A Statistical Study on Viscosities of Asphalt Cements Used by the Texas Highway Department

by
R. N. Traxler
Research Chemist
and
J. G. Darroch
Assistant Research Statistician
Texas Transportation Institute

Progress Report No. 12
Study No. 2-8-59-9
Research Area 8

Submitted to Research Committee
of the Texas Highway Department

August 1, 1967

Texas Transportation Institute
Texas A&M University
College Station, Texas 77843

CONTENTS

TABLES

FIGURES

A STATISTICAL STUDY ON VISCOSITIES OF ASPHALT CEMENTS USED BY THE TEXAS HIGHWAY DEPARTMENT

I. OBJECTIVES OF STUDY NO. 2-8-59-9 - RESEARCH AREA 8

The objectives of the study are to:

(1) Investigate the paving asphalts used by the Texas Highway Department,

(2) Establish specifications to assure use of superior asphalts by the Department, and

(3) Determine how the durability of asphalt cements can be improved.

The investigation discussed below applies to objective (2).

II. HISTORY

In November 1964 the Texas Highway Department, acting on the recommendation of the Texas Transportation Institute established new purchase specifications for asphalt cements. The purpose of this change, which comprised the replacement of penetration and other tests by viscosity values, was to assure more uniform hardness of the cements submitted by the numerous suppliers of asphalt to the Department. Included was a measure for the quality of asphalt based on its resistance to hardening by time, heat and oxidation.

This change resulted in the deletion of the following tests which had been used for many years:

Softening Points
ASTM Penetration at 32°F. 200 g/60 sec
ASTM Penetration at 77°F. 100 g/5 sec
ASTM Penetration at 115°F. 50 g/5 sec
Thin Film Oven Test, 1/8 in. film 50 g/5 hrs. at 325°F.
- Per cent loss of wt. of residue
- Pen of residue at 77°F.
- Ductility of residue at 77°F. 5 cm/min, cms.

Spot Test on original asphalt.
Float Test at 122°F.

and replacement by the 7 items shown in Table 1, following.

Table 1

1964 Specifications for Asphalt Cement.
The material shall be homogeneous, shall be free from water, shall not foam when heated to 347°F. and shall meet the following requirements:

Type-grade	AC-5		AC-10		AC-20		AC-40	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Viscosity at 275°F., stokes	1.5	___	2.0	___	3.0	___	4.0	___
Viscosity at 140°F., stokes	500	750	1000	1500	2000	3000	4000	6000
Solubility in CCl_4, %	99.5	___	99.5	___	99.5	___	99.5	___
Flash Point C.O.C., F.	375	___	425	___	450	___	450	___
Ductility, 77°F., 5cm/min., cms.	100*	___	100	___	100	___	100	___
Relative Viscosity (after oxidation, 15 u films for 2 hours at 225°F., viscosities determined at 77°F.)	___	4.0	___	4.5	___	5.0	___	6.0

* For AC-5 grade only, a minimum ductility value of 60 cm. at 60°F. will be acceptable in lieu of 100 cm. at 77°F.

III. CONCLUSIONS

The following conclusions are drawn from the data shown in this report.

(1) Satisfactory distribution of data between the limits established at 140°F for the AC-5, AC-10 and AC-20 grades of asphalt cements was found for 20 of the 29 groups studied by means of machine plots.

(2) Machine plots of viscosity at 140°F versus ASTM Penetration at 77°F confirm the well-known fact that there is no satisfactory correlation between penetration and viscosity for various asphalts made from different crude sources and by different processes.

(3) Hand plots of viscosity at 140°F against penetration at 77°F for the different asphalts, and for particular grades show that the suppliers tend to fall into groups in respect to penetration.

(4) Machine plots of viscosity at 140°F versus viscosities at 77°F on original asphalts and on the same asphalts at 77°F after hardening by heating 15 micron films in a dark air oven for 2 hours at 225°F showed that 15 groups failed to meet the proposed specification on the original asphalt. Only 4 groups failed the requirement on the laboratory hardened asphalt. Thus, this quality test is met by a high percentage of the asphalt cements used by THD.

(5) Machine plots of viscosity at 140°F versus viscosity at 275°F showed that three AC-5 asphalts fell below the minimum requirements at 275°F and one was marginal. Ten of the other two grades were marginal in respect to the requirements at 275°F.

IV. RECOMMENDATIONS

It is recommended that:

(1) The limits proposed in Table 2 of this report be incorporated into the Texas Highway Department's current purchase specifications for Asphalt Cements.

(2) The information given in this report be made available to the companies who supply asphalt cements to the THD. From the data given they should be able, when necessary, to change their operations so that asphalts of uniform viscosity become available State wide to the Department.

V. FUTURE WORK

Studies will continue to:

(1) Evaluate the uniformity in hardness and quality of the asphalts used by the Texas Highway Department by statistical methods.

(2) Expand our knowledge about the importance of the various environmental effects on paving asphalts during their service in the road.

Table 2

Specifications Recommended (1966) for Asphalt Cements. The material shall be homogeneous, shall be free from water, shall not foam when heated to 347°F. and shall meet the following requirements:

Type-grade	AC-5		AC-10		AC-20	
	Min.	Max.	Min.	Max.	Min.	Max.
Viscosity at 275°F., stokes	2.0	5.0	2.5	7.0	3.5	9.0
Viscosity at 140°F., stokes	500	750	1000	1500	2000	3000
Viscosity at 77°F., megapoises	___	0.50	___	1.25	___	2.50
Viscosity at 77°F., megapoises after heating in air (1)	___	2.0	___	5.6	___	12.5
Solubility in CCl_4, %	99.5	___	99.5	___	99.5	___
Flash Point C.O.C. °F.	375	___	425	___	450	___
Ductility, 77°F., 5 cm/min/cms.	100*	___	100	___	100	___

* For AC-5 grade only, a minimum ductility value of 60 cm. at 60°F. will be acceptable in lieu of 100 cm. at 77°F.

(1) A 15 micron film of the asphalt on 4cm x 4cm glass plates is heated in a dark air oven for 2 hours at 225°F. The hardened film is scraped from the plates and transferred to plates used in the sliding plate viscometer. Viscosity is calculated at 5×10^{-2} x sec^{-1} rate of shear for both the original and hardened asphalt at 77°F.

VI. EXPERIMENTAL WORK

1. Adjustment and Modification of 1964 Specifications.

During 1965-66 and-67 continuing studies were made on tests supplied by the Materials and Tests Laboratory of the Texas Highway Department. These investigations, based on hundreds of samples submitted to the Highway Department by about 15 different asphalt manufacturers, indicated the need for several slight modifications of the 1964 specifications now in use. Thus, as the investigation proceeded and more data became available minor adjustments were made to assure more suitable limits. Specifications currently recommended for the three commonly used grades of asphalt cement are shown in Table 2, facing. These requirements do not necessitate any more tests than are used at present. The recommended changes are:

(1) The addition of an upper viscosity limit for each grade of cement at $275^{o}F$

(2) An upper viscosity only for each grade of cement at $77^{o}F$

(3) An upper viscosity only for each grade of asphalt at $77^{o}F$ after heating a 15 micron film of the asphalt in a dark air oven for 2 hours at $225^{o}F$.

The recommended viscosity limits for each grade of asphalt cement are shown in the following three graphs (Figures I, II and III) in which log temperatures are plotted versus log viscosities.

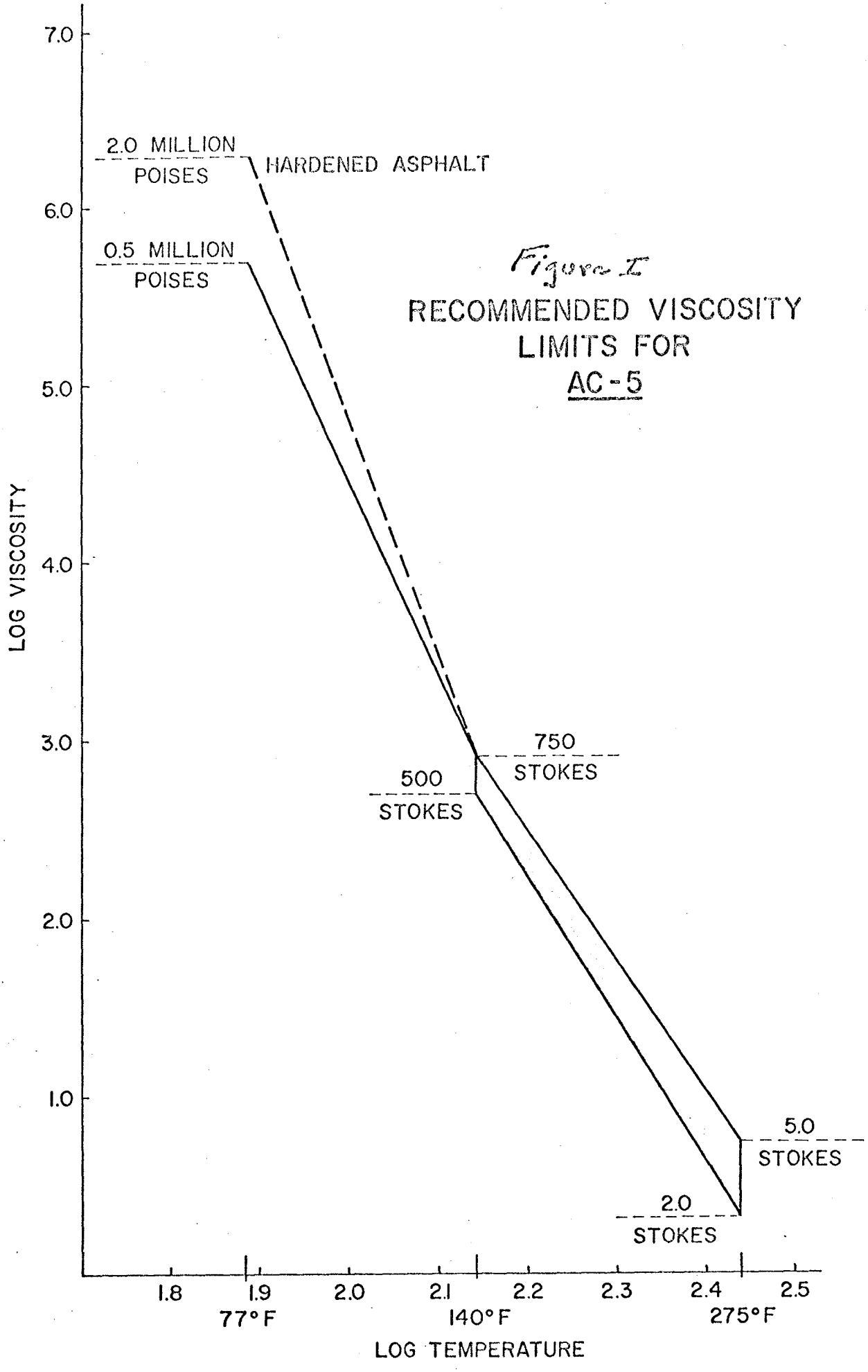


Figure 1

RECOMMENDED VISCOSITY LIMITS FOR AC-5

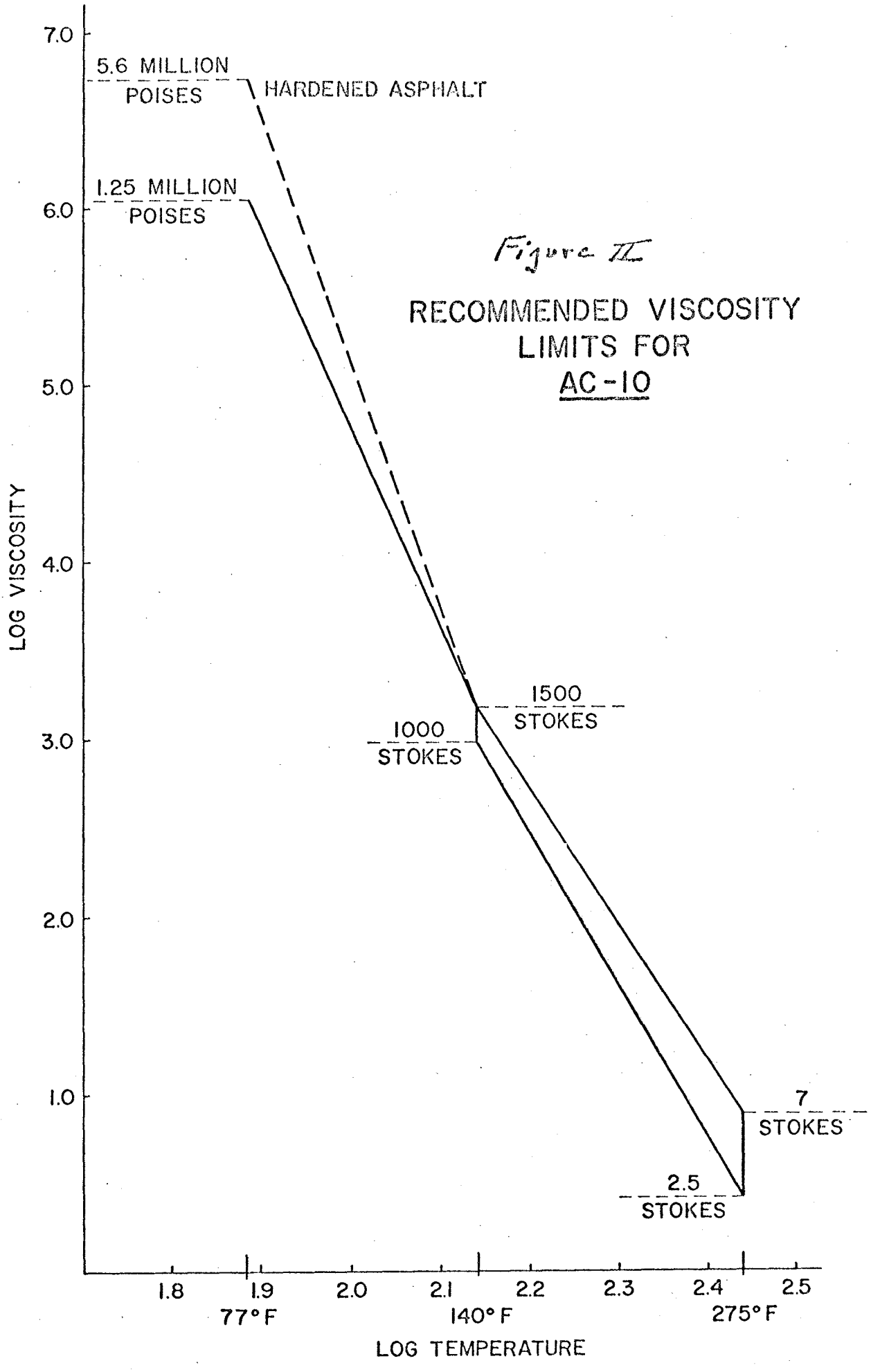


Figure II

RECOMMENDED VISCOSITY LIMITS FOR AC-10

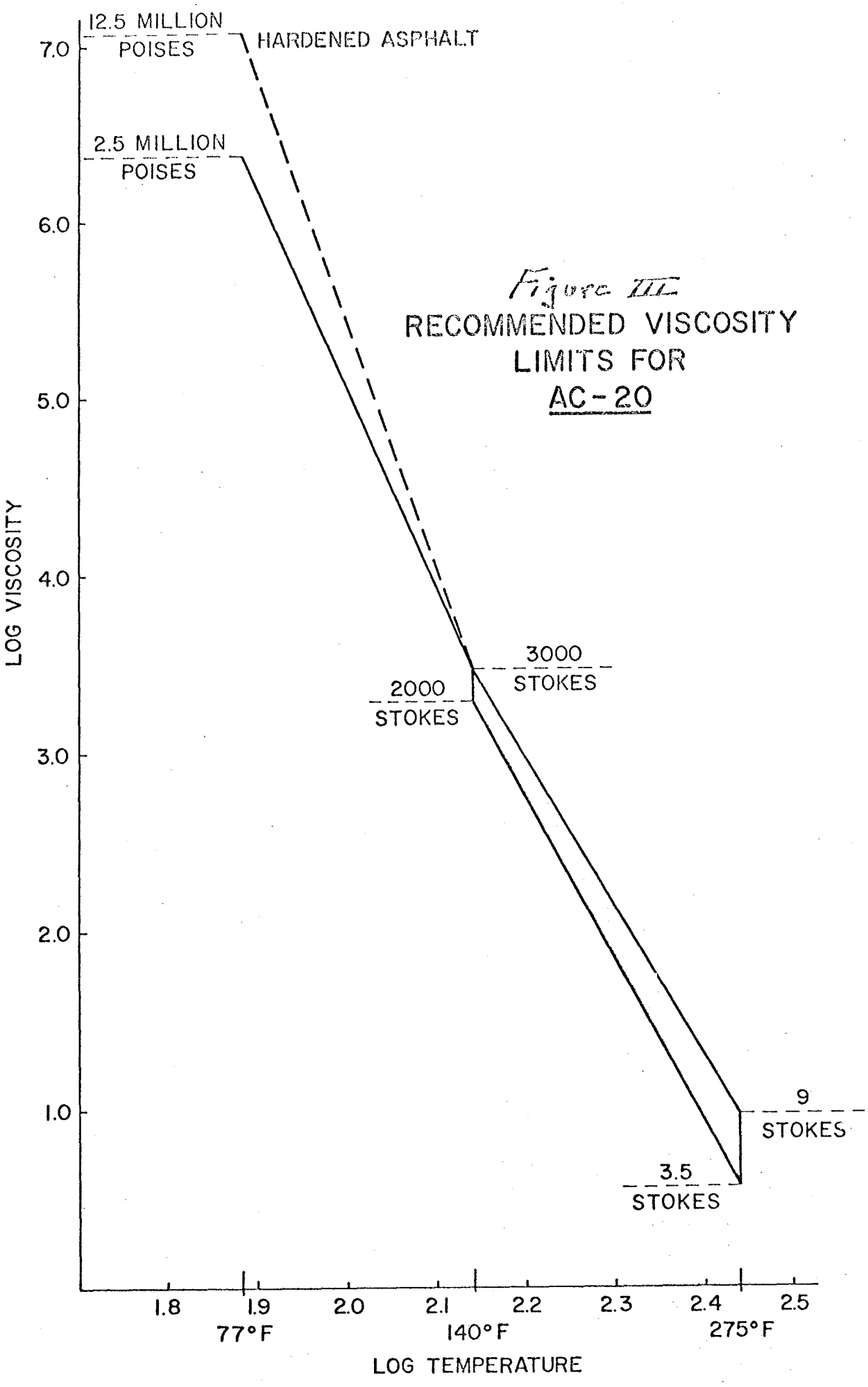


Figure III

RECOMMENDED VISCOSITY LIMITS FOR AC-20

2. Statistical Studies

Test data obtained during 1965-66 by the Materials and Tests Laboratory at Austin Texas for each grade of asphalt submitted by each supplier were plotted by machine in the Texas A&M University Data Processing Center. Three kinds of plot were made and are shown at the back of this report.

(a) Viscosities, stokes, at 140°F were plotted as abscissa versus ASTM Penetrations at 77°F. All samples received at the laboratory were subjected to these two tests. To reduce the number of sheets in this report it was decided to print only those cases in which a supplier submitted 10 or more samples of a particular grade for a given year. Data from both years are plotted on the same sheet using 0 for 1965 and * for 1966. The character M indicates that 2 identical tests occurred in both years.

(b) A similar plot was made using viscosities, stokes, at 140°F as the abscissa versus viscosities in poises at 77°F, both for the original asphalts and after the laboratory hardening test. Original viscosity at 77°F for 1965 is shown by * and for 1966 by X. Viscosity at 77°F after heating in air is shown by 0 for 1965 and $ for 1966. Since only 25 per cent of the total samples were tested at 77°F we have included all of the available data in these plots.

(c) Finally, plots are shown of viscosities, stokes, at 140°F as abscissa vs viscosities, stokes, at 275°F. About 90 per cent of the available samples were tested at 275°F and all data are shown.

For convenience of inspection the numerous plots are arranged at the back of this report in the following order:

Suppliers by increasing Code Number.

A colored title page is inserted ahead of the plots pertaining to each source of supply.

Under each Code Number data are arranged as follows:

Grade AC-5

Viscosity at 140°F vs ASTM Penetration at 77°F
Viscosity at 140°F vs Viscosities at 77°F
Viscosity at 140°F vs Viscosity at 275°F

Grade AC-10

Viscosity at 140°F vs ASTM Penetration at 77°F
Viscosity at 140°F vs Viscosities at 77°F
Viscosity at 140°F vs Viscosity at 275°F

Grade AC-20

Viscosity at 140°F vs ASTM Penetration at 77°F
Viscosity at 140°F vs Viscosities at 77°F
Viscosity at 140°F vs Viscosity at 275°F

In the sheets showing viscosity at 140°F vs viscosities at 77°F and for viscosity at 140°F vs viscosity at 275°F it will be noted that some sheets are blank. This indicates that although tests were made at 140°F for at least one or more samples no tests were made at 77° or 275°F.

The sampling program should provide for representative samples being drawn from the material offered by every supplier and tested at all temperatures.

3. Discussion of the Plotted Data

The plotted data, shown at the end of this report, are discussed in the order mentioned under Section 2 above. This is done to help the reader find the data applicable to particular asphalt sources and grades.

(a) In all plots, the data should cluster near the center of the space between the heavy vertical lines which indicate the specification limits for each grade of asphalt at 140°F. For example, looking at the plots of viscosity at 140°F versus ASTM penetration at 77° good distributions between the limits at 140°F are noted on 20 of the 29 sheets. Less than satisfactory distribution between the required limits at 140°F are shown by the following:

AC-5 samples from suppliers 7, 8, 10 and 12
AC-10 samples from suppliers 1, 7 and 19
AC-20 samples from suppliers 6 and 13

Efforts should be made by these suppliers to make the necessary modest adjustments in viscosity to eliminate "riding" either the upper or lower limit.

(b) An examination of the viscosity at 140°F versus ASTM penetration at 77°F plots shows there is no valid relationship between viscosity and penetration for asphalts. This fact has been recognized for three decades and the data shown from these statistical studies offer additional confirmation of a long established fact. Much effort has been expended in an effort to establish a sound relationship

between viscosity and penetration. The best correlation has been obtained on essentially viscous asphalts but it does not hold for shear susceptible (non-Newtonian) materials. Practically all commercial asphalt paving cements show some shear susceptibility.

ASTM penetration is not a satisfactory test for hardness because:

(i) tests are made at constantly changing shearing stresses, or rates of shear,

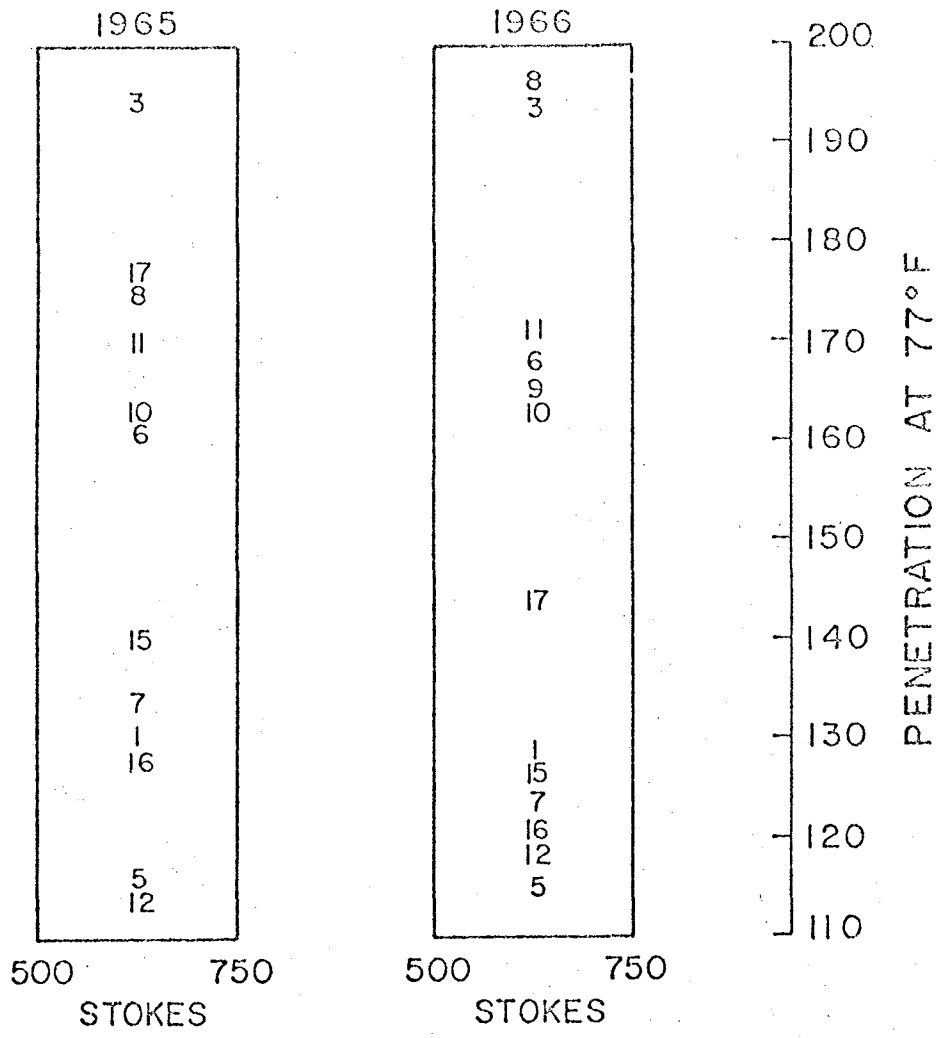
(ii) a constantly changing volume is sheared as the test proceeds,

(iii) interfacial tension at the water-asphalt interface affects the length of the needle that is in contact with the asphalt, and finally,

(iiii) the varying degrees of adhesion between the asphalt and the steel needle influence the penetration of the needle. Poor adhesion between the bitumen and steel needle permits the needle to penetrate to a greater distance than when good adhesion exists at the interface.

Viscosity measurements are not affected by the above mentioned conditions and variables and, thus, give truer measures of hardness.

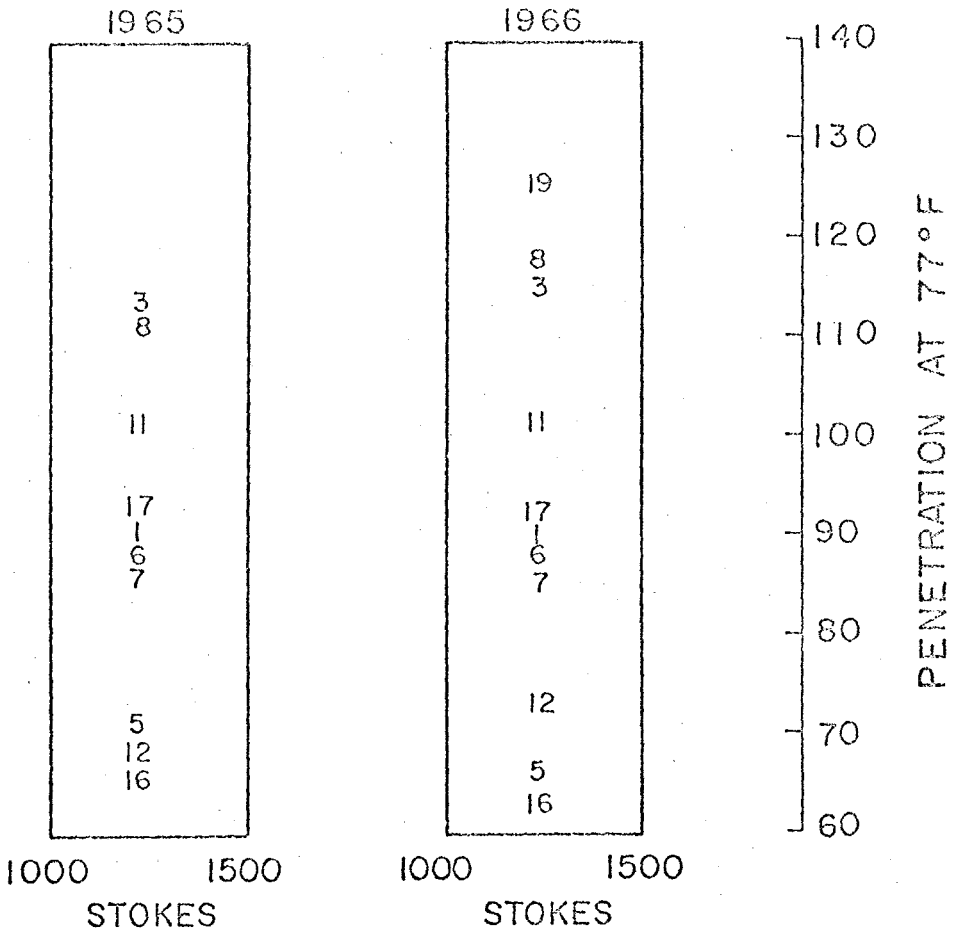
The plots, for AC-5, AC-10 and AC-20 asphalts, (Figures IV, V and VI) which follow show the relationship between viscosity at 140°F and the <u>average</u> penetration for samples submitted to THD during both 1965 and 1966. In these plots the numbers shown within the boxes are the code numbers for the various suppliers. These charts show that, for a particular viscosity range (abscissa), the average penetration values (ordinates) show a wide range, although certain sources of supply tend to group together.



AC-5 ASPHALTS

VISCOSITY AT 140°F - PENETRATION AT 77°F

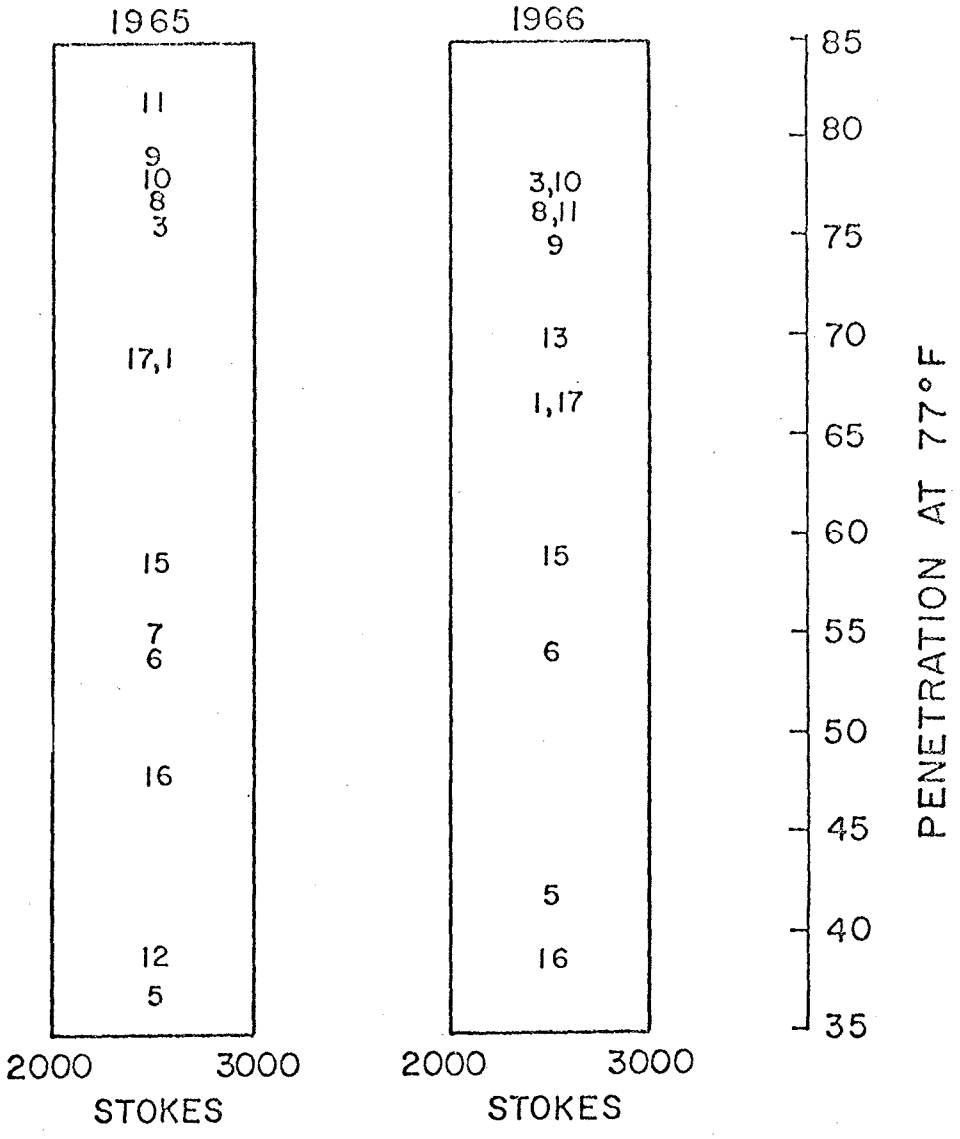
FIGURE IV



AC-10 ASPHALTS

VISCOSITY AT 140° F – PENETRATION AT 77° F

FIGURE V



AC-20 ASPHALTS

VISCOSITY AT 140° F – PENETRATION AT 77° F

FIGURE VI

Of course, if a particular supplier for a given grade processes his asphalt to a higher viscosity (moves the value to the right hand side of the box) he simultaneously lowers the penetration to some degree.

(c) A review of the machine plots shown in the back of this report for viscosity at 140°F versus viscosity at 77°F for the original and laboratory hardened asphalt indicate that the following material indicated by X are less than desirable:

AC-5 at 77°F

Supplier No.	Original	Hardened
1	X	X
7	X	X
12	X	OK
15	X	OK

Four suppliers did not meet the prescribed viscosity at 77°F on original AC-5 grade material but only two failed the test on the laboratory hardened asphalt.

AC-10 at 77°F

Supplier No.	Original	Hardened
1	X	X
5	X	OK
7	X	X
12	X	OK
15	X	OK
16	X	OK

Among the suppliers of AC-10 grade asphalt, 6 did not meet the viscosity at 77°F on the original but again only two failed the test at 77°F on the laboratory hardened asphalt.

AC-20 at 77°F

Supplier No.	Original	Hardened
1	X	OK
5	X	OK
7	X	OK
12	X	OK
16	X	OK
17	Marginal	OK

Five suppliers of AC-20 grade did not meet the viscosity and one was marginal at 77°F on the original asphalt. All six producers passed the test at 77°F on the laboratory hardened asphalts.

It should be easy for most of the seven suppliers listed in the above tabulation to meet the viscosity at 77°F on their original asphalt without encountering trouble with the laboratory hardening test at 77°F.

(d) Plots of viscosity at 140°F vs viscosity at 275°F indicate that the following samples do not fall within the prescribed limits.

AC-5

Supplier No.		
7	low	
12		marginal
16	low	
20	low	

AC-10

Supplier No.	
1	marginal
7	marginal
12	marginal

AC-20

Supplier No.	
1	marginal
6	marginal
7	marginal
8	marginal
11	marginal
12	marginal
16	marginal

The viscosities of AC-5 grade asphalts at 275°F from three suppliers were low and one was marginal. AC-10 grade samples from three suppliers were marginal. Seven suppliers of AC-20 grade asphalt showed marginal data. Most of the marginal materials were low but one was close to the top of the recommended specification limits.

VII. Machine Plots of 1965 and 1966 Data from the Material and Tests Laboratory, Texas Highway Department, Austin, Texas

Data are arranged in the following order:

Asphalt Suppliers by increasing Code Number. A colored title page is inserted ahead of the plots pertaining to each supplier.

Under each Code Number data are arranged as follows:

Grade AC-5

Viscosity at 140°F vs ASTM Penetration at 77°F
Viscosity at 140°F vs Viscosities at 77°F
Viscosity at 140°F vs Viscosity at 275°F

Grade AC-10

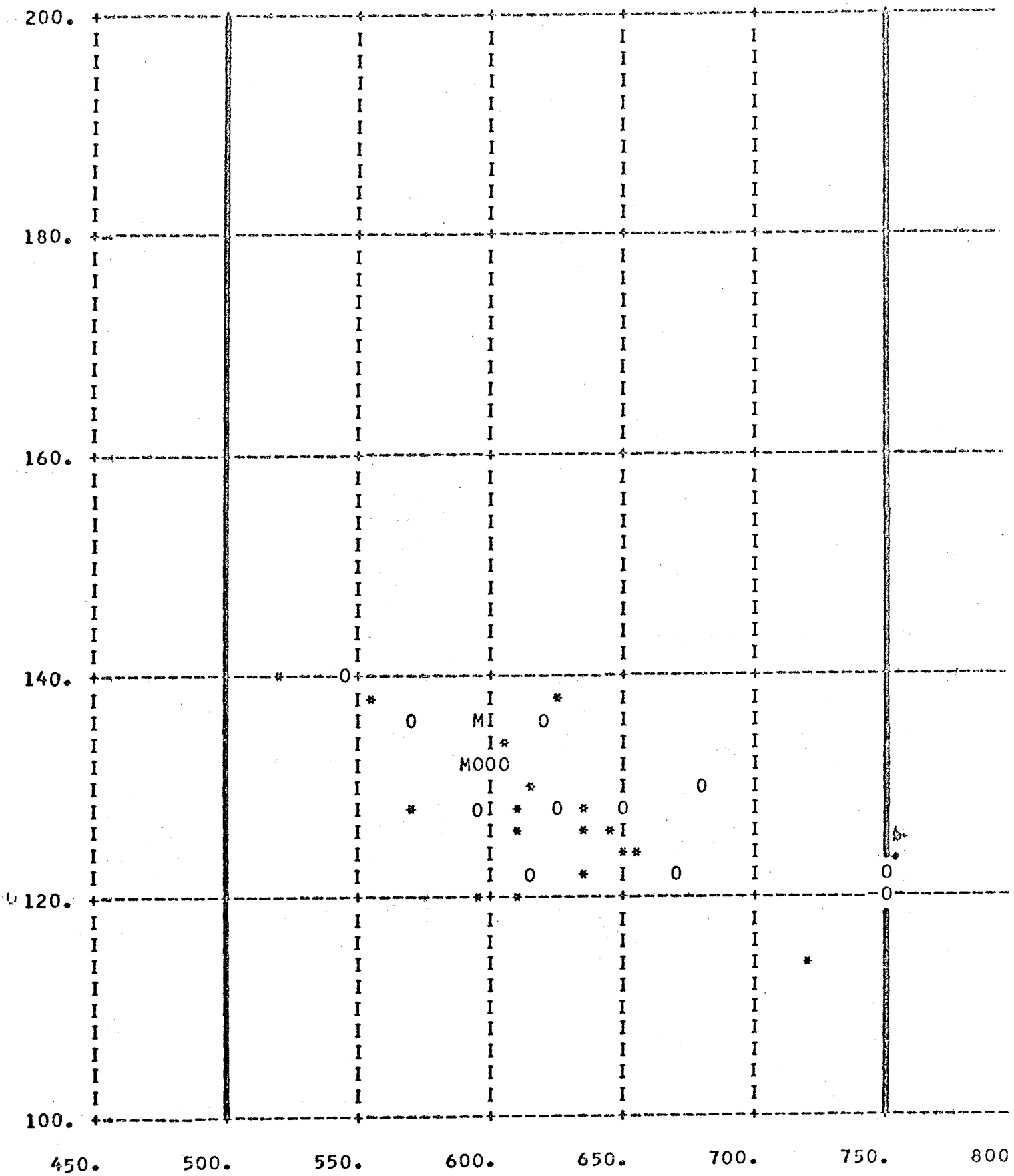
Viscosity at 140°F vs ASTM Penetration at 77°F
Viscosity at 140°F vs Viscosities at 77°F
Viscosity at 140°F vs Viscosity at 275°F

Grade AC-20

Viscosity at 140°F vs ASTM Penetration at 77°F
Viscosity at 140°F vs Viscosities at 77°F
Viscosity at 140°F vs Viscosity at 275°F

Asphalt Supplier
No. 1

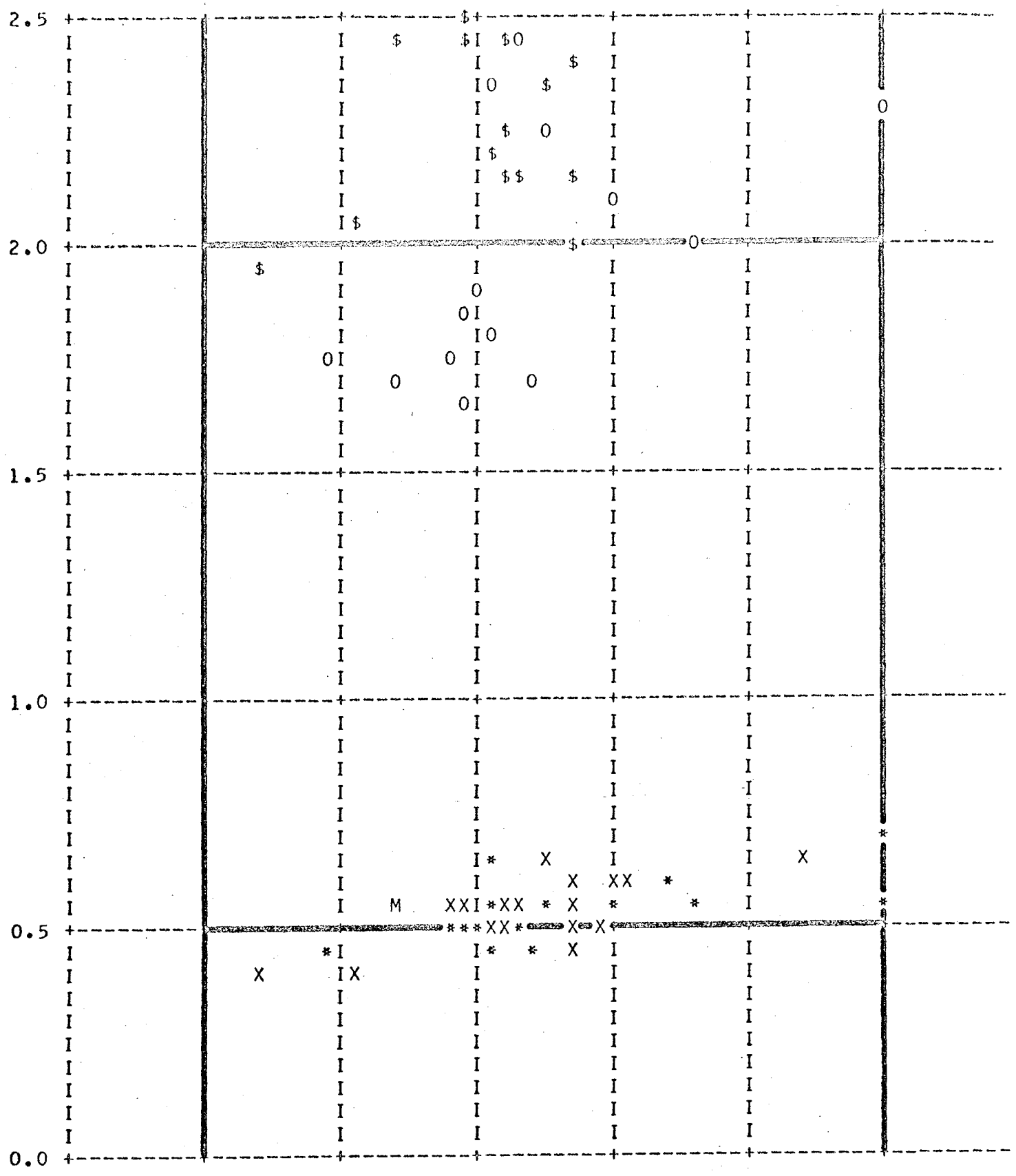
PRODUCER 1 GRADE AC 5



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 1 GRADE AC 5



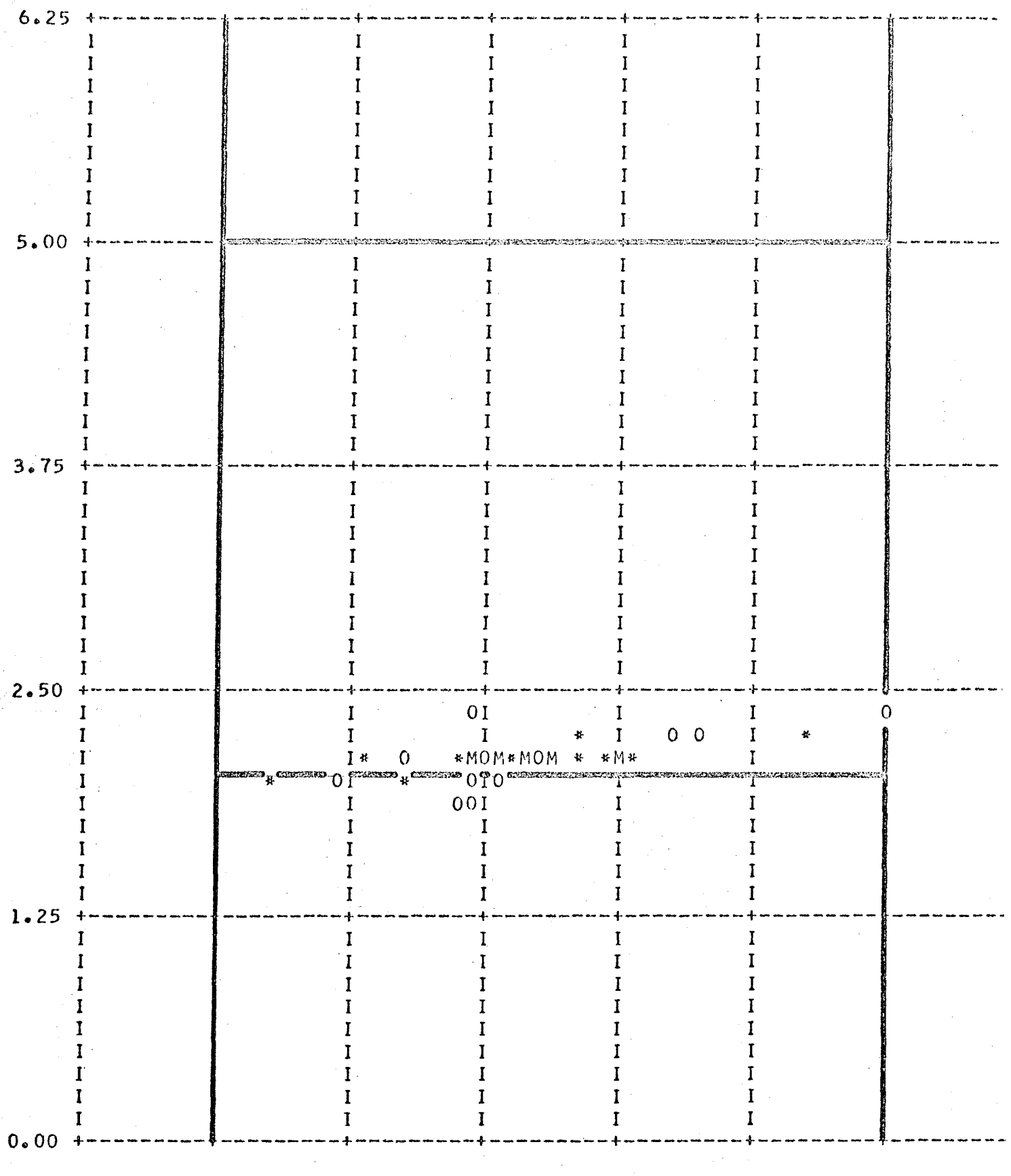
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

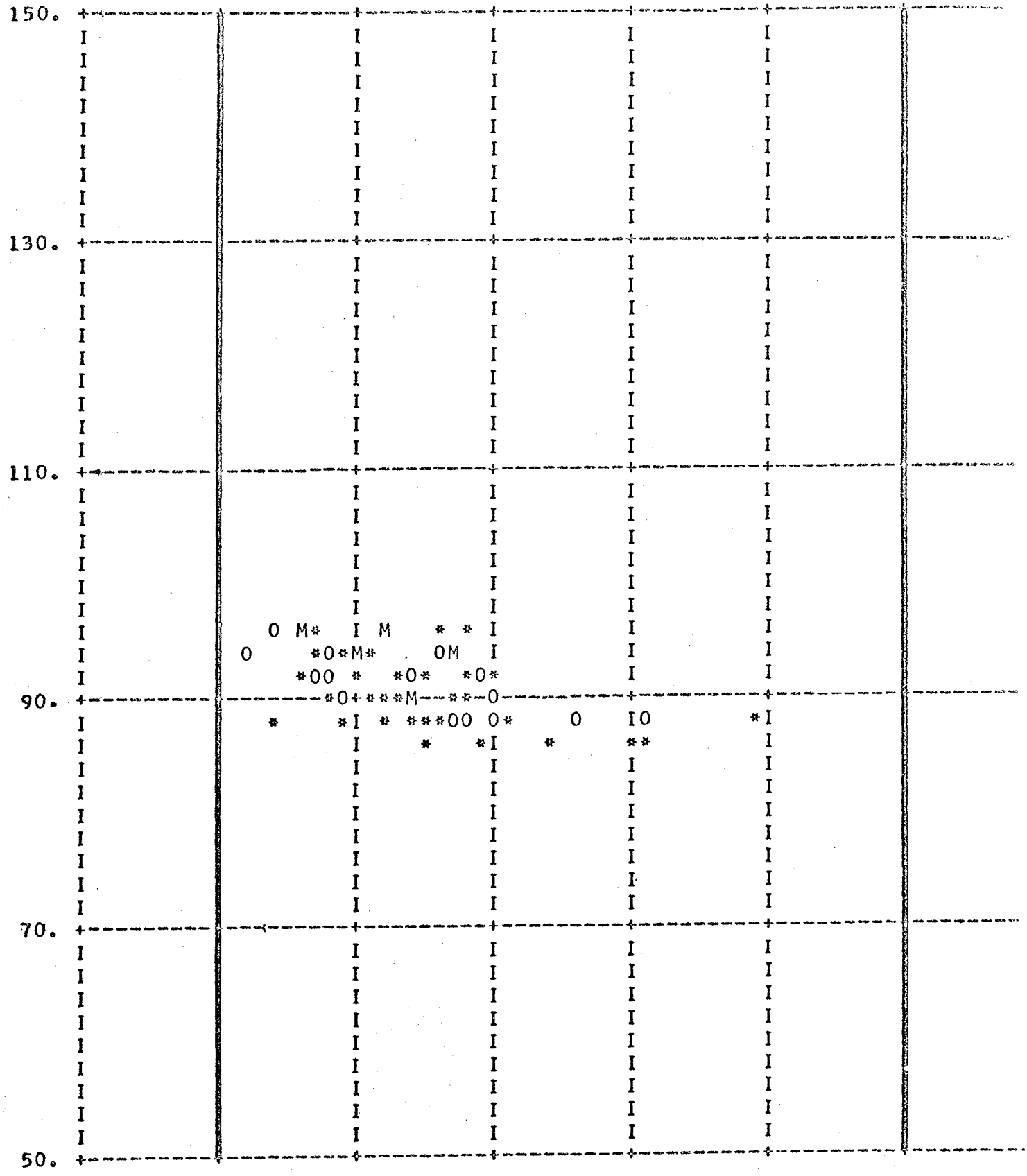
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 1 GRADE AC 5



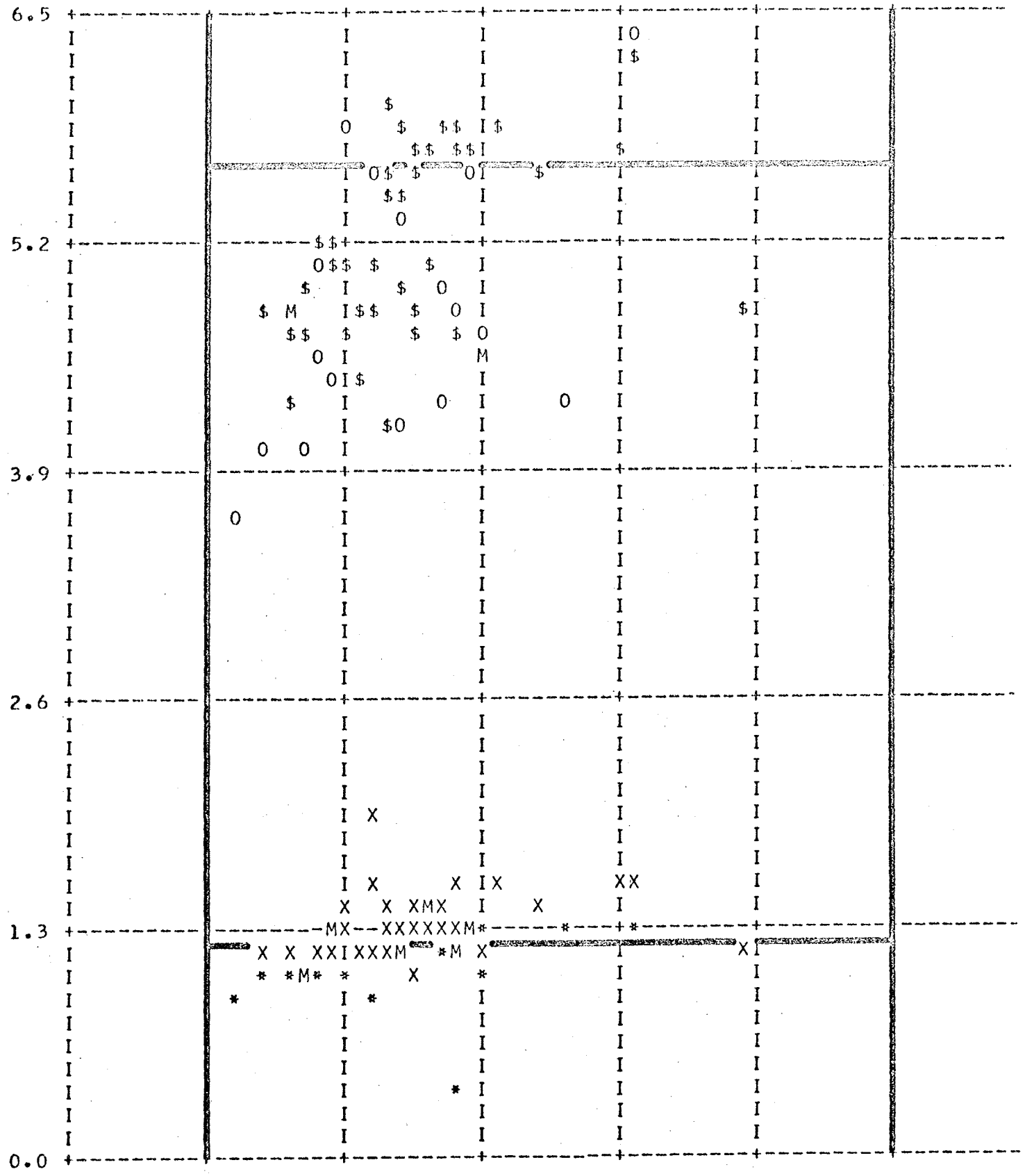
PRODUCER 1 GRADE AC 10



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 1 GRADE AC 10



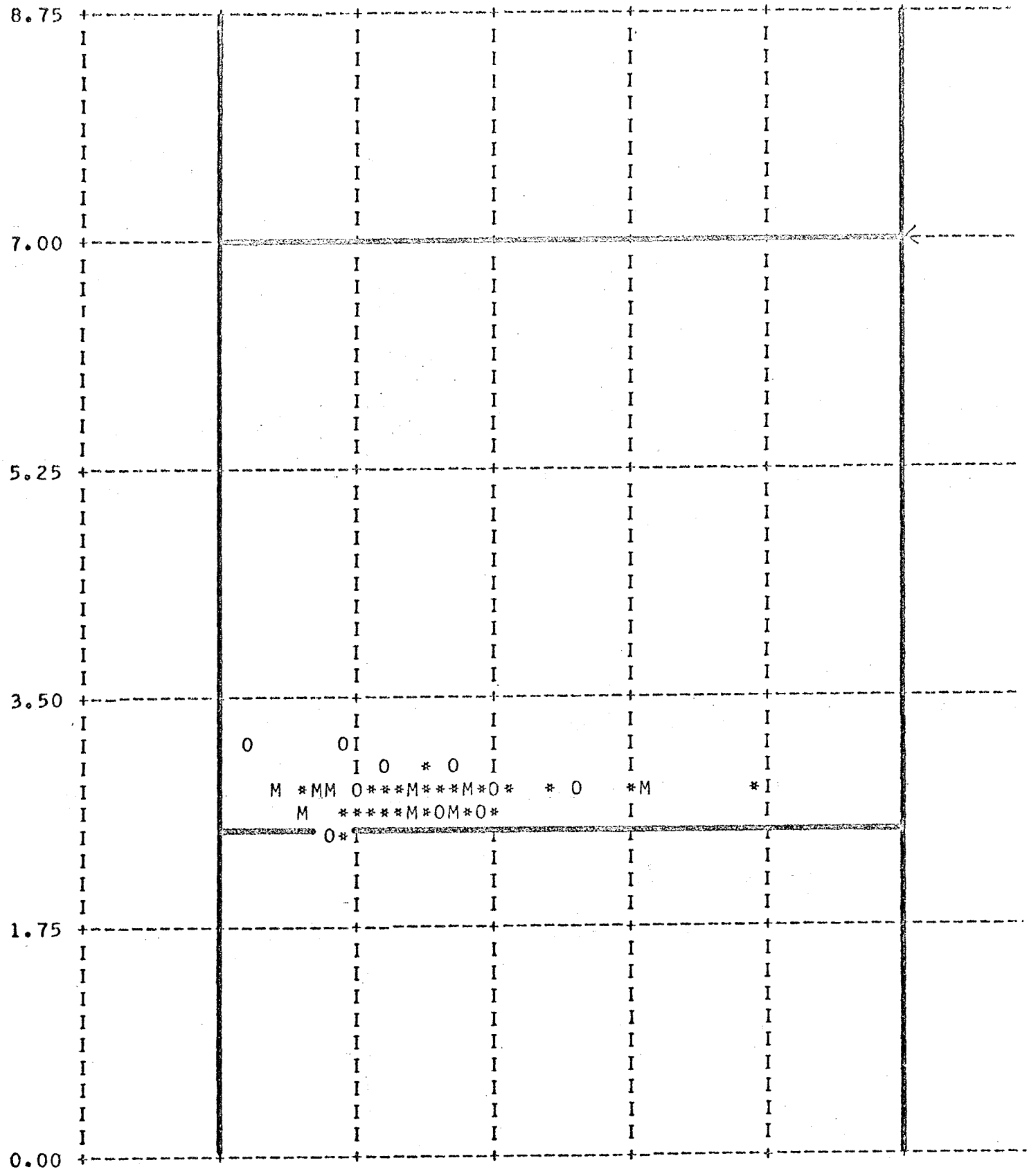
VISCOSITY STOKES 140F

LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

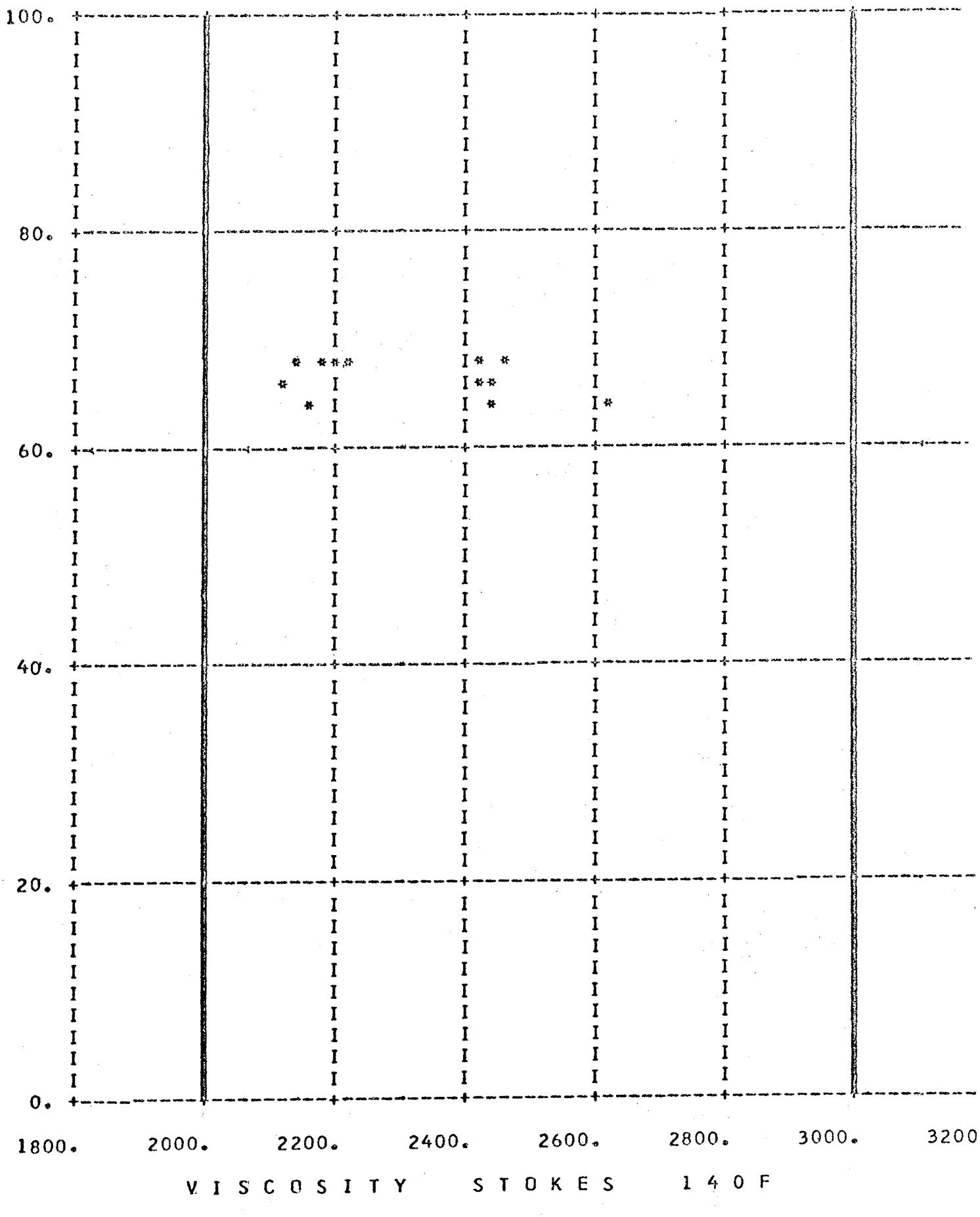
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 1 GRADE AC 10

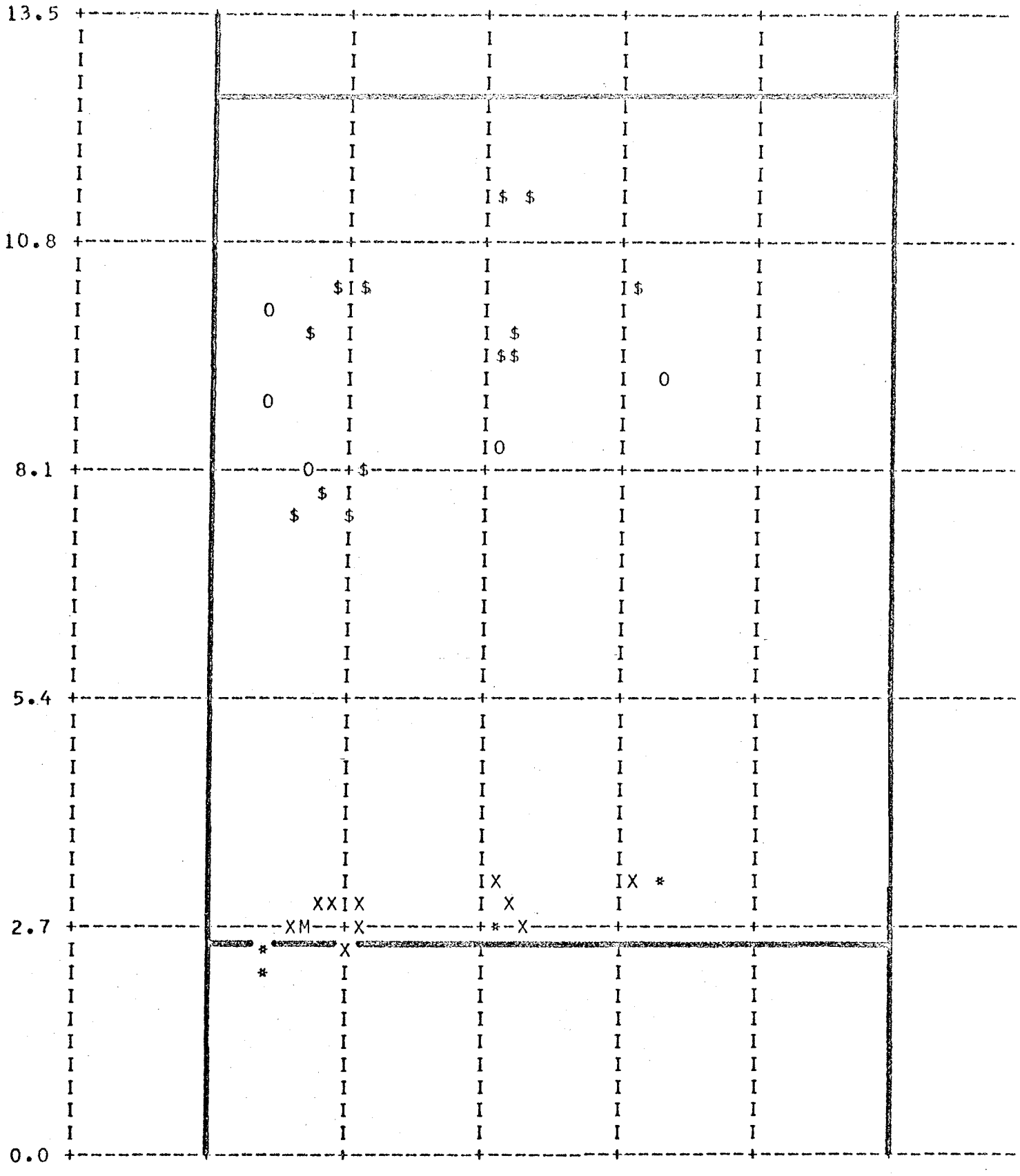


VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966


PRODUCER 1 GRADE AC 20
100.
80.
60.
40.
20.
0.
1800.
2000.
2200.
2400.
2600.
2800.
3000.
3200
V I S C O S I T Y S T O K E S 1 4 0 F
LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 1 GRADE AC 20

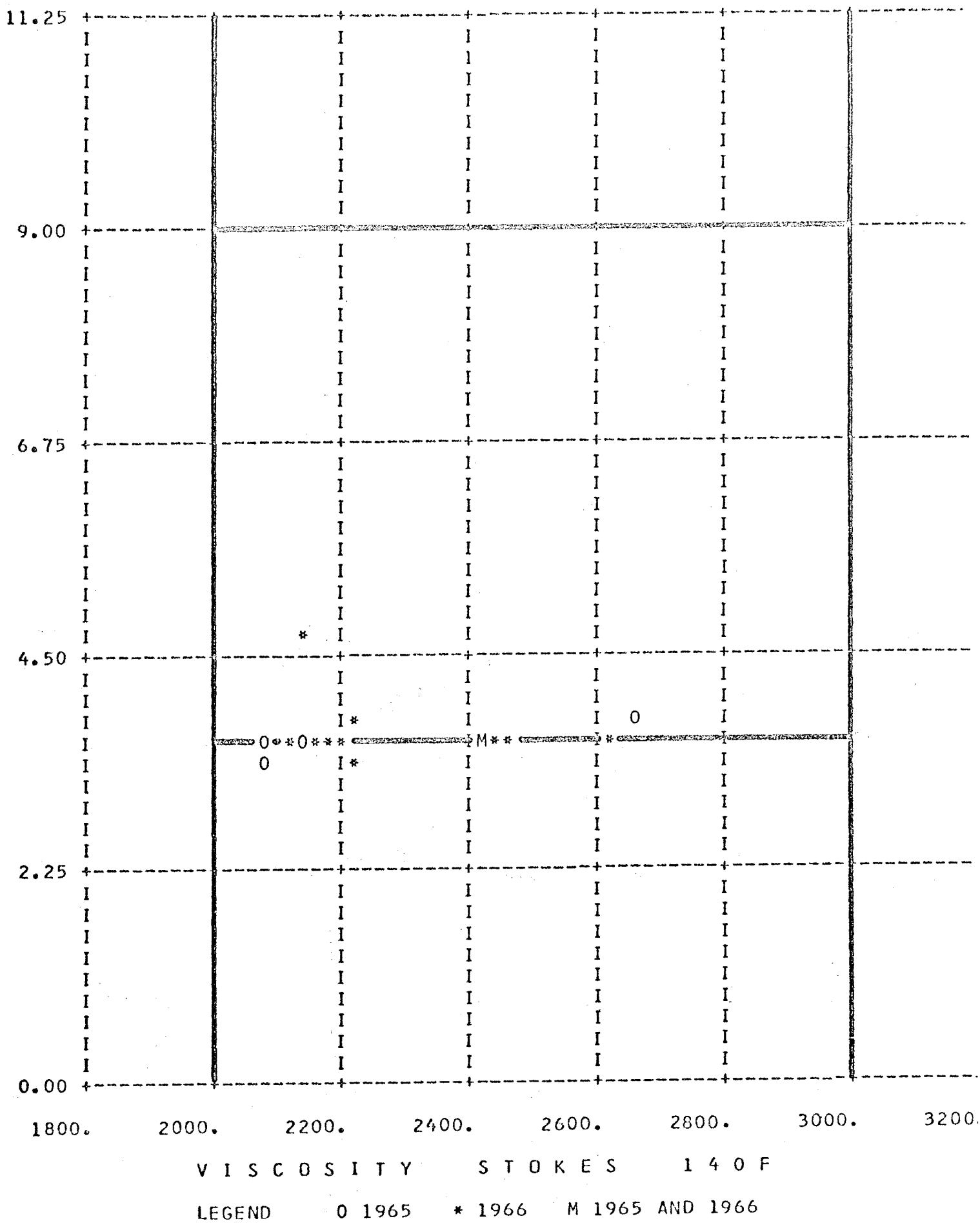


VISCOSITY STOKES 140F

LEGEND
M MULTIPLE

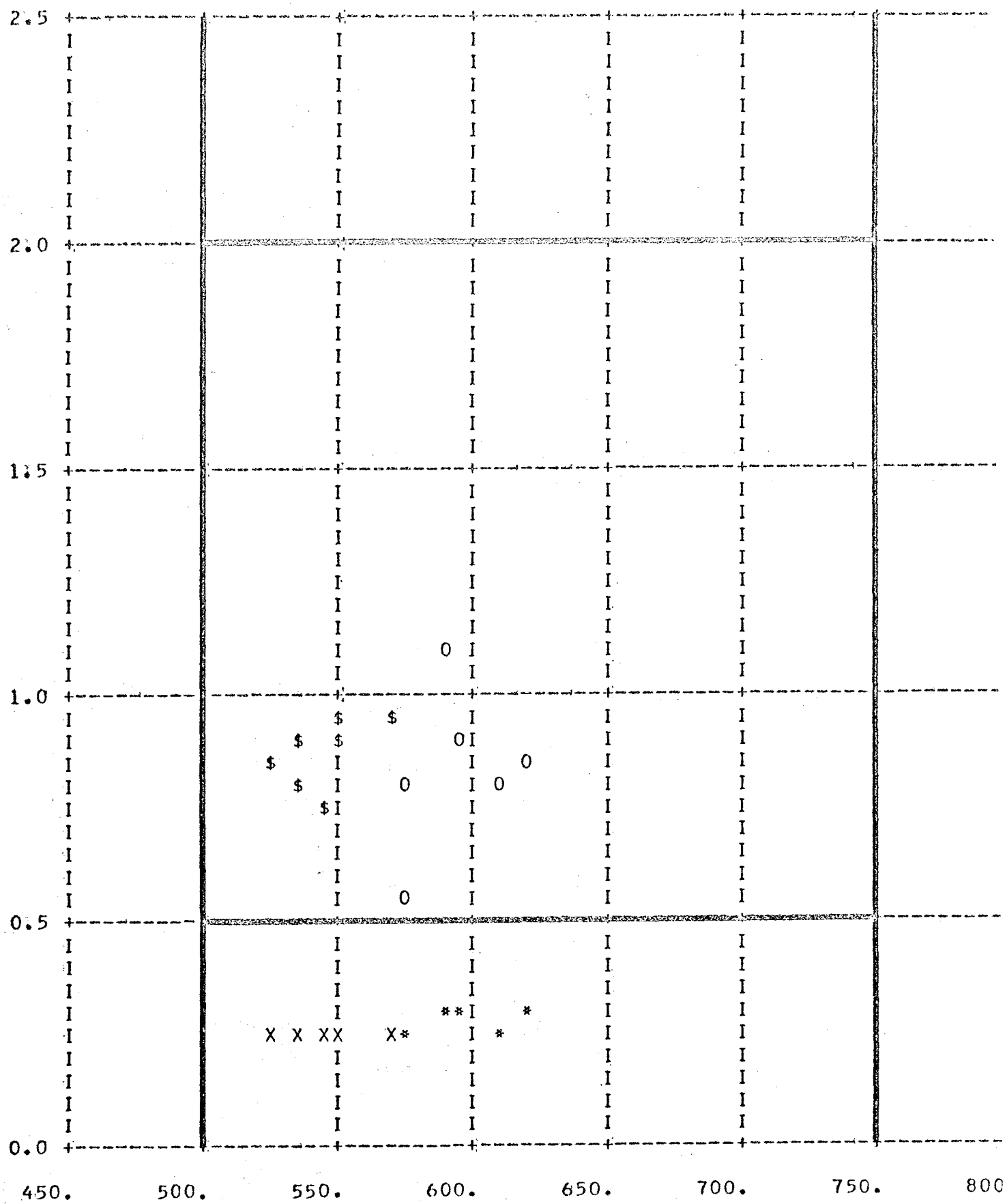
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966


PRODUCER 1 GRADE AC 20
11.25
9.00
6.75
4.50
2.25
0.00
1800.
2000.
2200.
2400.
2600.
2800.
3000.
3200.
V I S C O S I T Y S T O K E S 1 4 0 F
LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 3

PRODUCER 3 GRADE AC 5

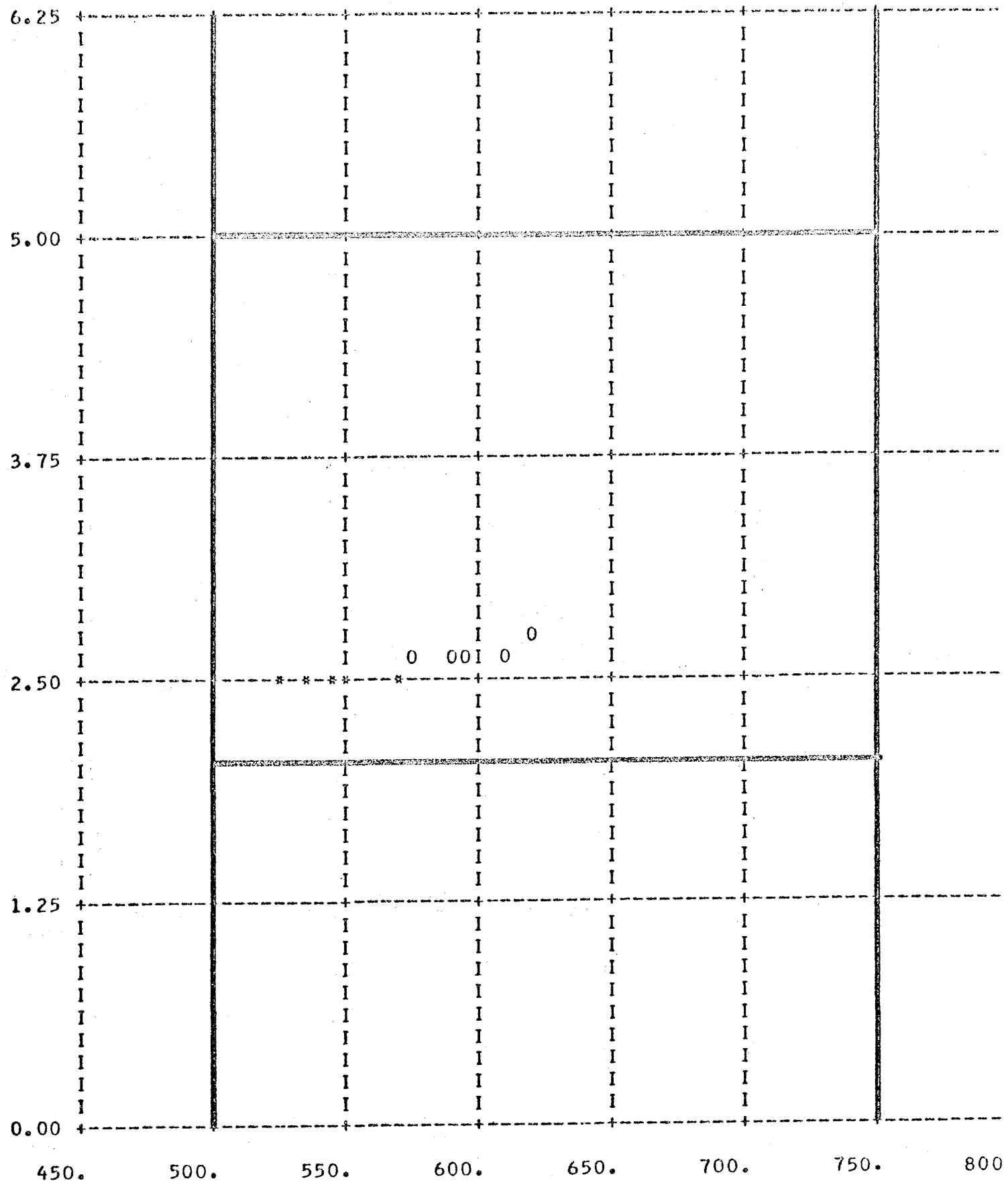


LEGEND
M MULTIPLE

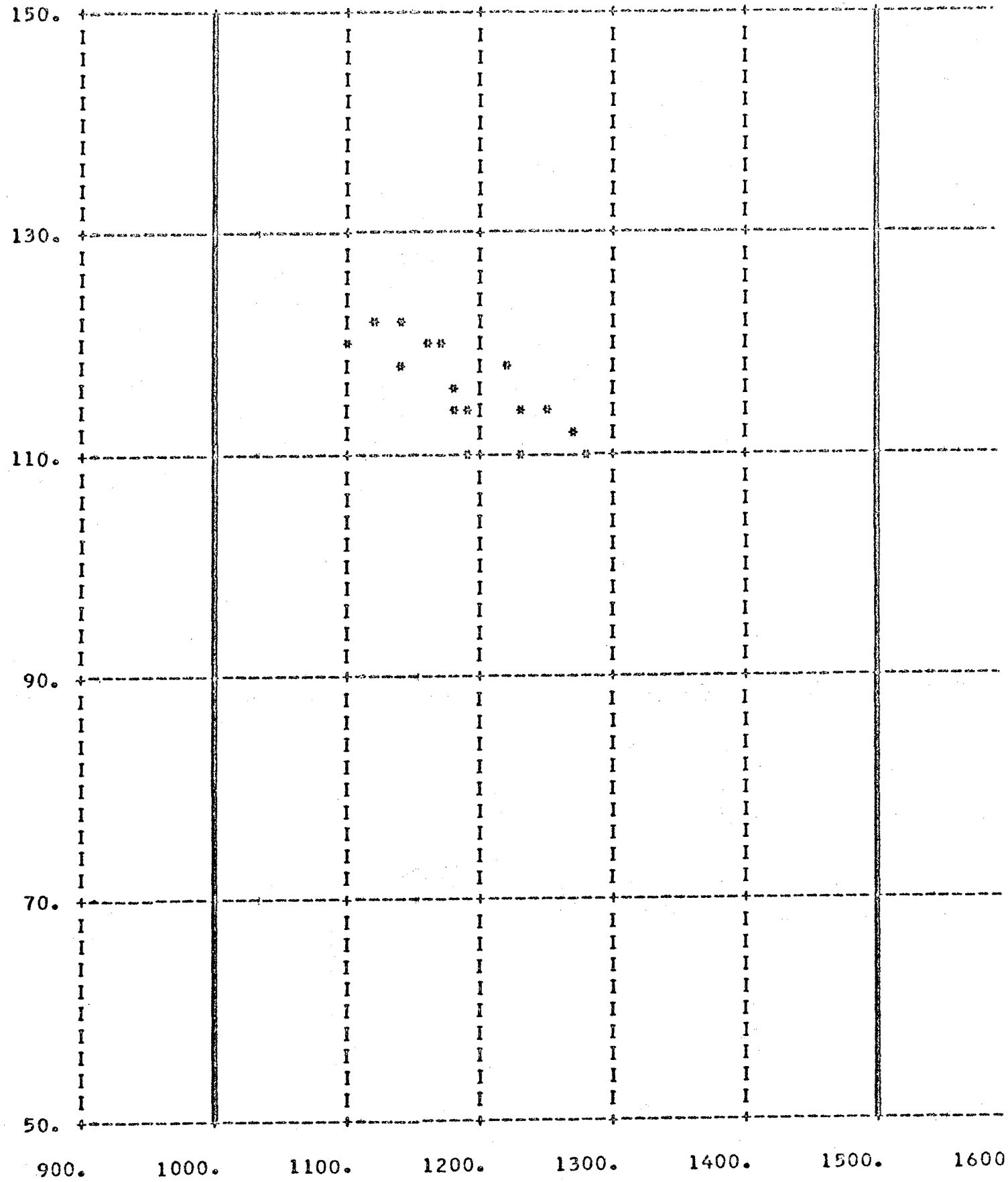
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 3 GRADE AC 5



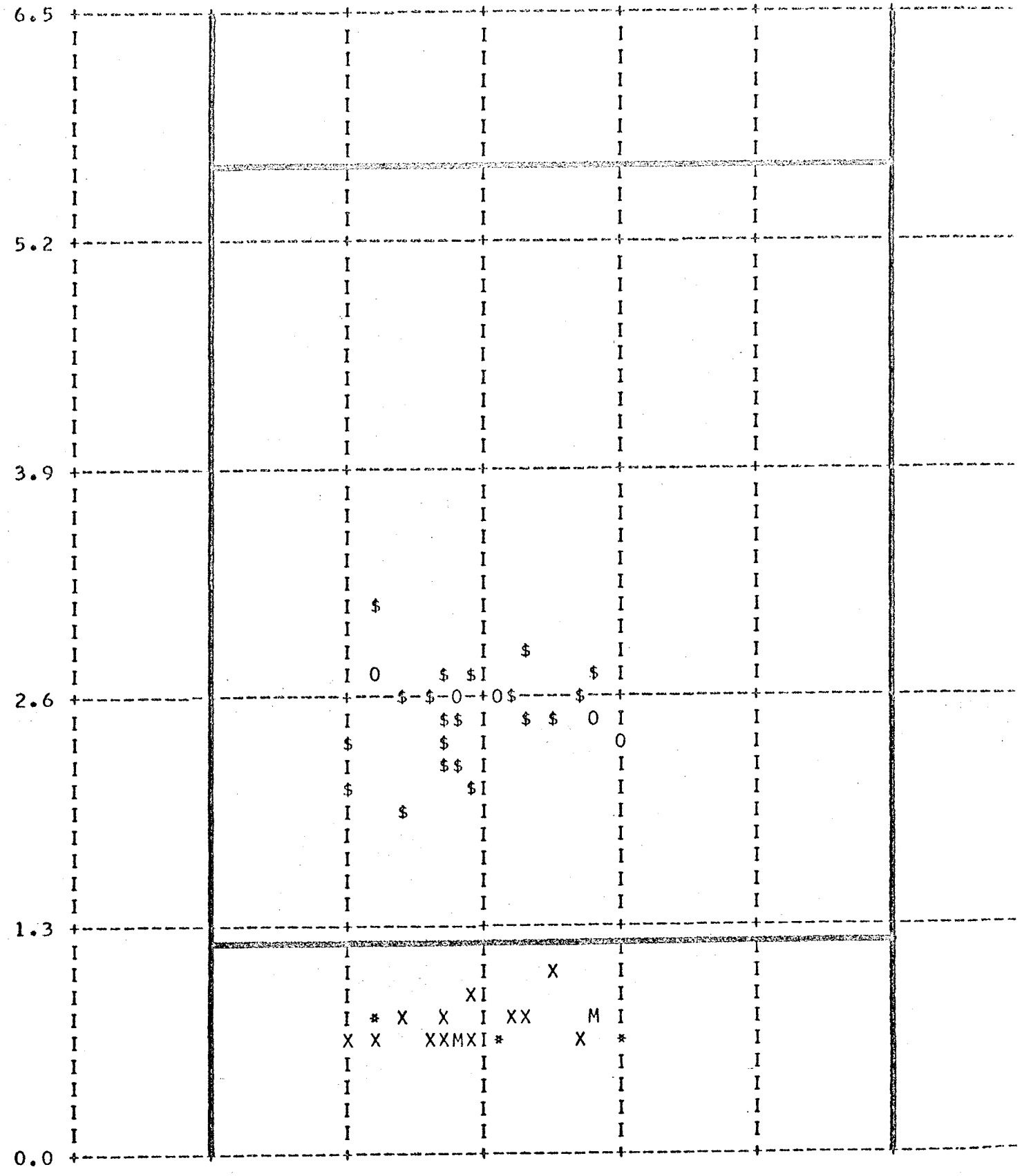
PRODUCER 3 GRADE AC 10



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 3 GRADE AC 10

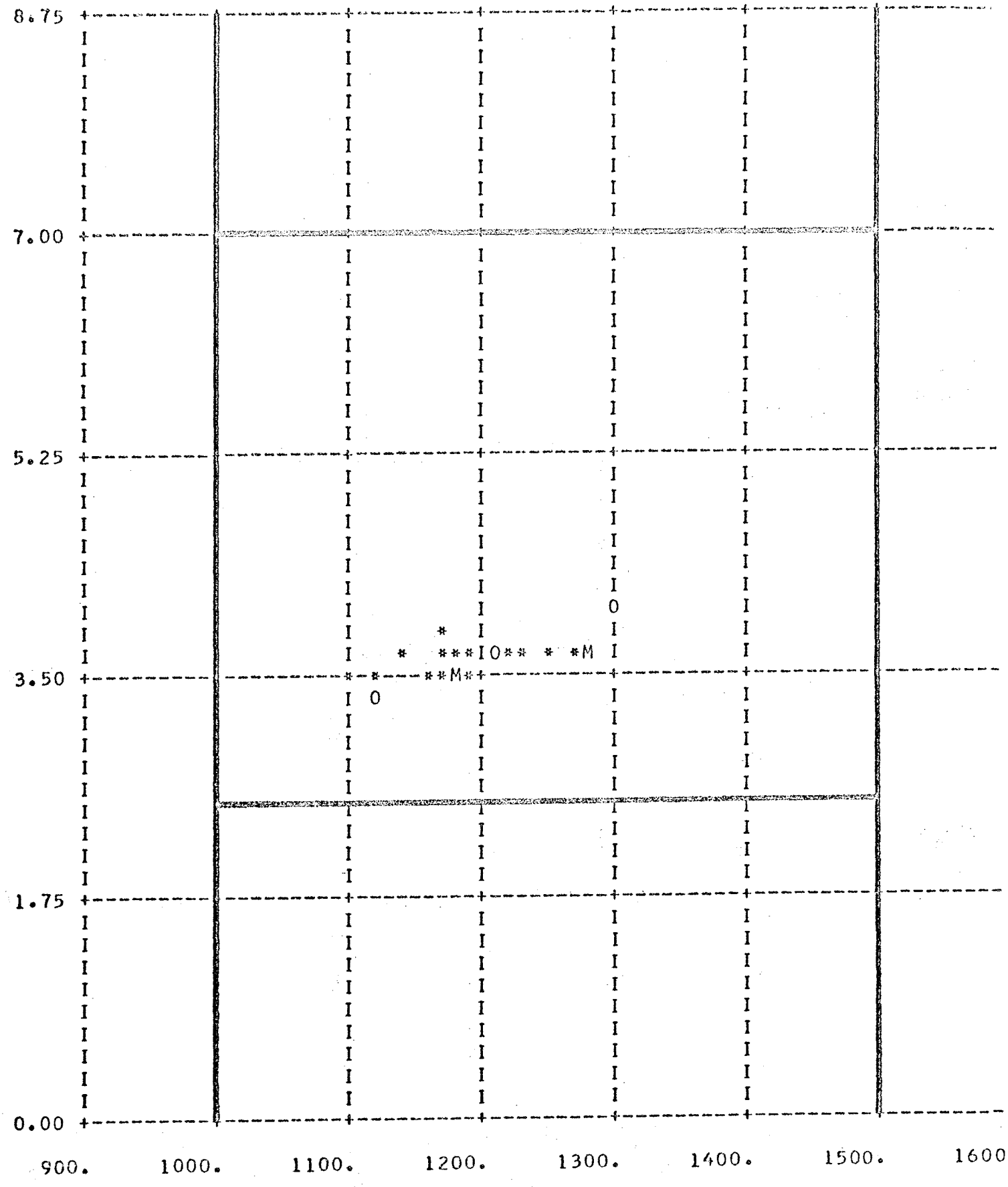


LEGEND
M MULTIPLE

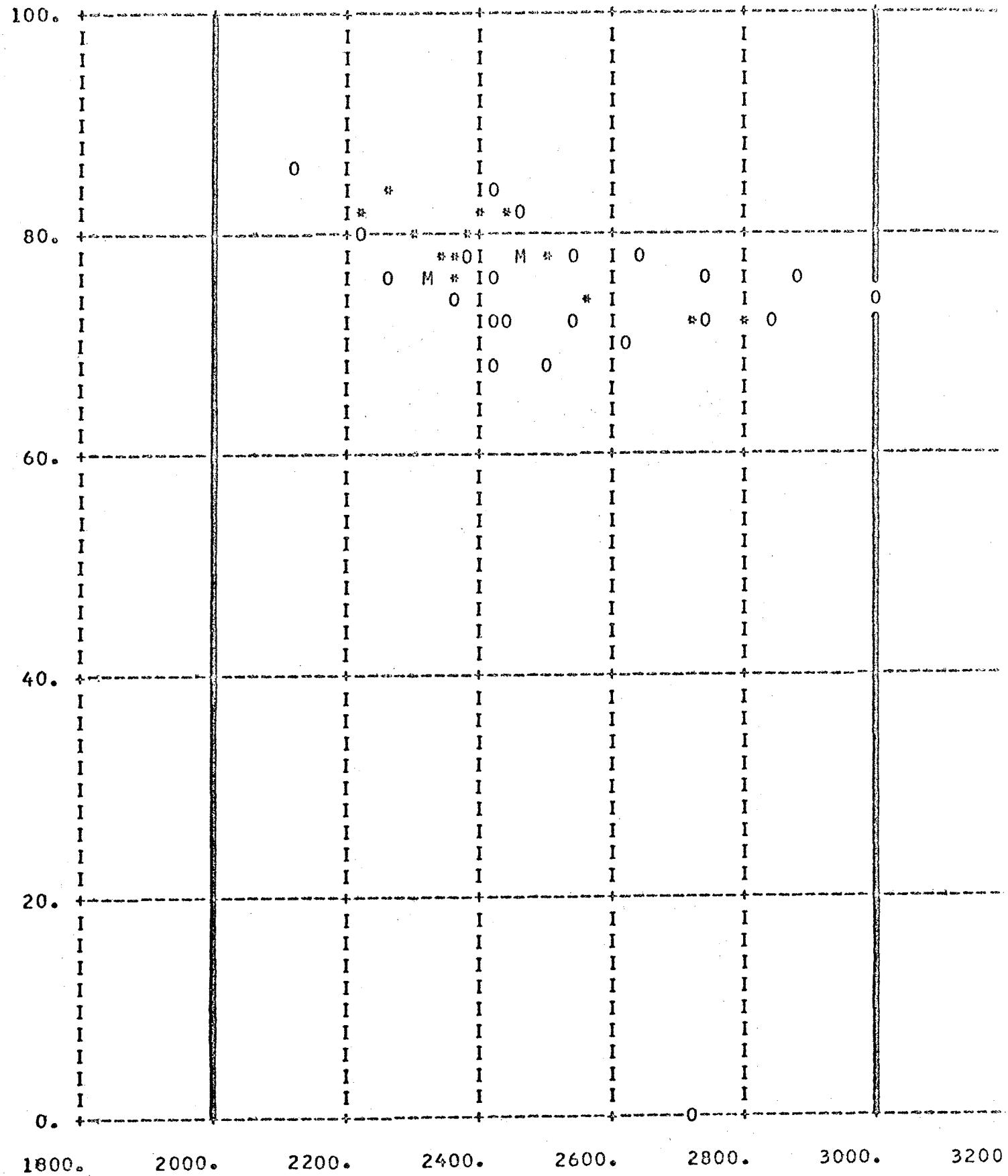
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 3 GRADE AC 10



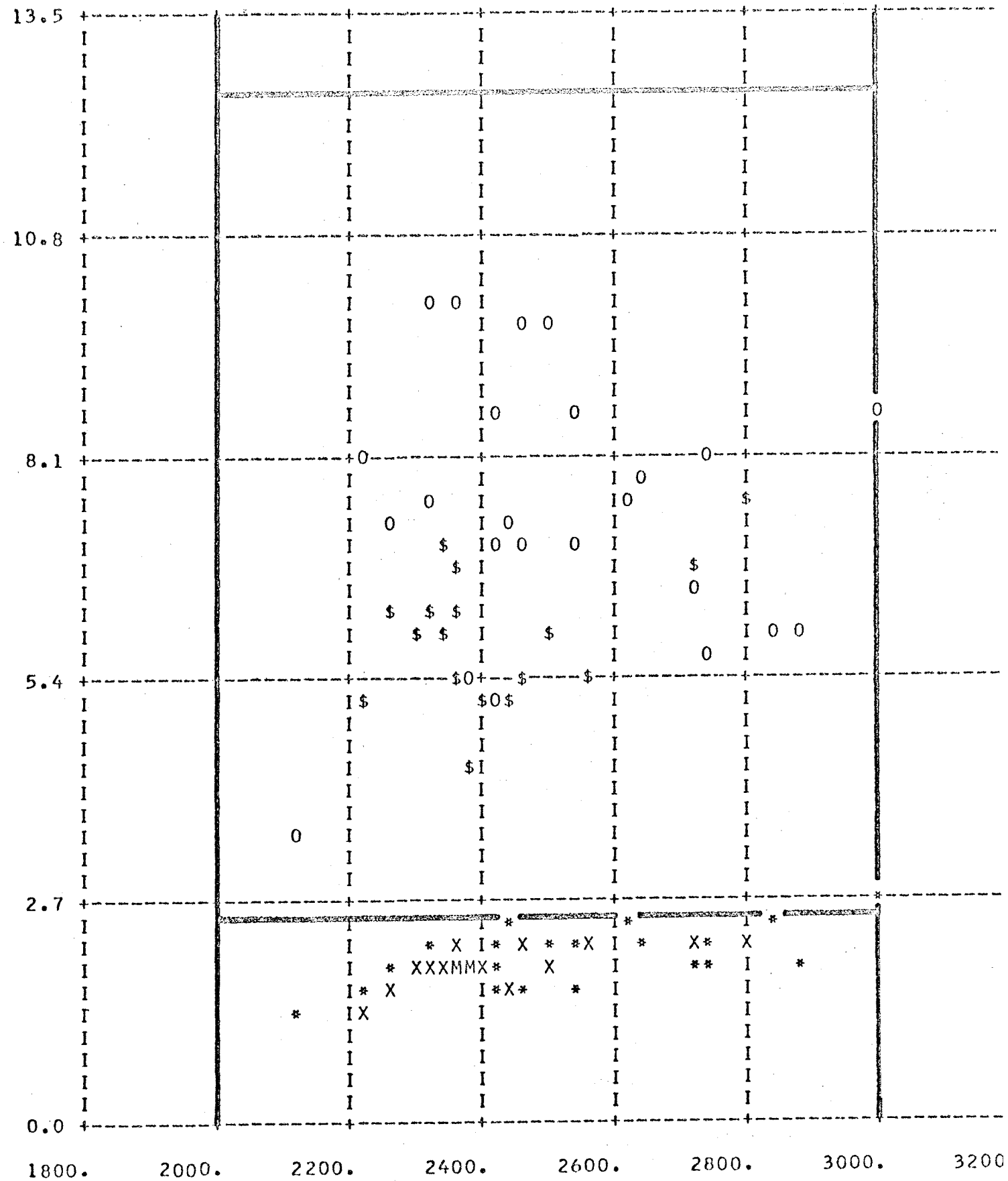
PRODUCER 3 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 3 GRADE AC 20

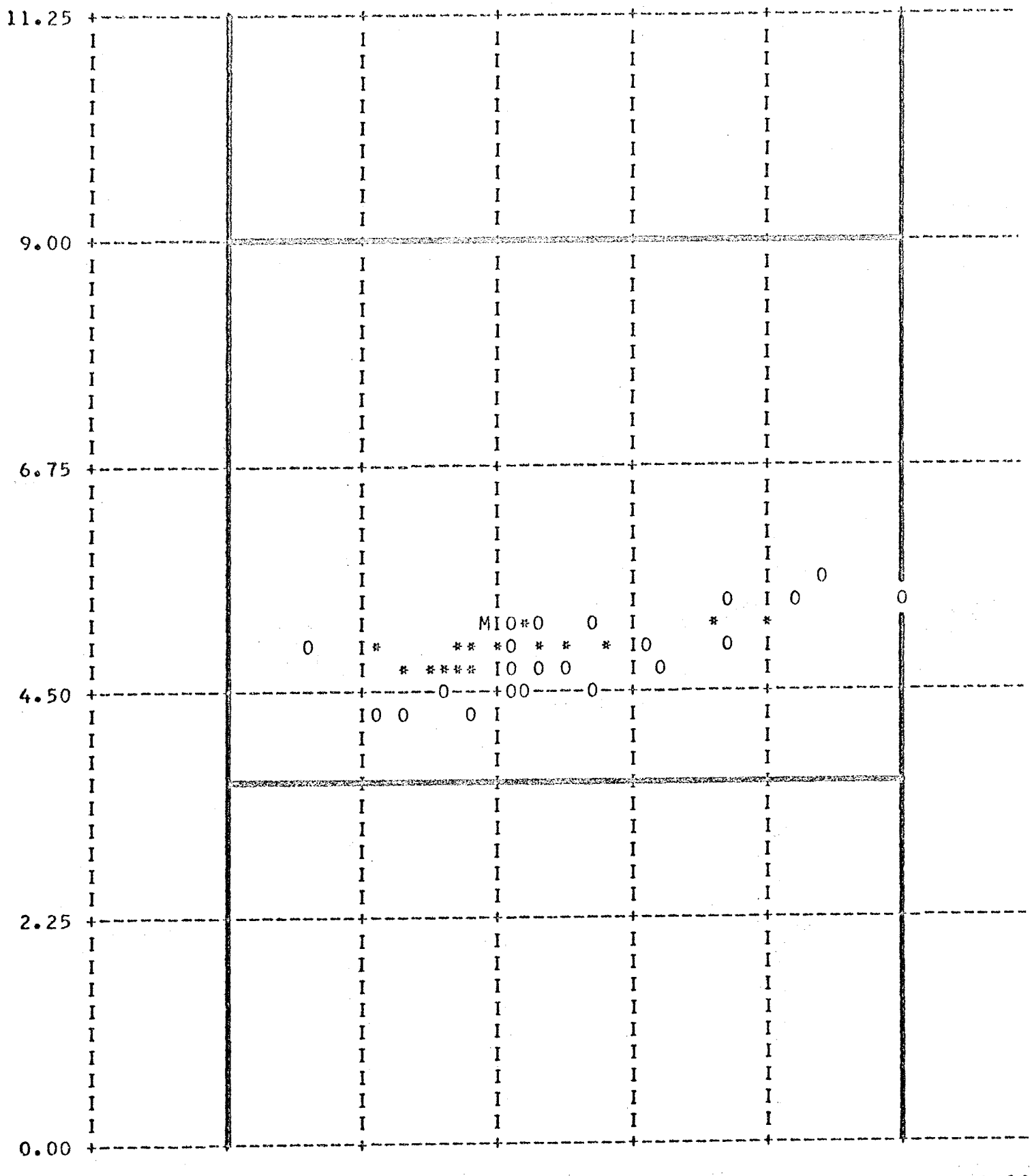


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 3 GRADE AC 20

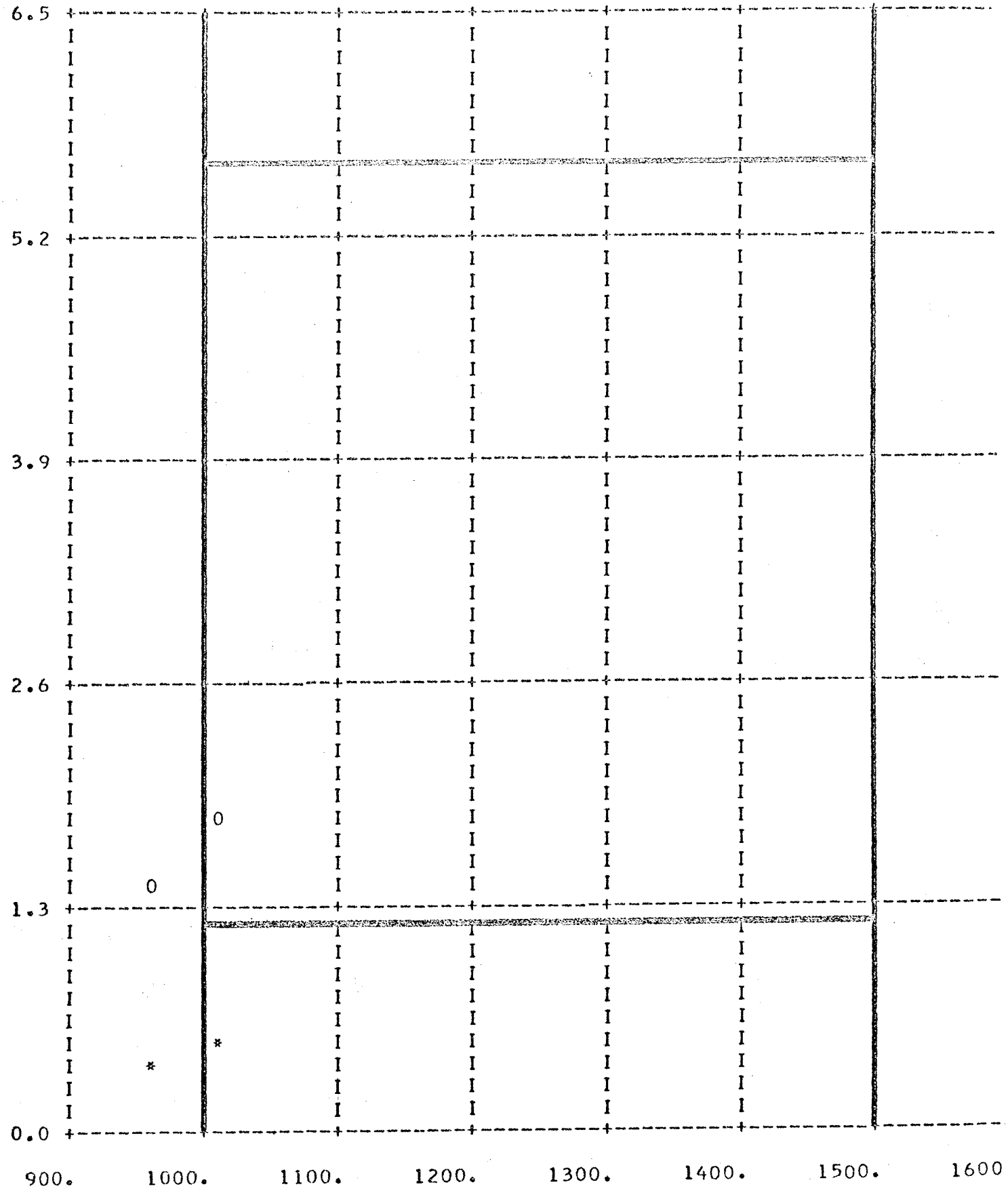


V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 4

PRODUCER 4 GRADE AC 10

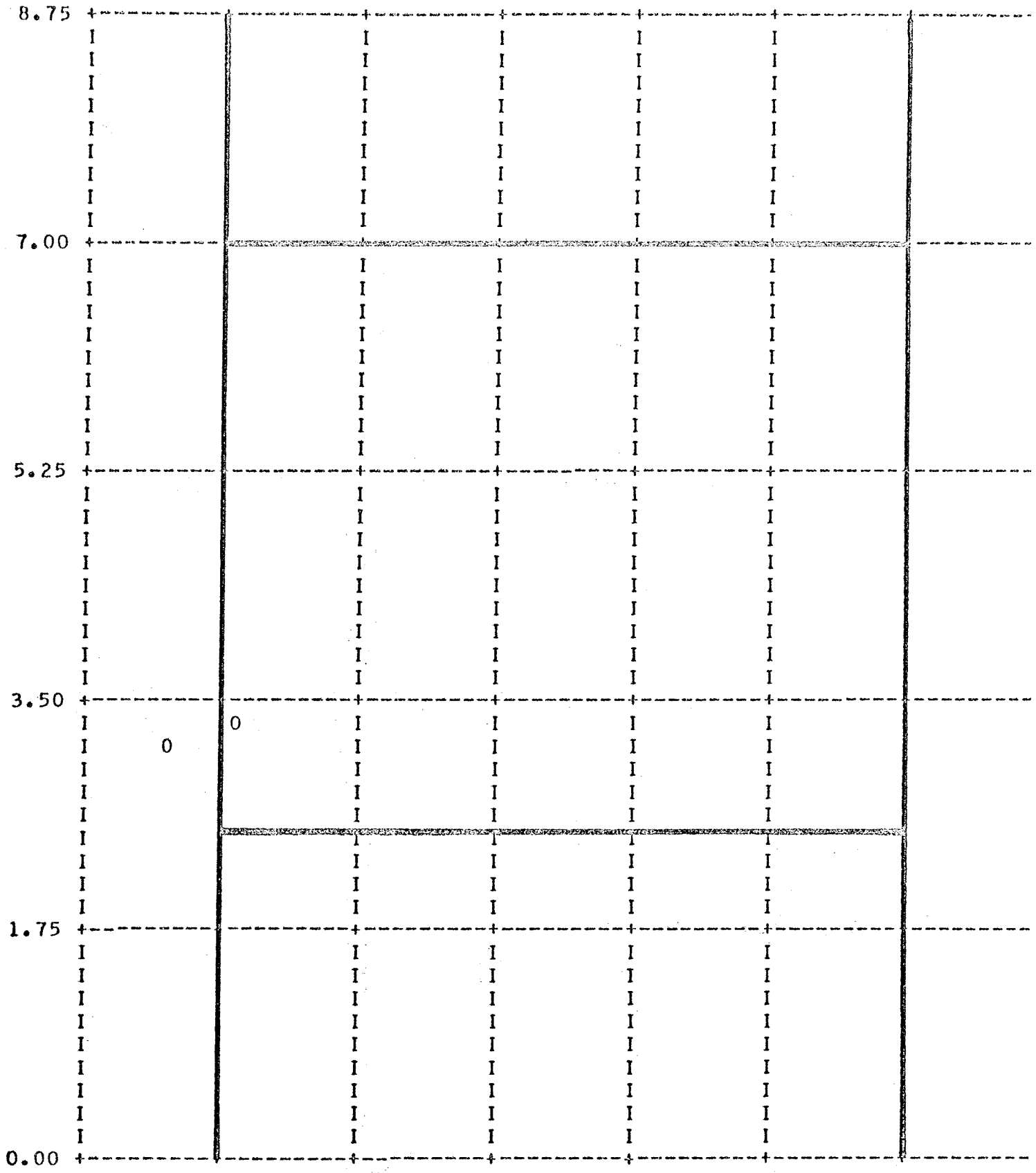


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

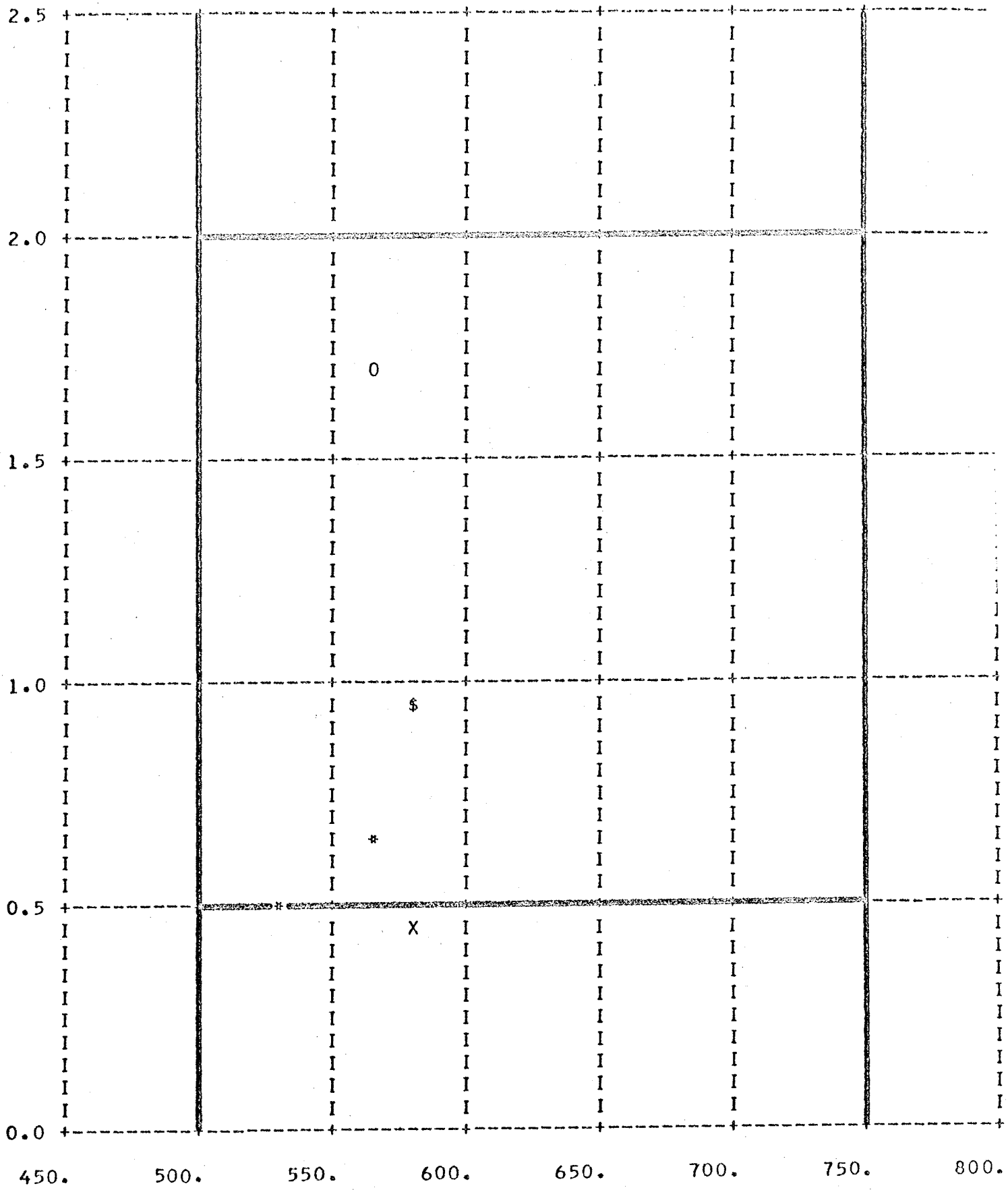
PRODUCER 4 GRADE AC 10



LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 5

PRODUCER 5 GRADE AC 5

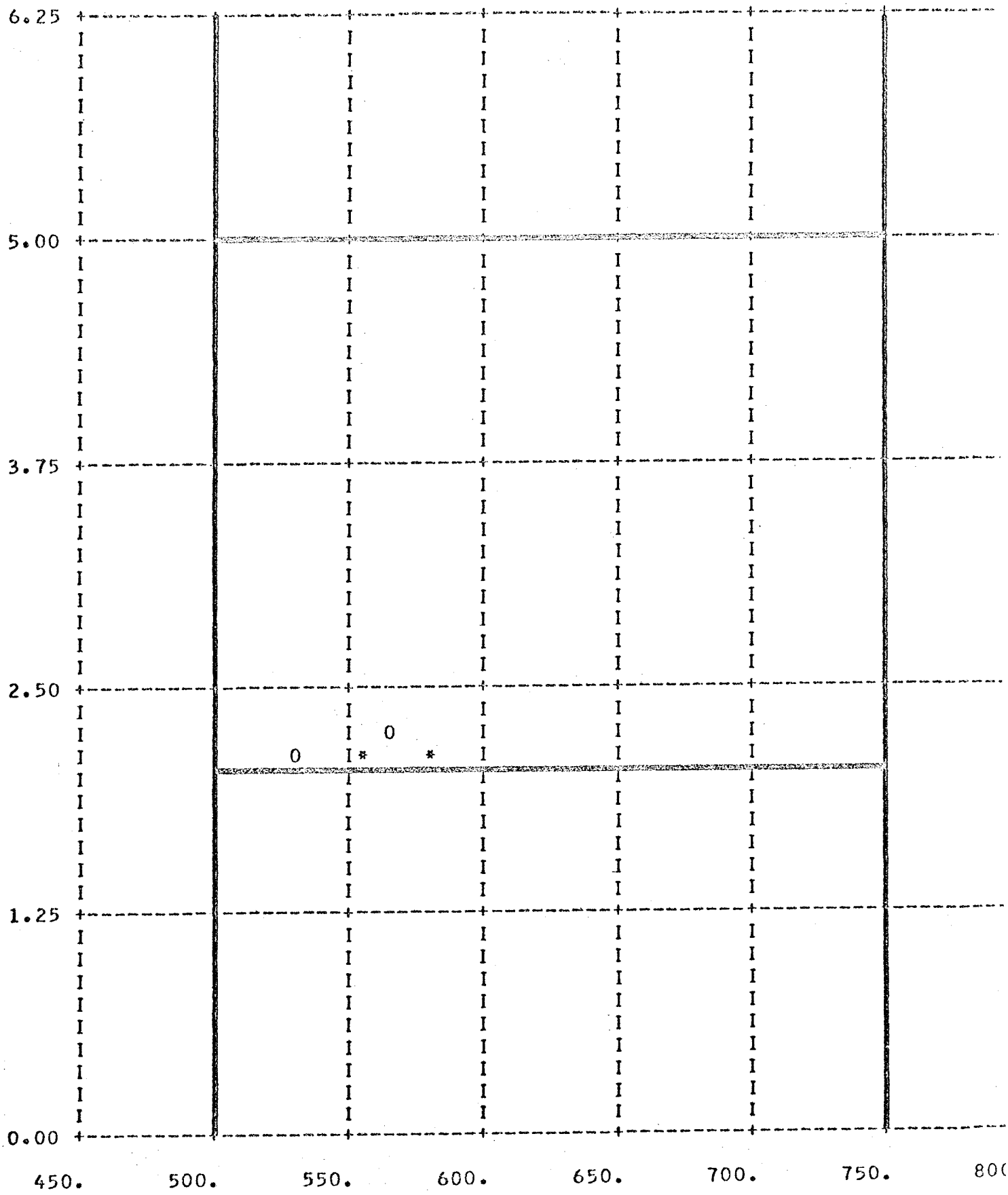


LEGEND
M MULTIPLE

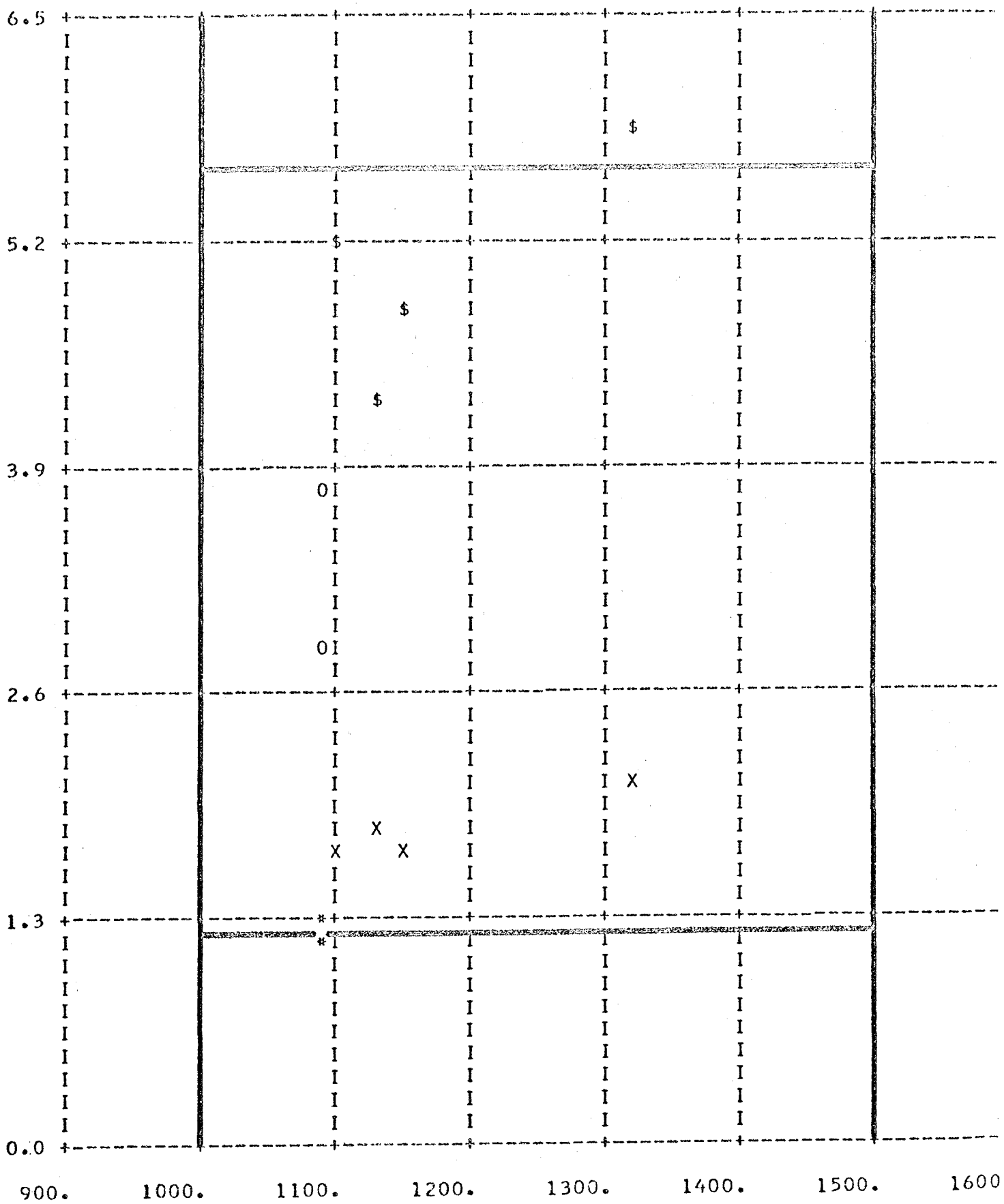
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 5 GRADE AC 5



PRODUCER 5 GRADE AC 10

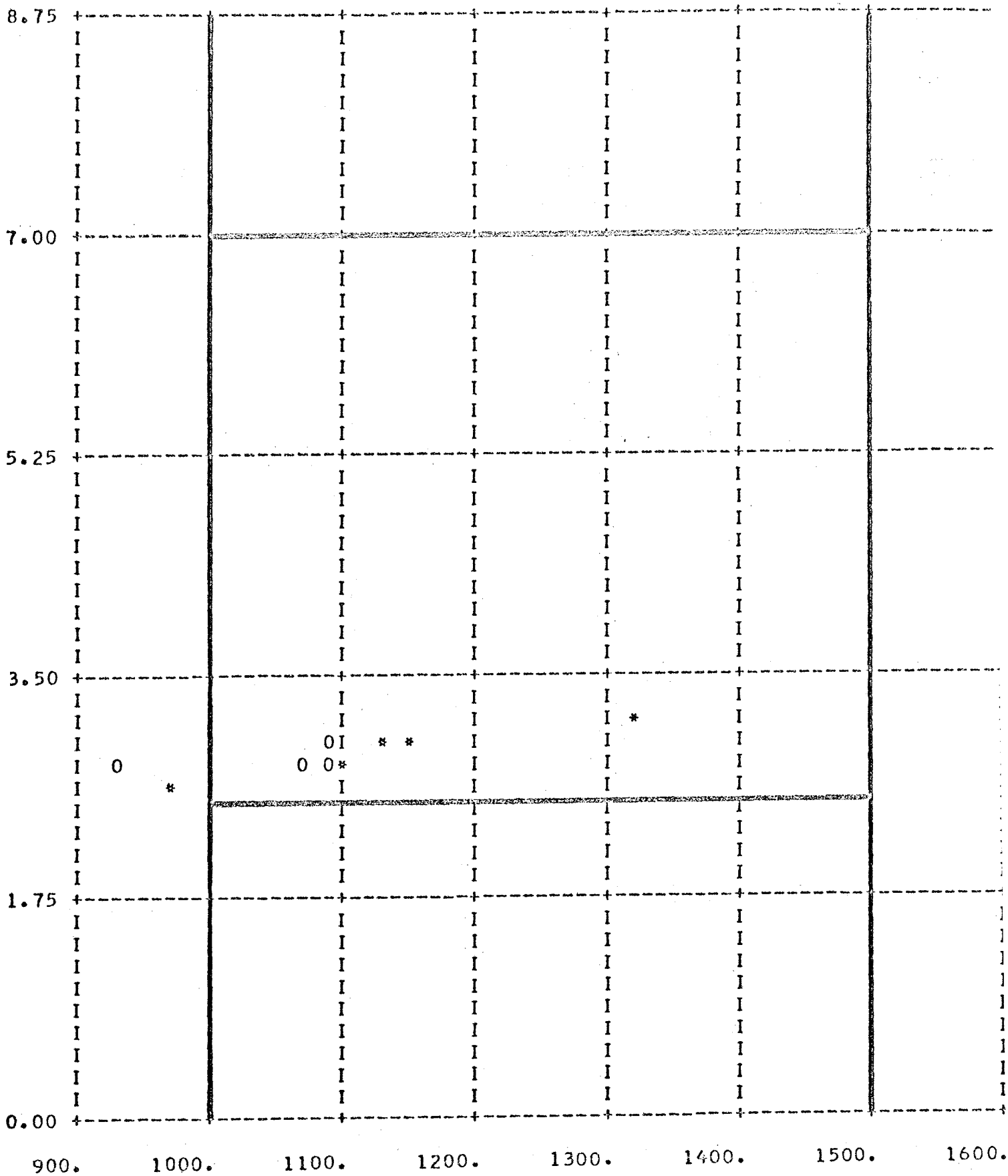


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

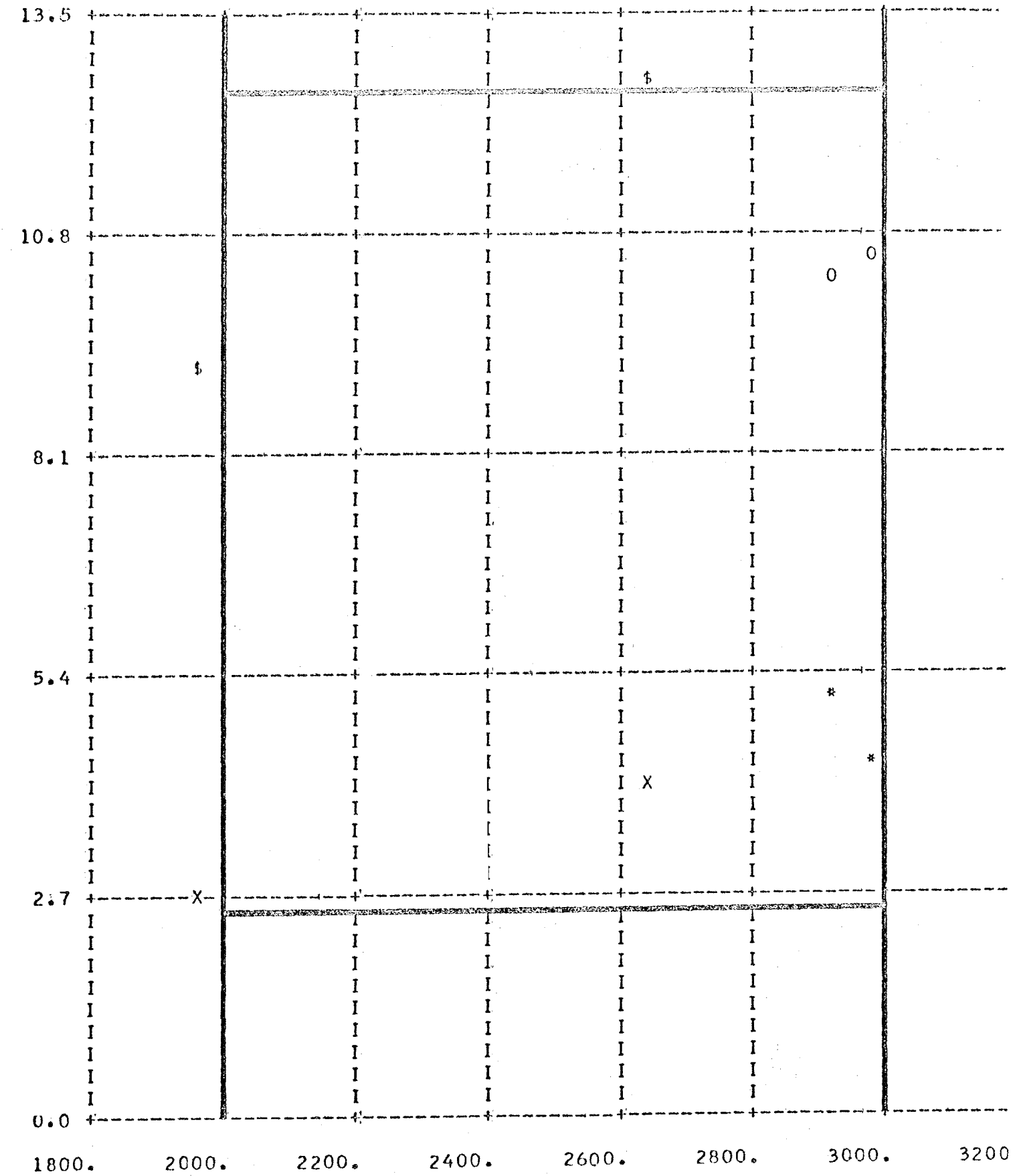
PRODUCER 5 GRADE AC 10



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 5 GRADE AC 20

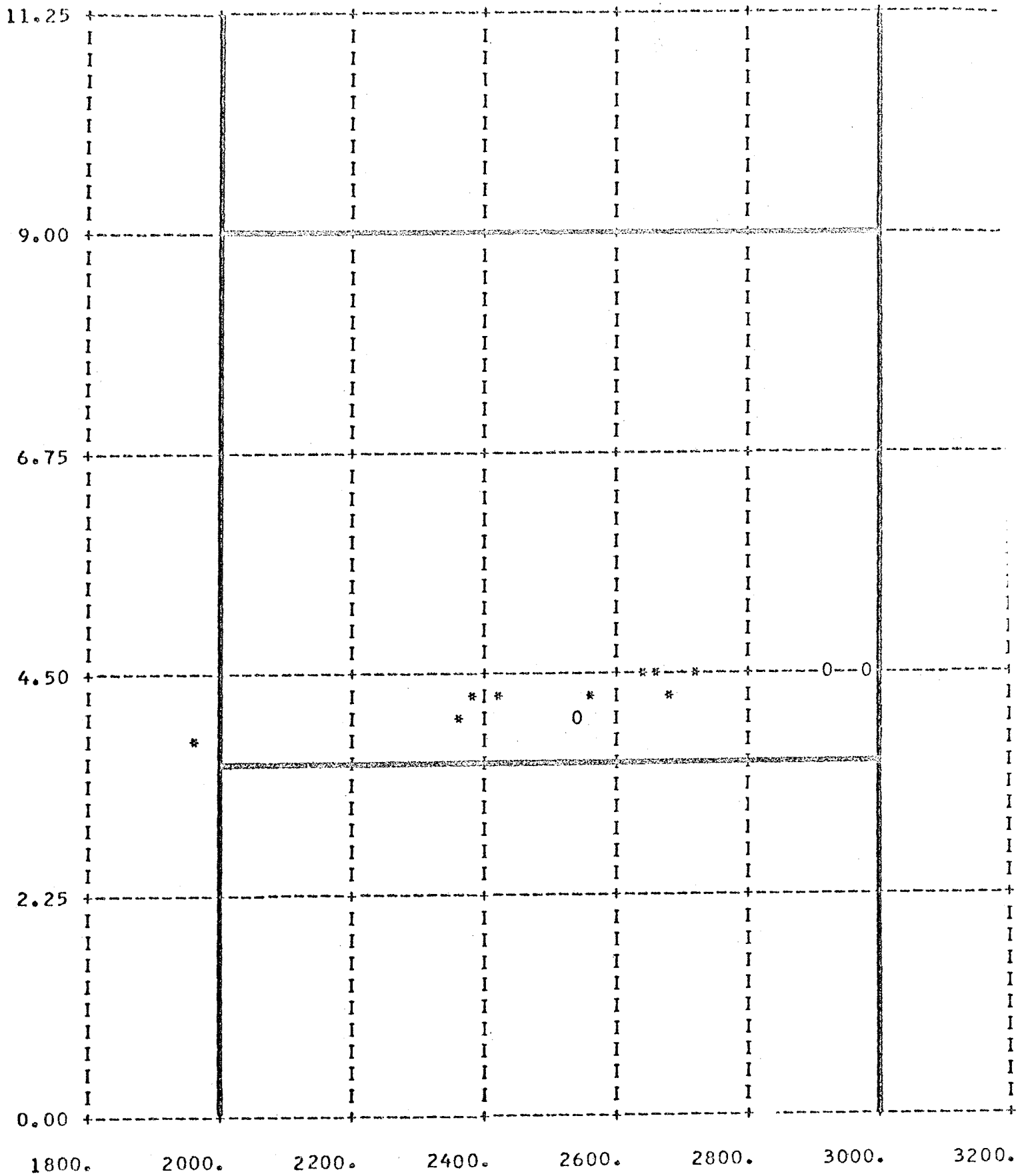


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

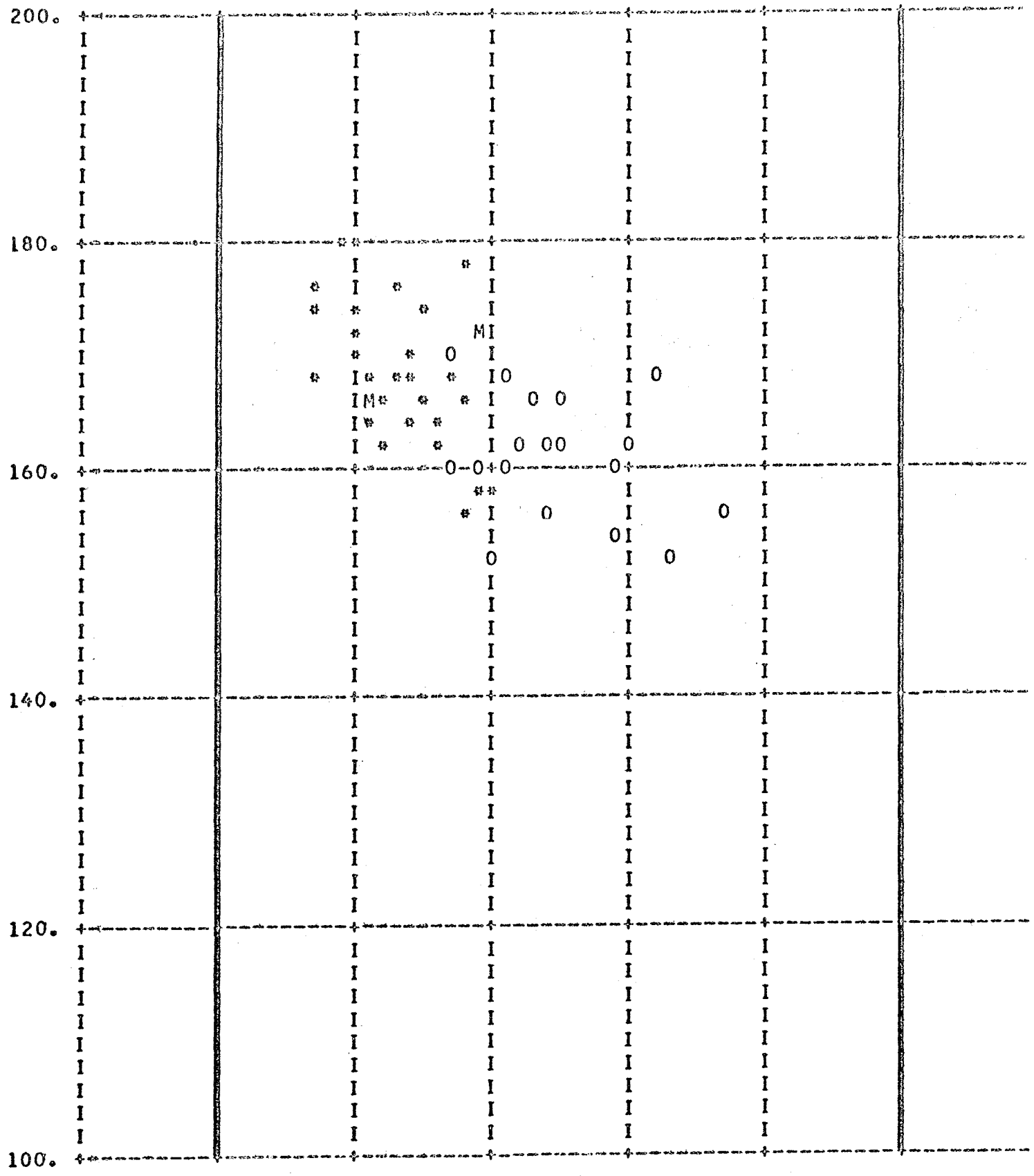
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 5 GRADE AC 20



Asphalt Supplier
No. 6

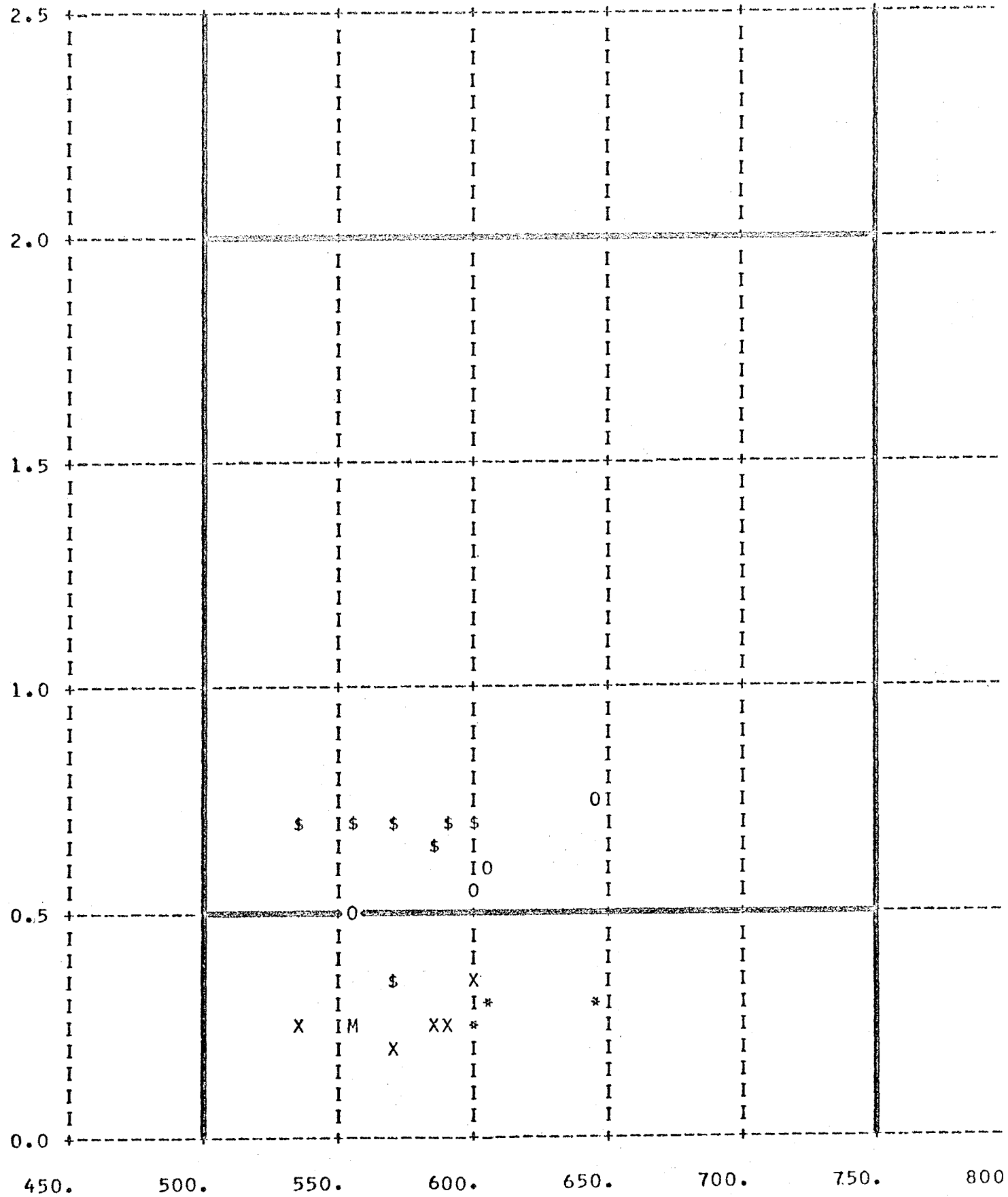
PRODUCER 6 GRADE AC 5



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 6 GRADE AC 5

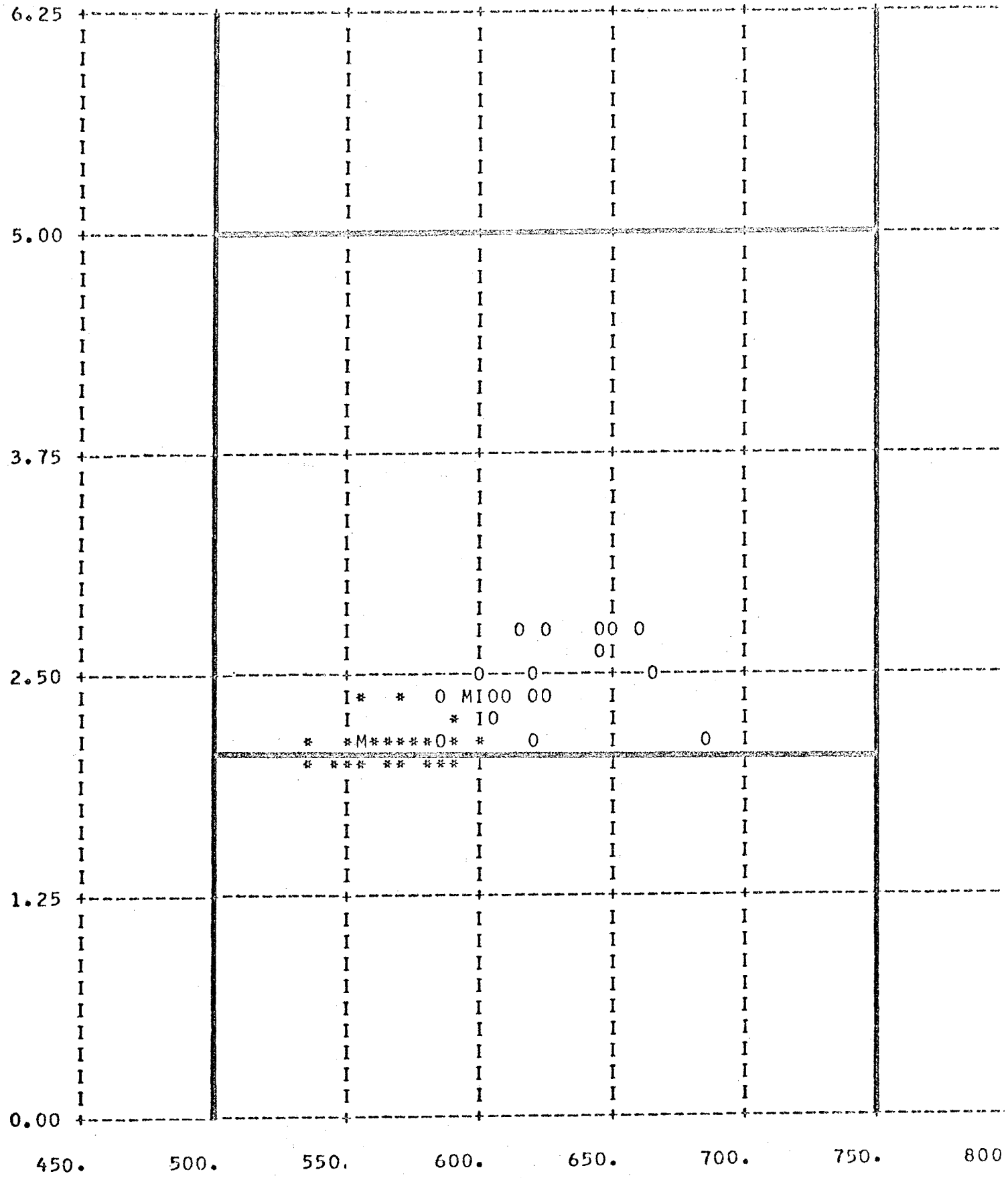


LEGEND
M MULTIPLE

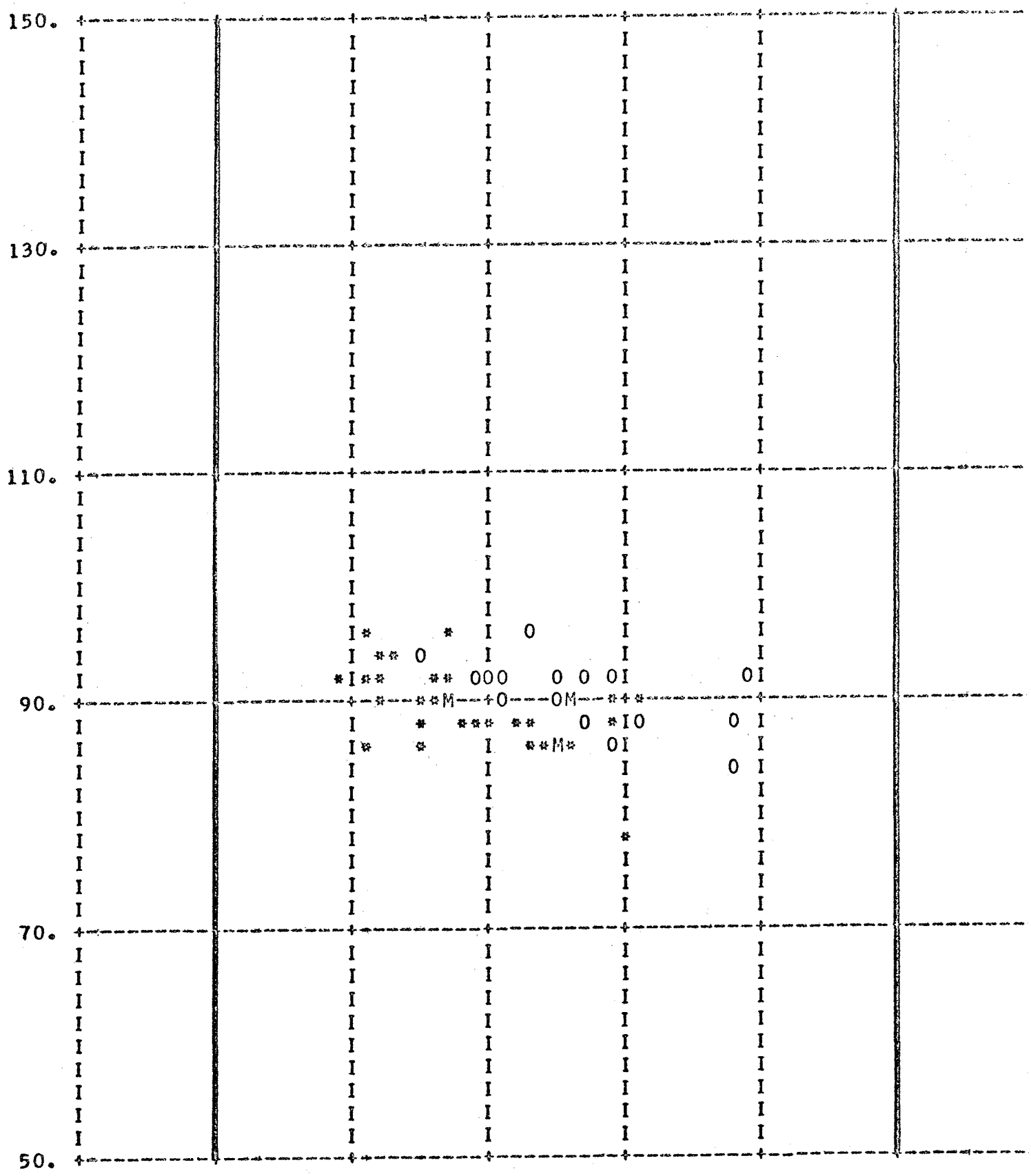
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 6 GRADE AC 5



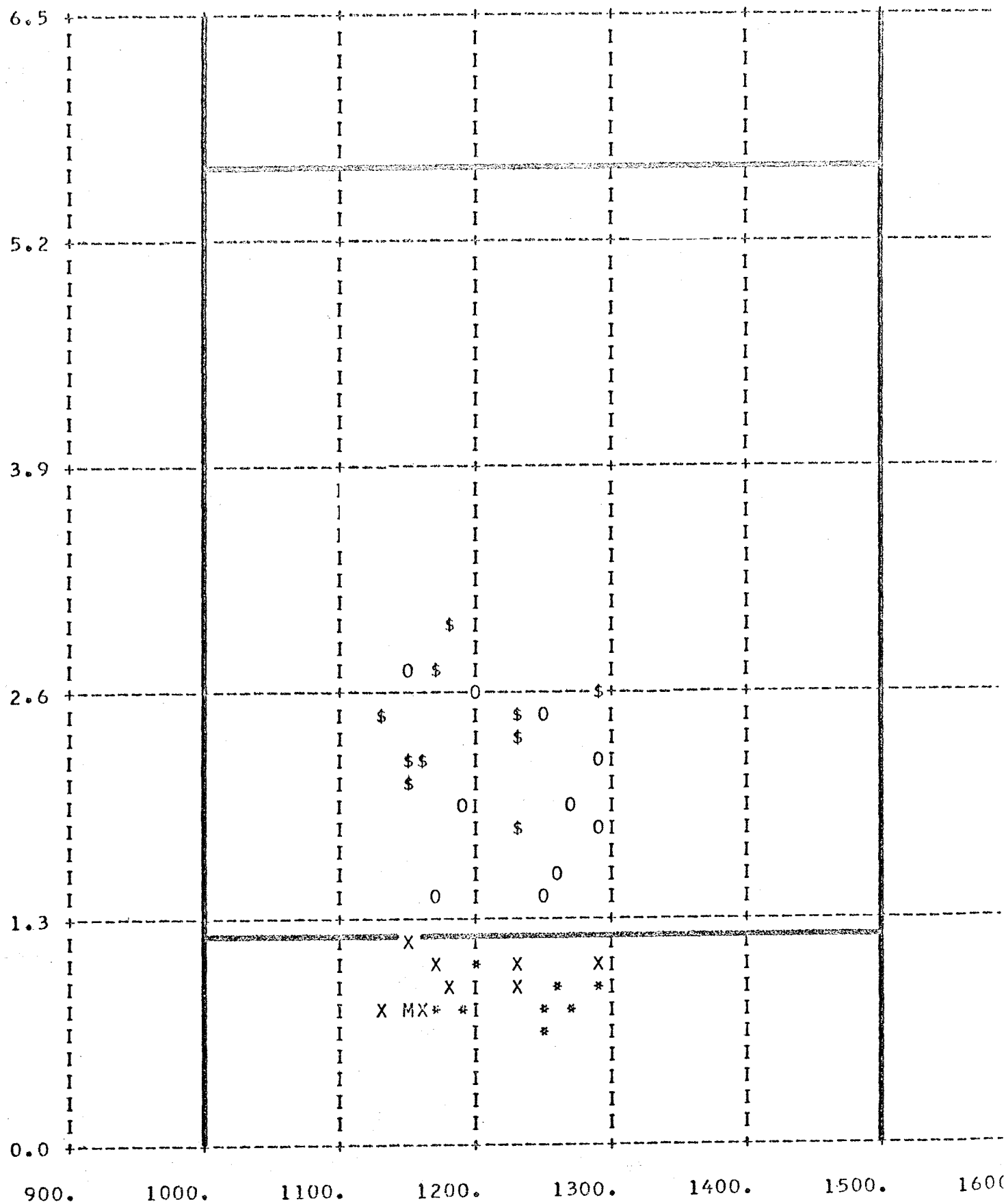
PRODUCER 6 GRADE AC 10



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 6 GRADE AC 10



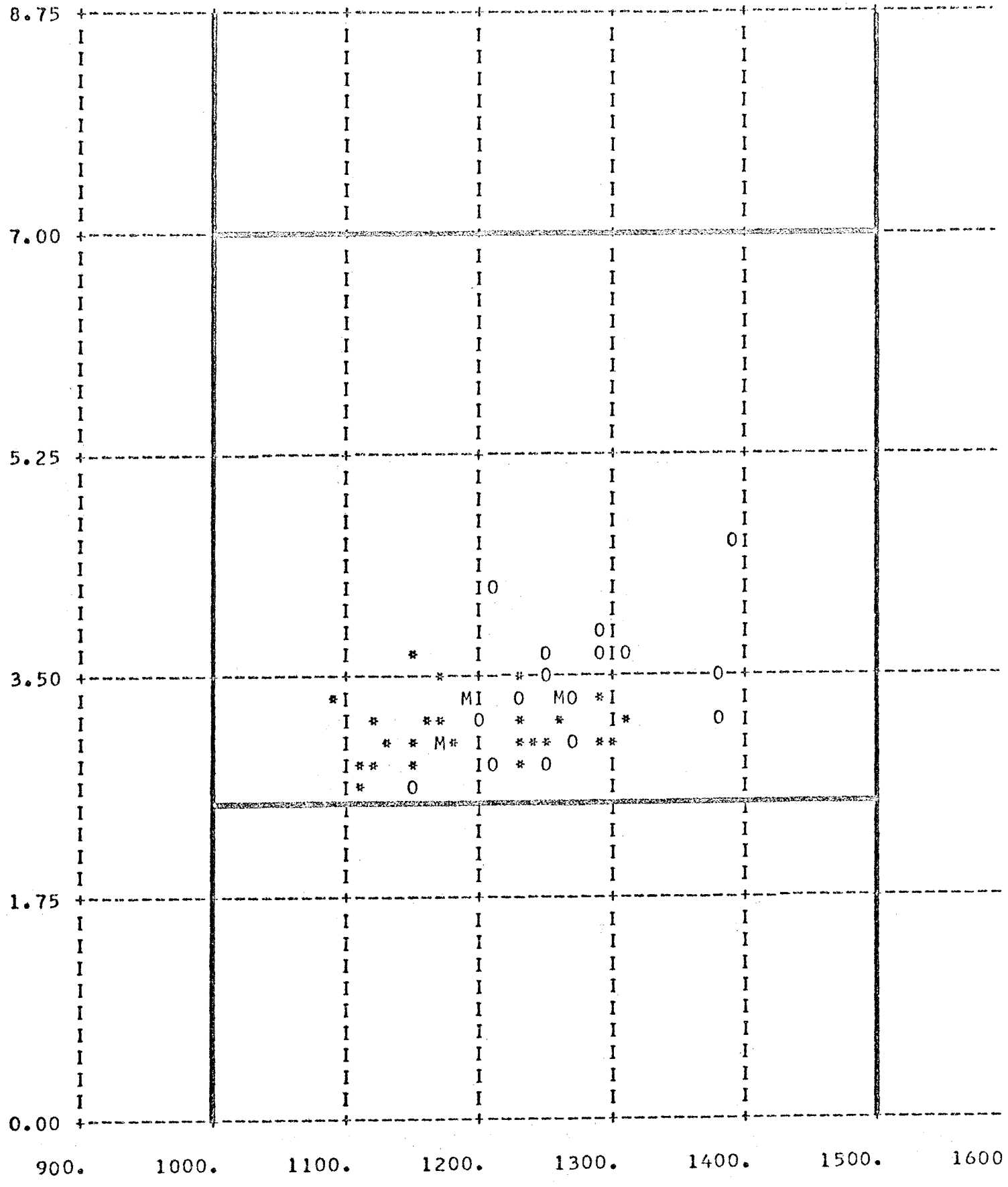
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

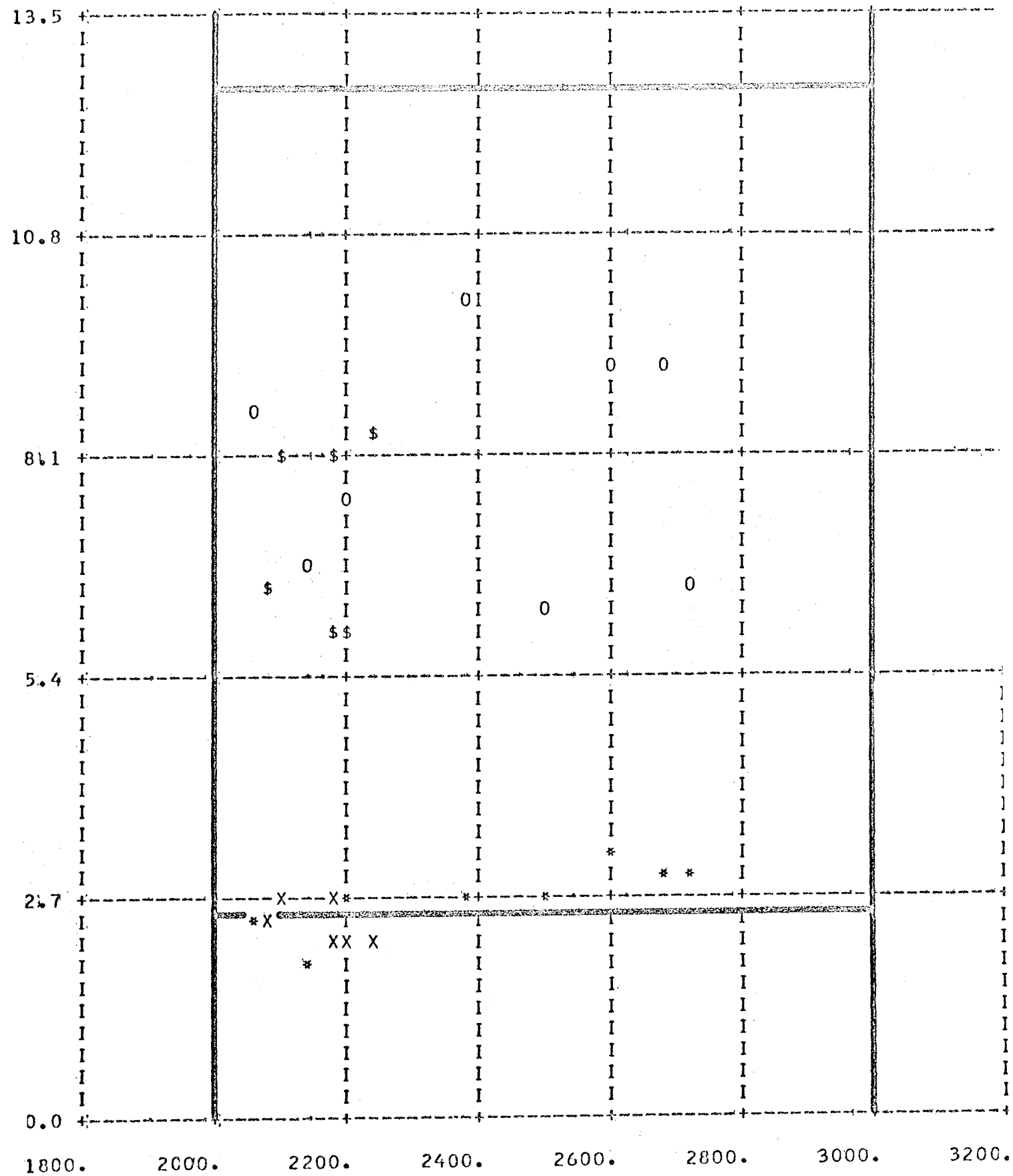
PRODUCER 6 GRADE AC 10



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 6 GRADE AC 20

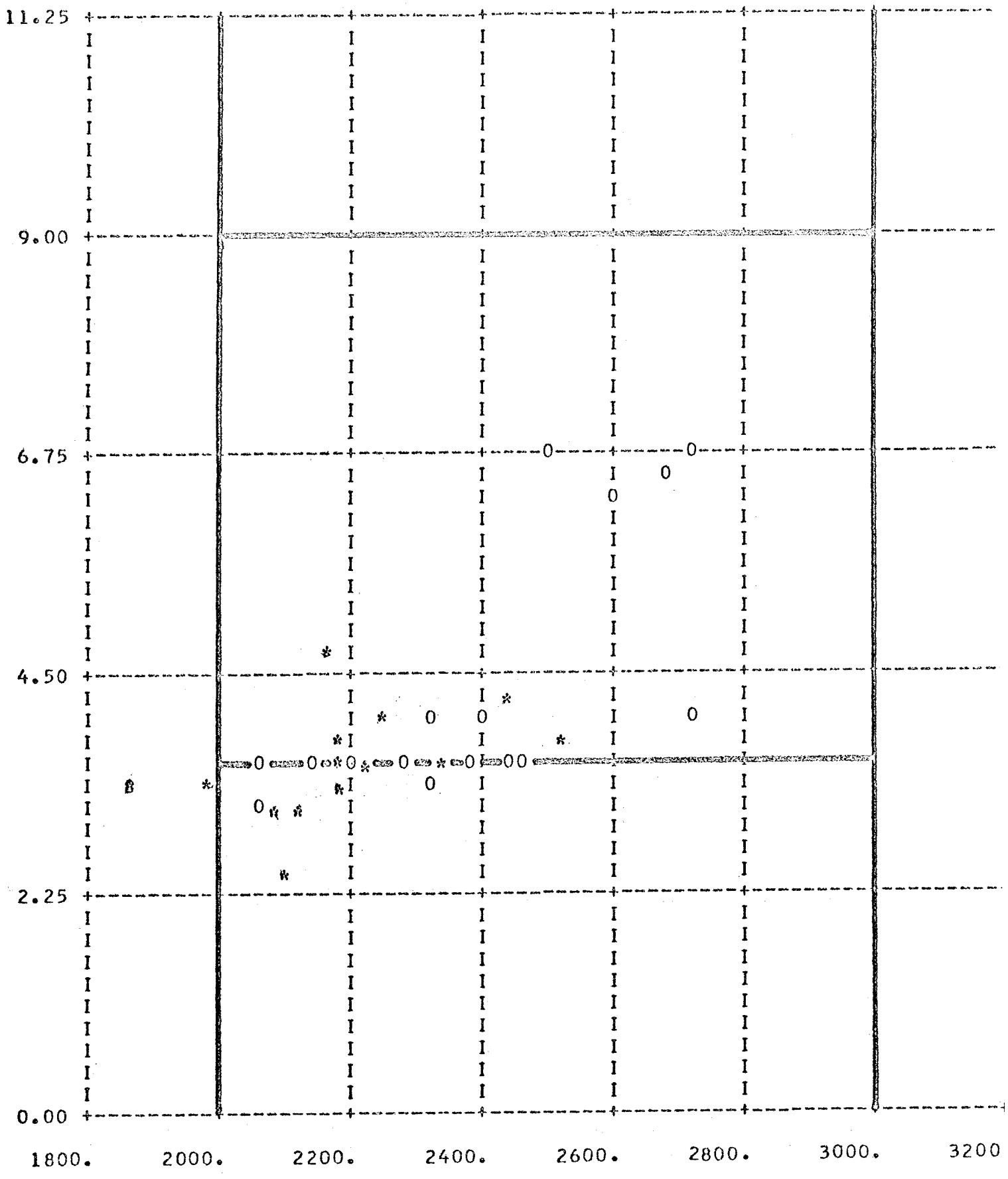


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 6 GRADE AC 20

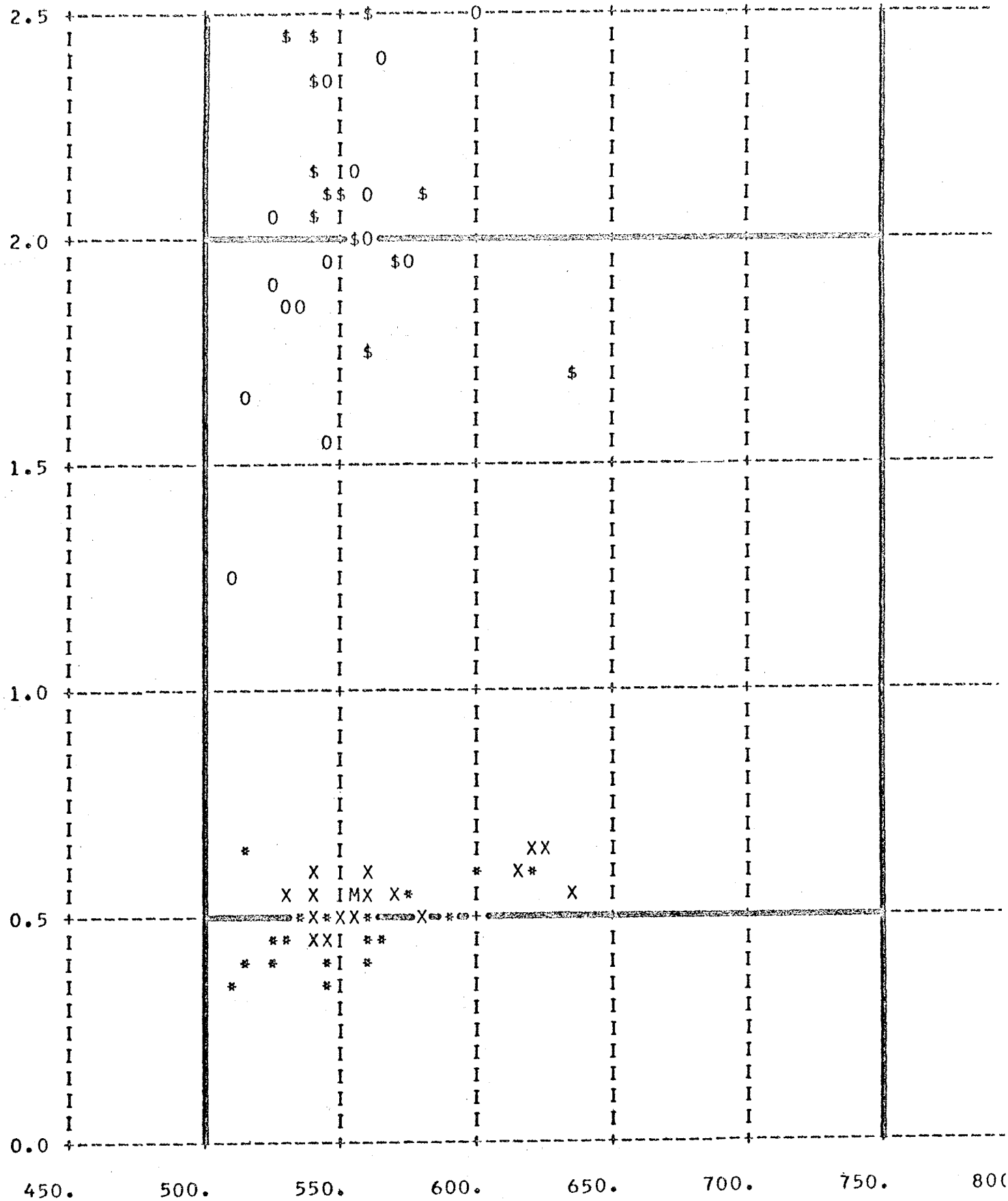


V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 7

PRODUCER 7 GRADE AC 5



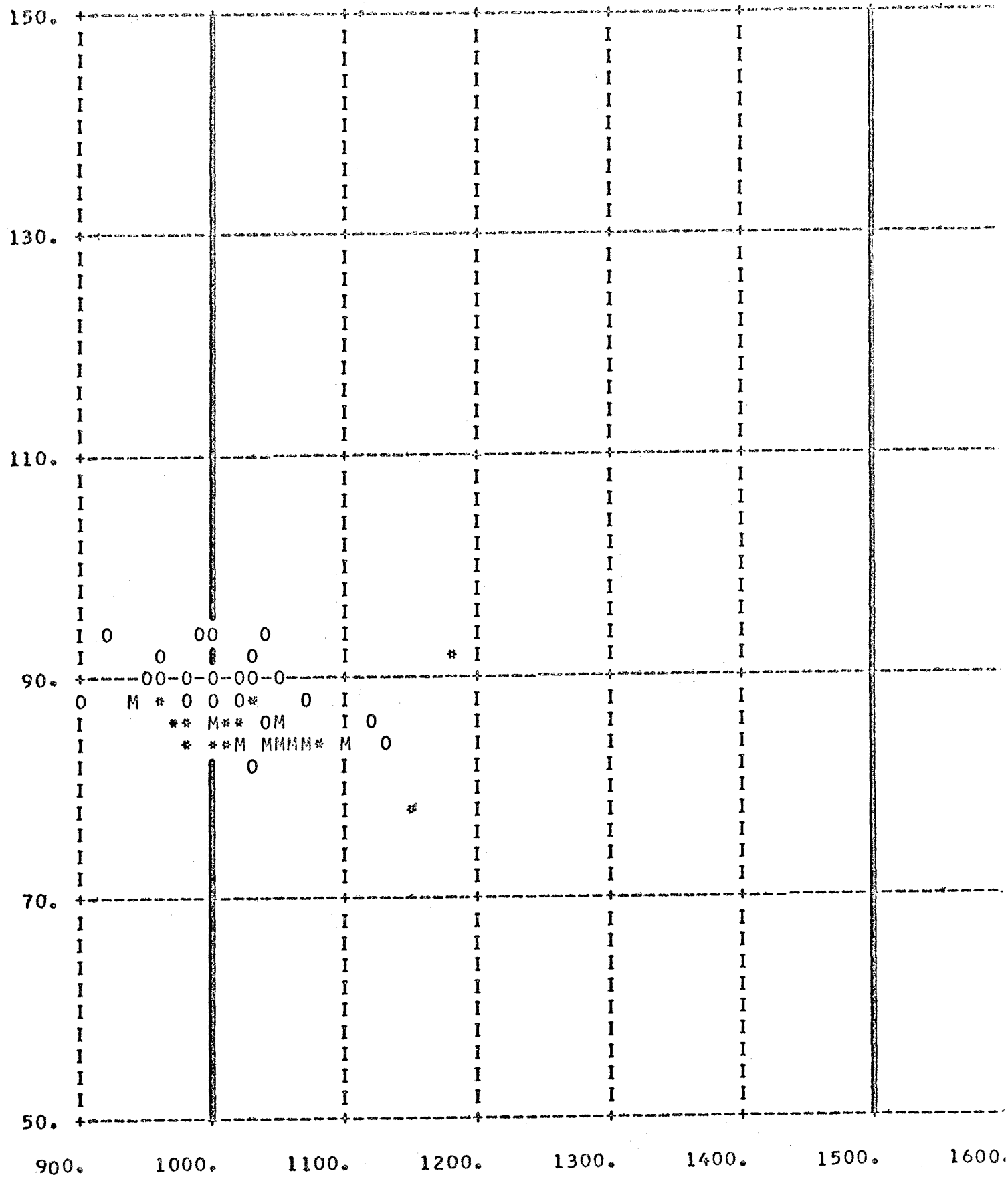
VISCOSITY STOKES 140F

LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

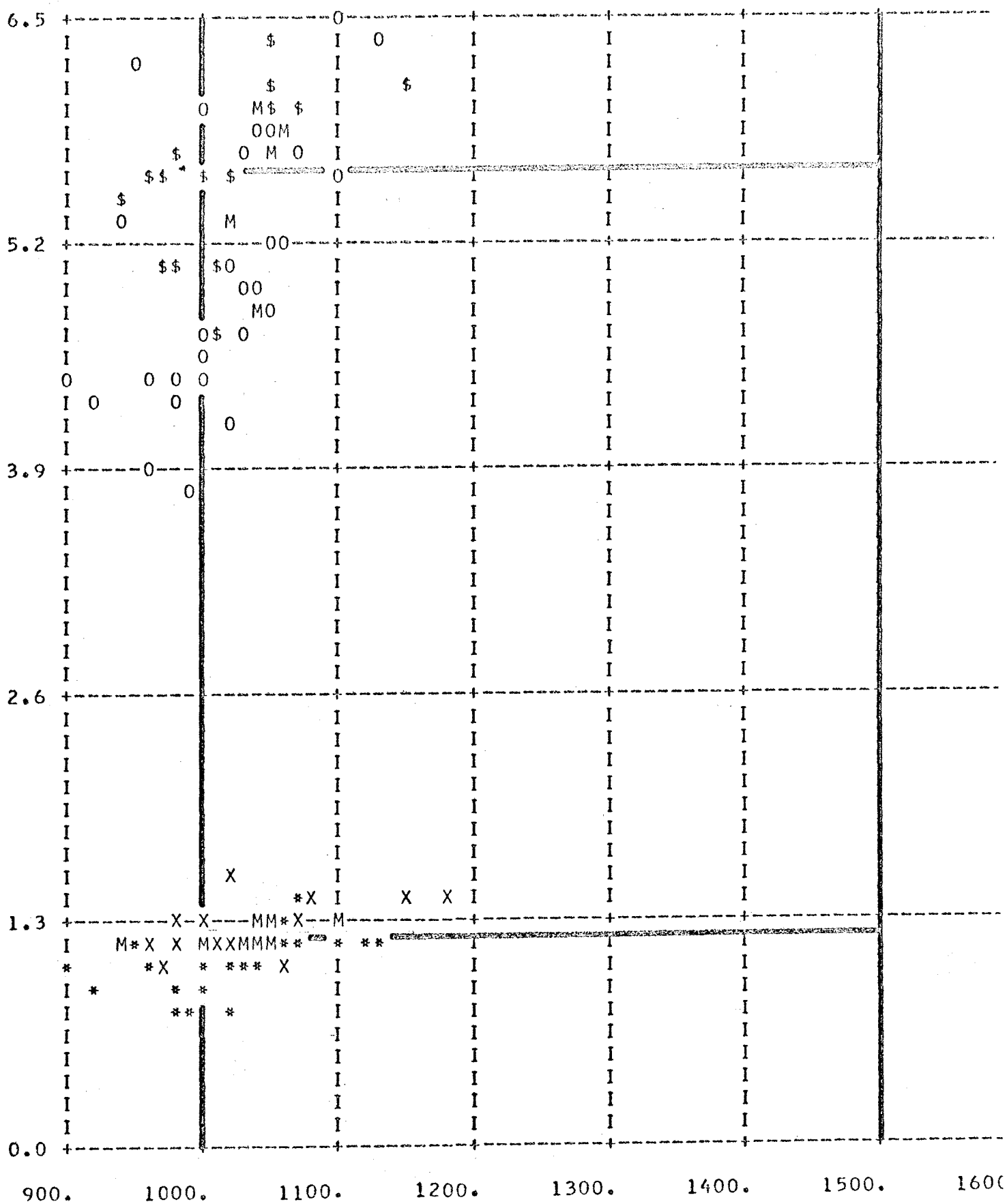
PRODUCER 7 GRADE AC 10



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 7 GRADE AC 10



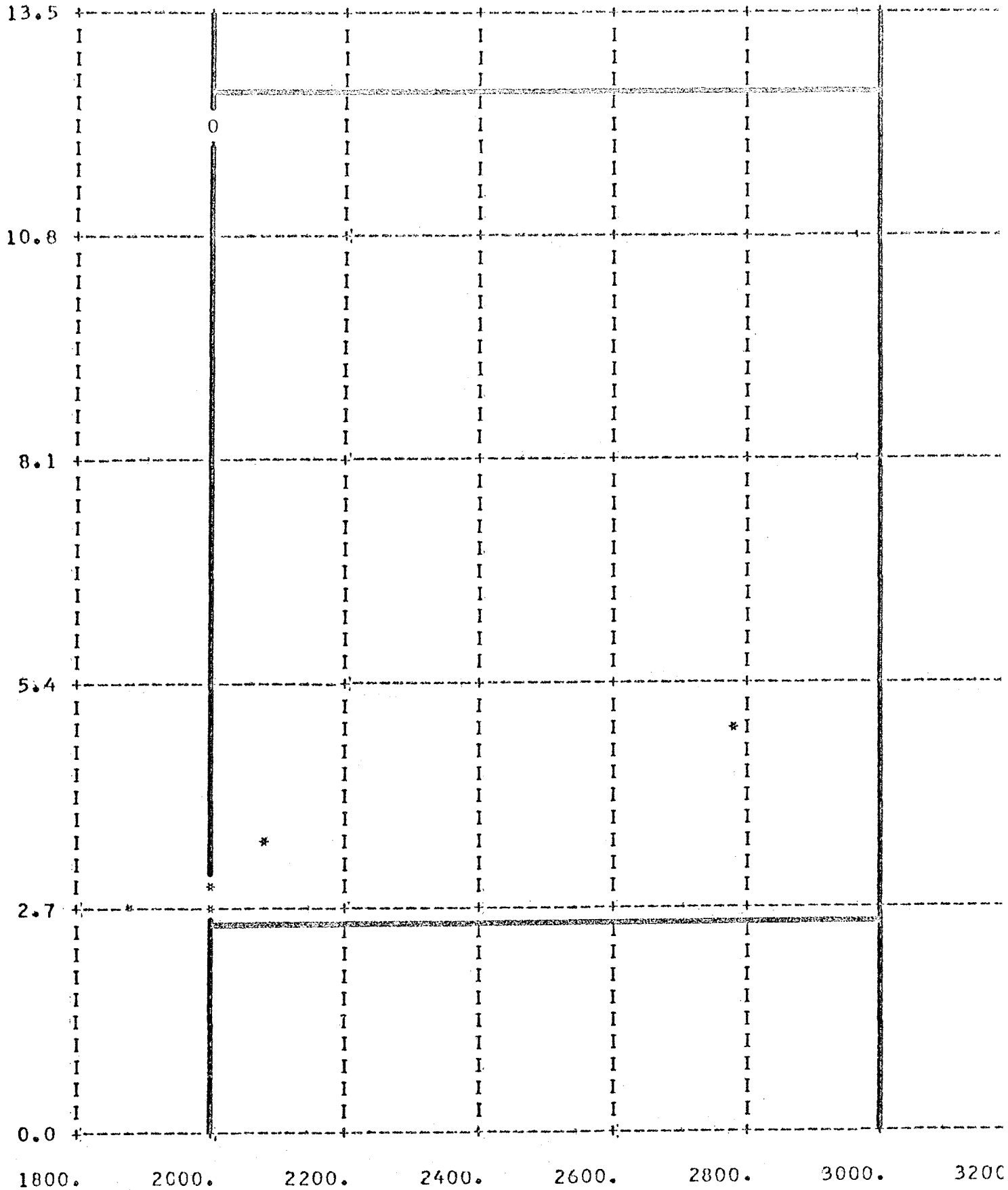
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 7 GRADE AC 20

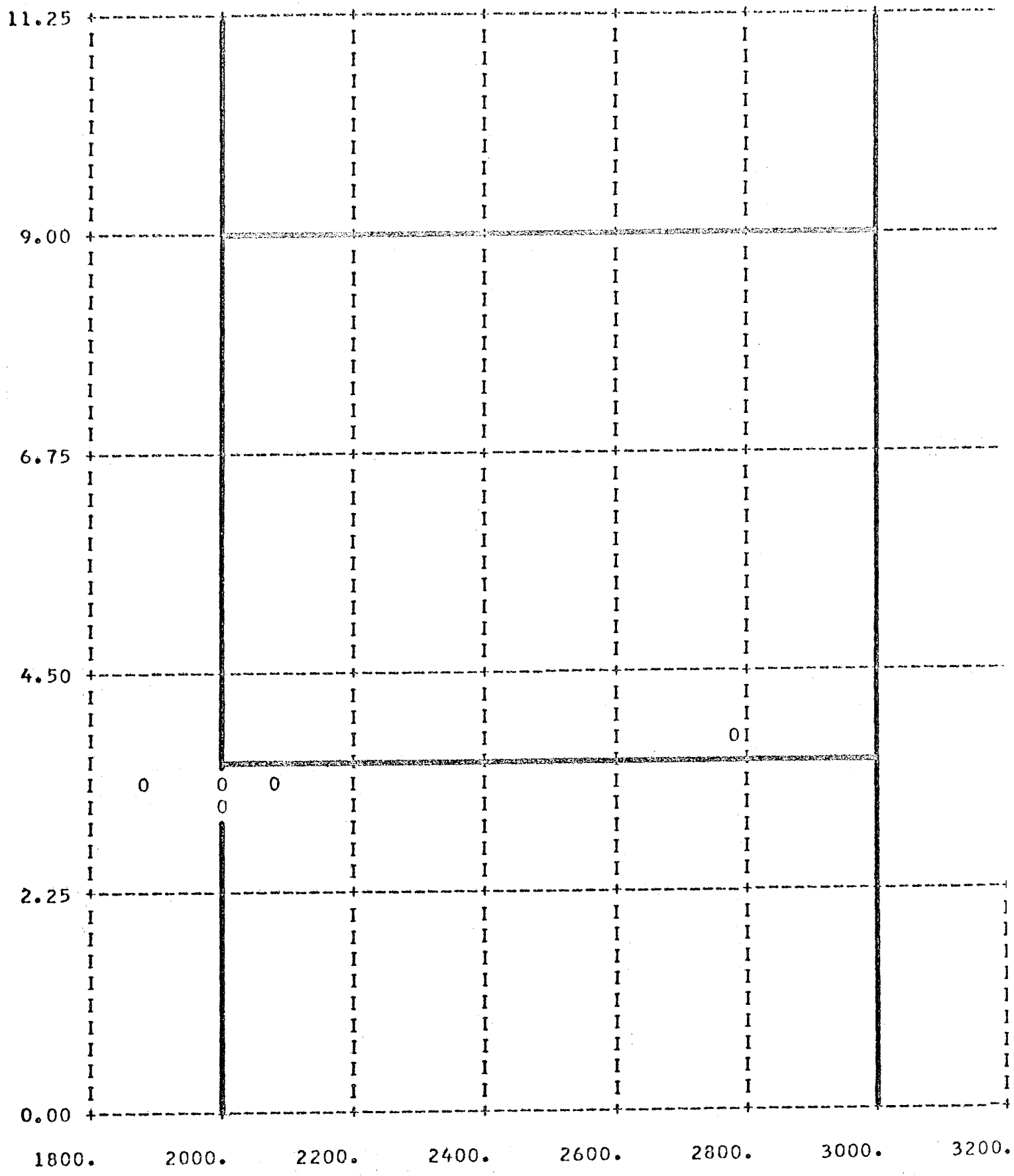


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

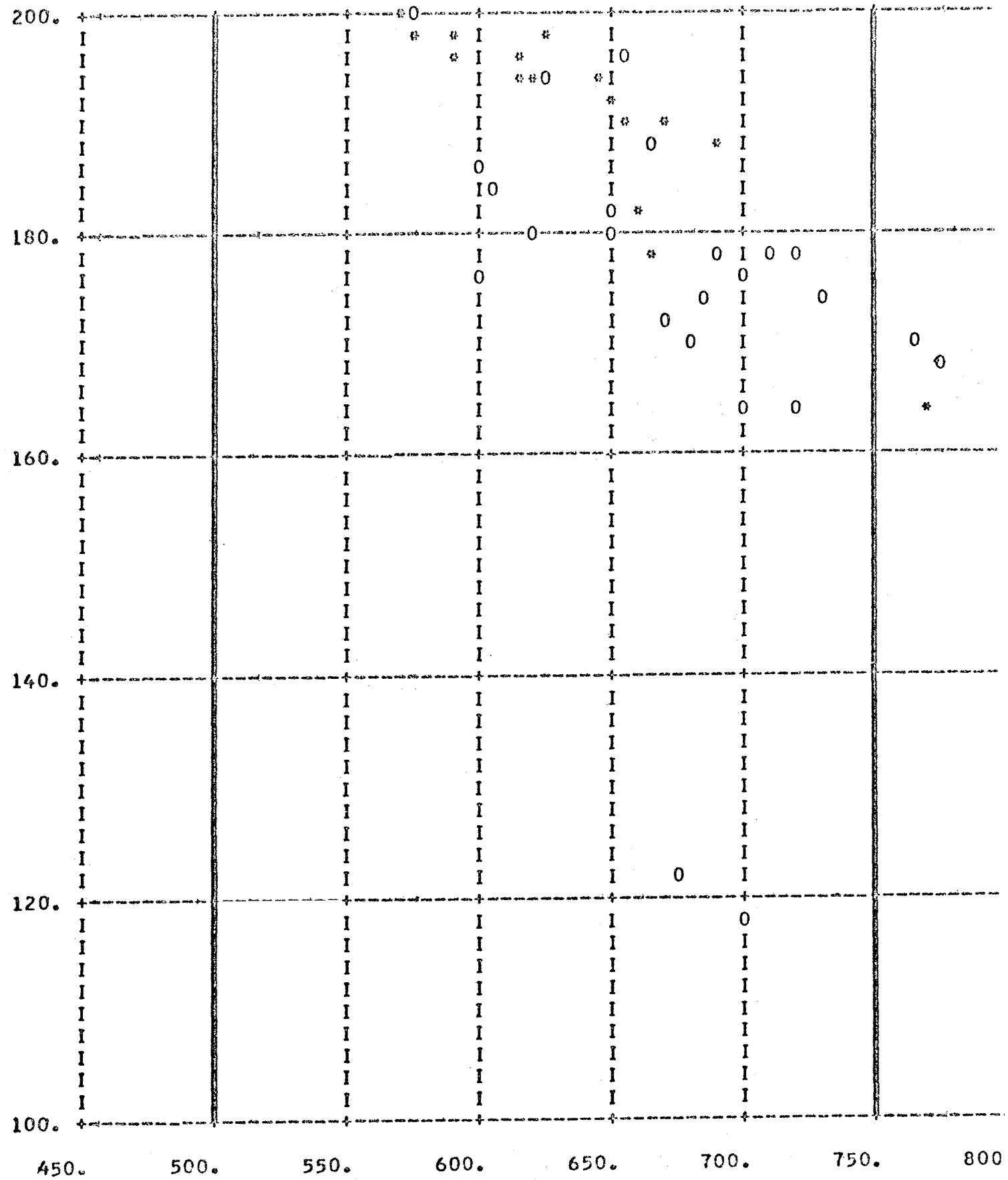
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 7 GRADE AC 20



Asphalt Supplies
No. 8

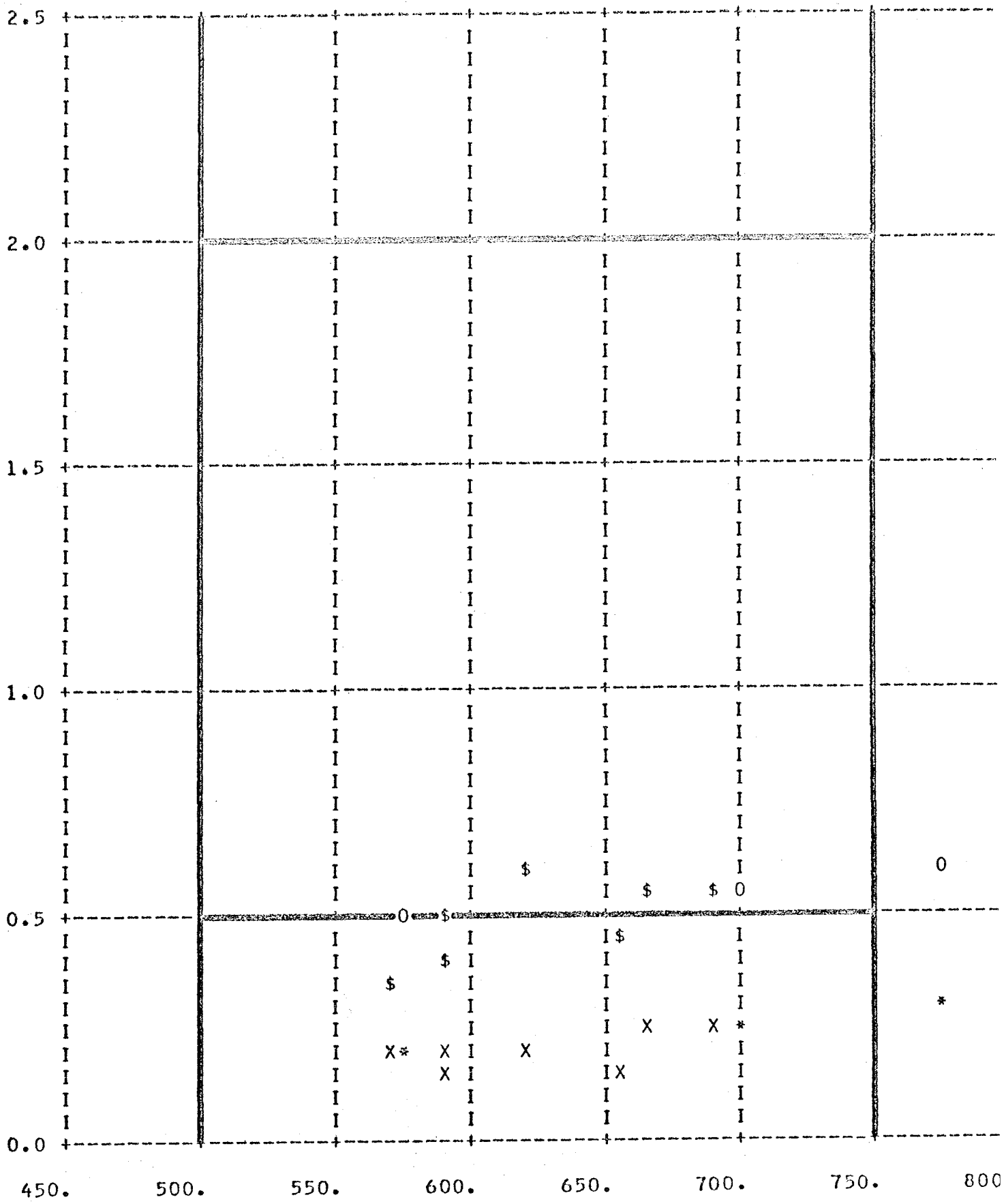
PRODUCER 8 GRADE AC 5



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 8 GRADE AC 5

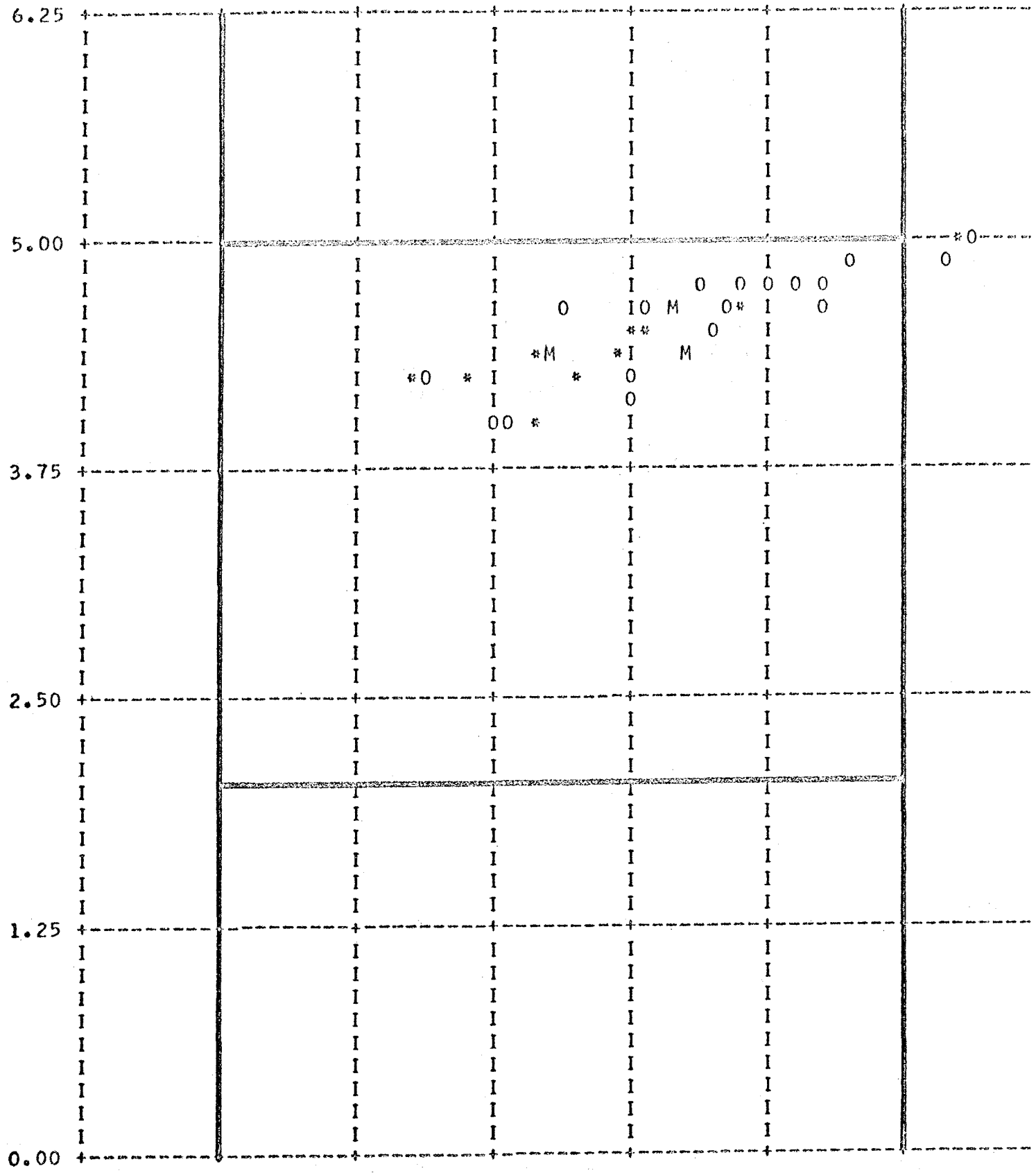


LEGEND
M MULTIPLE

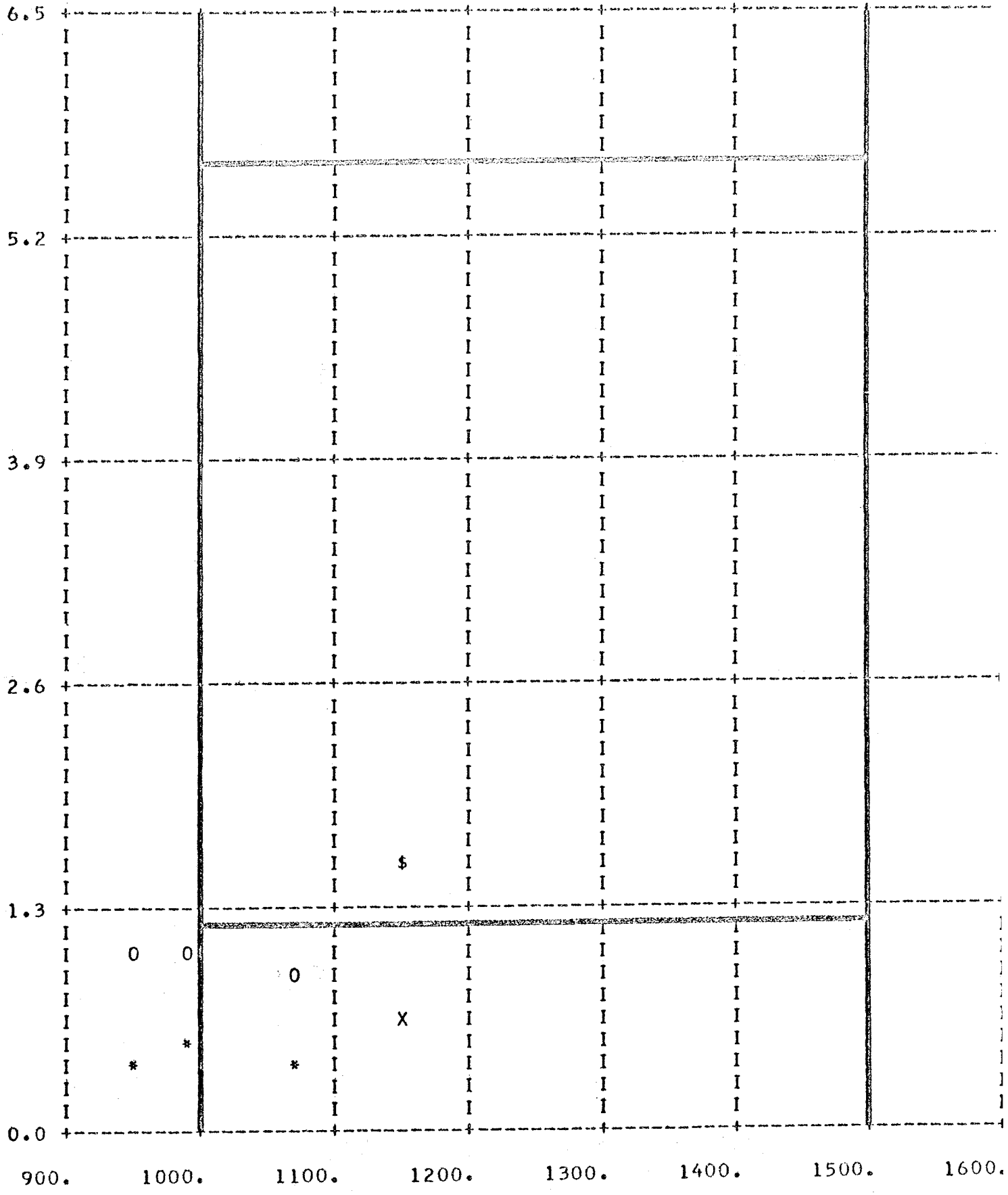
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 8 GRADE AC 5



PRODUCER 8 GRADE AC 10

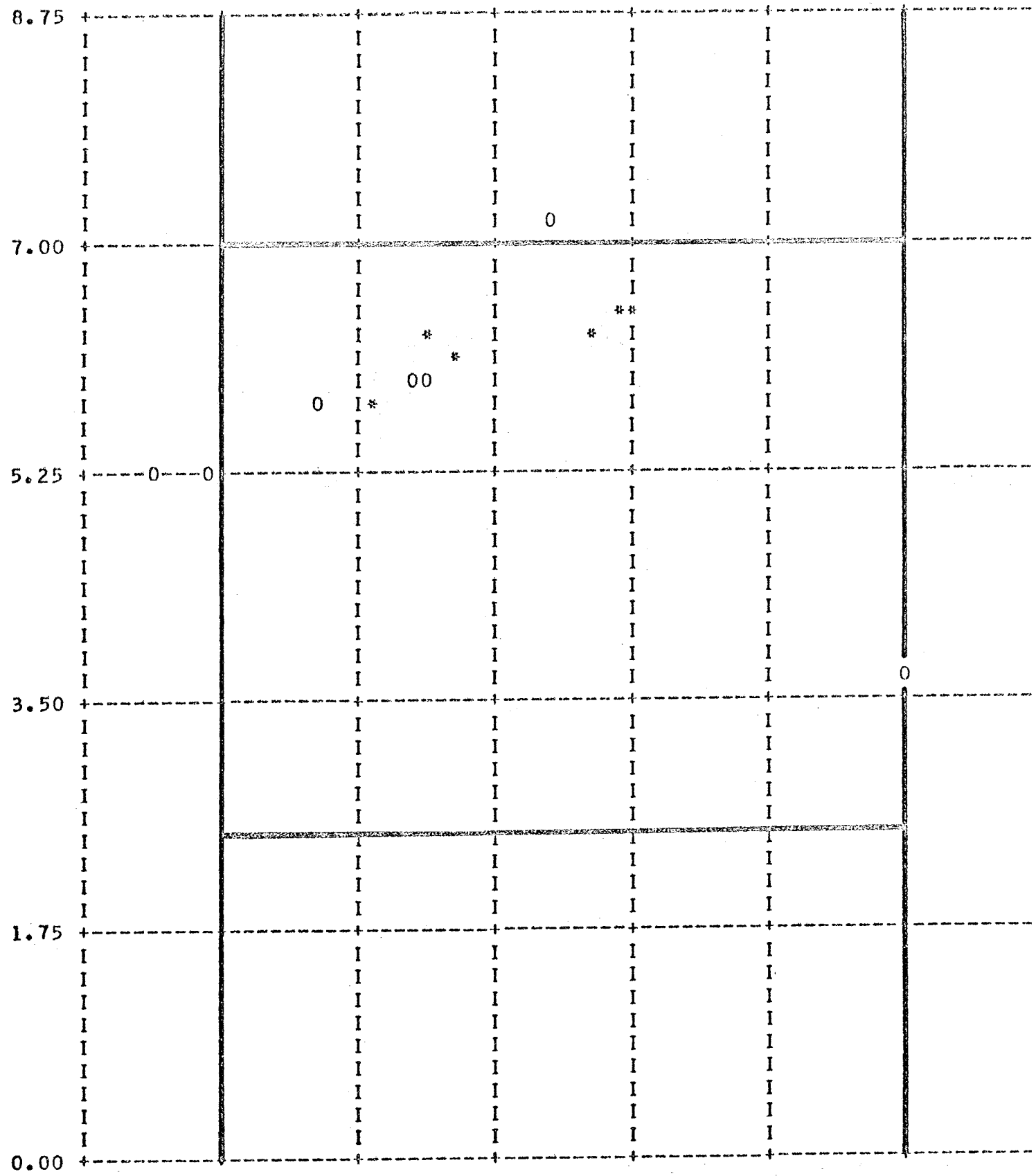


LEGEND M MULTIPLE

VISCOSITY AT 77F * 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR 0 1965 $ 1966

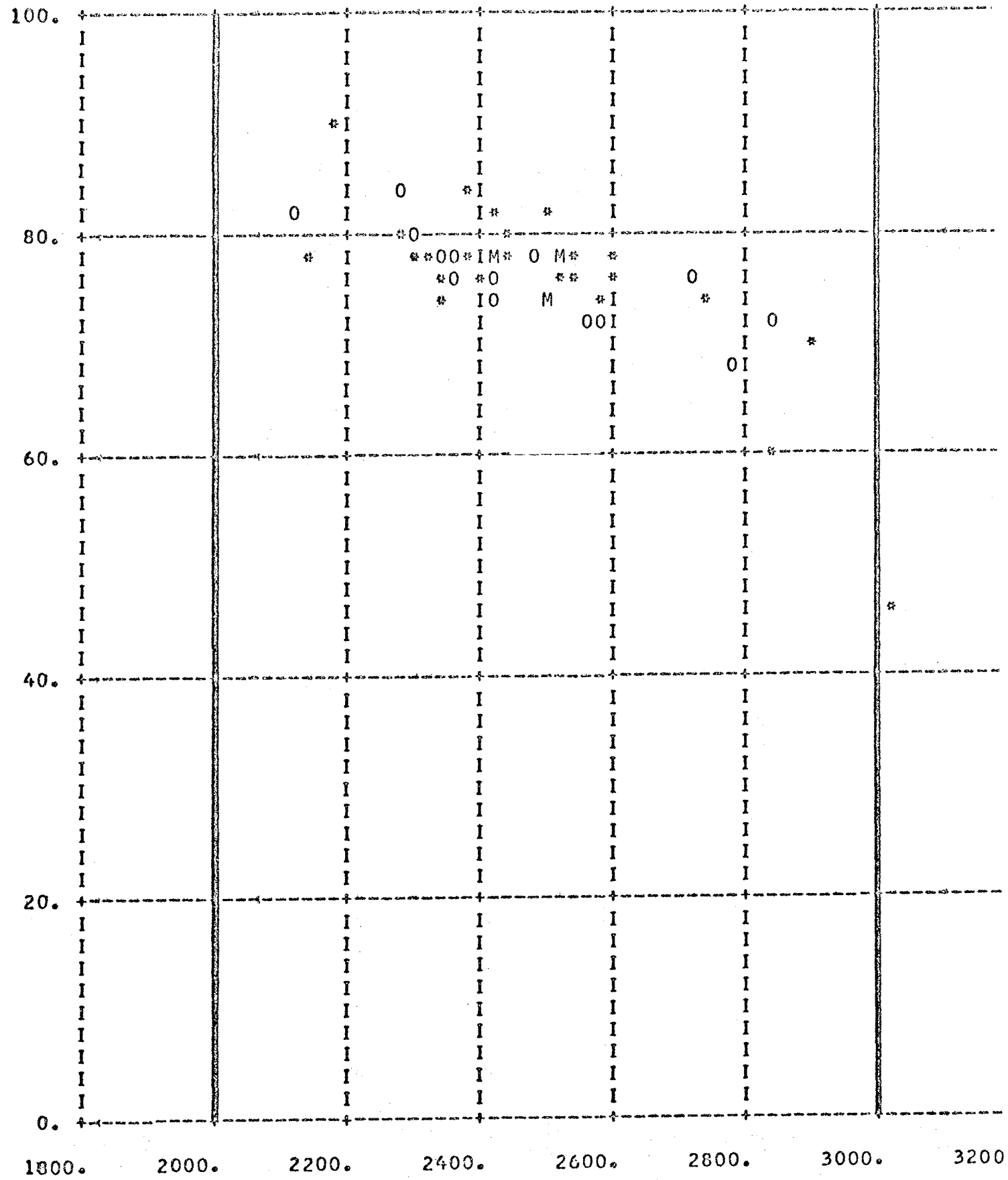
PRODUCER 8 GRADE AC 10



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

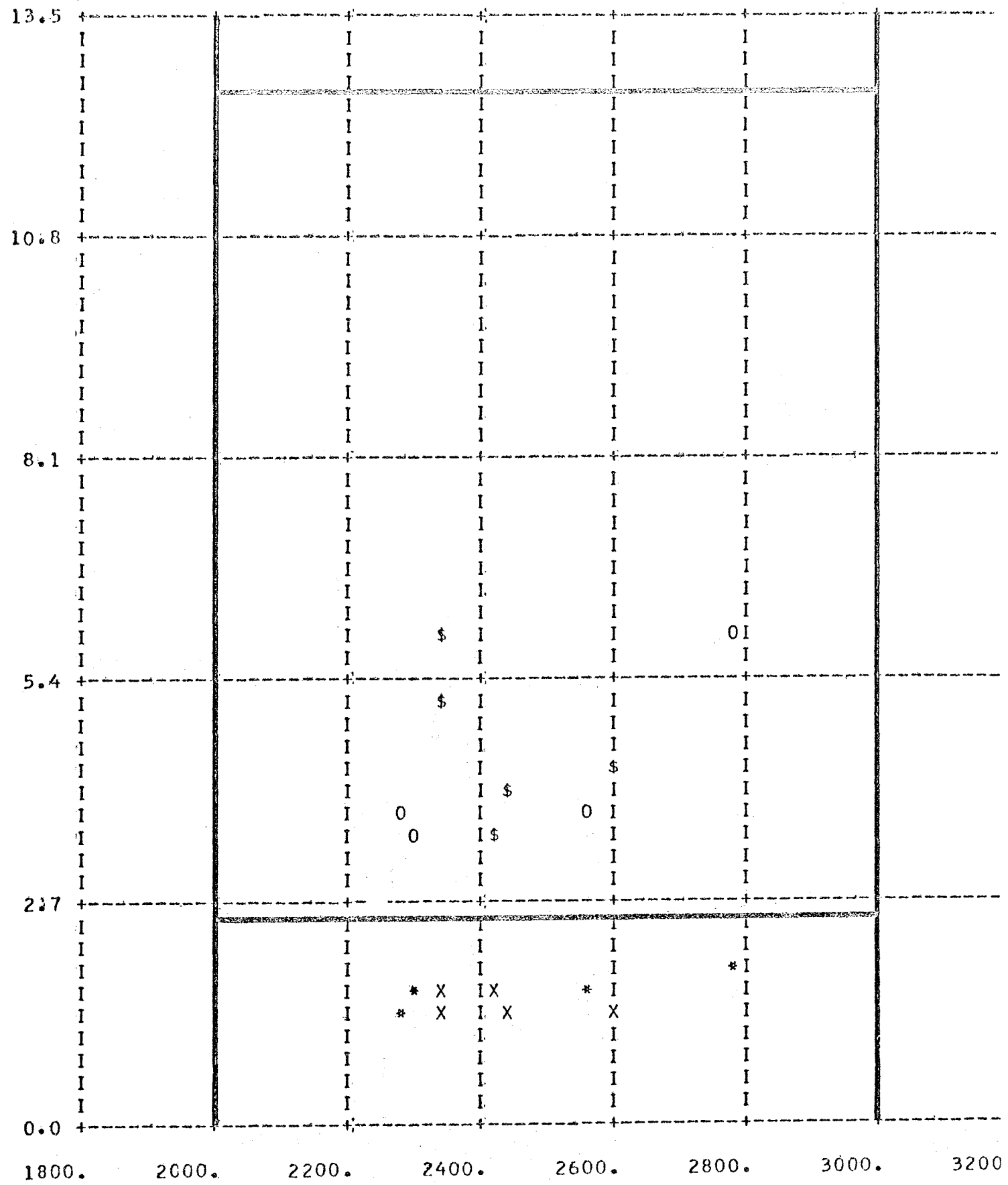
PRODUCER 8 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 8 GRADE AC 20

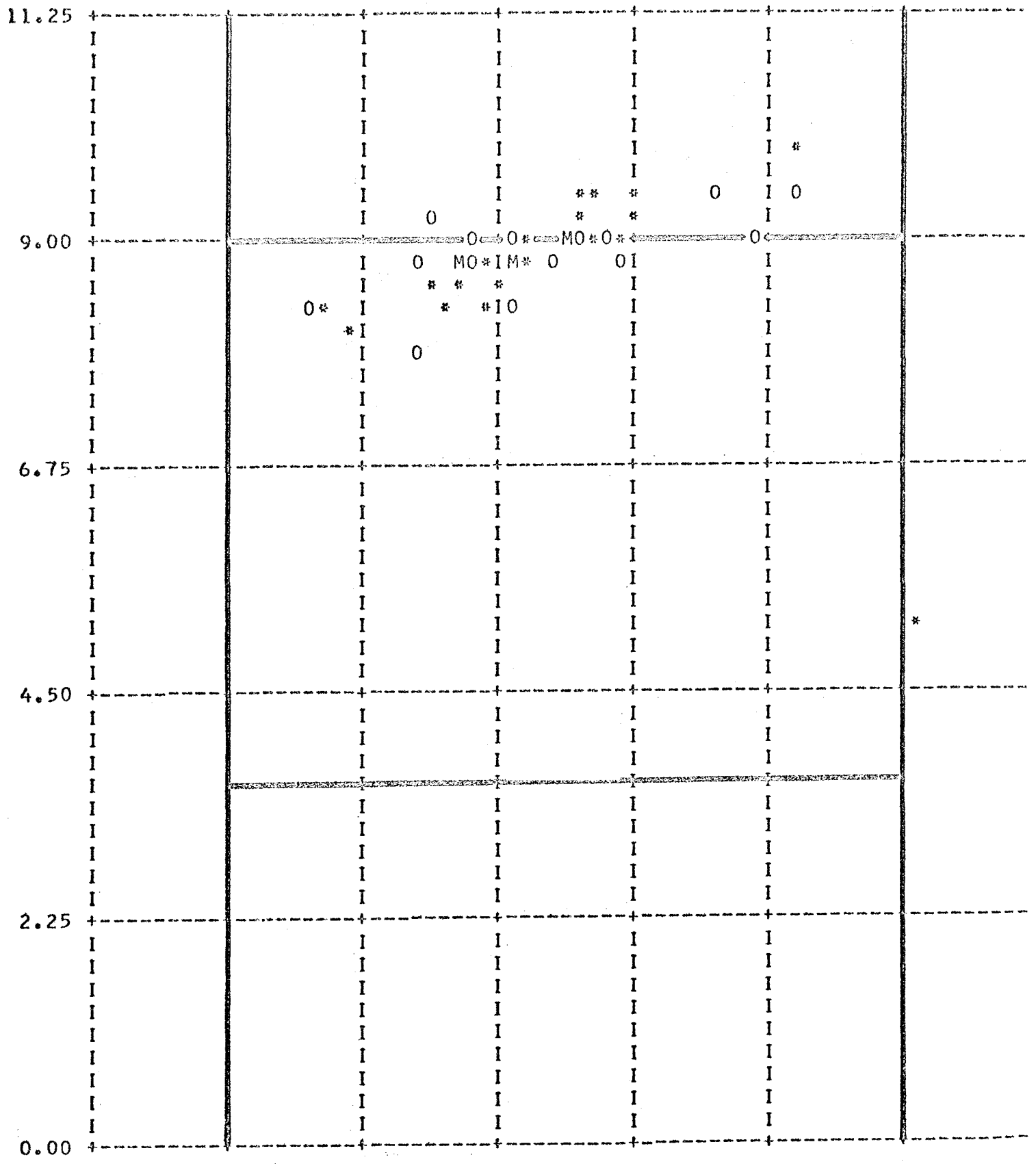


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 8 GRADE AC 20

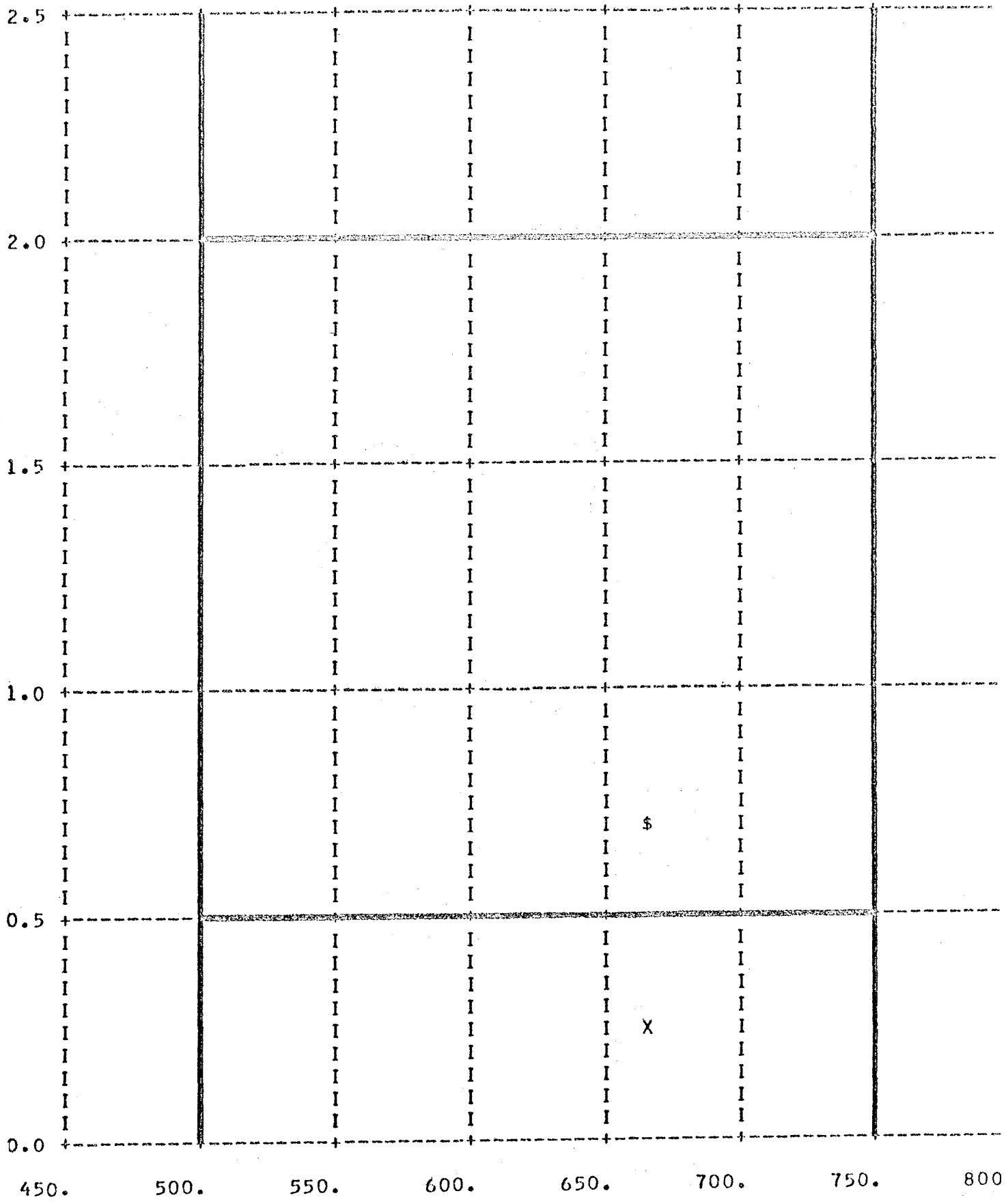


VISCOSITY STOKES 140 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplies
No. 9

PRODUCER 9 GRADE AC 5



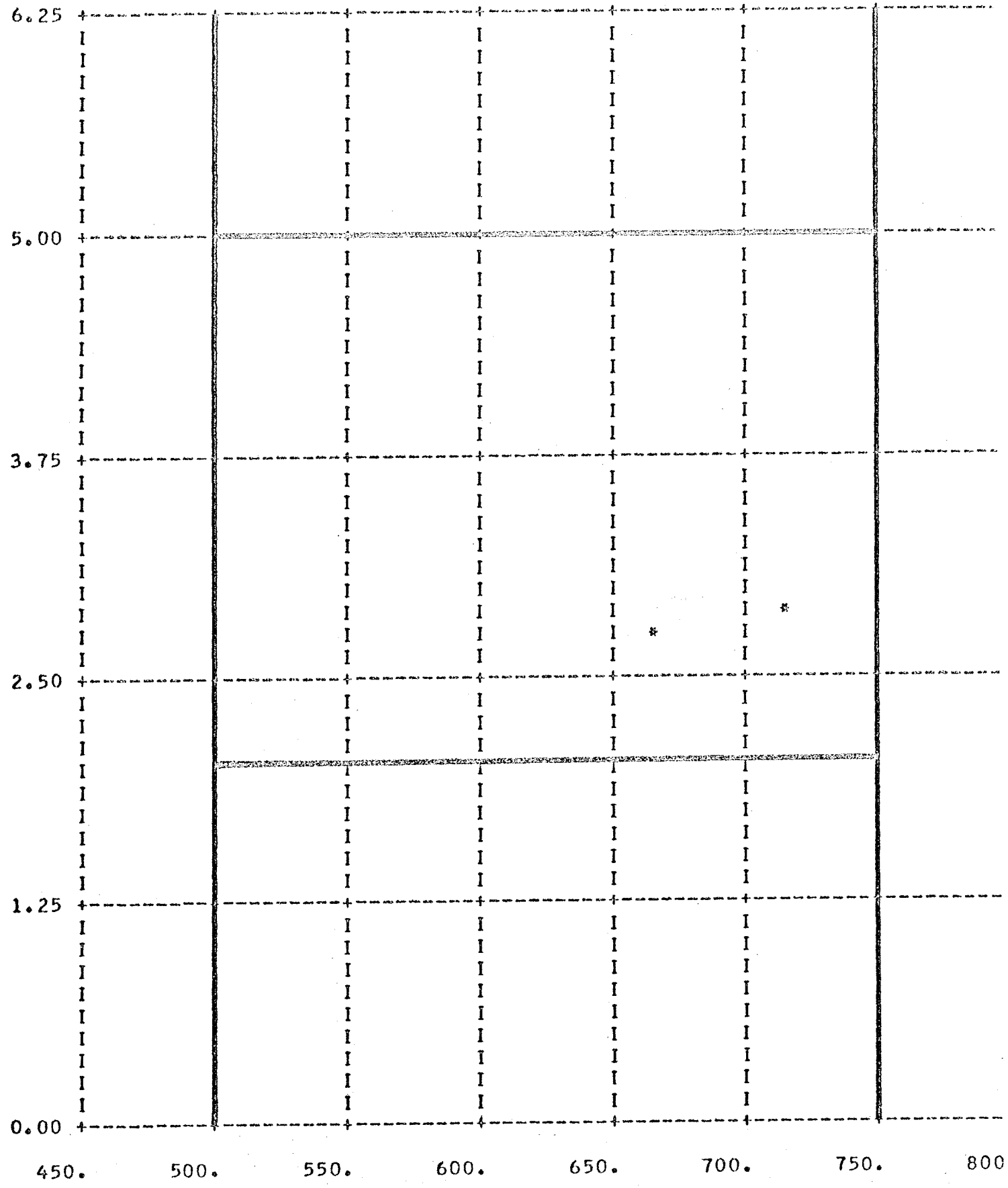
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

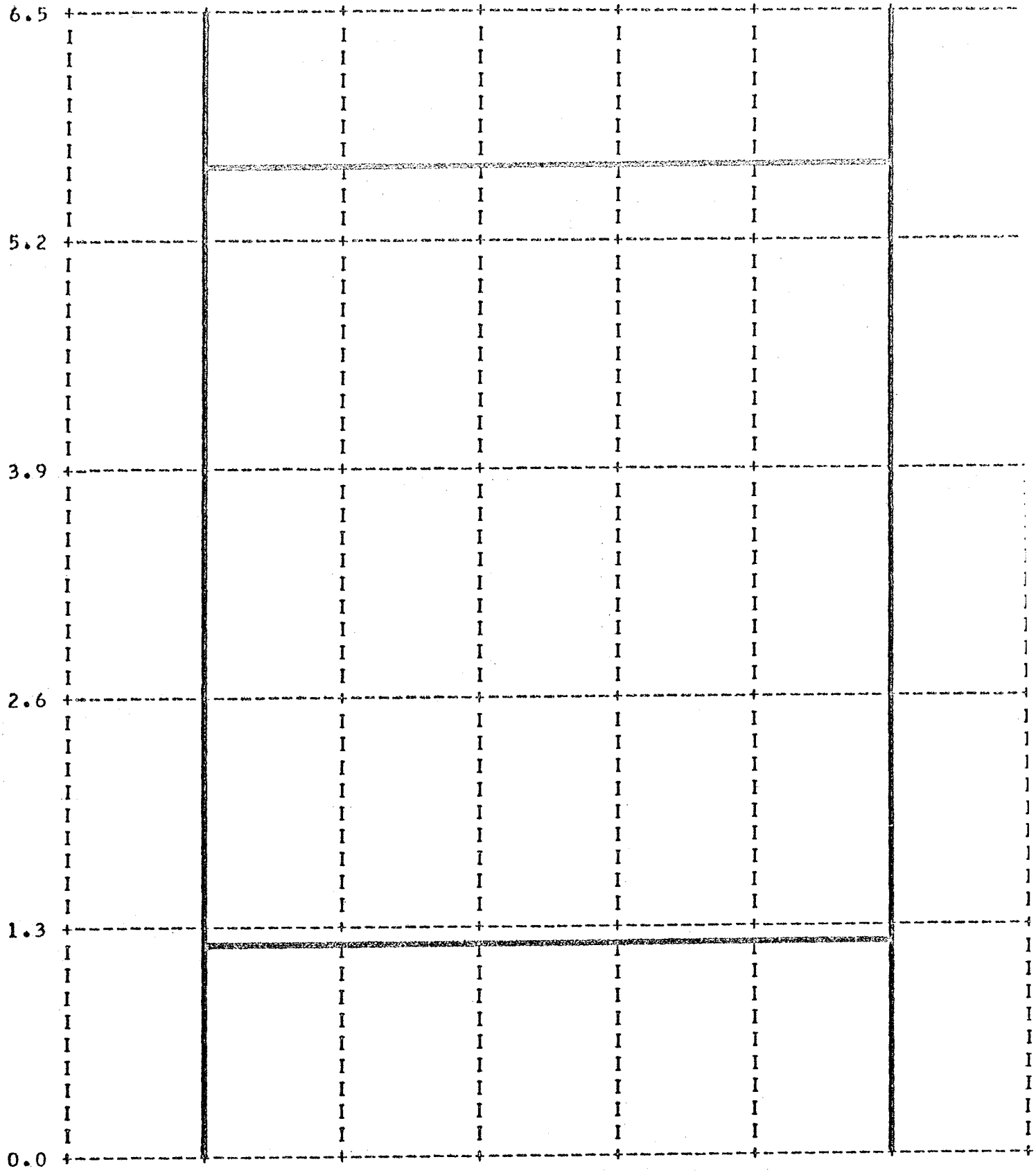
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 9 GRADE AC 5



PRODUCER 9 GRADE AC 10

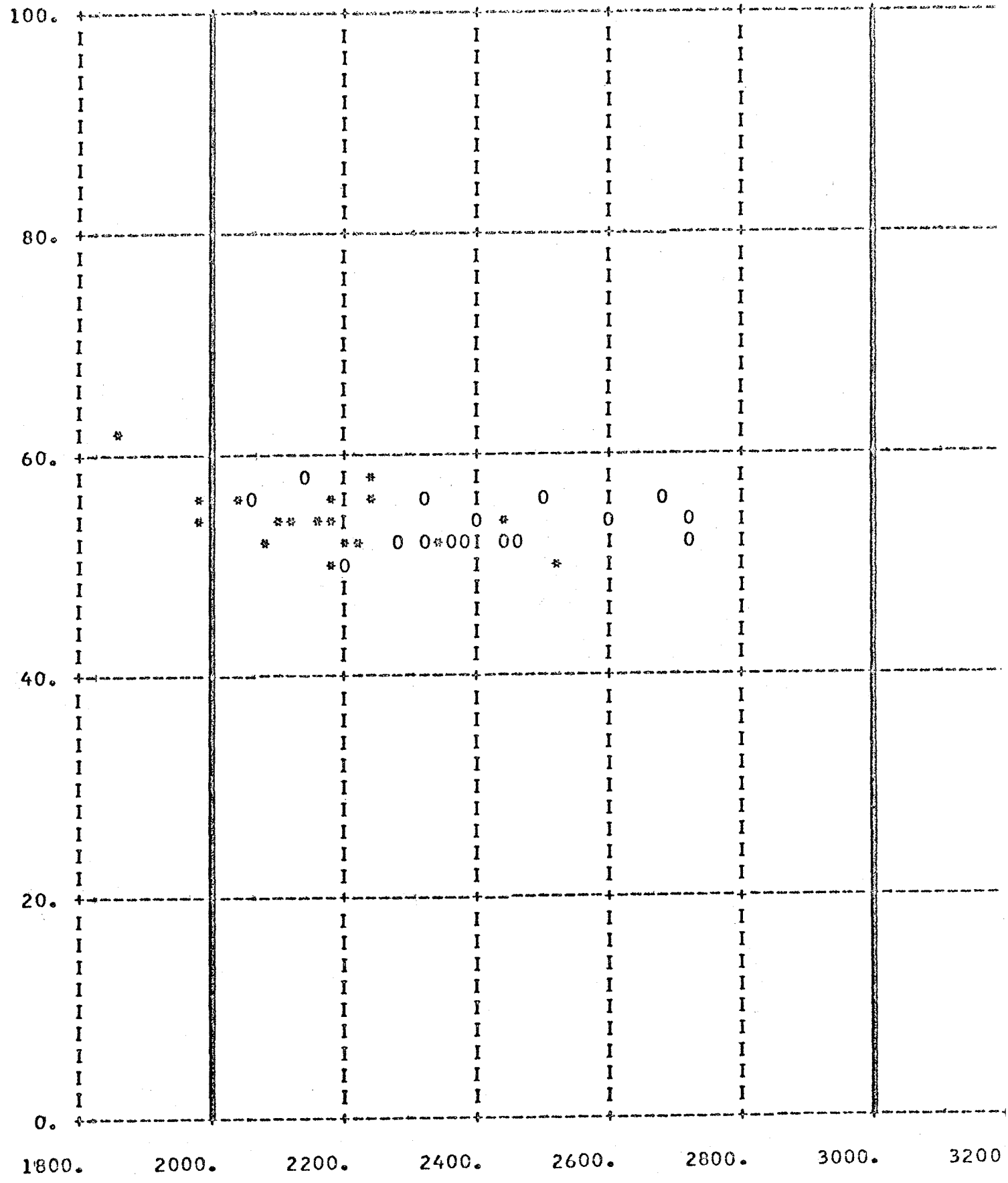


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

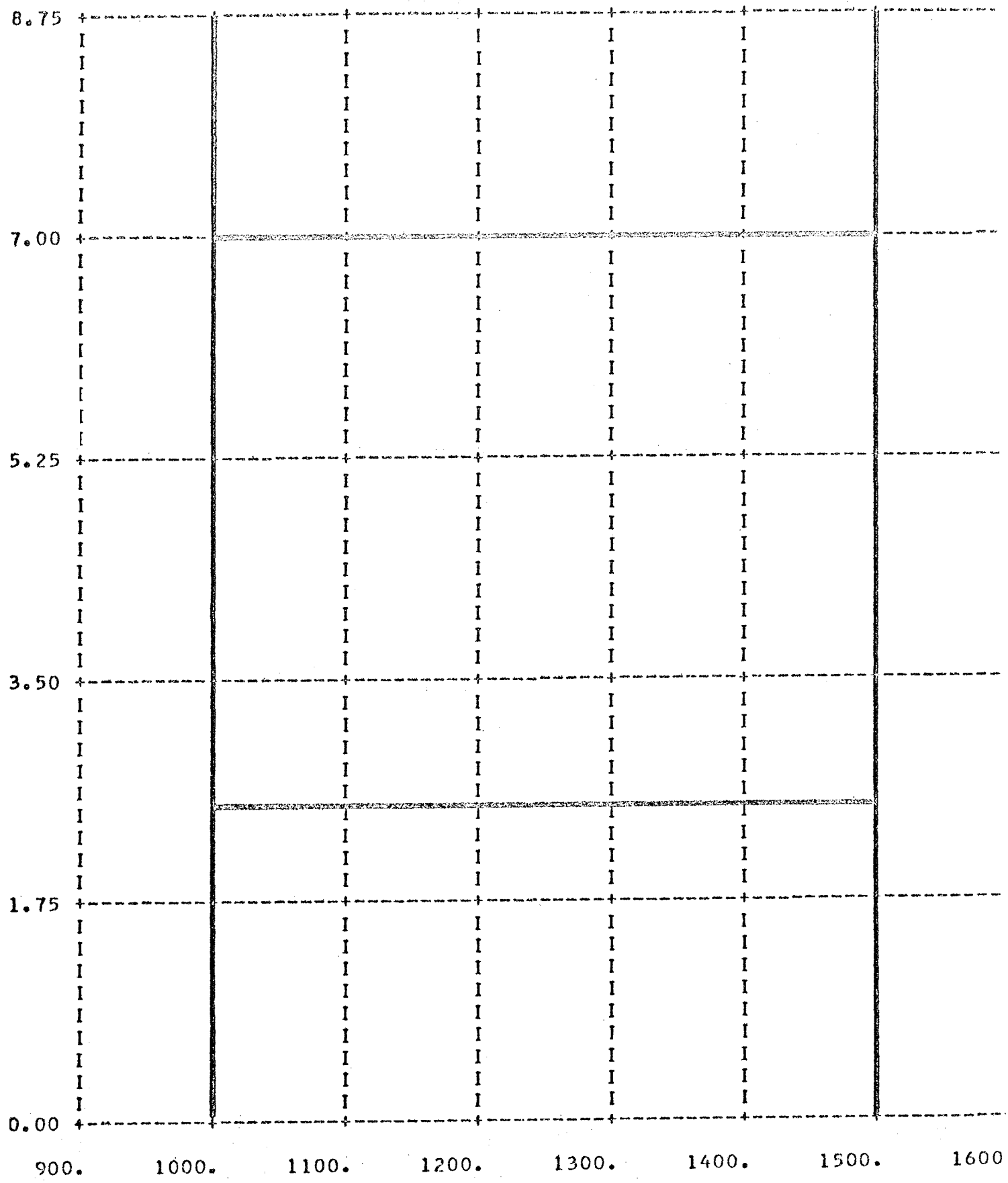
PRODUCER 6 GRADE AC 20



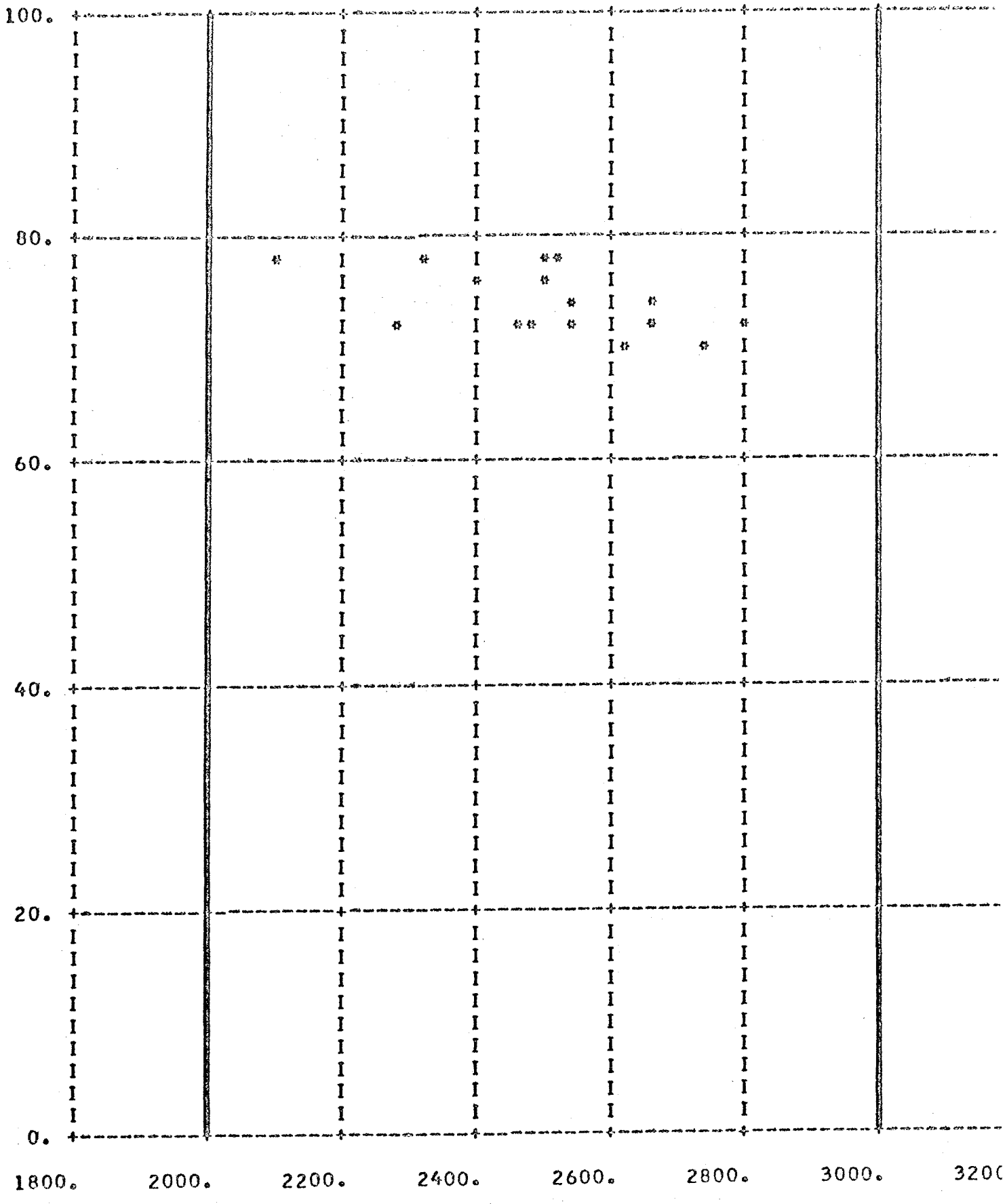
VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 9 GRADE AC 10



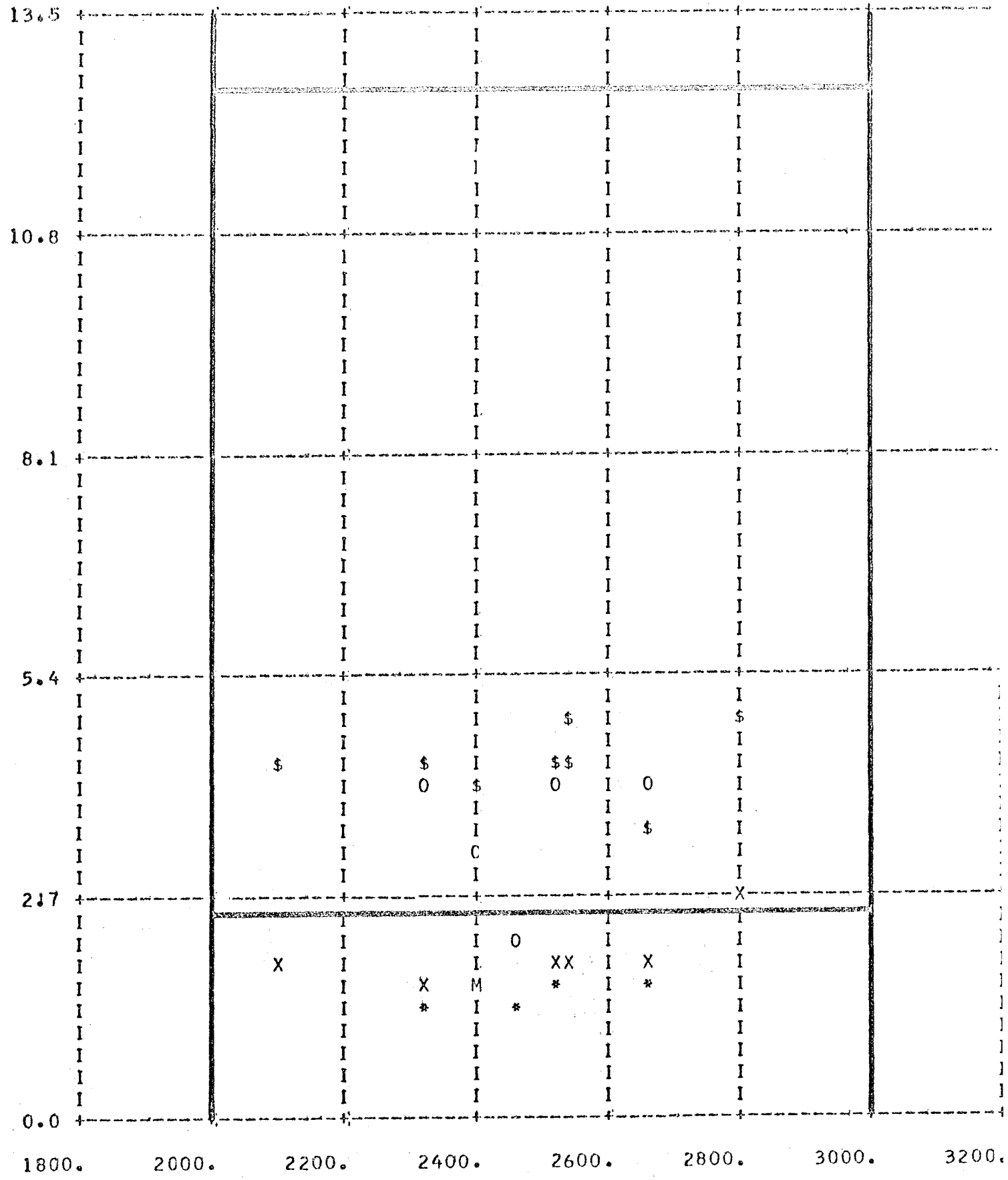
PRODUCER 9 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 9 GRADE AC 20

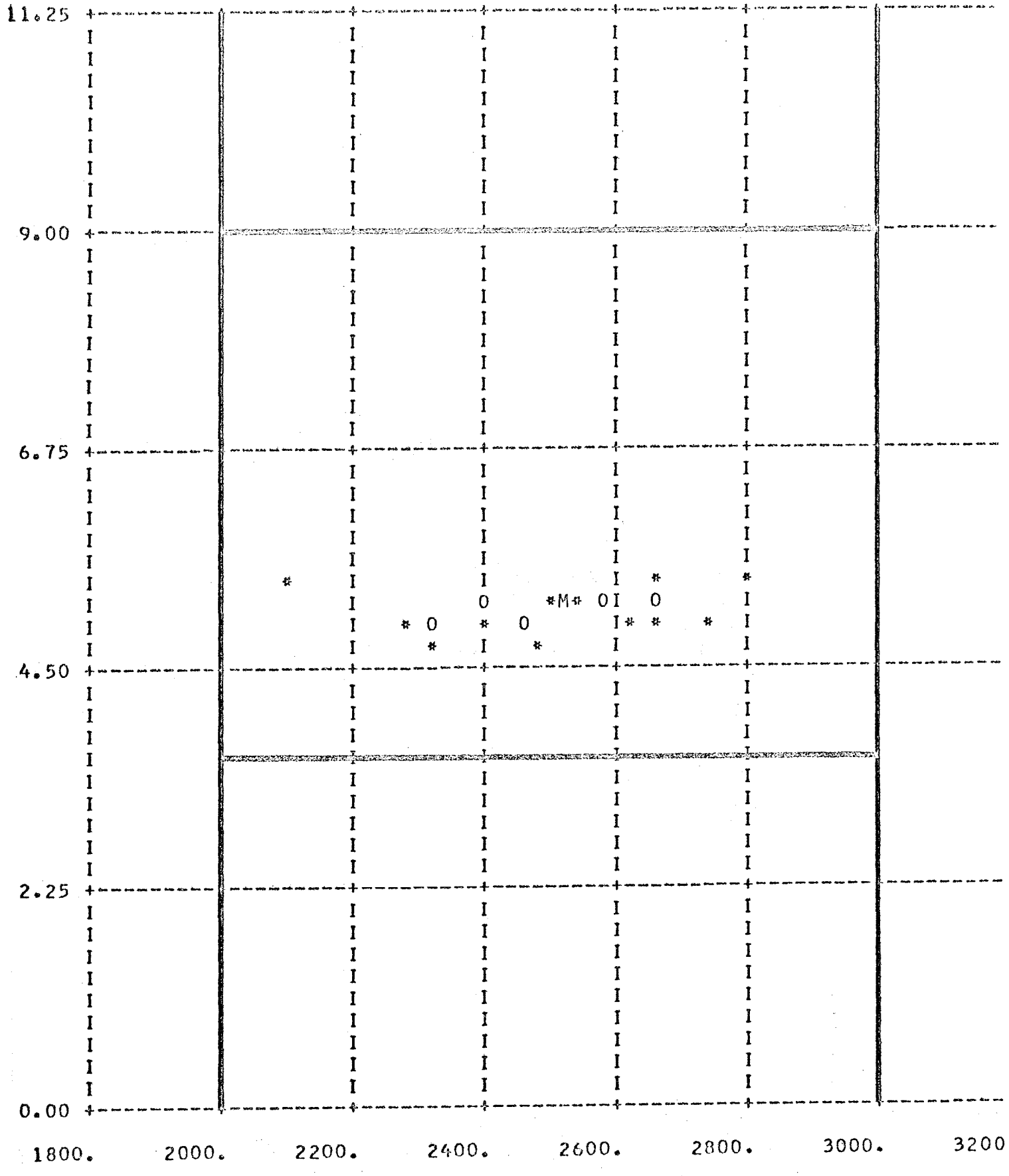


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

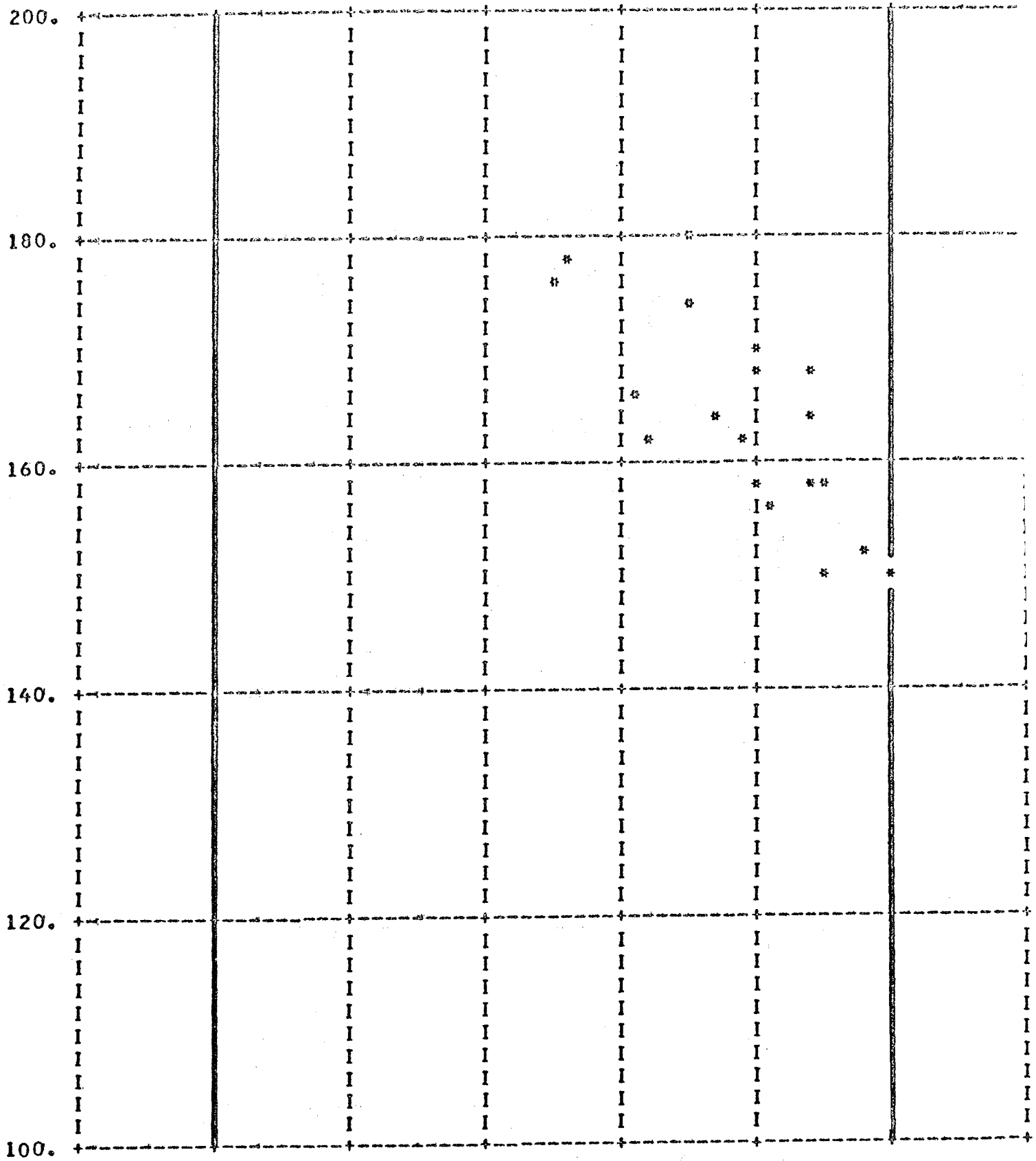
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 9 GRADE AC 20



Asphalt Supplier
No. 10

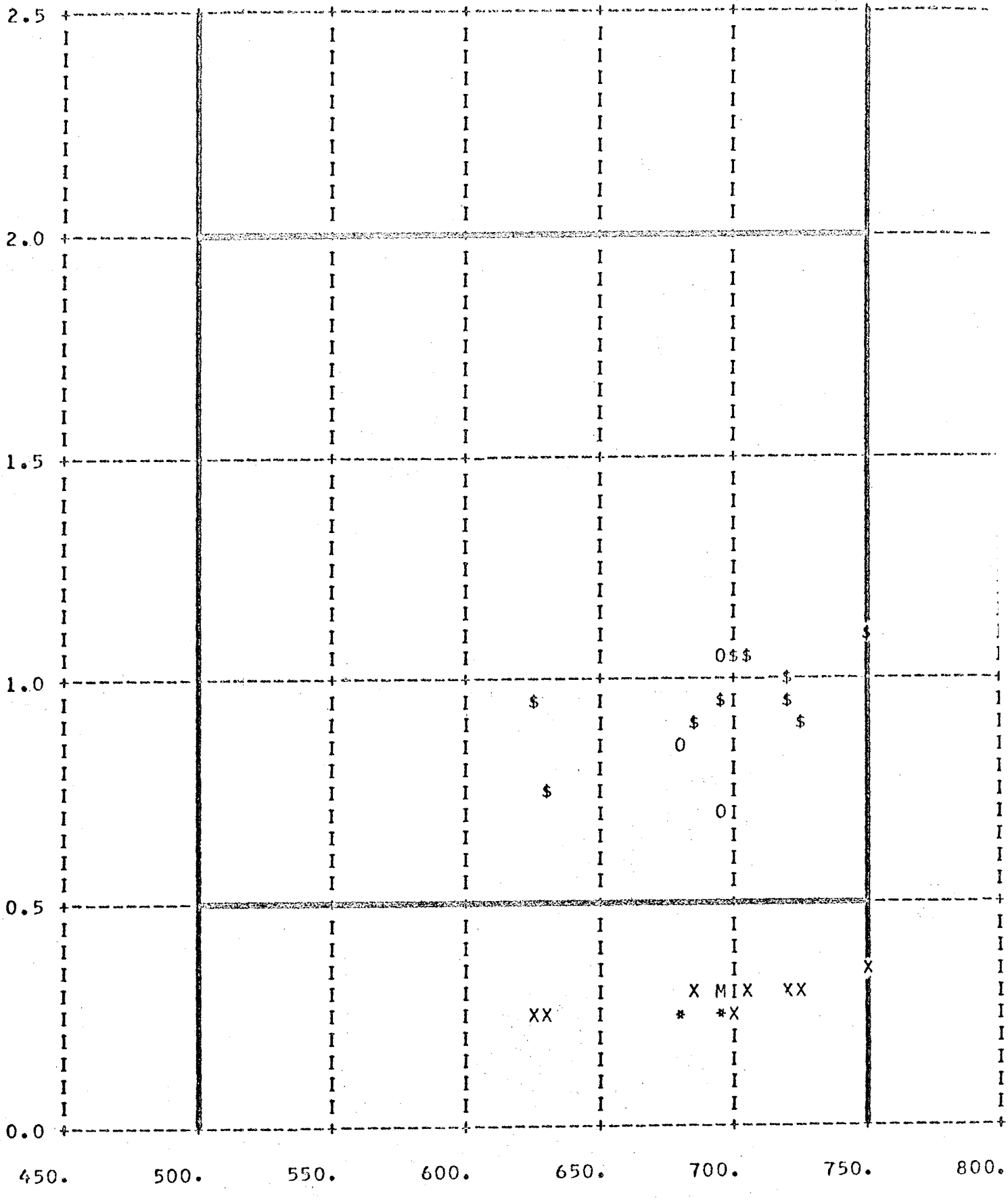
PRODUCER 10 GRADE AC 5



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 10 GRADE AC 5

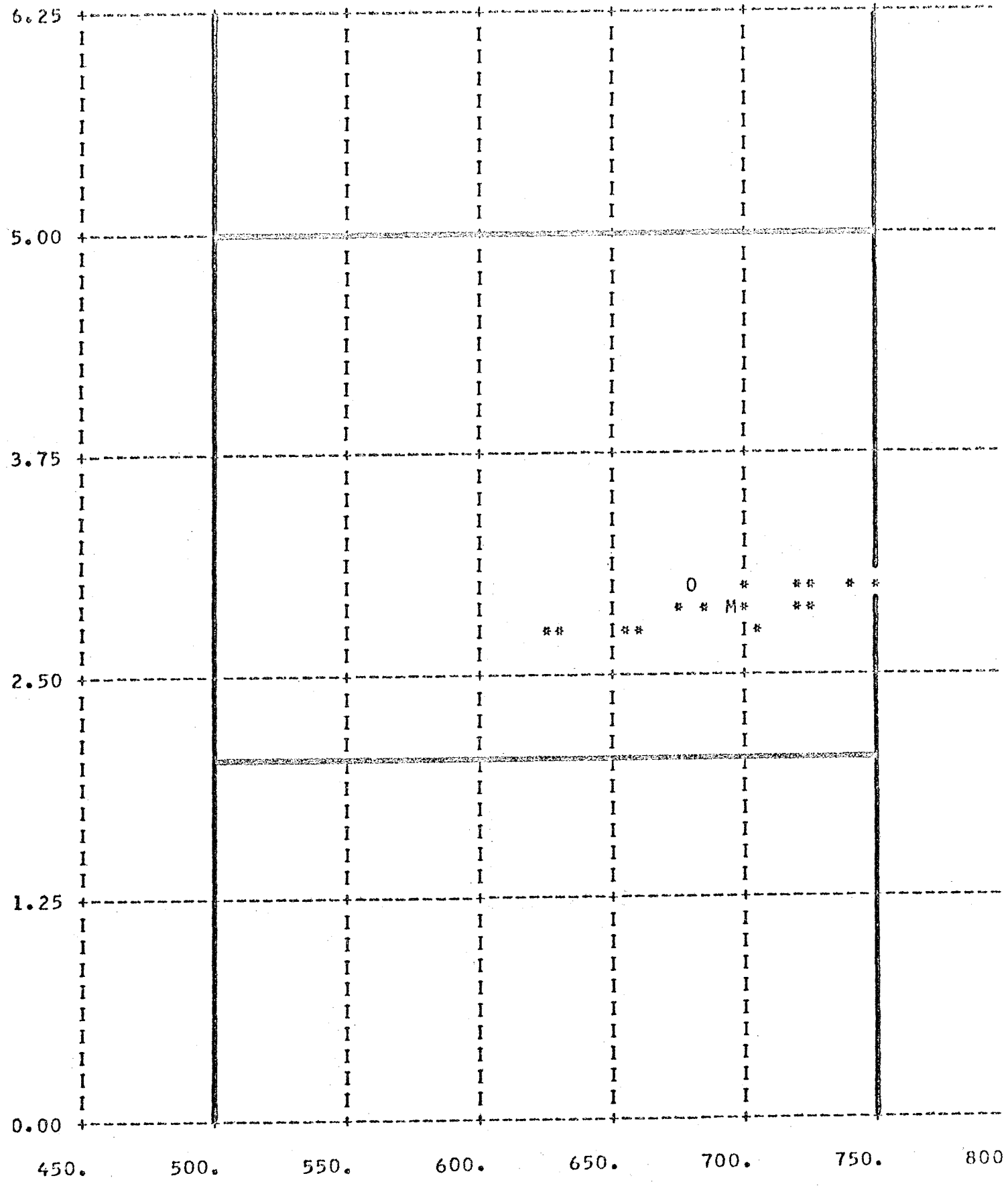


LEGEND
M MULTIPLE

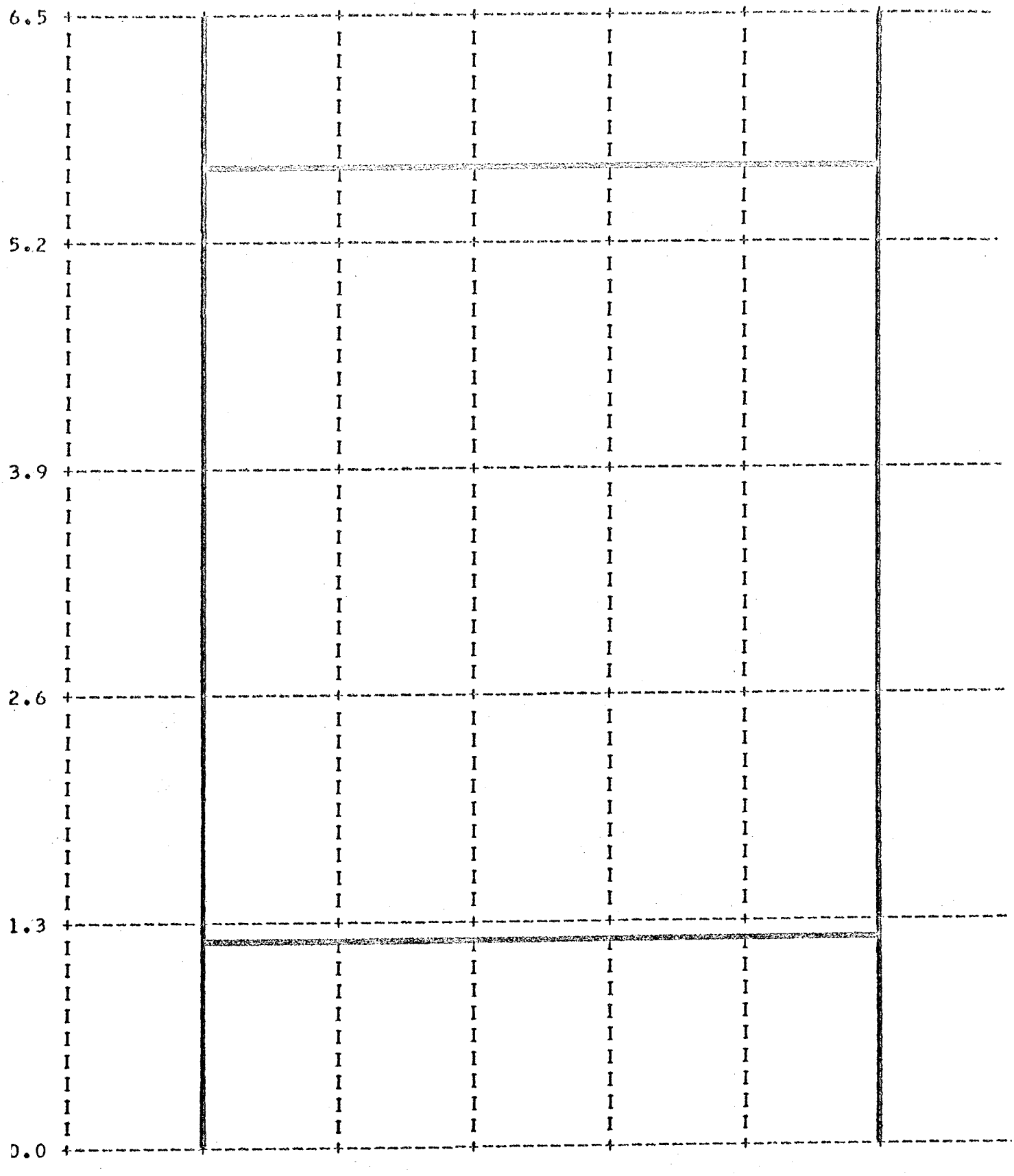
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 10 GRADE AC 5



PRODUCER 10 GRADE AC 10

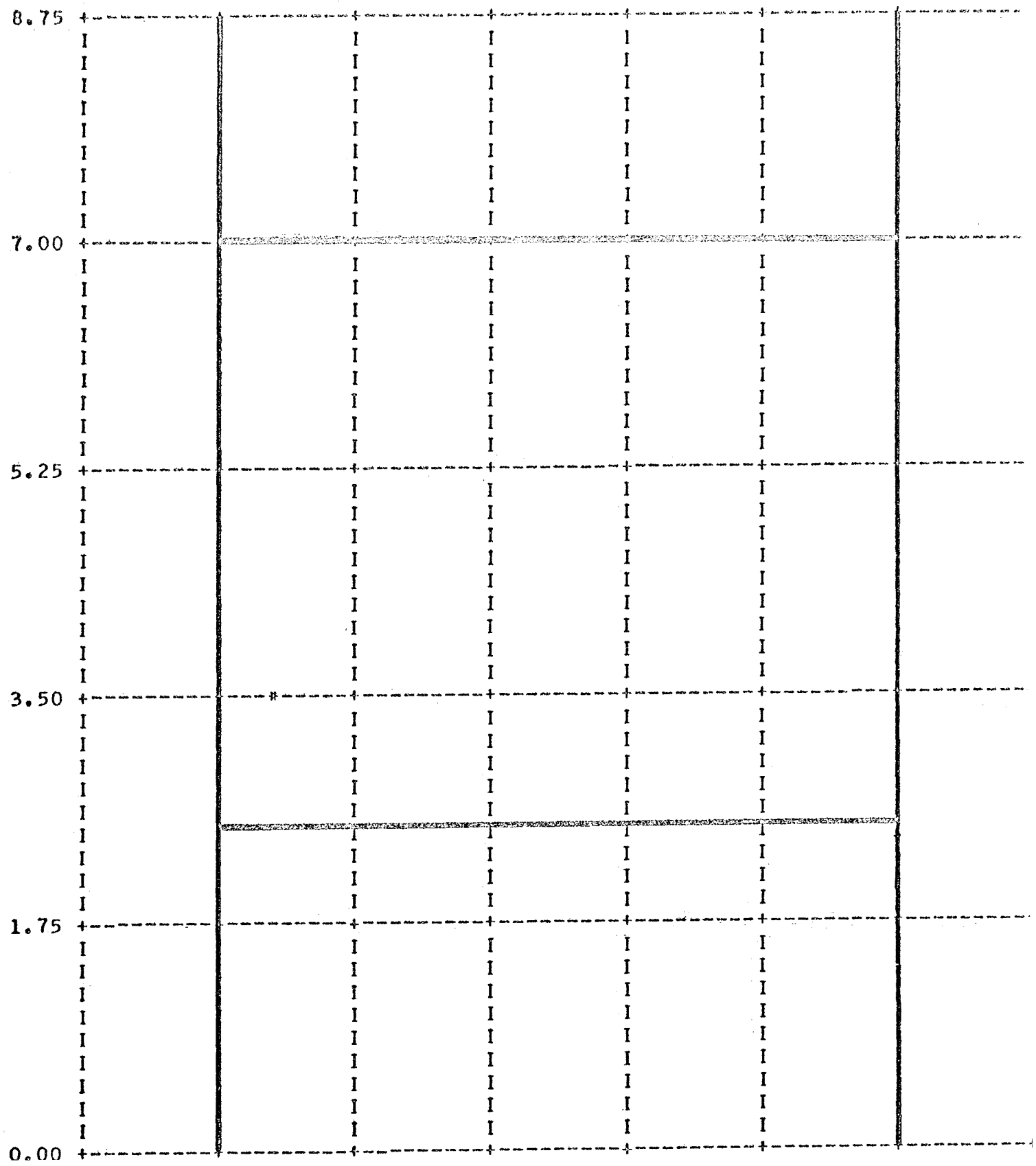


LEGEND
M MULTIPLE

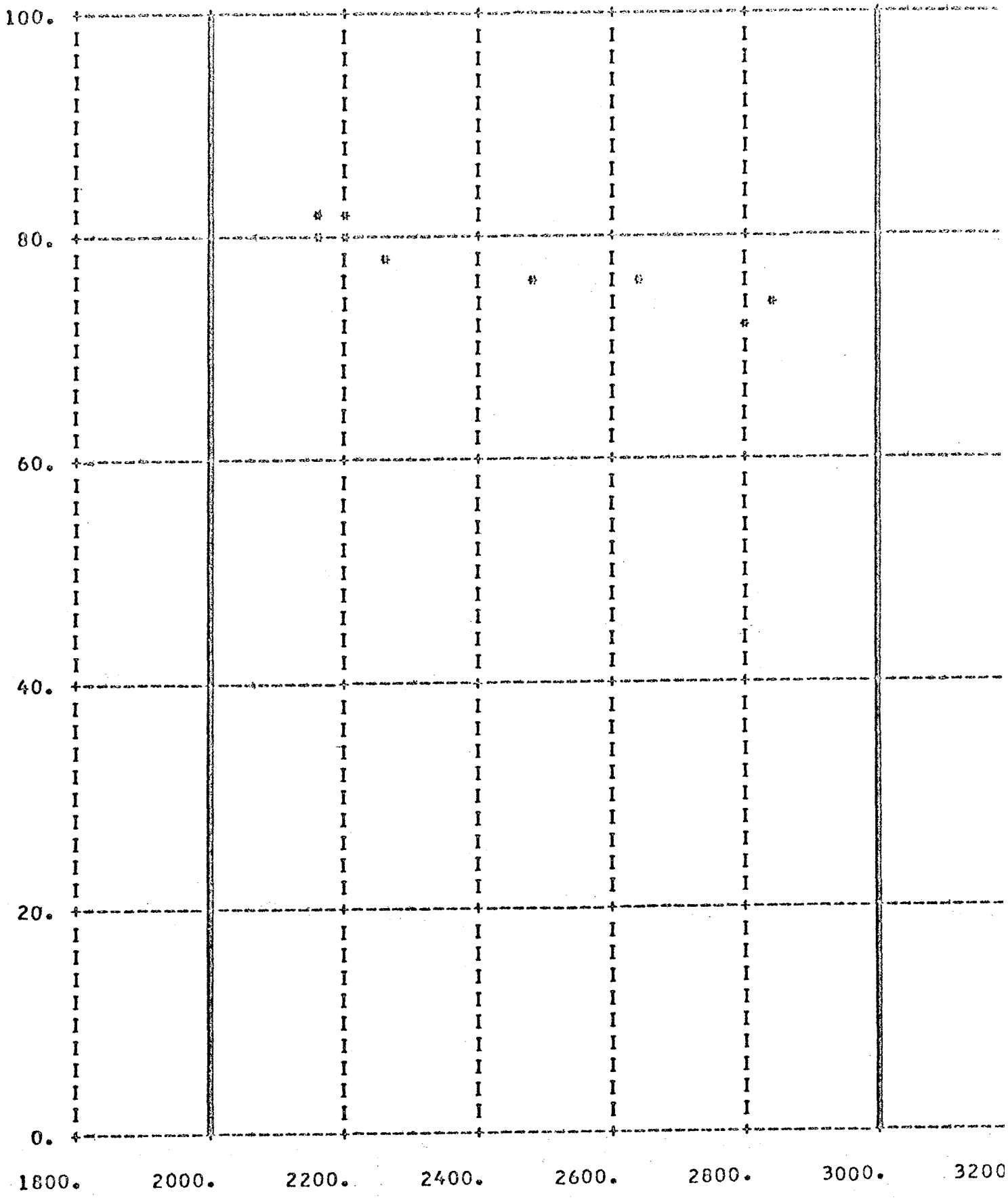
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

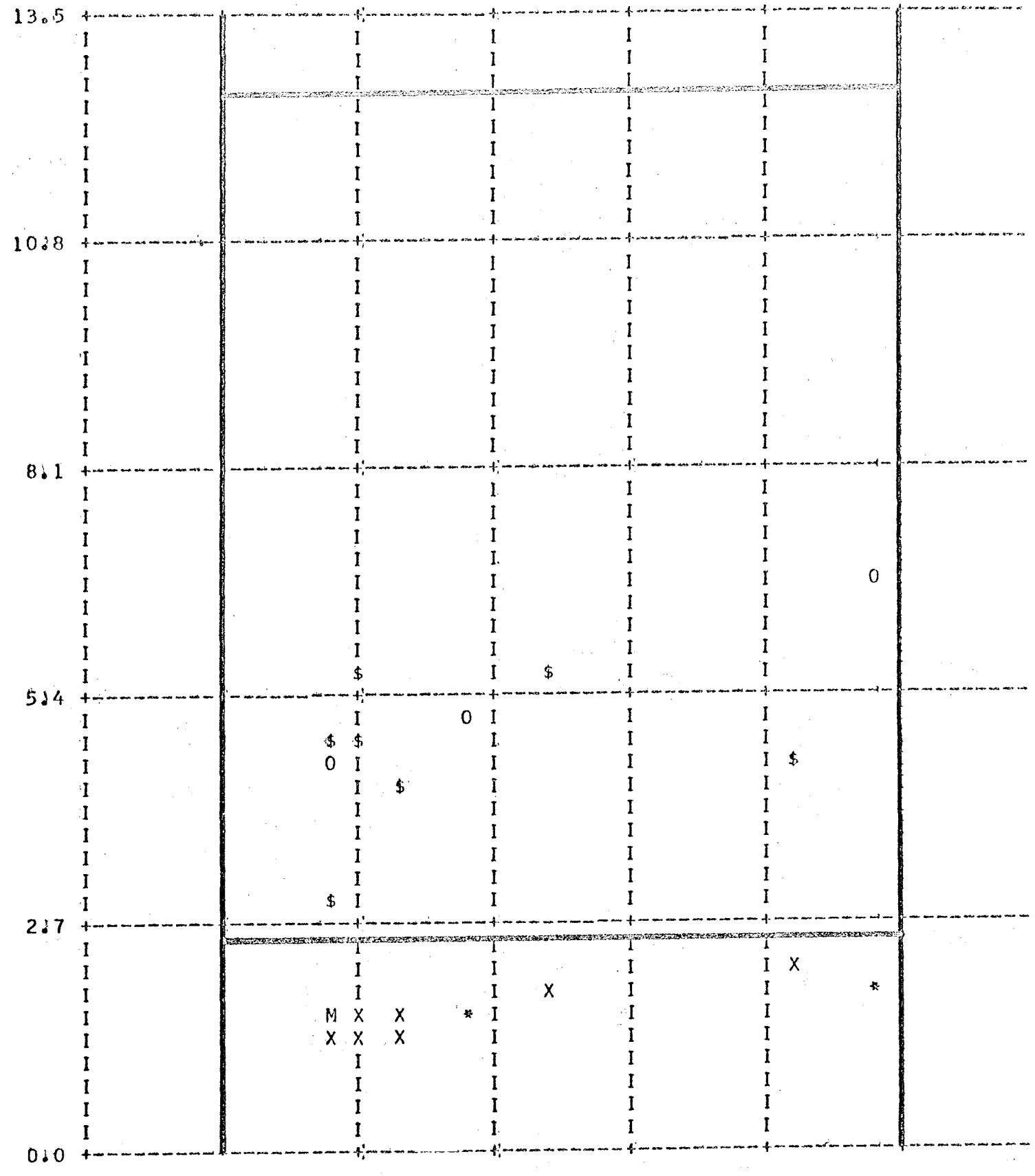
PRODUCER 10 GRADE AC 10



PRODUCER 10 GRADE AC 20



PRODUCER 10 GRADE AC 20

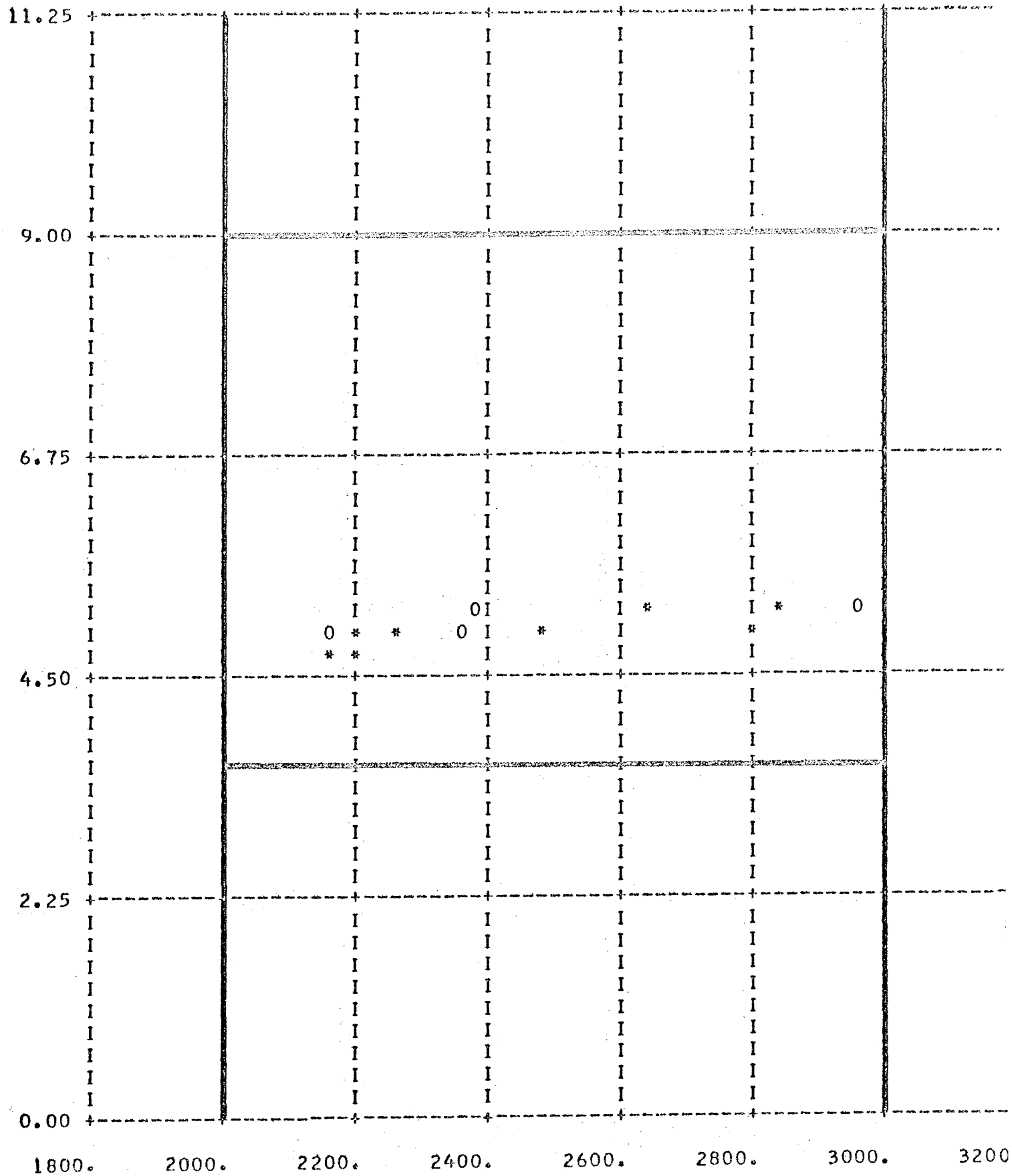


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

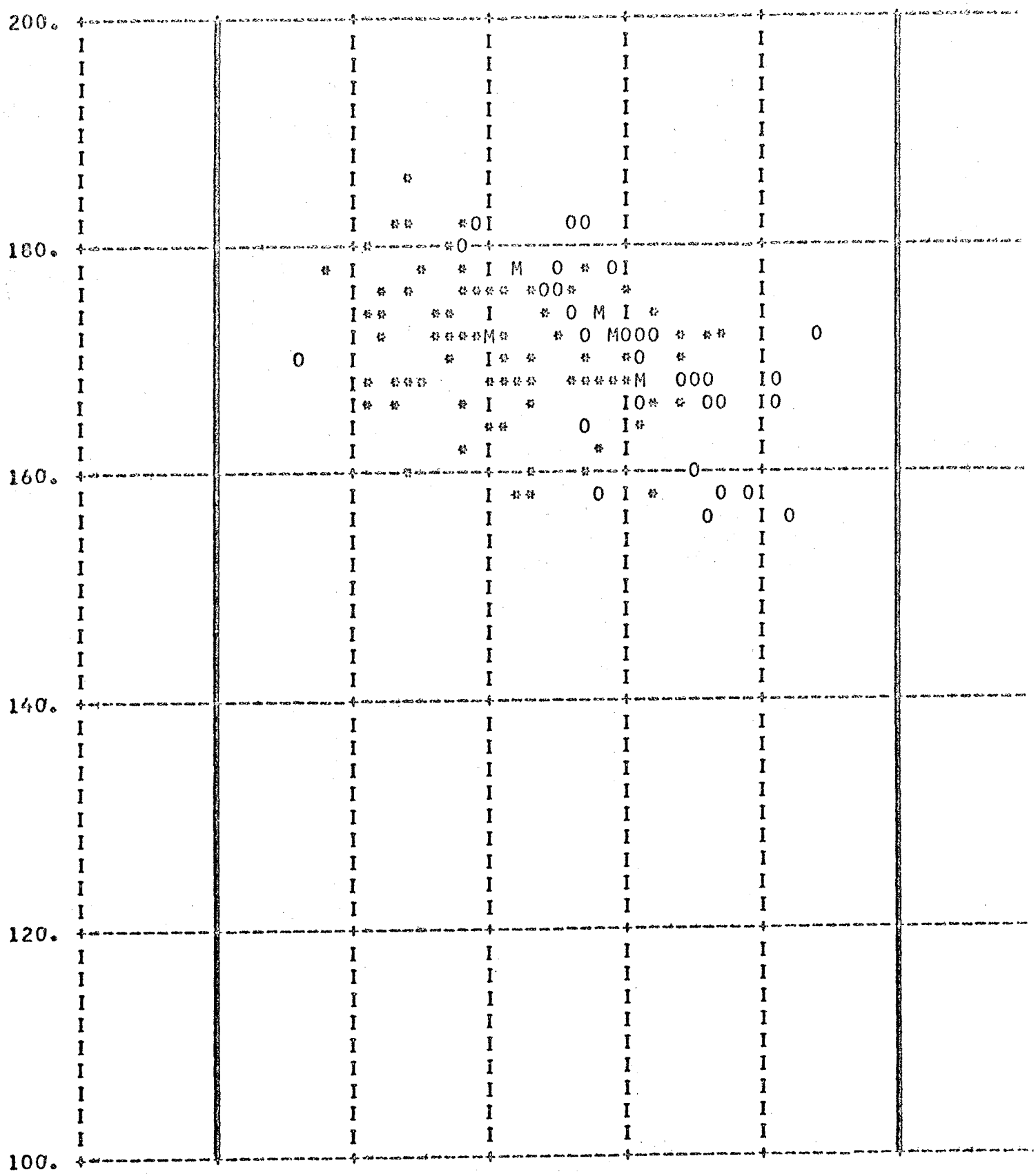
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 10 GRADE AC 20



Asphalt Supplier
No. 11

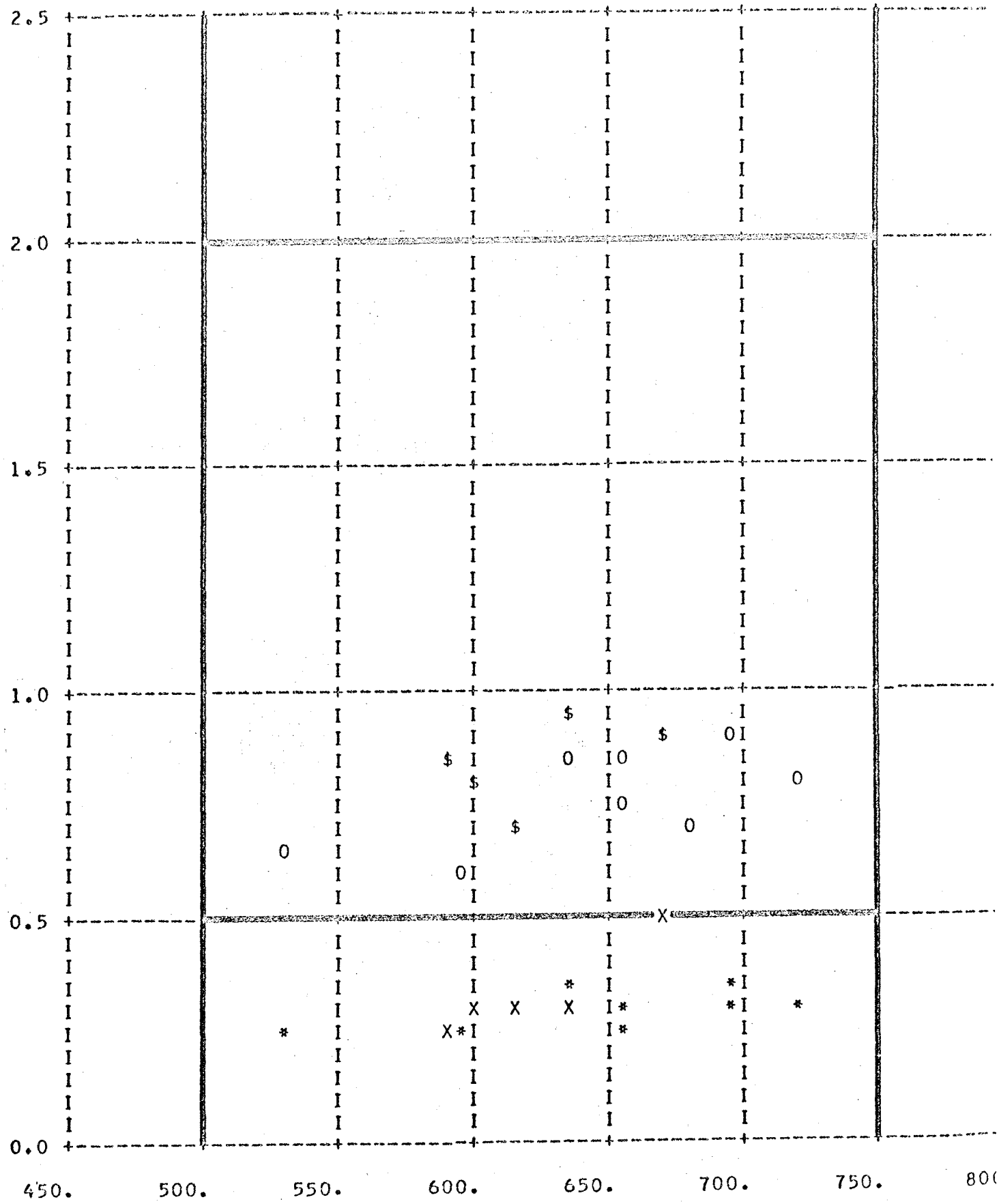
PRODUCER 11 GRADE AC 5



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 11 GRADE AC 5



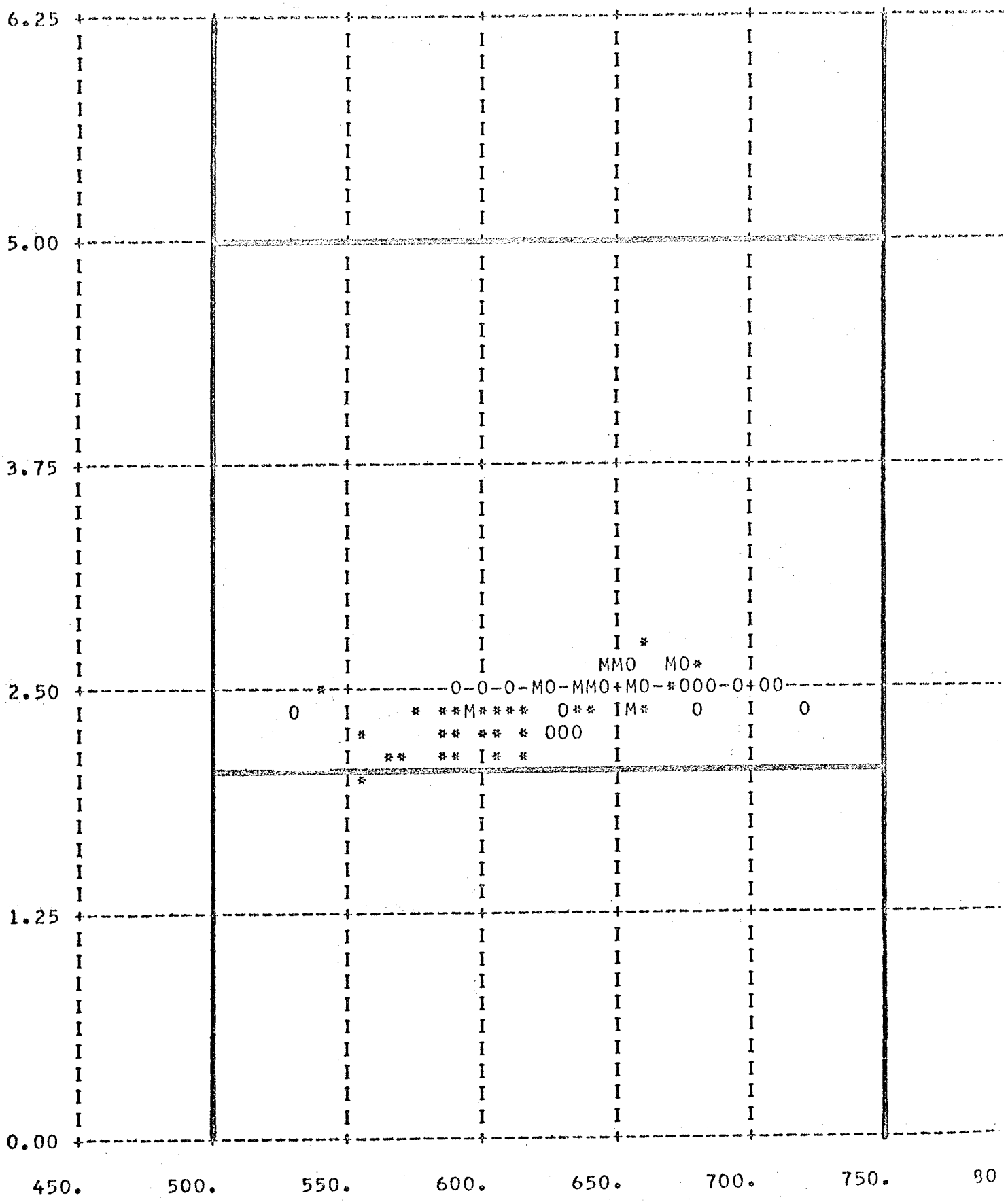
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

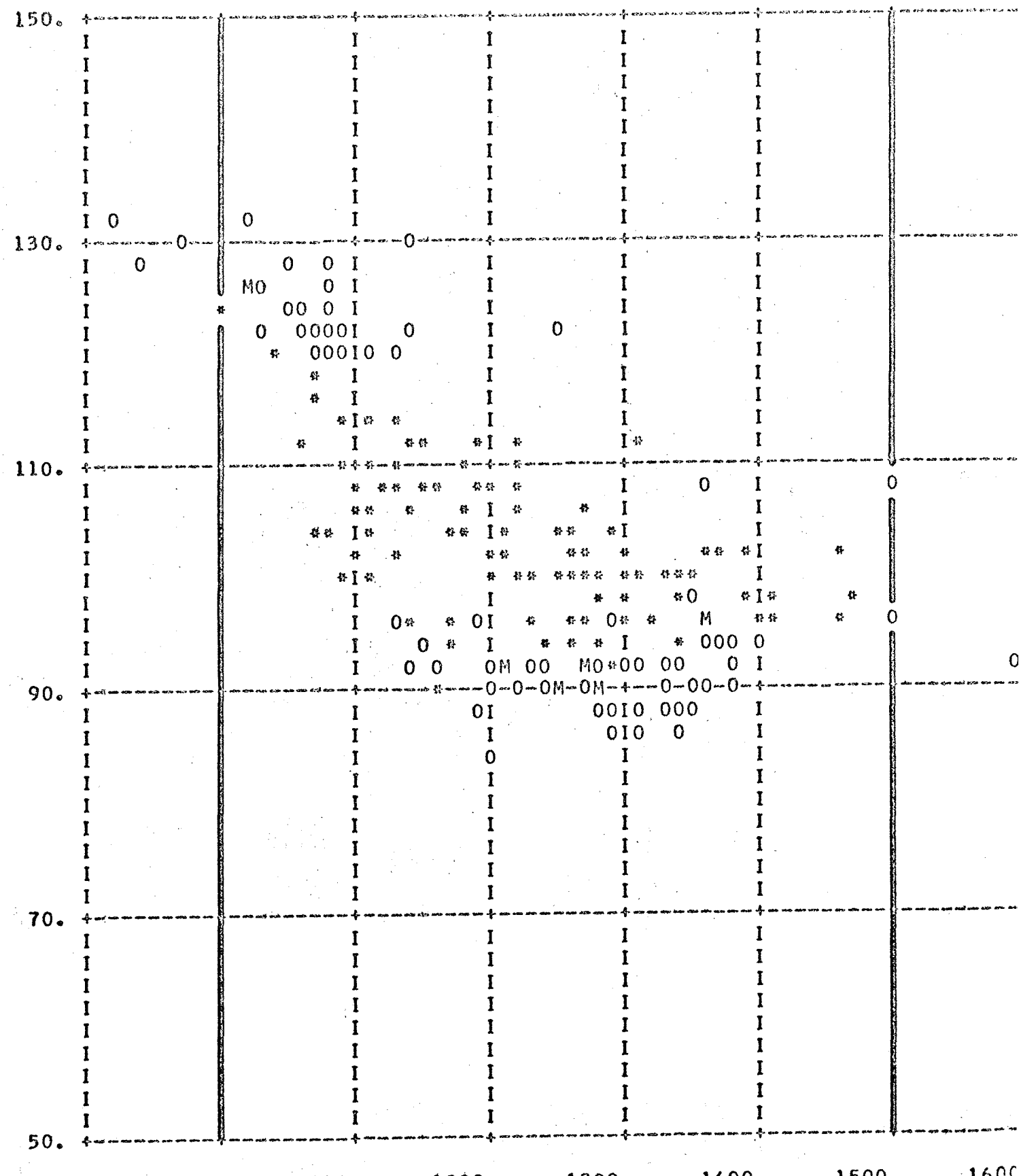
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AI
0 1965 $ 1966

PRODUCER 11 GRADE AC 5



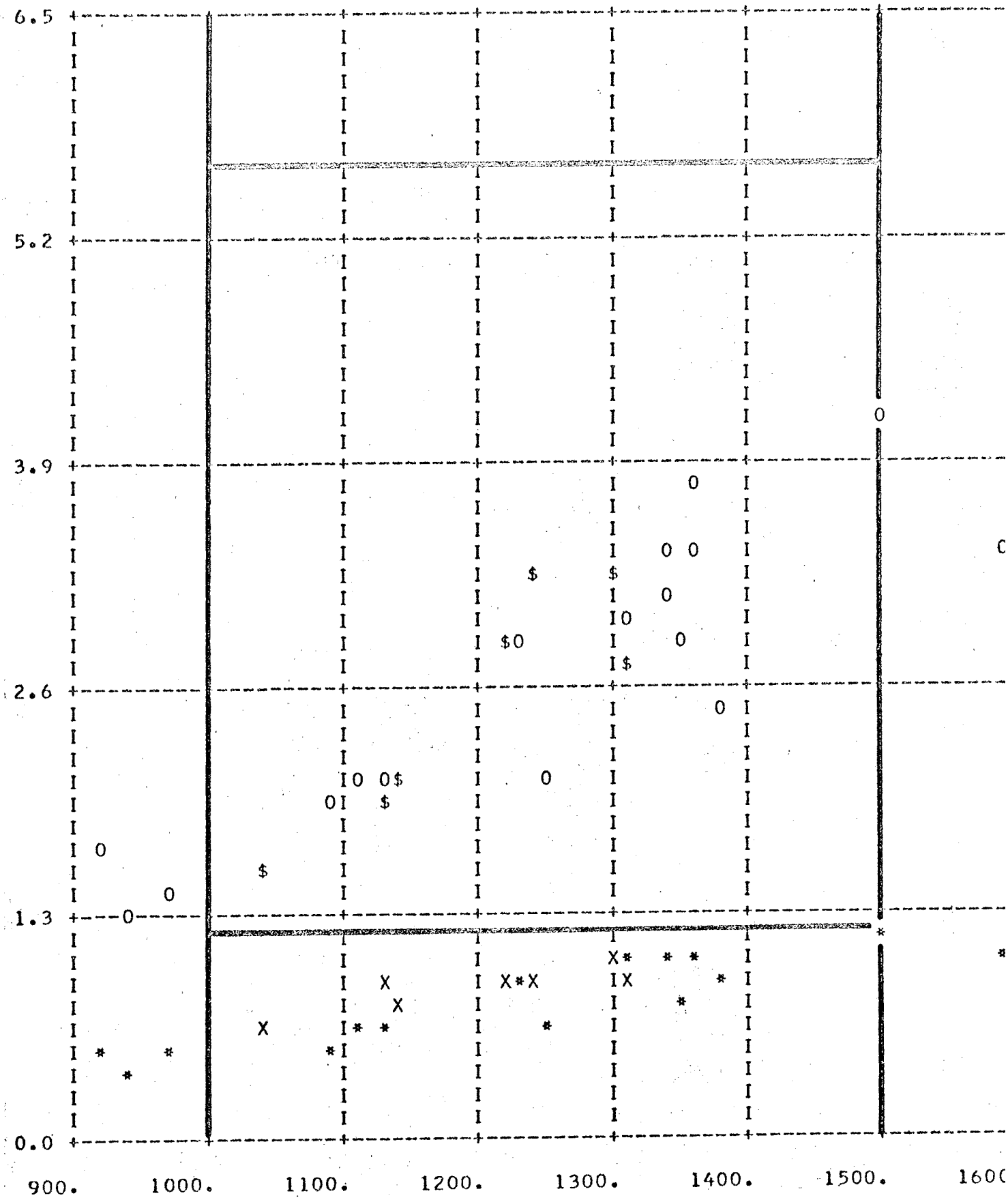
PRODUCER 11 GRADE AC 10



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 11 GRADE AC 10

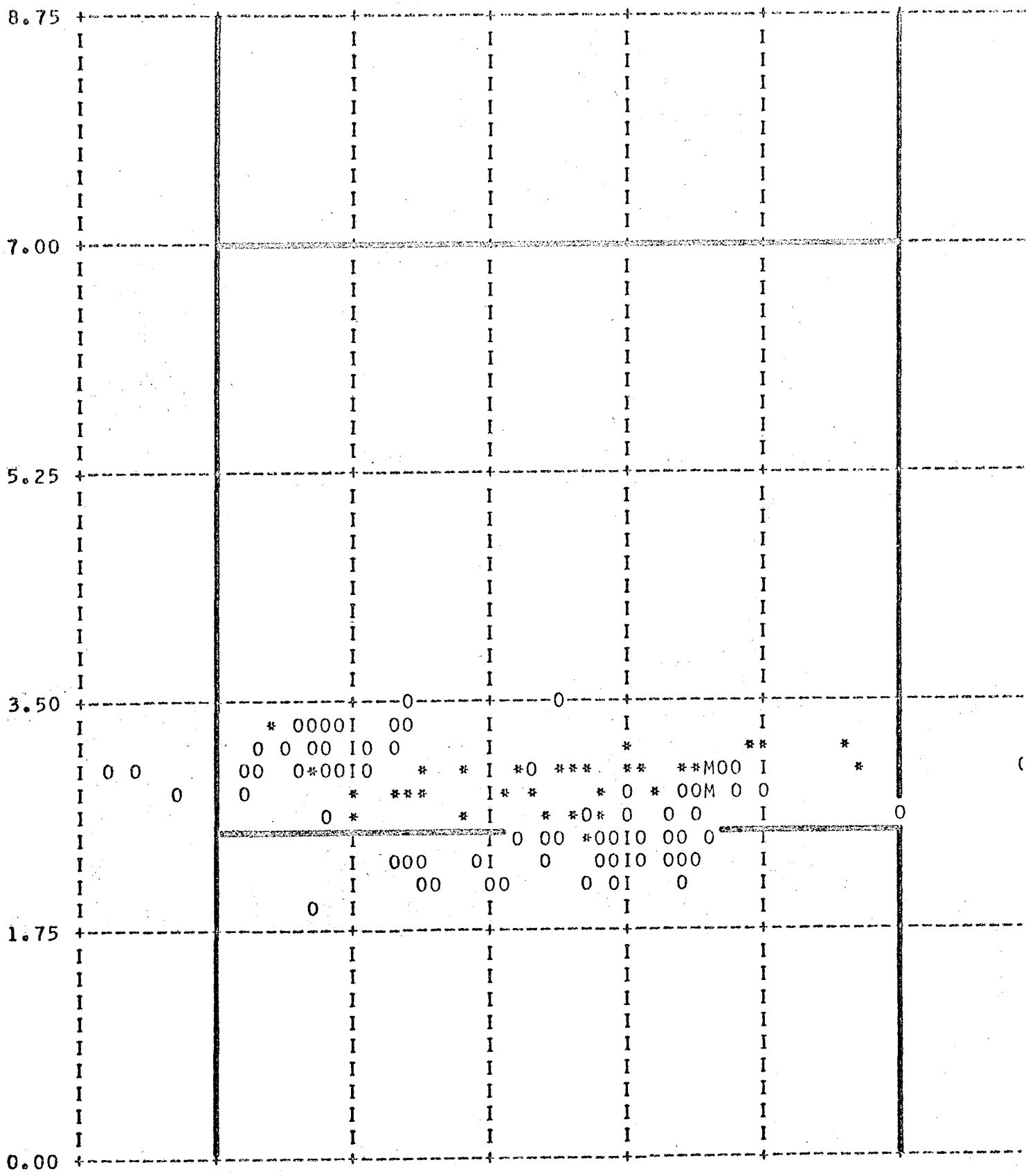


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

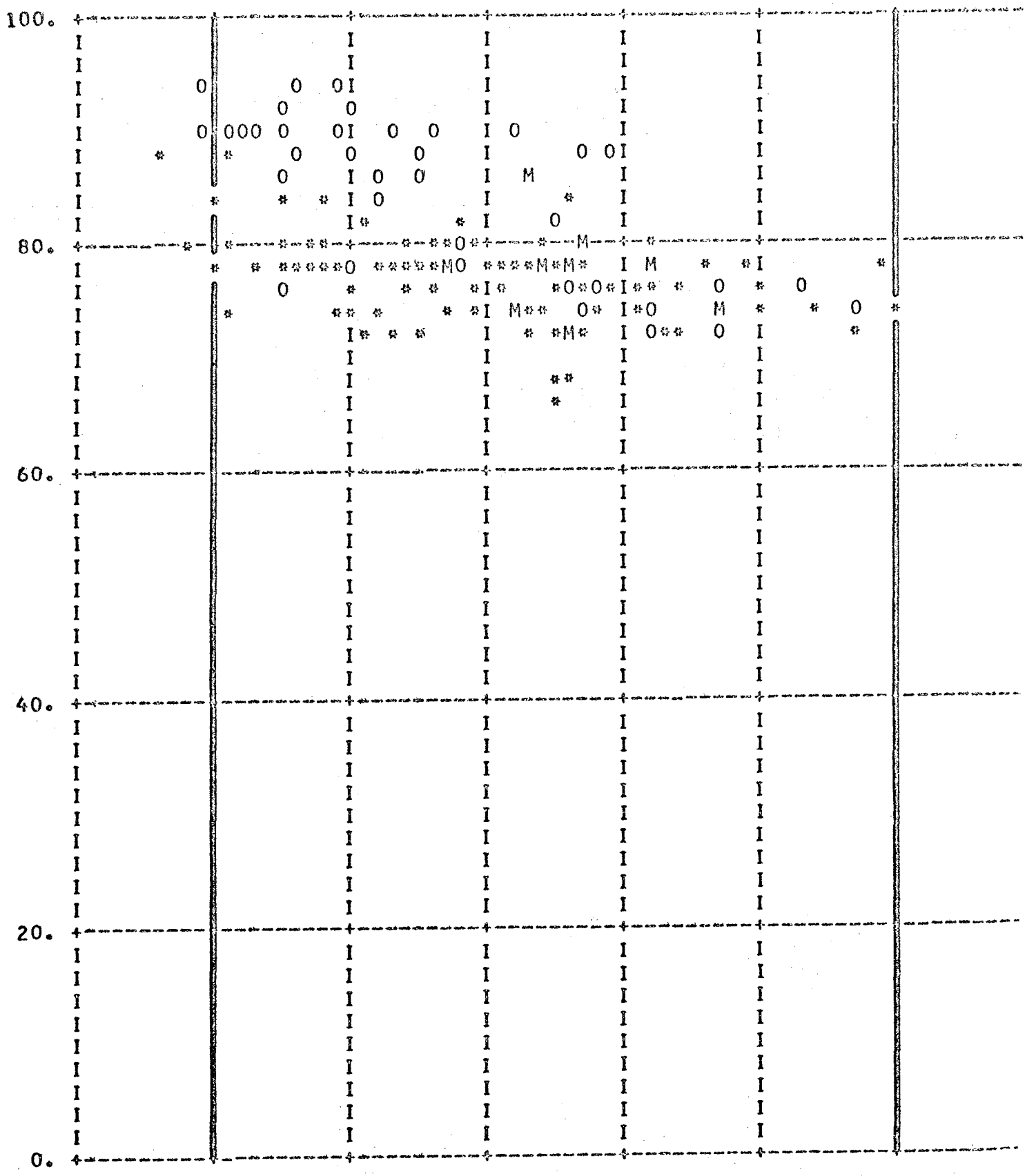
PRODUCER 11 GRADE AC 10



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

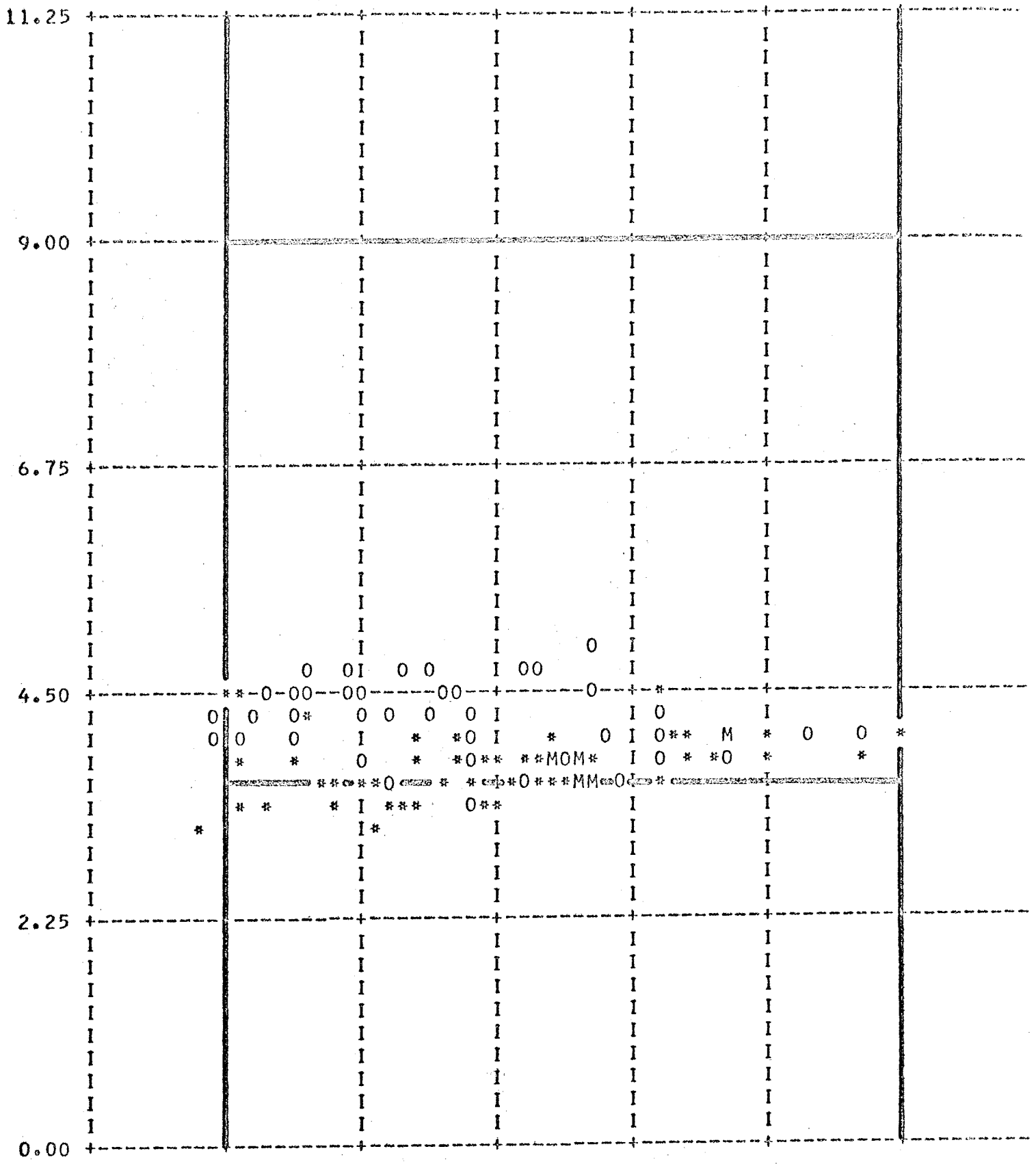
PRODUCER 11 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 11 GRADE AC 20

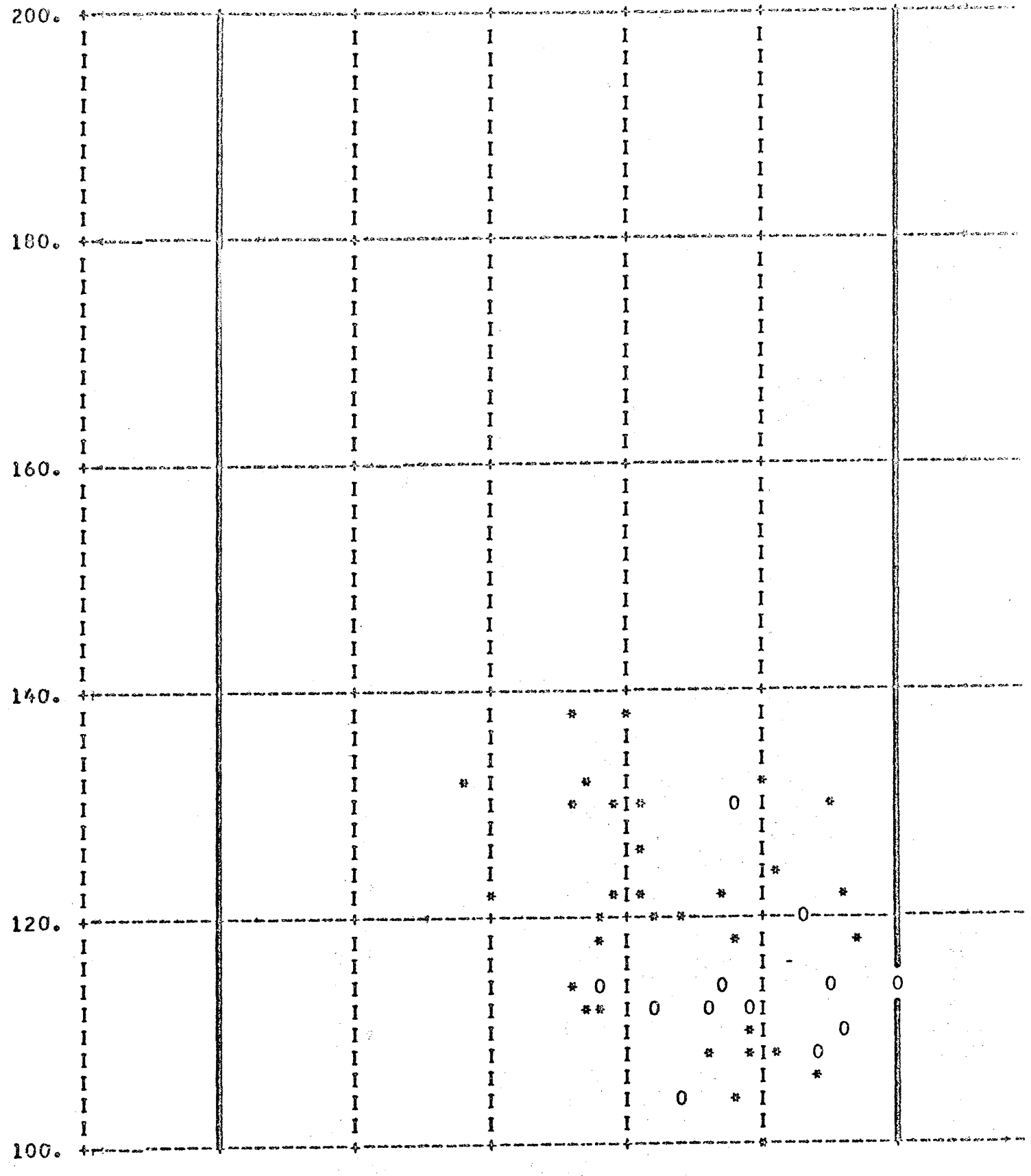


V I S C O S I T Y S T O K E S 1 4 0 F

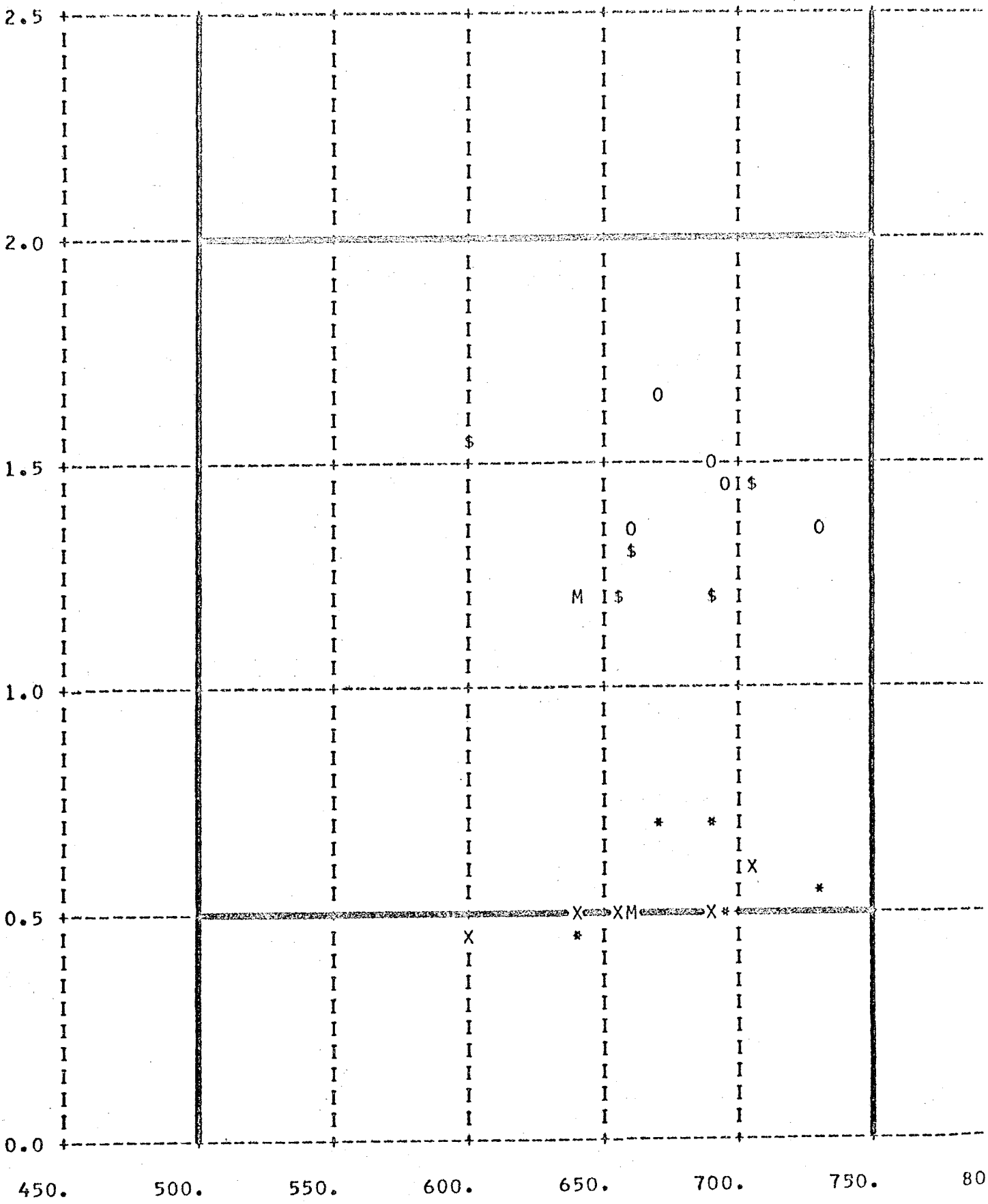
LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 12

PRODUCER 12 GRADE AC 5



PRODUCER 12 GRADE AC 5

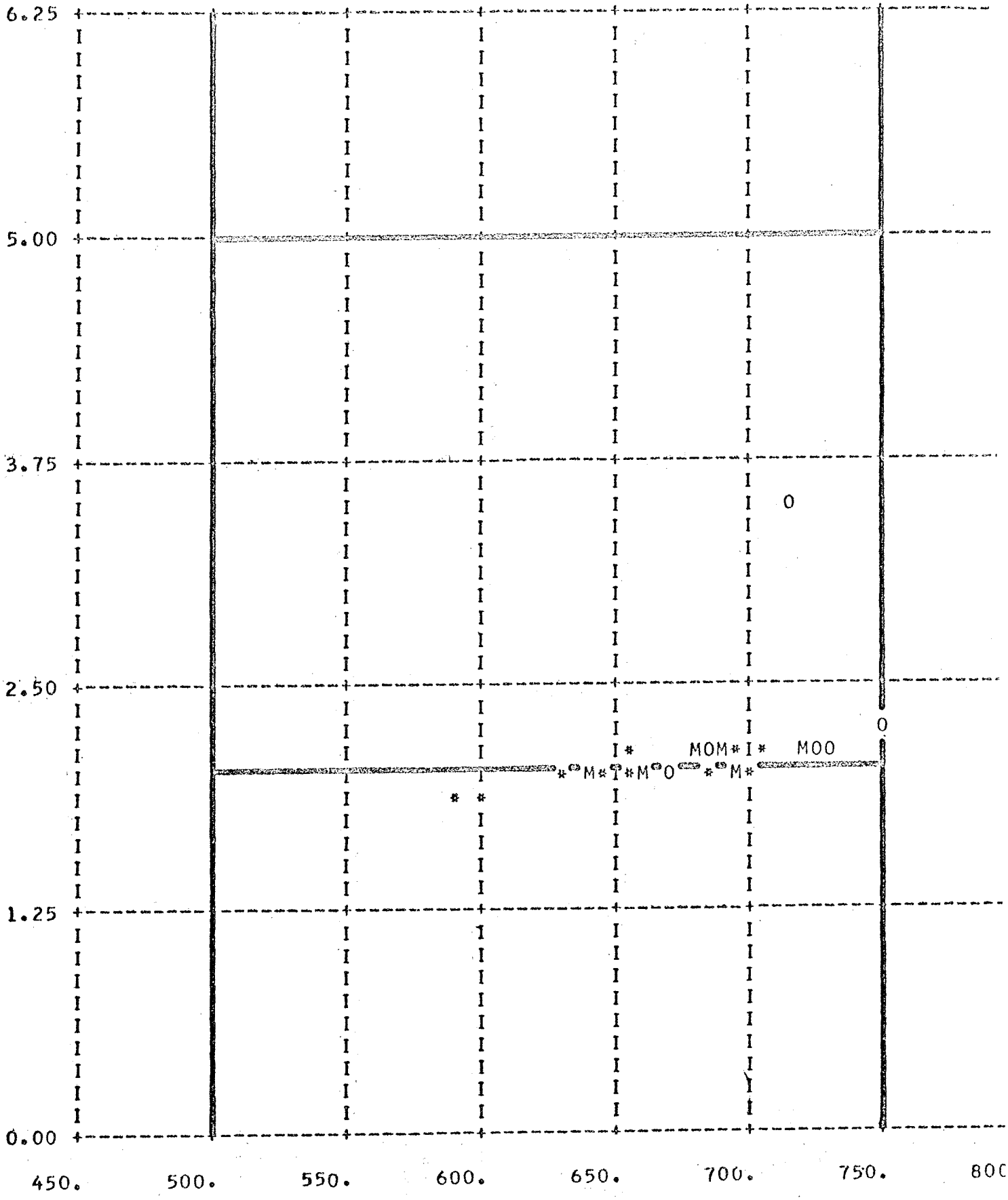


LEGEND
M MULTIPLE

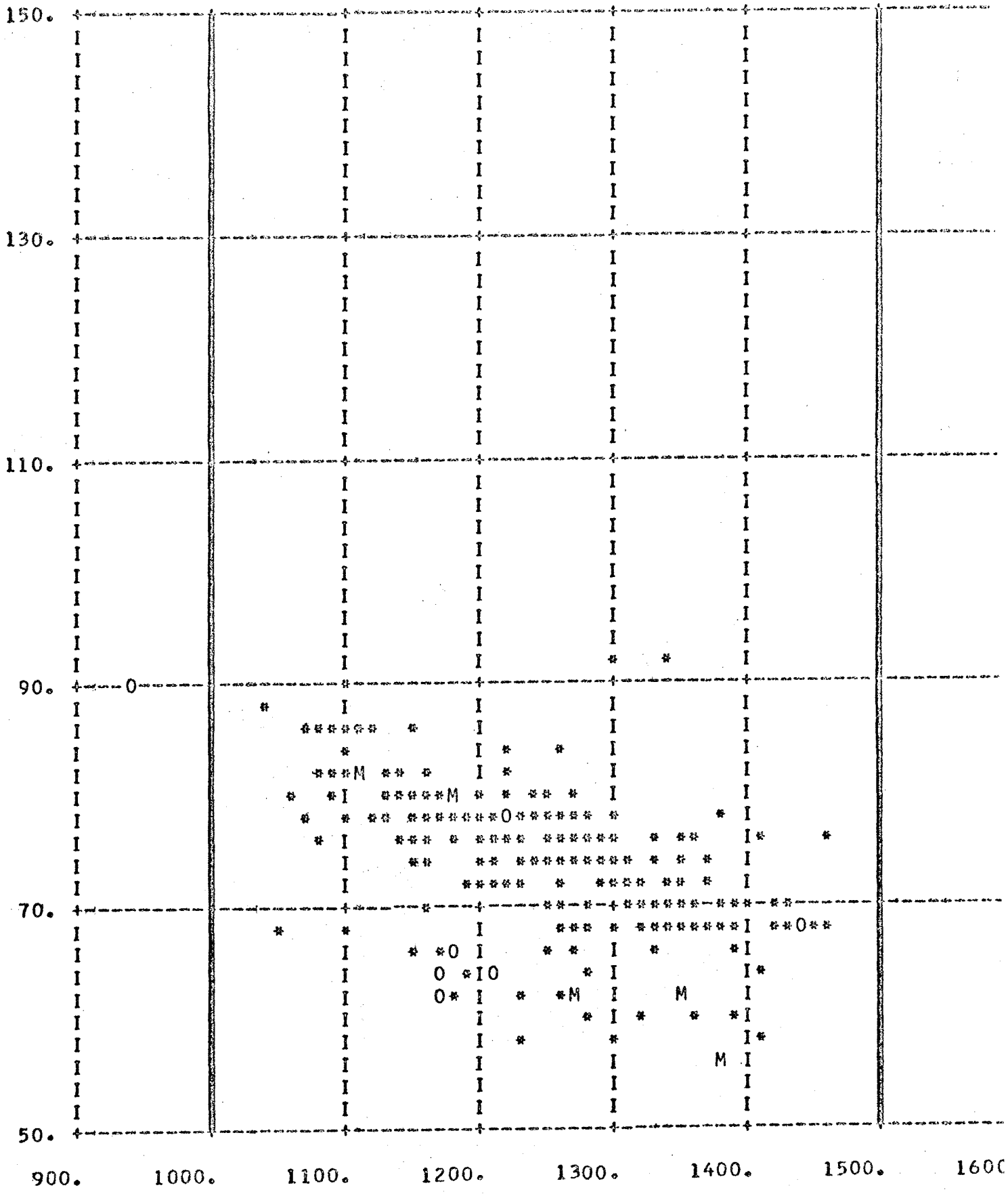
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AI
0 1965 $ 1966

PRODUCER 12 GRADE AC 5



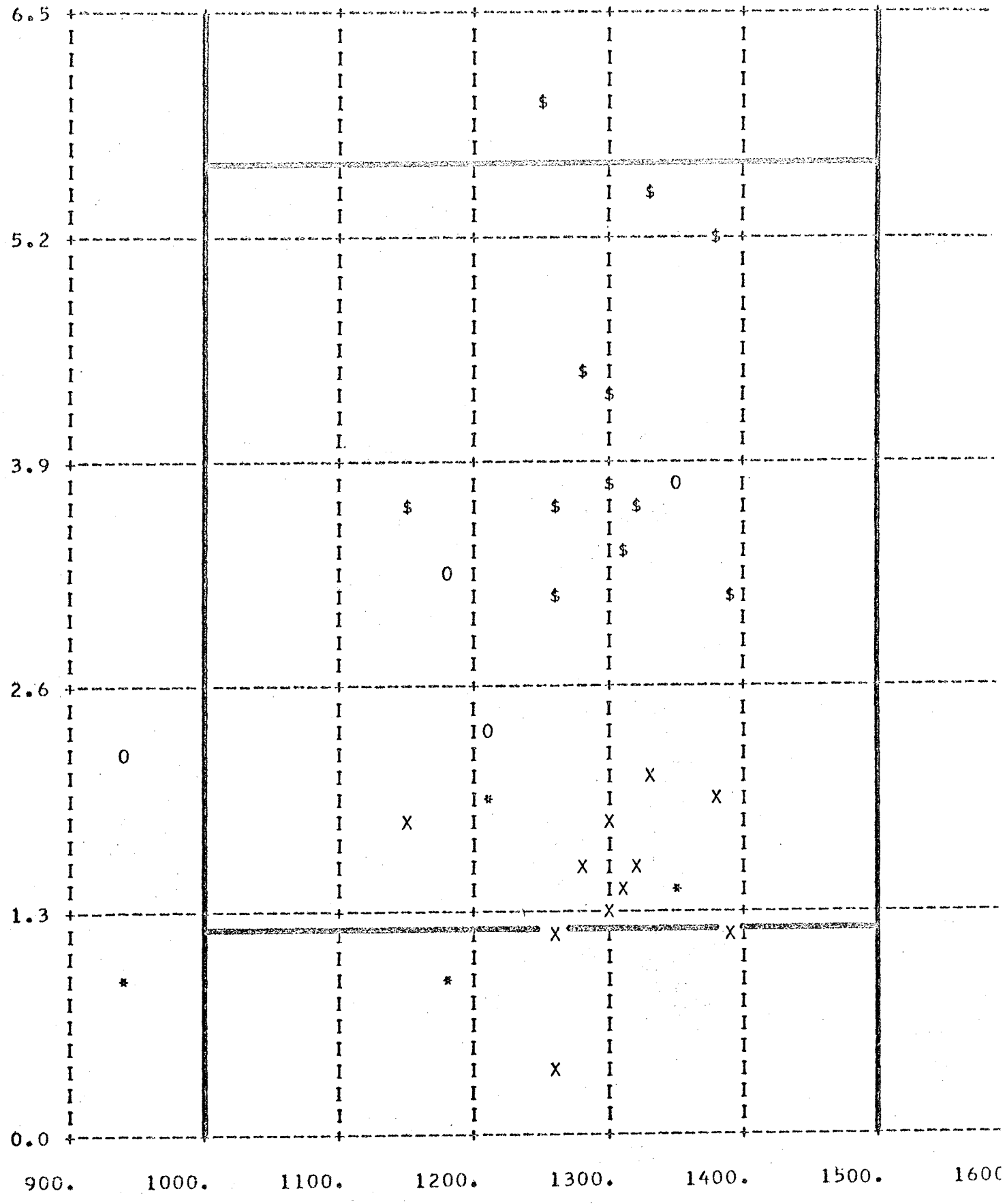
PRODUCER 12 GRADE AC 10



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 12 GRADE AC 10



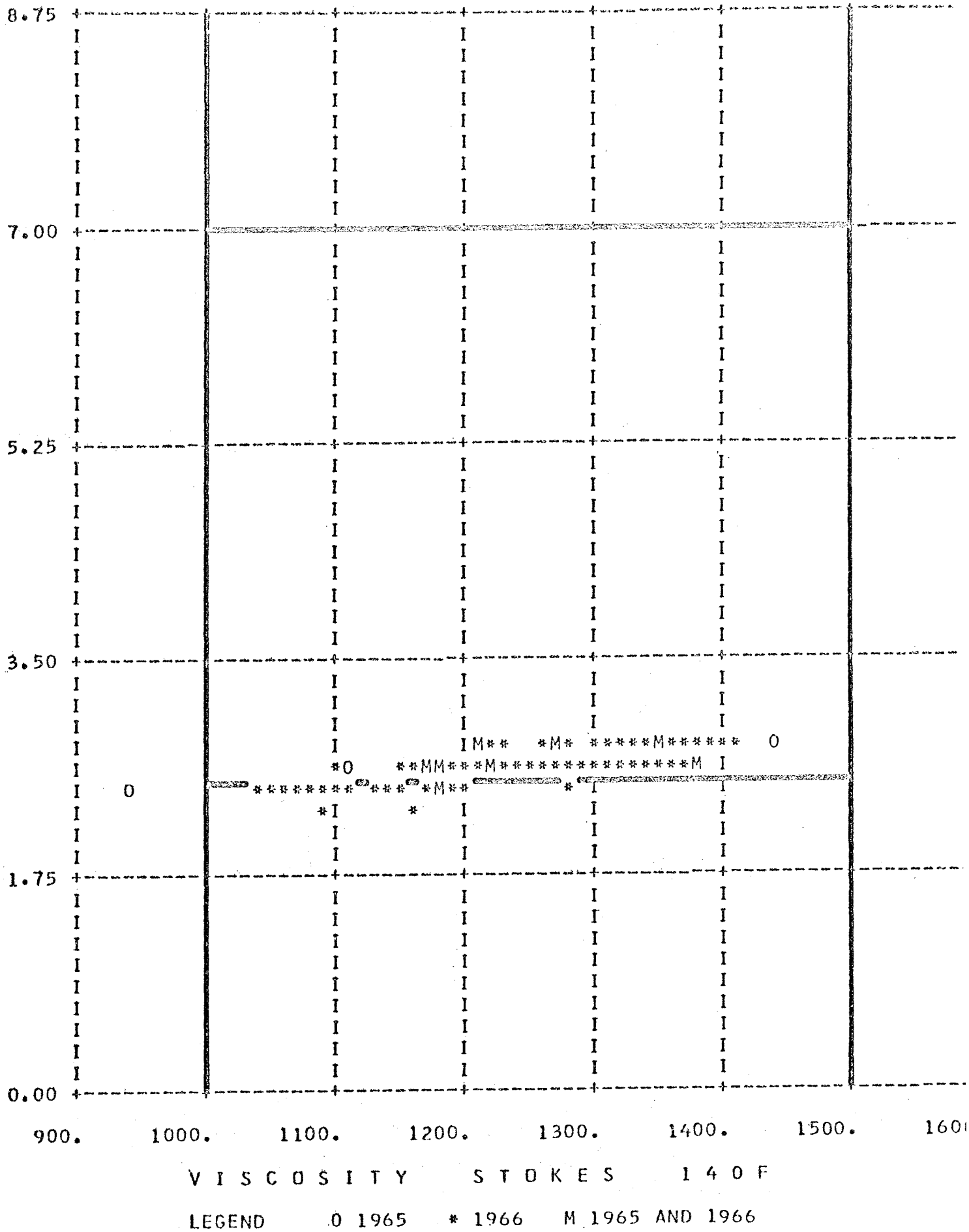
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

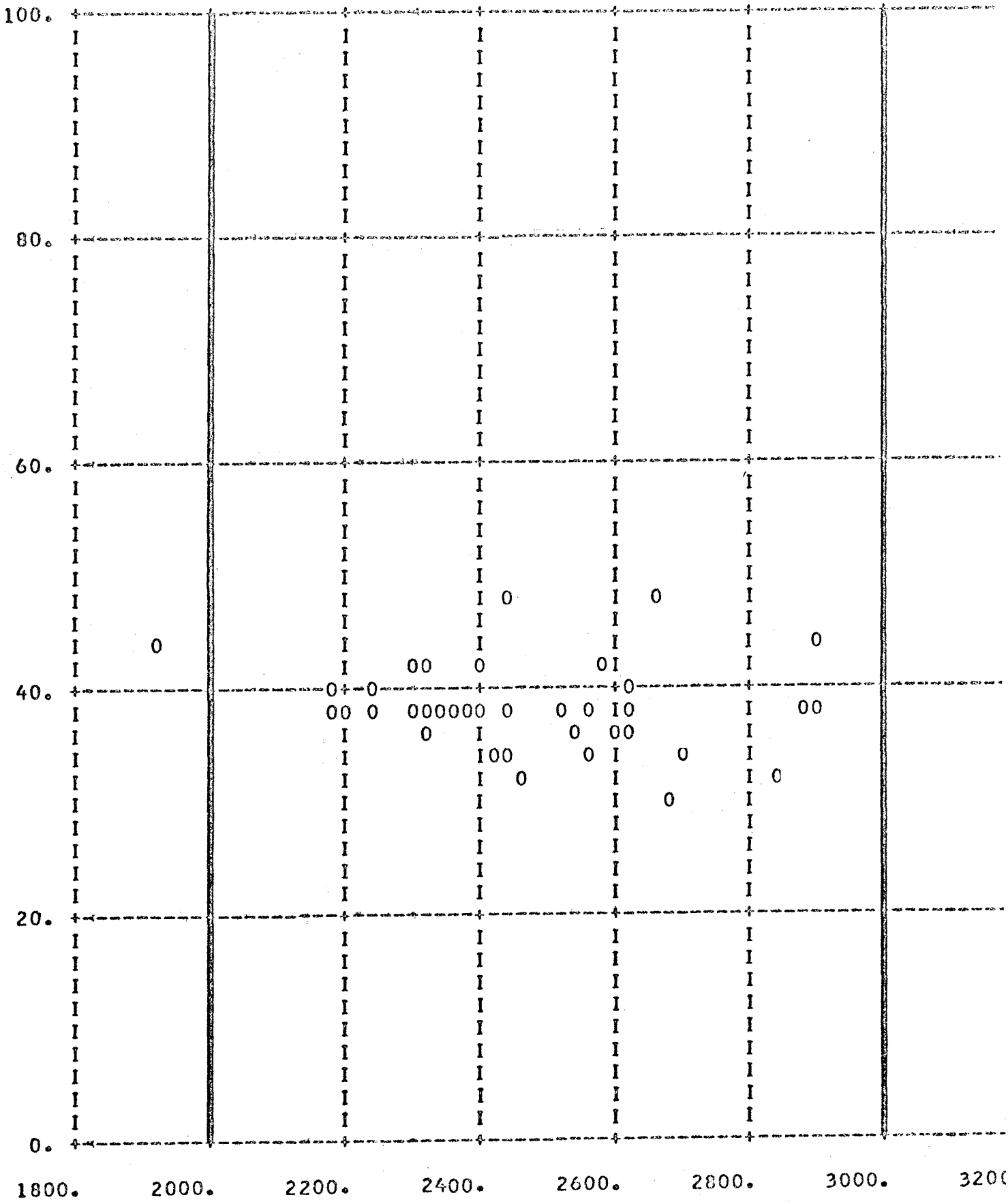
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 12 GRADE AC 10



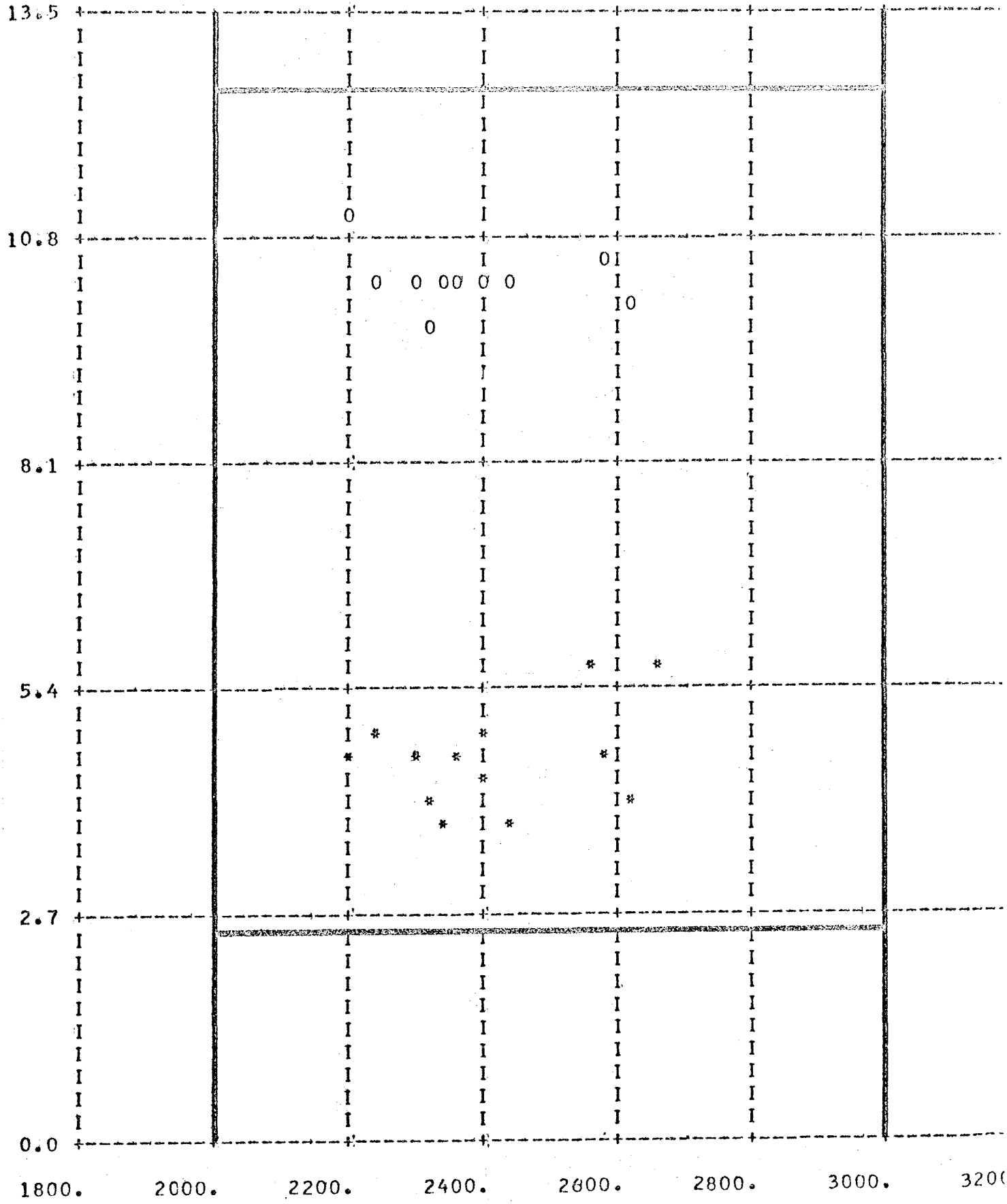
PRODUCER 12 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 12 GRADE AC 20

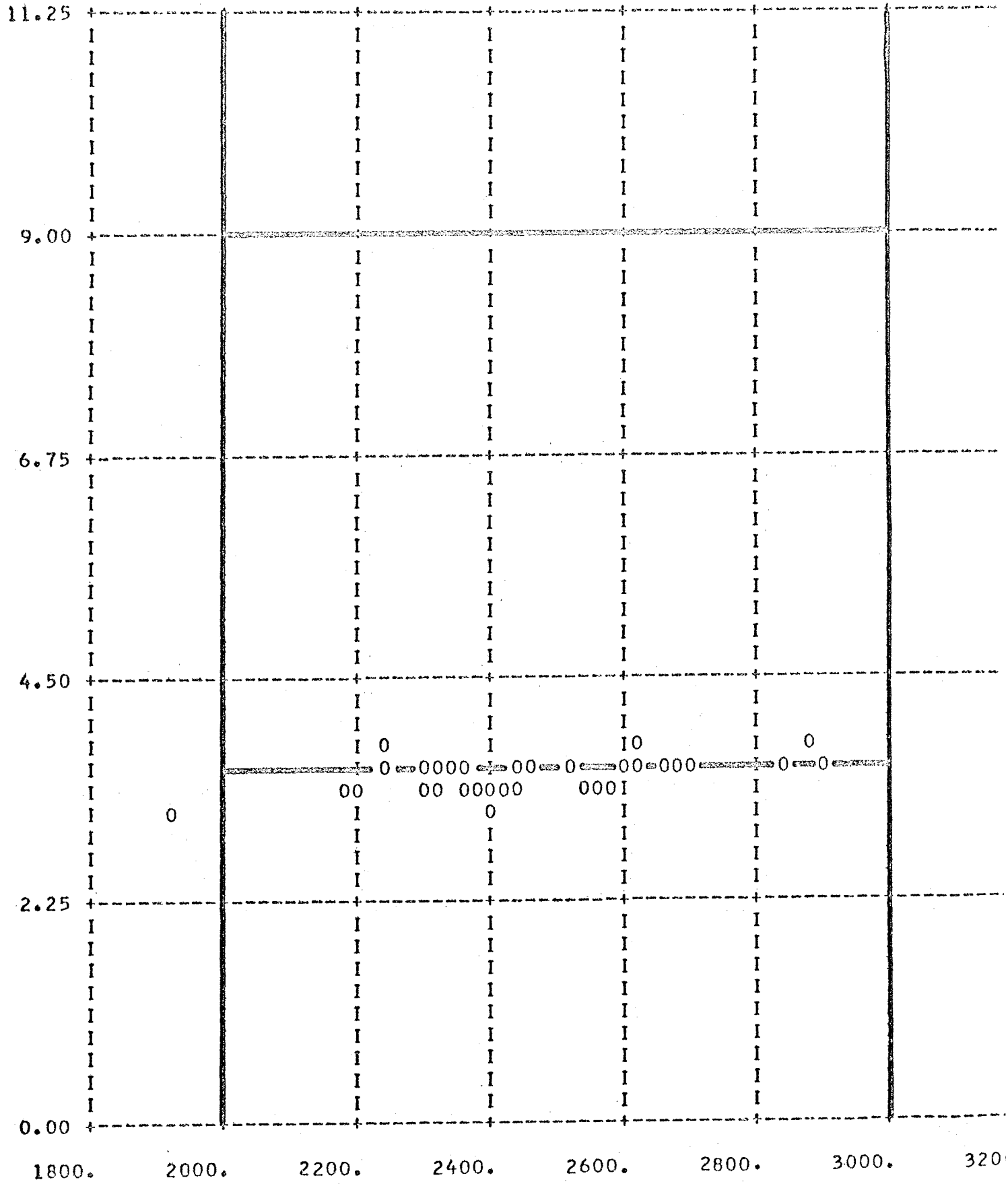


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

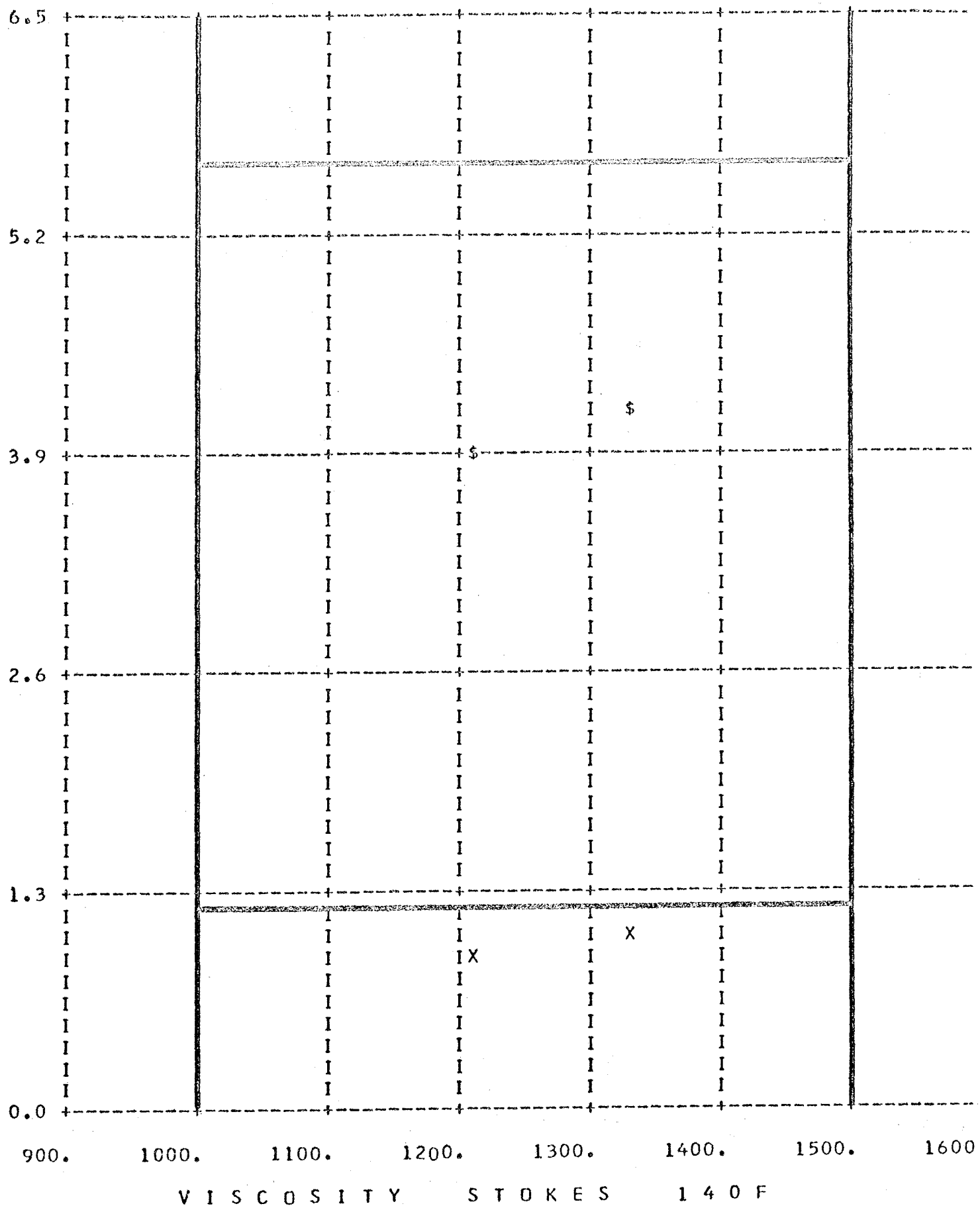
VISCOSITY AT 77F AFTER HEATING IN AI
0 1965 $ 1966

PRODUCER 12 GRADE AC 20



Asphalt Supplier
No. 13

PRODUCER 13 GRADE AC 10

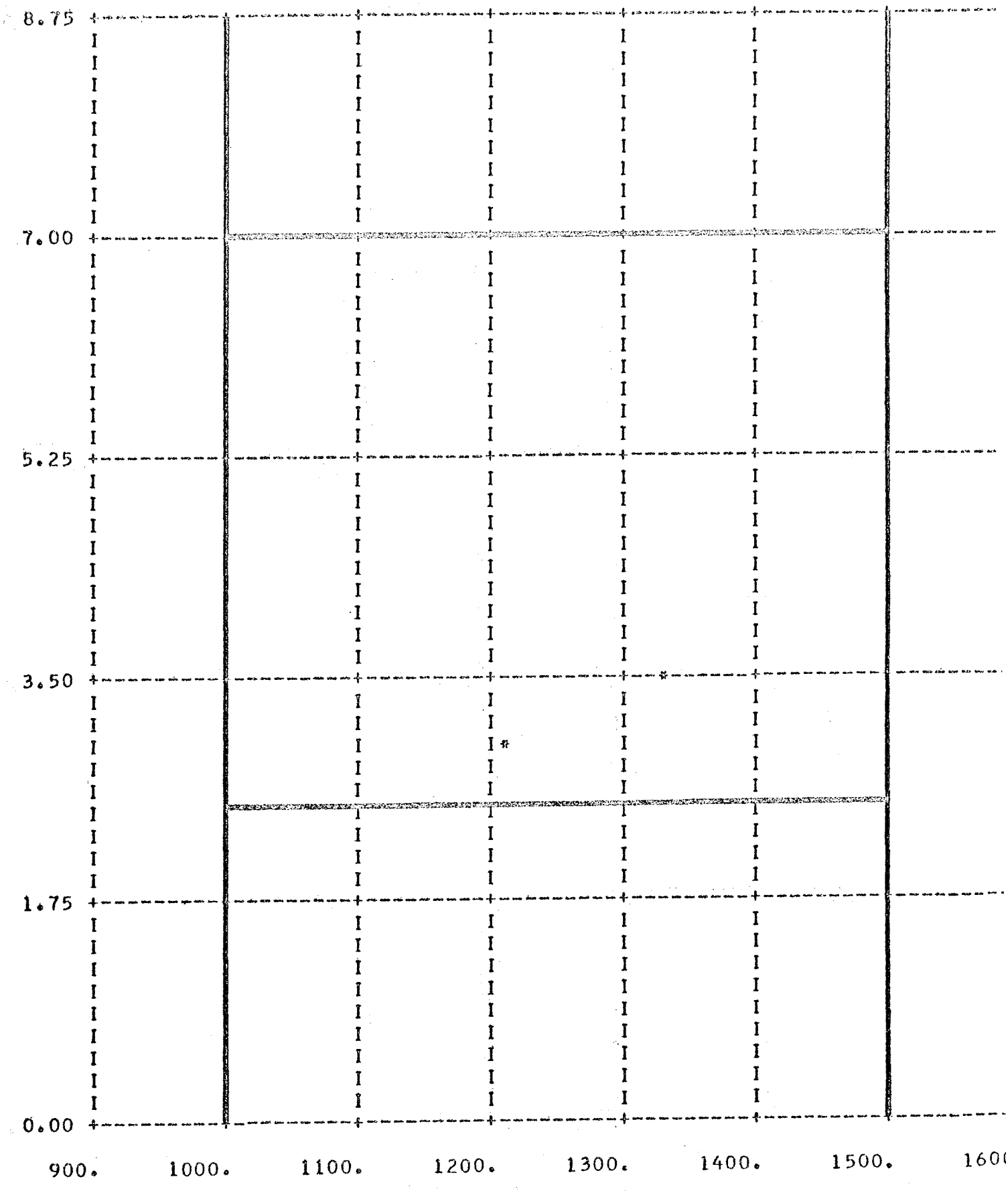


LEGEND
M MULTIPLE

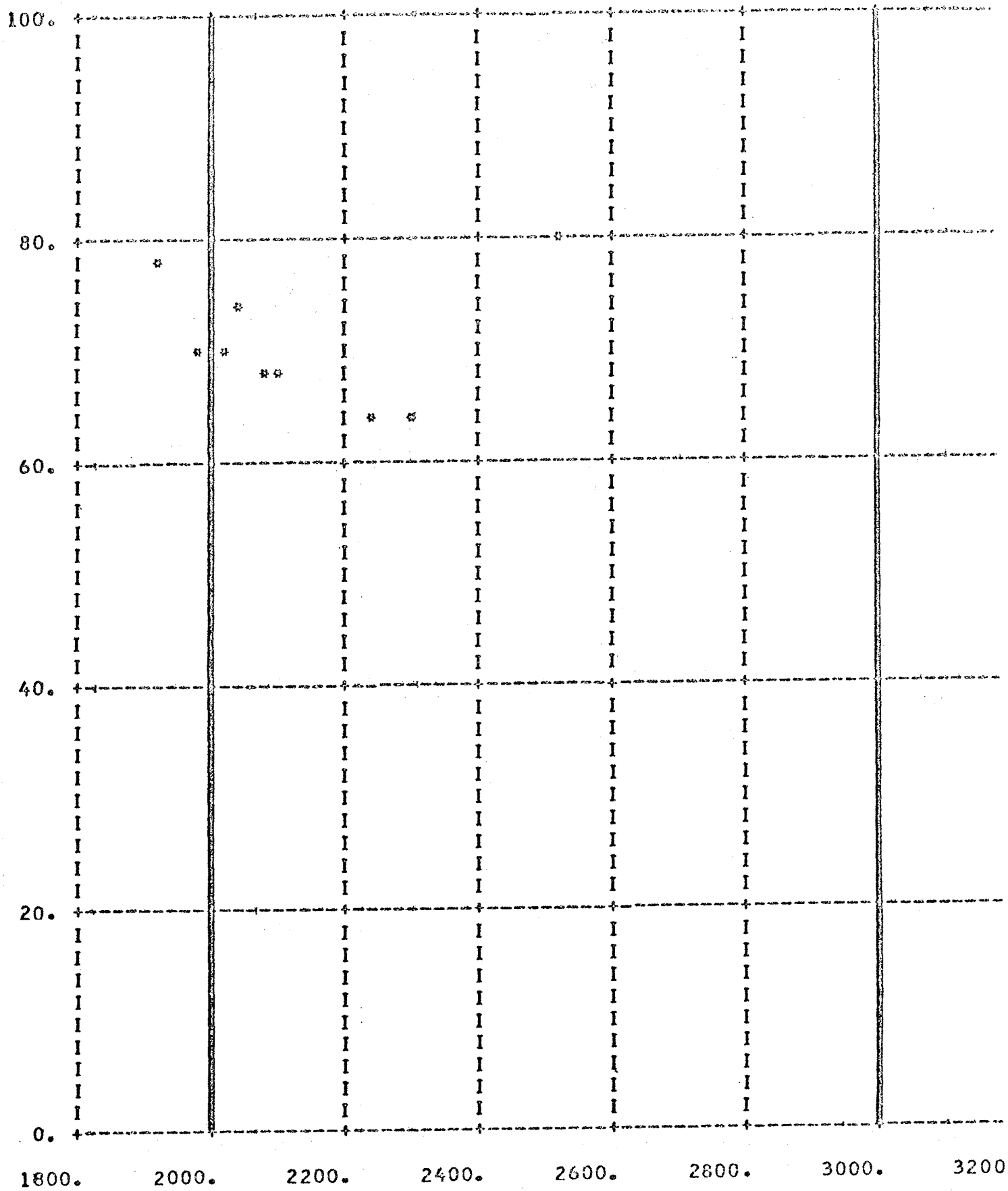
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 13 GRADE AC 10



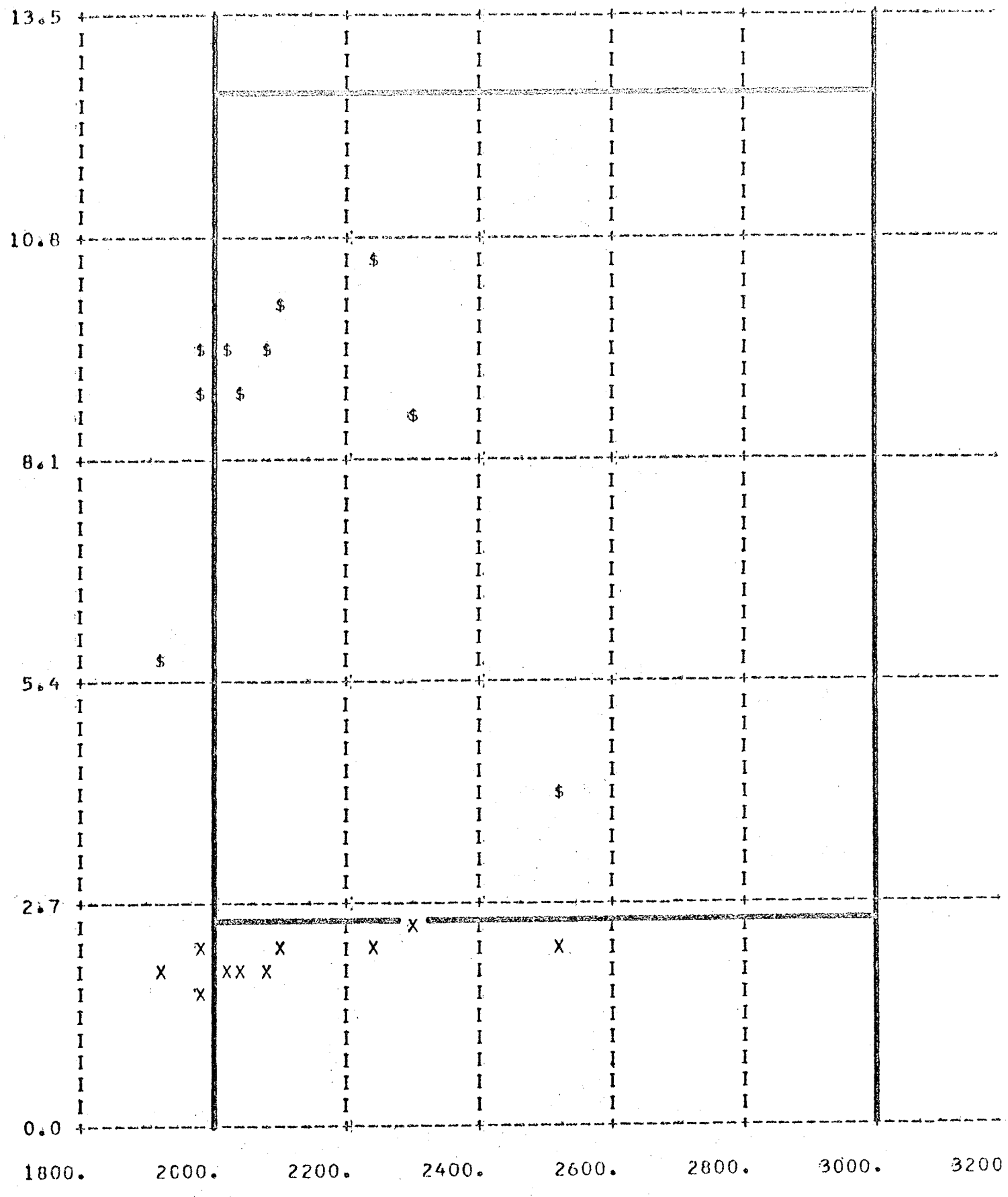
PRODUCER 13 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 13 GRADE AC 20

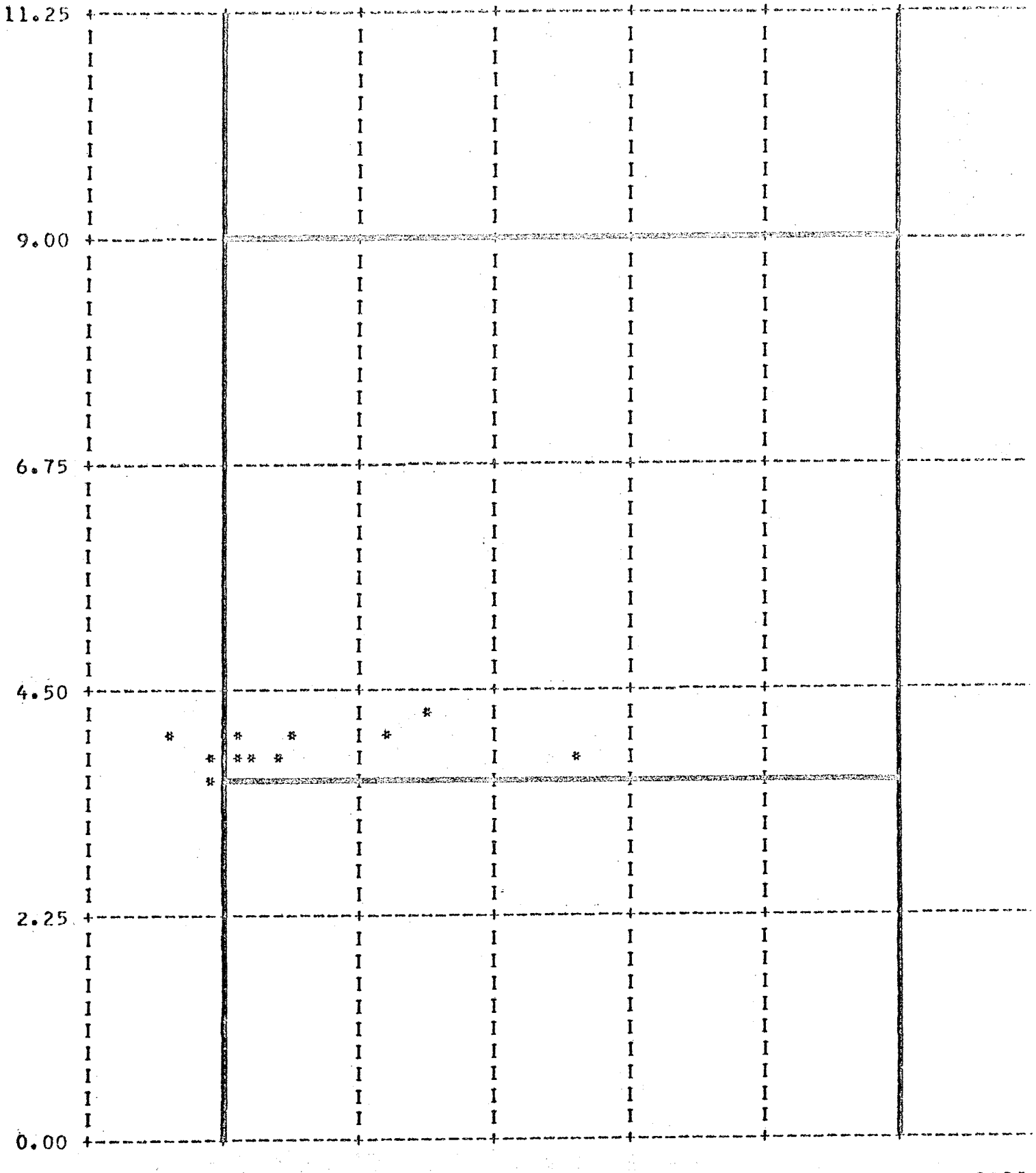


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 13 GRADE AC 20

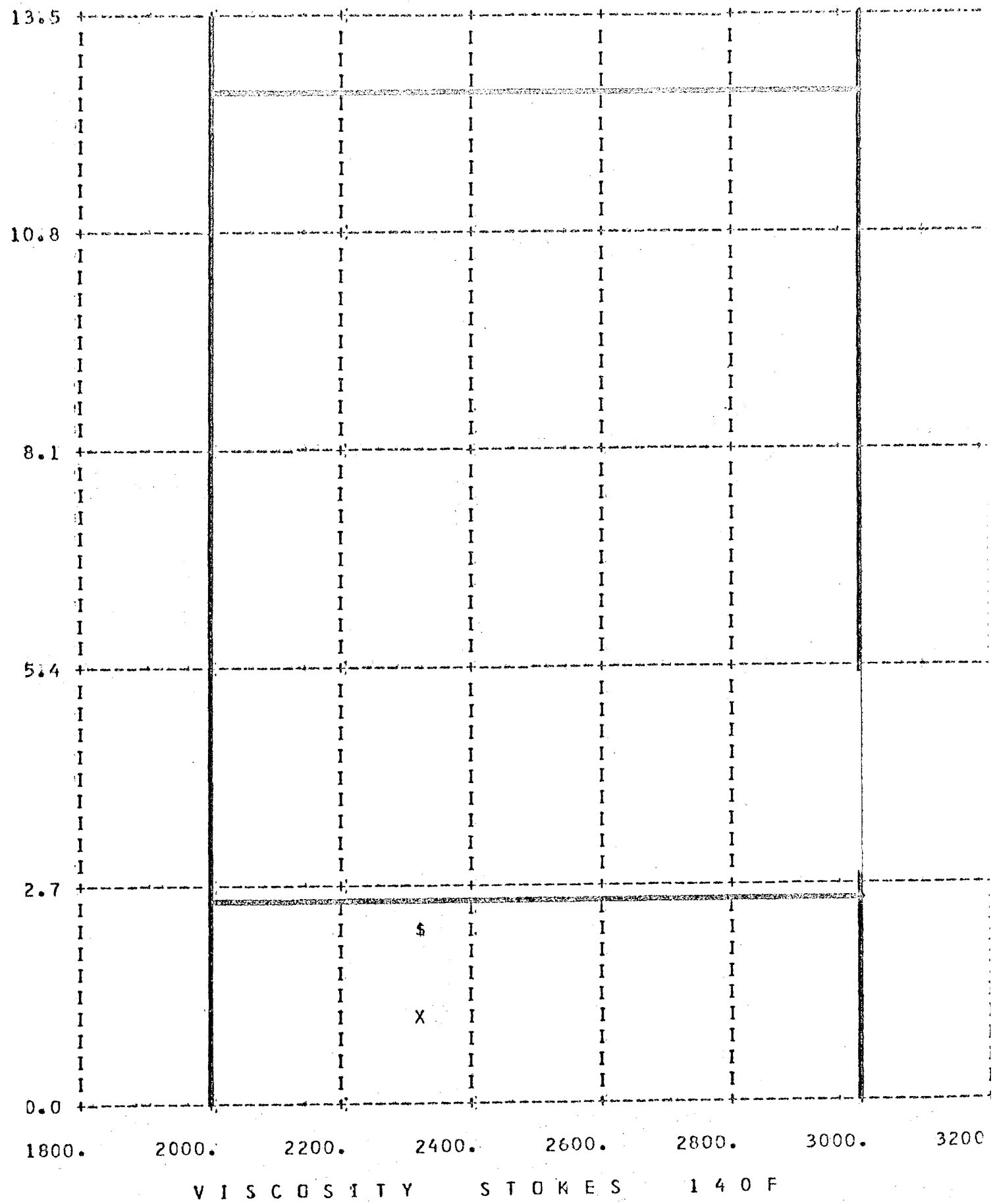


V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 14

PRODUCER 14 GRADE AC 20



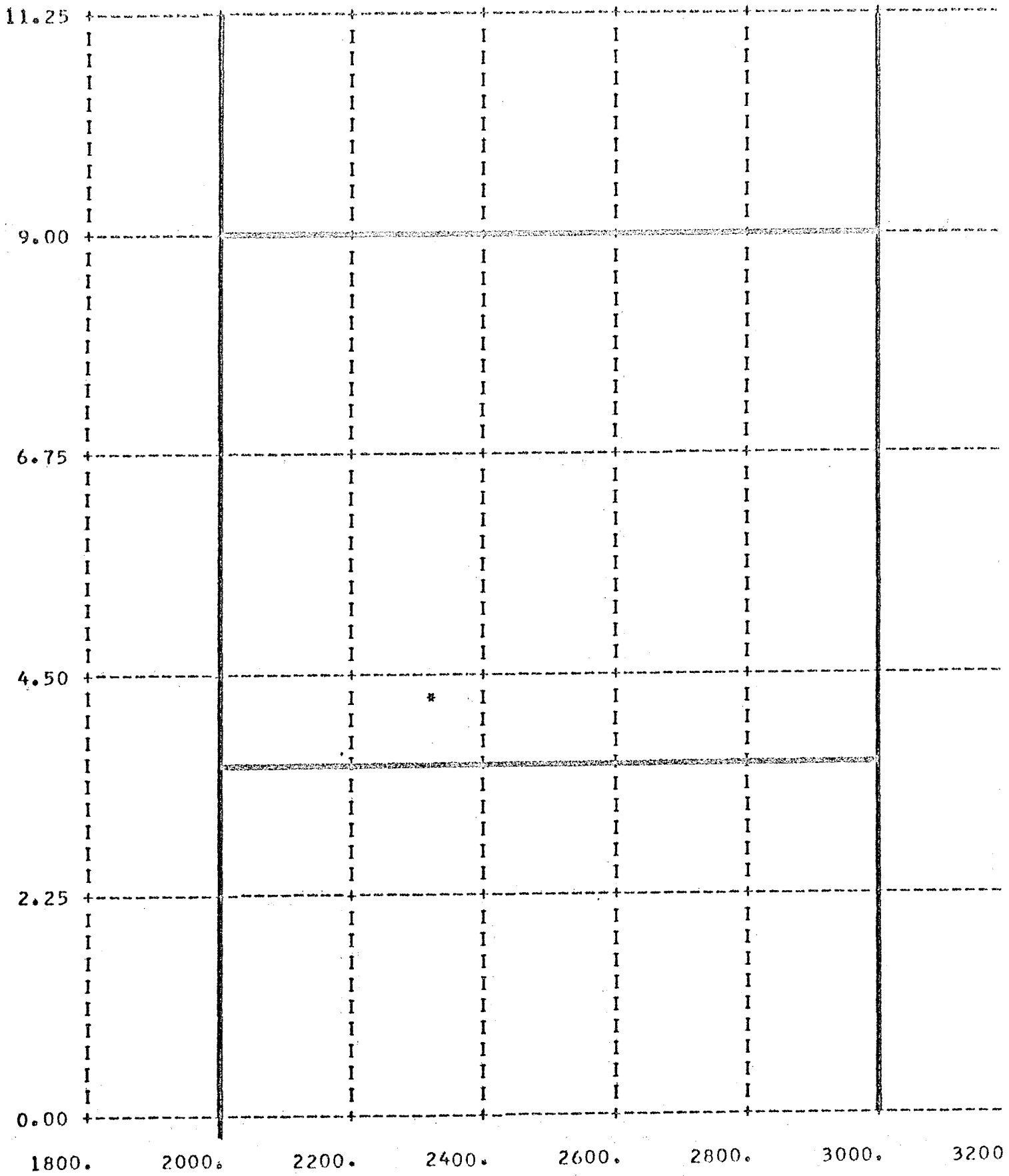
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

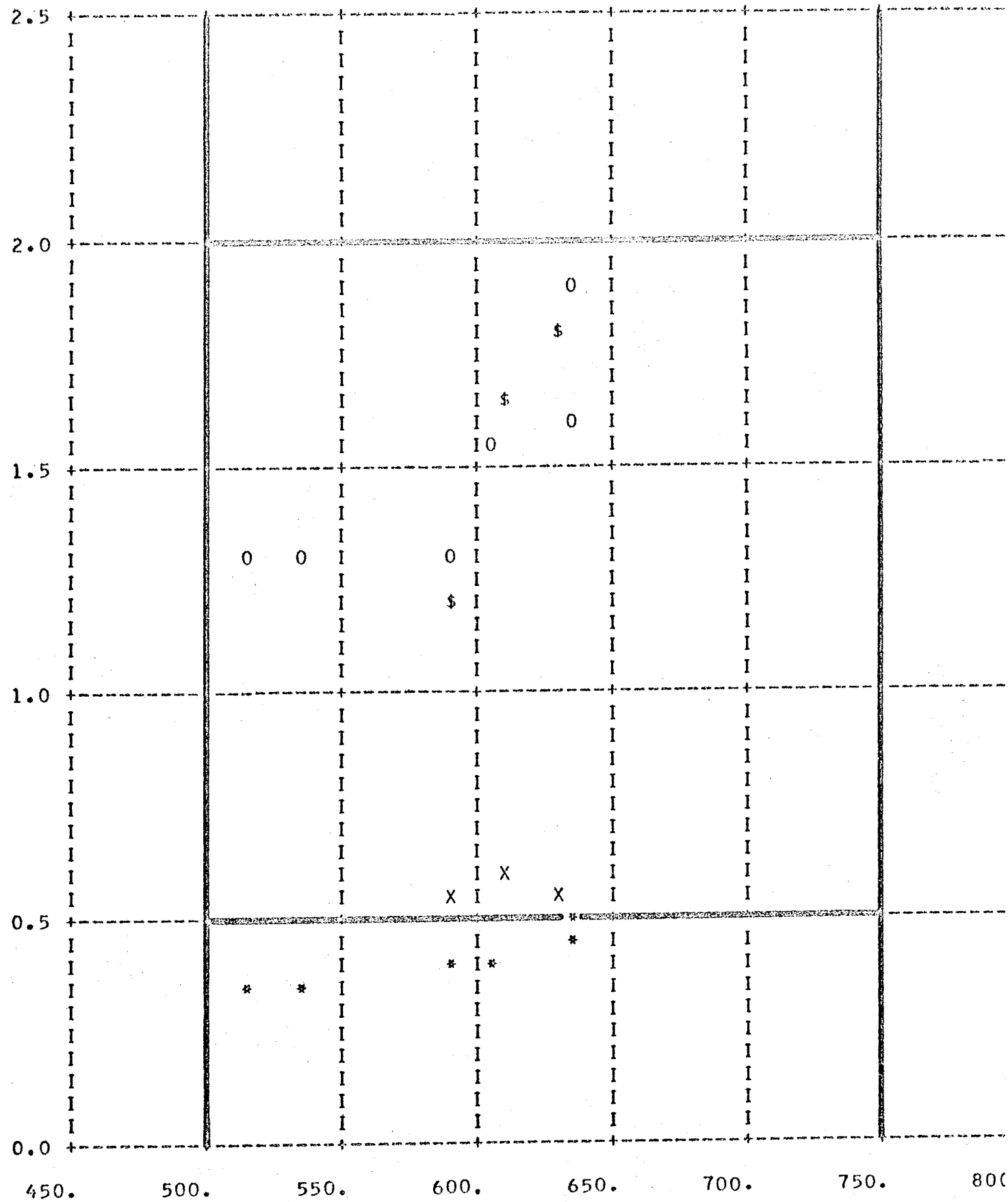
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 14 GRADE AC 20



Asphalt Supplier
No. 15

PRODUCER 15 GRADE AC 5

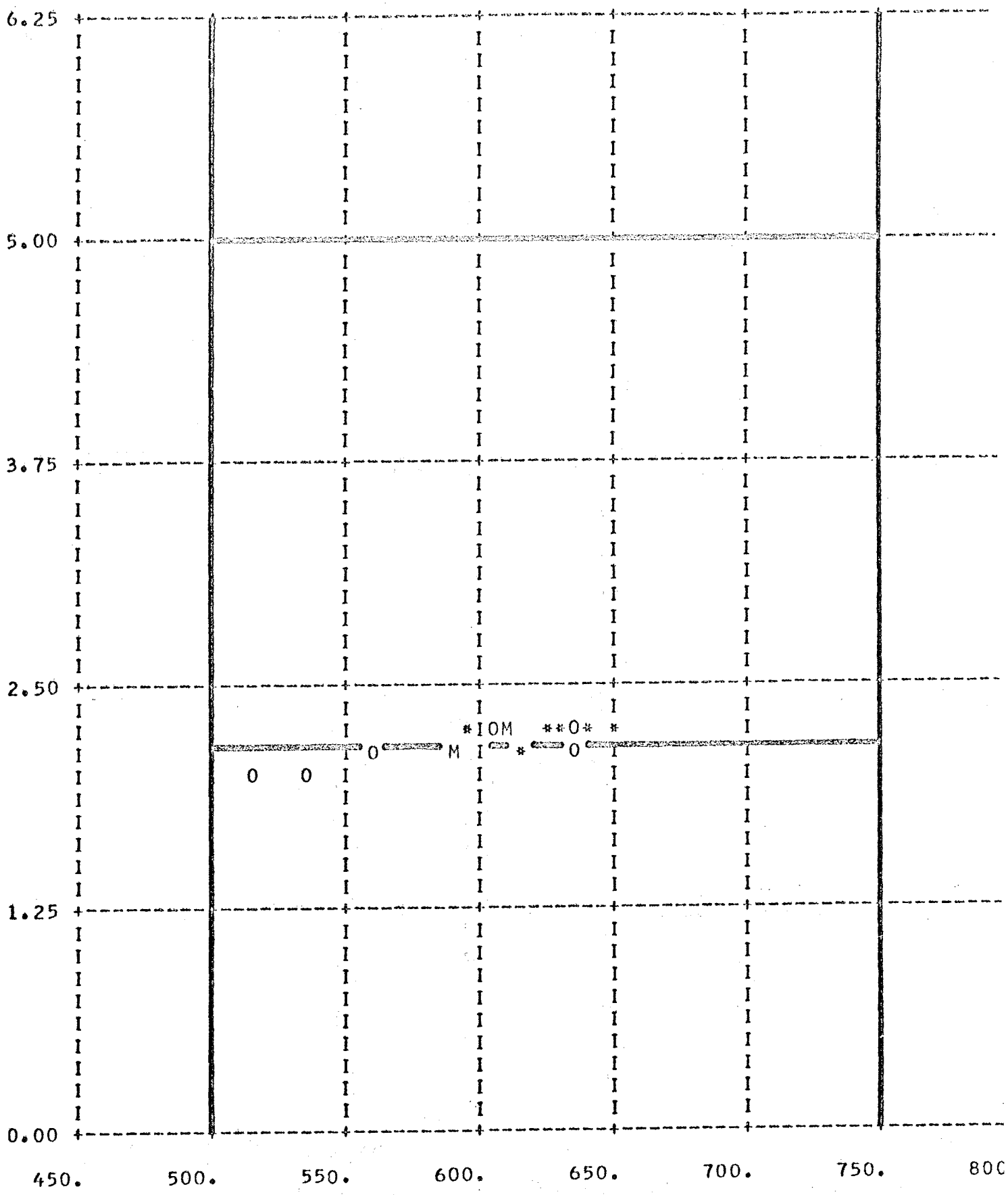


LEGEND
M MULTIPLE

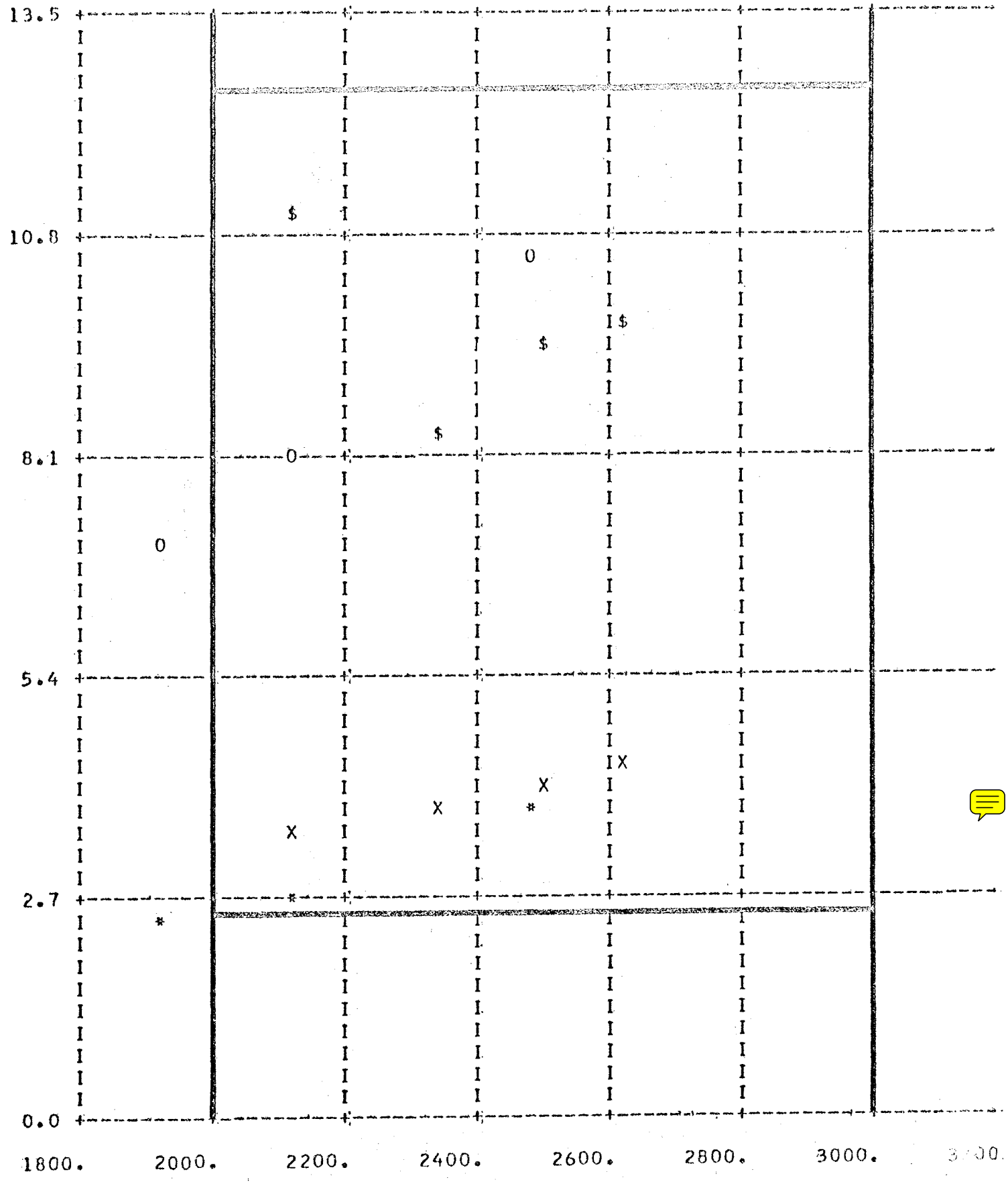
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 15 GRADE AC 5



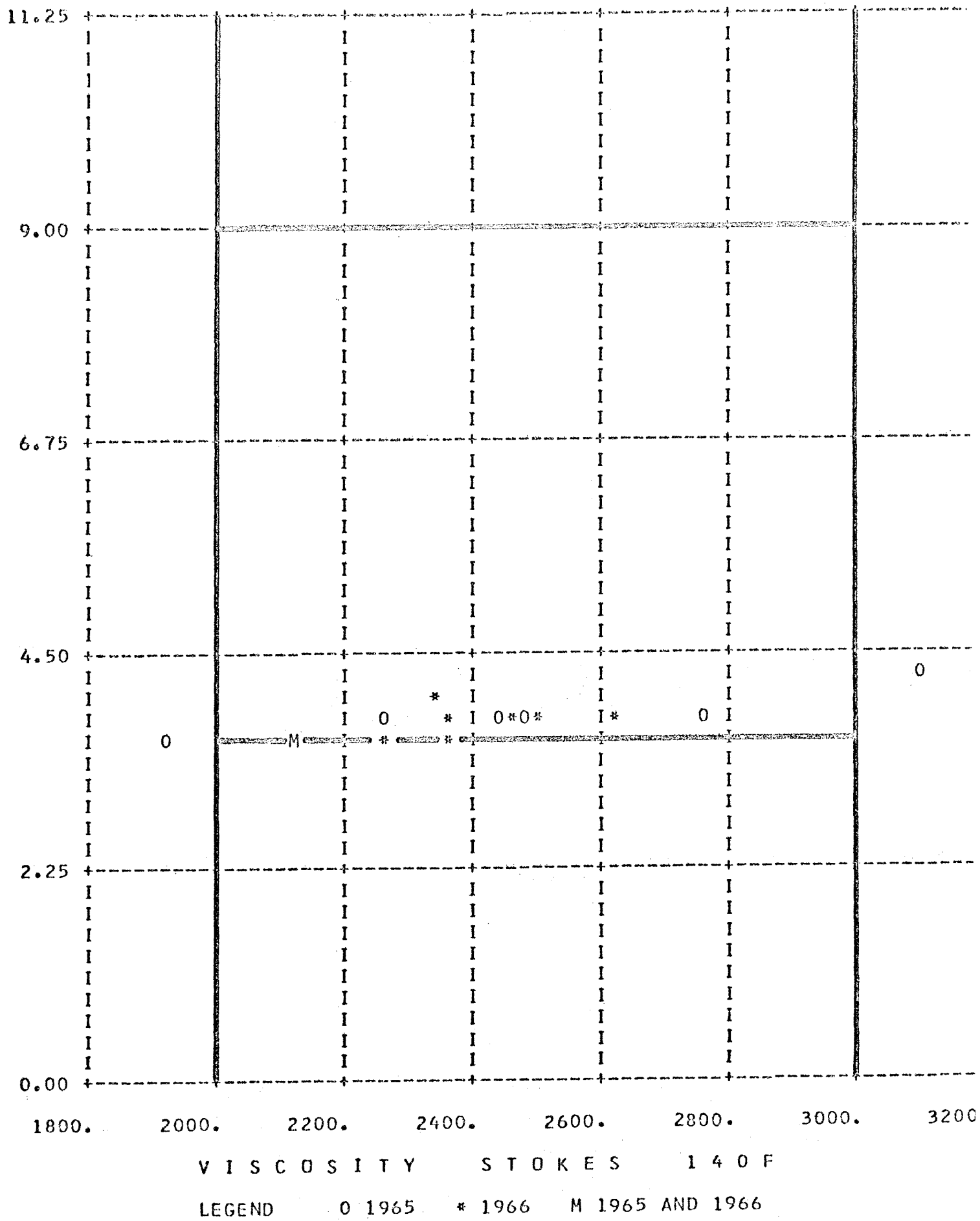
PRODUCER 15 GRADE AC 20



LEGEND
M MULTIPLE

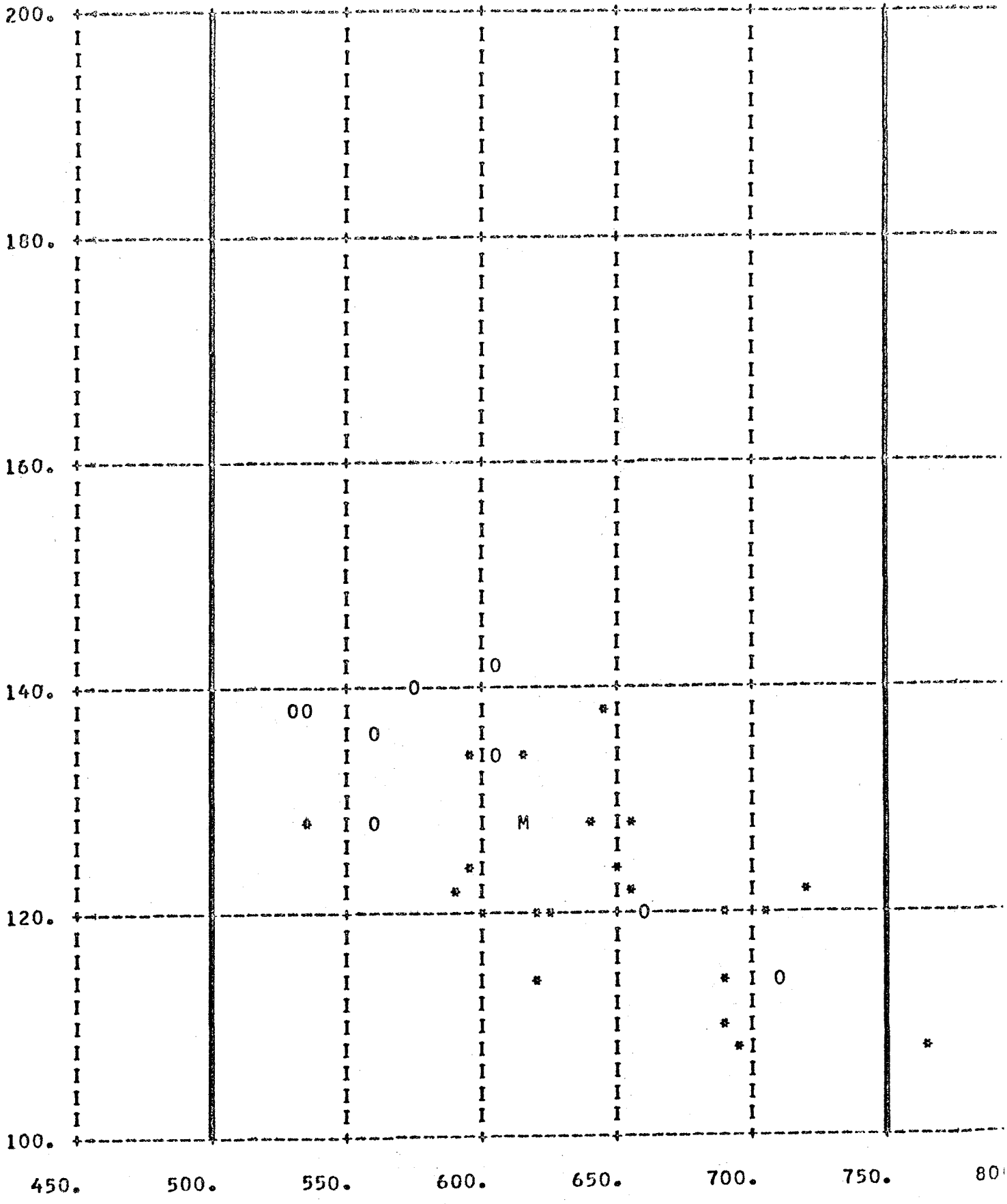
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966


PRODUCER 15 GRADE AC 20
11.25
9.00
6.75
4.50
2.25
0.00
1800.
2000.
2200.
2400.
2600.
2800.
3000.
3200
VISCOSITY STOKES 140F
LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 16

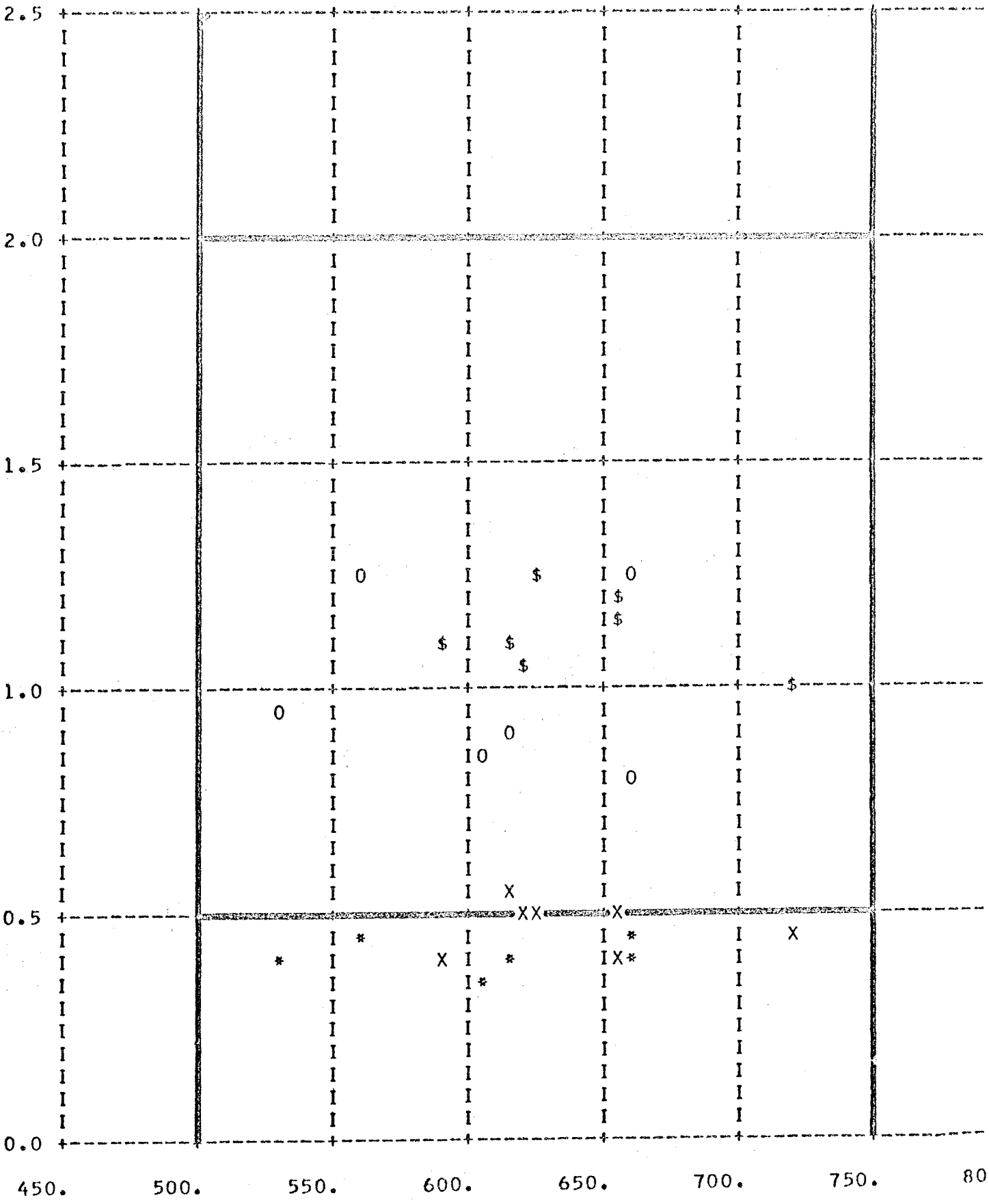
PRODUCER 16 GRADE AC 5



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 16 GRADE AC 5

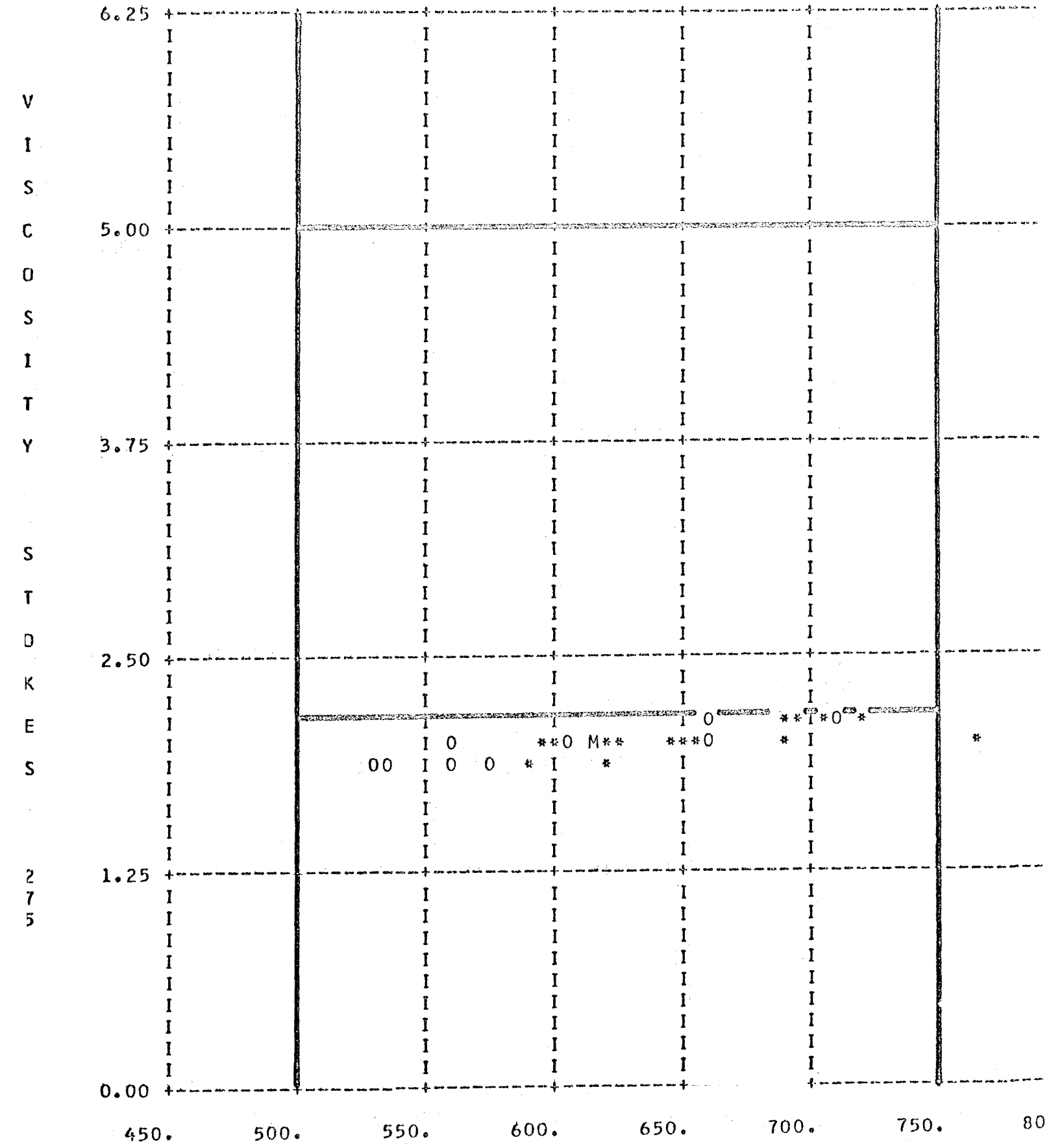


LEGEND
M MULTIPLE

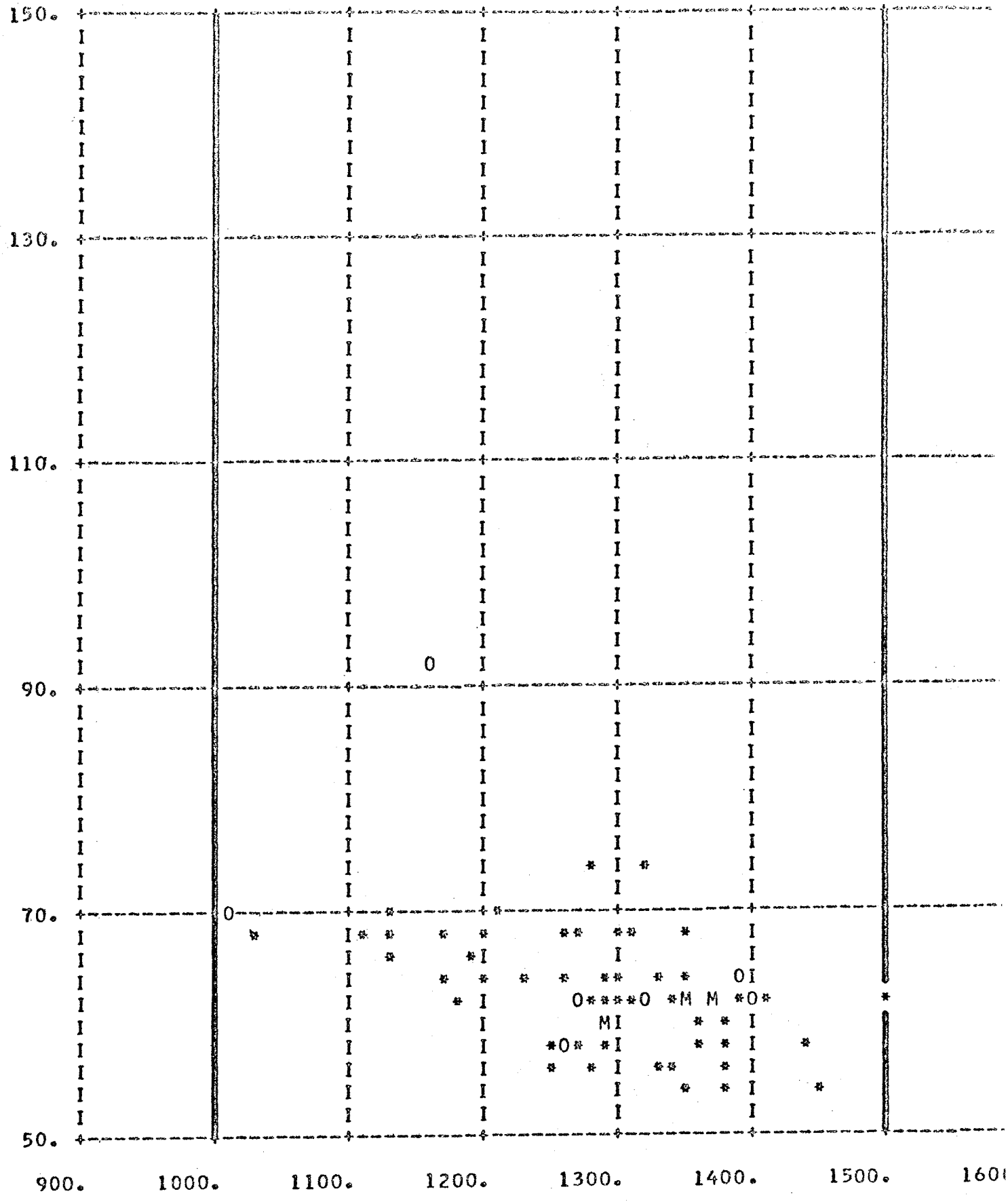
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AI
0 1965 $ 1966

PRODUCER 16 GRADE AC 5



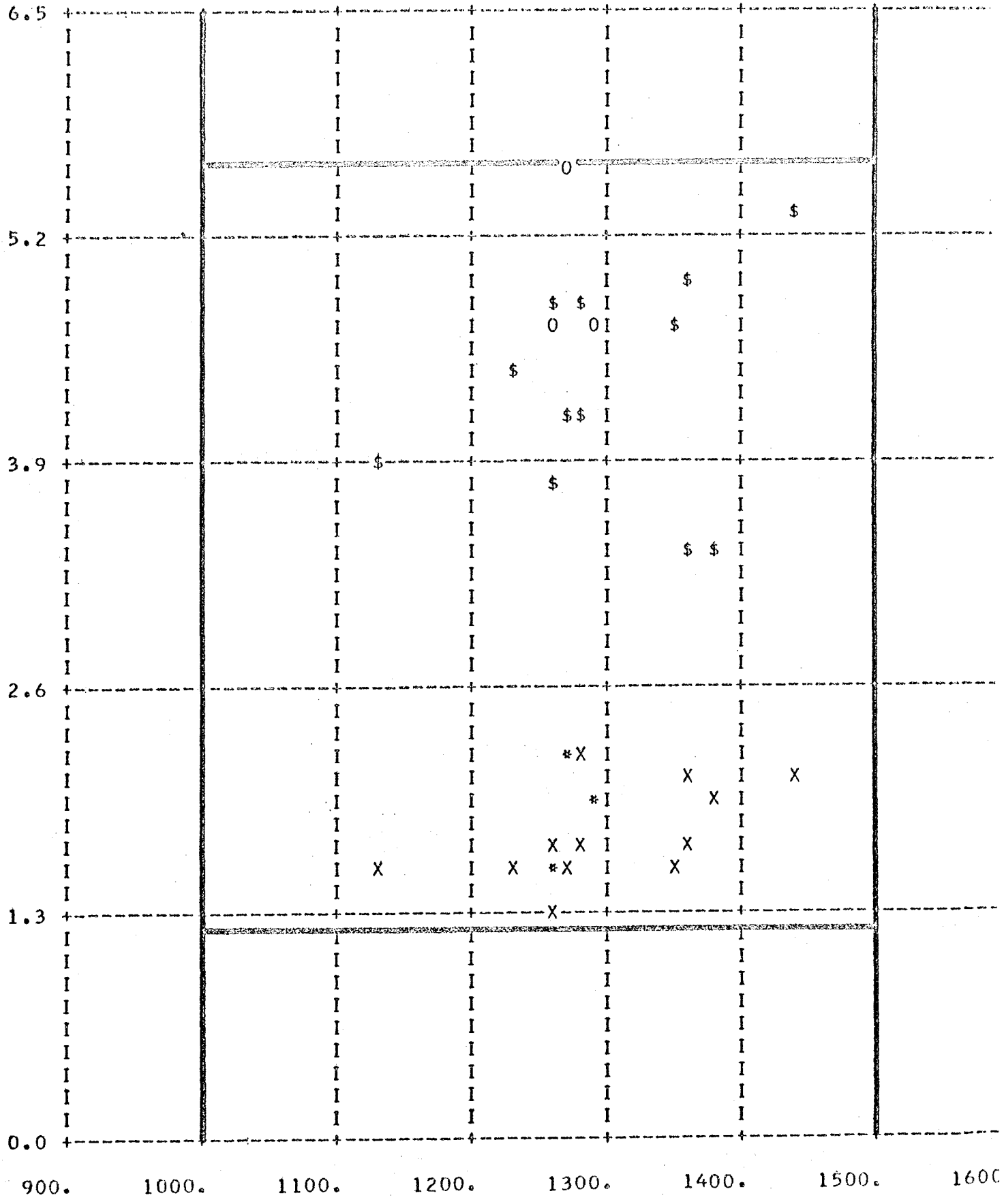
PRODUCER 16 GRADE AC 10



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 16 GRADE AC 10

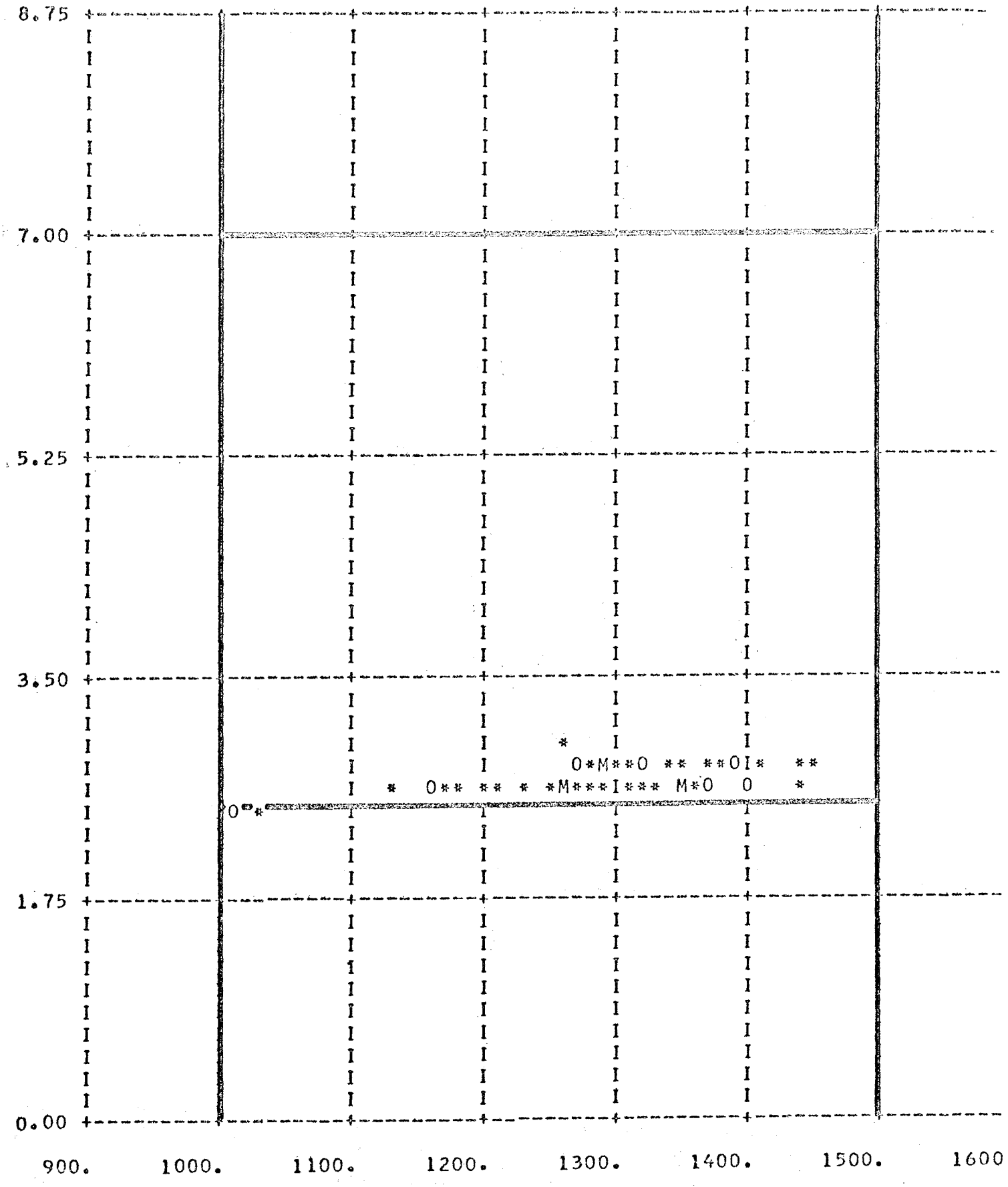


LEGEND
M MULTIPLE

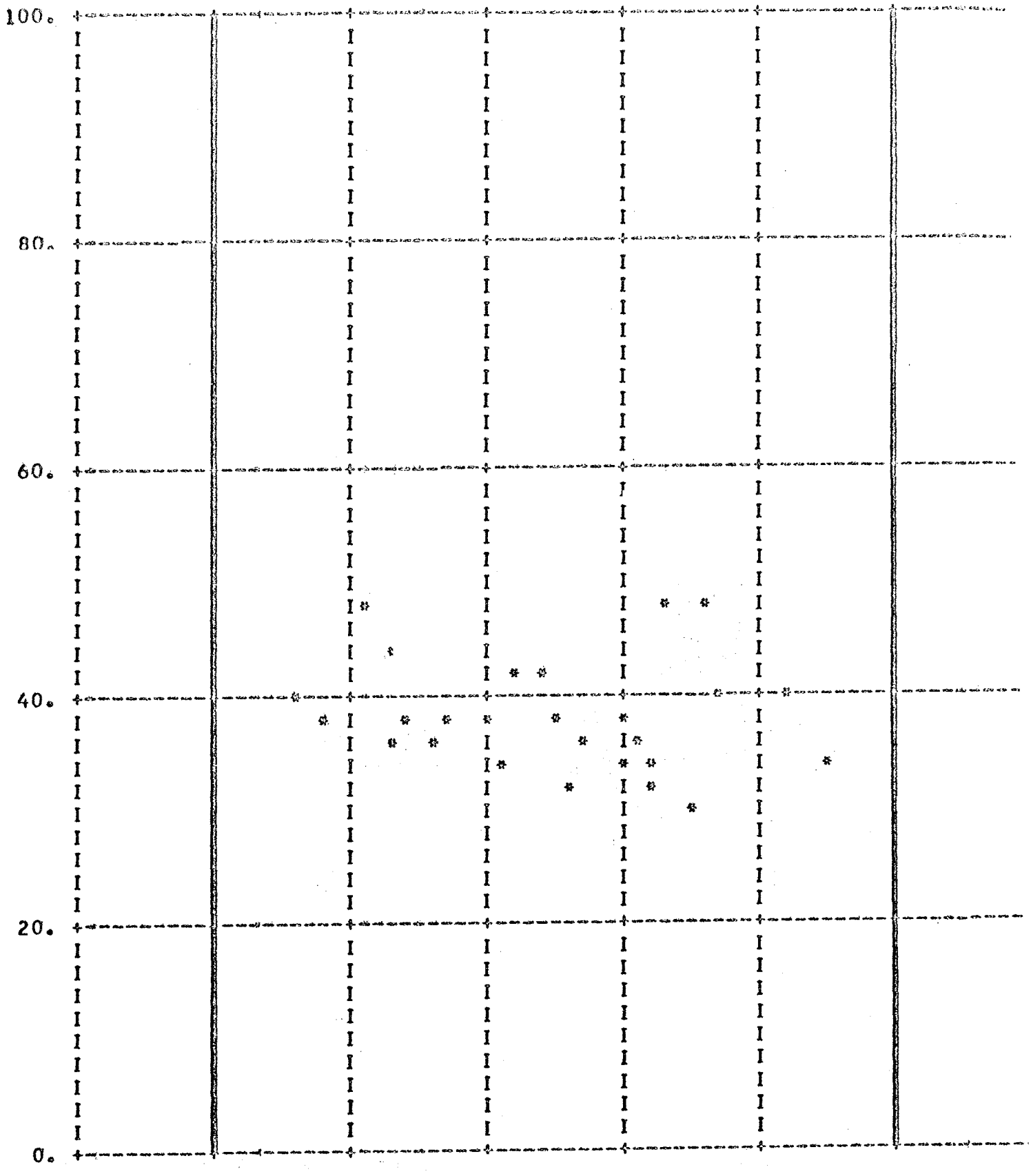
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 16 GRADE AC 10



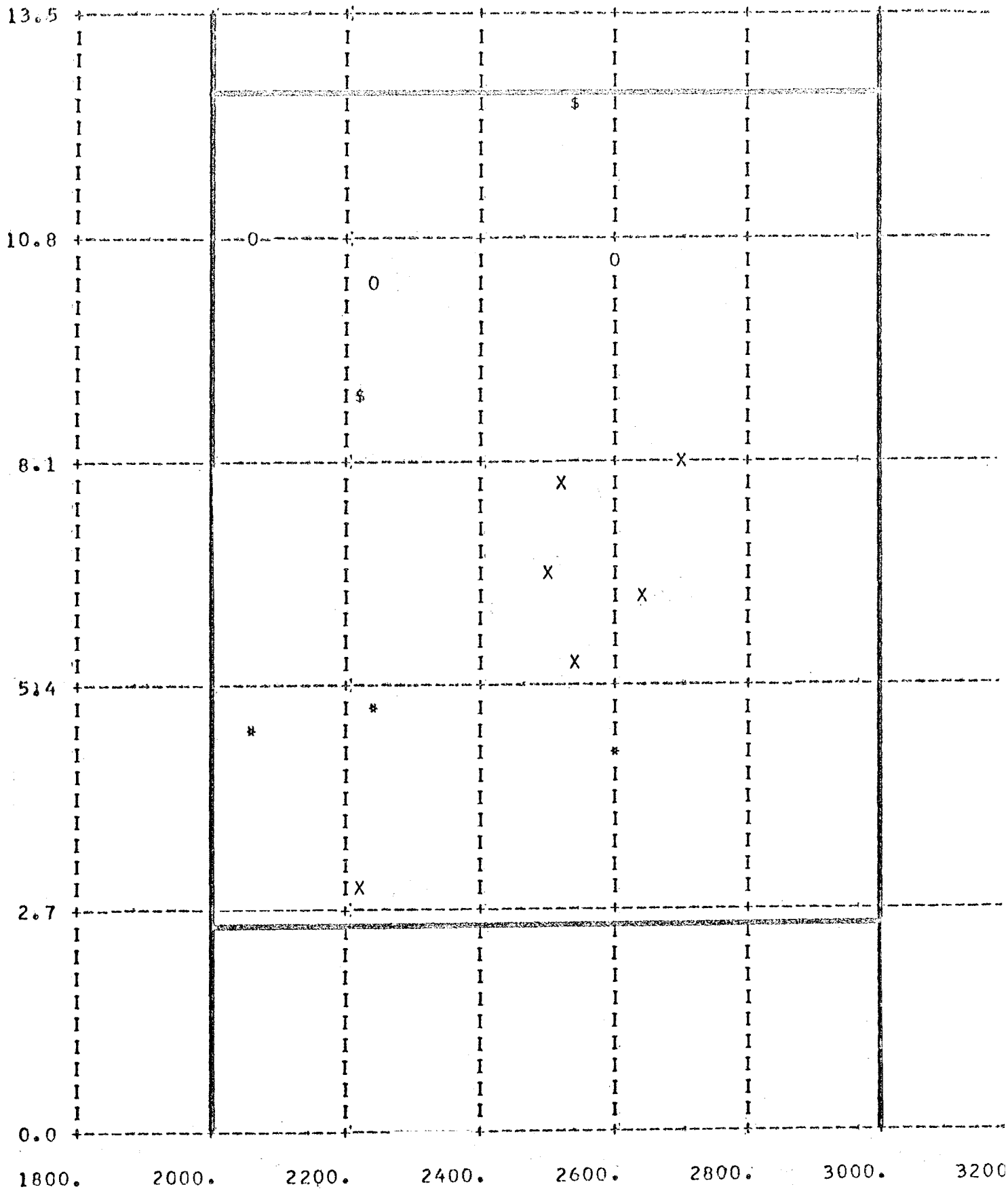
PRODUCER 16 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 16 GRADE AC 20

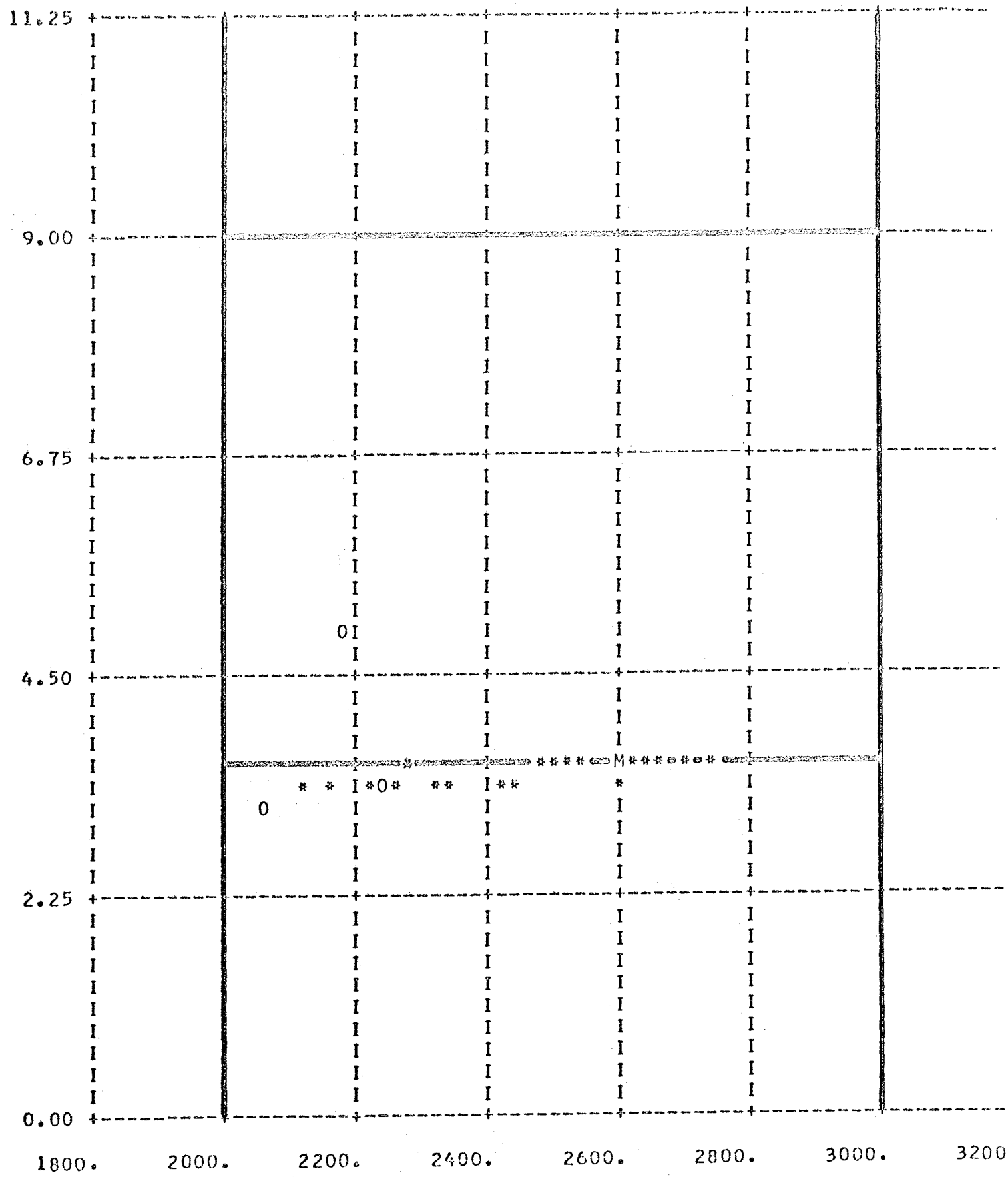


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

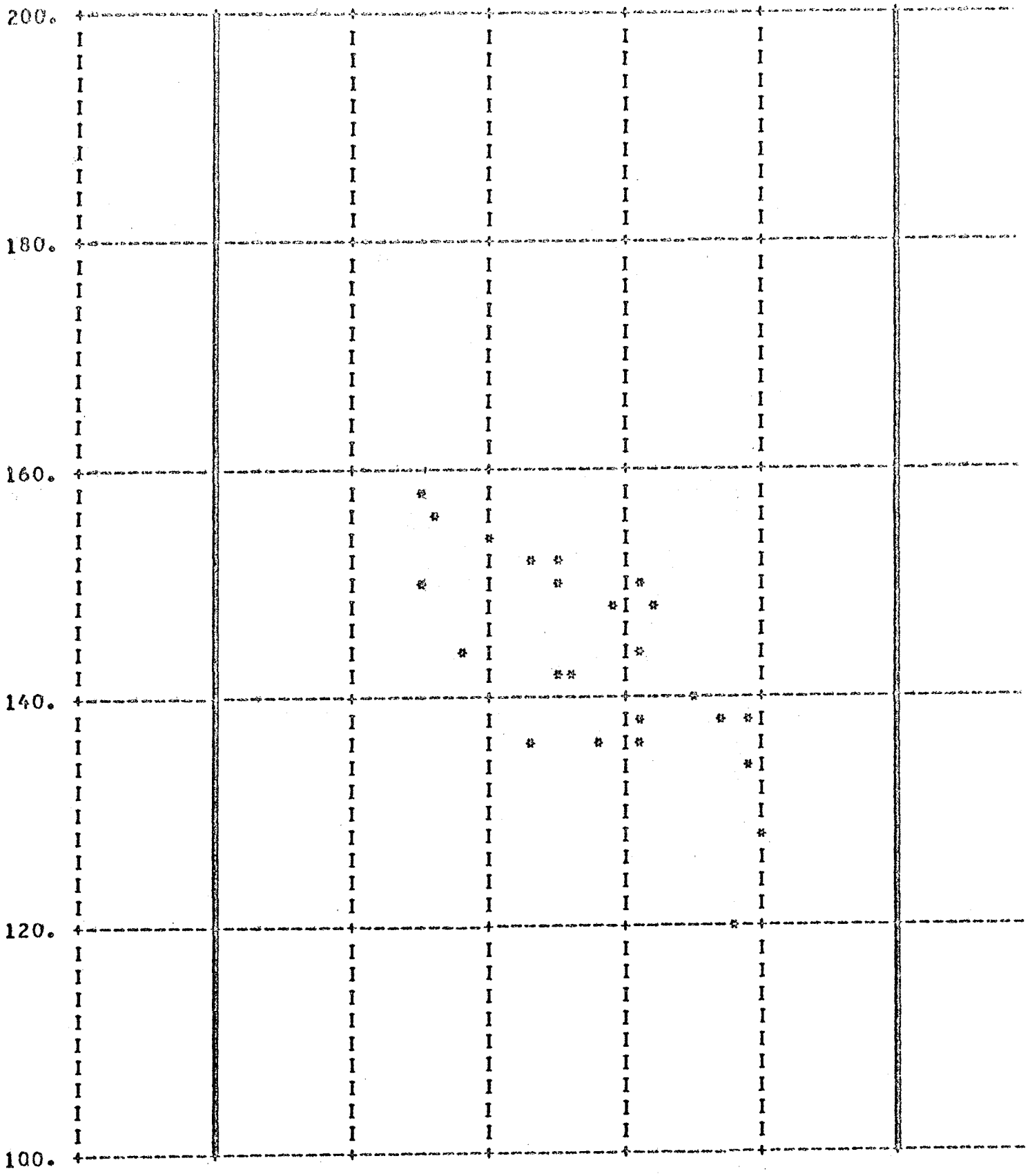
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 16 GRADE AC 20



Asphalt Supplier
No. 17

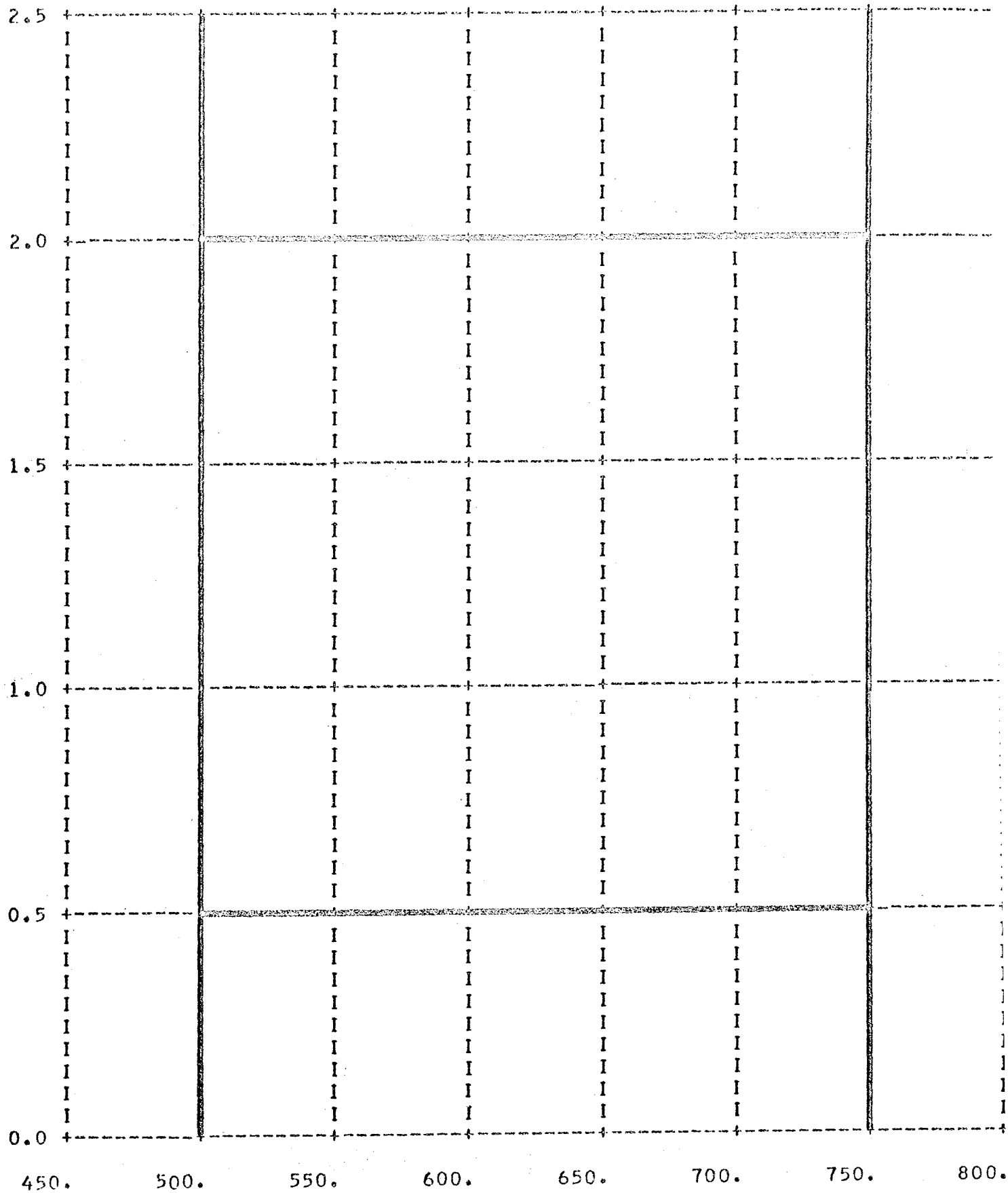
PRODUCER 17 GRADE AC 5



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

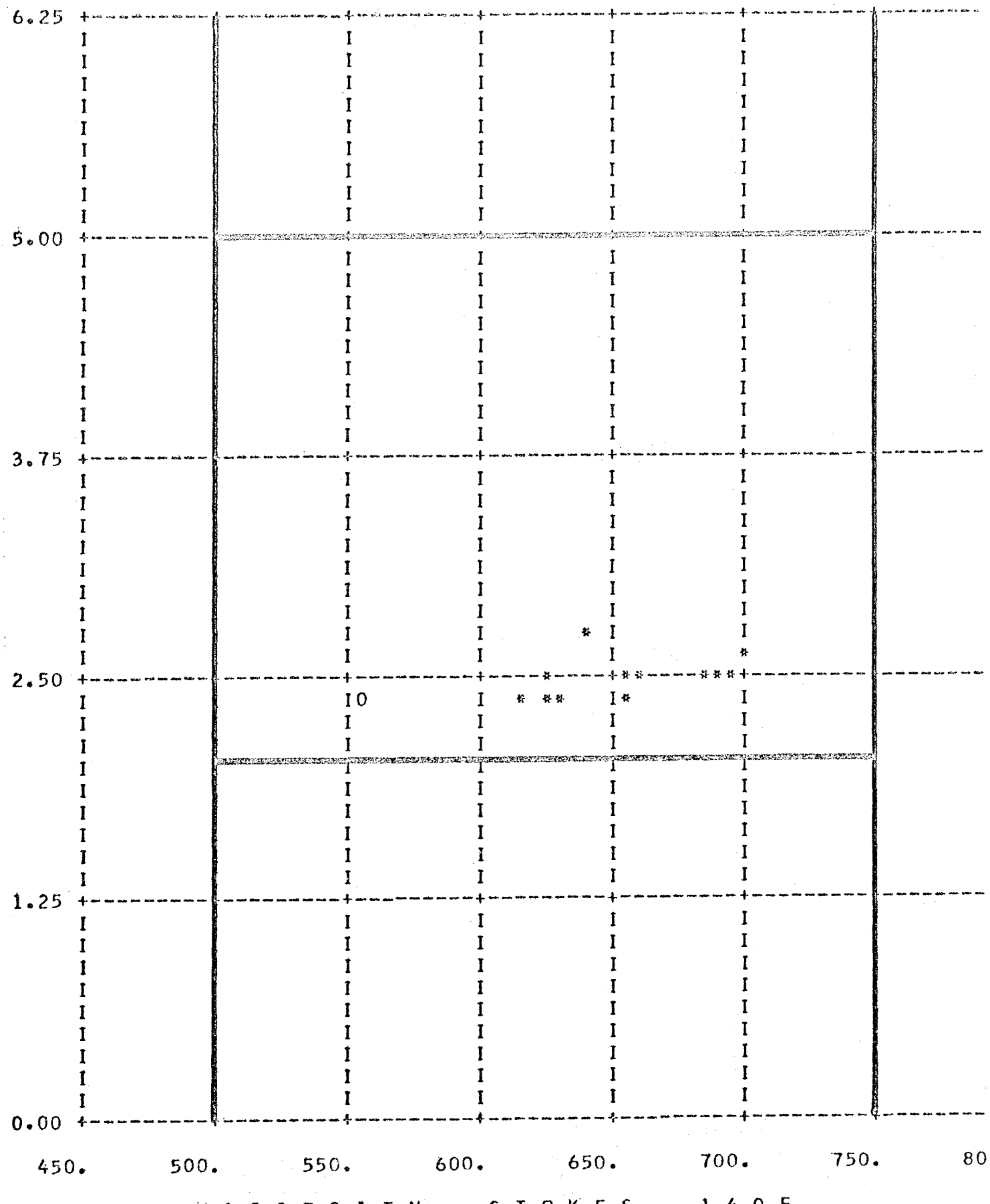
PRODUCER 17 GRADE AC 5



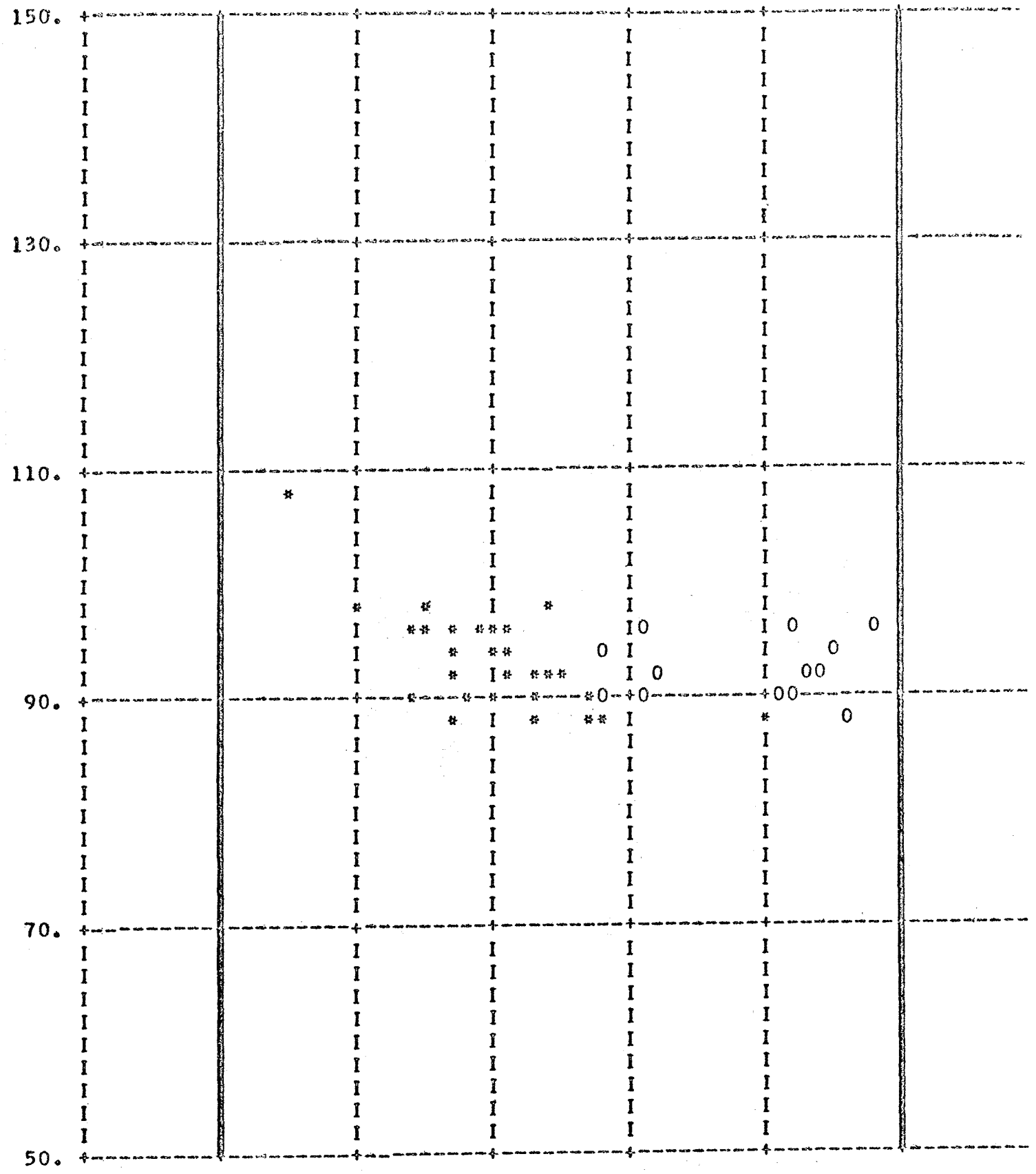
LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966


PRODUCER 17 GRADE AC 5
6.25
5.00
3.75
2.50
1.25
0.00
450.
500.
550.
600.
650.
700.
750.
80
VISCOSITY STOKES 140F
LEGEND 0 1965 * 1966 M 1965 AND 1966

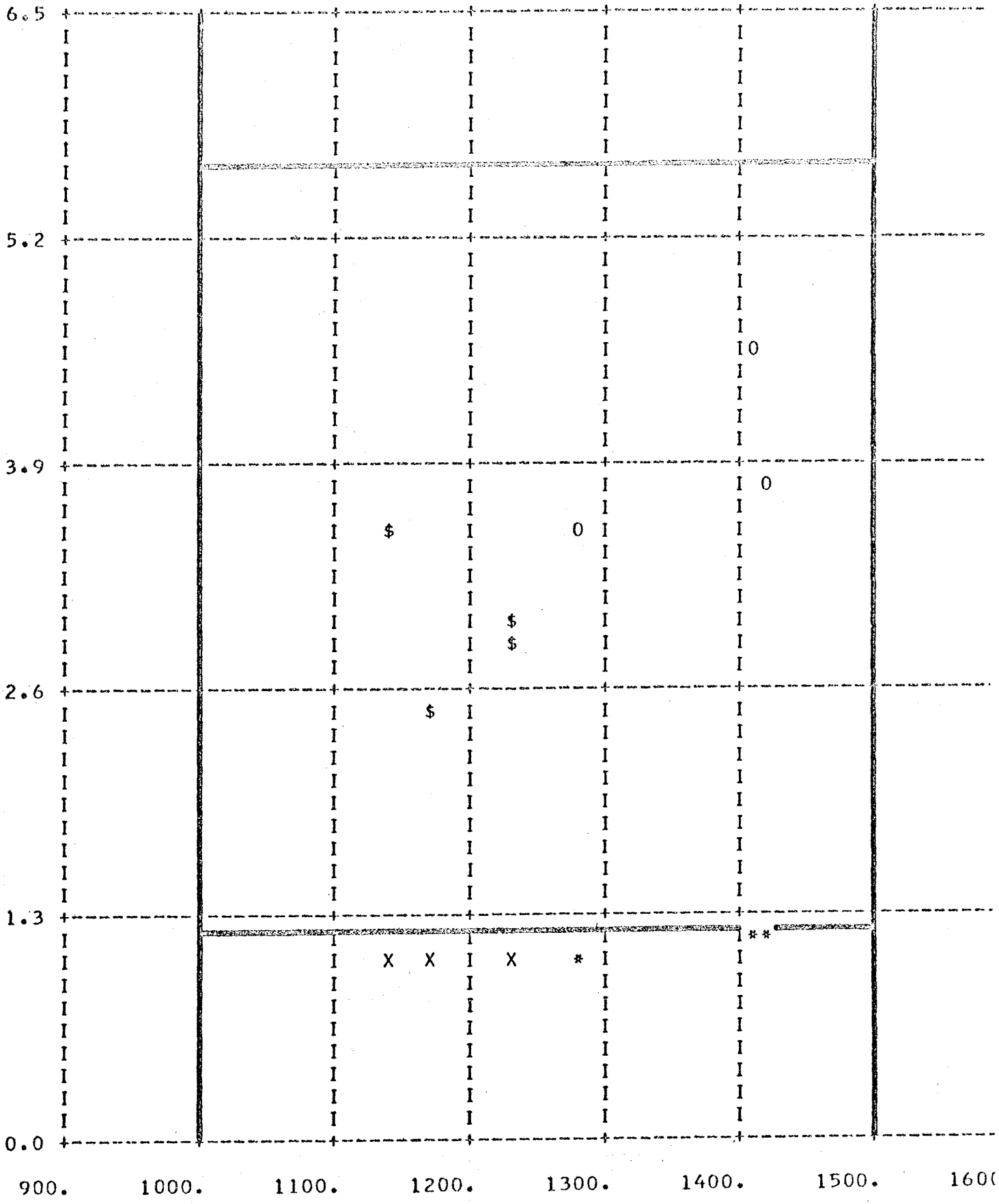
PRODUCER 17 GRADE AC 10



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 17 GRADE AC 10

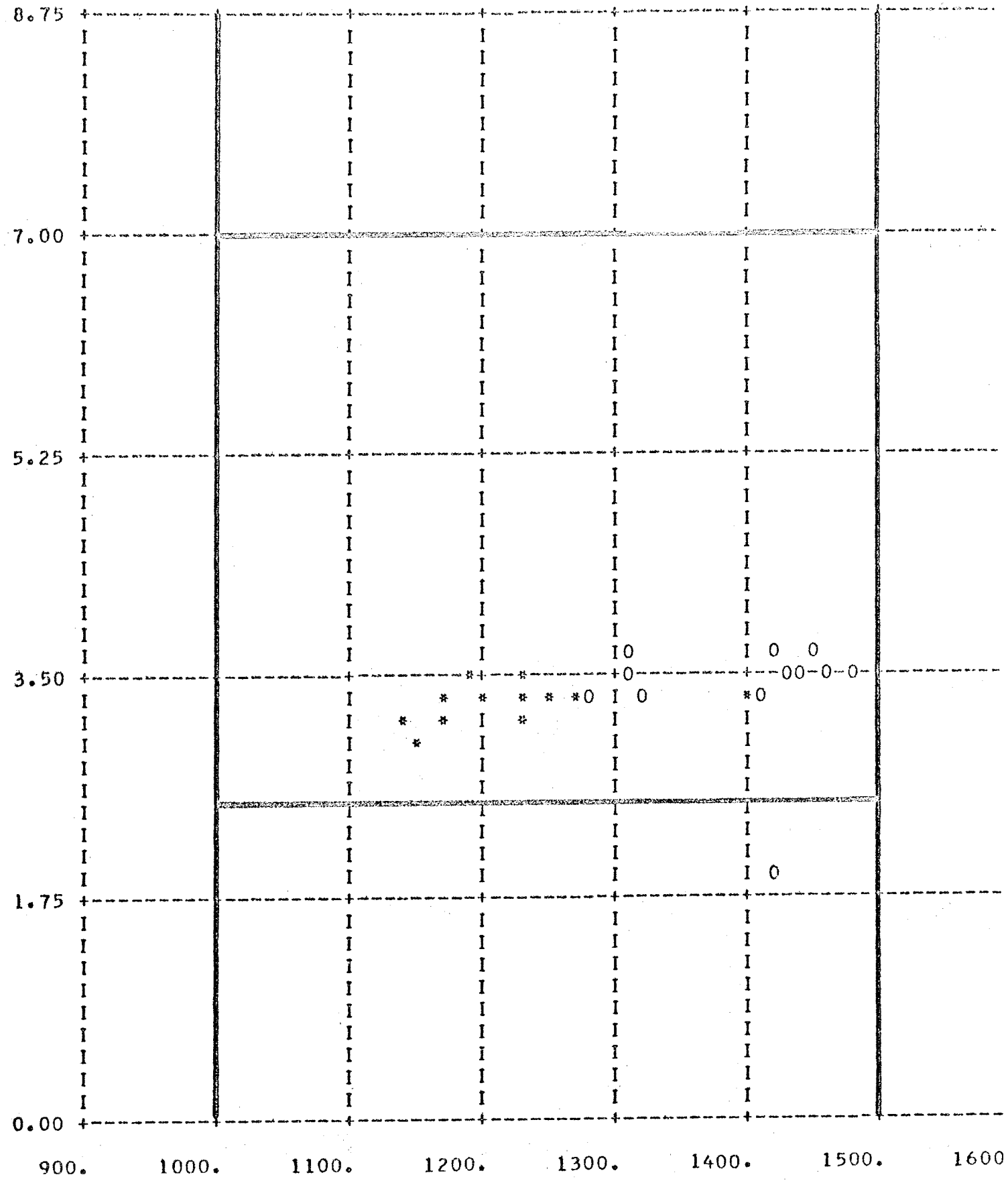


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

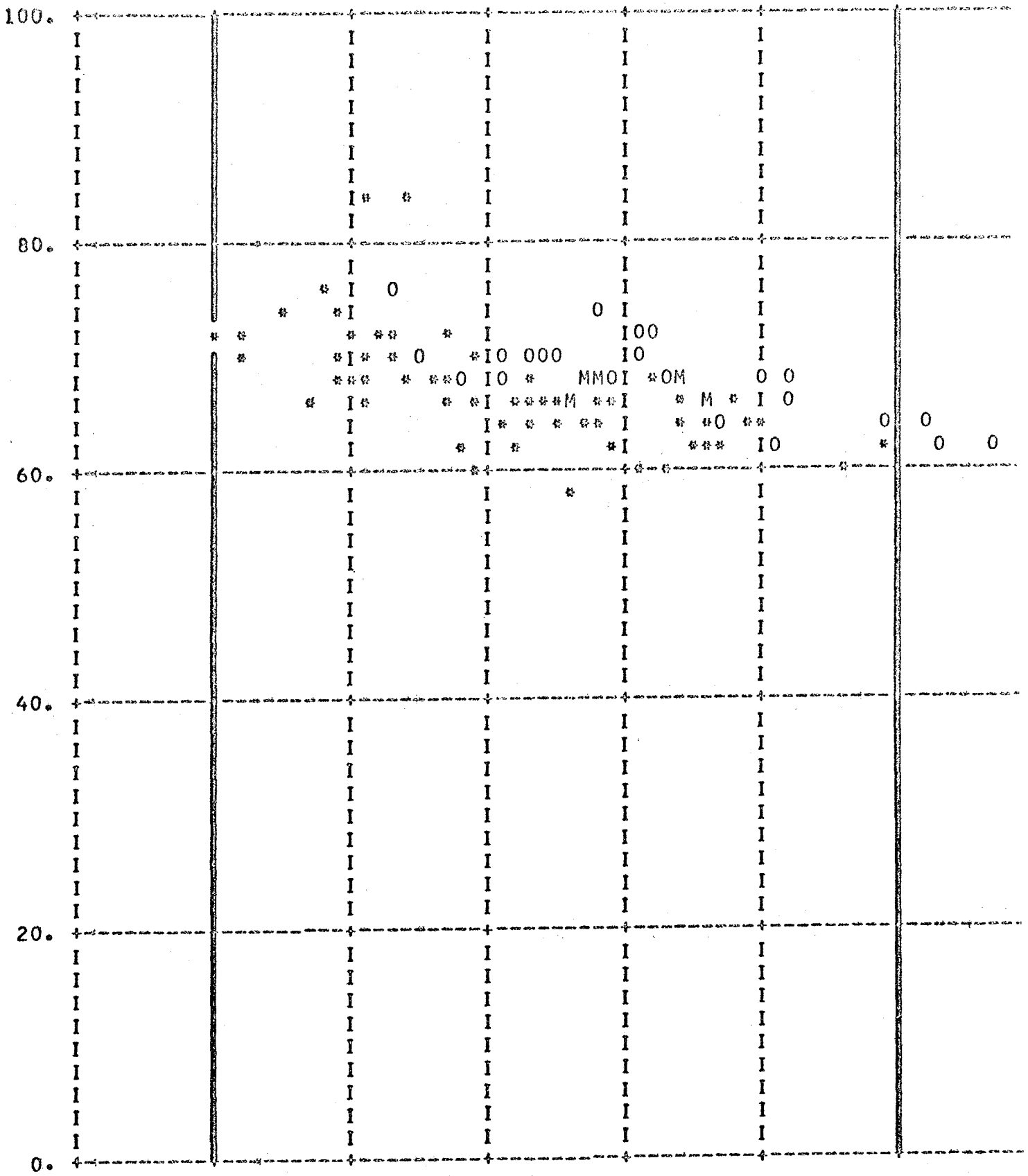
PRODUCER 17 GRADE AC 10



V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

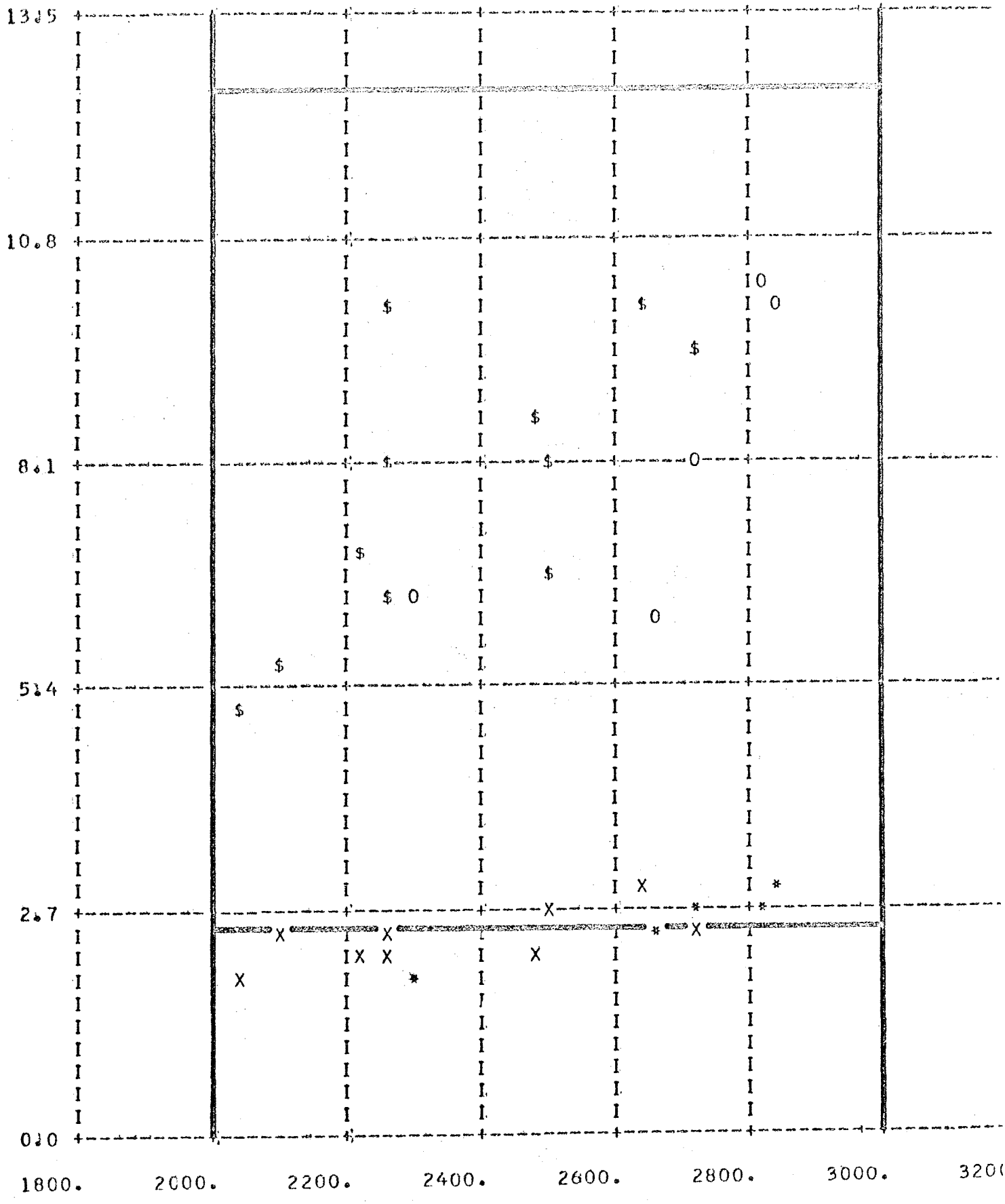
PRODUCER 17 GRADE AC 20



VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

PRODUCER 17 GRADE AC 20



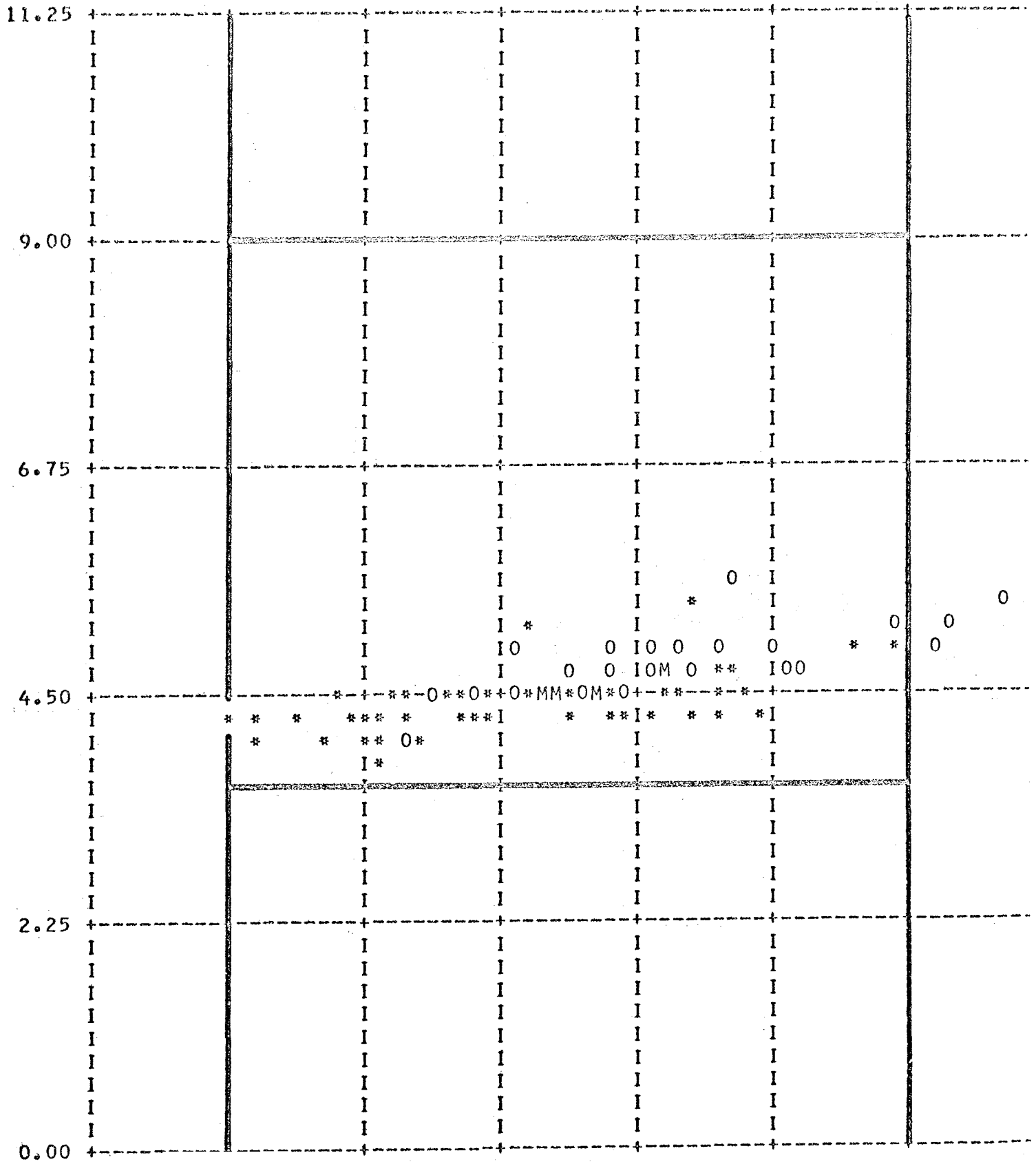
V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AI
0 1965 $ 1966

PRODUCER 17 GRADE AC 20

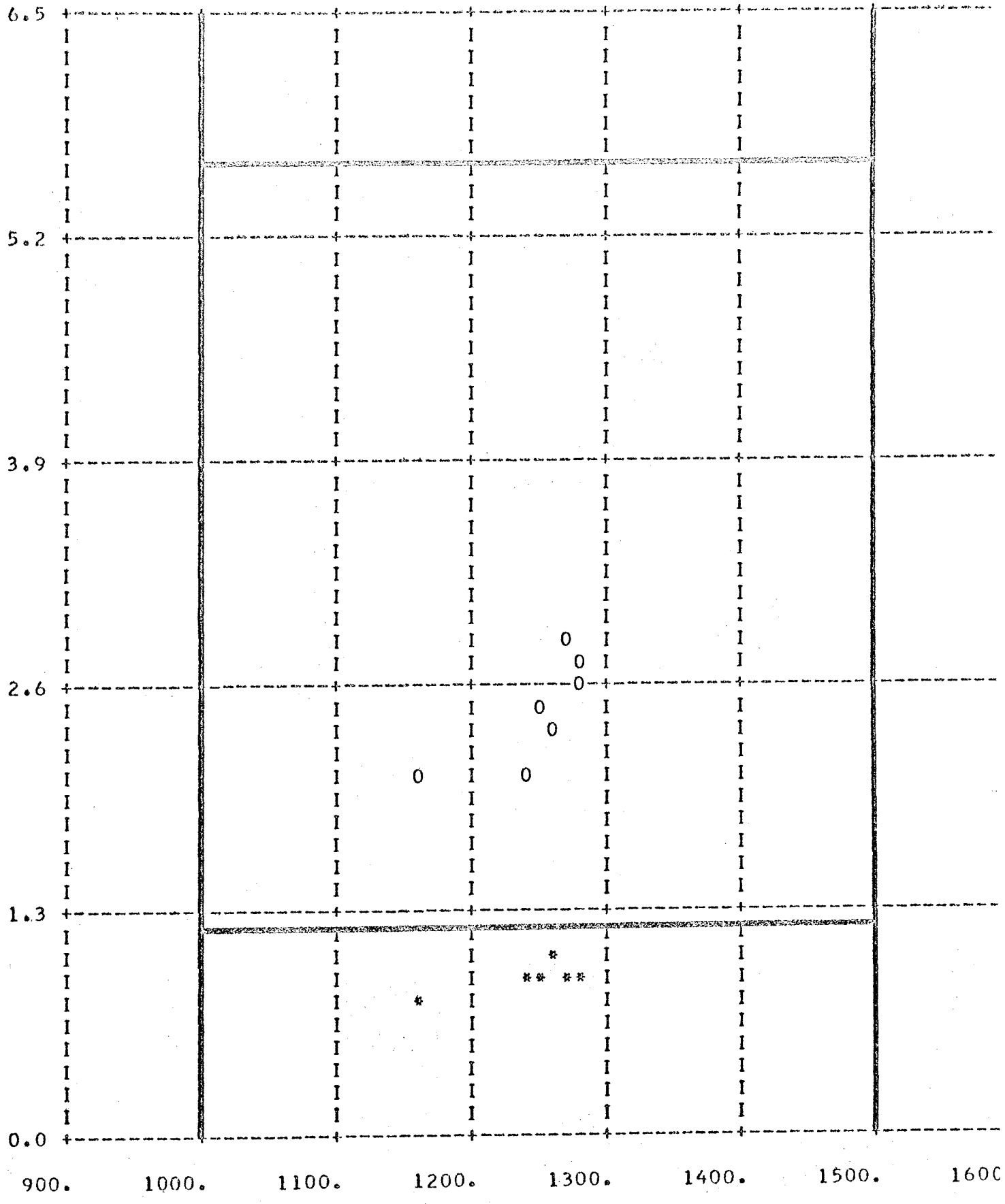


V I S C O S I T Y S T O K E S 1 4 0 F

LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 16

PRODUCER 18 GRADE AC 10

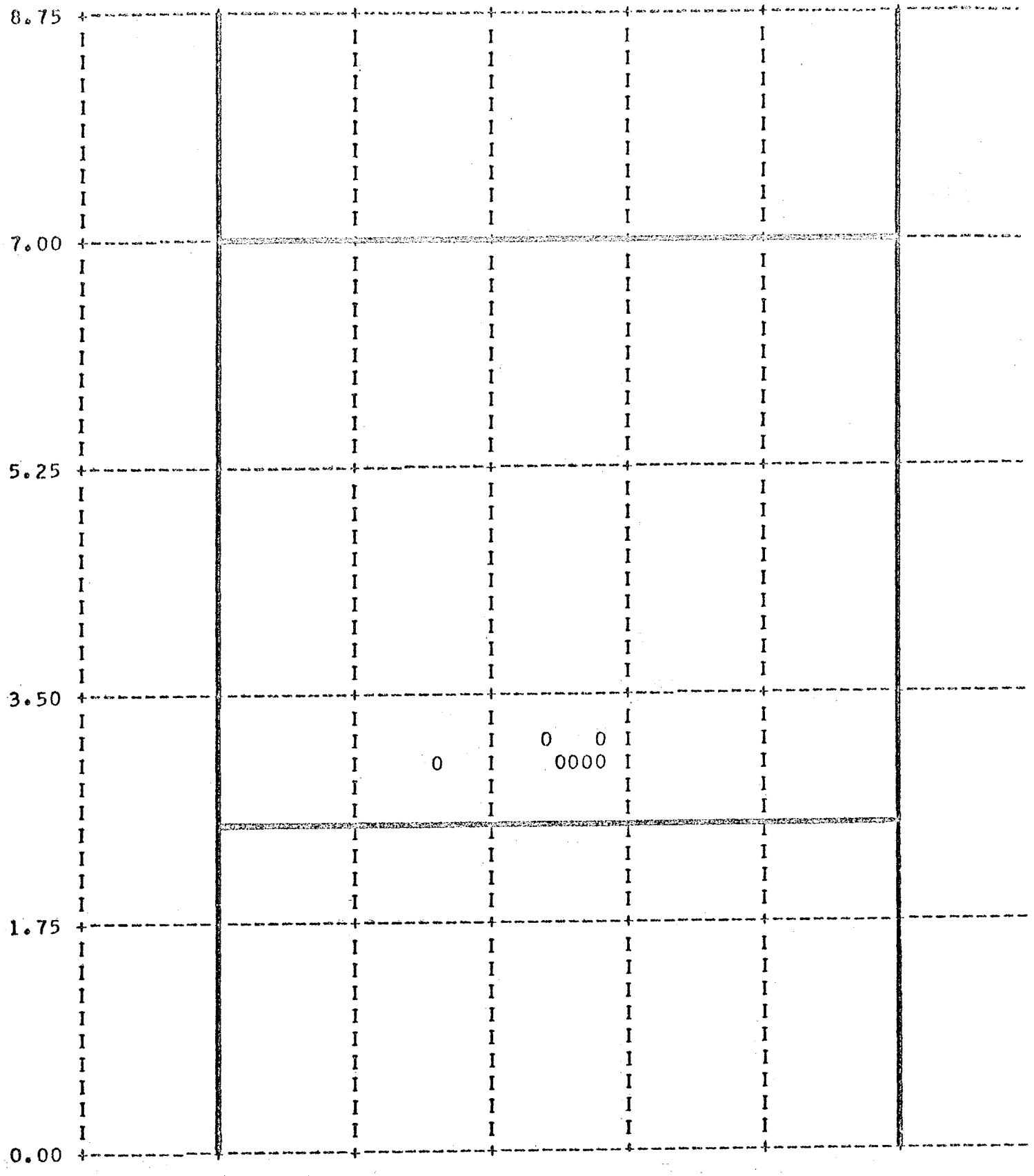


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

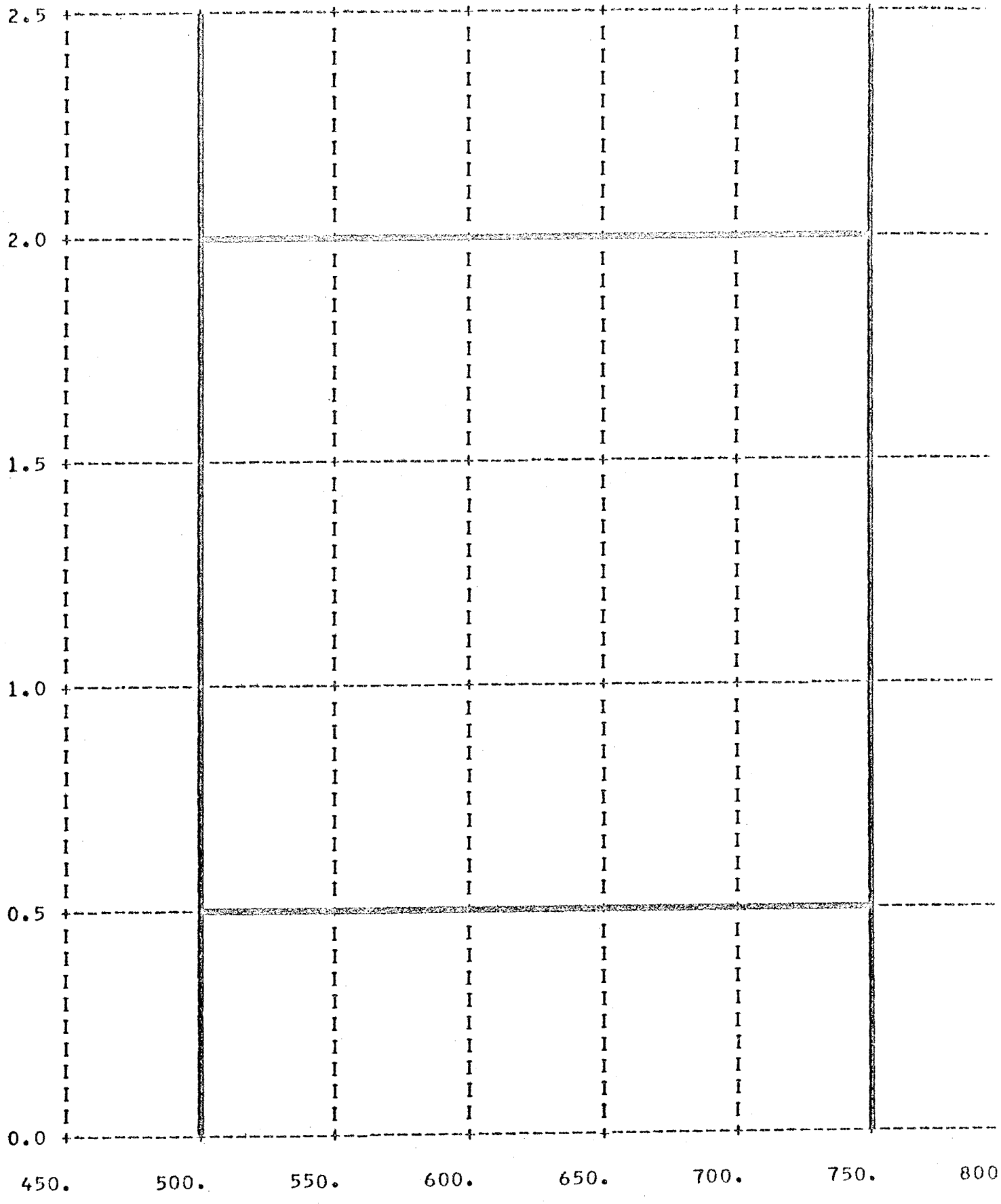
VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 18 GRADE AC 10



Asphalt Supplier
No. 19

PRODUCER 19 GRADE AC 5

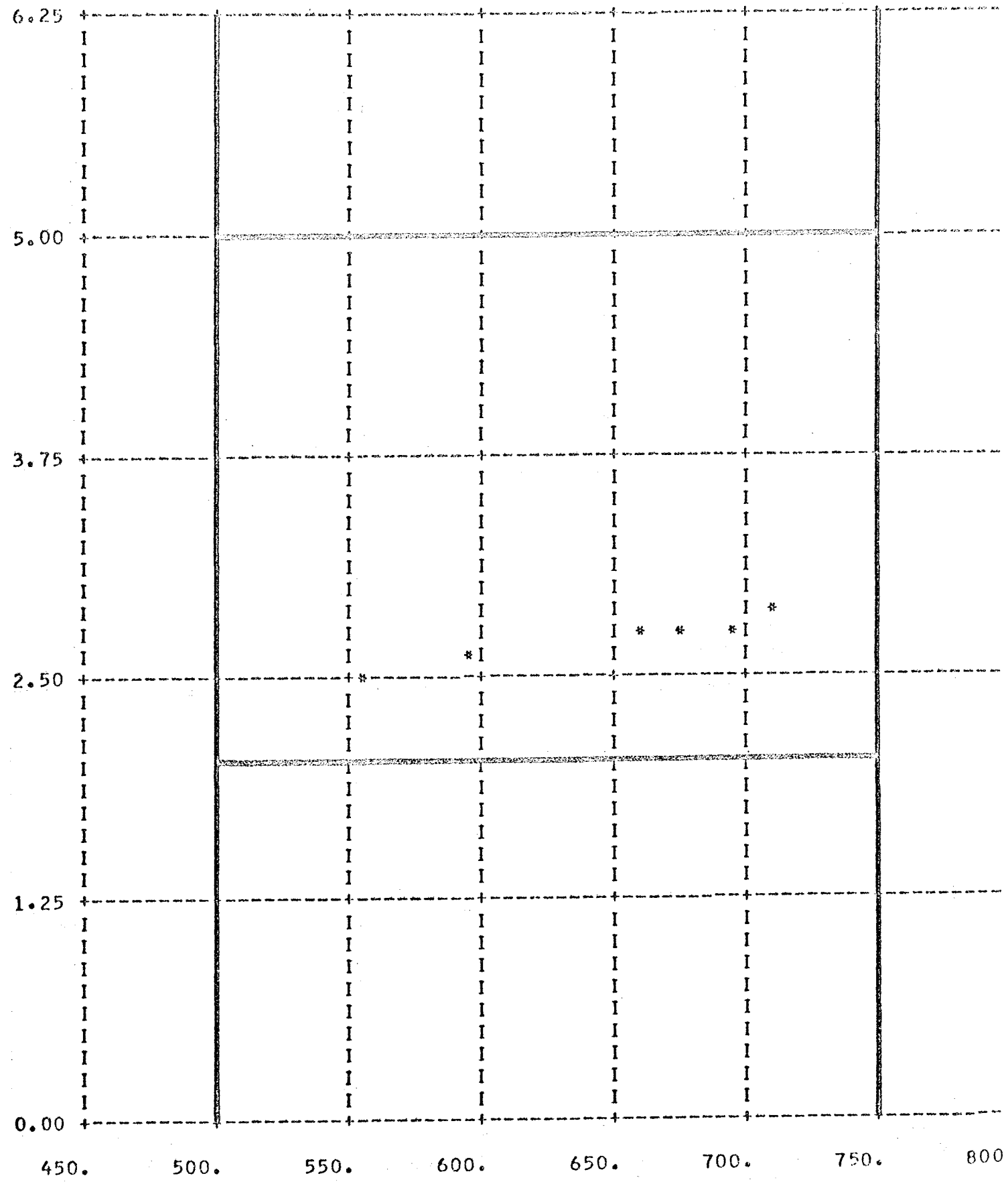


LEGEND
M MULTIPLE

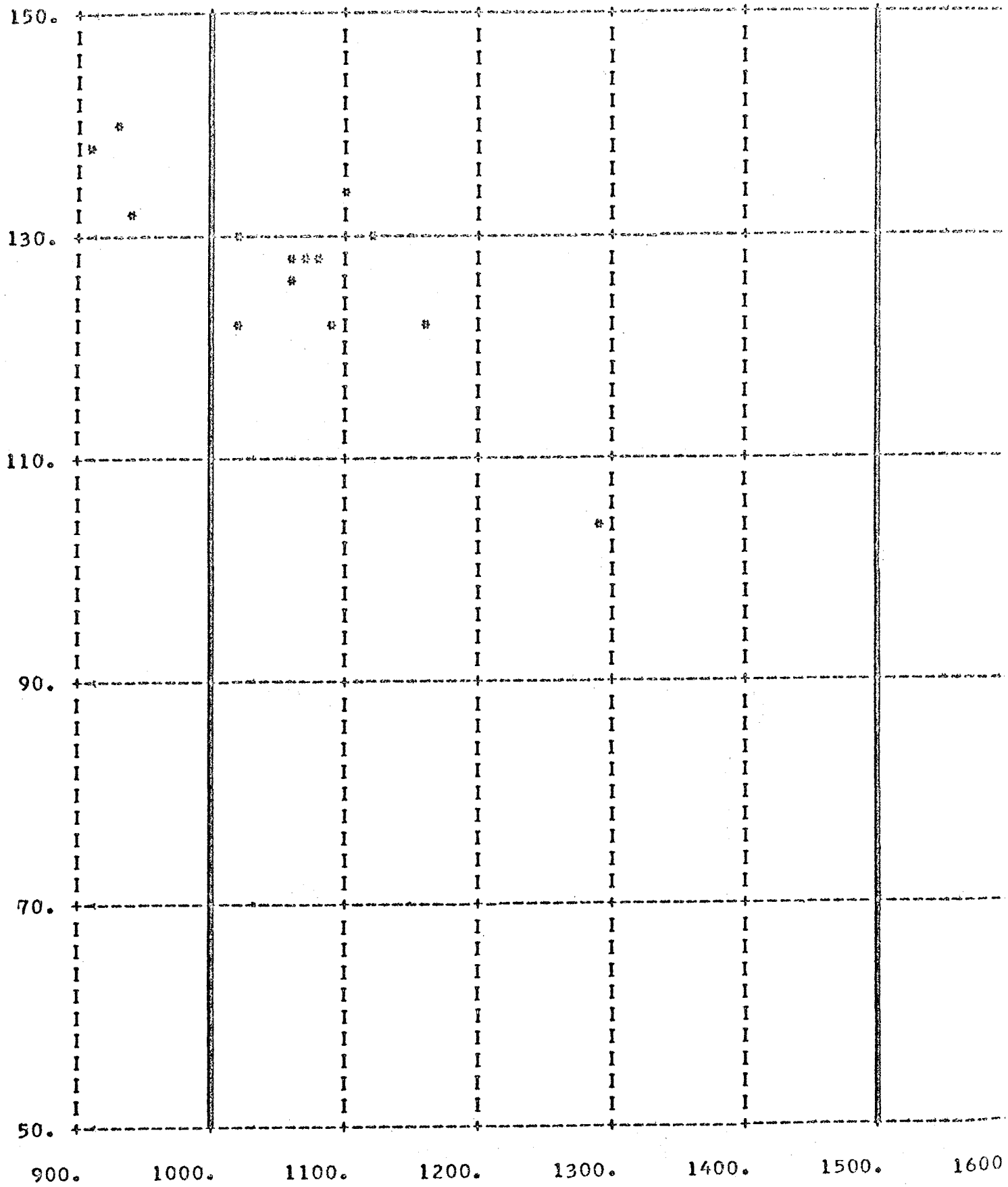
VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

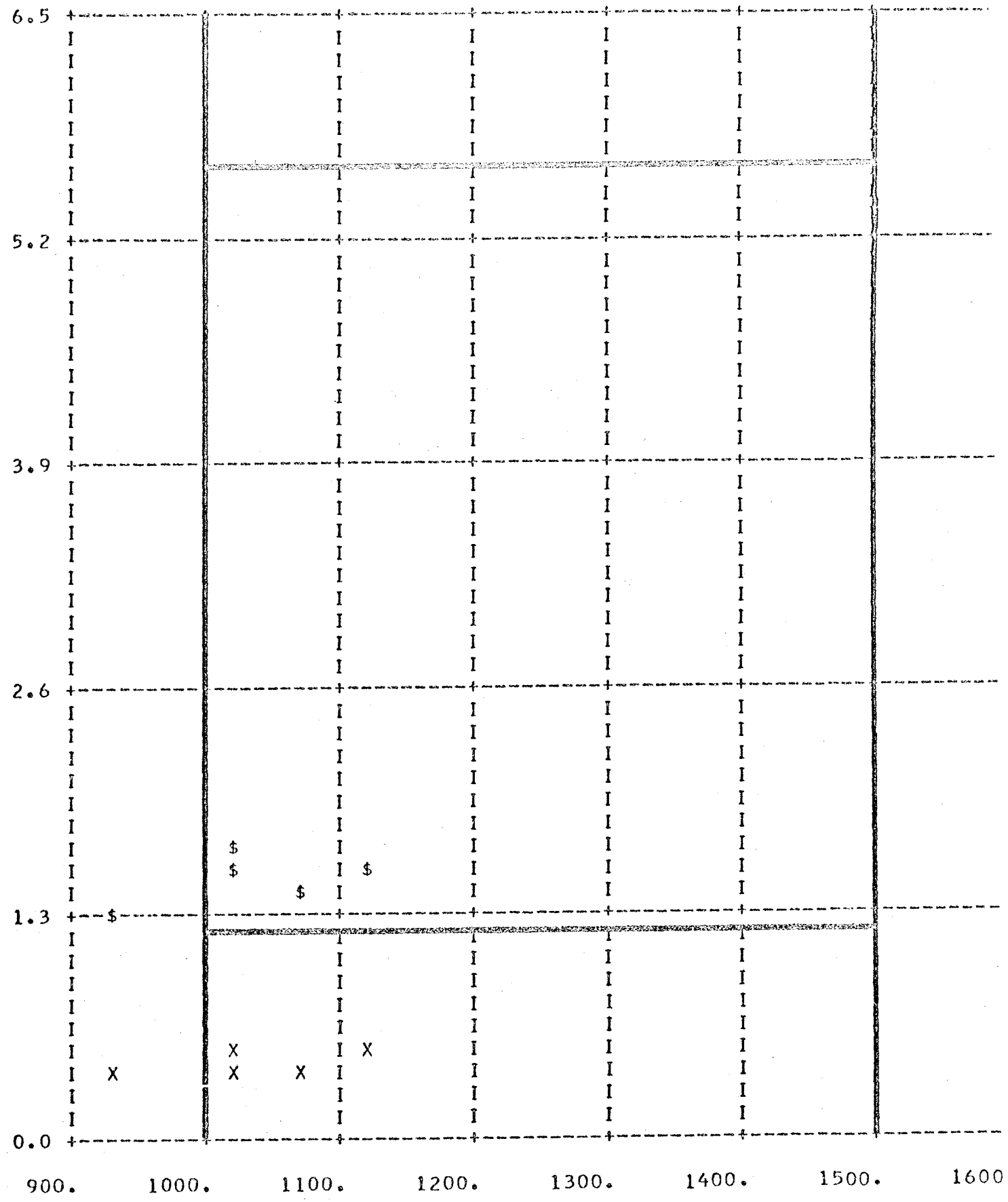
PRODUCER 19 GRADE AC 5



PRODUCER 19 GRADE AC 10



PRODUCER 19 GRADE AC 10

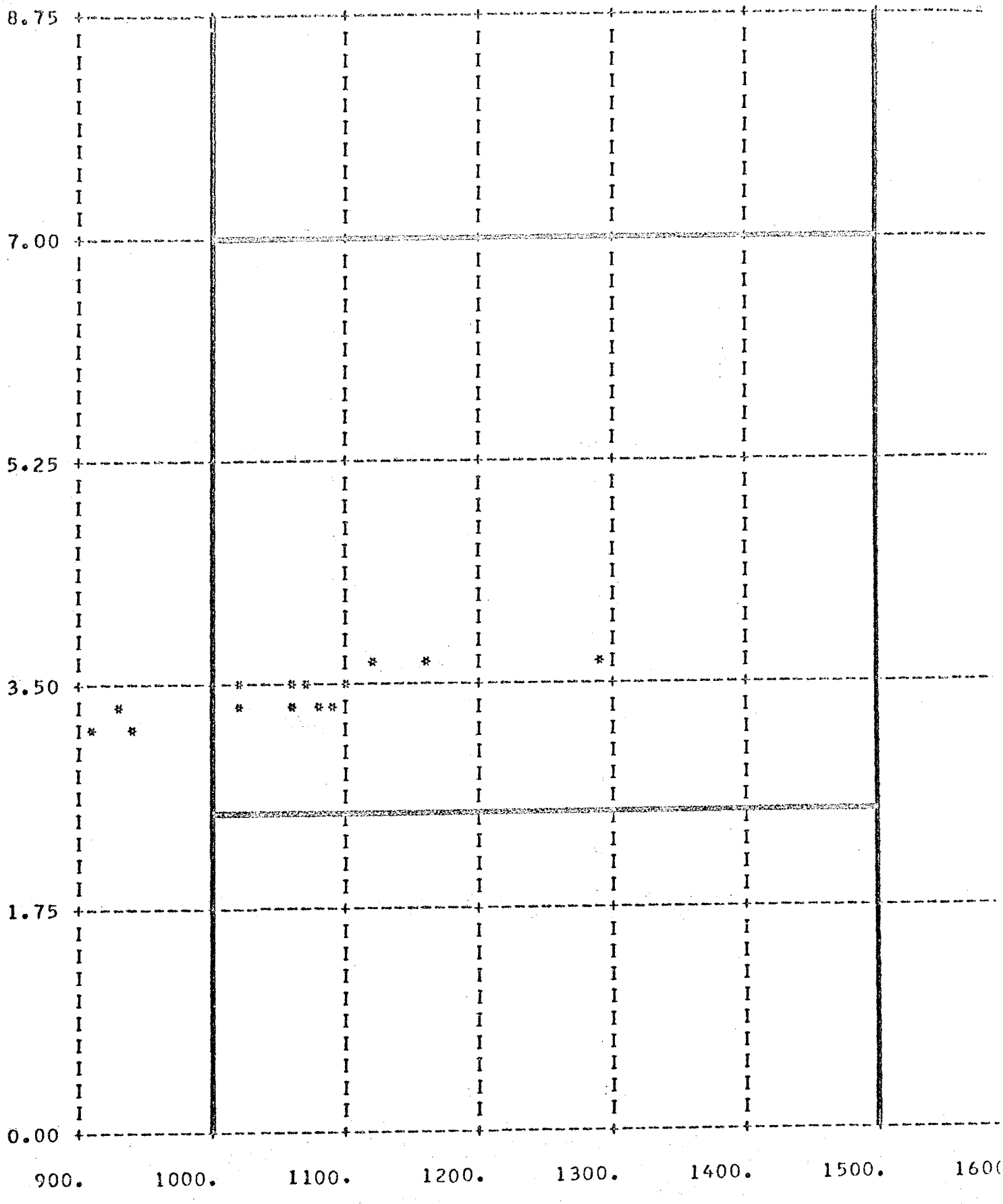


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 19 GRADE AC 10

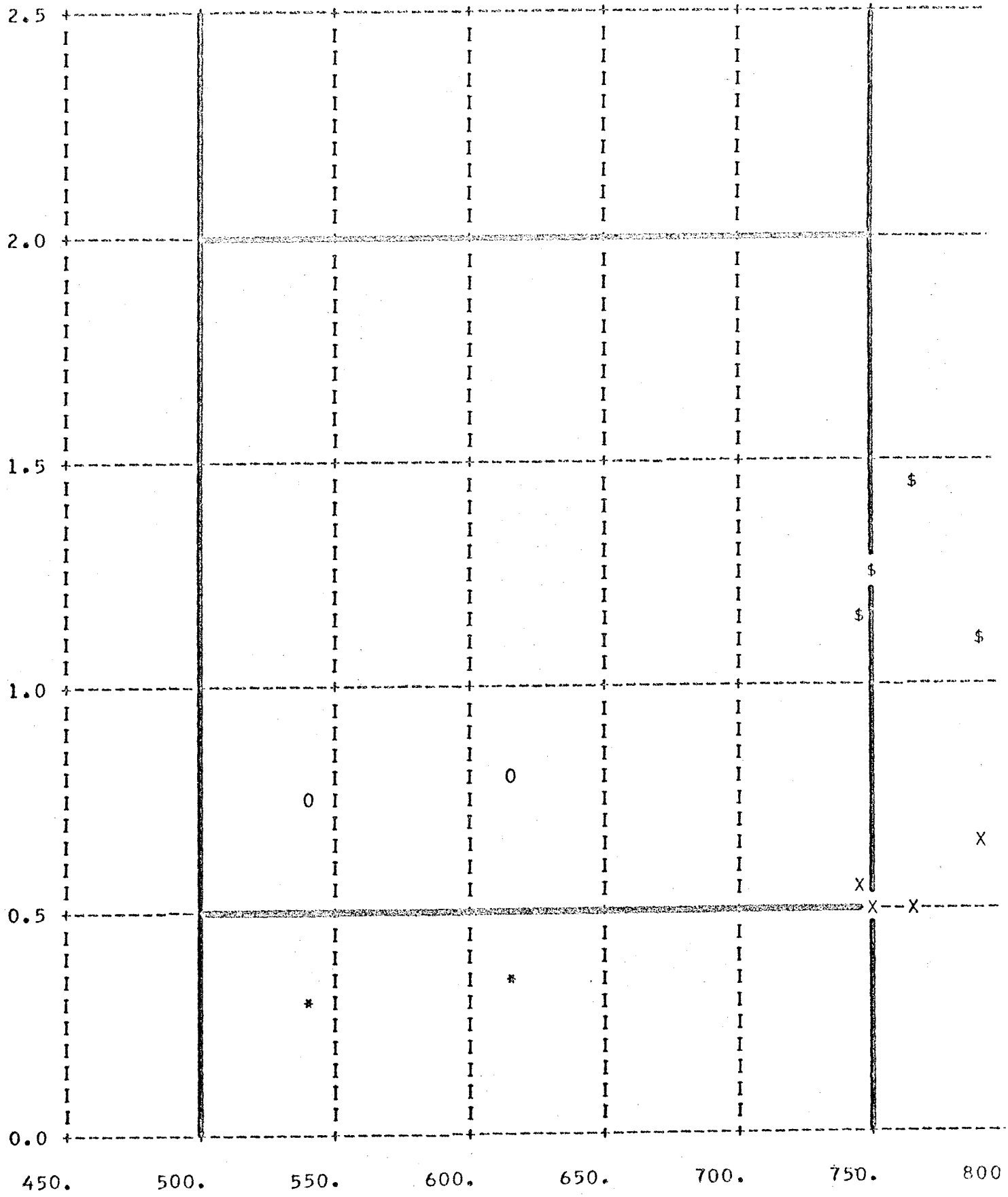


VISCOSITY STOKES 140F

LEGEND 0 1965 * 1966 M 1965 AND 1966

Asphalt Supplier
No. 20

PRODUCER 20 GRADE AC 5

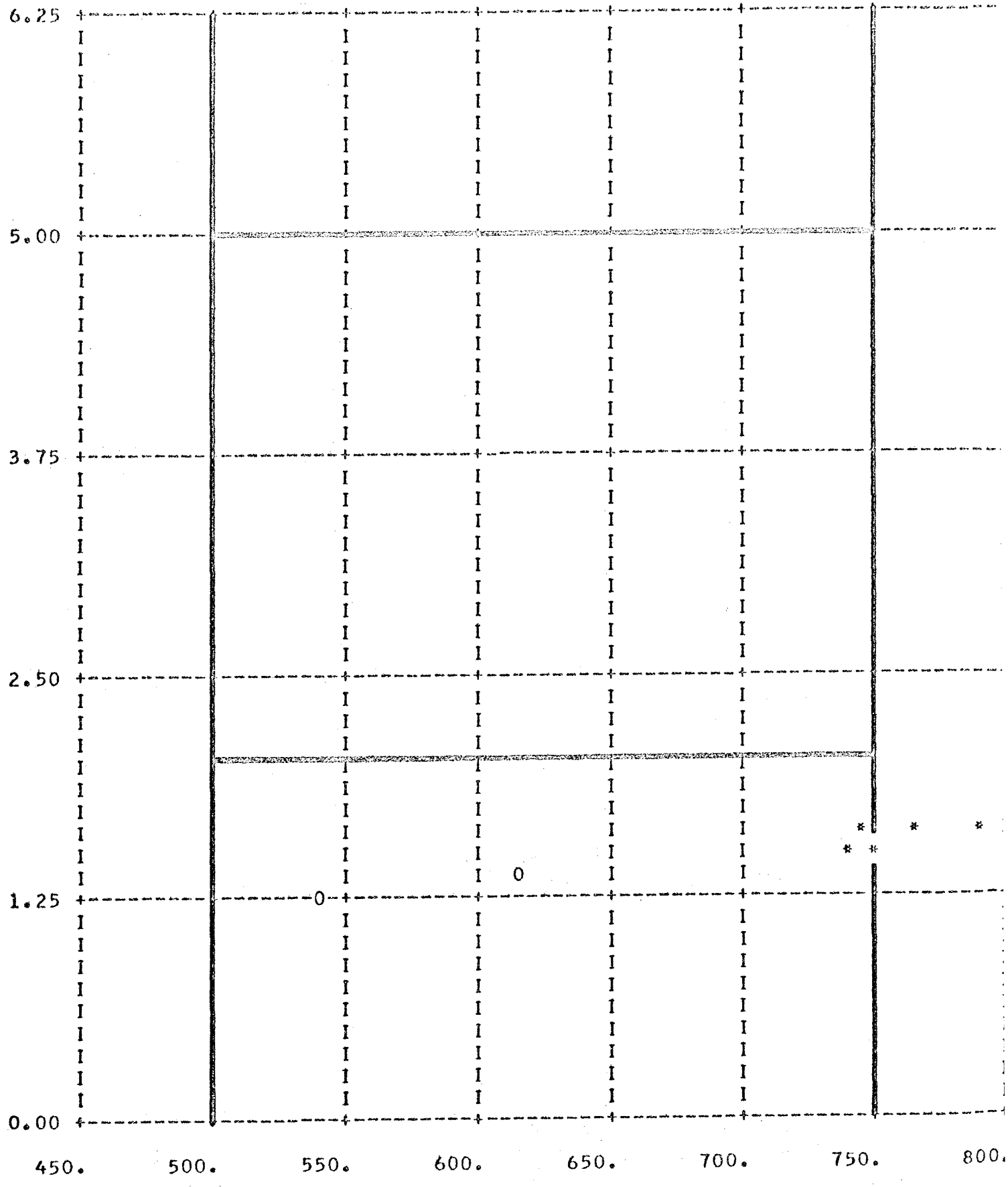


LEGEND
M MULTIPLE

VISCOSITY AT 77F
* 1965 X 1966

VISCOSITY AT 77F AFTER HEATING IN AIR
0 1965 $ 1966

PRODUCER 20 GRADE AC 5



VIII. Tabulation of 1965 and 1966 Asphalt Viscosity Data from the Material and Tests Laboratory, Texas Highway Department, Austin, Texas.

This material was prepared prior to a decision to use the visual presentation embodied in this report. All sample information was included, and the tabulation includes number of samples, percentages of samples meeting and failing to meet the specifications, as well as means and standard deviations for each set of samples. Those samples subjected to tests at multiple temperatures are tabulated in accordance with the combination of temperatures used.

Since this material largely duplicates what has been included in a pictorial form, the tabulations are not presented in this report. However, they are available as a supplement, a copy of which may be obtained by addressing your request to

Dr. R. N. Traxler
Asphalt Technology Department
Texas Transportation Institute
Texas A&M University
College Station, Texas 77843