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BRIX-DETERMINATION IN FIRST EXPRESSED JUICE BY MASS FLOW METER

by

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SD97011

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ABSTRACT

A series of trials have been carried out to evaluate the performance of a Micro Motion CMF025 mass flow meter in place of the standard hydrometer for brix measurement in cane pay analyses. Tests were conducted at ten sugar mills over 1994 and 1995 seasons.

The evaluation has been painstaking and extensive in scope and has culminated in the proposal to include a Method 3A in the Laboratory Manual for Australian Sugar Mills, " Brix Determination in Juice by Vibrating Tube Density Measurement ". The process has involved millers' and the growers' technical personnel.

The repeatability of the hydrometer and mass flow meter measurement methods was identical at 0.09 ° Bx. The instruments gave one to one correspondence in brix result. Clean juices and non settling suspensions gave identical results within the repeatability of the methods. Dirty juices did show differences in result and required the development of alternative methodology.

A sampling and analysis methodology was developed for the mass flow meter which was based on the settling rate of mill juices containing dirt. A balance is achievable, in volume required for analysis in the mass flow meter, between required settling rate and vessel diameter. This has lead to the conclusion that the mass flow meter with the appropriate settling vessel can function in a number of juices that would otherwise require a refractometer reading instead of a hydrometer.

The user can select the most appropriate settling vessel for the analysis system and the desired minimum measurable settling rate.

The mass flow meter used in conjunction with the 200 mm by 100 mm diameter mill billy at South Johnstone Mill was suitable for juices in which the hydrometer exceeded the refractometer brix by greater than three units.

The performance of the mass flow meter has been monitored in a range of operating conditions in order to enable a considered evaluation of its potential. The stability of the instrument, its response to temperature variation, the influence of air, calibration procedures and audit arrangements have been set out.

1.0 INTRODUCTION

The Australian Sugar Milling Council (ASMC) and the Bureau of Sugar Experiment Stations (BSES) have been seeking an alternative to the hydrometer or spindle for measurement of brix of first expressed juice. An instrument was sought that would enable reduced dependence on the recording of results by the analyst and ultimately the development of automated methods.

Fisher Controls produced an EXAC instrument, a mass flow meter, capable of being calibrated to record density of liquids being pumped through it. The instrument was promising but lacked electrical reliability. Fisher Controls were taken over by Rosemount Instruments giving rise to the company Fisher-Rosemount Pty Ltd. This company marketed a range of mass flow meters, the Micro Motion Density Monitoring System featuring Elite Model Sensors. Initial testing with this equipment showed promise and reliability.

With the support of the Industry Measures Committee of the Queensland Sugar Corporation, SRDC funding was sought and granted to undertake proving trials with these instruments in mill juice laboratories. The Model CMF025 instrument was selected and purchased. Fisher - Rosemount loaned a further instrument for the 1994 season and the next size up, CMF050, for portion of the 1995 season.

This report provides a summary of the work undertaken . It supplements Interim Reports dated 27/3/95 and 18/9/95 and is the basis for a new Method 3A for the Laboratory Manual for Australian Sugar Mills, "Brix- Determination in Juice by Vibrating Tube Density Measurement".

1.1 Objectives

- Investigate the suitability of a coriolis effect density sensor for measuring brix in first expressed juice
- Develop satisfactory calibration methods for a mill situation
- Develop satisfactory juice presentation methods
- Identify a system for direct capture of meter output for use in computerised cane payment

1.2 Outputs

- Proof of accuracy and acceptability of the Rosemount machine for brix measurement
- Development of satisfactory systems for automation of brix measurement and subsequent use.
- Develop certification standards and procedures for specifying appropriate instrument compliance

1.3 Modifications to Outputs

The Industry Measures Committee of the Queensland Sugar Corporation strongly advised that the development of satisfactory systems for the automation of brix measurement was outside the scope of this work. The nuts and bolts of such a system will, in the current cane pay arrangements be developed by local mill area negotiations.

This work has thus focussed on the provision of an appraisal of the instrument and promulgation of the factors that should be considered in system development, calibration of the equipment and ongoing audit and certification.

2.0 OVERVIEW OF THE TRIALS

The two Elite Model CMF025 instruments were tested in the juice laboratories of 10 mills from Mulgrave to Harwood in the 1994 season. The instrument was found to produce brix measurements results which were essentially identical with those of a brix spindle in clean juices but were affected by mud. There was a concern that the CMF025 instrument with a bore size of 5.23 mm could be susceptible to blockage.

The CMF025 was given a retest at South Johnstone Mill in the 1995 season, initially in comparison with the Elite Model CMF050. The Model 050 has a bore size of 8.76 mm. The trials sought "dirty" juices and demonstrated that settling vessels could be selected for these juices that would enable the mass flow meter to produce density measurements free of mud influence. In contrast, refractometer readings were necessary in spindle based analyses. The CMF025 did not block and the CMF050 instrument provided no advantage.

The CMF025 was used by the Cane Testers at South Johnstone Mill for the remainder of the 1995 season to accumulate additional comparison with the brix spindle.

3.0 PRINCIPLE OF THE METHOD

The mass flow meter operates on the Coriolis principle in which the behaviour of a vibrating tube of liquid is directly correlated with the density of that liquid. Mass flow is derived from the twist of the tube and density from the frequency of vibration. The physics of the instrument is further described in Appendix 1

The sample of juice is cooled if necessary and allowed to stand so that suspended solids can settle out and air bubbles can escape. A portion of the juice sample is then drawn through the mass flow meter by means of a peristaltic pump, the pump stopped, and the brix as displayed by the instrument is recorded manually, or by interlocked computer or printer. The analyst may use the interlocked computer to compute brix from a density and temperature result provided by the instrument. This latter approach is recommended in Method 3A of the Laboratory Manual.

4.0 APPARATUS

4.1 Mass Flow Meter.

A Micro Motion Density Monitoring System featuring an Elite Model CMF025 Sensor was the prime instrument used in this work. The mass flow meter was capable of measuring mass flow rate, volumetric flow rate, density and temperature and presenting the data to a computer. Density was measurable as g/cc, SGU or Brix and had a manufacturer's specification on accuracy of ±0.0005 g/cc (0.11 Bx). Solution temperature was measured to ±1°C. The meter, constructed of 316L stainless steel, was capable of withstanding temperatures as high as 200°C and pressures up to 300 psi.

Further details on the sensor may be found in the Appendix to this report.

The instrument is calibrated with two sugar solutions of known brix or density (depending or the measurement mode selected). The calibration processes and check calibrations developed are fully described in Appendix 2.

4.2 Peristaltic Pump

Juice was passed through the mass flow meter by means of a Masterflex
I/P (Industrial/Process) Peristaltic Pumping system with rated capacity of 8 litres / min at 650 RPM, comprising

- Model 7591-55 Pump Drive.
- Model 7529-10 Easy Load Pump Head
- High Capacity Pump Controller Model 7591-25 with external operation capability.
- Norprene A60G grade tubing, type 5404-73, 9.5 mm diameter

4.3 Sampling

The sampling device evolved to be a 350 mm of 3.5 mm glass tubing and 770 mm of 4.5 mm plastic tubing were connected to the meter in the configuration as shown in Figure 1. This tube was used in the 1995 research trial work at South Johnstone.

The 1994 season work and the Cane Tester's work in the 1995 season differed in that a float was used rather than a sample tube or proboscis. An advantage of the float is the analyst needs not be concerned with the pump sucking air through the instrument. It does require that the sample point be deeper into the liquid than it need be by the probe and will encounter mud before the probe system.

Two floats were used.

A metal float was used in the 1994 season. It displaced 95 ml and the sampling point at the base of the float was 112 mm below liquid surface. This was a cut off and suitably bored and weighted metal brix spindle bulb.

A fibre float was used in 1995 season. The float was displaced 23 ml liquid and sampled at 39 mm beneath the liquid surface. It is more effective than the metal float in providing a sample from above the mud layer in dirty juice. The float was simply a fishing net supporting float 75 mm long with a maximum diameter of 42 mm with a rigid plastic tube or proboscis pushed through the centre hole to the base of the float.

Layout of Density Monitoring System

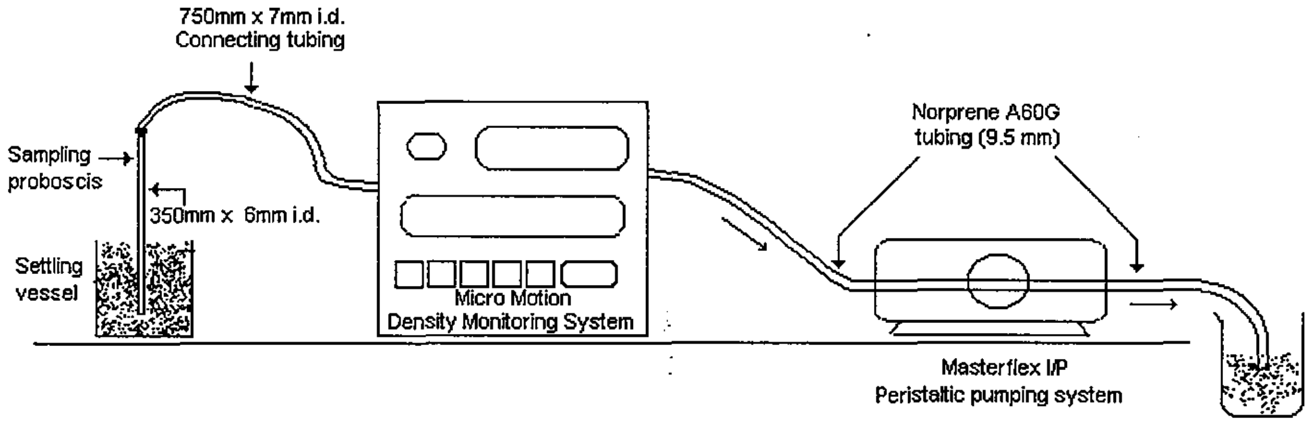


FIGURE 1

4.4 Juice Settling Vessel

A number of juice settling vessels were used. The selection of the most appropriate vessel for the measuring technique being used has been found to be crucial to the work. Dimensions and capacity required can be selected in the manner set out in Section 7.3.

4.5 Instrument Layout

The apparatus was set up with the peristaltic pump drawing the sample through the meter. A sketch is shown in Figure 1 The sampling proboscis or float was connected to the meter by means of small diameter plastic tubing to reduce to a minimum the volume of solution needed for analysis. The larger diameter peristaltic pump tubing is attached directly to the meter's plumbing and run to waste via an overflowing sump to provide a seal to discourage air entry into the system. Similarly, the inlet proboscis is kept under water when not sampling. It is important that the pump not be run when the proboscis is out of liquid.

5.0 TRIALS IN 1994 SEASON

5.1 Methodology

During this test program, approximately 100 brix determinations were made on first expressed per mill. Three methods were employed:

- Brix by normal mill method using the spindle
- Brix by more accurate BSES method using the spindle
- Brix by Rosemount density meter

Two standard brix cylinders were set up with well mixed first expressed juice.

Details regarding the three methods of brix determination are as follows:

Test A Mill Spindle method

In this method, the spindle is read to the nearest 0.1 degrees brix. The temperature is read to the nearest 1.0 degrees Centigrade and the correction off Table I of Laboratory Directions applied to the spindle reading. No spindle correction is applied.

All other usual precautions in the brix determination were applied.

Test B BSES Spindle Method

This method of brix determination was similar to the mill method except that the spindle reading was made to the nearest 0.05 degrees brix, the temperature read to the nearest 0.1 degrees Centigrade and the spindle correction applied.

As previously all other usual precautions were applied.

Test C and Test D Density Meter Method

These tests were conducted on the residue in the brix cylinders after measurements A and B, respectively, were completed. No topping up was permitted.

The procedure followed in this method was as follows:

The instrument was set in **brix** mode

1. Carefully place the float in the cylinder of juice allowing no overflow of sample
2. Start the pump at a setting delivering about 300 - 350 cm^3/min and pump about 200 cm^3 to waste. This was to flush out the instrument.
3. Turn the pump off and wait for the meter to reach a stable brix reading (the display has temperature correction applied).
4. Turn the pump on again for a few seconds and turn the pump off again. Wait until a stable reading is obtained and note the reading.
5. Repeat step 4 several times until a constant brix reading is obtained. Record the final brix reading and the temperature of measurement.
6. Leave the instrument filled with juice until the next reading was commenced
7. Flush the instrument out with warm water after the last reading of the day.

Note: The cleaning stipulated for these trials proved inadequate as the operators at Broadwater and Harwood, the last mills at which the instruments were tested, reported instability and calibration difficulties. Subsequent trials required water washing between batches of analyses and periodic nitric acid cleaning. This successfully avoided problems in solids build up.

Adhering solids change the mass of the tubes and also the volume of liquid in them. This spoils calibrations that have been incorporated in the instrument before the solids build up.

5.2 Results

Trials were completed at ten mills evaluating the Micro Motion Rosemount Model CMF025 Mass Flow and Density Sensor for measurement of brix of first expressed juice. In each test, the reading obtained with the density meter has been compared with that obtained using a brix spindle. After the instruments were set up by BSES Research Officer, Alan Noble, the comparisons were carried out by the Cane Tester in Charge, having received training in operation and calibration procedures. Trials were carried out as follows, using two instruments.

<u>Instrument 1</u>

South Johnstone Mill **	28 tests	11/9/94 to 14/9/94
Macknade	31	17/9/94 to 20/9/94
Proserpine	38	1/10/94 to 10/10/94
Bingera *	36	14/10/94 to 20/10/94
Broadwater ***	34	2 /11/94 to 13/11/94

Alan Noble used instrument 1 for additional work at Broadwater from 30/11/94 to 7/12/94

<u>Instrument 2</u>

Mulgrave Mill *	33 tests	13/9/94 to 15/9/94
Inkerman	30	20/9/94 to 24/9/94
Marian *	35	6/10/94 to 10/10/94
Moreton	27	18/10/94 to 27/10/94
Harwood	30	4/11/94 to 11/11/94

* 1 trial omitted as it is obvious the float entered dirt layer
**15 trials omitted as it is obvious the float entered dirt layer
*** 5 trials omitted as it is obvious the float entered dirt layer

The results were as follows:

Average Brix Differences

	A-B	C-A	D-B	D-C
South Johnstone	-0.014	-0.051	-0.011	+0.039
Macknade	+0.105	-0.079	+0.029	+0.003
Proserpine	+0.018	+0.004	+0.030	+0.008
Bingera	-0.046	+0.063	+0.026	+0.012
Broadwater	-0.040	+0.015	-0.017	+0.008
Mulgrave	+0.047	+0.012	+0.084	+0.026
Inkerman	-0.034	+0.080	+0.083	+0.029
Marian	-0.027	+0.052	+0.030	-0.007
Moreton	+0.050	-0.030	+0.017	-0.003
Harwood	+0.007	-0.112	-0.050	+0.056

It may be seen from the averages of the results that meter and spindle determinations are very comparable. There are however individual differences of significance.

The range of results obtained are found in the following tables

Maximum Positive Brix Difference

	A-B	C-A*	D-B*	D-C
South Johnstone	+0.10	-	+0.28	+0.12
Macknade	+0.28	+0.13	+0.16	+0.20
Proserpine	+0.14	+0.35	+0.40	+0.12
Bingera	+0.19	+0.28	+0.16	+0.16
Broadwater	+0.18	+0.34	+0.19	+0.14
Mulgrave	+0.16	+0.24	+0.35	+0.22
Inkerman	+0.17	+0.33	+0.26	+0.17
Marian	+0.07	+0.24	+0.20	+0.04
Moreton	+0.15	+0.15	+0.13	+0.11
Harwood	+0.11	+0.07	+0.16	+0.32

* Meter reads high relative to the spindle

Maximum Negative Brix Difference

	A-B	C-A**	D-B**	D-C
South Johnstone	-0.09	-0.14	-0.16	-0.02
Macknade	-0.05	-0.26	-0.16	-0.10
Proserpine	-0.25	-0.26	-0.12	-0.11
Bingera	-0.14	-0.10	-0.13	-0.12
Broadwater	-0.25	-0.19	-0.19	-0.11
Mulgrave	-0.16	-0.14	-0.10	-0.08
Inkerman	-0.25	-0.32	-0.15	-0.21
Marian	-0.14	-0.12	-0.10	-0.07
Moreton	-0.04	-0.15	-0.07	-0.08
Harwood	-0.11	-0.29	-0.30	-0.06

** Meter reads low relative to the spindle

The frequency distributions for the combined mill data (excluding those clearly affected by dirt) are shown in Figures 2 and 3.

Full results are presented in Appendix 3. Histograms displayed in the Appendix show the distribution of the individual comparisons A-B, D-B etc. for each mill.

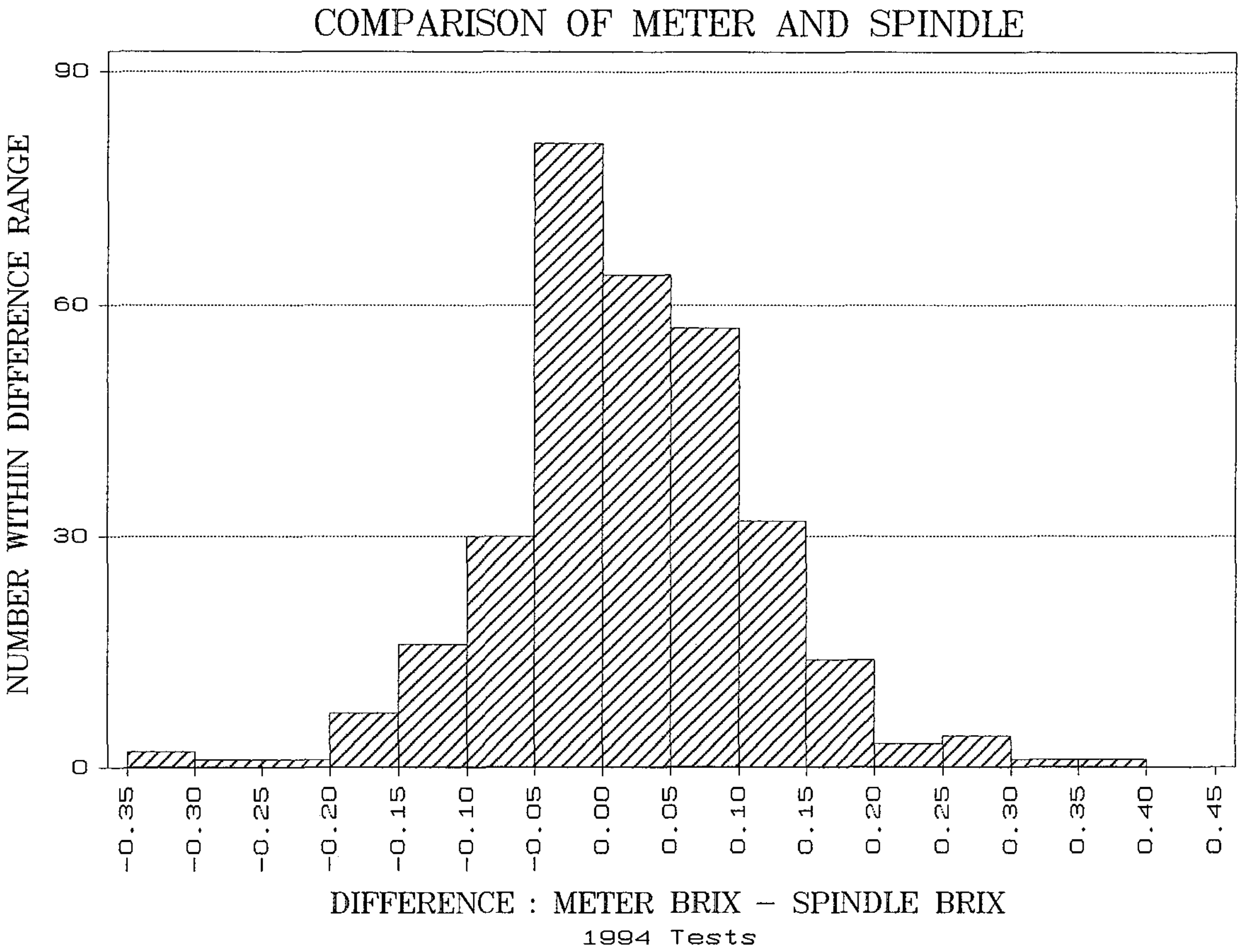

COMPARISON OF METER AND SPINDLE
NUMBER WITHIN DIFFERENCE RANGE
0
30
60
90
-0.35
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
DIFFERENCE : METER BRIX − SPINDLE BRIX
1994 Tests

FIGURE 2

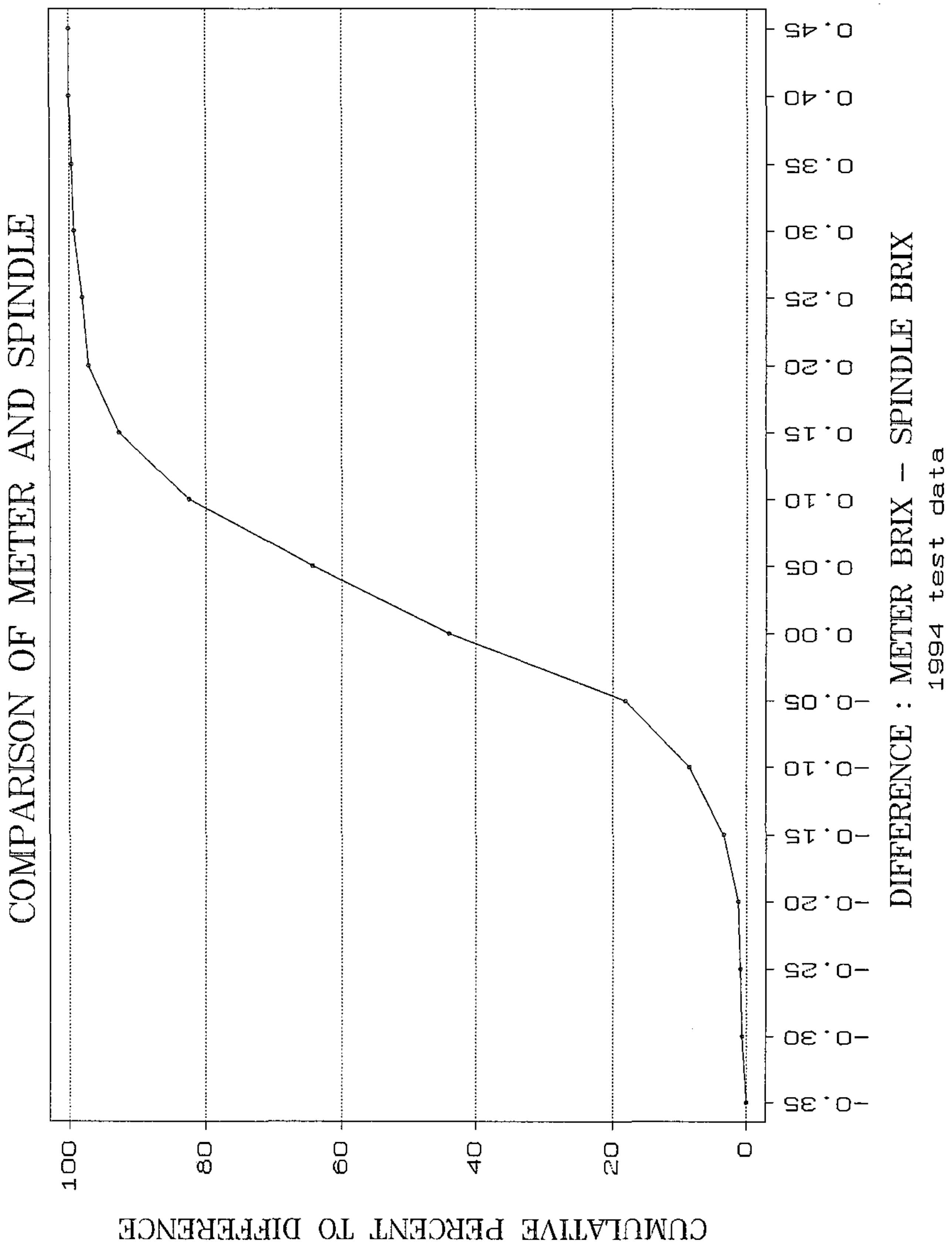

COMPARISON OF METER AND SPINDLE
CUMULATIVE PERCENT TO DIFFERENCE
0
20
40
60
80
100
-0.35
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
DIFFERENCE : METER BRIX − SPINDLE BRIX
1994 test data

FIGURE 3

5.3 Repeatability of Spindle and Meter Measurements

A measure of the repeatability of the spindle and the meter was necessary to put the results in perspective. Alan Noble completed sets of trials at Broadwater.

A large sample of first expressed juice was obtained and after thorough mixing poured into 10 brix cylinders. Following the standard 20 minute settling period, the brix of the 10 subsamples was determined by spindle. The brix of each subsample was then determined using the meter. Two such sets were measured. In a third set, no comparison with spindle was made

The results for each set are as follows.

Set 1

	Meter	Spindle	Meter - Spindle
Number of readings	10	10	10
Mean	21.703	21.677	+0.026
Minimum	21.66	21.64	- 0.02
Maximum	21.77	21.74	+0.08
Standard Deviation	0.032	0.033	
Repeatability	0.09	0.09	

Set 2

Number of readings	10	10	10
Mean	21.372	21.341	+0.031
Minimum	21.33	21.30	0.00
Maximum	21.41	21.40	+0.08
Standard Deviation	0.025	0.030	
Repeatability	0.07	0.09	

Set 3

Number of readings	10
Mean	20.557
Minimum	20.52
Maximum	20.60
Standard Deviation	0.028
Repeatability	0.08

The spindle and the meter have identical performance under the conditions of the experiment.

Furthermore, it is expected that, under these ideal conditions, two readings on the same juice with either instrument or between instruments, identically calibrated, can differ by up to 0.10 Bx.

5.4 Discussion of Mill Results

South Johnstone trials were carried out under the most adverse conditions of dirty juice.

The histograms with a $\pm$ 0.10 Bx range give an indication of the quality of the comparisons between spindle and spindle, meter and meter and meter and spindle readings. The overall performance measured in the previous section would lead us to expect few differences outside the range -0.10 to +0.10.

The majority of differences in determinations between the spindle and the meter lie in the expected range however 30% lie outside this range primarily in the range -0.3 to -0.1 or +0.1 to +0.3. Some, particularly in the mills South Johnstone, Mulgrave and Broadwater, were in obviously dirty juice and resulted in larger differences.

The spindle and the meter results were internally consistent. The results for the comparisons spindle to spindle or meter to meter were more tightly distributed about the difference $\pm$0.10 although Macknade mill in the case of the spindles and Broadwater in the case of the meter show greater difference.

The deviations in the meter reading from the expected relationship with the spindle are certainly due to dirt being drawn up by the float in sample presentation for the meter.

The bottom of a spindle, reading 22 Bx, in a typical brix cylinder is located approximately 166 mm above the base of the "standard" cylinder. The metal float in the work described, after spindle brix reading and withdrawal of 350 ml for the brix determination, has its bottom and sampling point approximately 60 mm above the base of the cylinder.

Thus, the sampling configuration and sample volume required for the meter can result in a situation where the instrument, measuring the liquid well below the spindle, can sample juice with a higher level of mud than was present for the spindle reading. This will lead to elevated readings in the meter relative to the spindle and is the most probable explanation for the high differences observed.

Large negative difference between meter and spindle were only noted in numbers at South Johnstone where severe dirt conditions created difficulties in obtaining two identical sub samples from a juice billy when poured into measuring cylinders.

The problem caused by the sampling point in the brix cylinder may be alleviated in three ways, viz, using a sampling device with a higher draw off point; increasing the diameter of the brix cylinder; providing an expanded chamber for the mud to settle into, thus reducing its height in the cylinder.

The mass flow meter was capable of accurately measuring brix and is directly comparable with the brix spindle. No other instrument has this capability and automation facility. There are, however, issues that would need to be accepted or resolved before proceeding to adoption of the instrument.

Flow Rate

What is the optimum flow rate through the instrument to clear out the previous sample and remove settled material or air?

Turbulent flow would be achieved in measuring tubes of the CMF025 at 1500 cm^3/min

[If the next size up , the CMF050, were in use , this would be achieved at 2500 cm^3/min]

We needed to investigate this with a pump that delivers these rates and to investigate the effect of flow rate on the mud /juice interface as well as on the flushing of the instrument.

Does a higher flow rate lead to the incursion of settled material into the instrument ?

Is the flow rate in use (about 350 cm^3/min) adequate?

In the event that flow rate needs to be at the higher levels, is there benefit in having a larger diameter cylinder? How large?

Instrument Size

The next size of instrument up is the CMF050 with internal tubes 8.8 mm Dia (cf 5.2 mm for the CMF025) but this would need at least twice the juice volume for brix determination.

The instrument manufacturers expect both instruments could block if the conditions were appropriate.

Is the CMF025 likely to present a blockage problem that would be overcome by the CMF050?

Is the CMF050 unlikely to block in our worst conditions? Will the CMF025 block in these conditions?

We needed to carry out comparative tests with dirty juice to evaluate the CMF025 and the CMF050 if the issue was of sufficient concern.

The CMF025 was badly blocked when subjected to very high dirt loadings (about 40% on juice by weight) in an artificial mixture of small mill juice with added dirt. High pressure water was needed to clean it.

A cleaning procedure should be incorporated in operating specifications. The CMF's can withstand high pressures and temperatures.

Which Instrument?

The CMF instruments have two measuring tubes sealed within the instrument and this is a concern should one block and the other remain clear. This would change the calibration which could be corrected for but movement of the blockage may make calibration unachievable.

The smallest single tube instrument by Rosemount has a one inch tube and would be suitable for an on-line installation on the full juice flow, after appropriate clean up, but obviously too large for a method which utilises existing volumes.

The CMF025, the small diameter instrument, did not block in use with mill juices of the worst imaginable quality and may well be unlikely to block in extended use. The need existed to check this out.

Trials were carried out in the early weeks of the 1995 season in a wet belt mill to resolve the questions raised above.

6.0 TRIALS IN 1995 SEASON

6.1 General

A Rosemount CMF050 instrument with 8.73 mm ID tubing was leased for comparison trials with the CMF025 instrument (5.232 mm ID) in mud handling characteristics.

Trials were conducted at South Johnstone Mill by D.H. Sanders and D. L. Mackintosh over the periods 17/7/95 to 28/7/95 and 31/7/95 to 11/8/95. The conditions of the first period were very fine and dirty juices relatively few in number. The second period was marked by the onset of a wet period leading to infrequent crushing and limiting the actual juice trials to a few days only. It was possible to obtain juices with sufficient variation in dirt to test the capability of the meters and develop relationships which enable a potential user to select a procedure suited to local needs or from which to draw up industry wide standards.

The trials at South Johnstone Mill positively sought out high mud solids juices and used a range of settling vessels for sample presentation. The vessels used are itemised in Table 1.Trials were carried out with screened and unscreened juice. Sample withdrawal was effected by a proboscis inserted to the appropriate depth for 350 ml or by a moving proboscis following the liquid meniscus down during pumping, The latter was the basic measurement methodology. Spindle brixes were determined by the more precise method B of the 1994 trial work. A juice flow rate of approximately 465 cm^3/min was determined as suitable for the instruments (for details see Section 7.1).

26 trials were carried out, comparing, in most cases, meter sampling from a standard brixing cylinder as a settling vessel (vessel 4) and the "mill billy" (vessel 6) with a standard spindle brix and a standard refractometer brix measurement on supercel filtered juice. Other settling vessels were introduced as appropriate to explore other vessel diameters and filled heights.

Where glass vessels were used the 20 min settled heights of mud were observed and noted. The mud height in the metal "mill billy" was determined by lowering the proboscis to the point where mud was drawn up. In a few trials the fall in mud height was charted over the 20 minutes period.

SETTLING VESSELS USED IN SOUTH JOHNSTONE TRIALS

	Settling Vessels Used	Filled Volume ml	Filled Height mm	Diameter mm	CSA sq cm	Height for 350 ml mm	
1	Glass Measuring Cylinder	2448	442	84	55.39	64	
2	Glass Measuring Cylinder	2155	488	75	44.16	80	
3	Glass Measuring Cylinder	933	330	60	28.26	124	
4A	500 ml Glass Measuring Cylinder	633	350	48	18.09	194	Moving Proboscis
4B	500 ml Glass Measuring Cylinder	633	350	48	18.09	194	Stationary Proboscis
5	Large Glass Beaker	3709	210	150	176.63	20	
6	South Johnstone Juice Can	1570	200	100	78.50	45	Screened Juice
7	500 ml Glass Beaker	609	110	84	55.42	64	Screened Juice
8	500 ml Glass Beaker	609	110	84	55.42	64	Non Screened Juice
9	South Johnstone Juice Can	3709	200	100	78.50	45	Non Screened Juice
10	Standard Brixing Cylinder	633	350	48	18.09	*Max 211	Screened Juice
	Other Possible Vessels						
	Tully Juice Can	1990	150	130	132.67	27	
	Mourilyan Juice Can	1990	150	130	132.67	27	
	Mulgrave Juice Can	1496	126	123	118.76	30	
	Medium Glass Beaker	825	119	94	69.36	51	

* Clear juice for unhindered flotation of spindle in 15 Bx solution

TABLE 1

Settling vessels were used in sufficient numbers so that in no case were two brix determinations made from the one vessel and homogeneity in the filled vessels contents within a trial was given great attention.

A difficulty in carrying out work of this kind lay in matching meter and spindle results. Settling continues after the 20 minute period (at which time the spindle brix is carried out) and while the meter testing is being completed. This can lead to meter brix determinations which are unaffected by mud where the position of the mud after 20 minutes would have indicated otherwise.

6.2 No Benefits from Large Bore Meter

The CMF050 meter under test performed equally to the CMF025 in brix measurement, although requiring increased sample size. The accuracy and characteristics of the instruments were identical in all tests.

The CMF025 was tested in artificially prepared soil slurries with juice of both red volcanic and yellow clay soils. Meter brix readings as high as 62.80 Bx in red volcanic and 38.44 Bx in yellow clay soil / juice slurries were observed. The probe was inserted into settled muds from juices. No blockages were achieved and the instrument was always cleanable in the normal manner with a water wash via the peristaltic pump.

A user of the mass flow meter should be aware that the instrument does contain fine tubing and that foreign matter should not be left to settle out or otherwise "harden "in the tubes.

Trials with the larger meter were discontinued when it became apparent that the CMF025 could handle the duty required.

6.3 Results

Brix results are presented in Table 2 and graphed in Figure 4.

Mud information is presented in Tables 3 and 4 for " 20 min settled height as % of filled height" and "mean settling rate over 20 minutes" respectively.

The soil types, where known, relevant to the trials are identified in Table 5.

The standard mud volume % by centrifuging is reported in Table 4 for those juices where the analysis was performed.

A key index in evaluating the usefulness of a settling vessel is the measure of 20 minute mud height expressed as a % of filled height as related to vessel diameter. Table 3 shows the value of this index for each settling vessel where precisely 350 ml of supernatant settled liquid exists. It is the absolute maximum in mud height that can exist for a "mud free" brix result. In practice slightly more than 350 ml clear supernatant is necessary to be sure of a clear reading. These indices may be compared with the observed mud levels in the trials.

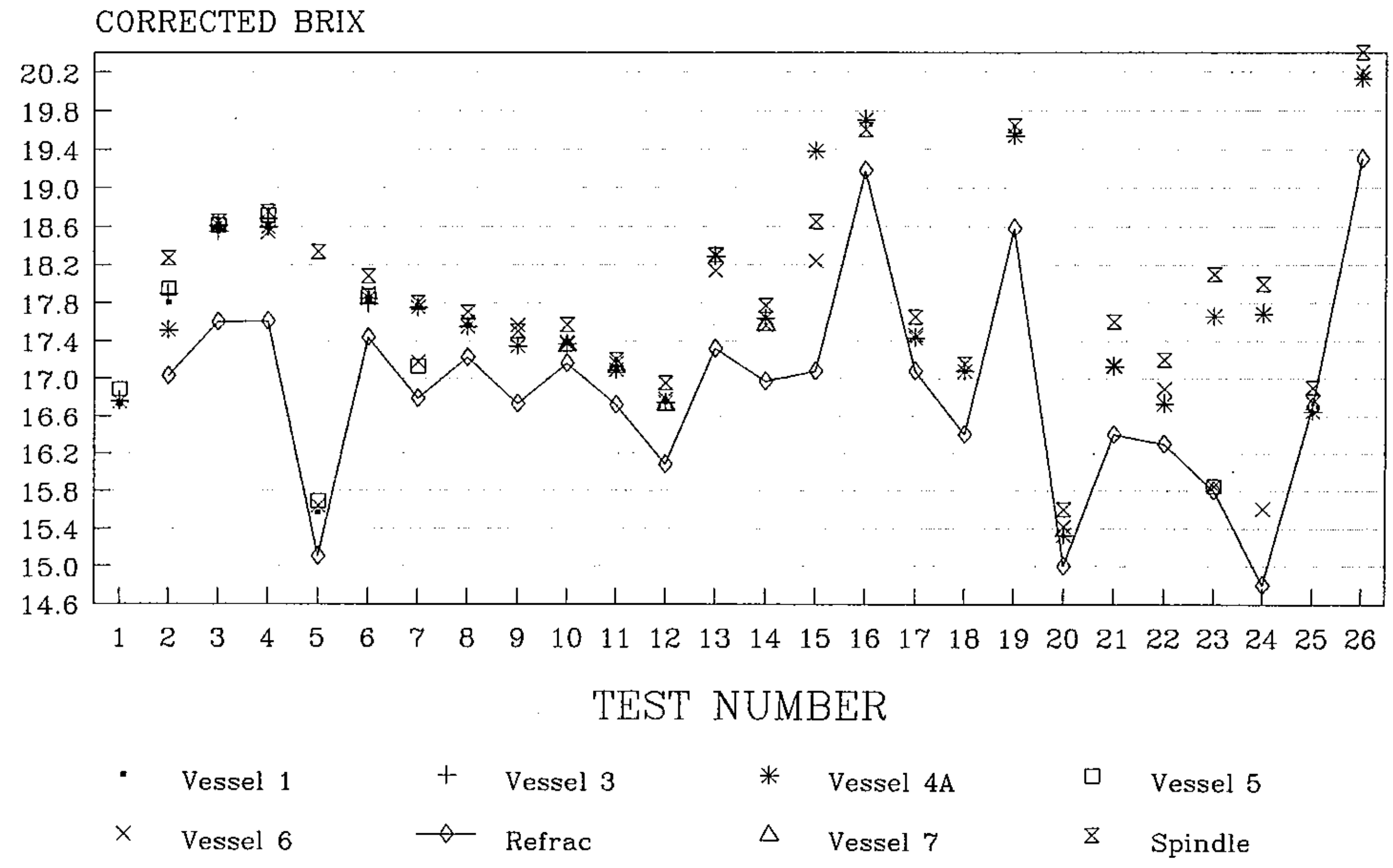
BRIX RESULTS BY SETTLING VESSEL

Trial No	Vessel 1	Vessel 2	Vessel 3	Vessel 4A	Vessel 4B	Vessel 5	Vessel 6	Vessel 7	Vessel 8	Vessel 9	Spindle	Refrac
1	16.72	16.73	16.76	16.75		16.88						
2	17.80	17.84	17.90	17.51		17.95					18.27	17.03
3	18.55	18.58	18.55	18.61		18.61					18.65	17.60
4	18.60		18.68	18.59		18.71	18.54				18.75	17.61
5	15.57					15.69	15.64				18.33	15.10
6	17.82		17.79	17.85		17.87	17.90	17.86			18.08	17.44
7				17.75		17.13	17.17	17.48			17.80	16.79
8				17.55			17.60	17.64			17.70	17.22
9				17.34			17.56	17.44			17.50	16.73
10				17.37			17.38	17.40		17.35	17.57	17.16
11				17.09			17.16	17.18		17.12	17.20	16.72
12				16.74			16.78	16.84	16.75	16.72	16.95	16.08
13				18.29			18.14	18.27	18.08		18.30	17.32
14				17.64			17.56	17.68		17.57	17.77	16.97
15				19.38			18.24	18.25	18.30		18.65	17.08
16				19.70			19.70	19.76			19.60	19.18
17				17.43			17.46	17.62	17.63		17.65	17.08
18				17.08							17.15	16.40
19				19.54				19.84	19.78		19.64	18.58
20				15.33	15.25		15.42				15.60	15.00
21				17.13	17.10		17.14				17.60	16.40
22				16.73	16.73		16.89				17.20	16.30
23				17.66	16.04	15.85	15.85				18.10	15.80
24				17.68	15.96		15.61				18.00	14.80
25				16.65	16.58		16.74				16.90	16.70
26				20.13	20.20		20.20				20.40	19.30

TABLE 2

BRIX RESULTS SUMMARY

BY VESSEL TYPE, SPINDLE & REFRAC



5,7,15,23,24;10,13,16,19,20,25 high dirt

FIGURE 4

20 MIN SETTLED HEIGHT - MUD HEIGHT % FILLED HEIGHT

	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 4A	Vessel 5	Vessel 6	Vessel 7	Vessel 8	Lab fugal % mud by vol
1	40	43	32	35		24				
2	27	27	20	21		18				
3	10	10	8	8		8				
4	24		18	15		15	24			
5	83		76	78		53	63			
6	12		10	9		10		9		
7	65		56	57		40	36			20
8				19				9		
9				9				9		
10				50			20	33		
11				17			9	16		
12				20			2	14	14	
13				53			2	32	37	22
14				36			13	23		
15				67			42	41	50	
16				46			19	25		
17				39			18	25	27	
18				9						
19				55				35	45	
20	50			37	37		20	26		10
21	53			40	40		20	27		11
22	46			23	23	15		16		6
23	80			75	74	55		47		12
24	91			86	84	67		53		13
25	61			49	48	34		34		9
26	25			25	25	19	16			
% at 350 ml settled volume available	86	83	62	45	45	90	77	42	42	

A result for the 20 minute settled height % filled height greater than that for the % at 350 ml settled volume available indicates that the instrument will be interfered with by mud

MEAN SETTLING RATE - AVERAGE OVER 20 MINS - MM/MIN

Trial No	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 4A	Vessel 5	Vessel 6	Vessel 7	Vessel 8	Vessel 9
1	13.4	14.0	11.3	12.0		8.0				
2	16.2	17.9	13.3	14.5		8.7				
3	20.0	22.1	15.3	16.8		10.0				
4	16.9		15.0	15.3		8.9	7.7			
5	3.9		4.0	4.1		4.9	3.8			
6	19.5		14.8	16.0		9.4		5.0		
7	7.7		7.3	7.5		6.3		3.3		
8				14.3				5.0		
9				15.9				5.0		
10				8.8			8.0	3.9		
11				14.5			9.2	4.6		
12				14.0			9.8	4.8	4.8	
13				8.3			8.0	3.8	3.5	
14				11.3			8.8	4.3		
15				5.8			5.8	3.3	2.8	
16				8.0			8.1	4.1		
17				10.8			8.2	4.1	4.0	
18				16.0						
19				7.8				3.6	3.0	
20	11.1			11.0	11.0		8.0	4.1		
21	10.4			10.5	10.5		8.0	4.0		
22	11.9			13.5	13.5	8.5	4.6			
23	4.5			4.4	4.5	4.6		2.9		
24	1.9			2.5	2.9	3.4		2.6		
25	8.7			8.9	9.1	6.6		3.7		
26	16.6			13.1	13.1	8.1		4.6		

SOIL TYPE FOR RAKES SAMPLED

Trial No.	Soil Type
1	
2	
3	red volcanic
4	
5	red volcanic
6	sandy loam
7	red volcanic
8	black sandy loam
9	red volcanic
10	old alluvial clay
11	sandy loam
12	red volcanic
13	
14	
15	
16	sandy loam
17	sandy loam
18	
19	red volcanic
20	black sandy loam
21	red volcanic
22	red volcanic
23	granitic loam
24	red volcanic
25	granitic loam
26	red volcanic

TABLE 5

For example, vessel 6, the "mill billy", may be used when the mud is at the 77% level. This height was never exceeded in mill juices in this work. Vessel 7, a small beaker requires a maximum of 42 % filled height. This vessel would have been unsatisfactory for trials 24 and 25 and borderline in trial 14. Vessel 4, the standard mill cylinder equivalent, requires mud no higher than 45 % and is at risk from mud influence in many of the trials.

In instances, because of continued settling after 20 minutes and before measurement or perhaps by the proboscis clearing for itself a well of settled liquid in the mud, readings unaffected by dirt were obtained when that outcome did not fit the mud levels noted. The latter phenomenon was investigated in a number of trials which compared stationary and moving sample probes.

Figures 5 and 6 are graphics which show the interrelationship between brix , mud height and settling vessel characteristics in density measurement by spindle or meter. Figure 5 depicts the juices of the trials in a standard 48 mm diameter cylinder and 350 mm tall. Figure 6 shows the same juices in the South Johnstone juice can which is 100 mm diameter and 200 mm tall. The figures show the position of the lowest point of the spindle relative to the bottom of the vessel. The spindle is used in the uppermost half of its scale eg a 10 - 20 Bx spindle is used in the range 15 - 20 Bx. A discontinuity is thus introduced when the spindle is swapped over at 20 Bx. As may be seen from Figure 5, the spindle drops a further 75 mm into the juice when using a standard brixing cylinder.

The use of the meter avoids this discontinuity as a major benefit.

Figures 5 and 6 show the mud height for each trial in the series and the juice brix that would have been read off the spindle. The figures also show the sampling height after 350 ml sample has been withdrawn (with and without prior spindle brix determination) for the density meter instrument with the probe 10 mm plus the height equivalent of 20 ml below the liquid surface.

Standard brix cylinder: It may be easily seen that in trials 7, 15, 5, 23 and 24 the spindle would have settled into mud. Other trials 20, 25, 10, 13, 16, 19 show the spindle at or around the mud level, the remainder have the spindle well clear of mud. The proboscis method developed for these trials would, in this cylinder, be unsatisfactory for the above trial numbers and at or about the mud level for the trials 14, 17, 21 and 20. The method of the 1994 trials, spindle brix followed by the metal float would have been suitable for only 5 trials, 3, 4, 6, 9 and 18, and read high results due to mud in the others. It may also be seen that the spindle followed by a fibre float, as used by the cane testers in subsequent 1995 trials is better, but will encounter mud when a spindle was not influenced by the mud.

South Johnstone juice can: The can could not be intended for spindle use. The spindle would touch the bottom for brixes near to 15 and just above 20. Juices 2, 3, 4, 6, 11, 12, 14 and 16 would have been measurable as the brix and mud levels were favourable. **All** juices were measurable free of mud at 350 ml sample volume by proboscis.

This confirms that a method of analysis could be developed by appropriate selection of juice settling vessel to deal with any sample volume and very high dirt levels.

EFFECTIVE SAMPLE POINT FOR SPINDLE AND 350 ML BY FLOAT - MUD HEIGHT AS REFERENCE

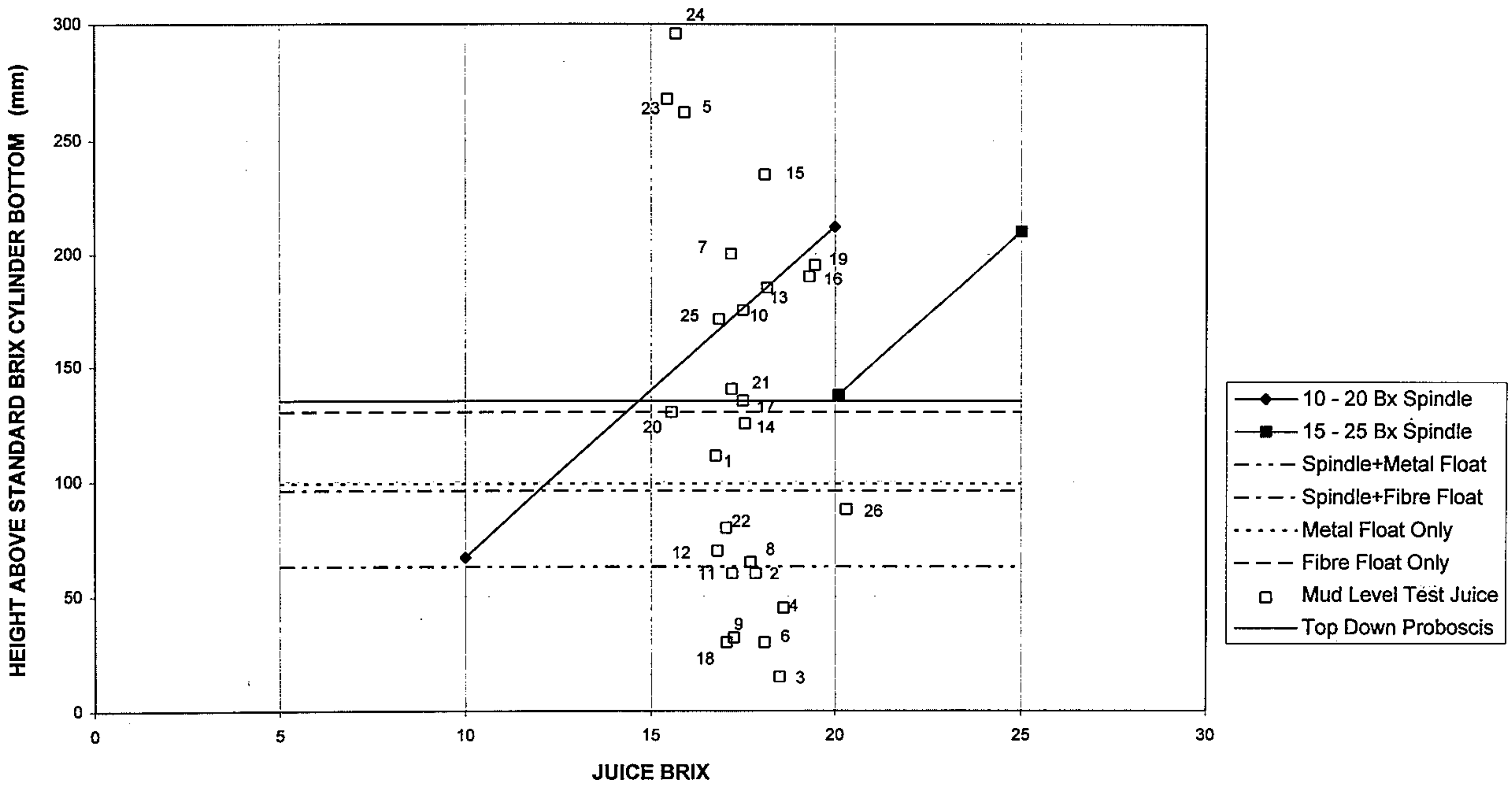


FIGURE 5

EFFECTIVE SAMPLE POINT FOR SPINDLE AND 350 ML BY FLOAT - MUD HEIGHT AS REFERENCE

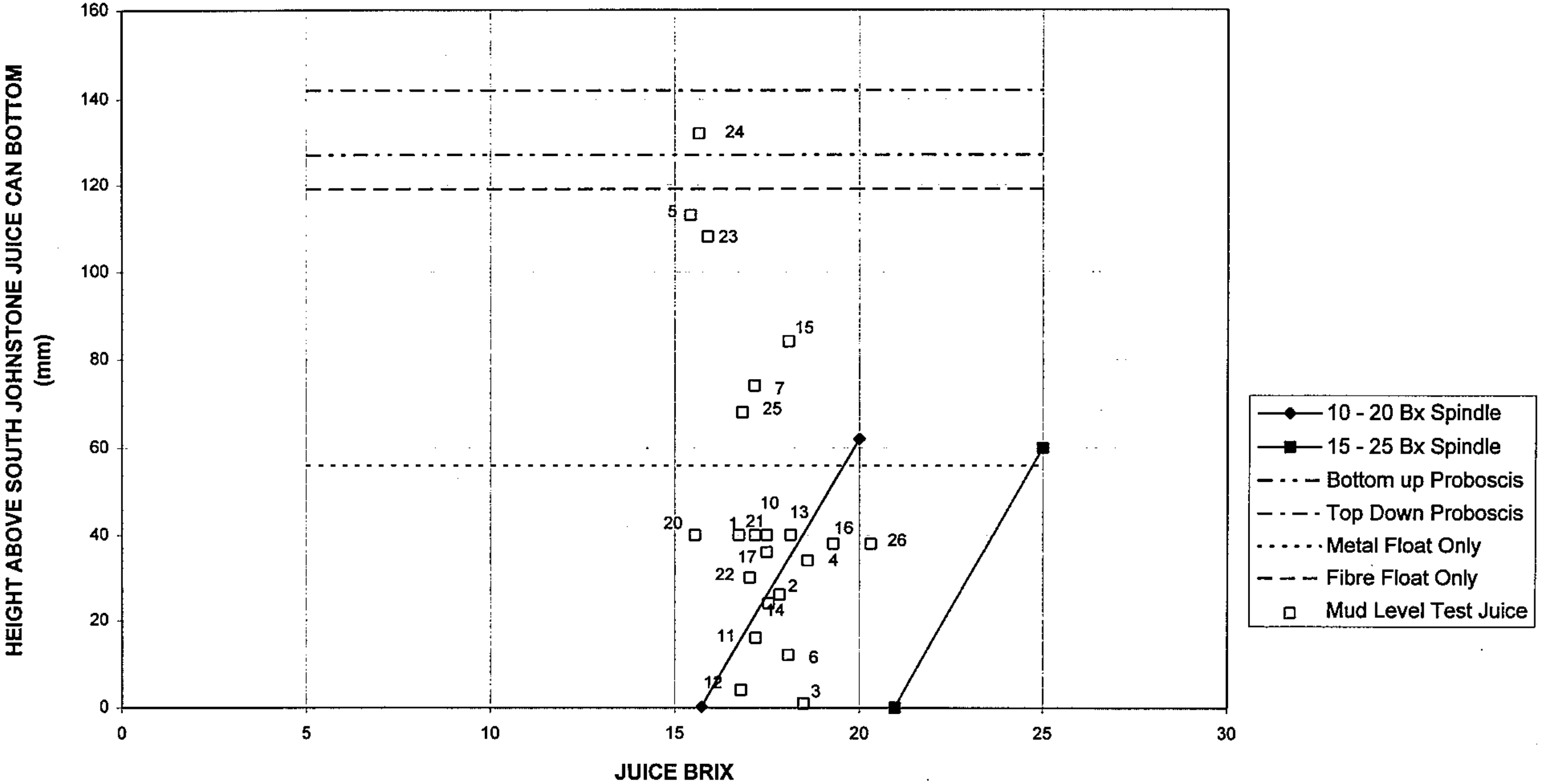


FIGURE 6

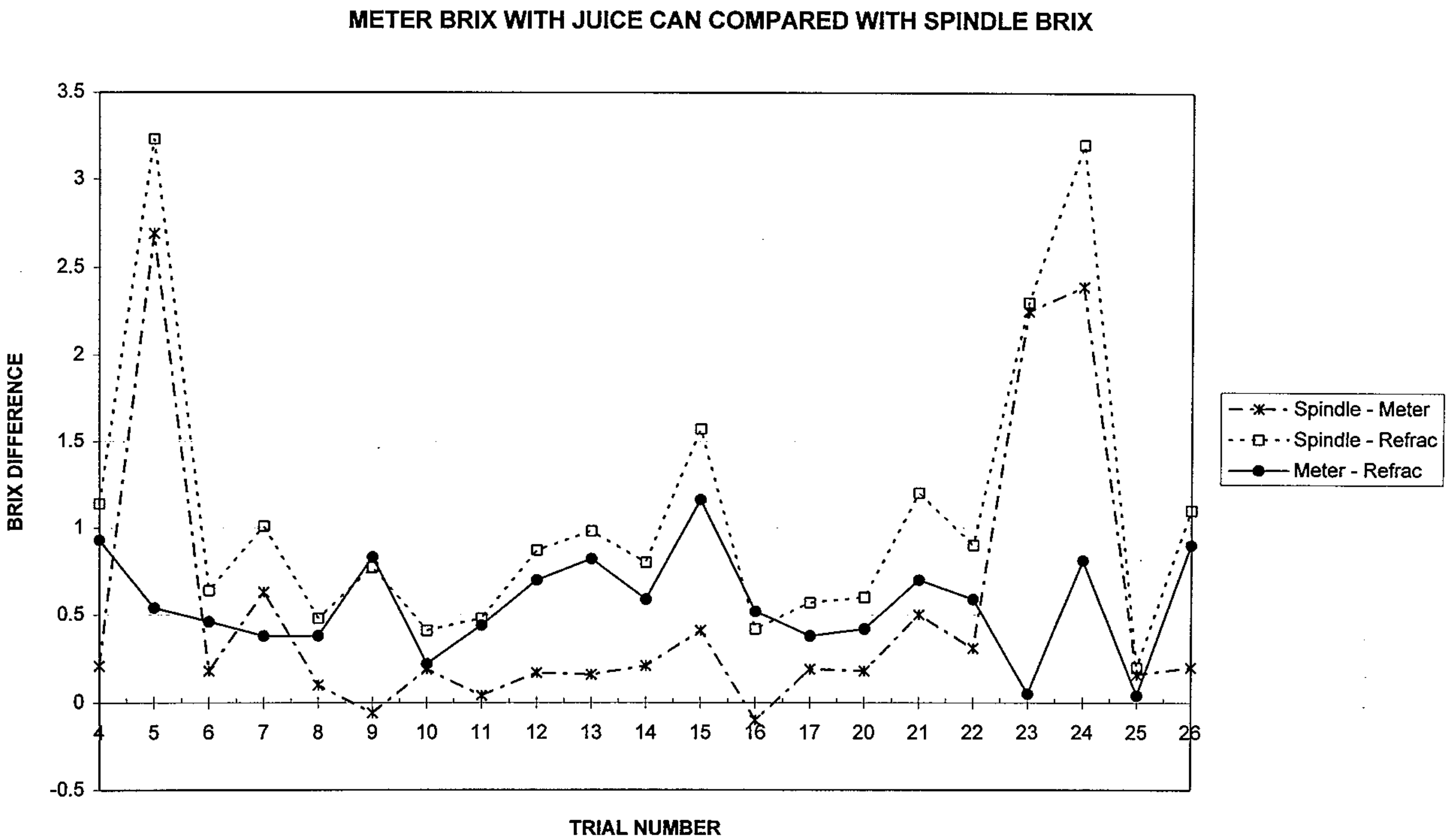

METER BRIX WITH JUICE CAN COMPARED WITH SPINDLE BRIX
BRIX DIFFERENCE
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
4
5
6
7
8
9
10
11
12
13
14
15
16
17
20
21
22
23
24
25
26
TRIAL NUMBER
Spindle - Meter
Spindle - Refrac
Meter - Refrac

FIGURE 7

Spindle, refrac and say the South Johnstone can (vessel 6) readings may be compared in Table 2 for those where high mud will generate a refrac with the spindle but are measurable by meter. Figure 7 is a graphical representation of all the trials where the South Johnstone juice can was used, highlighting the mud influence in trials 5, 7, 15, 23 and 24.

Where mud was unlikely to be an influence,(trials 4, 6, 8, 9, 11, 12, 14, 17, 20 and 26) the meter averaged 0.14 Bx below the spindle indicating a small systematic error generated by the calibration process.

6.4 Extended Testing at South Johnstone Mill

The Cane Testers undertook to use the CMF025 Density meter over the remainder of the season to extend the comparisons with the brix spindle. In this work the fibre float sampling device was dropped into the brixing cylinder after the spindle test had been carried out. 350 ml of sample was taken at the rate of 465 cm^3/minute. The tests were carried out in batches without cleaning out the meter between juices in the batch. The instrument was washed through with water after each batch tested.

1019 juices were tested. Thirty three nitric acid check calibrations were carried over the period 7/9/95 (week 7) to 12/11/95 (week 18) without the instrument deviating sufficiently to necessitate a full scale re-calibration with sugar solutions.

The individual nitric acid checks are plotted in Figure 8. The $\pm$0.0005 g/cm^3 limits within which no sugar recheck is necessary are included. See Appendix 2 for details of calibration and checking. Check 3 warranted a full re-calibration but was not carried out. Subsequent results tend to indicate that check 3 could have been in error.

Figure 9 is a plot of 953 of the results where the difference between spindle and meter did not exceed 0.5 Bx. The data indicated that there was a strong tendency for the first test in a batch to have a lower meter reading relative to the spindle than the other tests. All first in batch tests are excluded from Figure 10 with improvement in the tightness of the distribution of difference between meter and spindle.

These tests are extremely encouraging for the instrument. The Cane Testers were not experienced with the equipment and in carrying out their testing on the residue from spindle brix determinations increased the likelihood of encountering dirt in the 350 cm^3 sampled.

The tendency to a lower result in first samples of the batch gives warning to make sure that the sample volume is sufficient to flush out the water or previous sample in the system or alternatively run a "wash" in the same way that we do with pols. Accordingly, recommendation in Method 3A is to use a 400 cm^3 sample. The user can, of course, select the system and methodology most suitable to them.

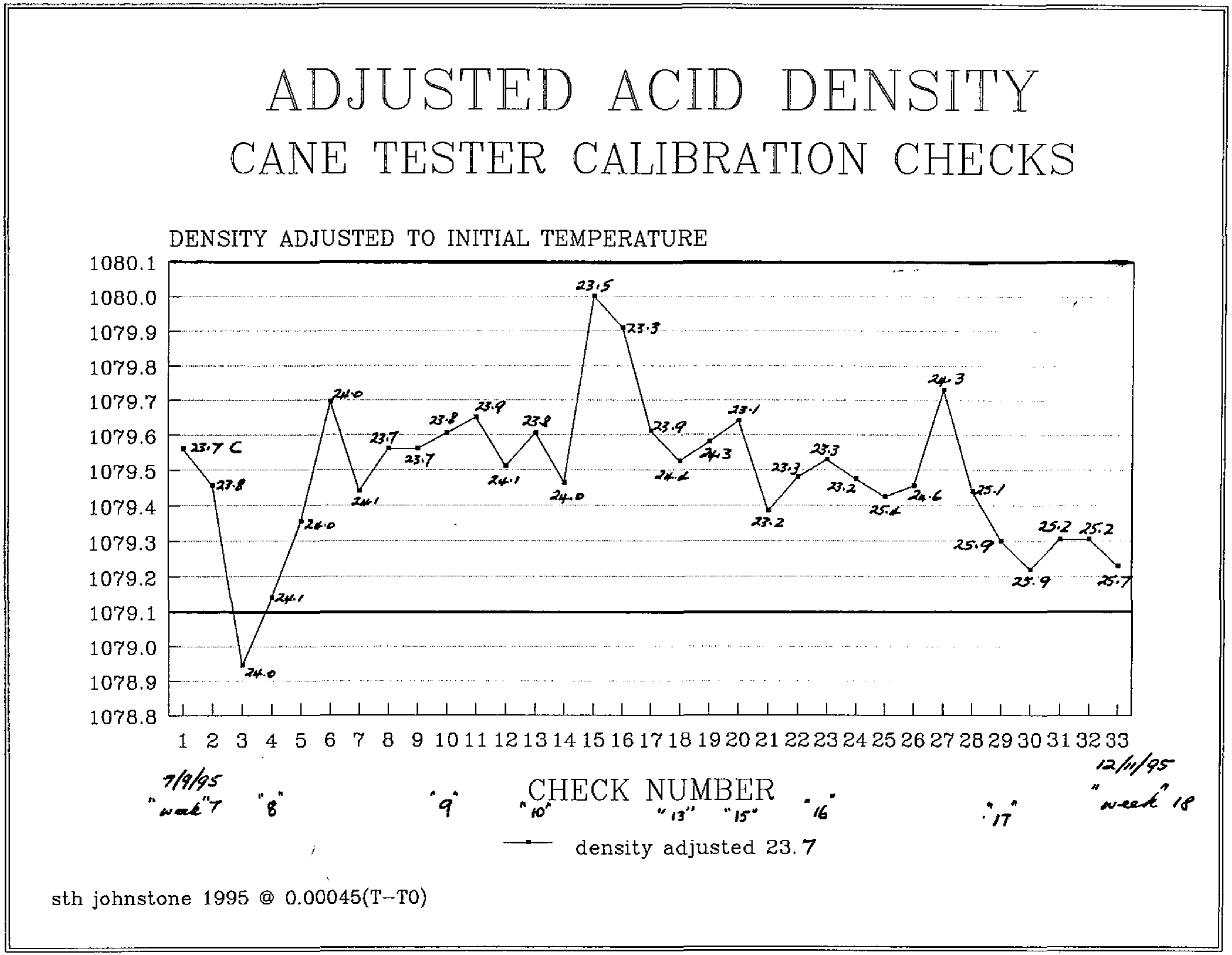
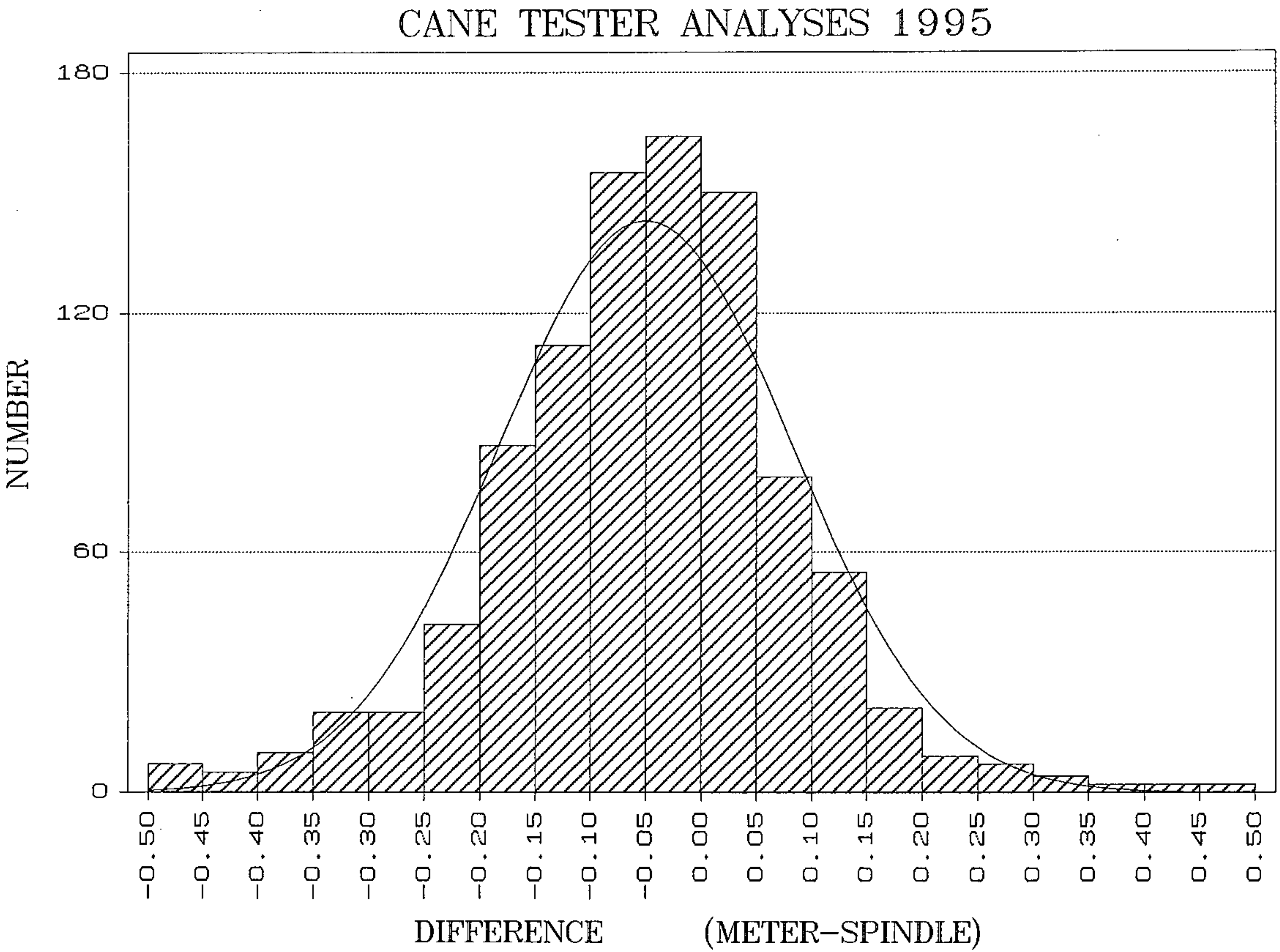
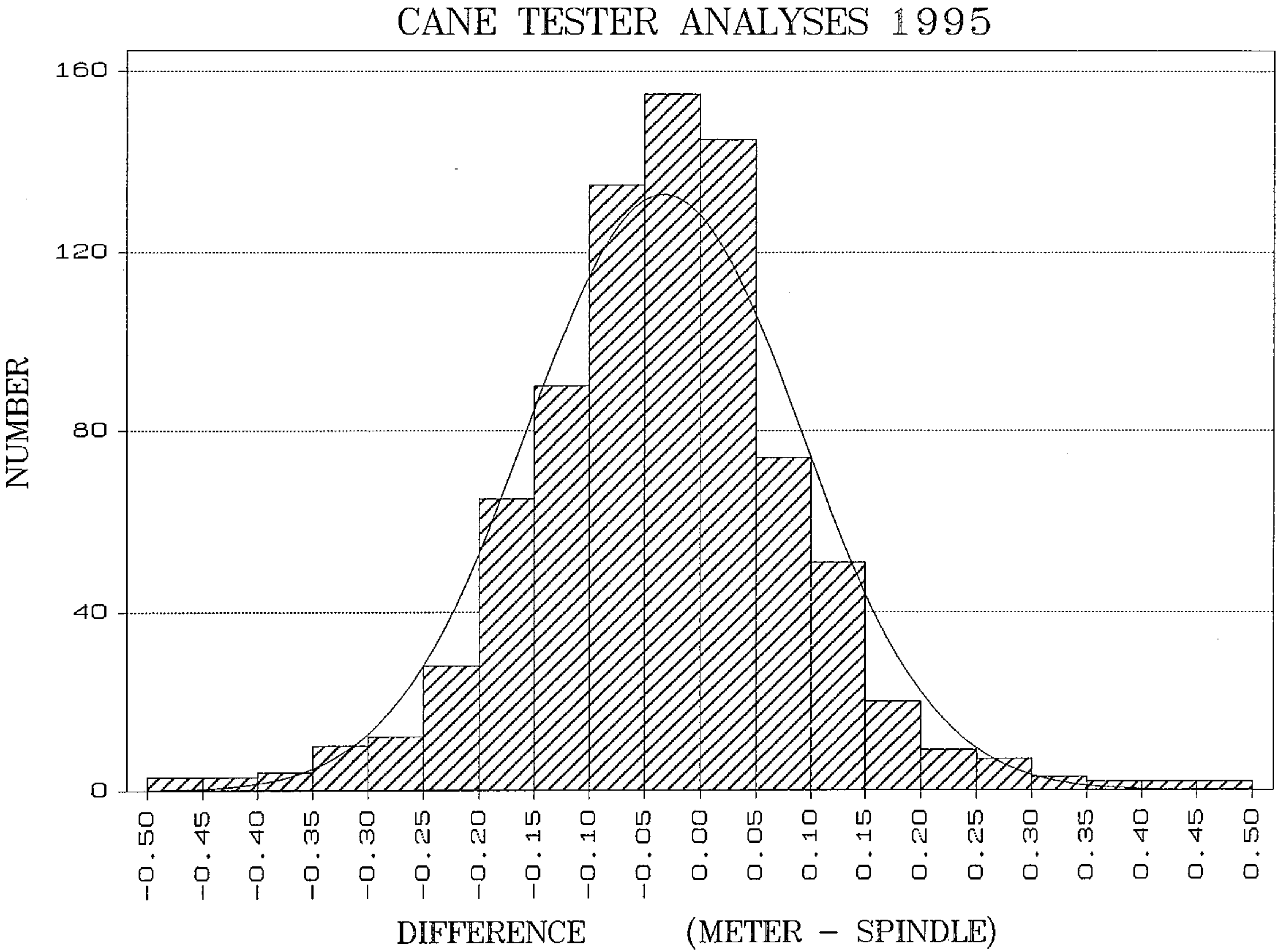

ADJUSTED ACID DENSITY
CANE TESTER CALIBRATION CHECKS
DENSITY ADJUSTED TO INITIAL TEMPERATURE
1080.1
1080.0
1079.9
1079.8
1079.7
1079.6
1079.5
1079.4
1079.3
1079.2
1079.1
1079.0
1078.9
1078.8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
CHECK NUMBER
density adjusted 23.7
sth johnstone 1995 @ 0.00045(T−T0)
7/9/95
"week" 7
12/11/95
"week" 18
23.7 C
23.8
24.0
24.1
24.0
24.0
24.1
23.7
23.7
23.8
23.9
24.1
23.8
24.0
23.5
23.3
23.9
24.2
24.3
23.1
23.2
23.3
23.3
23.2
25.4
24.6
24.3
25.1
25.9
25.9
25.2
25.2
25.7

FIGURE 8



953 cases plotted, excludes refracs and 66 results with diff > 0.5

FIGURE 9



820 cases plotted, excludes refracs, diff > 0.50, first tests in batch

FIGURE 10

7.0 IDENTIFYING THE CHARACTERISTICS OF THE INSTRUMENT

The investigations extended to peripheral matters which define the operation of the density meters and/or allow selection of methodology of their use.

7.1 Pumping Rate

The pumping rate used in the South Johnstone trials evolved to 7.78 cm^3/sec (350 cm^3 in 45 seconds). This rate equates to a flow velocity of 18.084 cm/sec in each of the two 5.2324 mm tubes of the CMF025 instrument. These conditions correspond to a Reynolds Number of 603. No problems were encountered which could have been attributed to flow stratification and consequent poor flushing of the instrument even in the dirtiest of juices.

It is not thought necessary to select this flow velocity for work with an instrument of different bore. The CMF050 instrument with tube diameter of 8.763 mm would have a Reynolds Number of 1010 at this flow velocity whereas in practice it performed without problem at a flow velocity of 6.04 cm/sec and a pumping rate of 7.29 cm^3/sec where the Reynolds Number was 337. Thus it is not strictly necessary to maintain constant Reynolds Number or flow velocity for satisfactory operation in dirty juices.

For simplicity, it is suggested that a Reynolds Number of 600 in each tube of the vibrating tube density measuring instrument allows a sufficient flow rate to avoid blockage of the instrument when measuring cane juice solutions containing typically high soil concentrations.

For configurations other that of CMF025 instrument, the flow rate for each measuring tube may be determined from the relationship:

Flow rate per tube (cm^3/min) = 45 x Tube ID (mm)

with assumptions

viscosity $\mu = 0.001695$ Pa.s
density $\rho = 1080$ kg/m^3

7.2 Sample Volume

The required sample volume is a function of the complete system geometry (from the sampling tube to the end of the measuring tubing) and pumping rate. For increasing flows steady state in density reading is achieved in a shorter time but larger sample volumes are required.

The following process was developed to determine the appropriate sample volume.

Flush the meter with water at high flow rate to purge any entrapped air from the system.

Draw a pure sucrose solution, approximately 16° to 20° Bx, through the meter at the rate determined by the considerations of Section 7.1 above. Record the density or brix readings and instrument temperature as nearly as possible to every 5 seconds and determine the time to reach stability. Record the computed brix and corresponding pumping times.

The sample volume is determined from the estimated time at which the computed brix is constant ± 0.05 Bx.

Note the volume, the pumping rate and the time.

(Volume = Pumping Rate x Time)

The **required sample volume** for the analysis procedure is the volume determined above plus 50 cm^3 (added as a factor of safety).

7.3 Selection of Settling Vessels

It has been shown in previous sections that the meter result corresponds to the spindle in clean juices and with, careful selection of settling vessel, outperforms it in dirty juices.

The aim is to select a vessel that has sufficient diameter to enable the required sample volume to be drawn off the supernatant liquid without taking from the mud layer. Vessel selection is thus the result of a balance between depth of liquid for the required volume and the rate of settling of the mud in the juice.

Settling characteristics

The settling of South Johnstone juices was studied in settling vessels of various heights and diameters. The notional or mean settling rate over 20 minutes for an individual juice increased with increase in the height of liquid. For reasons that were not explored in the testing, some juices showed higher settling rates than others sampled.

The trial results for notional settling rate versus settling vessel height are presented in Figures 11 to 15 grouped from fast to very slow settling. Curves were fitted to the data. The combined fitted curves are shown in Figure 16 together with the mathematical relationships that have been derived.

Very slow settling : Rate = [25.941x vessel height/(1+(0.3111 x vessel height))] -78.14

Slow settling : Rate = [50.546 x vessel height/(1+(0.2516 x vessel height))] -189.99

Medium settling : Rate = [82.489 x vessel height/(1+(0.25679 x vessel height))] -306.41

Fast settling : Rate = [0.18136 x vessel height/(1+(0.0046975 x vessel height))] -9.20

In the context of the conventional brixing cylinder, 350 mm tall, and the brix spindle:
"very slow" juices are immeasurable by spindle
"slow" juices are measurable by spindle if the brix lies 17.5 to 20.0 or 22.5 to 25.0 °Bx
"medium" and "fast" juices present no problem for the spindle

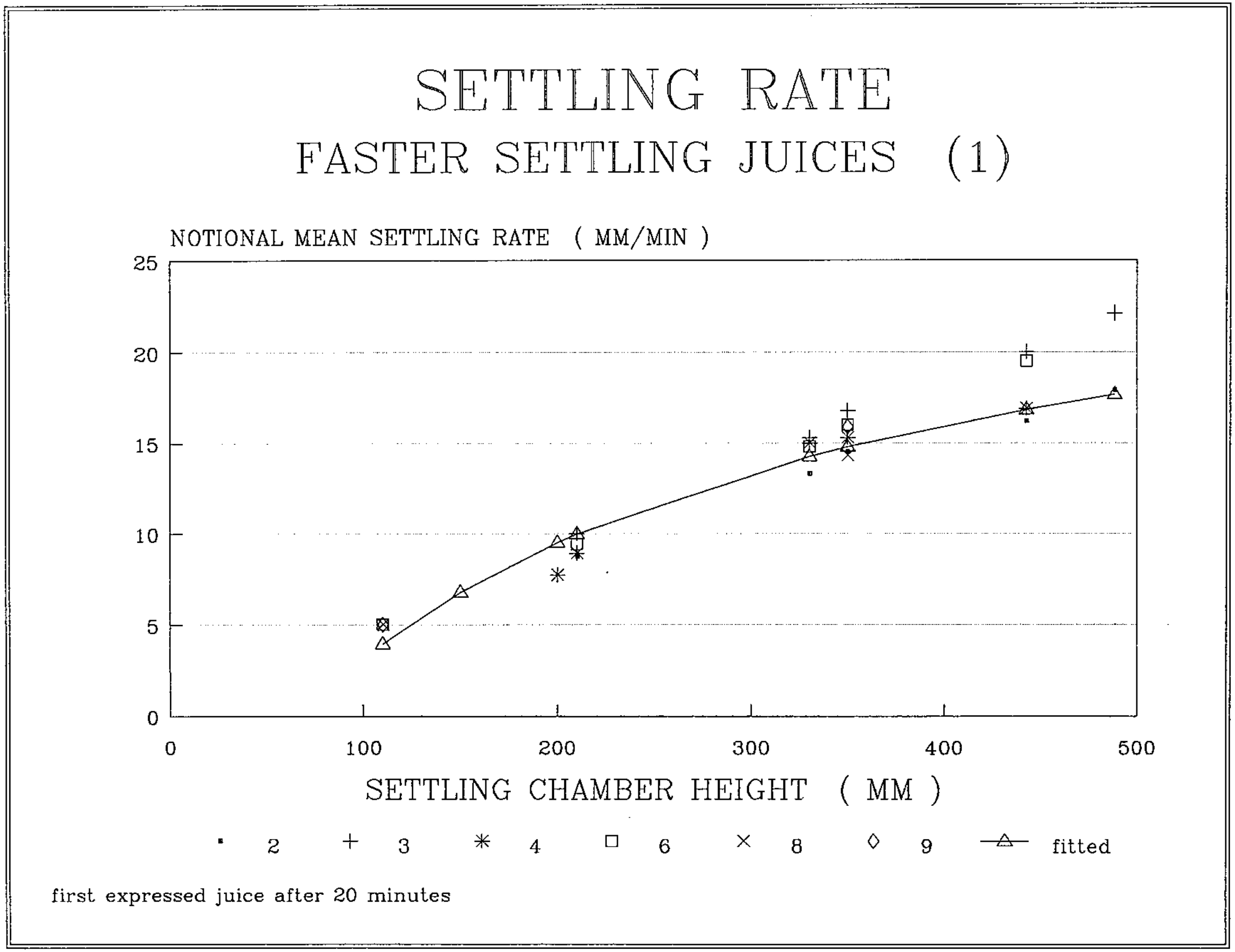
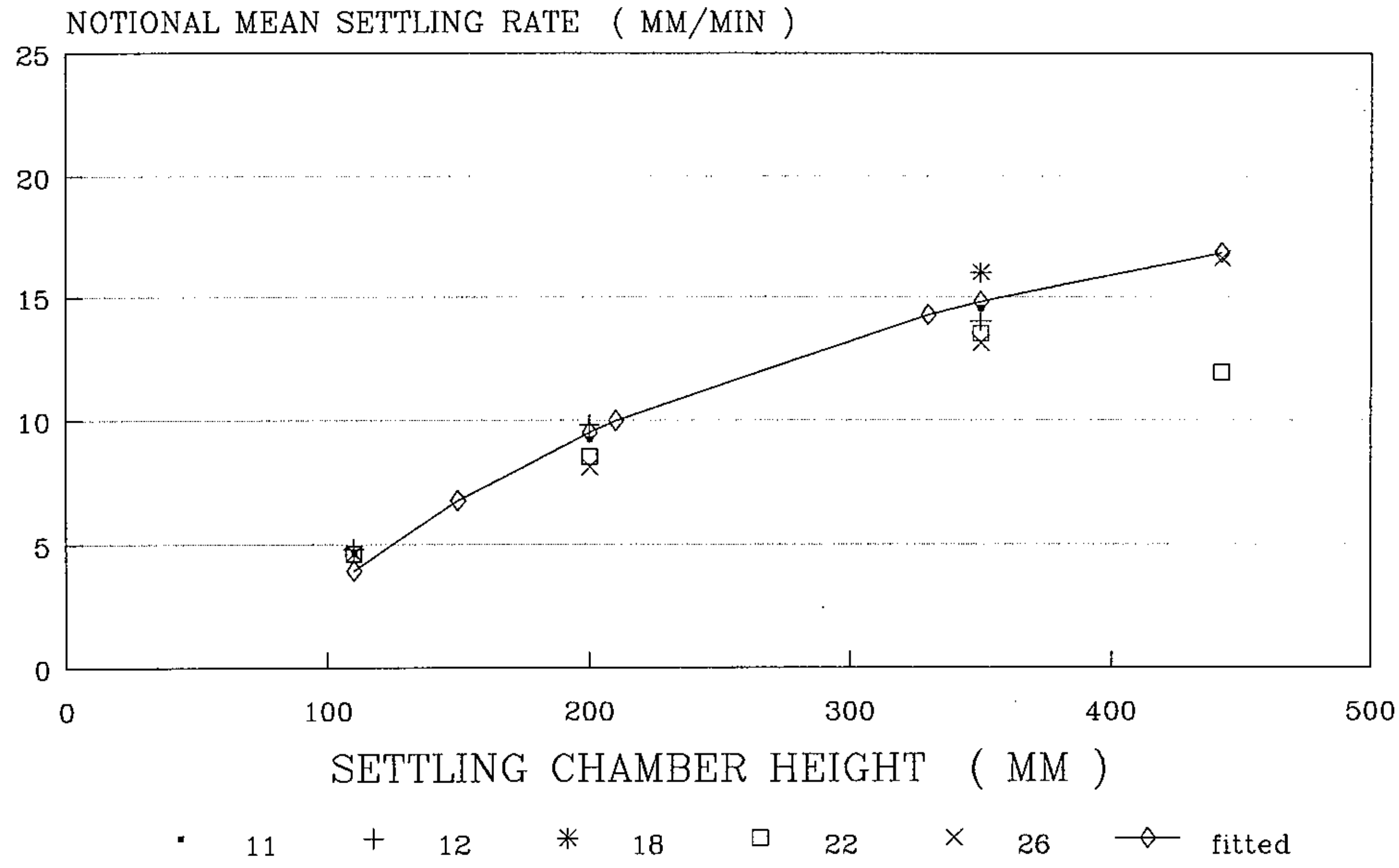

SETTLING RATE
FASTER SETTLING JUICES (1)
NOTIONAL MEAN SETTLING RATE (MM/MIN)
25
20
15
10
5
0
0
100
200
300
400
500
SETTLING CHAMBER HEIGHT (MM)
2
3
4
6
8
9
fitted
first expressed juice after 20 minutes

FIGURE 11

SETTLING RATE

FASTER SETTLING JUICES (2)

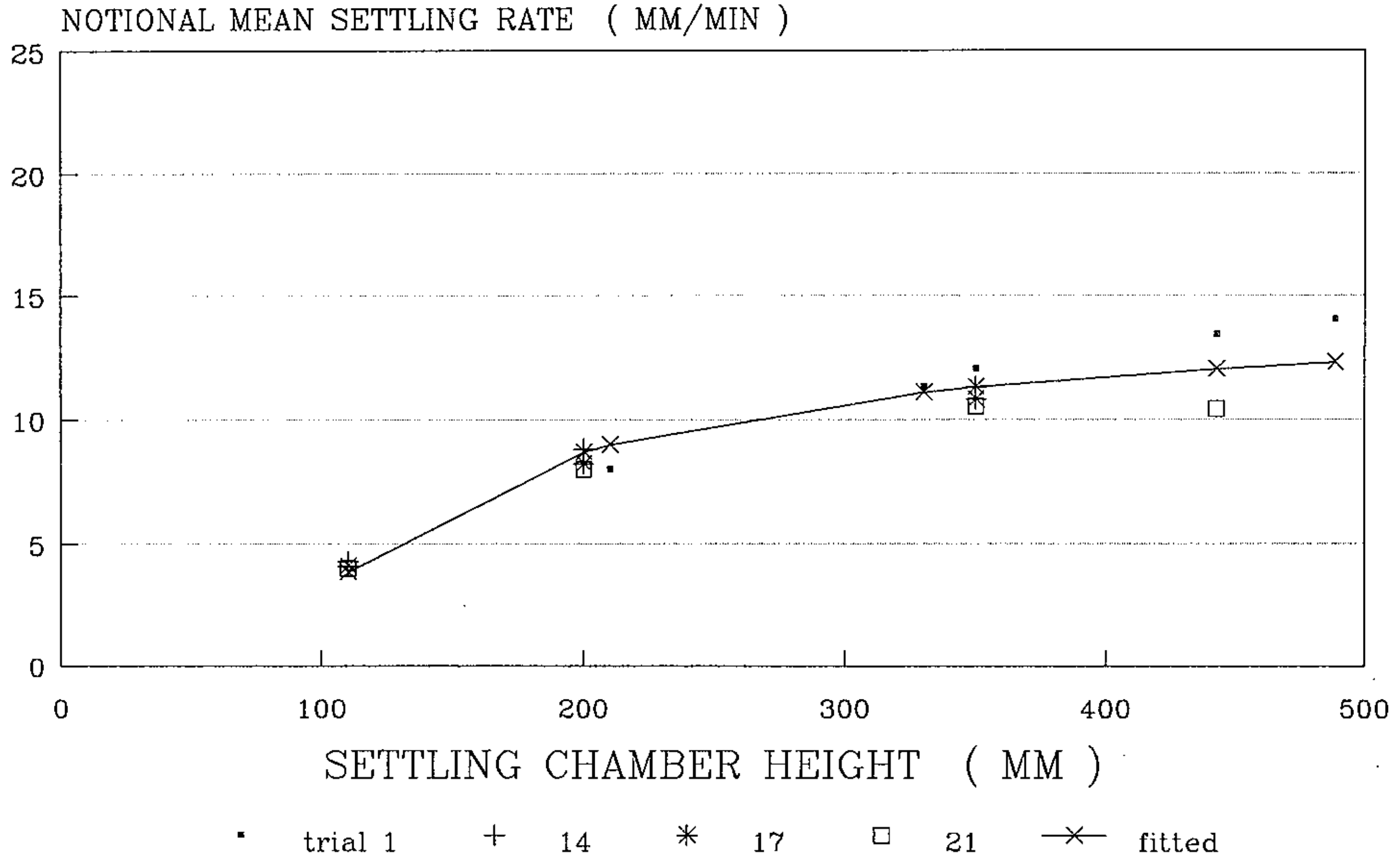


first expressed juice after 20 minutes

FIGURE 12

SETTLING RATE

MEDIUM SETTLING JUICES



first expressed juice after 20 minutes

FIGURE 13

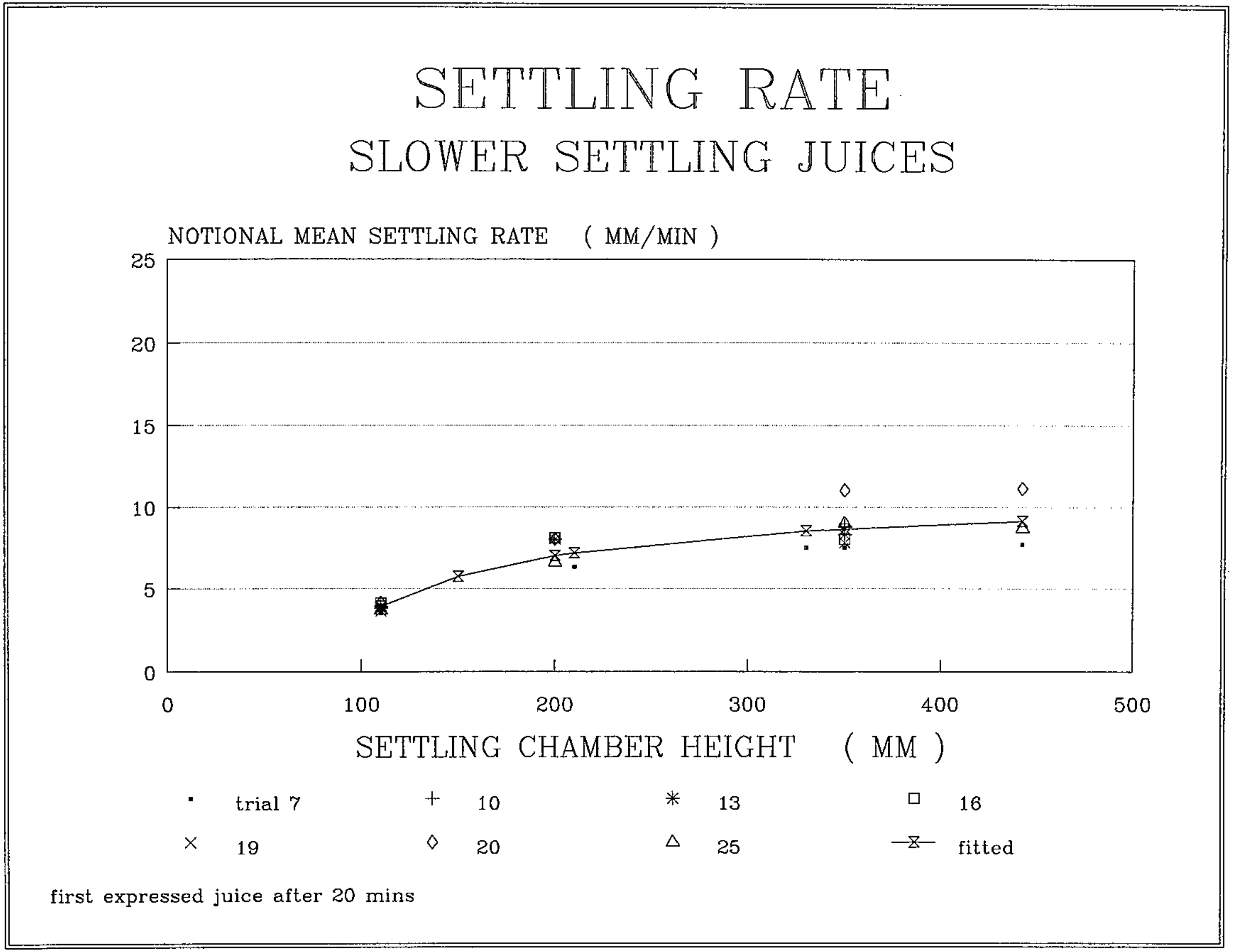

SETTLING RATE
SLOWER SETTLING JUICES
NOTIONAL MEAN SETTLING RATE (MM/MIN)
25
20
15
10
5
0
0
100
200
300
400
500
SETTLING CHAMBER HEIGHT (MM)
trial 7
10
13
16
19
20
25
fitted
first expressed juice after 20 mins

FIGURE 14

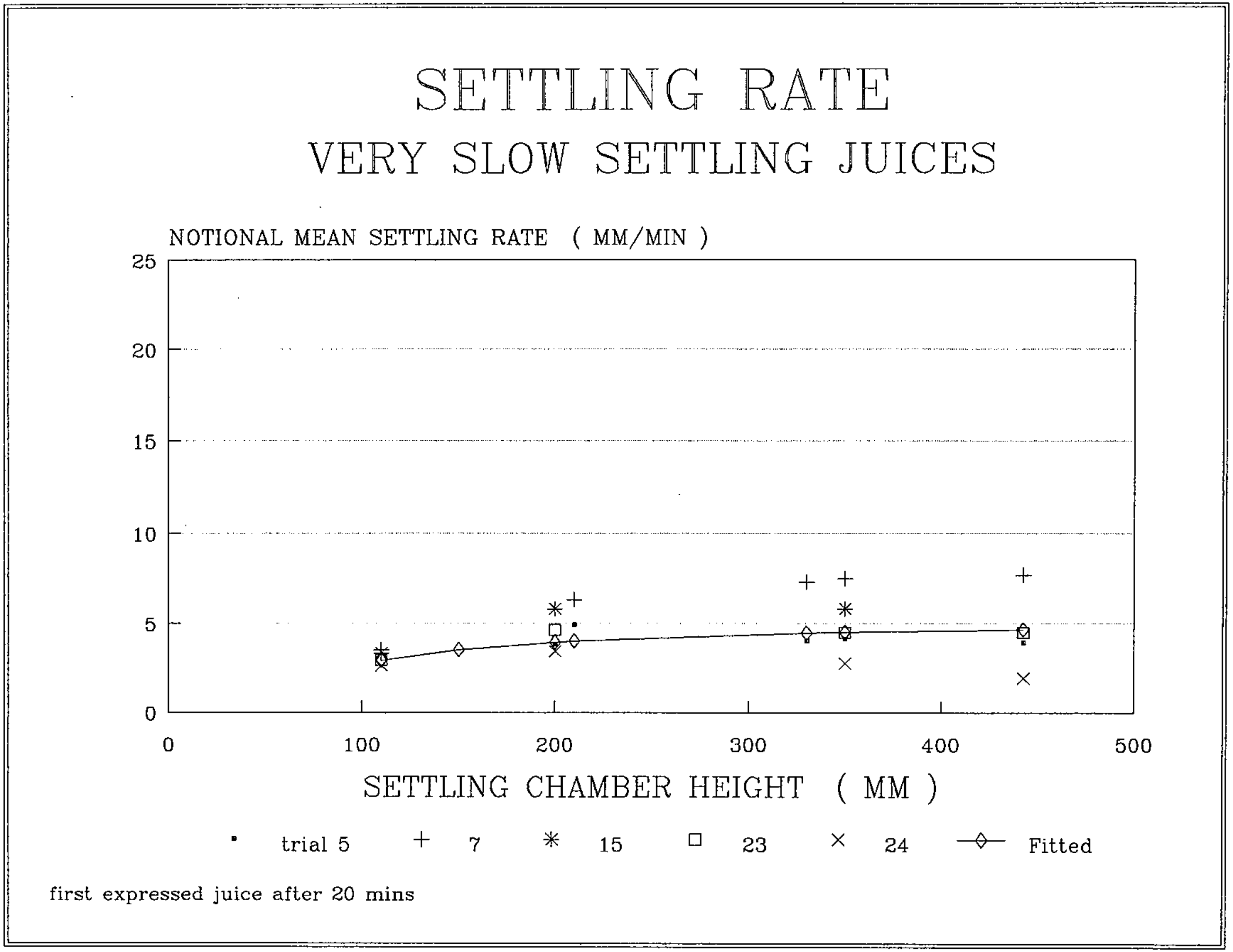

SETTLING RATE
VERY SLOW SETTLING JUICES
NOTIONAL MEAN SETTLING RATE (MM/MIN)
25
20
15
10
5
0
0
100
200
300
400
500
SETTLING CHAMBER HEIGHT (MM)
trial 5
7
15
23
24
Fitted
first expressed juice after 20 mins

FIGURE 15

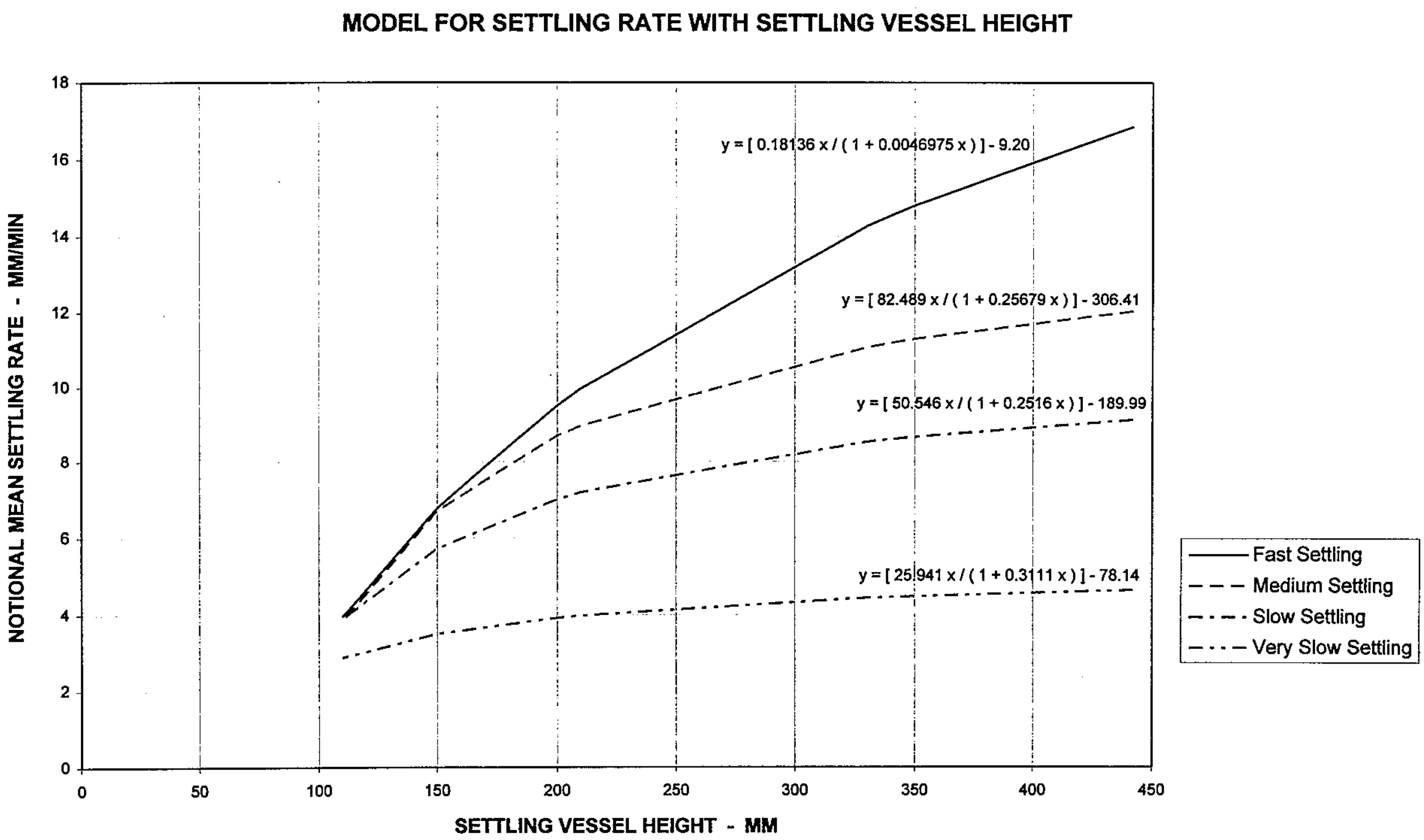

MODEL FOR SETTLING RATE WITH SETTLING VESSEL HEIGHT
NOTIONAL MEAN SETTLING RATE - MM/MIN
SETTLING VESSEL HEIGHT - MM
y = [0.18136 x / (1 + 0.0046975 x)] - 9.20
y = [82.489 x / (1 + 0.25679 x)] - 306.41
y = [50.546 x / (1 + 0.2516 x)] - 189.99
y = [25.941 x / (1 + 0.3111 x)] - 78.14
Fast Settling
Medium Settling
Slow Settling
Very Slow Settling

FIGURE 16

The " very slow " settling curve can be seen to be at or about the rate of the worst of the juices seen at the time of the trials. The notional settling rate for this juice is around 4.5 mm/min in a 350 mm tall vessel. Juices can be much slower than this. An example at Tully in the 1997 season settled over 20 minutes at an average rate of 0.2 mm/min.

Height of clear liquid required

It is assumed that sampling is effected with a simple proboscis where sample draw off can be achieved at a point minimally beneath the surface of the liquid. The height of the supernatant liquid required is a function of the sample volume selected and the vessel diameter.

If v = required sample volume in cm^3 as per section 7.2, the volume of supernatant available at the probe sample intake should be (v + 20) or V cm^3 to provide a further factor of safety. Sampling should take place at a depth of no less than 10 mm.

The height of supernatant now required for v cm^3 is :

$$h = [\{(1274 \times V) / D^2\} + 10]$$

where h = height (mm)
V = (sample volume + 20) (cm^3)
D = vessel diameter (mm)

Selection of settling vessel

The height of supernatant is required in 20 minutes and thus requires a minimum mean settling rate of

$$\text{Mean Settling Rate (mm/min)} = [\{(63.694 \times V) / D^2\} + 0.5]$$

The user selects the juice that must be measurable, for example " very slow " settling, and equates the settling rate for the sample volume and vessel diameter with the settling rate - liquid height prediction for that settling rate category. Thus :

$$[(25.941 \times \text{vessel height}) / \{1+(0.3111 \times \text{vessel height})\}] - 78.14=[\{(63.694 \times V) / D^2\}+0.5]$$

and solving for vessel height,

$$\text{Vessel height } H = \frac{\left\{ 1/D^2 + 1/(0.809944\text{x}V)\right\}\left\{2.455341\text{x}V\right\}}{\left[1 - \left\{1/D^2 + 1/(0.809944\text{x}V)\right\}\left\{0.7638565\text{x}V\right\}\right]}$$

This is the **minimum filled height** in mm for a vessel of diameter, D mm, which will allow withdrawal of v cm^3 of supernatant, free of mud, after 20 minutes settling of "very slow" settling juice. If the user chooses, the equation can be solved for other, faster, settling rates which would lessen the meter's advantage in muddy juices but perhaps allow a smaller, more suitable settling vessel.

The coefficients of the equation above for all the settling categories are :

very slow	0.809944	2.455341	0.7638566
slow	0.334369	1.260119	0.3170459
medium	0.207553	0.772151	0.1982807
fast	6.653956	351.202029	1.7445961

The relationships are plotted in Figures 17 and 18 for "very slow" and "slow" settling respectively for various required sample volumes (v). **Note, not V which is v+20.** We have included on the figures the size of the various mill billies in use in the industry as these vessels could be used directly in an automated operation.

A vessel is acceptable for use with a given required sample volume (v) if its coordinates lie to the right of the curve for the required sample volume.

The new Method 3A in the manual has been written in terms of measurement of "very slow" settling juices.

7.4 Selection of Sampling Point

Use of a density meter requires knowledge of the position of the liquid level, beneath the froth, in the settling vessel.

There are two approaches and variations with these that could be used.

Top down sampling

The techniques used in the trial work with a probe or float sampled relative to the liquid surface. The probe or proboscis enables sampling near to the liquid surface and the equations and the figures of section 7.3 were based on this technique.

This approach to sampling can be carried out by placing the sampling point of a proboscis 10 mm beneath the liquid surface, starting the sampling pump and moving the proboscis down to maintain the position relative to the liquid surface. This was used in the South Johnstone research trials.

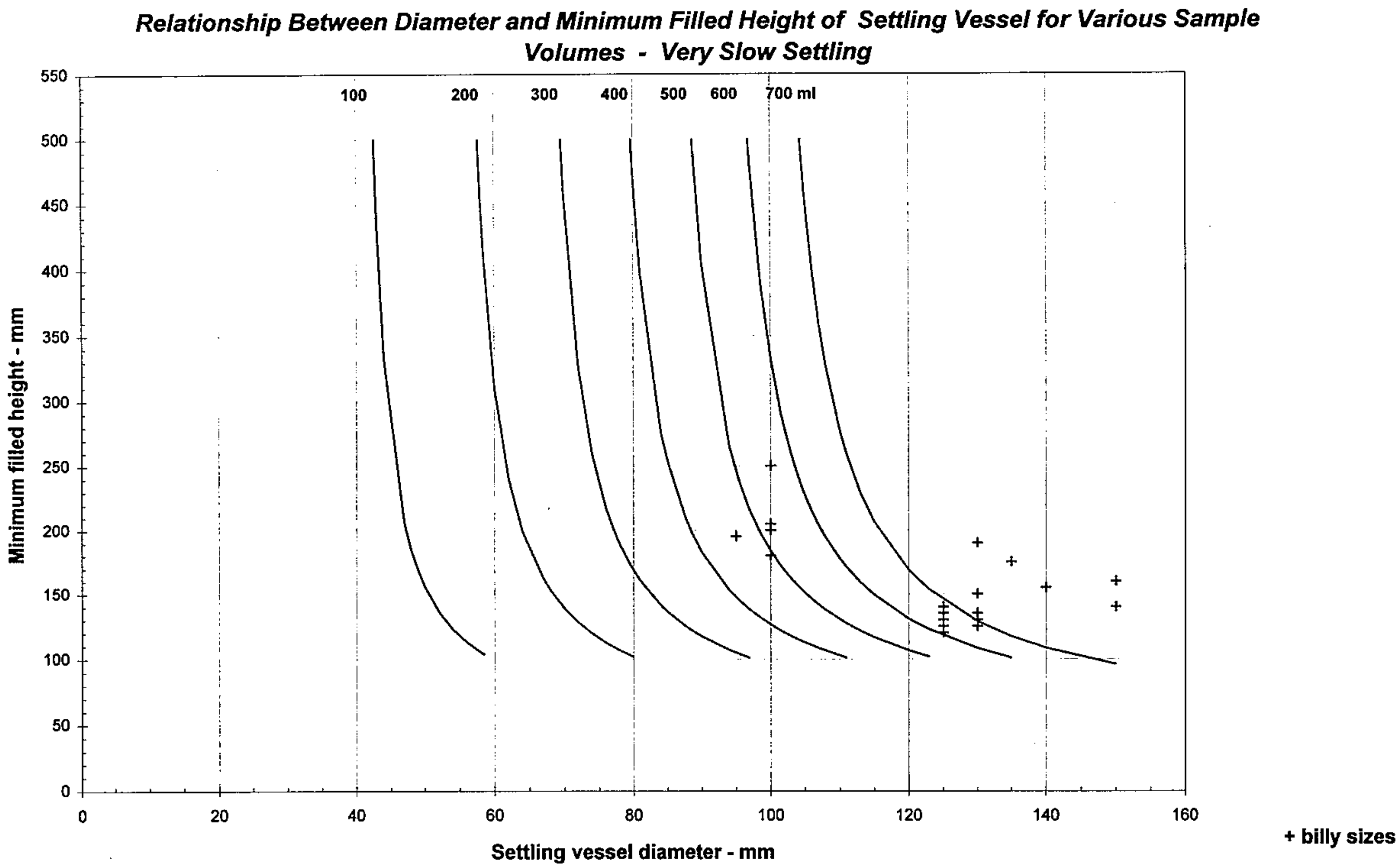

Relationship Between Diameter and Minimum Filled Height of Settling Vessel for Various Sample Volumes - Very Slow Settling
100
200
300
400
500
600
700 ml
Minimum filled height - mm
0
50
100
150
200
250
300
350
400
450
500
550
0
20
40
60
80
100
120
140
160
Settling vessel diameter - mm
+ billy sizes

FIGURE 17

Relationship Between Diameter and Minimum Filled Height of Settling Vessel for Various Sample Volumes - Slow Settling

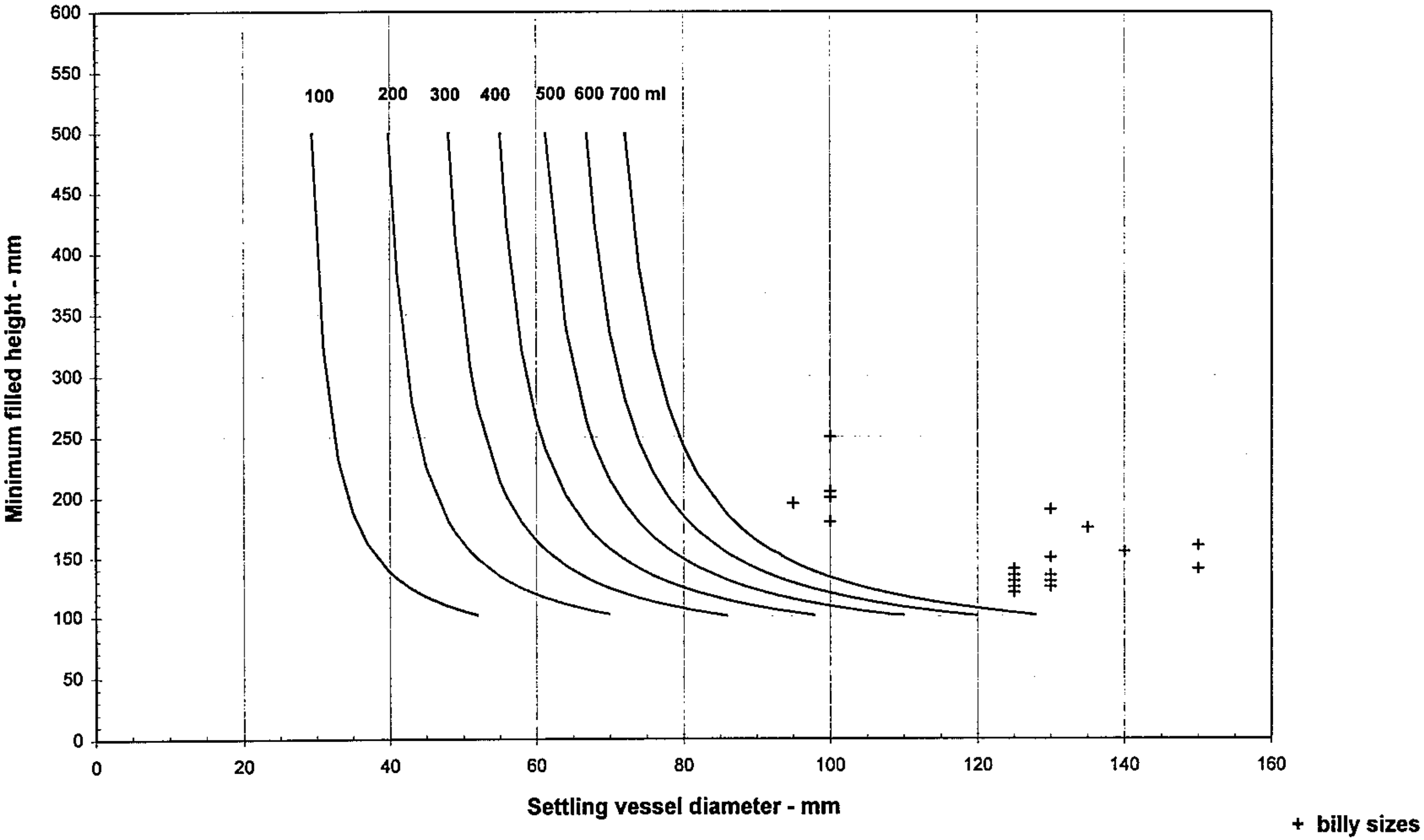


FIGURE 18

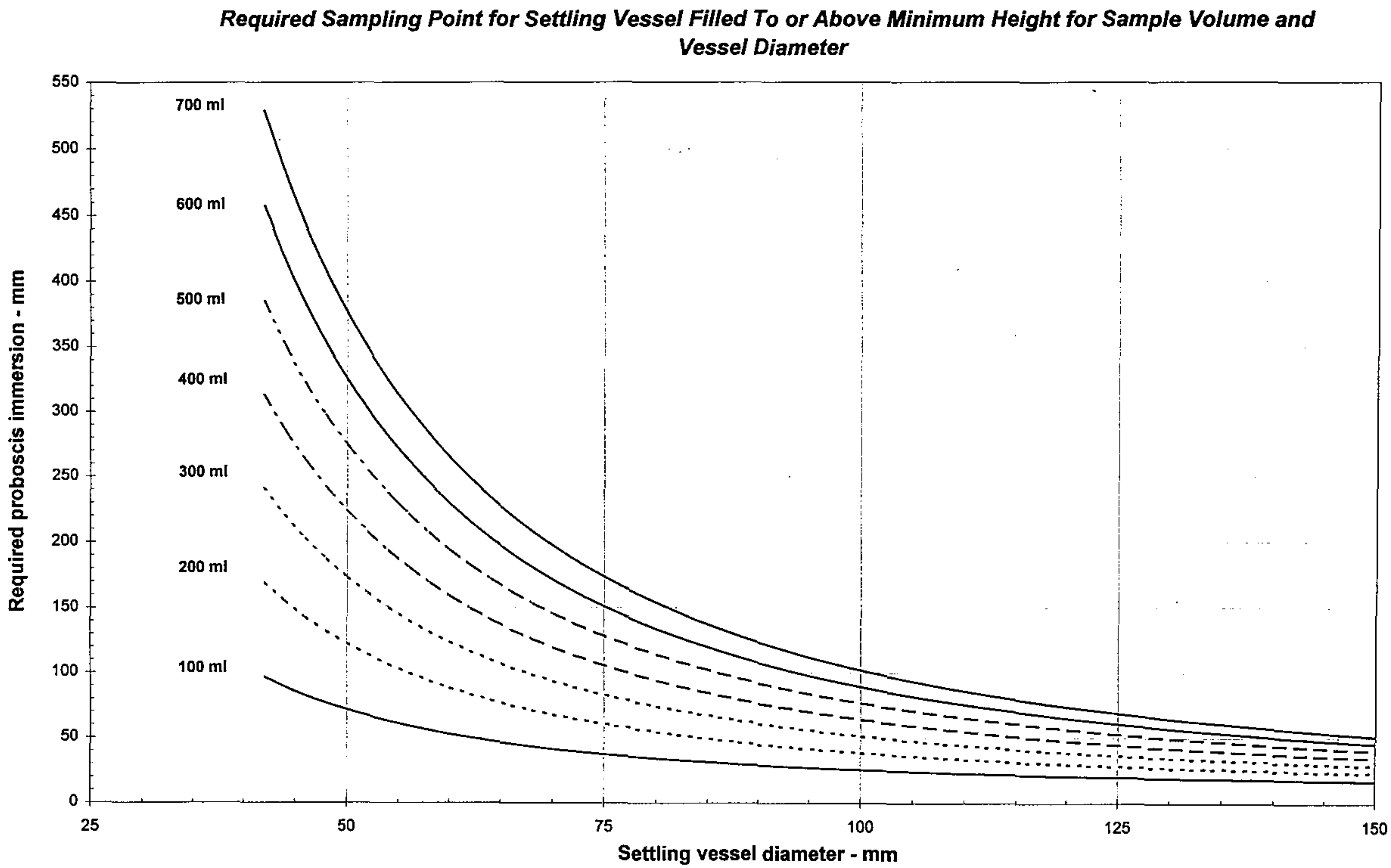

Required Sampling Point for Settling Vessel Filled To or Above Minimum Height for Sample Volume and Vessel Diameter
700 ml
600 ml
500 ml
400 ml
300 ml
200 ml
100 ml
550
500
450
400
350
300
250
200
150
100
50
0
25
50
75
100
125
150
Required proboscis immersion - mm
Settling vessel diameter - mm

FIGURE 19

An alternate arrangement would require the proboscis to be immersed directly to the lowest sampling point as defined by the equation

$$I = [\{ (1274 \times V) / D^2 \} + 10]$$

where I = immersion (mm)
V = (sample volume + 20) (cm^3)
D = vessel diameter (mm)

and then commence sampling. This technique was used in a number of trials. It was found that it extended the capability of the meter in marginal juices by pumping off the mud layer at the sampling point before drawing the supernatant through the meter.

The sampling point for the proboscis , 10 mm beneath the liquid surface, is plotted in Figure 19 for a range of required sample volumes and settling vessel diameters.

The following, Table 6, gives the relevant data for a required sample volume of 400 ml.

TABLE 6

SAMPLING POINT IMMERSION (v = 400 ml), using the proboscis.

Settling Vessel Diameter (mm)	Minimum Filled Height (mm)	Sampling Point Immersion (mm)
90	183	77
95	147	70
100	127	64
125	86	45
130	82	42
135	79	40
140	77	38
150	73	34

If a float was used, the height versus diameter relationship would be modified by the altered point of sampling beneath the liquid surface.

Thus

Mean Settling Rate (mm/min) $= [\{ (63.694 \times V) / D^2 \} + 0.5]$ for the proboscis

becomes, say

Mean Settling Rate (mm/min) $= [\{ (63.694 \times V) / D^2 \} + 39/20]$ for the fibre float which samples 39 mm beneath the liquid surface.

This relationship is equated against the desired settling rate regime and solved for vessel filled height as has been described.

The proboscis can be fixed in height in the vessel. In this case the height of liquid in the settling vessel should be fixed. This could be done by an overflow with subsequent top up or perhaps drain to the design height when the froth has risen to the liquid surface.

Bottom up sampling

It is possible to select a height above the base of the settling vessel as the sampling point and have some flexibility in filled height. This is achieved by building in some surplus when selecting the settling vessel and is termed here" bottom up sampling".

The settling vessel, if filled to vessel height H will settle according to the relationship

Rate = [25.941 x H /(1+(0.3111 x H))] -78.14 for very slow settling (from page 32)

and the mud would lie at

H - (20 x ([25.941 x H /(1+(0.3111 x H))] -78.14)) mm above vessel base after 20 minutes.

This would be the maximum mud height in this vessel and would occur when fully filled.

If it is required , that as a minimum, there should be 5 mm of supernatant under the sampling point and 10 mm above it, and that V or (v+20) ml should be provided for:

the minimum filled height =

H - (20 x ([25.941 x H /(1+(0.3111 x H))] -78.14)) + { (1274 x V) / D^2 } + 15 mm

The sampling holes would be placed at

(minimum filled height - height for[v+20 ml] -10) mm above the base of the settling vessel.

In this way, for example, a vessel such as a mill billy of 125 mm diameter and 120 mm height could be filled to 108 mm and still function for a required sample volume of 400 ml..

This technique would allow a certain amount of froth, up to about 16 mm (120 - 108 + height eq of 20 ml) if 400 ml taken and 420 ml allowed for.

In solving these equations the user should ensure that the a height H be selected which results in a minimum filled height ≤H.

Sampling Summary

In the case of the 125 mm diameter 120 mm tall mill billy ;

Proboscis sampling can take place when the vessel is filled to the minimum height, 85 mm, up to fully filled, 120 mm. The proboscis is placed 10 mm beneath the liquid surface and moved down with the withdrawal of sample. Alternatively, the proboscis could be inserted 45 mm into the liquid and the required sample volume of 400 ml withdrawn. These methods require lower filled height but require some surety in knowledge of the liquid surface position. It follows that the sampling proboscis location is determined by the filled height in the vessel and that sampling at the point for 85 mm filling is not suitable for 120 mm filling or vice versa.

The position of the sampling holes can be set for a vessel , termed bottom up sampling, but requires a minimum liquid height of 108 mm in the 120 mm vessel. It does allow uncertainty in liquid level due to froth when attempting to fill the vessel. The degree of flexibility in filling the vessel is related to the design fill height for a vessel diameter. For example, flexibility is minimal for this vessel with a design fill of 95 mm.

This information is summarised on Figure 20 .

7.5 Mass Flow Meter Density and the Spindle in " Homogeneous Suspensions"

Where settled mud is not sampled by the spindle or the meter, the spindle and meter provide comparable measures of the same physical entity. Two trials show this.

In the first, the effect of prolonged settling was monitored in glass cylinders of brixing cylinder dimensions. Separate cylinders were set up for spindle and meter. The results were as follows

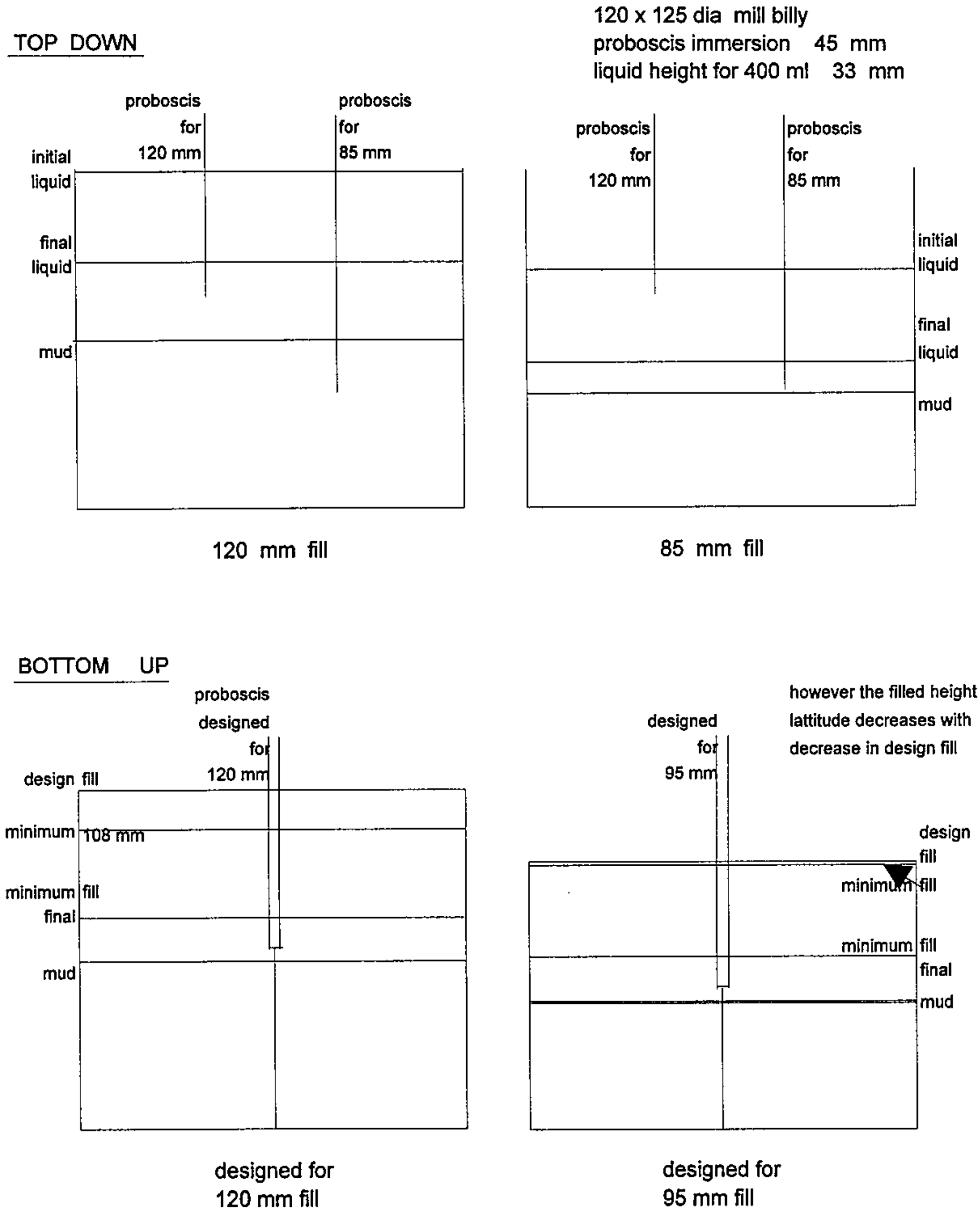
Time	Mud Height mm	Mud Height % Filled Height	Spindle Brix	Meter Brix
20 mins	194	55	19.64	19.54 *
30 mins	163	47	19.55	19.50
1 hour	125	36	19.39	19.43
5 hours	104	30	19.20	19.24

* Sampling has created a well of settled juice which has enabled a reading to be obtained at 55 % mud height.

The refrac Brix of this juice was 18.68 corrected to 20 C and the soil was red volcanic.

FIGURE 20

SAMPLING REGIMES



In the second trial, a heavy clay soil was blended 700 g clay to 2400 ml juice. The lab centrifuge test showed 87 % solids by volume and the mass flow meter indicated 38.44 Bx. 300 ml of this mixture was diluted to 1300 ml with juice. (finally 30 g clay to 650 ml juice).

The final dilution showed no sign of settling and was found to test 13% v/v mud solids in the centrifuge test. Brix results were:

Spindle Brix	24.87
Meter Brix	24.94
Refrac Brix	19.05

In both of the trials the meter and the spindle gave the same result in spite of testing what might be called a homogeneous slurry of mud solids and juice.

7.6 Air Entrainment Limits

Air in the instrument's measuring region will result in low results.

A trial was undertaken to monitor the effect of increasing volumes of air on the reading of water.

A measured quantity of air was introduced in to the meter via the proboscis and followed up with 350 ml of water and the pump stopped. The meter was observed during pumping and the no flow reading recorded after pumping was completed. Additional air was drawn into the instrument and the procedure repeated. The results are plotted in Figures 21 (at fine scale) and 22 (at coarse scale) where SGU1 is the no flow reading and SGU2 the lowest reading observed during the pumping of the 350 ml of water.

Points to note are that

- the system can tolerate 27 ml of air at this pumping rate (460 cm^3/min) before it has any effect on the results whether read while pumping or after pumping
- air is discharged from the instrument after about 35 ml has been ingested, giving an indication of the air hold up in the instrument of this configuration
- the meter reading while pumping began to show the presence of air at a cumulative 29.5 ml of air ingested
- the reading after pumping was not affected by air until 41.8 ml of air was introduced

This work indicates that air introduction is a significant consideration but not one to raise concern at low levels of air entrainment. The full inlet tubing would contain 19 ml of air, insufficient to upset the instrument.

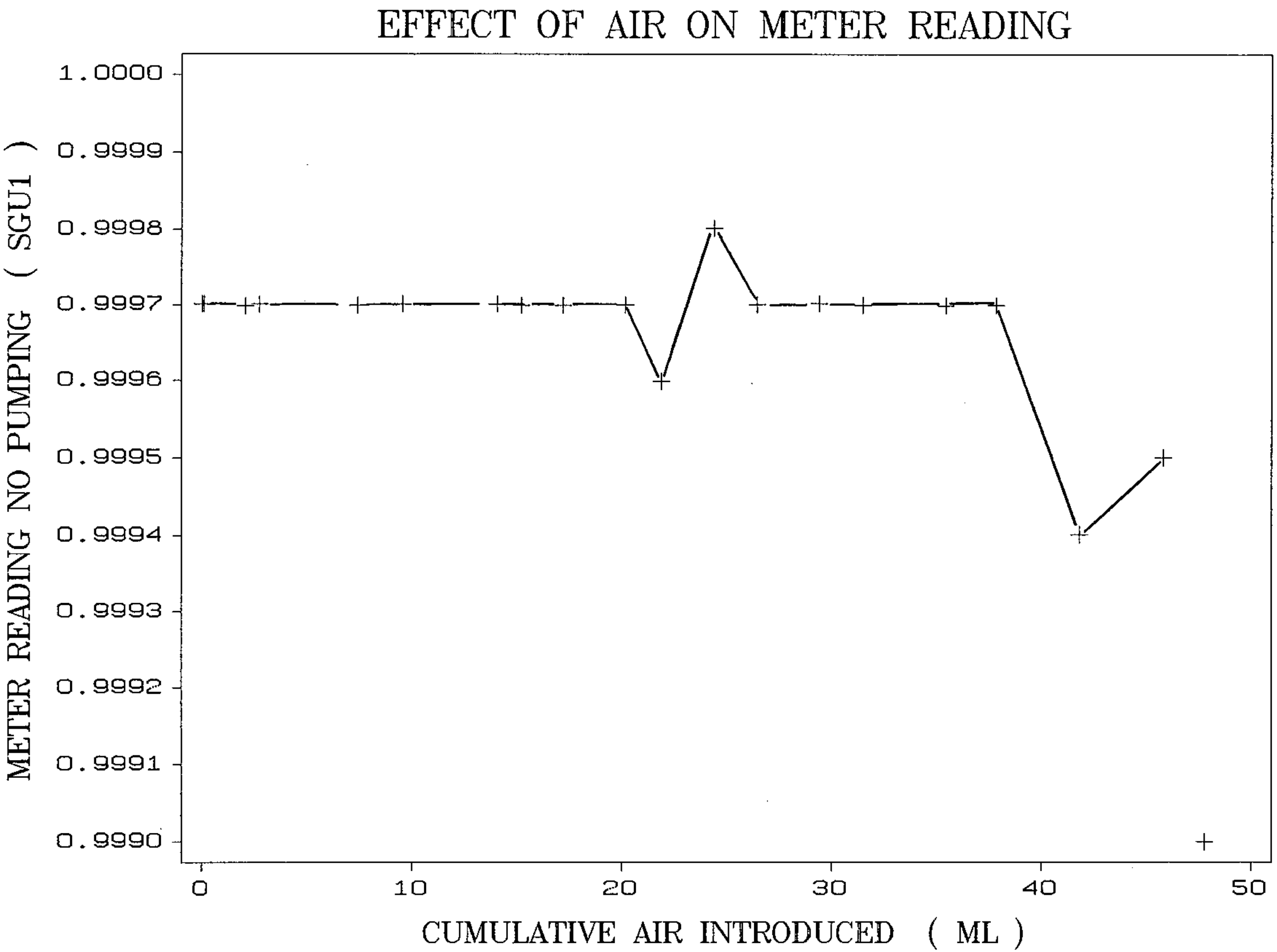
The manufacturers advise that air can accumulate in the inlet and exit tubing of the instrument, particularly at step changes in diameter and providing it does not impact on the measuring tube it will have no effect. After about 27 ml of air is introduced, the inlet space available for air is full and air passes through the measuring section to the outlet space affecting the flowing meter reading. When the outlet space is filled, at about 40 ml, air remains in the measuring region when the pump is stopped with adverse effect on that reading.

Air may be removed by pumping a suitable liquid, eg water, through the meter viz

1400 ml at 460 cm^3/min removed the air affecting the "stationary" reading.

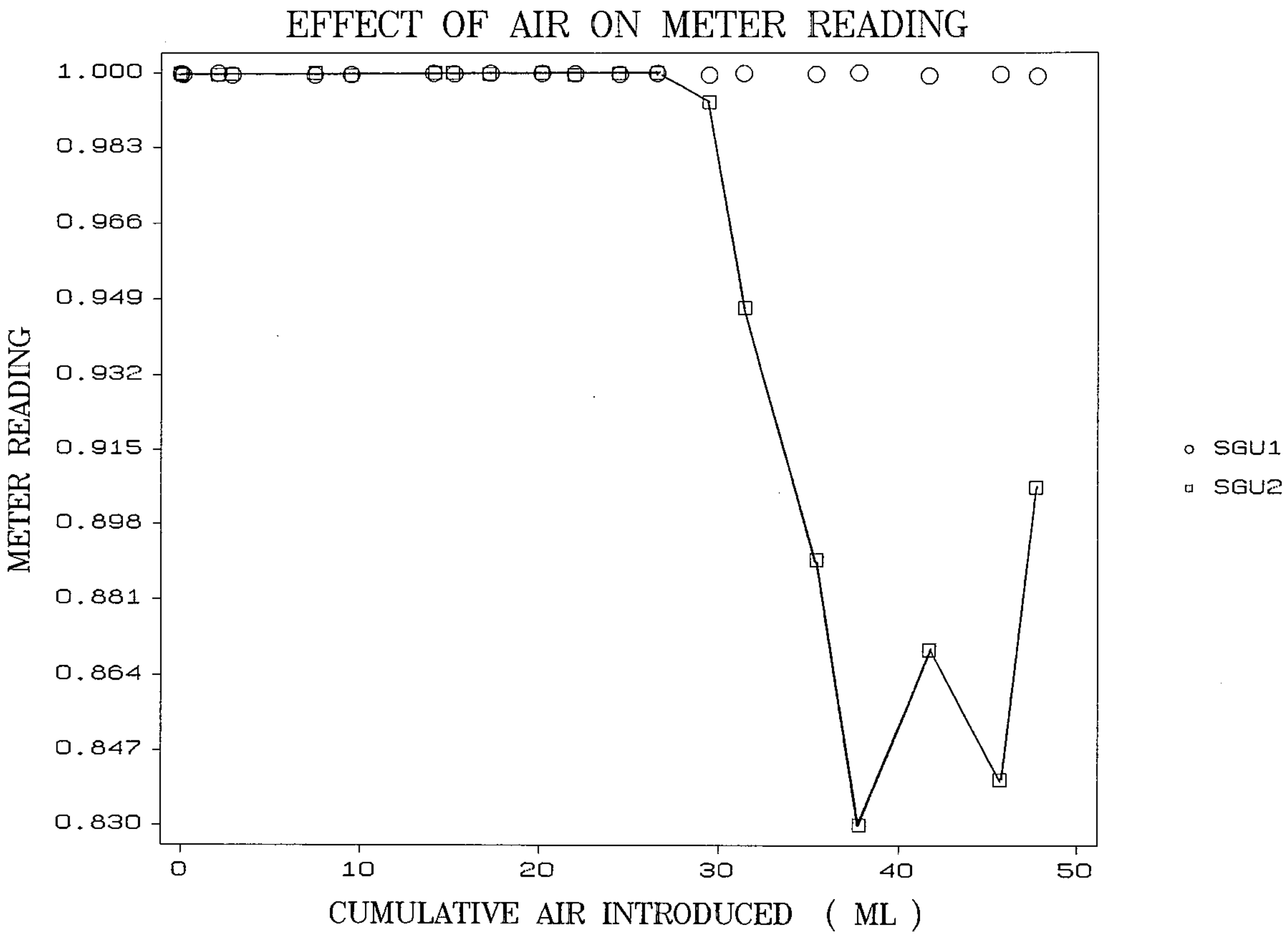
1400 ml at 1500 cm^3/min removed air affecting the "during pumping" reading. This volume may be reduced and the last trace of air removed by using short periods with flow reverses.

It has been observed that increasing flow rate in a situation where air is present but not influencing the during pumping reading will cause air to break away and lower the reading.



Air was introduced in small amounts followed by 350 ml water after each

FIGURE 21



SGU1 is stationary reading, SGU2 is lowest reading whilst pumping

FIGURE 22

7.7 Stability of Readout

2 litres of approximately 20 degrees brix solution was prepared and recirculated through the meter. The brix and temperature displayed by the meter was noted every minute over the next half hour. The results obtained were as follows:

Time	Brix Reading	Temperature C
0	20.04	22.4
1	20.07	22.4
2	20.04	22.4
3	20.07	22.4
4	20.04	22.4
5	20.07	22.4
6	20.05	22.5
7	20.05	22.5
8	20.05	22.5
9	20.09	22.5
10	20.07	22.6
11	20.08	22.6
12	20.04	22.6
13	20.07	22.6
14	20.08	22.7
15	20.09	22.7
16	20.09	22.7
17	20.06	22.7
18	20.04	22.8
19	20.09	22.8
20	20.09	22.8
21	20.04	22.8
22	20.08	22.9
23	20.05	22.9
24	20.05	22.9
25	20.09	22.9
26	20.09	23.0
27	20.08	23.0
28	20.06	23.0
29	20.09	23.1
30	20.07	23.1

The brix has not changed even though there has been a gradual increase in temperature.

7.8 Effect of Temperature

Several sets of work explored the effect of temperature.

Varying Temperature of Juice

In the first, the effect of a sudden step change in temperature of solution into the meter was observed. A solution of known brix, 20.02, was passed through the meter and a reading obtained. the solution was then heated and circulation recommenced. The solution was the cooled and the process repeated. The results were as follows:

Meter Temperature	Brix Reading
22.7	20.06
27.9	20.12
27.3	20.11
27.0	20.06
26.7	20.10
26.0	20.07
25.7	20.07
25.3	20.10
24.9	20.06
24.1	20.09
23.2	20.06
22.4	20.08
21.3	20.07
20.8	20.09
19.6	20.04

The variations in reading are no more than we have seen in repeated readings in earlier work. The changes in the temperature of the instrument and solution or the development of a steady state temperature situation is compensated for in the normal operation of the meter.

Inlet, Outlet and Meter Temperatures

The three temperatures were recorded during 22 tests.

Test No	Temperature of Juice (C) Inlet	Meter	Outlet
1	20.5	21.2	21.0
	20.0	20.9	20.9
	20.1	20.8	20.9
	20.6	21.2	21.0
2	20.6	21.6	21.5
	20.8	21.6	21.5
	20.8	21.6	21.5
	21.4	21.8	21.6
3	21.0	21.8	21.5
	20.7	21.6	21.7
4	21.1	22.5	22.2
	21.5	22.4	22.1
	21.4	22.1	22.0
	22.0	22.6	22.3
5	23.2	24.2	23.5
	22.7	23.8	23.5
	22.6	23.7	23.2
	24.0	25.0	24.8
Average	21.39	22.25	22.04

The temperature indicated at the instrument was the highest of the three.

As previous work has indicated that the instrument read correct brix independent of variation in the temperature displayed, it follows that the temperature compensations incorporated in the instrument for elasticity of the metal tube and the equations are satisfactory. Thus the instrument temperature, not inlet or outlet should be the temperature used in calibration computations.

This was confirmed when calibration on inlet temperature produced less than satisfactory calibration where liquid temperature varied.

A temperature is needed for pol computations. The pol calculation uses the apparent density at the temperature of the pol measurement which is taken to be that of the spindle brix measurement. Inlet temperature could be measured independently and the brix or density and temperature off the instrument could be converted to a density at the measured inlet temperature for the pol calculation.

Effect of Juice Temperature on the inlet, Outlet and Meter Temperature

A stable read out was obtained at 4 temperatures for a juice of spindle reading , corrected to 20°C of 20.02.

The readings were:

Inlet Temp	Meter Temp	Outlet Temp	Brix Reading
20.4	21.1	20.6	19.99
30.0	28.2	27.0	20.13
19.5	21.5	21.5	19.99
25.0	24.7	24.0	20.08

The readings are largely within the range expected from multiple readings (refer to 5.3).The average of the readings is 20.05 Bx .

8.0 OPPORTUNITIES FOR AUTOMATION

The following is an overview of the matters that require consideration or could be incorporated in the development of an automated sampling and analysis system

8.1 The Broad Principle

A sample of first expressed juice is to be analysed for Brix (weight % dissolved solids) using a Rosemount Micromotion Mass Flow Meter in the density mode. The sample is required to be cleaned up by standing for at least 20 minutes prior to analysis. The sampling process for brix determination must be such that the measurement by the Micromotion device will be no more susceptible to interference from substances that settle or float in the standing process than would be an analysis by a conventional sugar hydrometer using the standard method.

400 ml of settled juice is to be passed through the Micromotion device at a flow rate of approximately 465 cm^3 / min , the pumping stopped and the density and instrument temperature recorded on the operating computer and brix computed. An in-line sensor will measure the temperature of juice at the inlet to the meter and this temperature will be recorded with the other data to enable apparent density at the inlet temperature to be computed.

8.2 Analyst Duties

A juice sample will be provided to the analyst in a numbered container.

The analyst will subsample it for pol determination (% sucrose by polarimeter) into a 100 ml analysis bottle, add basic lead acetate and shake to mix. This subsample is set aside until, say, 6 such samples are obtained, whence filtration can commence. When approx 50 ml of filtrate has been obtained the batch of 6 juices is run through the polarimeter, according to standard procedure, the readings recorded and the results keyed into the computer by sample number. The pol readings obtained on these juices are to be double entered into the computer and are used in verification of the brix measurement obtained by density measurement and discussed in a later section.

The analyst will also fill a clean, dry, brixing cylinder set up in the autosampler rack. The analyst keys into the computer the location of the cylinder for this sample number (identifies the sample to the autosampler) and places an autosampler identification on the juice sample container. After approx 5 minutes, the froth and fibre which float to the surface will be scooped off the cylinder and the cylinder topped up to overflowing from the original sample container. On completion of this task, the analyst will activate a count down period on the autosampler for that sample. This period will be programmed so that not less than 20 minutes or longer than 25 minutes standing is achieved before juice is taken for analysis by the autosampler.

On completion of the analysis for brix, the brixing cylinders are to be removed from the autosampler, their contents discarded and the cylinders washed and drained prior to reuse. The contents of the cylinders MUST NOT be discarded until given clearance to do so by the controlling computer on the basis of acceptable comparison between the pol and brix readings on that juice. The programmer and subsequently the system manager selects the brix-pol average to be used and the acceptable pol range eg $\pm$ 3 or $\pm$ 4 etc. If the pol is not "read" by the time the brix reading is obtained then the clean up process must await satisfactory comparison when the pol reading is obtained. The computer will display the container numbers with satisfactory comparisons.

If the results lie outside the range of pol for the brix obtained, the computer will call for a refractometer brix to be carried out. The value for the refractometer brix will be manually entered into the computer with sample identification and another pol/brix comparison carried out by the computer. If still not in range, the computer will request another pol reading to be obtained. The analyst will at this stage provide the supervisor with all the results for the juice for adjudication as to the correct results to accept.

8.3 Requirements of Autosampler

- Capacity

Require 24 samples +4 calibration samples or 28 samples analysed per hour. This corresponds to 2 minutes per analysis.

- Sample storage

Provision for indexed storage of 20 settling vessels of appropriate diameter and height held upright by an appropriate device.

- Drainage

The brixing cylinders will be filled and topped up in the storage rack which must therefore have drainage and ability to withstand mildly acid sugar juice and cleaning solutions.

- Operation

Sample withdrawal will be by probe and peristaltic pump. Sampling will be initiated by the computer on completion of the 20 minutes standing period. An alarm will identify if the brix measurement has not commenced within 25 minutes of commencement of timing.
The probe internal diameter will be approx 3 mm and of appropriate length.
Pump rate will be 465 cm^3/min. The probe will be lowered into the brixing cylinder to the position defined by Table 6 before commencing pumping. Pumping will cease after a predetermined time to deliver the required sample volume.

When the instrument temperature has stabilised, the computer will acquire the density reading and instrument temperature together with the temperature of the inlet juice. Brix and apparent density at the inlet temperature will be calculated from ICUMSA equations.

- Material of Construction

The construction materials must be unaffected by mildly acidic sucrose solutions or calibration fluids of up to
14% Common salt (NaCl)
18% Nitric acid

8.4 Software

The elements of the software provided will include :

- Sample identification
  Rake number
  Container number (sample number)
  Autosampler grid position
  Date and time of initiation of sample
- Start timing out 20 minutes
- Alarm if Brix sampling not commenced in 25 minutes
- Sample initiation when sampler free and 20 minutes elapsed
- Positioning probe
- Starting pump
- Stopping pump
- Gathering data from Micromotion and temperature sensor (ave of 5 readings in 10 sec)
- Withdrawing probe and commencing next sample when appropriate
- Receiving and assimilating pol data from keyboard - by container number in double entry to avoid errors
- Comparison of pol and brix data for sample container
- Advise acceptability of comparison when reporting " OK to discard" or request "Refrac Brix required"
- Accept manually entered Refrac Brix and adjust according to convention
- Compare adjusted Refrac Brix with pol reading and advise acceptability, incorporating

the refrac brix into the record or request 'reread pol".

- Prepare for manual entries on the basis of the new pol reading
- Provision to accept manual data
- Provision to transfer data by rake number, container number and initiation time to Cane Pay computer
- Initiate water rinse once per 6 determinations and a nitric acid calibration check once per hour (or at whatever frequency is desired). Compare reading with expected. Alarm if >0.1 Bx or 0.0005 g/cm^3 difference. Lock up computer if difference >0.2 Bx or 0.0009 g/cm^3 until recalibration completed
- Provision for manual intervention, manual operation and manual entry mode for brix determination
- Data to be stored

Rake number, container number, date and time of sample initiation, pol reading, inlet temperature, Brix or deity, instrument temperature

8.5 Glossary

Brix: The brix of a solution is the concentration (in grams solute per 100 g solution) of a solution of pure sucrose in water, having the same density as the solution at the same temperature.

Pol - % sucrose in solution estimated by the rotation of polarised light by the solution in a polarimeter

Pol Reading - The reading off the polarimeter for undiluted juice which is converted to the pol of the solution by dividing by a factor [(100 x apparent density at reading temperature)/26]

Rake Number - The number allocated to the growers parcel of cane that is being analysed. The number ranges from 1 to 9999 and each week commences at 1.

Sample Number or Can Number - The means used to identify the juice from a rake of cane in the juice lab. The number is typically 1 to 20 and is recorded in the mill computer with the rake number.

8.6 Technical Assistance

The specifications outlined above were discussed with Stephen Pronk of A.I. Scientific, 91 Landsborough Avenue Scarborough, who are well experienced in production of racks and turntables for laboratory work.

A.I. Scientific have a programmer on staff. The principal of the company, Stephen Pronk, has made estimates of the costs of an automated system. He has indicated that the initial or development model could cost in the range $49500 to $80000 with subsequent models $22000 to $30000 with in each case approximately $15000 addition for the CMF025.

The equipment proposed is simple and the equipment basic but would involve considerable programming in recording and interpreting data from the polarimeter and density meter. I don't expect it could be done for much less unless a milling company could provide the programming expertise. A.I. Scientific have a policy, in development work, for putting costs of same up front and not amortising them over subsequent sales.

9.0 CERTIFICATION AND AUDIT

Mass Flow Meter

The mass flow meter is akin to a polarimeter in certification requirement. As is the case with the polarimeter, there is the need for ongoing audit and in service evaluation.

The calibration settings D1 and D2 (refer Appendix 3) will be maintained, in use, with sugar solution and routine nitric acid checks. A certification process will involve confirmation of the meter calibration and the linearity of the instrument using five prepared sugar solutions ranging from 14 to 27 ° Bx. If necessary the instrument would be recalibrated and an acid check completed.

The instrument is not known to present linearity problems but if it did is not repairable.

Certification would confirm that the instrument and inlet temperature RTD's are measuring correctly $\pm 1\,°$C. This test is conducted by circulating water through the meter for say one hour without the meter switched on. The meter is then briefly switching it on to get the temperature reading and compared with the temperature of the circulating water determined by other means. This approach avoids the normal heating of the instrument and the fluid in the tubes that occurs in extended operation.

The instrument in these trials gave a temperature reading within 0.2 °C of a standard thermometer.

Problems are not usually encountered with the instrument thermometer . A Hart Communicator can be used to access the instrument's smart electronics to adjust the temperature coefficient should this be necessary. A complete failure of the internal contact thermometer usually requires replacement of the sensing tube.

Measuring System

An additional standard method, Method 3A, is in preparation for the Laboratory Manual. The measuring system, if it does not conform to the standard, should be clearly defined by the user. The description should include design flow rate, required sample volume and the settling regime, eg very slow or slow etc, the system will cope with.

An auditor of the system should confirm that the delivery system is as per design and that the required sample volume sought corresponds to steady density measurement at the design flow rate.

The volumetric flow rate indication should be compared with actual periodically as well as in a formal audit.

The proboscis sampling arrangement should be confirmed to
- be positioned according to design specification distance beneath the **liquid surface**
- include a means of confirming design liquid filled height at specification
- hold its liquid column when not immersed to avoid air ingress into the system when pumping commences
- include an accurate timer or other means to deliver, correctly, the required sample volume

10.0 SUMMARY

A system has been developed which duplicates the measurement for hydrometer brix of sugar cane juices. A mass flow meter with RS232 capability, for integration with the mill cane pay computer, has been trialed at 10 mills over two seasons. The work confirmed a one to one correspondence between the two measuring methods.

The elements of an automated system have been identified.

The work has extended to include monitoring of the settling of cane juices in vessels of varying diameters and filled heights. This has lead to mathematical relationships which the industry can use to specify the total system in vessel size and sample withdrawal arrangements. The system may be such that juices which would otherwise require a refractometer measurement can be analysed free of mud interference.

11.0 ACKNOWLEDGMENTS

Thanks are extended to the Sugar Research and Development Corporation for funding of this work and to the Management and Staff and Cane Testers of Mulgrave, South Johnstone, Macknade, Inkerman, Proserpine, Marian, Bingera, Moreton, Broadwater and Harwood Mills who readily allowed the testing in their laboratories and contributed personal effort.

The concept has been given enthusiastic support by Mr J D Cameron of the Australian Sugar Milling Council, Mr P G Atherton, formerly of BSES and in secondment to The Queensland Sugar Corporation, Mr B Millford of CANEGROWERS and the Staff of Bundaberg Sugar Limited. These people and groups initiated the work in the field on this occasion and followed its progress with interest.

The Queensland Sugar Corporation's Industry Measure Committee and the ASMC Technical Committee have been highly significant in direction and in technical evaluation of the work as have members of the Editorial Committee of the Laboratory Manual for Australian Sugar Mills, Dr M R Player of CSR Limited, Dr O Crees of SRI, now QSC, and Dr R Broadfoot of SRI. The involvement is gratefully acknowledged.

APPENDIX 1
OPERATION OF THE MICRO MOTION DENSITY METER

The density meter consists of two roughly coat hanger shaped tubes in parallel. The liquid to be tested flows through the tubes. The tubes are placed in vibration with an electromagnetic drive coil and vibrate at the natural frequency of the system. The resonant frequency is a function of the geometry, material of construction and mass of the tube assembly. The mass and volume of the tube is fixed. Variation in the resonant frequency of the system is caused by variation in the density of the liquid in the tubes as well as any variation in the spring constant of the tubes with temperature. A temperature sensor accounts for changes in the modulus of elasticity of the tubes.

The system is calibrated with two liquids of known density. Thereafter, an unknown density is determined by comparison of its resonance frequency with that of the knowns.

The instrument may be calibrated to display brix or it can be calibrated in density units and the ICUMSA equations used to compute brix from the density and temperature displayed.

The Instrument Displays Brix

The Density monitoring System (DMS) in the CMF instruments displays brix as one of its options. In brix mode, the calibration constants D1 and D2 are in a unit devised by Rosemount called SGU_{20} where

SGU_{20} = Density of Solution at Temperature of Measurement / Density of Water at 20°C
(Instrument Temperature)

The microprocessor uses these calibrations to determine SGU_{20} for other solutions at their temperature of measurement (T) and then applies the relationship

$$\text{Brix at Temperature T} = -625.7853 + [1143.157 \times SGU_{20}]$$

$$- [667.0884 \times (SGU_{20})^2] + [149.7279 \times (SGU_{20})^3]$$

$$\text{Brix at Temperature 20°C} = \text{Brix at T} + A + [B \times T] + [C \times (T)^2]$$

where

$$A = -0.4043045 - [(2.598019 \times 10^{-2}) \times \text{Brix at T}] + [(1.549075 \times 10^{-4}) \times (\text{Brix at T})^2]$$

$$B = -[3.645586 \times 10^{-3}] + [(1.666074 \times 10^{-3}) \times \text{Brix at T}] - [(9.15178 \times 10^{-6}) \times (\text{Brix at T})^2]$$

$$C = [1.206985 \times 10^{-3}] - [(1.975728 \times 10^{-5}) \times \text{Brix at T}] + [(8.403768 \times 10^{-8}) \times (\text{Brix at T})^2]$$

The brix, after the above correction, is presented at DT mode.

Brix from Density and Temperature Using ICUMSA Equations

The instrument is set to **g/cc mode.** The DT reading of the DMS is g/cc and temperature in degrees Centigrade. The D1 and D2 constants are set from the known density in g/cc at the displayed temperature.

The following computation is then completed to determine brix.

$$
\begin{aligned}
w = {} & 2.596054r - 2.368154r^2 + 2.529236r^3 - 2.194249r^4 + 1.523668r^5 - 0.479275r^6 \\
& + (0.307874r - 0.651523r^2 + 0.689324r^3 - 0.527656r^4 + 0.051049r^5)\tau \\
& + (-0.355762r + 0.661862r^2 - 0.594131r^3 + 0.331665r^4)\tau^2 \\
& + (0.245401r - 0.366598r^2 + 0.232380r^3)\tau^3 \\
& + (-0.075075r - 0.012667r^2)\tau^4 \qquad (1)^*
\end{aligned}
$$

where

w = mass fraction of an aqueous sucrose solution. 'w' must be expressed as a decimal fraction in the formulae.

$$\tau = (t°C - 20)/100 \qquad (2)^*$$

ρ_{H2O} is the density of water calculated according to the updated Kell's formula

$$
\begin{aligned}
\rho_{H2O} = {} & (999.83952 + 16.952577t - 7.9905127 \times 10^{-3}t^2 - 46.241757 \times 10^{-6}t^3 \\
& + 105.84601 \times 10^{-9}t^4 - 281.03006 \times 10^{-12}t^5)/(1 + 16.887236 \times 10^{-3}t) \qquad (3)^{**}
\end{aligned}
$$

$$r = (\rho - \rho_{H2O})/1000 \qquad (4)^*$$

ρ = Density in kg/m^3
and
t = Temperature °C

Similarly,

$$
\begin{aligned}
\rho = {} & \rho_{H2O} + 385.1761w + 135.3705w^2 + 40.9299w^3 - 3.9643w^4 + 13.4853w^5 - 17.2890w^6 \\
& + (-46.2720w - 7.1720w^2 + 1.1597w^3 + 5.1126w^4 + 17.5254w^5)\tau \\
& + (59.7712w + 7.2491w^2 + 12.3630w^3 - 35.4791w^4)\tau^2 \\
& + (-47.2207w - 21.6977w^2 + 27.6301w^3)\tau^3 + (18.3184w + 12.3081w^2)\tau^4 \qquad (5)^*
\end{aligned}
$$

The apparent density, ρ_{App}, has been similarly described by ICUMSA , where

$$\rho_{App.} = \frac{\rho - 1.2}{0.99985} \qquad (6)^{**}$$

Note : Equation 5 can be used to convert brix to density at the temperature of polarisation reading (Inlet juice temperature).This value may then be converted to Apparent Density by the relationship given in Equation 6 and used to calculate the 'pol factor' for determining Pol per cent Juice.

* Proc. 21st Session ICUMSA, 1994, 332 - 334
** ICUMSA Methods Book, 1994, Specification Standard SPS - 4 (1994)

Comparison of Rosemount and ICUMSA Equations

The following table gives the brix calculated from the Rosemount and ICUMSA equations for various densities and temperatures

Density (g/cm^3)	1.0647	1.0877	1.1053	1.059.8	1.0798	1.0795
Temperature (C)	15	15	15	25	25	25
SGU_{20}	1.0666	1.0897	1.1073	1.0617	1.0817	1.0995
ICUMSA Bx	15.99	21.19	25.09	15.49	20.10	24.02
Rosemount Bx	16.02	21.24	24.04	15.45	20.05	24.01
Difference	-0.03	-0.05	+0.05	+0.04	+0.05	+0.01

APPENDIX 2
CALIBRATION OF THE MICRO MOTION DENSITY METER

This section details three calibration procedures:

- pre-season set up and calibration
- calibration of a new nitric acid working standard
- routine calibration checks as required.

Preparation of 16°Bx and 24°Bx Standard Solutions

These solutions are to be prepared immediately prior to use and discarded after the calibration is complete.

1. Spread sufficient refined sugar for a calibration run (approx. 500 g) on a tray in a layer of about 10 mm thick and dry in an oven at 96 - 100°C for 5 hours ± 10 minutes. Transfer to an oven dried beaker and cool to room temperature in a desiccator.

2. Weigh 171 ± 0.5 g of dried sugar into a dry stoppered conical flask. Record the weight of sugar to 0.01 g (x_{16}).

3. Add 900 ± 0.5 g of distilled water from a measuring cylinder. Record weight of water to 0.01g (y_{16}).

4. Stopper flask and dissolve sugar. $Bx_{16} = x_{16} \times 100/(x_{16} + y_{16})$

5. Weigh 284 ± 0.5 g of dried sugar into a dry stoppered conical flask. Record weight to 0.01 g (x_{24})

6. Add 900 ± 0.5 g of distilled water from a measuring cylinder. Record weight to 0.01 g (y_{24})

7. Stopper flask and dissolve sugar. $Brix_{24} = x_{24} \times 100/(x_{24} + y_{24})$

Preparation of Nitric Acid Working Standard

Prepare a nitric acid working standard of a density which approximates that of a 20° Bx sucrose solution by adding 3200 cm^3 of technical grade 70 % w/w nitric acid, stirring constantly, to 16800 cm^3 potable water in a suitable plastic or glass container. Seal the container, mix well, and allow to cool.

Set Up and Calibration

(a) Flush the meter with approx 1500 ml of water at a flow rate of 1500 ml/min.

(b) Dry the outside of the proboscis and lower it into the 16°Bx Standard Solution .

(c) Suck the required volume described in section 7.2 (400 ml for the instrument geometry used in evaluating the equipment) of this low brix solution through the meter at a predetermined pump setting to complete the transfer in 50 seconds. ($8.0 cm^3/sec$)

(d) Stop the pump.

(e) With the meter in g/cc mode, (see * below for brix mode procedure), note the DT readings (density and the displayed temperature) after the meter temperature has stabilised. Calculate the solution Brix using Equation 1 of Appendix 1. Compare this value with the calculated theoretical brix value ($Brix_{16}$). If this difference is greater than 0.05°Bx, the meter's calibration can be altered via the mode setting D1 (the calibration factor for the lower brix solution) by following the procedure in the manufacturer's instrument manual (see below).

(f) After altering D1, return to DT mode and note the new density and temperature value and recalculate Brix. If not within ± 0.05° Bx of the theoretical value, return to D1 mode and alter the factor. Continue to do so until satisfied the meter is reading within ± 0.05°Bx of the theoretical value.

(g) Repeat steps (b) to (f) using the 24°Bx Standard Solution, this time using D2 mode to alter the higher calibration factor if necessary.

(h) If the DT reading of the 24°Bx solution needs to be altered by more than the equivalent of 0.15°Bx , via the D2 calibration factor, in order for it to agree with the theoretical value, then the D1 value should be rechecked with 16°Bx Standard Solution to ascertain that it has not been affected by the change in D2. Should the 16°Bx solution have moved by more than ± 0.05 ° Bx from the theoretical value , it will be necessary to recalibrate via D1 and subsequently recheck D2 with the 24°Bx solution and so on as per this section.

(i) When the instrument has been calibrated, flush with water.

Note to Instrument Manufacturer's Procedures

The Rosemount Micro Motion system identifies the following procedure in altering D1.
Select D1 mode and press "Reset" twice. The current D1 factor may now be altered. The first number of the factor will be flashing. Press the "horizontal arrow key "→" to move the flashing to the digit you wish to alter. Use the upright arrow key "↑" to change the value. Press "Enter"to put this new D1 value in the microprocessor. D2 is similarly altered.

It has been found that the instrument does not respond evenly to changes in D1 or D2. Occasionally, it is necessary to make several alterations including a correction for overshoot

in completing the procedure for D1 or D2.

The calibration is extremely stable and, though checked daily by acid secondary standard at South Johnstone mill in 1995 when being used by the Cane Testers, was not deemed to have changed sufficiently for a sugar recalibration over 11 crushing weeks.

* Where the instrument is being used in brix mode, brix is directly displayed and is compared with the known brix ($Brix_{16}$) or ($Brix_{24}$). D1 and D2 are varied to drive the instrument to display the respective known brixes. The calibration equations of Rosemount and ICUMSA differ by up to 0.05°Bx over the range of temperatures and brixes experienced. The difference between the computed results is the same order as the differences that trigger recalibration. The ICUMSA equations are thought to be more solidly based on experimentation and consequently are recommended for future work.

Calibration of Nitric Acid Working Standard

Calibrate the working standard immediately on completion of the instrument calibration. Flush with water and draw 400 cm^3 of this standard through the meter at the prescribed rate of 8 cm^3 per second. Stop the pump, allow reading to stabilise and note the density reading and instrument temperature. Label the working standard with this information, including the date.

Carry out a full standardisation with sucrose solutions before use of a newly prepared bulk working standard.

Routine calibration checks

The meter should be checked with the working standard routinely or "at appropriate intervals" using the volume and flow rate above. The meter should be thoroughly flushed with potable water prior to and immediately after calibration. If the density after application of a temperature correction varies from that obtained in the working standard calibration by more than 0.0005g/cm^3, a full recalibration should be undertaken. (Temperature correction = +0.00045 g/cm^3 per degree Celsius rise in temperature from the initial check*)

Discard any excess nitric acid. On no account should any acid be returned to the bulk working standard. Discard the bulk working standard at the end of the season.

* Perry's Chemical Engineering Handbook, Sixth Edition, (1984). Densities of Aqueous Inorganic Solutions, Table 3-66, Nitric Acid (HNO_3)

APPENDIX 3
1994 TRIAL RESULTS

The results obtained in the 1994 extended mill evaluation trials follow. The results are presented in tabular and in histogram form for each mill.

APPENDIX 3

Results of tests carried out by cane testing staff

MULGRAVE MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C	
1	19.50	19.56	19.50	19.53	-0.06	0.00	-0.03	0.03	
2	19.60	19.57	19.64	19.65	0.03	0.04	0.08	0.01	
3	19.30	19.34	19.42	19.34	-0.04	0.12	0.00	-0.08	
4	18.30	18.21	18.38	18.18	0.09	0.08	-0.03	-0.20	*
5	19.00	18.93	18.86	18.83	0.07	-0.14	-0.10	-0.03	
6	17.90	17.82	17.81	17.77	0.08	-0.09	-0.05	-0.04	
7	17.70	17.65	17.65	17.68	0.05	-0.05	0.03	0.03	
8	18.10	18.05	18.21	18.22	0.05	0.11	0.17	0.01	
9	17.20	17.13	17.22	17.23	0.07	0.02	0.10	0.01	
10	18.60	18.54	18.60	18.70	0.06	0.00	0.16	0.10	
11	16.50	16.43	16.45	16.44	0.07	-0.05	0.01	-0.01	
12	17.90	17.81	17.90	17.84	0.09	0.00	0.03	-0.06	
13	21.50	21.41	21.51	21.52	0.09	0.01	0.11	0.01	*
14	21.80	21.83	21.88	21.89	-0.03	0.08	0.06	0.01	
15	21.30	21.29	21.41	21.40	0.01	0.11	0.11	-0.01	
16	20.10	19.95	20.00	20.00	0.15	-0.10	0.05	0.00	
17	19.80	19.73	19.75	19.75	0.07	-0.05	0.02	0.00	
18	19.90	19.82	19.83	19.82	0.08	-0.07	0.00	-0.01	
19	19.00	18.84	18.88	18.79	0.16	-0.12	-0.05	-0.09	
20	18.90	18.88	19.14	19.23	0.02	0.24	0.35	0.09	
21	20.00	20.00	20.05	20.06	0.00	0.05	0.06	0.01	
22	18.00	17.94	18.76	18.38	0.06	0.76	0.44	-0.38	*
23	17.60	17.58	17.46	17.68	0.02	-0.14	0.10	0.22	
24	20.60	20.55	20.65	20.81	0.05	0.05	0.26	0.16	
25	19.40	19.44	19.45	19.53	-0.04	0.05	0.09	0.08	
26	18.90	18.88	18.86	19.02	0.02	-0.04	0.14	0.16	
27	16.00	15.93	16.07	16.14	0.07	0.07	0.21	0.07	
28	18.60	18.55	18.58	18.71	0.05	-0.02	0.16	0.13	
29	18.20	18.18	18.21	18.28	0.02	0.01	0.10	0.07	
30	21.60	21.59	21.68	21.70	0.01	0.08	0.11	0.02	
31	20.00	19.91	19.98	19.95	0.09	-0.02	0.04	-0.03	
32	20.90	20.86	20.88	20.97	0.04	-0.02	0.11	0.09	
33	21.60	21.53	21.63	21.81	0.07	0.03	0.28	0.18	
34	20.00	19.99	20.15	20.09	0.01	0.15	0.10	-0.06	
mean					0.047	0.012	0.084	0.026	

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) Mud was reported to be present in the juice in those tests denoted by an asterisk

(iii) Trial 22 was omitted from the averages

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

SOUTH JOHNSTONE MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C	
1	19.30	19.23	-	19.32	0.07	-	0.09	-	
2	17.70	17.69	-	17.60	0.01	-	-0.09	-	
3	18.90	18.88	-	19.12	0.02	-	0.24	-	
4	19.50	19.45	-	19.29	0.05	-	-0.16	-	
5	18.90	18.91	-	18.90	-0.01	-	-0.01	-	
6	19.90	19.96	-	19.92	-0.06	-	-0.04	-	
7	18.80	18.80	-	18.66	0.00	-	-0.14	-	
8	18.90	18.95	-	18.99	-0.05	-	0.04	-	
9	19.30	19.36	-	19.64	-0.06	-	0.28	-	
10	18.90	18.85	-	18.84	0.05	-	-0.01	-	
11	19.40	20.39	-	-	-0.99	-	-	-	*
12	22.30	22.97	-	22.12	-0.67	-	-0.85	-	*
13	16.60	16.60	-	16.74	0.00	-	0.14	-	
14	18.30	20.82	-	-	-2.52	-	-	-	*
15	19.30	19.54	-	18.94	-0.24	-	-0.60	-	*
16	19.20	19.09	-	19.51	0.11	-	0.42	-	*
17	20.00	19.98	-	19.98	0.02	-	0.00	-	
18	19.50	19.40	-	19.38	0.10	-	-0.02	-	
19	20.40	20.40	-	-	0.00	-	-	-	*
20	17.30	17.39	-	17.45	-0.09	-	0.06	-	
21	20.40	20.47	-	-	-0.07	-	-	-	*
22	18.00	18.02	-	17.92	-0.02	-	-0.10	-	*
23	19.80	19.80	-	19.61	0.00	-	-0.19	-	*
24	23.00	22.93	-	23.23	0.07	-	0.30	-	*
25	23.10	23.15	-	23.71	-0.05	-	0.56	-	*
26	21.30	21.02	-	22.85	0.28	-	1.83	-	*
27	21.40	21.45	-	21.95	-0.05	-	0.50	-	*
28	19.50	19.58	-	19.49	-0.08	-	-0.09	-	
29	18.80	18.82	-	18.68	-0.02	-	-0.14	-	
30	18.50	18.59	-	18.51	-0.09	-	-0.08	-	
31	17.80	17.70	-	17.66	0.10	-	-0.04	-	
32	20.10	19.69	-	20.40	0.41	-	0.71	-	*
33	18.10	18.16	-	18.43	-0.06	-	0.27	-	*
34	16.90	16.99		17.01	-0.09	-	0.02	-	
35	19.60	19.59	19.46	19.52	0.01	-0.14	-0.07	0.06	
36	18.50	18.54	18.50	18.54	-0.04	0.00	0.00	0.04	
37	19.60	19.65	19.51	19.51	-0.05	-0.09	-0.14	0.00	
38	20.30	20.33	20.22	20.28	-0.03	-0.08	-0.05	0.06	
39	19.80	19.80	19.78	19.78	0.00	-0.02	-0.02	0.00	
40	20.30	20.34	20.27	20.29	-0.04	-0.03	-0.05	0.02	
41	20.90	20.92	20.84	20.91	-0.02	-0.06	-0.01	0.07	
42	18.30	18.38	18.30	18.42	-0.08	0.00	0.04	0.12	
43	18.80	18.80	18.76	18.74	0.00	-0.04	-0.06	-0.02	
mean					-0.014	-0.051	-0.011	0.039	

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) Mud was reported to be present in the juice in those tests denoted by an asterisk and were omitted

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

MACKNADE MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C
1	23.10	23.09	23.11	23.01	0.01	0.01	-0.08	-0.10
2	21.80	21.53	21.54	21.58	0.27	-0.26	0.05	0.04
3	23.20	23.13	23.10	23.13	0.07	-0.10	0.00	0.03
4	23.30	23.35	23.39	23.35	-0.05	0.09	0.00	-0.04
5	21.50	21.52	21.46	21.45	-0.02	-0.04	-0.07	-0.01
6	21.80	21.70	21.76	21.72	0.10	-0.04	0.02	-0.04
7	21.30	21.13	21.15	21.14	0.17	-0.15	0.01	-0.01
8	24.50	24.34	24.39	24.31	0.16	-0.11	-0.03	-0.08
9	23.40	23.33	23.37	23.39	0.07	-0.03	0.06	0.02
10	23.40	23.40	23.39	23.38	0.00	-0.01	-0.02	-0.01
11	20.20	19.96	20.00	19.99	0.24	-0.20	0.03	-0.01
12	23.40	23.25	23.15	23.20	0.15	-0.25	-0.05	0.05
13	21.90	21.62	21.72	21.73	0.28	-0.18	0.11	0.01
14	21.60	21.39	21.55	21.55	0.21	-0.05	0.16	0.00
15	22.30	22.06	22.22	22.22	0.24	-0.08	0.16	0.00
16	23.70	23.52	23.46	23.56	0.18	-0.24	0.04	0.10
17	22.80	22.67	22.75	22.73	0.13	-0.05	0.06	-0.02
18	22.60	22.48	22.60	22.59	0.12	0.00	0.11	-0.01
19	23.70	23.49	23.61	23.60	0.21	-0.09	0.11	-0.01
20	23.60	23.52	23.59	23.62	0.08	-0.01	0.10	0.03
21	22.20	22.06	22.05	22.04	0.14	-0.15	-0.02	-0.01
22	22.50	22.36	22.39	22.39	0.14	-0.11	0.03	0.00
23	22.80	22.78	22.93	22.93	0.02	0.13	0.15	0.00
24	22.90	22.80	22.77	22.80	0.10	-0.13	0.00	0.03
25	23.50	23.50	23.53	23.50	0.00	0.03	0.00	-0.03
26	23.20	23.08	23.08	23.04	0.12	-0.12	-0.04	-0.04
27	24.20	24.17	24.05	24.01	0.03	-0.15	-0.16	-0.04
28	23.30	23.20	23.04	23.24	0.10	-0.26	0.04	0.20
29	22.60	22.58	22.60	22.60	0.02	0.00	0.02	0.00
30	22.20	22.18	22.19	22.21	0.02	-0.01	0.03	0.02
31	23.10	23.14	23.20	23.23	-0.04	0.10	0.09	0.03
mean					0.105	-0.079	0.029	0.003

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) No mud was reported to be present in any of the juices involved in the tests carried out at Macknade Mill

FIGURE 25
APPENDIX 3

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

INKERMAN MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C	
1	24.30	24.33	24.34	24.41	-0.03	0.04	0.08	0.07	
2	22.20	22.05	22.18	22.24	0.15	-0.02	0.19	0.06	
3	23.30	23.39	23.31	23.32	-0.09	0.01	-0.07	0.01	
4	24.80	24.77	24.75	24.86	0.03	-0.05	0.09	0.11	
5	23.50	23.54	23.66	23.67	-0.04	0.16	0.13	0.01	
6	24.70	24.95	25.03	25.09	-0.25	0.33	0.14	0.06	
7	23.50	23.62	23.46	23.59	-0.12	-0.04	-0.03	0.13	
8	22.70	22.77	22.95	22.91	-0.07	0.25	0.14	-0.04	
9	23.20	23.33	23.31	23.35	-0.13	0.11	0.02	0.04	
10	24.00	24.05	23.99	24.08	-0.05	-0.01	0.03	0.09	
11	23.10	23.02	23.18	23.11	0.08	0.08	0.09	-0.07	*
12	23.10	23.06	23.18	23.18	0.04	0.08	0.12	0.00	
13	23.10	23.17	23.29	23.33	-0.07	0.19	0.16	0.04	*
14	23.90	23.96	24.06	24.07	-0.06	0.16	0.11	0.01	
15	22.40	22.33	22.22	22.32	0.07	-0.18	-0.01	0.10	
16	22.90	22.91	22.92	23.00	-0.01	0.02	0.09	0.08	
17	21.70	21.68	21.99	21.78	0.02	0.29	0.10	-0.21	
18	21.80	21.77	21.83	21.83	0.03	0.03	0.06	0.00	
19	23.90	23.94	24.18	24.20	-0.04	0.28	0.26	0.02	
20	23.50	23.57	23.16	23.53	-0.07	-0.34	-0.04	0.37	
21	24.10	24.09	24.12	24.16	0.01	0.02	0.07	0.04	
22	23.10	23.20	23.33	23.31	-0.10	0.23	0.11	-0.02	
23	23.60	23.71	23.77	23.84	-0.11	0.17	0.13	0.07	
24	23.10	23.16	23.29	23.27	-0.06	0.19	0.11	-0.02	
25	22.50	22.59	22.44	22.54	-0.09	-0.06	-0.05	0.10	
26	23.20	23.19	23.39	23.39	0.01	0.19	0.20	0.00	
27	23.10	23.18	23.32	23.35	-0.08	0.22	0.17	0.03	
28	23.00	22.83	22.68	22.68	0.17	-0.32	-0.15	0.00	*
29	19.40	19.44	19.57	19.57	-0.04	0.17	0.13	0.00	
30	20.50	20.61	20.72	20.71	-0.11	0.22	0.10	-0.01	
mean					-0.034	-0.08	0.083	0.029	

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) Mud was reported to be present in the juice in those tests denoted by an asterisk

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

PROSERPINE MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C
1	22.90	22.88	22.86	22.91	0.02	-0.04	0.03	0.05
2	21.20	21.27	21.18	21.24	-0.07	-0.02	-0.03	0.06
3	22.60	22.71	22.74	22.75	-0.11	0.14	0.04	0.01
4	24.90	24.94	24.93	24.92	-0.04	0.03	-0.02	-0.01
5	21.60	21.71	21.80	21.75	-0.11	0.20	0.04	-0.05
6	23.50	23.75	23.73	23.72	-0.25	0.23	-0.03	-0.01
7	22.90	22.91	23.16	23.05	-0.01	0.26	0.14	-0.11
8	22.80	22.87	22.92	22.91	-0.07	0.12	0.04	-0.01
9	22.60	22.51	22.58	22.59	0.09	-0.02	0.08	0.01
10	22.90	22.88	22.97	22.94	0.02	0.07	0.06	-0.03
11	23.30	23.26	23.25	23.21	0.04	-0.05	-0.05	-0.04
12	22.80	22.73	22.77	22.81	0.07	-0.03	0.08	0.04
13	23.40	23.34	23.35	23.31	0.06	-0.05	-0.03	-0.04
14	23.40	23.40	23.30	23.35	0.00	-0.10	-0.05	0.05
15	22.90	22.87	22.77	22.77	0.03	-0.13	-0.10	0.00
16	23.50	23.37	23.36	23.37	0.13	-0.14	0.00	0.01
17	23.90	23.85	23.77	23.73	0.05	-0.13	-0.12	-0.04
18	22.70	22.73	22.79	22.80	-0.03	0.09	0.07	0.01
19	23.80	23.78	23.67	23.79	0.02	-0.13	0.01	0.12
20	22.30	22.21	22.27	22.25	0.09	-0.03	0.04	-0.02
21	23.10	23.01	22.97	23.00	0.09	-0.13	-0.01	0.03
22	22.20	22.14	22.25	22.29	0.06	0.05	0.15	0.04
23	23.30	23.25	23.17	23.26	0.05	-0.13	0.01	0.09
24	22.40	22.38	22.45	22.40	0.02	0.05	0.02	-0.05
25	21.00	20.88	21.14	21.11	0.12	0.14	0.23	-0.03
26	23.70	23.73	24.05	24.13	-0.03	0.35	0.40	0.08
27	24.50	24.50	24.52	24.50	0.00	0.02	0.00	-0.02
28	23.80	23.83	23.84	23.89	-0.03	0.04	0.06	0.05
29	23.10	23.05	23.07	23.06	0.05	-0.03	0.01	-0.01
30	22.00	22.00	22.13	22.11	0.00	0.13	0.11	-0.02
31	23.00	22.96	22.88	22.86	0.04	-0.12	-0.10	-0.02
32	22.70	22.72	22.78	22.79	-0.02	0.08	0.07	0.01
33	23.40	23.31	23.14	23.22	0.09	-0.26	-0.09	0.08
34	23.40	23.26	23.35	23.22	0.14	-0.05	-0.04	-0.13
35	23.30	23.24	23.26	23.28	0.06	-0.04	0.04	0.02
36	23.40	23.39	23.29	23.35	0.01	-0.11	-0.04	0.06
37	23.50	23.43	23.42	23.45	0.07	-0.08	0.02	0.03
38	22.80	22.78	22.79	22.78	0.02	-0.01	0.00	-0.01
mean					0.018	0.004	0.03	0.008

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) No mud was reported in any of the juices involved in the tests carried out at Proserpine Mill

FIGURE 27
APPENDIX 3

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

MARIAN MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C
1	24.10	24.20	24.22	24.21	-0.10	0.12	0.01	-0.01
2	23.20	23.31	23.28	23.30	-0.11	0.08	-0.01	0.02
3	23.00	22.98	23.09	23.13	0.02	0.09	0.15	0.04
4	24.50	24.54	24.71	24.68	-0.04	0.21	0.14	-0.03
5	24.40	24.39	24.37	24.32	0.01	-0.03	-0.07	-0.05
6	23.40	23.36	23.47	23.46	0.04	0.07	0.10	-0.01
7	24.90	24.97	25.07	25.06	-0.07	0.17	0.09	-0.01
8	23.10	23.14	23.12	23.13	-0.04	0.02	-0.01	0.01
9	23.80	23.86	23.92	23.88	-0.06	0.12	0.02	-0.04
10	22.70	22.78	22.89	22.85	-0.08	0.19	0.07	-0.04
11	22.40	22.42	22.61	22.61	-0.02	0.21	0.19	0.00
12	22.90	22.92	22.89	22.90	-0.02	-0.01	-0.02	0.01
13	23.70	23.84	23.72	23.74	-0.14	0.02	-0.10	0.02
14	24.10	24.06	24.17	24.15	0.04	0.07	0.09	-0.02
15	23.20	23.22	23.27	23.29	-0.02	0.07	0.07	0.02
16	22.40	22.40	22.37	22.41	0.00	-0.03	0.01	0.04
17	24.20	24.29	24.24	24.26	-0.09	0.04	-0.03	0.02
18	22.80	22.82	22.72	22.73	-0.02	-0.08	-0.09	0.01
19	23.60	23.54	23.56	23.54	0.06	-0.04	0.00	-0.02
20	23.60	23.63	23.68	23.68	-0.03	0.08	0.05	0.00
21	21.70	21.75	21.83	21.80	-0.05	0.13	0.05	-0.03
22	24.00	23.93	23.97	23.94	0.07	-0.03	0.01	-0.03
23	24.80	24.84	24.89	24.91	-0.04	0.09	0.07	0.02
24	25.30	25.36	25.54	25.47	-0.06	0.24	0.11	-0.07
25	23.20	23.19	23.13	23.17	0.01	-0.07	-0.02	0.04
26	24.80	24.81	24.82	24.84	-0.01	0.02	0.03	0.02
27	23.20	23.20	23.28	23.26	0.00	0.08	0.06	-0.02
28	23.50	23.47	23.48	23.47	0.03	-0.02	0.00	-0.01
29	23.80	23.86	23.88	23.84	-0.06	0.08	-0.02	-0.04
30	23.90	23.88	23.84	23.85	0.02	-0.06	-0.03	0.01
31	23.70	23.73	24.24	23.93	-0.03	0.54	0.20	-0.31 *
32	24.10	24.14	24.20	24.17	-0.04	0.10	0.03	-0.03
33	23.70	23.73	23.75	23.73	-0.03	0.05	0.00	-0.02
34	23.00	23.02	23.07	23.02	-0.02	0.07	0.00	-0.05
35	23.90	23.96	24.02	24.02	-0.06	0.12	0.06	0.00
mean					-0.027	0.052	0.03	-0.007

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) Mud was reported to be present in the juice in test 31 denoted by an asterisk and omitted from the averages

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

BINGERA MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C
1	21.90	21.92	21.94	21.91	-0.02	0.04	-0.01	-0.03
2	22.40	22.44	22.50	22.52	-0.04	0.10	0.08	0.02
3	22.90	22.80	23.01	22.95	0.10	0.11	0.15	-0.06
4	22.50	22.51	22.54	22.53	-0.01	0.04	0.02	-0.01
5	22.40	22.37	22.38	22.37	0.03	-0.02	0.00	-0.01
6	25.40	25.52	25.35	25.41	-0.12	-0.05	-0.11	0.06
7	25.40	25.49	25.39	25.38	-0.09	-0.01	-0.11	-0.01
8	25.80	-	25.65	-	-	-0.15	-	-
9	24.40	24.21	24.39	24.37	0.19	-0.01	0.16	-0.02
10	23.60	23.71	23.72	23.73	-0.11	0.12	0.02	0.01
11	23.40	23.49	23.58	23.51	-0.09	0.18	0.02	-0.07
12	22.10	22.21	22.38	22.37	-0.11	0.28	0.16	-0.01
13	22.80	22.83	22.70	22.70	-0.03	-0.10	-0.13	0.00
14	22.60	22.65	22.62	22.62	-0.05	0.02	-0.03	0.00
15	22.70	22.80	22.69	22.76	-0.10	-0.01	-0.04	0.07
16	24.70	24.80	24.66	24.77	-0.10	-0.04	-0.03	0.11
17	24.30	24.34	24.26	24.33	-0.04	-0.04	-0.01	0.07
18	24.70	24.73	24.67	24.73	-0.03	-0.03	0.00	0.06
19	23.50	23.52	23.48	23.50	-0.02	-0.02	-0.02	0.02
20	23.30	23.34	23.37	23.35	-0.04	0.07	0.01	-0.02
21	23.00	23.04	23.09	23.13	-0.04	0.09	0.09	0.04
22	23.60	23.69	23.71	23.74	-0.09	0.11	0.05	0.03
23	24.20	24.24	24.37	24.36	-0.04	0.17	0.12	-0.01
24	24.30	24.35	24.35	24.37	-0.05	0.05	0.02	0.02
25	24.10	24.26	24.15	24.69	-0.16	0.05	0.43	0.54 *
26	25.20	25.24	25.15	25.16	-0.04	-0.05	-0.08	0.01
27	23.80	23.82	23.90	23.89	-0.02	0.10	0.07	-0.01
28	24.30	24.33	24.45	24.33	-0.03	0.15	0.00	-0.12
29	25.00	25.08	24.98	25.14	-0.08	-0.02	0.06	0.16
30	22.80	22.90	22.97	22.97	-0.10	0.17	0.07	0.00
31	23.80	23.93	23.98	24.01	-0.13	0.18	0.08	0.03
32	20.90	20.82	20.99	20.93	0.08	0.09	0.11	-0.06
33	23.50	23.64	23.55	23.60	-0.14	0.05	-0.04	0.05
34	22.50	22.62	22.63	22.65	-0.12	0.13	0.03	0.02
35	23.50	23.54	23.58	23.63	-0.04	0.08	0.09	0.05
36	23.70	23.84	23.90	23.93	-0.14	0.20	0.09	0.03
mean					-0.046	0.063	0.026	0.012

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) Mud was reported to be present in the juice in test 25 denoted by an asterisk and omitted from the averages

(iii) The brix of the juice in test 8 exceeded the range of the brix spindle

FIGURE 29
APPENDIX 3

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

MORETON MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C
1	22.00	22.01	22.04	22.03	-0.01	0.04	0.02	-0.01
2	22.10	22.11	22.07	22.04	-0.01	-0.03	-0.07	-0.03
3	20.80	20.81	20.80	20.78	-0.01	0.00	-0.03	-0.02
4	22.90	22.77	22.81	22.80	0.13	-0.09	0.03	-0.01
5	20.60	20.52	20.58	20.53	0.08	-0.02	0.01	-0.05
6	22.10	21.96	21.95	21.99	0.14	-0.15	0.03	0.04
7	21.80	21.77	21.95	21.90	0.03	0.15	0.13	-0.05
8	23.40	23.25	23.26	23.24	0.15	-0.14	-0.01	-0.02
9	23.70	23.61	23.56	23.55	0.09	-0.14	-0.06	-0.01
10	23.90	23.90	23.85	23.91	0.00	-0.05	0.01	0.06
11	21.10	21.01	21.13	21.08	0.09	0.03	0.07	-0.05
12	22.80	22.65	22.66	22.64	0.15	-0.14	-0.01	-0.02
13	22.10	21.97	22.06	22.06	0.13	-0.04	0.09	0.00
14	23.70	23.70	23.80	23.75	0.00	0.10	0.05	-0.05
15	22.70	22.72	22.76	22.74	-0.02	0.06	0.02	-0.02
16	21.60	21.52	21.63	21.55	0.08	0.03	0.03	-0.08
17	21.30	21.24	21.32	21.34	0.06	0.02	0.10	0.02
18	21.30	21.27	21.32	21.26	0.03	0.02	-0.01	-0.06
19	21.50	21.52	21.52	21.52	-0.02	0.02	0.00	0.00
20	22.30	22.34	22.21	22.28	-0.04	-0.09	-0.06	0.07
21	22.70	22.64	22.61	22.62	0.06	-0.09	-0.02	0.01
22	22.90	22.89	22.85	22.95	0.01	-0.05	0.06	0.10
23	22.60	22.59	22.55	22.66	0.01	-0.05	0.07	0.11
24	23.80	23.77	23.72	23.74	0.03	-0.08	-0.03	0.02
25	21.90	21.81	21.83	21.88	0.09	-0.07	0.07	0.05
26	21.20	21.08	21.11	21.04	0.12	-0.09	-0.04	-0.07
27	21.30	21.23	21.25	21.23	0.07	-0.05	0.00	-0.02
mean					0.05	-0.03	0.017	-0.003

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) No mud was reported in any of the juices involved in the tests carried out at Moreton Mill

APPENDIX 3 (continued)

Results of tests carried out by cane testing staff

BROADWATER MILL

Test	A	B	C	D	A - B	C - A	D - B	D - C	
1	18.90	18.93	18.78	18.90	-0.03	-0.12	-0.03	0.12	
2	20.50	20.25	21.39	20.67	0.25	0.89	0.42	-0.72	*
3	19.30	19.12	19.26	19.31	0.18	-0.04	0.19	0.05	
4	20.30	20.37	20.33	20.24	-0.07	0.03	-0.13	-0.09	
5	19.40	19.46	19.26	19.27	-0.06	-0.14	-0.19	0.01	
6	19.50	19.55	19.44	19.40	-0.05	-0.06	-0.15	-0.04	
7	22.30	22.13	22.29	22.25	0.17	-0.01	0.12	-0.04	
8	22.00	21.98	22.75	22.99	0.02	0.75	1.01	0.24	*
9	22.40	22.18	22.90	22.75	0.22	0.50	0.57	-0.15	*
10	22.40	22.38	22.38	22.38	0.02	-0.02	0.00	0.00	
11	21.70	21.78	21.73	21.79	-0.08	0.03	0.01	0.06	
12	20.90	21.00	20.93	20.98	-0.10	0.03	-0.02	0.05	
13	21.90	22.00	21.88	21.90	-0.10	-0.02	-0.10	0.02	
14	22.40	22.36	22.38	22.38	0.04	-0.02	0.02	0.00	
15	22.40	22.45	22.38	22.41	-0.05	-0.02	-0.04	0.03	
16	16.50	16.54	16.59	16.55	-0.04	0.09	0.01	-0.04	
17	21.70	21.74	21.78	21.72	-0.04	0.08	-0.02	-0.06	
18	19.50	19.40	19.31	19.28	0.10	-0.19	-0.12	-0.03	
19	20.80	21.05	21.14	21.03	-0.25	0.34	-0.02	-0.11	
20	20.70	20.74	20.76	20.72	-0.04	0.06	-0.02	-0.04	
21	21.60	21.69	21.67	21.69	-0.09	0.07	0.00	0.02	
22	20.80	20.89	21.20	20.89	-0.09	0.40	0.00	-0.31	*
23	21.80	21.82	21.84	21.87	-0.02	0.04	0.05	0.03	
24	22.00	22.05	22.06	22.00	-0.05	0.06	-0.05	-0.06	
25	20.90	20.93	20.94	20.95	-0.03	0.04	0.02	0.01	
26	21.20	21.28	21.21	21.20	-0.08	0.01	-0.08	-0.01	
27	21.30	21.31	21.31	21.45	-0.01	0.01	0.14	0.14	
28	20.40	20.37	20.38	20.42	0.03	-0.02	0.05	0.04	
29	20.40	20.51	20.48	20.48	-0.11	0.08	-0.03	0.00	*
30	20.80	21.01	20.81	20.88	-0.21	0.01	-0.13	0.07	
31	18.80	18.88	18.87	18.89	-0.08	0.07	0.01	0.02	
32	21.80	21.92	21.88	21.90	-0.12	0.08	-0.02	0.02	
33	20.90	20.92	20.97	20.98	-0.02	0.07	0.06	0.01	
34	20.90	20.97	20.87	20.93	-0.07	-0.03	-0.04	0.06	
mean					-0.04	0.015	-0.017	0.008	

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

(ii) Mud was reported to be present in the juice in those tests denoted by an asterisk and were omitted from the averages

FIGURE 31
APPENDIX 3

APPENDIX 3 (continued)

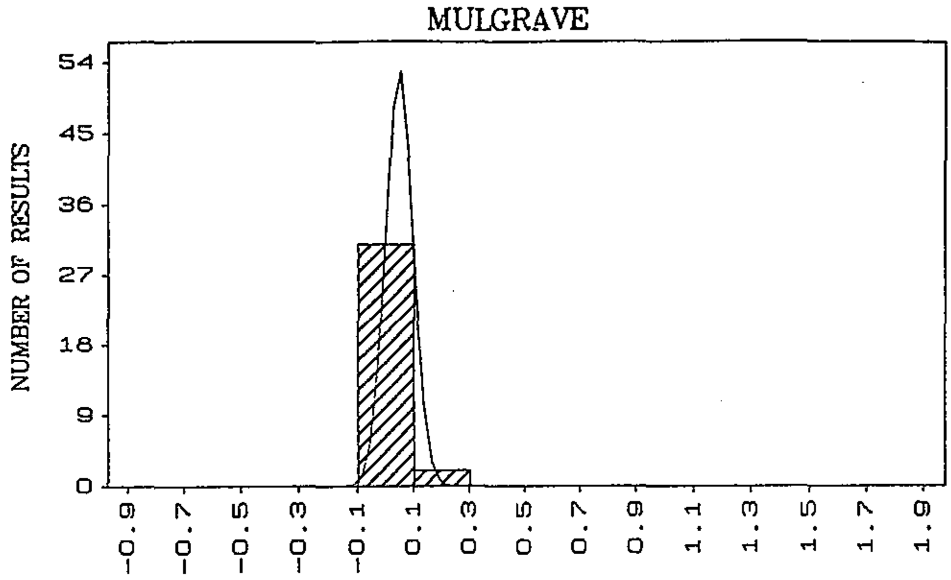
Results of tests carried out by cane testing staff

HARWOOD MILL

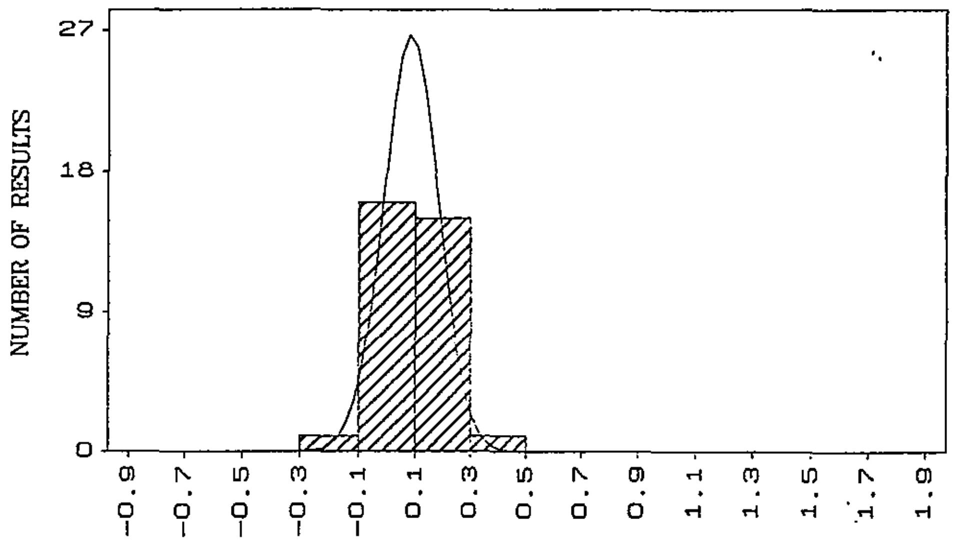
Test	A	B	C	D	A - B	C - A	D - B	D - C
1	20.40	20.51	20.12	20.21	-0.11	-0.28	-0.30	0.09
2	22.00	22.07	21.74	21.77	-0.07	-0.26	-0.30	0.03
3	21.50	21.41	21.35	21.49	0.09	-0.15	0.08	0.14
4	21.20	21.15	21.08	21.22	0.05	-0.12	0.07	0.14
5	21.40	21.36	21.11	21.43	0.04	-0.29	0.07	0.32
6	21.00	20.96	21.03	21.00	0.04	0.03	0.04	-0.03
7	20.50	20.44	20.42	20.40	0.06	-0.08	-0.04	-0.02
8	21.40	21.33	21.23	21.38	0.07	-0.17	0.05	0.15
9	20.90	20.94	20.79	20.73	-0.04	-0.11	-0.21	-0.06
10	20.60	20.66	20.38	20.48	-0.06	-0.22	-0.18	0.10
11	21.70	21.73	21.70	21.76	-0.03	0.00	0.03	0.06
12	20.60	20.57	20.48	20.51	0.03	-0.12	-0.06	0.03
13	20.70	20.68	20.61	20.76	0.02	-0.09	0.08	0.15
14	20.80	20.69	20.57	20.62	0.11	-0.23	-0.07	0.05
15	20.70	20.74	20.61	20.63	-0.04	-0.09	-0.11	0.02
16	21.70	21.71	21.60	21.62	-0.01	-0.10	-0.09	0.02
17	20.00	19.99	19.98	19.98	0.01	-0.02	-0.01	0.00
18	19.90	19.95	19.96	19.95	-0.05	0.06	0.00	-0.01
19	20.80	20.82	20.68	20.67	-0.02	-0.12	-0.15	-0.01
20	20.10	20.09	19.96	19.99	0.01	-0.14	-0.10	0.03
21	21.00	21.05	20.86	20.99	-0.05	-0.14	-0.06	0.13
22	20.50	20.46	20.44	20.46	0.04	-0.06	0.00	0.02
23	20.80	20.74	20.70	20.72	0.06	-0.10	-0.02	0.02
24	19.10	19.00	19.17	19.16	0.10	0.07	0.16	-0.01
25	21.40	21.33	21.45	21.43	0.07	0.05	0.10	-0.02
26	20.10	20.14	20.11	20.14	-0.04	0.01	0.00	0.03
27	19.00	19.09	18.74	18.82	-0.09	-0.26	-0.27	0.08
28	19.90	19.90	19.79	19.87	0.00	-0.11	-0.03	0.08
29	22.70	22.66	22.49	22.56	0.04	-0.21	-0.10	0.07
30	21.40	21.43	21.28	21.36	-0.03	-0.12	-0.07	0.08
mean					0.007	-0.112	-0.05	0.056

NOTE (i) A = Spindle brix on cylinder 1 by the normal mill method
B = Spindle brix on cylinder 2 by the more accurate BSES method
C = Brix reading on cylinder 1 by density meter
D = Brix reading on cylinder 2 by density meter

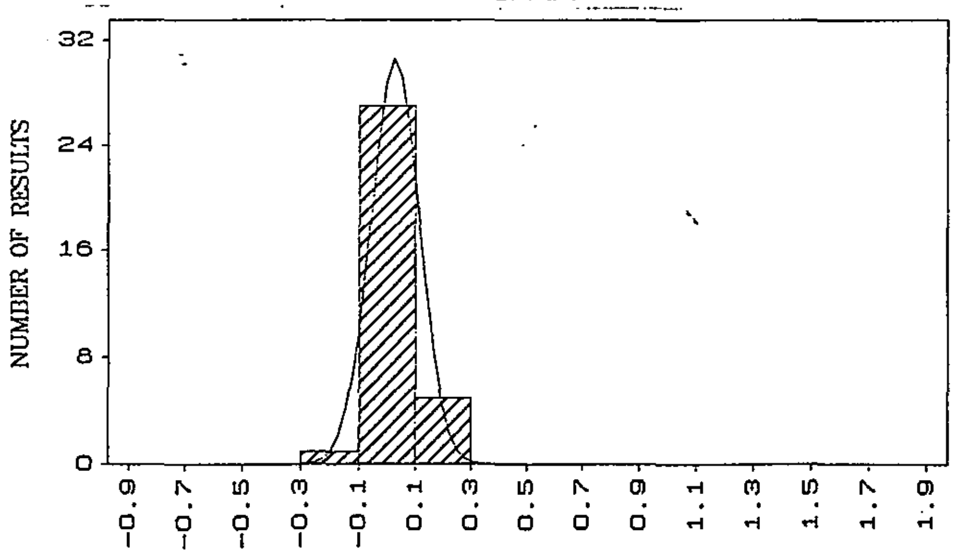
(ii) No mud was reported in any of the juices involved in the tests carried out at Harwood Mill



SPINDLE - SPINDLE
DIFFAB



METER - SPINDLE
DIFFDB



METER - METER
DIFFDC

FIGURE 33
APPENDIX 3

SOUTH JOHNSTONE

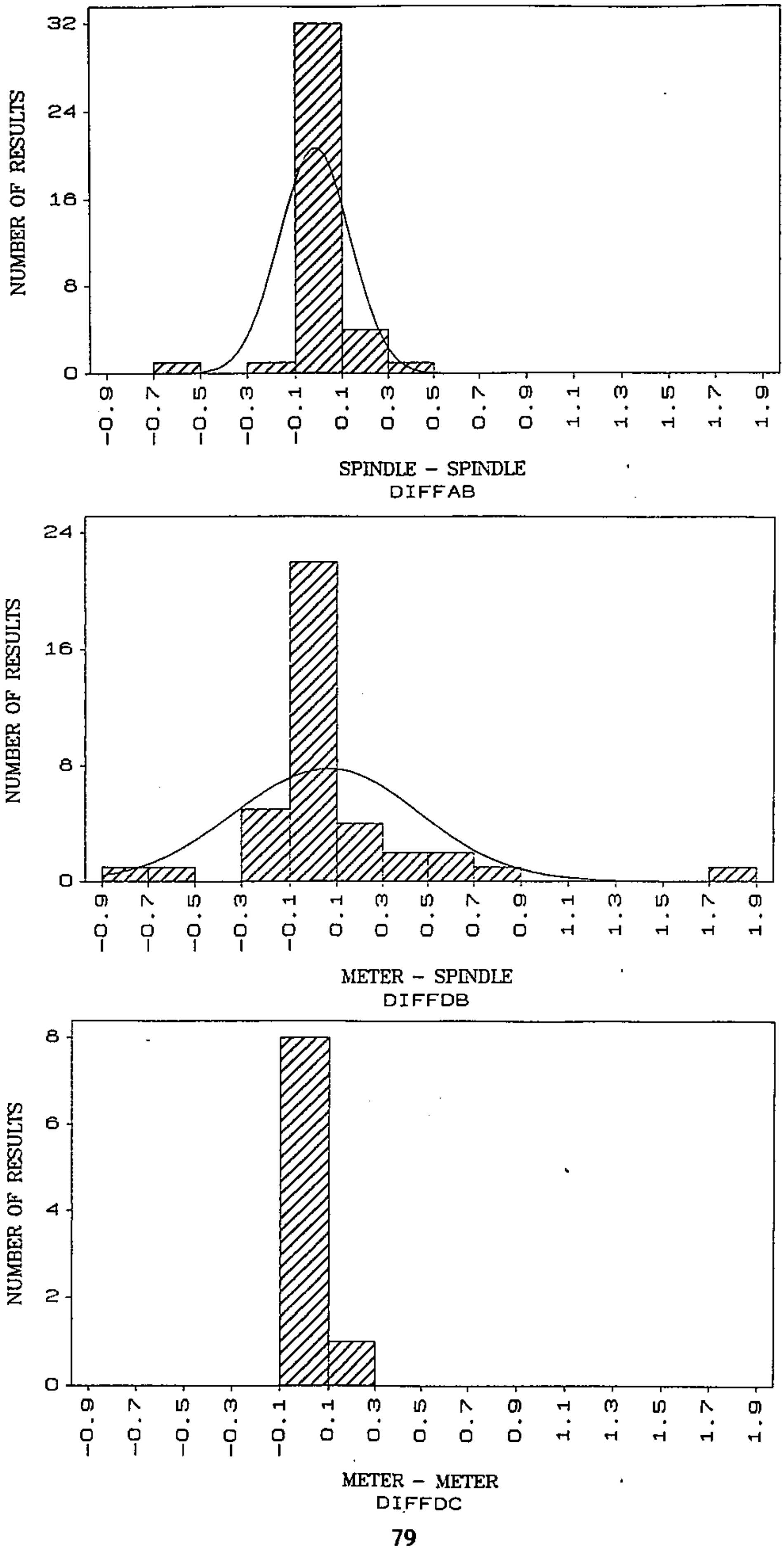


FIGURE 34

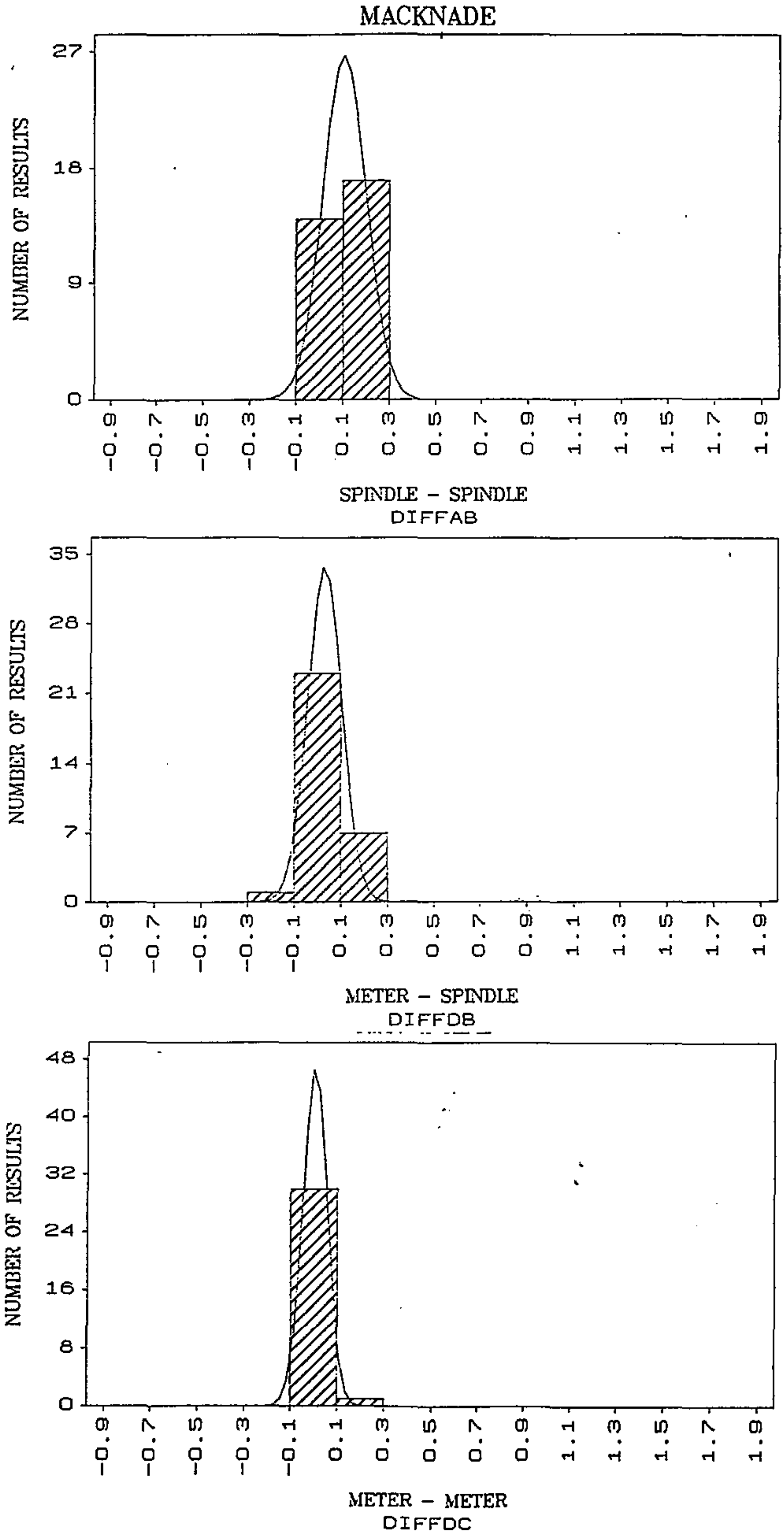
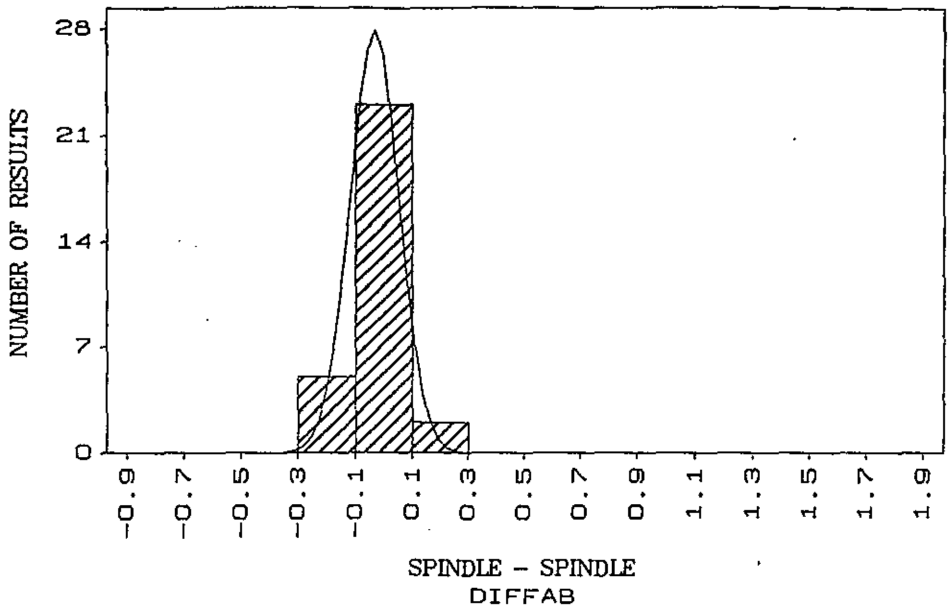
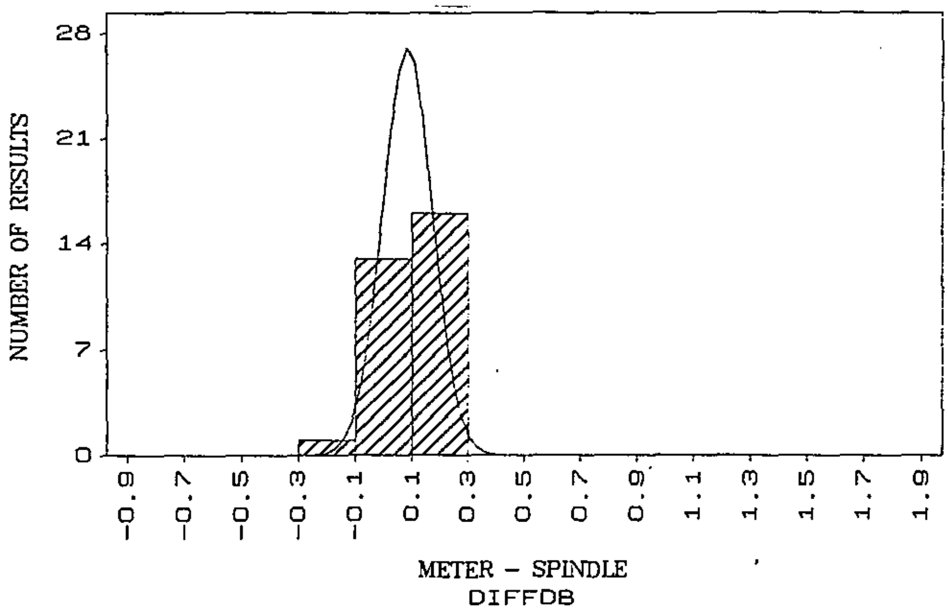


FIGURE 35
APPENDIX 3

INKERMAN





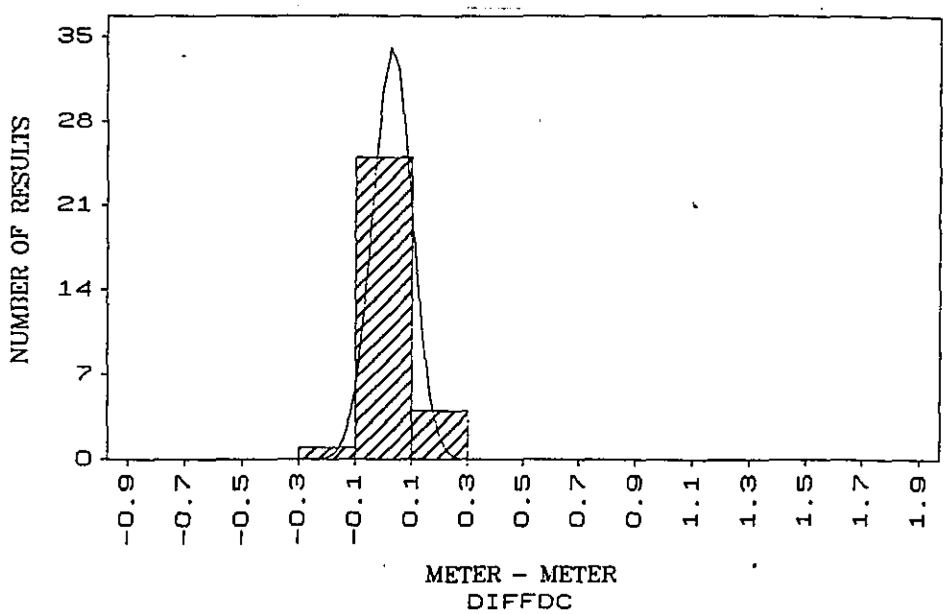
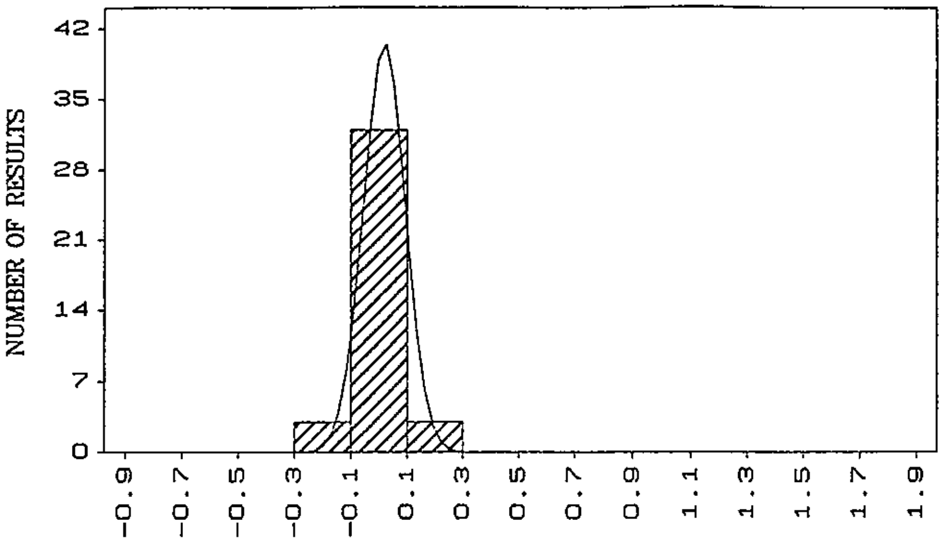
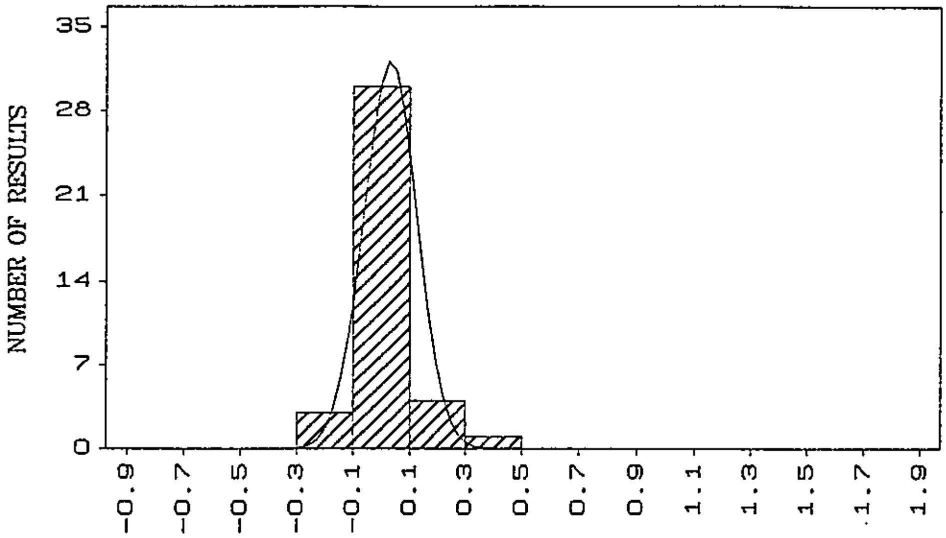


FIGURE 36
APPENDIX 2

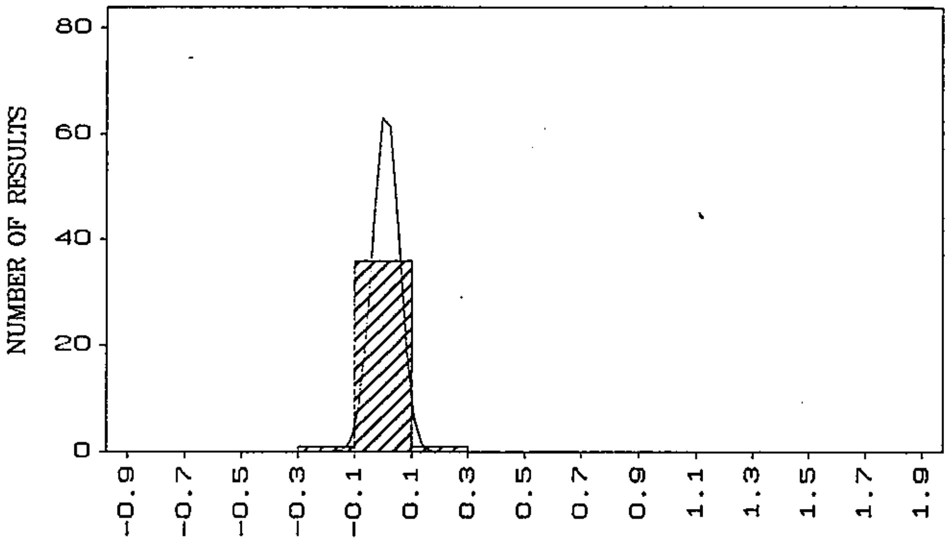
PROSERPINE



SPINDLE – SPINDLE
DIFFAB



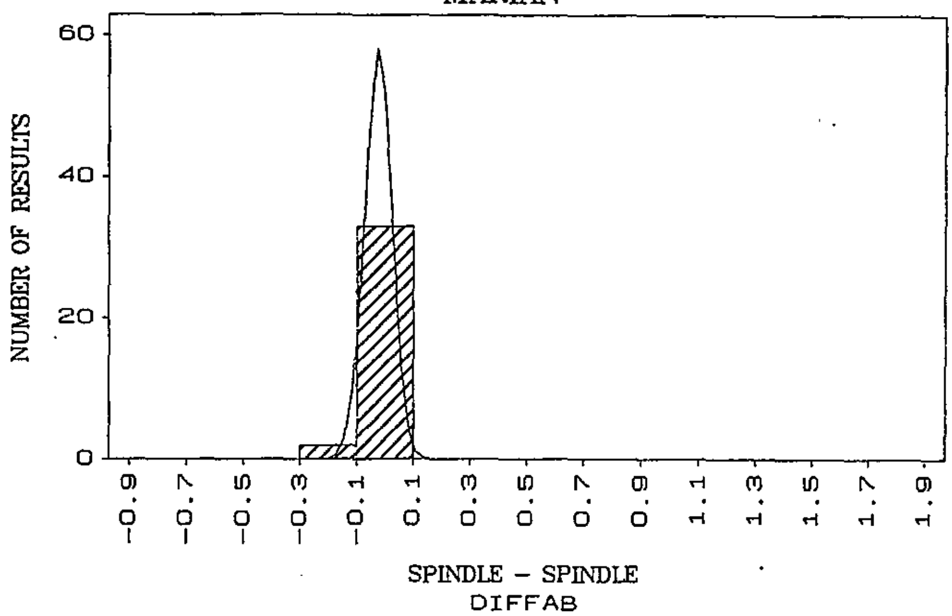
METER – SPINDLE
DIFFDB

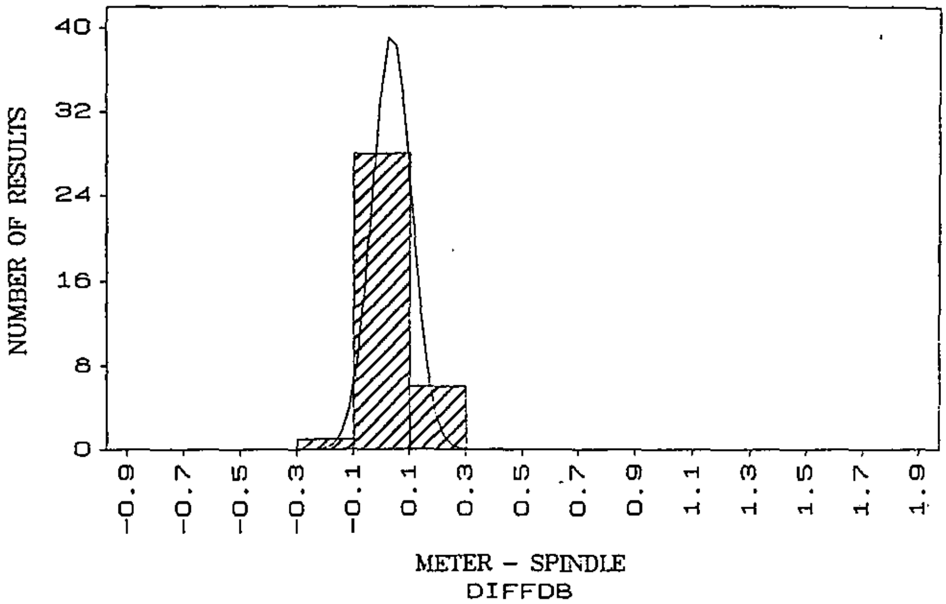


METER – METER
DIFFDC

FIGURE 37
APPENDIX 3

MARIAN





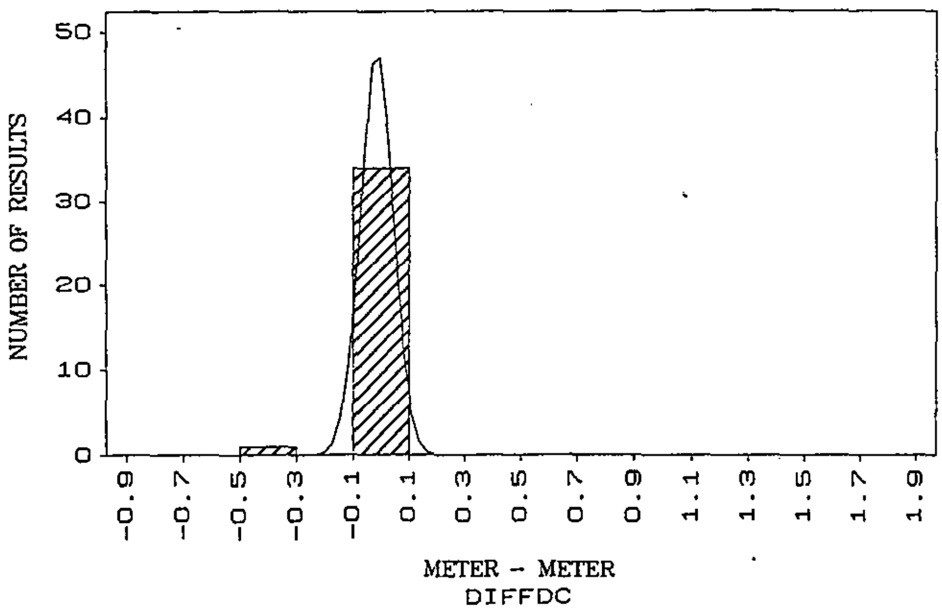


FIGURE 38
APPENDIX 3

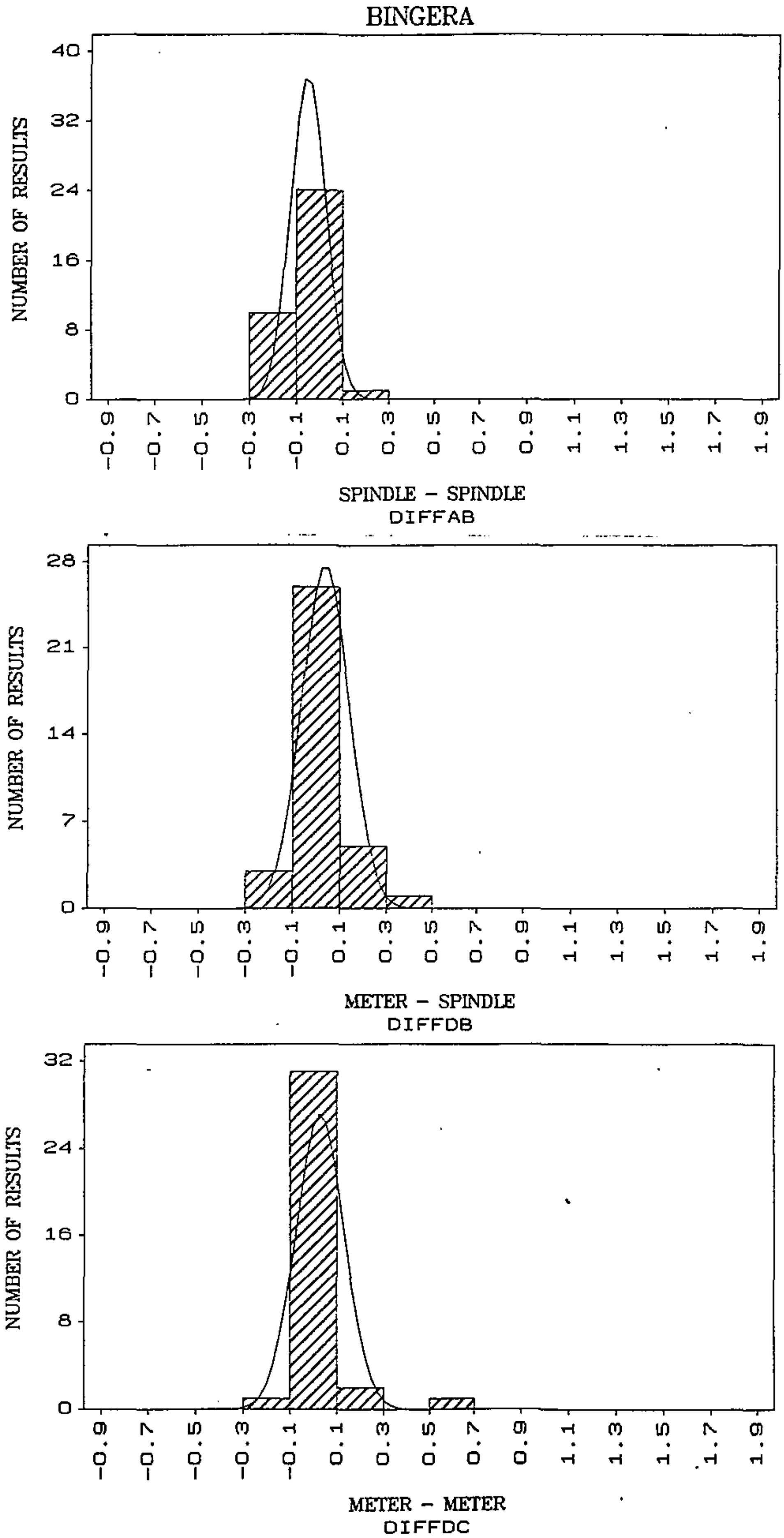


FIGURE 39
APPENDIX 3

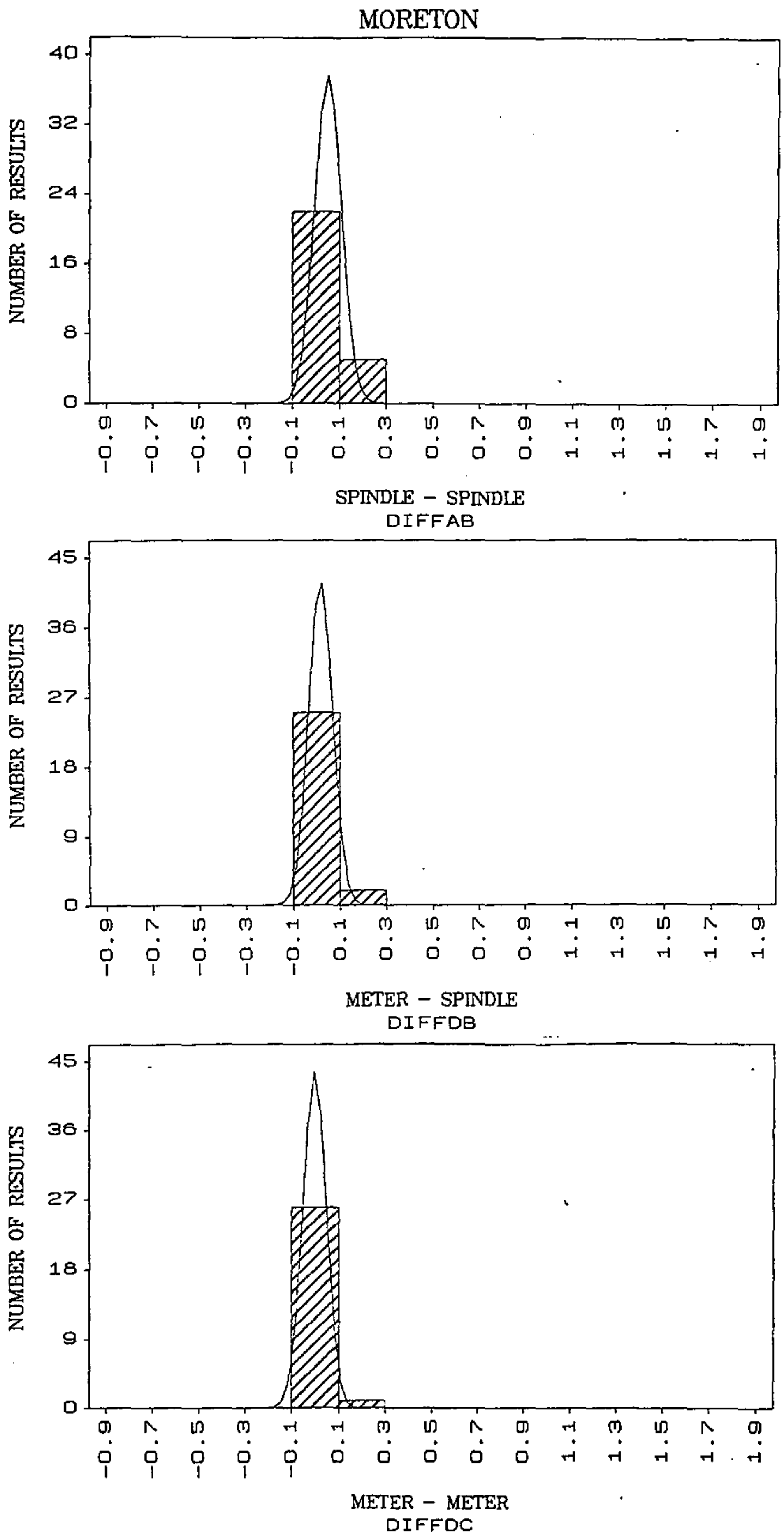


FIGURE 40
APPENDIX 3

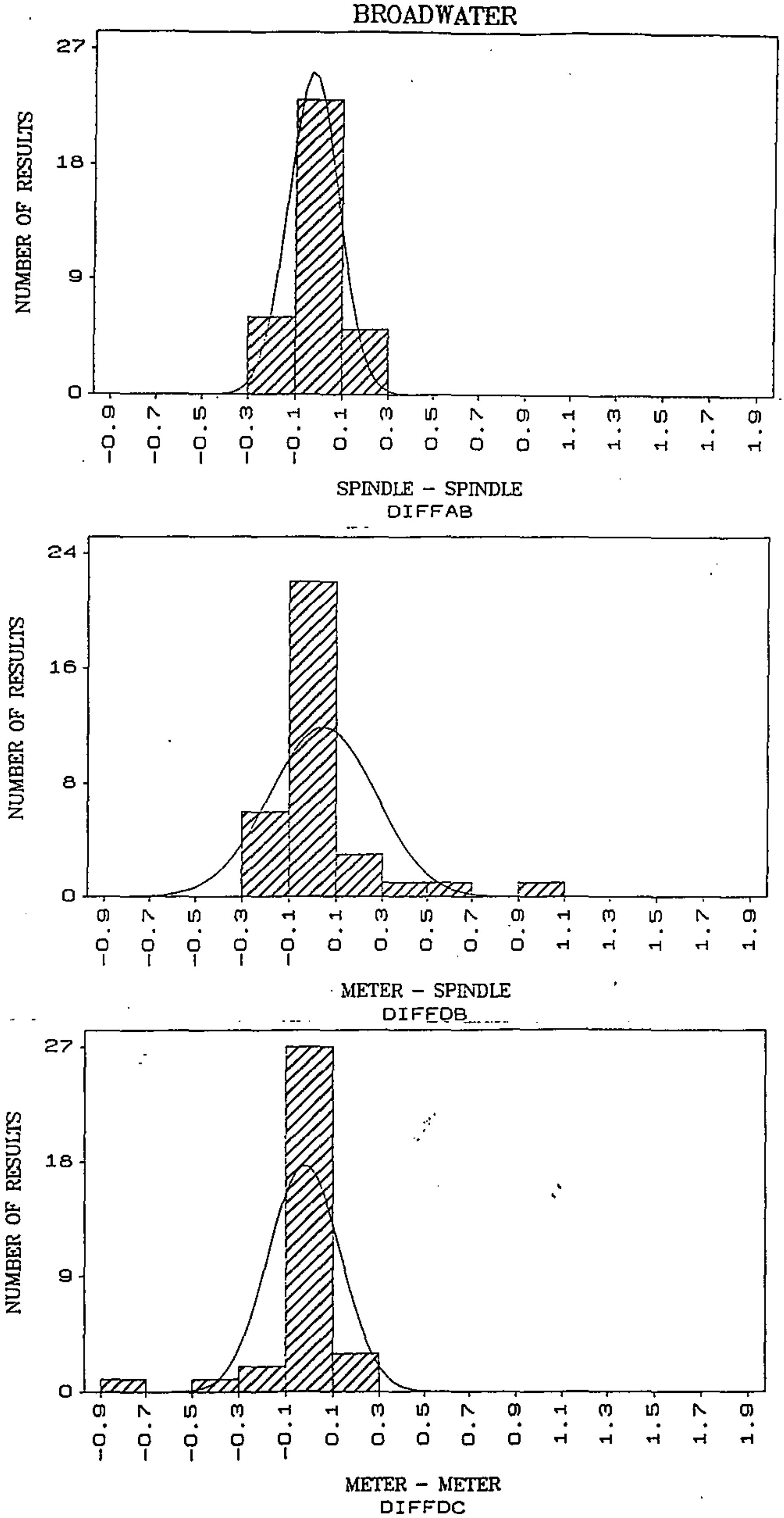


FIGURE 41
APPENDIX 3

HARWOOD

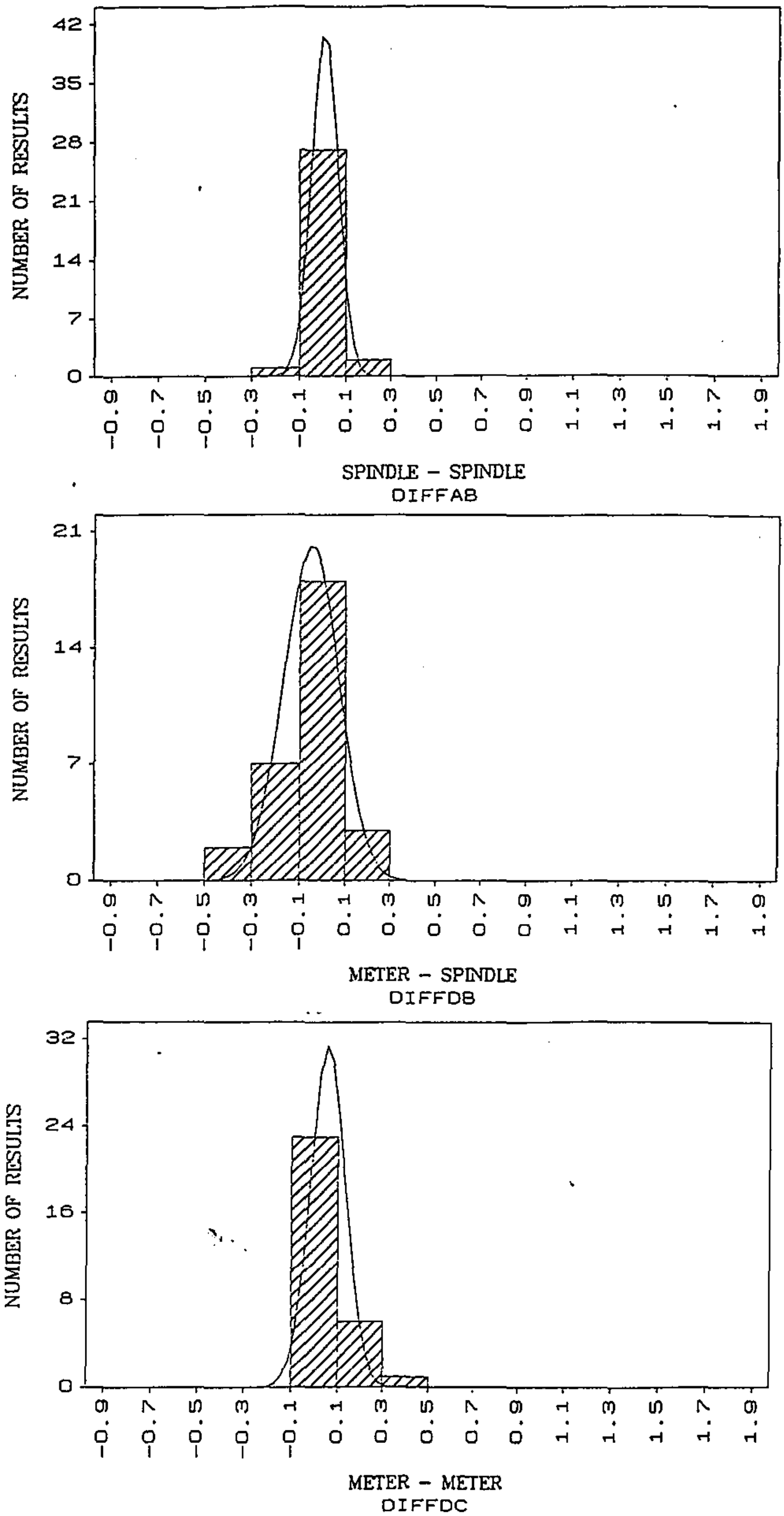


FIGURE 42

APPENDIX 4
MILL BILLY DIMENSIONS 1995 SEASON

The following table gives the mill by mill billy sizes used in the 1995 season. These dimensions could be used in the development of sampling systems for the mass flow meter.

JUICE CAN DIMENSIONS

MILL	Height(mm)	ID(mm)
Mossman	125	125
Mulgrave	125	125
Babinda	195	95
Mourilyan	150	130
Sth. Johnstone	200	100
Tully	150	130
Victoria	180	100
Macknade	205	100
Invicta	155	140
Pioneer	140	125
Kalamia	200	100
Inkerman	135	130
Proserpine	120	125
Farleigh	135	130
Racecourse	130	130
Pleystowe	130	125
Marian	135	125
Plane Creek	200	100
Fairymead	190	130
Millaquin	250	100
Bingera	175	135
Isis	160	150
Maryborough	140	150
Moreton	125	130
Rocky Point	140	125

TABLE 7
APPENDIX 4