OIL RECOVERY FACTORS IN THE FEEDMILL

The aim of this study was to find some generalizations in regards to citrus oil in feedmill press cake. It was hoped that both useful guidelines could be developed and focus areas for further study could be identified. Peel samples were taken at sixteen different Florida citrus feedmills late in May 1996. These samples were quick snapshots, taken randomly at the time our engineers arrived at the processing plant.

No definitive conclusions should be drawn because of the limited nature of the sample taking. While this study points out several interesting conditions, its purpose is to encourage further research.

An observation that gave initial impetus to this paper was made at the Cargill feedmill in Frostproof in January 1995. It happened when separate samples of press liquor were taken from the inlet hopper screen, main screen, and discharge cone screen of their horizontal screw press. It was noted that as the peel progressed through the press, both the pH and Brix of the liquor became progressively lower. This hinted that, as the peel was progressively squeezed, more cells were broken open and, possibly, more oil was being expelled with the press liquor. This is illustrated graphically in Exhibit I which compares mason jars of press liquor taken from the main screen and discharge cone of a press. In the end we concluded that a condition such as this is indicative of incomplete reaction between the peel and the lime.

SAMPLING

It is uncertain which of the samples are representative of typical operation at each of the sixteen feedmills. There was room for error: upset conditions may have been occurring, especially because it was the end of the season and some plants were winding down; at least one plant was running sour peel; two plants were having press problems; molasses tank levels were not necessarily at equilibrium; some plants were running grapefruit along with their Valencias; etc. Rather than arbitrarily exclude data, we have attempted to present the full range of possible operating conditions.

The following are the tests that were conducted (Exhibit II):

A. Oil content of the peel at the peel bin.
B. Particle size distribution of the peel exiting the shredder.
C. Particle size distribution of press cake leaving the screw press.

D. Moisture content of press cake leaving the screw press (final pressing in plants with double pressing).
E. Oil content of press cake leaving the screw press.
F. Oil content of the press liquor.
G. Brix of the press liquor and, where applicable, molasses.

The peel and press liquor samples were kept refrigerated from the time they were gathered until the tests were conducted.

MATERIAL BALANCE

Moisture tests were run with two different moisture balances as well as with a laboratory oven and scale. Several tests were run on each sample to verify the results; we feel that the readings presented herein are fair for analysis purposes. These readings are key because they were used to determine the proportion of press cake and press liquor, as a percentage of inbound peel.

Material Balances were found necessary to determine the proportion figures. These were run for each of the sixteen plants, taking into account single pressing, double pressing or pumped peel. It was during this step that something very interesting in regards to molasses diffusion was observed.

MOLASSES DIFFUSION

Almost half of the plants were running with press liquor Brix of 20° or higher. Despite many hours of computer time it was impossible to fit this high a Brix into a reasonable material balance for most of the plants. It possibly could be achieved by drawing down the molasses tank (using more molasses than was being produced), but this was not logically occurring at so many feedmills. Finally it was recognized that the most reasonable explanation for high press liquor Brix is incomplete diffusion of molasses into the peel.

This theory tied to the oft-repeated question, "Why add molasses in a delay conveyor between first and second pressing if it is just going to be pressed out again?" Our conclusion is that this is definitely what is taking place at many feedmills. Many years ago Dan Vincent did testing at Lykes Pasco that showed that it takes ten to twenty minutes for complete diffusion between peel and molasses. Yet most feedmills have only one to three minutes of delay between first and second pressing, thus explaining our data.

We feel that even a short diffusion period is better than none. Diffusing molasses into peel that is about to be pressed does improve the pressing action and ultimate thermal efficiency of a feedmill. We are anxious to see the results in the 1996-97 season at Southern Gardens: there a reaction conveyor has been relegated into service as a delay conveyor between first and second pressing. The size of the conveyor should allow around eight minutes for diffusion of the molasses. It will be interesting to see the extent to which pressing action is enhanced.

The press cake moisture readings of the samples taken for this presentation almost all read quite a bit higher than was expected for late season Valencias. We feel that this can be related to the fact that the Brix readings of peel coming from extraction were unusually low: our readings were almost all in the range of 7° to 9°, whereas normal readings are 10° to 11° Brix.

Oil analyses were made using the Scott method.

SHREDDER MODELS

Peel samples were taken from four different models of shredders. The two most common were the Rietz RD-18 Disintegrator manufactured by Hosokawa Bepex and the 18" horizontal shredder manufactured by the former Gulf Machinery Company. Both models are 75 hp machines.

The other two brands are relatively new to Florida citrus: the Jacobson and Gumaco (Brazil) hammermills. These are larger machines, ranging from 150 to 300 hp. Exhibit III has photos of these various machines.

All four shredders can be operated with a variety of screen sizes. In fact, some were being operated with no discharge screens, and, being the end of the season, some were being operated with damaged screens and worn hammers.

PARTICLE SIZE DISTRIBUTION

An interesting technique was used to measure the particle size distribution of the shredded peel. The required equipment was loaned to us by CSC Scientific of Fairfax, Virginia. Their laboratory air lift dryer was used to gently dry the peel before vibrating it through a stack of sieves.

Samples from the shredder frequently were quite wet with molasses, and they took 25 minutes to dry. In contrast, samples of press cake dried out in 15 minutes. Appendix I shows and describes the apparatus that was used.

The photos in Exhibit IV show some typical peel samples before and after they were air dried and sieved. In the tests, sieve screen sizes ranging from 9.5 mm down to 0.212 mm were used. The photos illustrate the separations that were achieved.

The bar charts in Exhibit V illustrate the particle size distribution by weight. In general, one of two distributions was found: ether a bell shaped curve or a curve skewered to the larger sized particles. It is interesting to note that the same shredder will produce different particle profiles depending on the type of juice extractor that is used.

The results in the bar charts are in remarkably close agreement with measurements published by Dr. Bob Braddock in 1978 (slide).

SHREDDER PERFORMANCE FACTORS

Our preconception was that the best shredding resulted in (a) a minimum of fines and (b) a minimum of large pieces. The fines are undesirable because they are likely to either burn in the dryer or to be carried into the waste heat evaporator (WHE) where they result in problematic black water. At the same time the large pieces were thought to be undesirable because they seemed apt to contain oil that is not expressed from the peel in the pressing operation. (This proved to be not necessarily true.)

PEEL FINES

The reason that fines are likely to burn in the dryer is explained by the concept of latent heat of evaporation. As long as a particle of peel in the dryer contains moisture, it is cooled by evaporation and will not go much above 212° F. A small particle has much more surface area in proportion to its volume; evaporation is proportional to the surface area, so small particles become bone dry before the larger particles. Once bone dry, the particle increases in temperature until a point is reached where combustion occurs.

Fines leaving the dryer are very low in moisture, and some of these escape past the cyclone dust separators. Such particles either go to the WHE or they are recirculated back to the burner area. Being dry to start with, they are likely to burn upon being re-admitted to the hottest portion of the dryer.

In the study it was found that the percentage by weight of fine particles in the peel (the two smaller sieve sizes) varied significantly. The range was 1/2% to 6% fines in samples of peel coming from the shredder. If these are lost in the dryer, they can have a measurable effect in peel recovery (as measured by pounds of citrus pellets produced per box of fruit).

The percentage of fines could not be tied to any particular style of shredder or hammermill. As one would expect, the peel from FMC extractors did average somewhat more fines than that of Brown extractors, but this was not enough to explain the range of values that was measured. Possibly the disposition of extraction pulp would explain the differences we observed. I wish I could say more, but more study will be required to explain the wide range in the percentage of fines.

The percentage of fines did increase during the reaction and pressing operations. This increase of about 2-1/2 percentage points is shown in Exhibit VI.

The increase in the amount of fines was compared between the vertical and horizontal presses. They averaged virtually the same increase, right at 2-1/2 percentage points. Furthermore, the fines could not be tied to the moisture content (tightness of pressing) of the press cake from these presses.

It is noteworthy that in 1949 Dan Vincent was awarded US Patent 2,490,564 covering a "Vegetable Pulp Shredder Screen Having Cutter Blades". This patent dealt with using thin 1/16" blades to both reduce fines and improve the peel reaction. These machines were used in citrus for many years, and they gave good results compared to units with 1/2" and wider hammers. However, the design ultimately proved impractical due to its vulnerability to tramp metal.

PRESS CAKE OIL

We did not measure oil recovery in this study. Clearly the oil recovery systems used in both the juice extraction operation and in the WHE will govern oil recovery. Instead, we looked at the oil (mostly d-limonene) carried into the drier with the press cake. This oil is almost entirely evaporated in the dryer and released to the atmosphere. It exhausts as an unburned hydrocarbon.

LARGE PIECES OF PEEL

Seeking a correlation between large pieces of peel and the oil going into the dryer with the press cake proved interesting. To begin with there are two key measurements: (1) the pounds of oil going into the dryer per ton of peel entering the feedmill, and (2) the percentage of oil going into the dryer relative to the quantity of oil in the peel entering the feedmill.

Note that the raw measurement of percent oil in the press cake is only part of the equation. A tricky part of the analysis is to recognize that the percentage of oil in the press cake must be adjusted for the pounds of press cake per one hundred pounds of peel. Because of this, a feedmill that presses very tight will have a little less oil going into the dryer. This is true even though the percentage of oil in the press cake may be higher than what is found in more moist press cake.

In general, as expected, the plants running Brown extractors had a higher proportion of large pieces of peel after the shredding operation than did those plants with FMC extractors. We were interested to see if the presence of large pieces of peel led either to increased oil in the press cake or to higher press cake moisture. Therefore a comparison was made separating samples from the extractor manufacturers. Each of these two groups were further split so that comparison could be made between shredders that were producing predominantly large pieces of peel and those that had a lesser proportion of large pieces.

The results were surprising, as shown in Exhibit VII. The pressing operation was definitely able to achieve dryer press cake when there were fewer large pieces of peel. The average was about 2-1/2 percentage points lower moisture content.

On the other hand, the pounds of oil in the press cake per ton of inbound peel went down only slightly. In the spreadsheet it is seen that generally the presses that pressed tighter had only a little less oil in the press cake than the pressing operations characterized by high press cake moisture.

In other words, shredding to reduce the fraction of large pieces of peel will reduce press cake moisture (and therefore improve thermal efficiency). However, the quantity of oil going into the dryer does not change appreciably.

Looking at it from another perspective, contrary to our expectations, we cannot say that press cake oil was significantly higher in samples that had a higher percentage of large pieces. Thus the data supports the postulate that fine shredding allows oil to be absorbed into the albedo, and that this oil does not press out of the peel.

The oil analysis brought attention to another condition. On the average, there was a noticeably higher oil content in peel from plants using Brown extractors as compared to FMC extractors. On an approximate basis, raw Brown peel had 1.0% oil, while FMC had 0.5%. The surprising thing is that about one third of the oil in the Brown peel was measured going into the dryer, as compared to two thirds of the oil in the FMC peel. The end result is that almost equal pounds of oil per one hundred pounds of peel were found in the press cake, regardless of which juice extraction system is employed!

Unfortunately our study of shredding and press cake had to ignore some very important considerations. Brown plants that made more use of the BOE (Brown Oil Extractor) did better than those that did not. Similarly, the FMC oil recovery system employed undoubtedly governed the results of the FMC plants. Other important factors which could have distorted our analysis are (1) the sufficiency of the peel reaction system and (2) the oil stripping characteristics of the WHE.

SUNPURE FEEDMILL

Before concluding this presentation I want to make mention of the new feedmill at SunPure. This processor takes pride in the high level of citrus oil recovery that they achieve. The day that we took the first samples there was an upset that led to a second set of samples being gathered.

Both sets showed a high level of oil recovery. In fact, the inclusion of the SunPure results are enough to distort the averages shown in Exhibit VII.

The minimal amount of oil going to the dryer at SunPure is helped by the fact that they are able to press the peel to the same low level of moisture content as the best feedmills in the State. However, we suspect that the outstanding low levels of press cake oil can be tied to the Cook Machinery Company technology used in the feedmill. This technology involves a combination of (1) improvements on the Brazilian pumped peel flow schematics, (2) using available heat to accelerate the peel reaction, and (3) WHE technology.

Recently a number of modifications have been made at the SunPure feedmill, so we are anxious to measure performance once again in the 1996-1997 season.

SUMMARY

To summarize this presentation, let's look at citrus oil recovery in a broader sense. Clearly the two most important considerations are the oil recovery systems used (1) at extraction and (2) in the WHE. This paper has not examined either of these. Rather, we have focused narrowly on the shredding and pressing operations. It should be obvious that differences in extraction and WHE systems may have distorted our analysis.

At the same time some interesting points can be made:

A decline of press liquor pH between the inlet and outlet of the screw press is indicative of under-reacted peel.

High Brix press liquor is frequently an indication of incomplete diffusion of molasses into the peel.

Plants with Brown juice extraction systems will tend to have a higher proportion of larger pieces in their shredded peel. They should be sure their shredding equipment is doing a good job in order to achieve the best thermal efficiency.

There can be a significant fraction of peel fines going into the dryer, more so at plants using the FMC juice extraction system. Therefore dryer dust separation equipment is of importance.

Shredding the large pieces of peel into smaller pieces does not significantly improve oil recovery in the feedmill. However, it does improve pressing action and, consequently, thermal efficiency.

Let me conclude by warning against blindly accepting the results of this study. Our intent has not been to give the final word, but rather to point the way and to encourage additional and more thorough investigation.

ACKNOWLEDGMENTS

This paper could not have been prepared without the assistance of a great many individuals and their firms. We want to extend our appreciation to the following:

CSC Scientific Company, 8315 Lee Highway, Fairfax, Virginia. Telephone 1-800-458-2558. The loan of their Test Sieves, High Performance Compact Shaker, and Fluid Bed Dryer proved invaluable.

Automatic Machinery and Electronics, Inc., 333 Avenue M, N.W., Winter Haven, Florida. Telephone 941-299-2111. Their laboratory took on the task of running oil content analysis on almost eighty samples of peel and liquor.

Lala Produce Inc., 1402 25th Street, Tampa, Florida, 33605. The generous use of their cold storage facilities was most helpful in controlling close to one thousand pounds of peel samples.

Participating Citrus Processors

Alcoma Packing Company
Cargill Citro America Inc.
Citrus World, Inc.
Coca-Cola Foods, Auburndale
Coca-Cola Foods, Leesburg
Florida Juice Partners, Ltd.
Golden Gem Growers Inc.
Holly Hill Fruit Products
Indian River Foods Inc.
Orange-co of Florida Inc.
Peace River Citrus Products
Silver Springs Citrus Co-op.
Southern Gardens
SunPure, Ltd.
Tropicana Products, Inc., Bradenton
Tropicana Products, Inc., Ft. Pierce

Technical Review

Dr. Robert J. Braddock, University of Florida, Lake Alfred
Messrs. John and Ralph Cook, Cook Machinery Company, Dunedin
Mr. Don Kimball, retired, Coca-Cola Foods, Winter Haven
Dr. Ashley Vincent, Savant-Vincent, Tampa

August 3, 1996

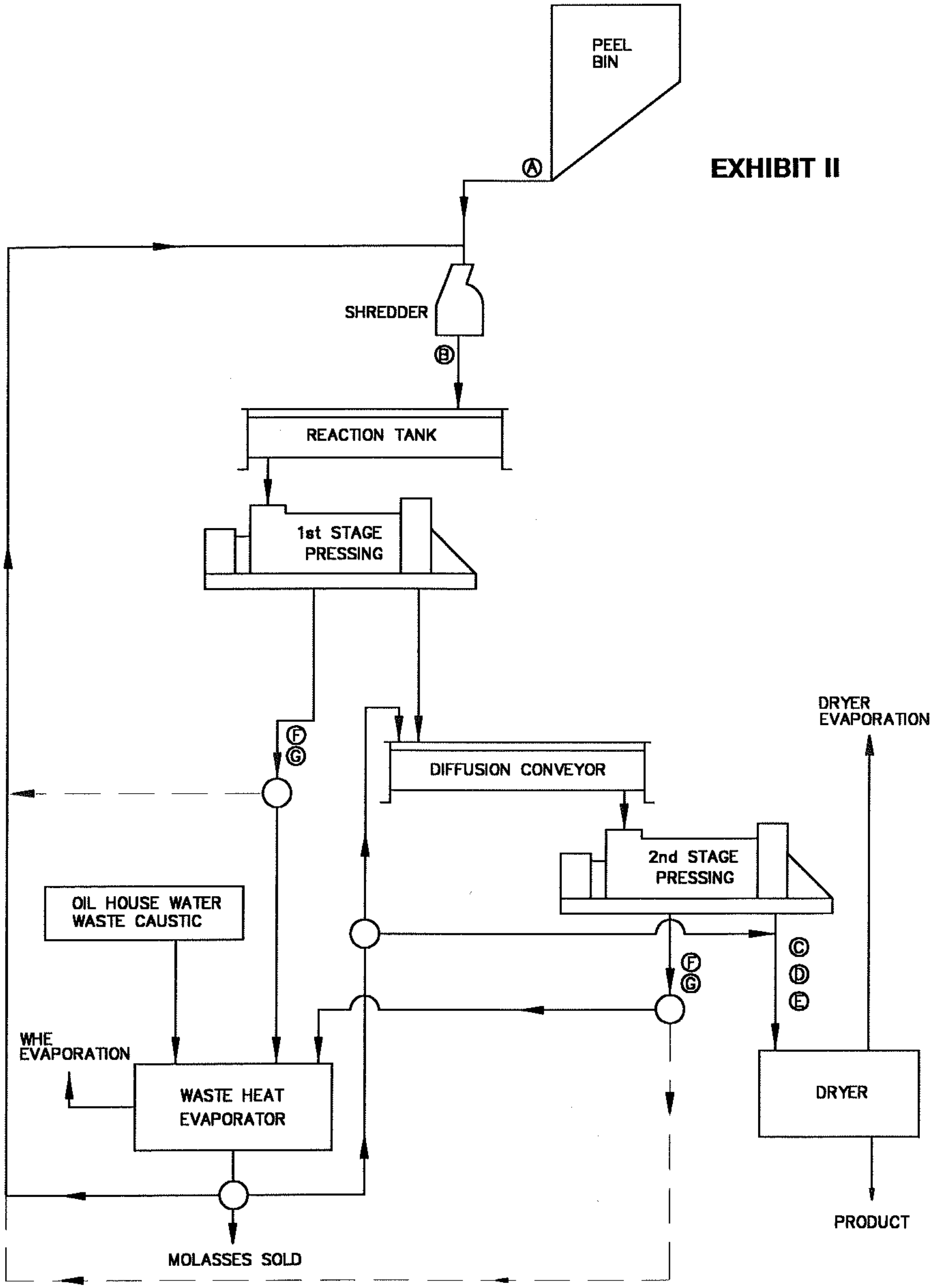
EXHIBIT I

<u>PRESS LIQUOR SAMPLES</u>

RIGHT: **FROM MIDDLE OF PRESS**

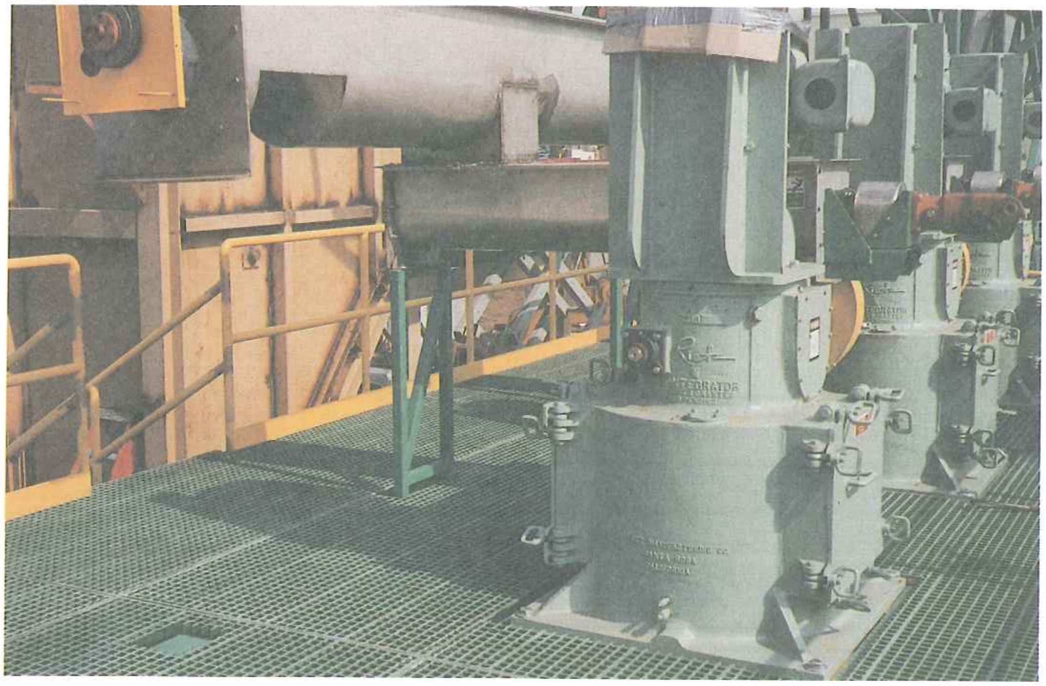
LEFT: **FROM DISCHARGE CONE SCREEN SET AT HIGH PRESSURE**

EXHIBIT II

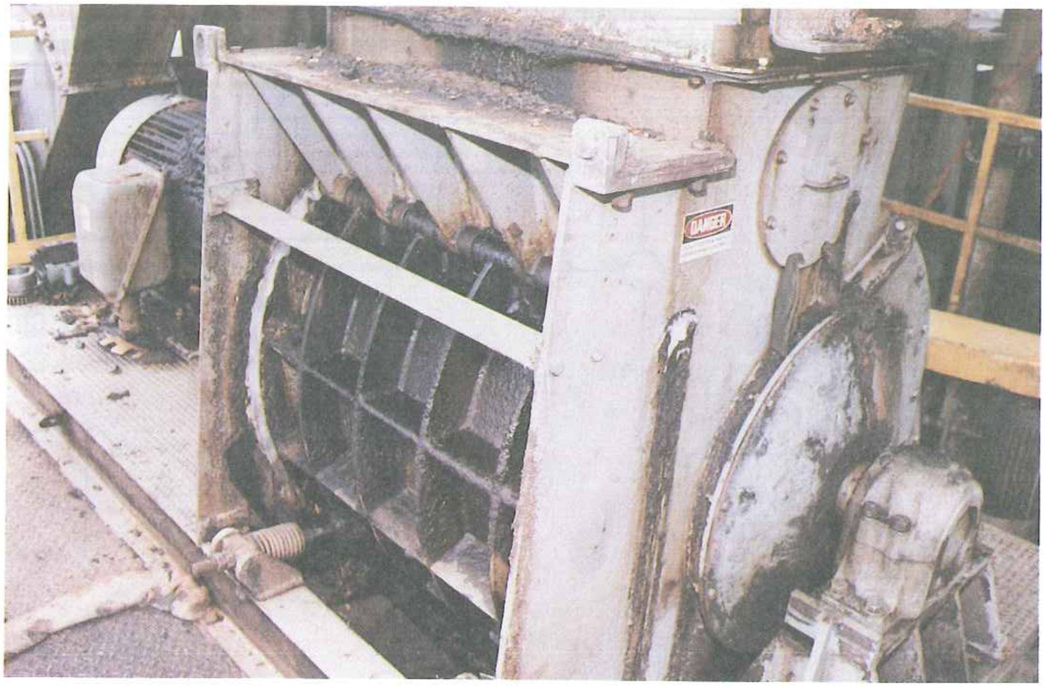


PEEL BIN
A
SHREDDER
B
REACTION TANK
1st STAGE PRESSING
F
G
DIFFUSION CONVEYOR
2nd STAGE PRESSING
OIL HOUSE WATER WASTE CAUSTIC
C
D
E
DRYER EVAPORATION
DRYER
PRODUCT
WHE EVAPORATION
WASTE HEAT EVAPORATOR
MOLASSES SOLD

EXHIBIT III (a)



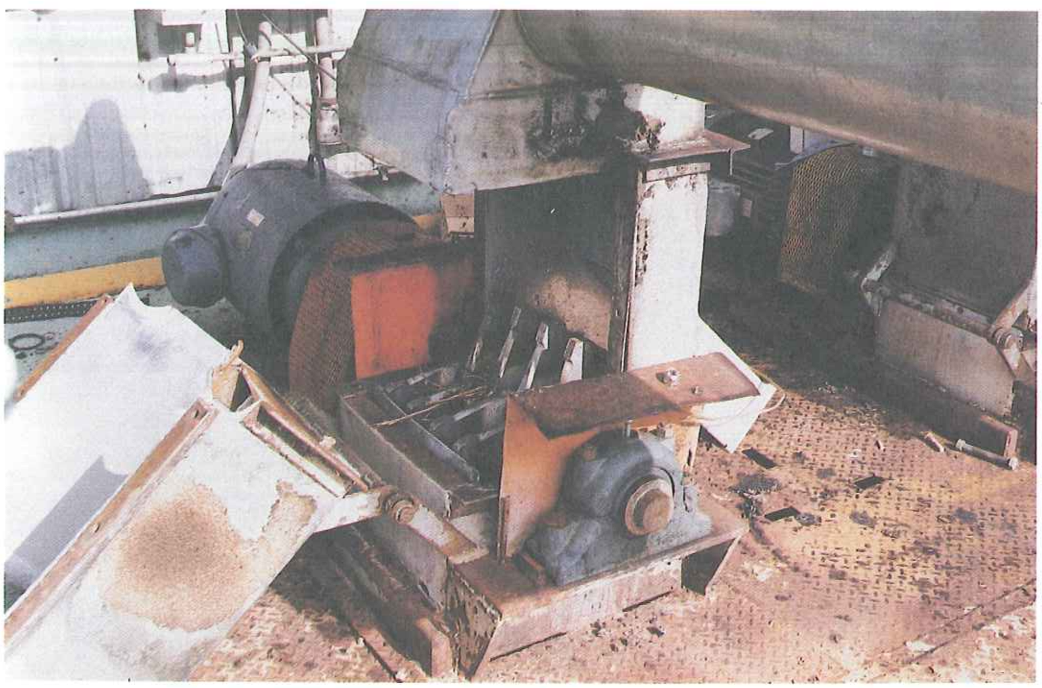
RIETZ RD-18 DISINTEGRATOR



GUMACO HAMMERMILL

EXHIBIT III (b)

JACOBSON HAMMERMILL



GULF 18" SHREDDER

EXHIBIT IV (a)

MILLIMETER SCREEN SIZE

FOUR SETS OF SIEVED PEEL

RELATIVE SIZE ILLUSTRATION

PRESS CAKE, FINE SHRED, FULL SCALE:

PRESS CAKE, COARSE SHRED, FULL SCALE:

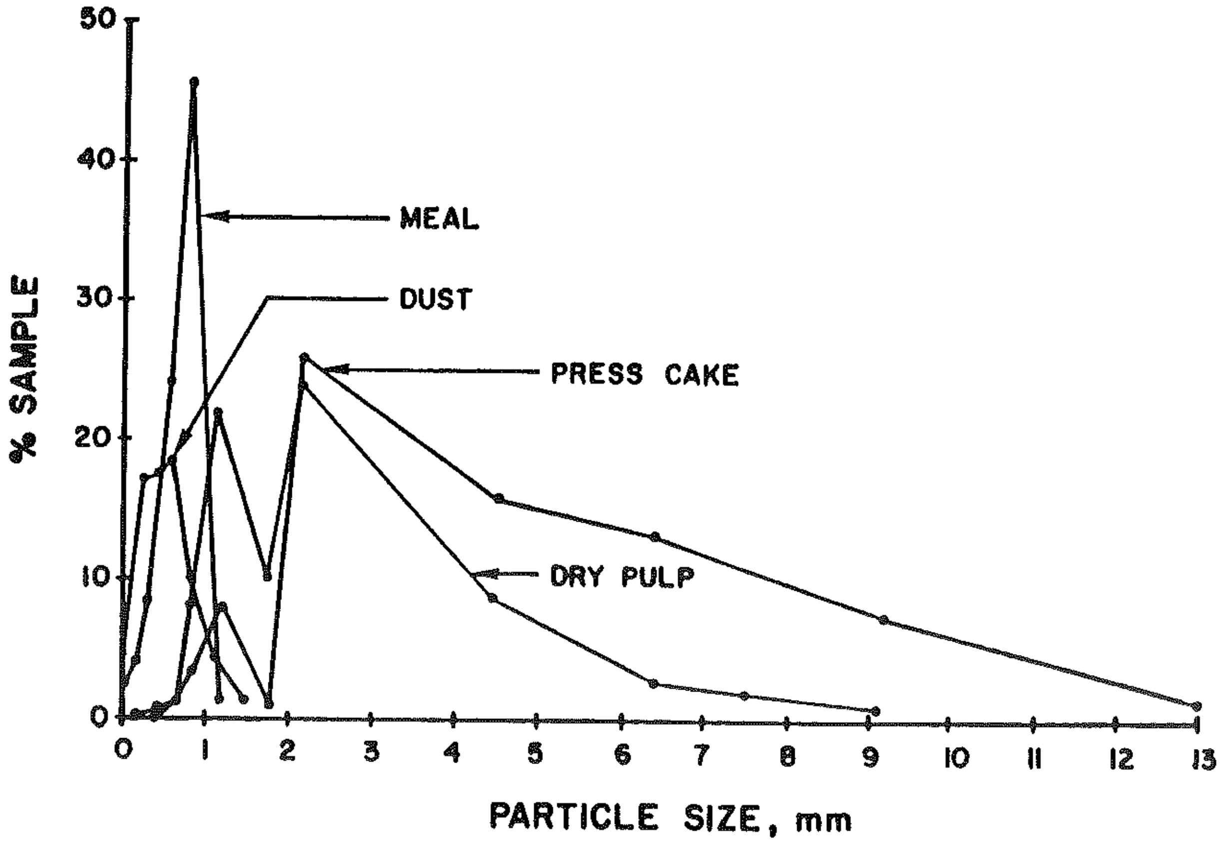
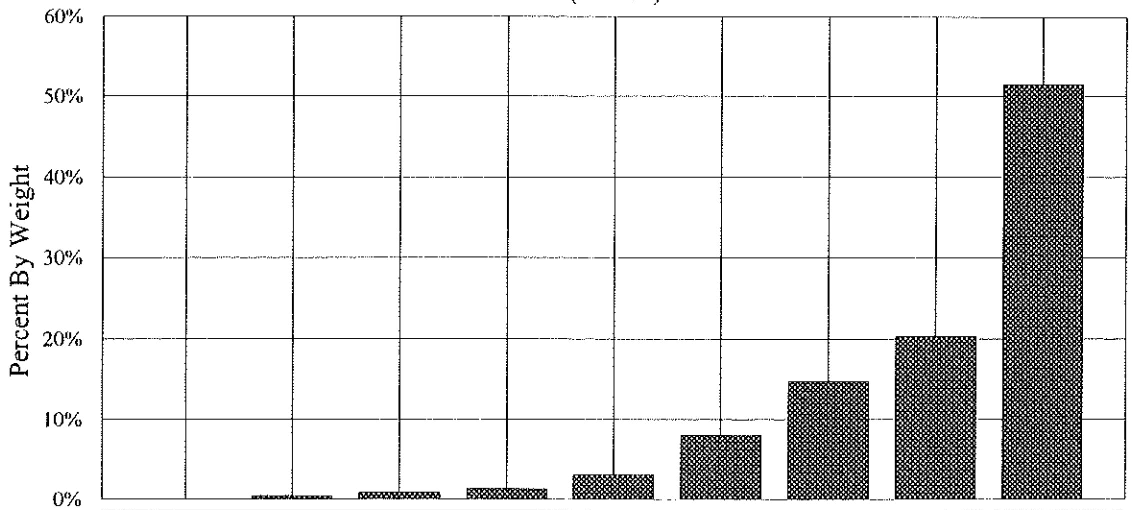


Fig. 1. Particle size distribution of citrus press cake, dried pulp, meal, and dust.

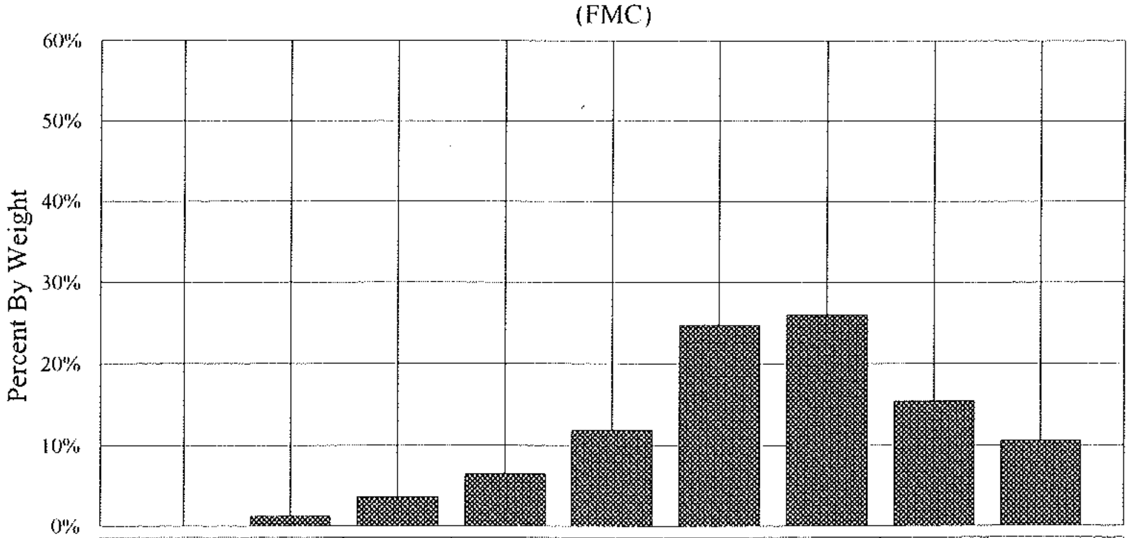
EXHIBIT V (a)

Rietz RD-18
(Brown)



Millimeter	0.212	0.425	0.850	1.400	2.360	4.000	6.300	9.500
Percent	0.4%	0.8%	1.3%	3.0%	8.0%	14.7%	20.3%	51.5%

Rietz RD-18
(FMC)

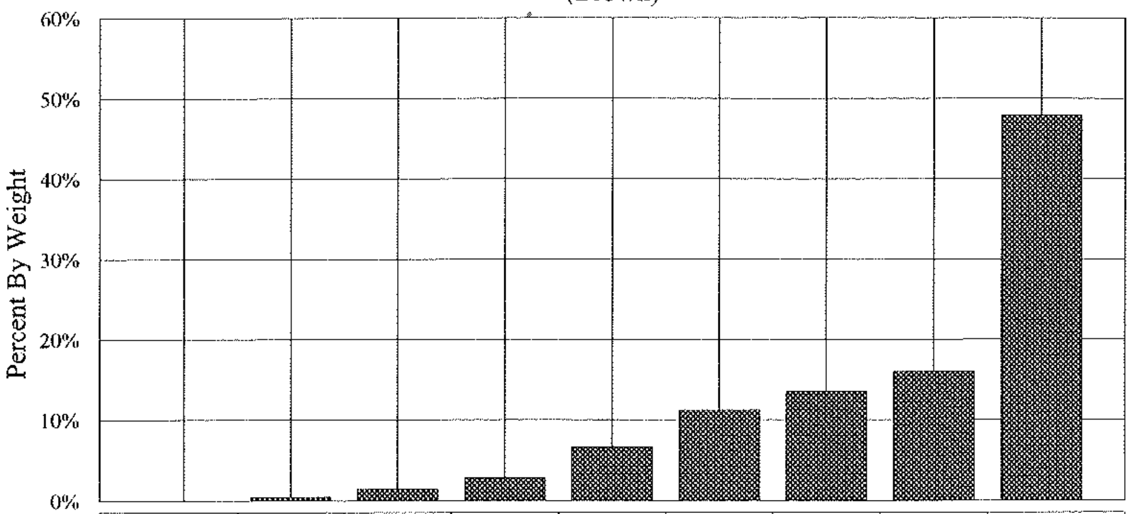


Millimeter	0.212	0.425	0.850	1.400	2.360	4.000	6.300	9.500
Percent	1.2%	3.6%	6.5%	11.9%	24.8%	26.1%	15.4%	10.5%

EXHIBIT V (b)

Pumped Peel In Large Hammer Mill

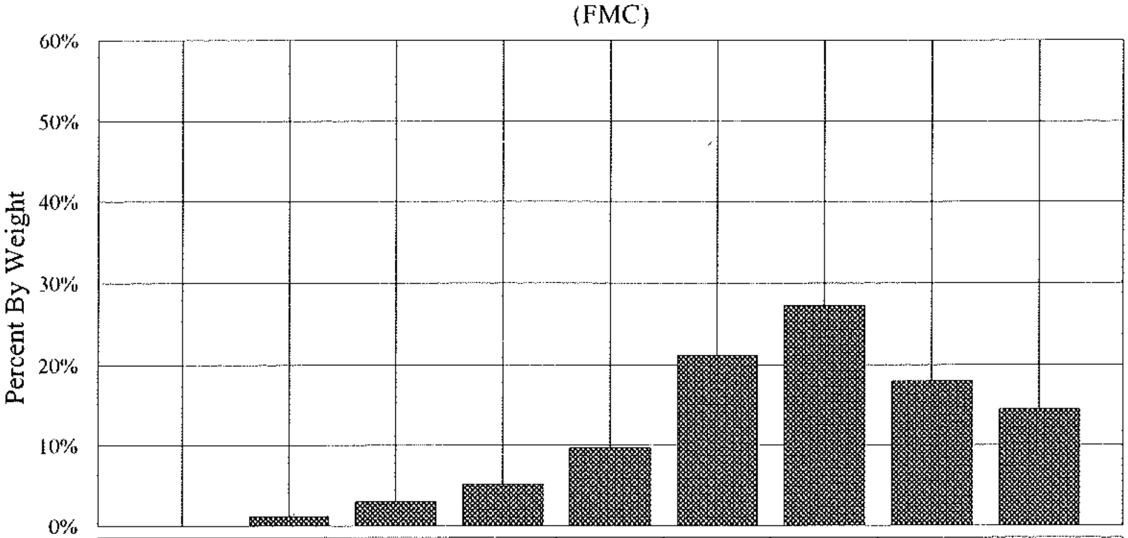
(Brown)



Millimeter	0.212	0.425	0.850	1.400	2.360	4.000	6.300	9.500
Percent	0.5%	1.4%	2.9%	6.7%	11.2%	13.5%	16.0%	47.9%

Gulf 18" Horizontal Shredder

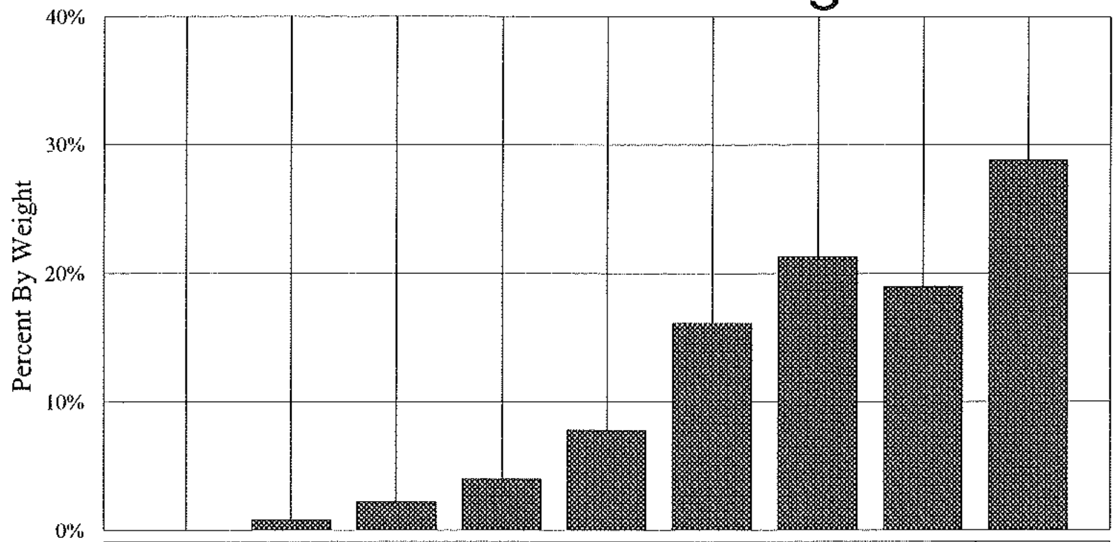
(FMC)



Millimeter	0.212	0.425	0.850	1.400	2.360	4.000	6.300	9.500
Percent	1.2%	3.0%	5.2%	9.7%	21.2%	27.3%	18.0%	14.5%

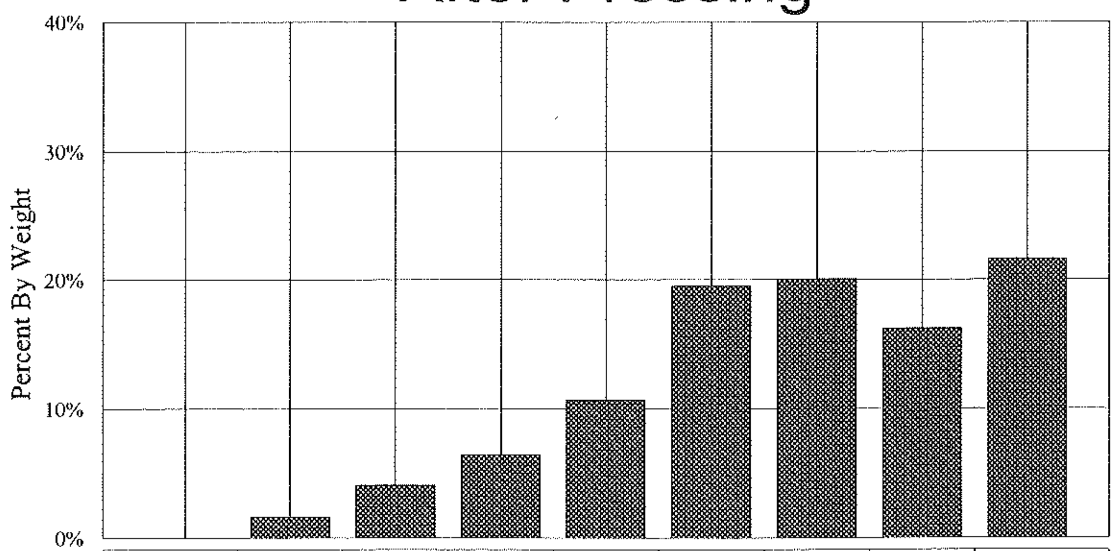
EXHIBIT VI

Before Pressing



Millimeter	0.212	0.425	0.850	1.400	2.360	4.000	6.300	9.500
Percent	0.8%	2.3%	4.0%	7.8%	16.1%	21.3%	19.0%	28.8%

After Pressing



Millimeter	0.212	0.425	0.850	1.400	2.360	4.000	6.300	9.500
Percent	1.6%	4.0%	6.4%	10.7%	19.5%	20.0%	16.2%	21.6%

EXHIBIT VII

RESULTS SORTED BY % LARGE PEEL PARTICLES

PLANT	% LARGE PARTICLES (9.5mm+)	RAW PEEL % OIL	PRESS CAKE % OIL	PRESS CAKE MOIST	POUNDS OF OIL PER TON OF PEEL *************** OIL IN PEEL	OIL IN CAKE
		BROWN EXTRACTION				
L	11%	0.736	.574	73%	14.7	7.5
C	23%	1.860	.615	67%	37.2	7.5
D	30%	0.220	.100	68%	4.4	1.2
J	44%	0.974	.383	72%	19.5	5.5
I	45%	0.666	.315	71%	13.3	4.3
N	65%	1.440	.591	74%	28.8	9.1
G	77%	0.748	.464	71%	15.0	6.3
AVERAGES:						
LEAST 4	27%	0.95%	0.42%	70%	19.0	5.4
ALL 7	42%	0.95%	0.43%	71%	19.0	5.9
MOST 3	62%	0.95%	0.46%	72%	19.0	6.6

PLANT	% LARGE PARTICLES (9.5mm+)	RAW PEEL % OIL	PRESS CAKE % OIL	PRESS CAKE MOIST	OIL IN PEEL	OIL IN CAKE
		FMC EXTRACTION				
B	6%	0.480	.316	66%	9.6	3.7
M	9%	0.300	.389	74%	6.0	5.0
K	10%	0.582	.542	73%	11.6	8.0
A	11%	0.518	.488	65%	10.4	5.6
F	13%	0.904	.905	70%	18.1	12.1
P	16%	0.582	.493	75%	11.6	6.5
Q	21%	0.418	.450	76%	8.4	6.3
E	25%	0.294	.299	68%	5.9	3.7
H	26%	0.545	.465	71%	10.9	6.5
AVERAGES:						
LEAST 4	9%	0.47%	0.43%	69%	9.4	5.6
ALL 9	15%	0.51%	0.48%	71%	10.3	6.4
MOST 4	22%	0.46%	0.43%	73%	9.2	5.8

Endecotts

FLUID BED DRYER

A bench top unit for the rapid drying of chemicals, foodstuffs and minerals prior to sieve analysis and other tests.

The FBD 2000 is a compact, portable dryer. Its powerful air delivery system makes drying a very fast operation. The fluidisation mixes and separates the particles minimising the risk of abrasion and the creation of lumps resulting in a truly representative sample.

The comprehensive set of controls makes it ideal for use in the laboratory on a wide selection of materials.

★ **Fast**
Drying times range from a few seconds to minutes.

★ **Efficient**
High rates of heat transfer ensure faster and more homogeneous drying than oven, microwave or vacuum drying.

★ **Versatile**
Suitable for most granular and powder materials.

★ **Reproducible results**
Precise controls ensure uniform and reproducible results.

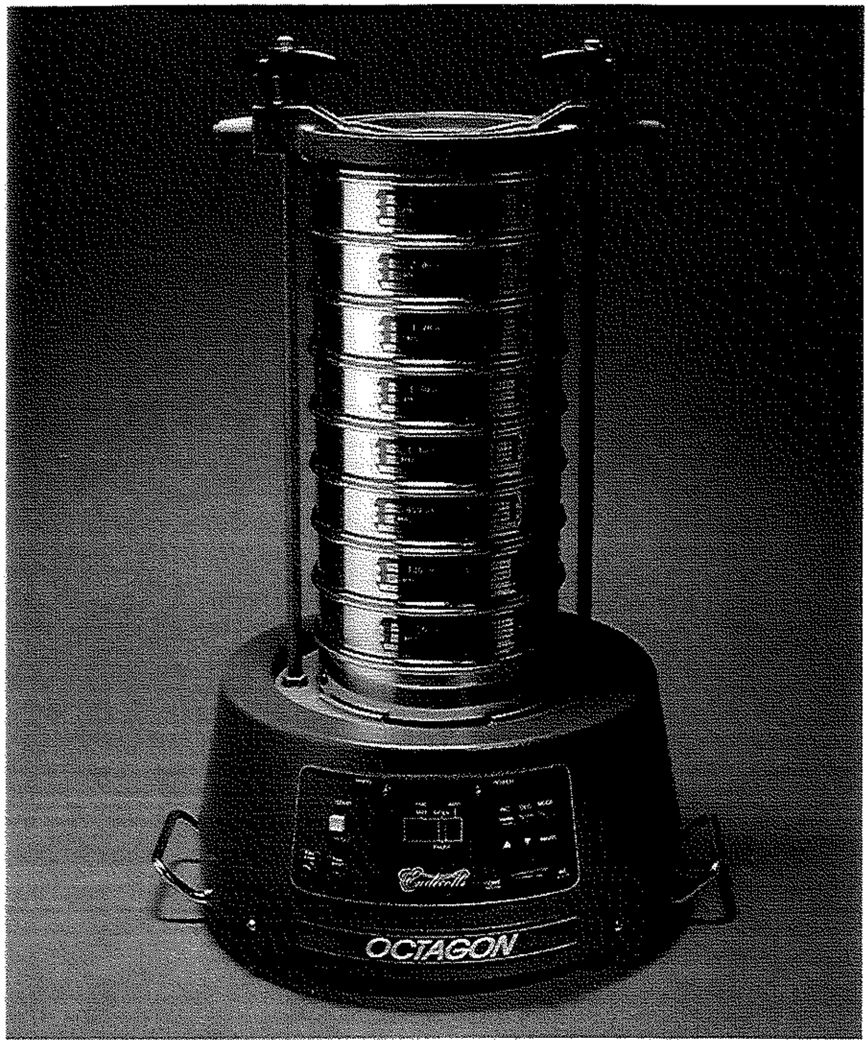
★ **Easy to use**
Manageable controls with straightforward settings .

Simply the most efficient method of drying samples for analysis

FBD 2000

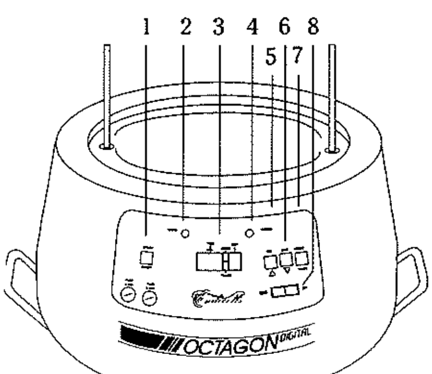
OCTAGON DIGITAL

The high performance digital shaker



THE OCTAGON DIGITAL CONTROLS:

1. Start/reset button
2. Mains light
3. Separate LEDs display: Setting and running times, time or amplitude setting mode, intermittent vibration setting mode and amplitude level.
4. Power light
5. Increment control
6. Decrement control
7. Mode switch
8. Continuous or intermittent vibration switch



Octagon 2000

Specification
Height including rods: 730mm
Diameter: 410mm (Handles: 2x35mm)
Unpacked Weight: 43kg
Packed Weight: 65kg
Power Supply: 220/240v 50Hz 300VA,
100/110v 60Hz 300VA
Other voltages & frequencies on request.

Sieve capacity	200mm or 8"	100mm or 3"
Full height	8	12
Half height	18	24

The New Octagon Digital is a high performance test sieve shaker offering excellent operator control for maximum efficiency.

The Octagon is ideal for laboratory or on site use. It is robust, compact and sufficiently lightweight to be portable. A digital display makes the setting of the microprocessor controlled functions very straightforward. The Octagon is powered by an electromagnetic drive which has no rotating parts to wear making it maintenance free and extremely quiet in operation. The vibratory action produced by the power unit moves the sample over the sieve in a unique way producing faster more efficient sieving, while the rapid vertical movements also help to keep the apertures from blinding.

The Octagon's digital controller is used to set both the process time and the amplitude setting while a further control enables the vibration to run continuously or intermittently. Intermittent vibration improves performance and helps to clear apertures that may have become blocked. The controller will also set the duration of both the on and off times of the vibration. The Octagon Digital offers total flexibility enabling optimum settings to be established for virtually any material under test.

Octagon shakers are fitted with a new and totally unique clamping device. It ensures sieves are held firmly without overtightening and allows them to be quickly removed and replaced. Non-metallic springs and anti-vibration mountings are fitted to isolate vibrations from work surfaces and reduce noise levels.

CE

Octagon shakers are designed to comply with the latest European EC standards of safety.

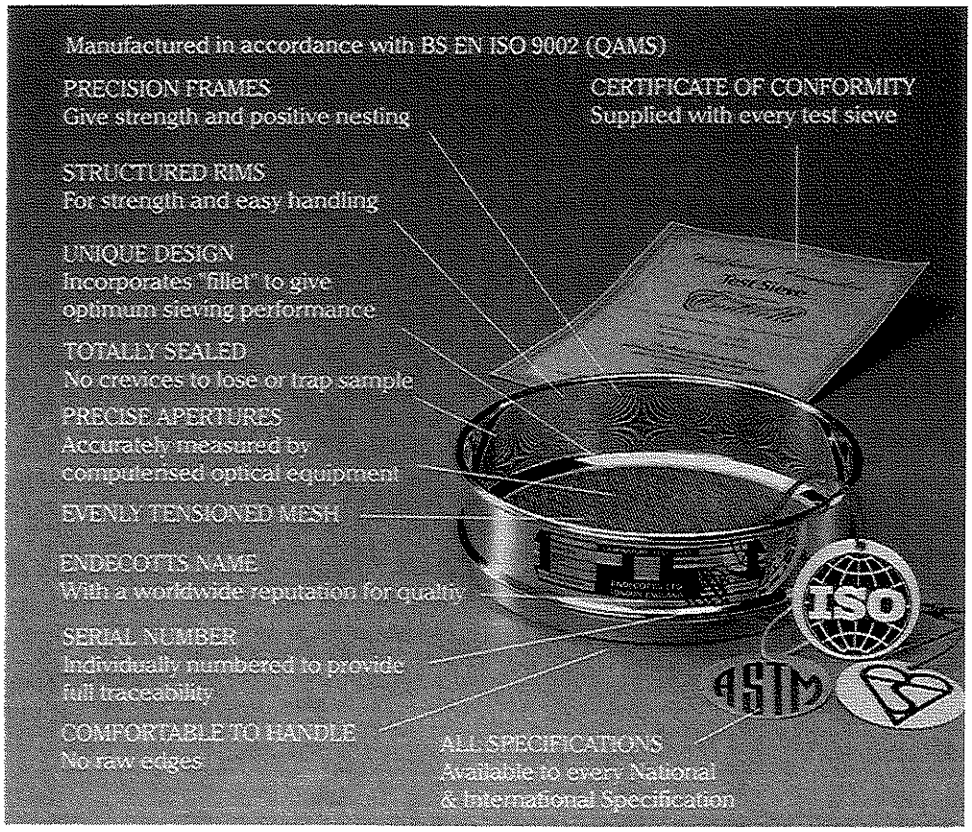
It is features like these that count

"Endecotts test sieves are of the highest quality and are designed for accurate and efficient particle size analysis"

For accurate dependable results you can't buy a better test sieve than Endecotts. The combination of its many features and the quality of manufacture make it the perfect measuring instrument.

At every stage of manufacture each sieve is individually inspected by optical projection including the very latest computer based optical measuring equipment.

With so many features it is hardly surprising Endecotts test sieves are specified by more laboratories worldwide.

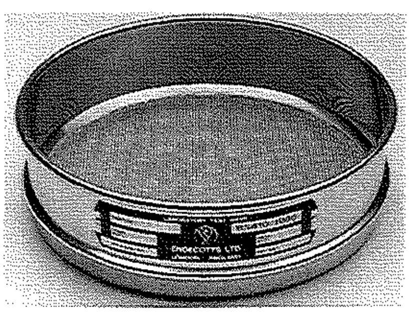


Types of Laboratory Sieve

Endecotts test sieves can be supplied in a variety of different inspection levels depending on the information requirements specified.

Certified Sieves

These are the most widely used test sieves and are manufactured to a National or International Specification. Each is supplied with a Certificate of Conformity and individually numbered to provide full traceability.

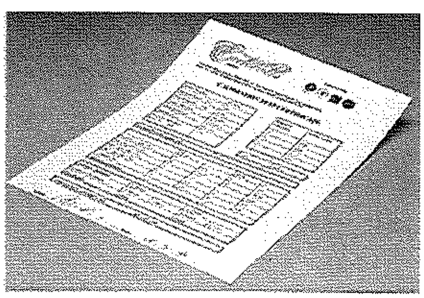


Matched Sieves

Two or more test sieves each fitted with a sieving medium having similar aperture characteristics. Each is supplied with a Certificate of Conformity marked "Matched with sieve serial No.... "

Calibrated Sieves

These sieves are calibrated in accordance with the specification. Each sieve is supplied with a calibration test certificate giving the range of tolerances and measurements taken.



Matched and Calibrated Sieves

A combination of Matched and Calibrated Sieves. Each is supplied with a calibration test certificate marked "matched with sieve serial No...."

Mid Point Sieves

Test sieves with a more precise sieving medium where specification tolerances are reduced by 30% where attainable. Each sieve is supplied with a test certificate giving the range of tolerances and measurements taken.

Re-Certification Service

Sieves may be re-examined and re-inspected in accordance with the appropriate specification. Complying sieves are issued with a Certificate of Re-Inspection.