0.2 PERCENT IN TWO REGIONS OF SAMPLE

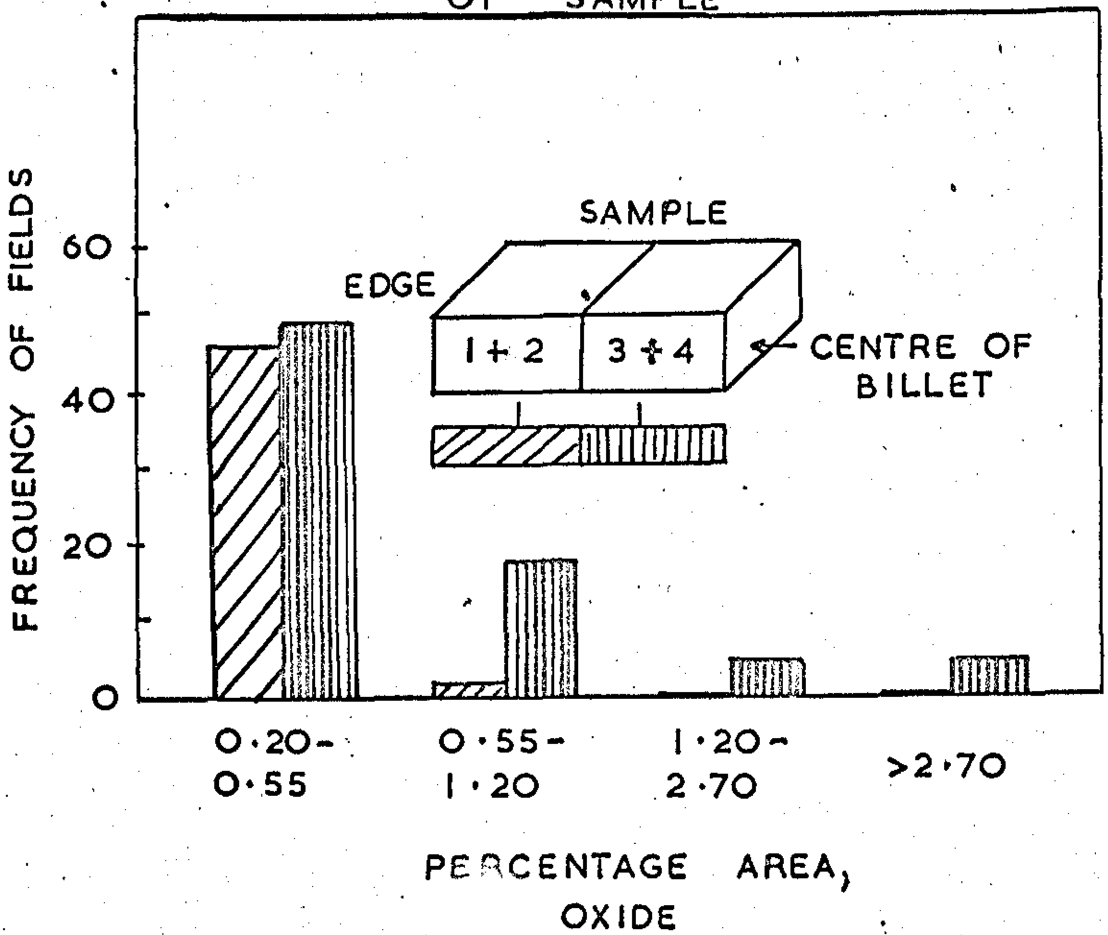


FIG. 54

DISTRIBUTION OF MEAN PERCENTAGE AREA COUNTS IN TWO ZONES OF 53 SAMPLES

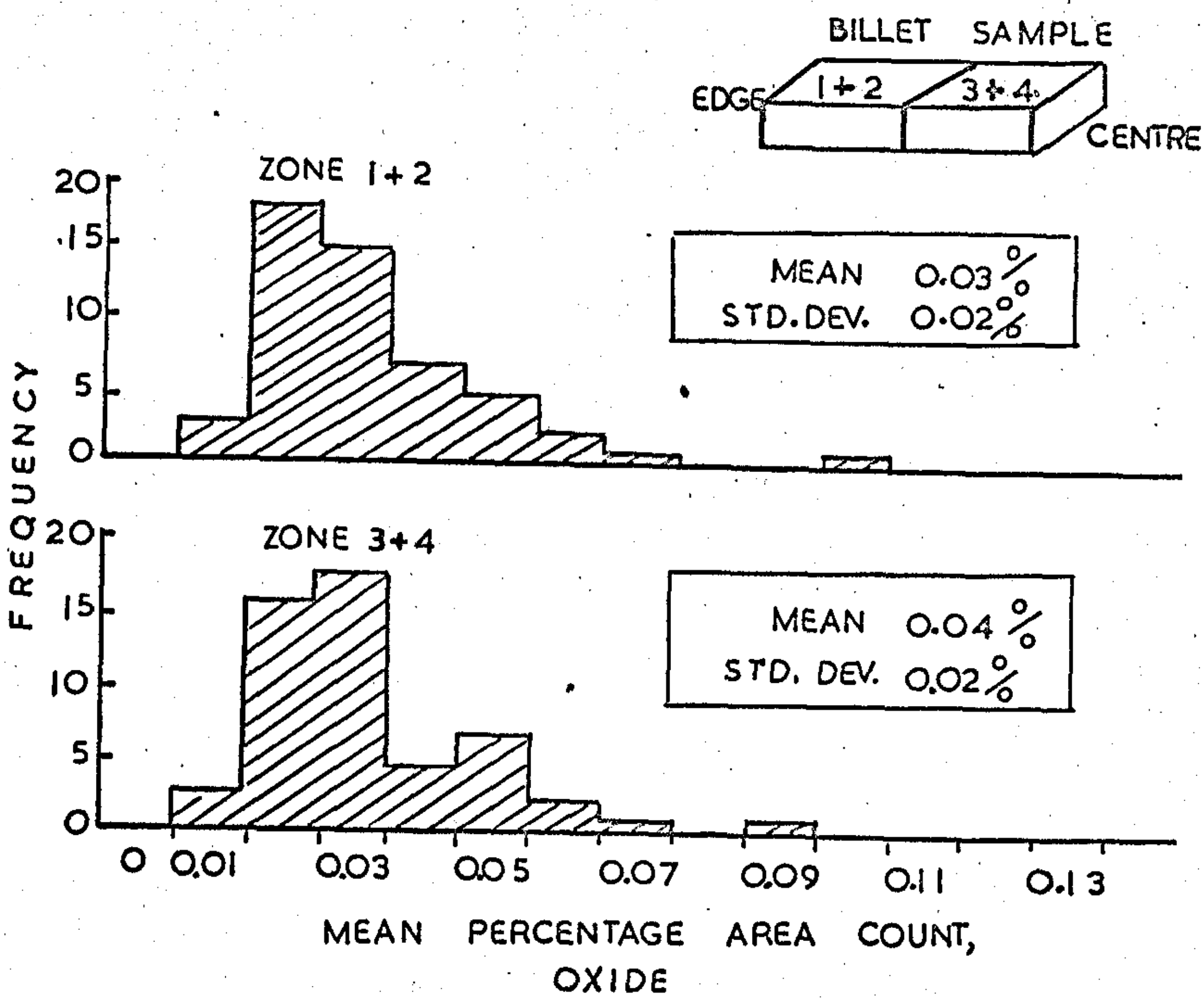


FIG. 55

MEAN PERCENTAGE AREA AND PROJECTION COUNTS ON OXIDES IN BILLET SAMPLES FROM FOUR POSITIONS IN INGOT

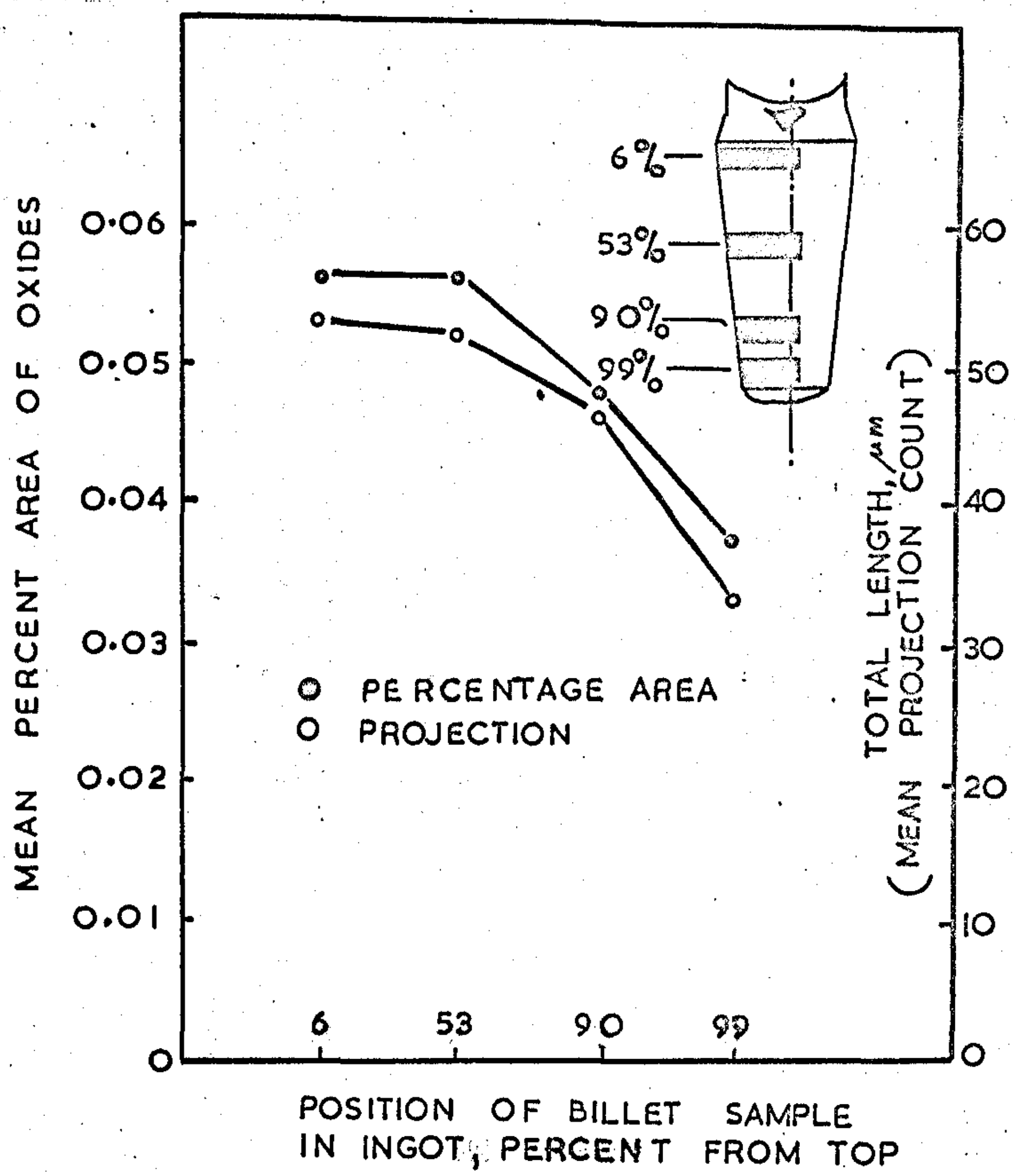


FIG. 56

SUMMARY OF PERCENTAGE AREA COUNTS OBTAINED ON 212 BILLET SAMPLES REPRESENTING FOUR POSITIONS IN 53 INGOTS

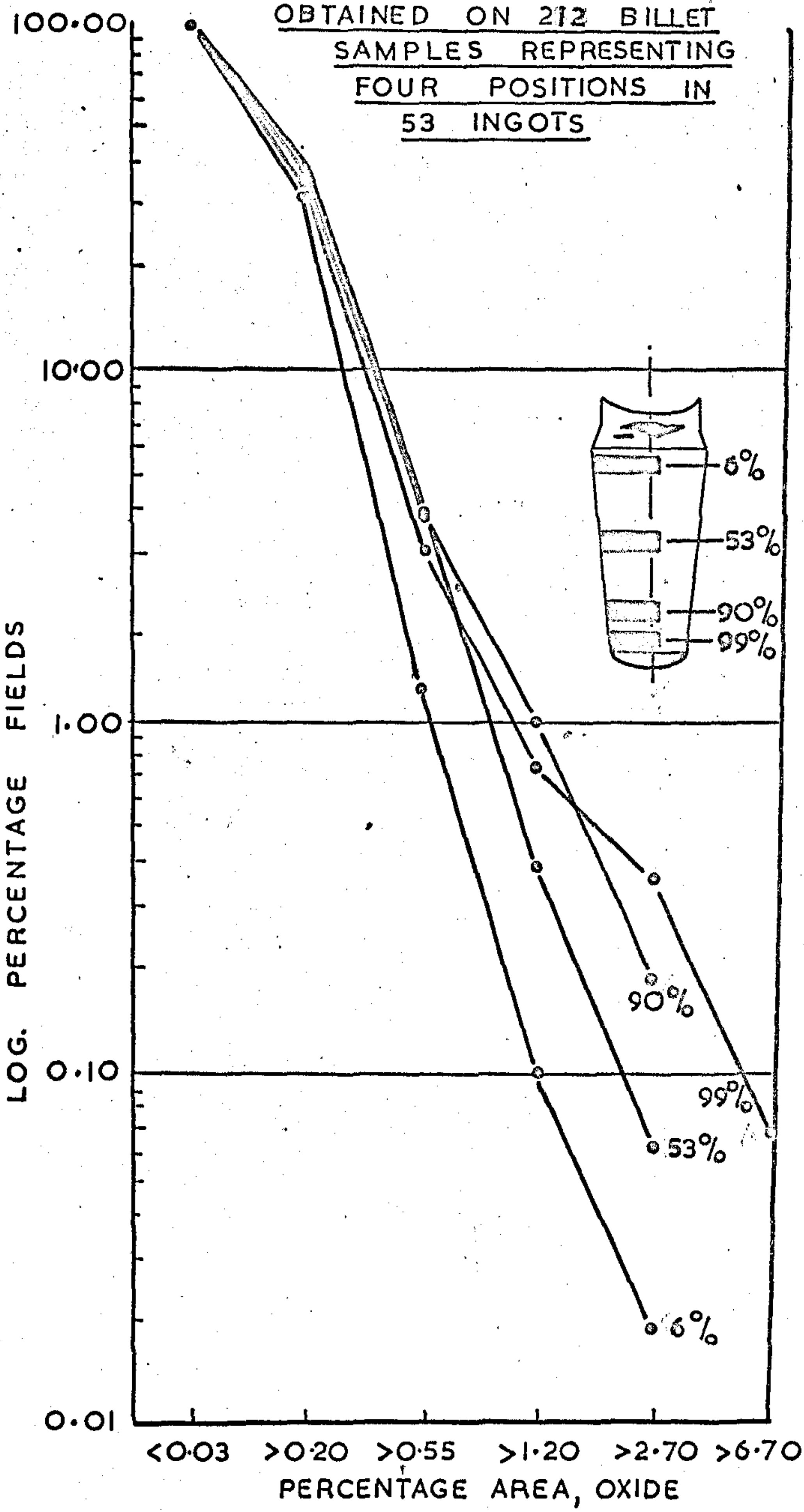


FIG. 57

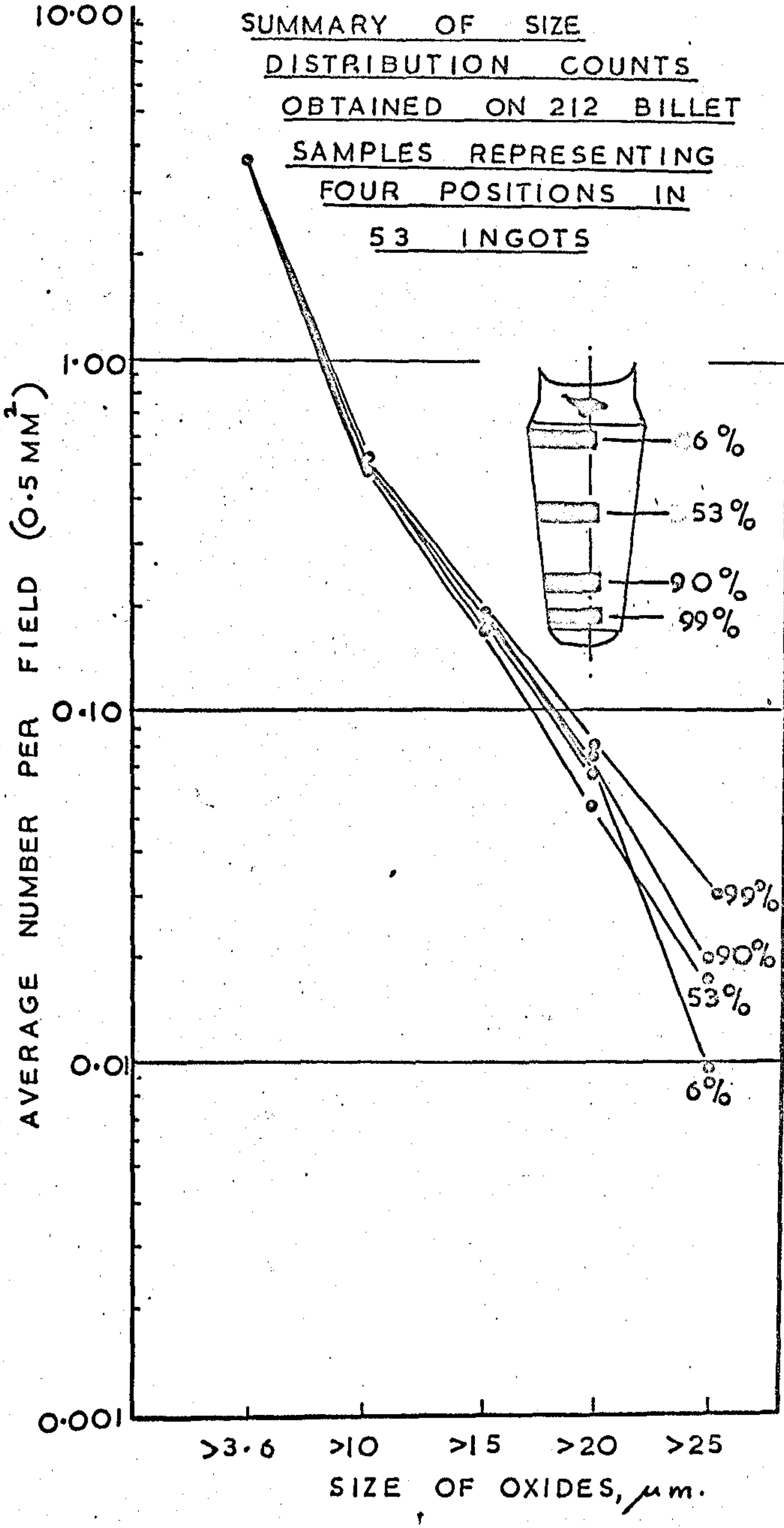

SUMMARY OF SIZE DISTRIBUTION COUNTS OBTAINED ON 212 BILLET SAMPLES REPRESENTING FOUR POSITIONS IN 53 INGOTS
10·00
1·00
0·10
0·01
0·001
AVERAGE NUMBER PER FIELD (0·5 MM^2)
6 %
53 %
90 %
99 %
99%
90%
53%
6%
>3·6
>10
>15
>20
>25
SIZE OF OXIDES, µm.

FIG.58

PERCENTAGE OF SAMPLES FROM FOUR POSITIONS IN THE INGOT, 6, 53, 90 & 99% WITH HIGHEST OXIDE CONTENT

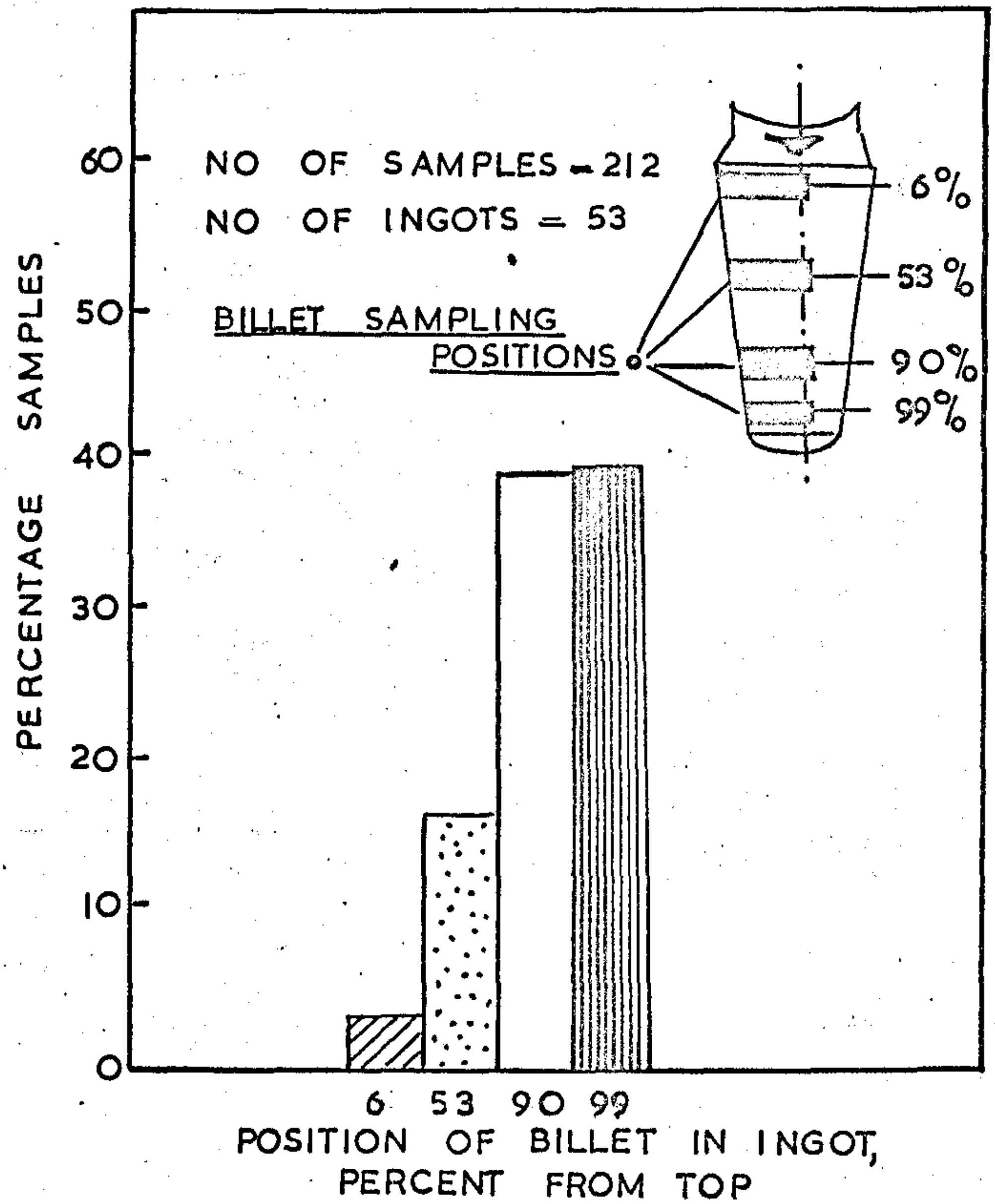


FIG. 59

DISTRIBUTION OF PERCENTAGE AREA COUNTS GREATER THAN 0·2 PERCENT FOR INGOTS FROM DIFFERENT GROUP

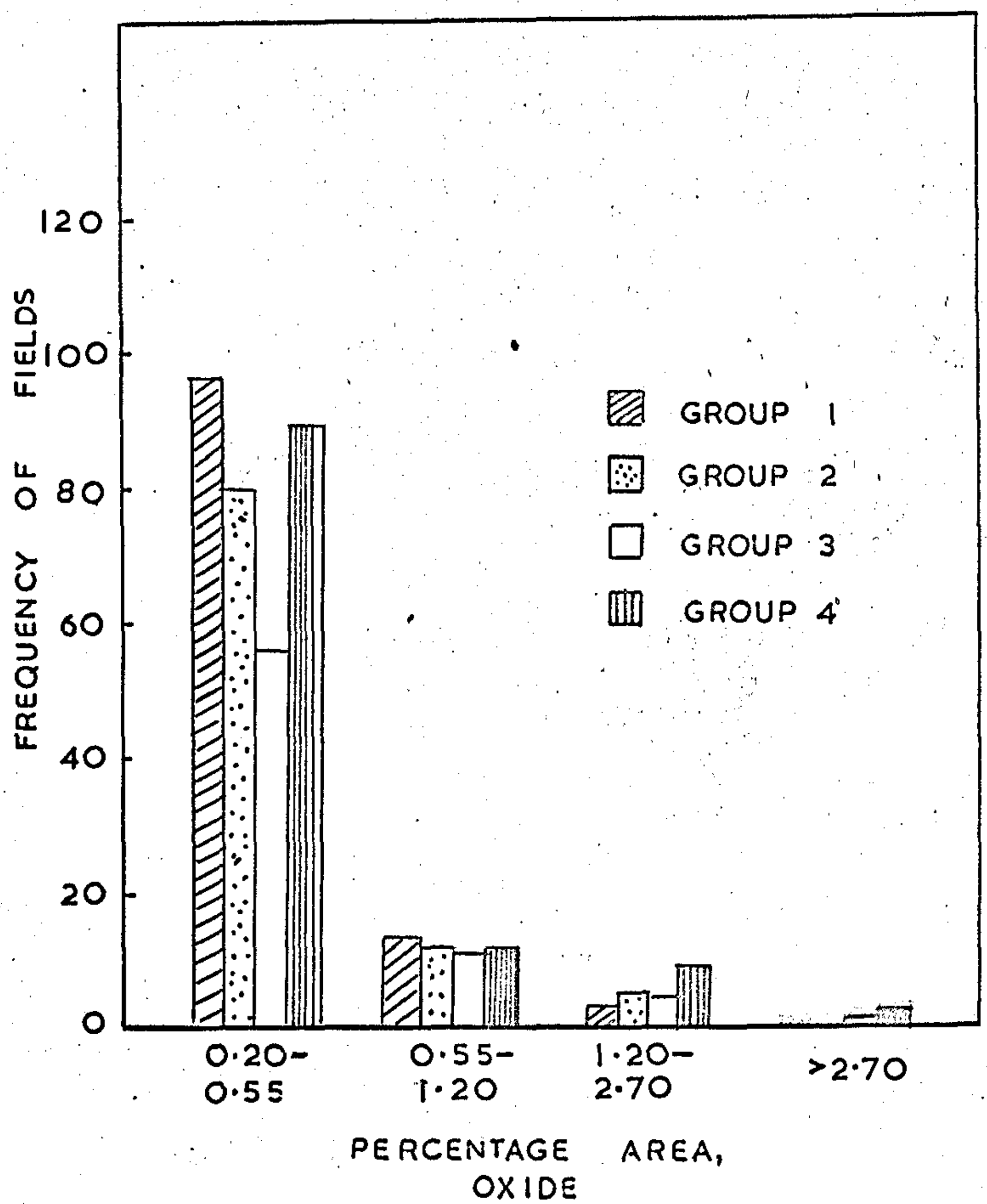


FIG. 60

DISTRIBUTION OF MEAN PERCENTAGE AREA COUNTS FOR INGOTS FROM DIFFERENT GROUP

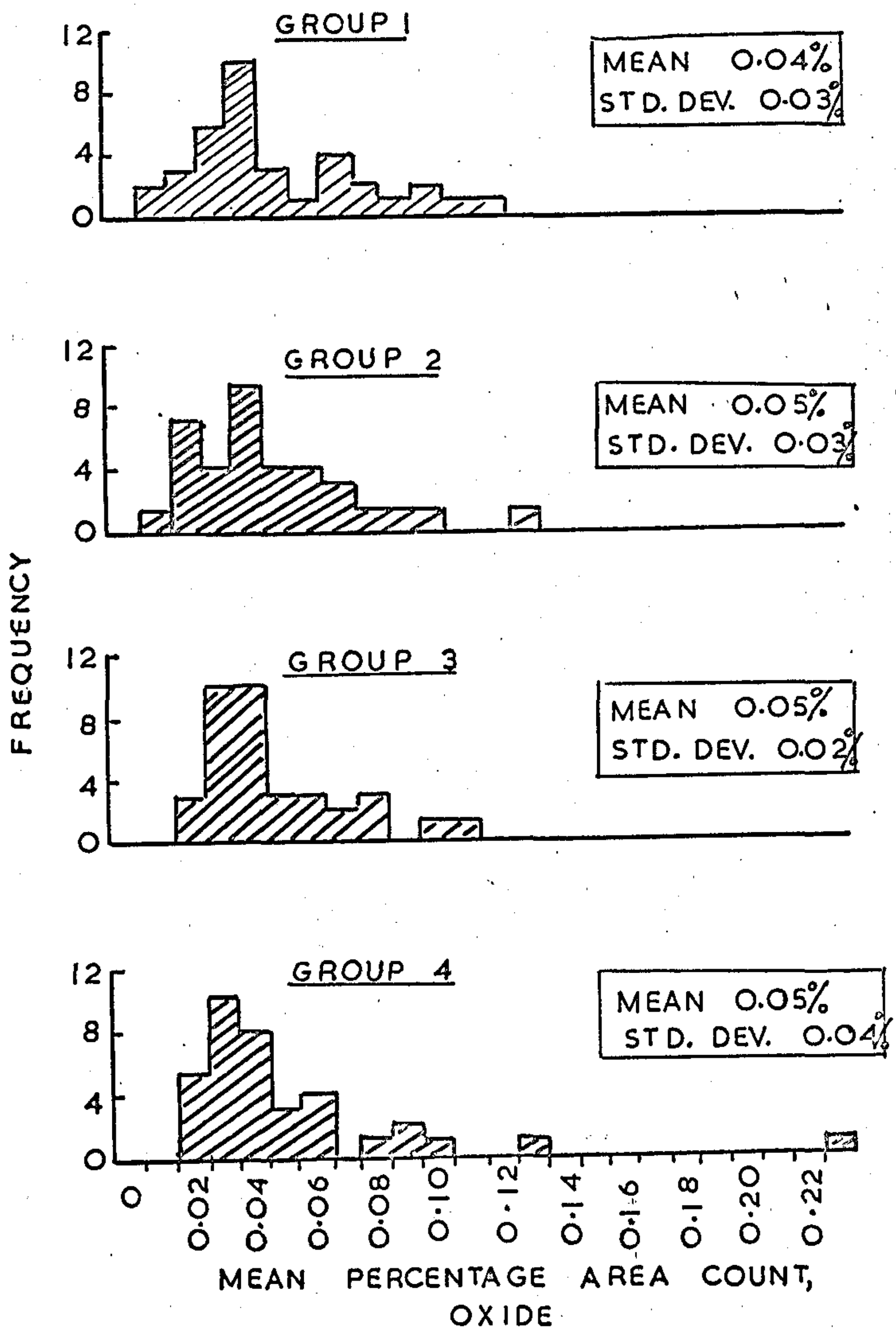
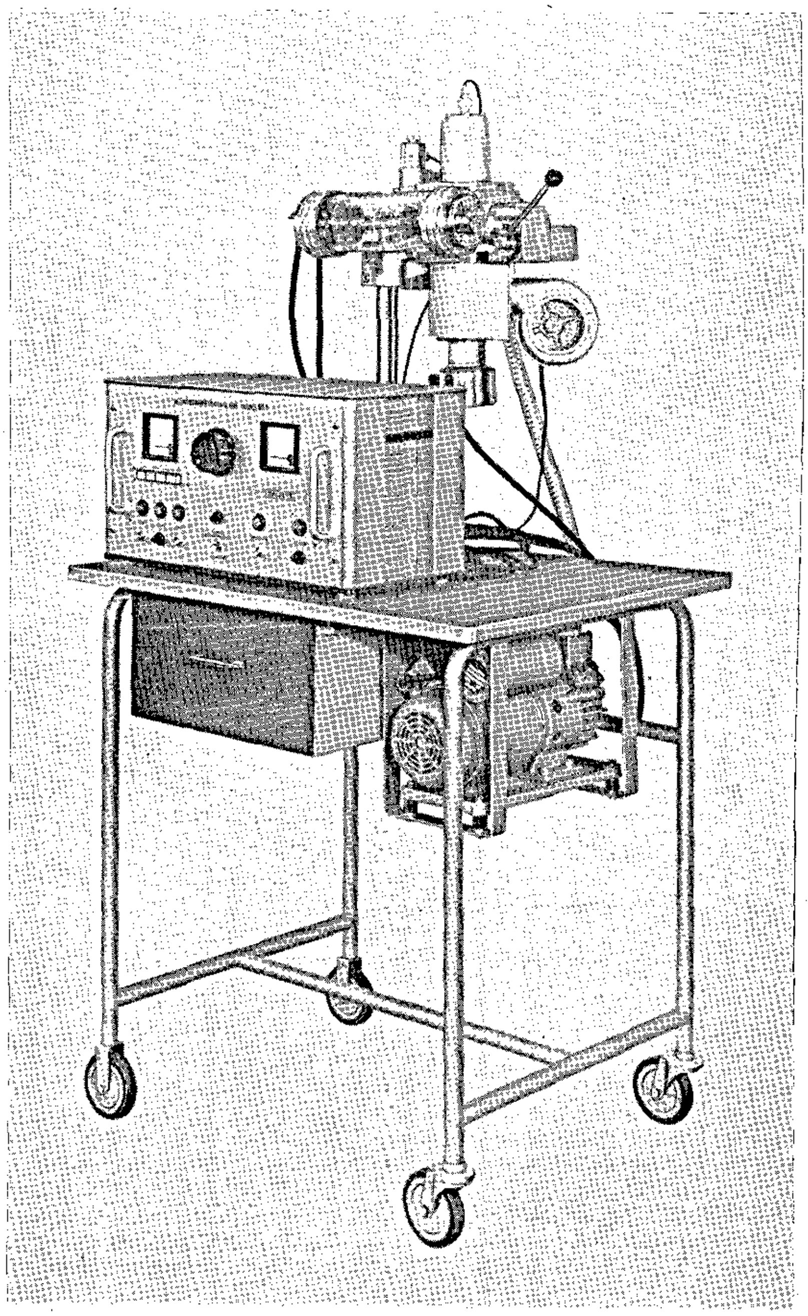


Fig. 61 General view of Miniature Coating Unit MICRO BA-3



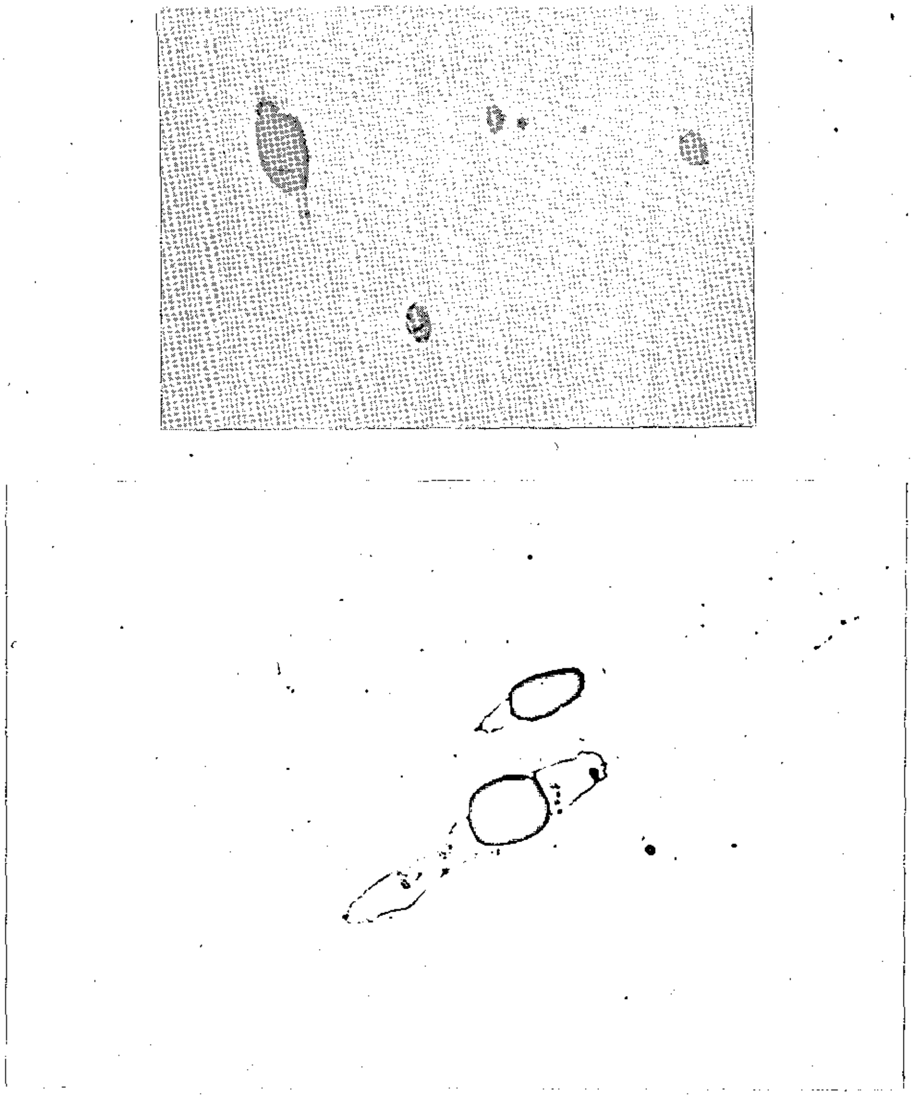


Fig.62 Photomicrograph of manganese sulphide inclusions in high sulphur free-cutting steel: (a) before etching, (b) after etching in nital. Grey phase MnS; light phase lead telluride, 250X.

Fig. 63 Photomicrograph of same type of inclusion as in Figure 62 as seen by the interference film technique. MnS orange; lead-telluride yellow. The dark phase bluish in colour is manganese-lead-telluride. Steel matrix bluish-green, 400X

Fig. 64 Photomicrograph of manganese sulphide stringer-type inclusions in high sulphur free-cutting steel bars; unetched, 200X.

Fig. 65 Photomicrograph of same type of inclusions as in Figure 64 as seen by the interference film technique: MnS orange; steel matrix blue, 200X.

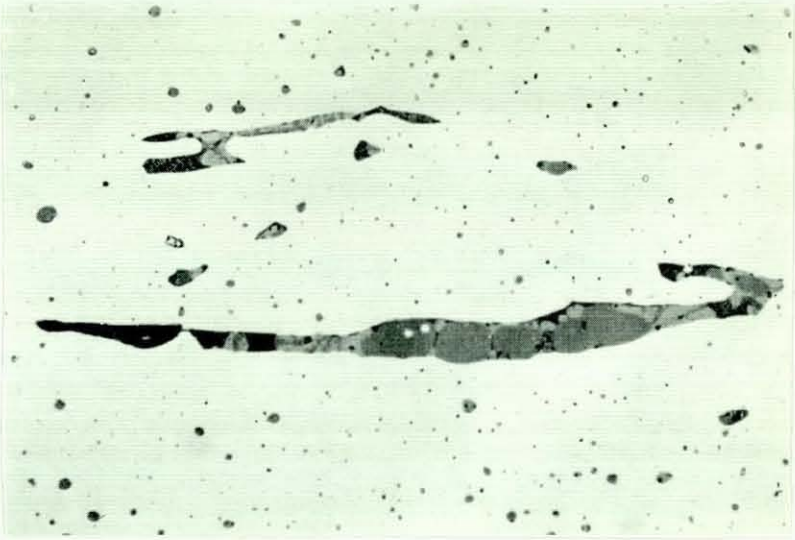


Fig. 66 Composite oxy-sulphide inclusion in high sulphur free-cutting steel before coating with ZnSe film; 400X.

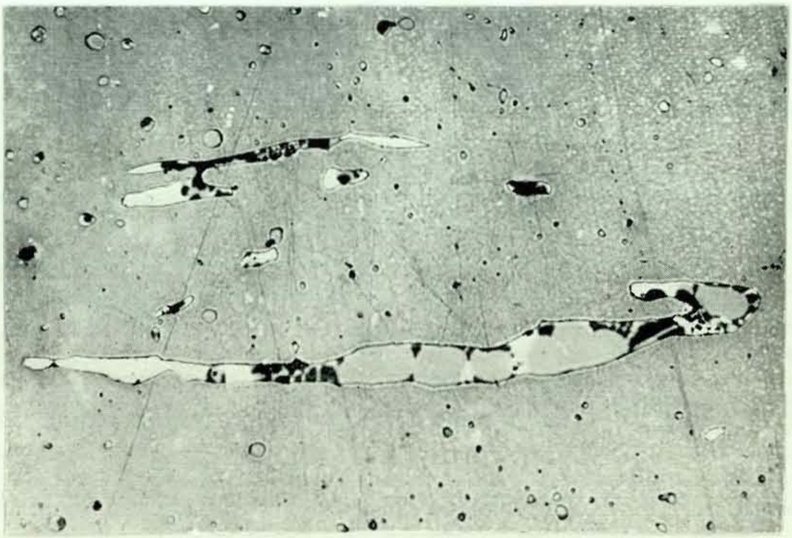


Fig. 67 Same inclusions as in Figure 66 as seen by the interference film technique, 400X.

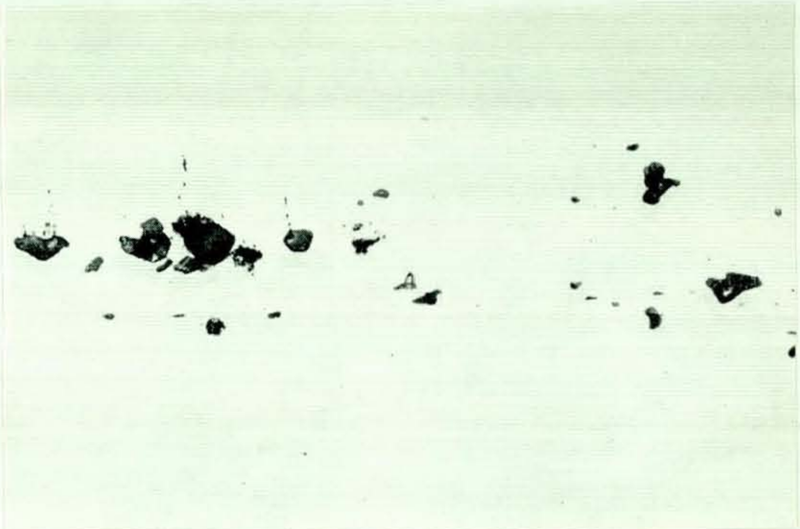


Fig. 68 An inclusion aggregate in a longitudinal billet section before coating; unetched, 400X.

Fig. 69 Same type of inclusion aggregate as in Figure 68 as seen by the interference film technique; 400X.

Fig. 70 Silicate and manganese sulphide inclusions in longitudinal section of a low alloy steel billet as seen by the interference film technique, 100X.

Orange MnS; yellow silicate.

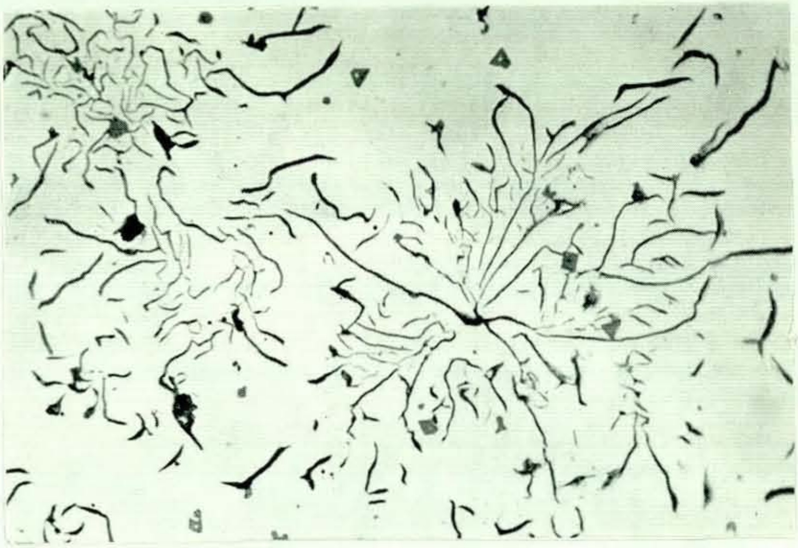


Fig. 71 Microstructure of grey cast-iron as seen before coating with a ZnSe film, 600X.

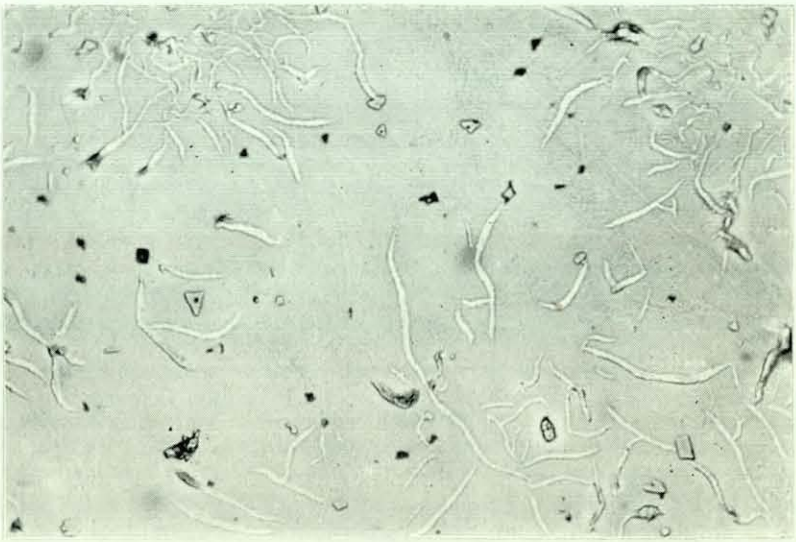


Fig. 72 Same type of structure as in Figure 71 as seen by the interference film technique, 600X.

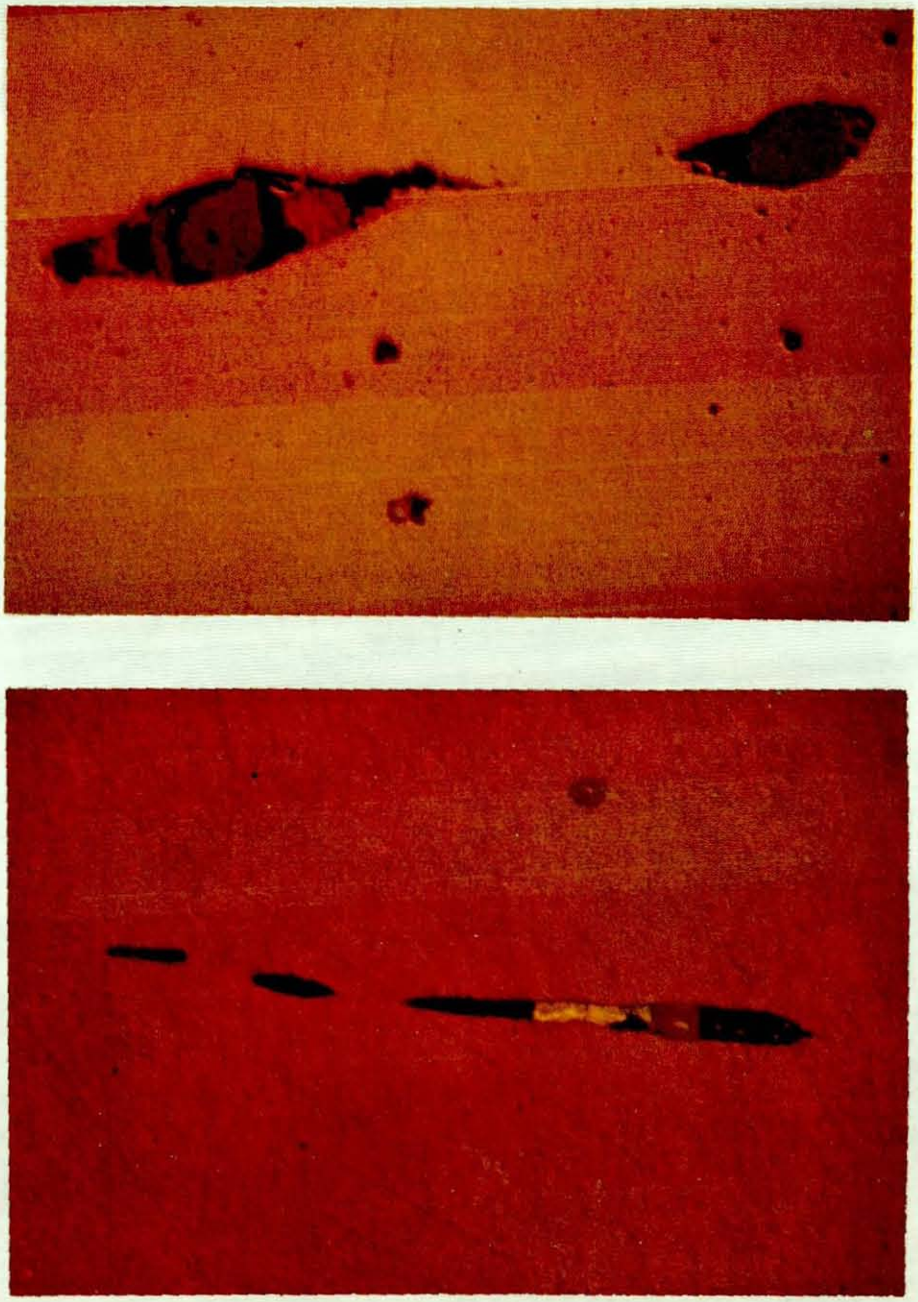


Fig. 73 Examples of same type of inclusions as in Figures 62 and 63 but under a thinner film (red) of ZnSe, 250X.

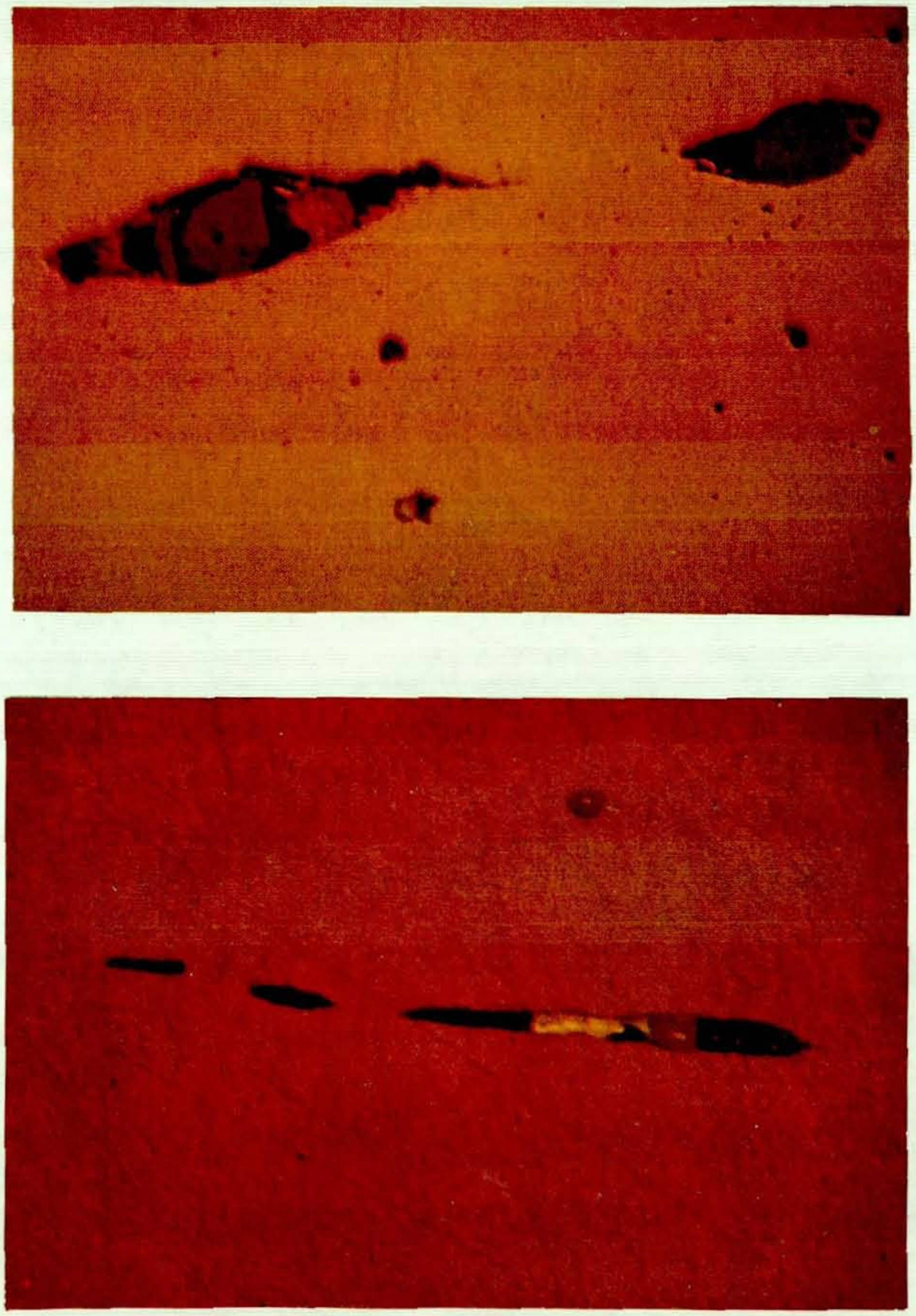


Fig. 73 Examples of same type of inclusions as in Figures 62 and 63 but under a thinner film (red) of ZnSe, 250X.