TRANSACTIONS of the 1995

CITRUS ENGINEERING CONFERENCE

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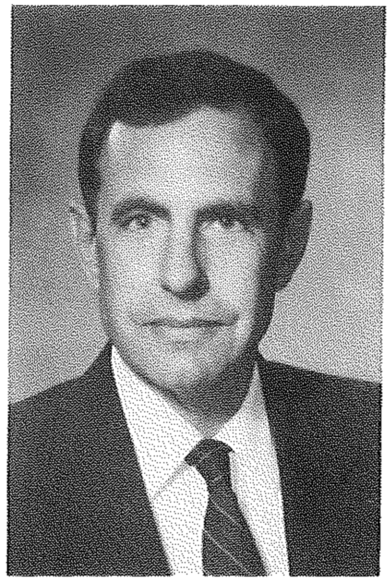
FLORIDA SECTION

AMERICAN SOCIETY of MECHANICAL ENGINEERS

LAKELAND, FLORIDA
MARCH 23, 1995
VOLUME XXXXI



LATEST DEVELOPMENTS IN PRESSING CITRUS PEEL

by
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BACKGROUND

A newcomer to the citrus industry can find papers and speeches of earlier decades that deal with pressing citrus peel. Many of these, including some by Vincent Corporation, speak of 60% and 62% press cake moisture. Yet, in practice, this was not being achieved on any consistent basis until relatively recently.

What is this percent moisture, and why is it important? The percent moisture is simply the amount of water that can be evaporated from a sample of peel, leaving the solids behind. Most generally it is measured by placing a 10 gram sample of homogeneous (blended) press cake on a scale. Heat is applied gradually, being careful not to burn off any solids. When the sample is bone dry, the solids remaining are weighed.

Since peel arrives at the dewatering press in a range of 80% to 84% moisture, then the moisture content of the press cake reveals how hard and how effectively the press is working. The moisture not removed from the peel by the press will have to be removed in the dryer. The amount of fuel consumed by the dryer is directly proportional to the amount of moisture being removed. Thus the effectiveness of the press has a direct bearing on the monthly fuel bill.

This thermal efficiency is illustrated in the Material Balances presented in Figures I through IV. These are very detailed, so they are included only for your later study. You will find that in the first the peel is pressed to 72% moisture, while in the second another extreme, 65%, is achieved. The fuel cost per ton is significantly lower with the 65% peel.

These Material Balances have the "givens" listed at the top of the page and the variable "Ratio Percents" selected in the third column. All of the rest of the figures calculate automatically when a spread sheet is set to reiterate to a common solution. These spread sheets are readily modified to analyze other conditions, such as (a) sale of part or all of the molasses, (b) addition of press liquor to the reaction conveyor, (c) recirculation of press cake, and (d) use of recirculated molasses for peel pumping purposes.

The Material Balances assume that the moisture in the press liquor from the press can be evaporated for free. And, generally it is. In a properly balanced system the waste (free) heat in the exhaust gasses coming from the dryer is sufficient to allow the waste heat evaporator (WHE) to remove the moisture from the press liquor.

FIGURE I
SINGLE PRESSING

FILE: SINGLE.A
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BOXES PER DAY	80,000	BOXES
BOXES PER HOUR	3,636	BOXES
POUNDS of PEEL/BOX	40.0	LBS
PEEL THROUGHPUT	145,455	LBS/HR
WATER, OTHER SOURCES	8	LBS/BOX
TOTAL PEEL MOISTURE	79%	%
PEEL SOLUBLE SOLIDS	12.0	BRIX
PRODUCT MOISTURE	12%	%
MOLASSES SOLIDS	45.0	BRIX

KEY FIGURES FROM BELOW:

PRESS CAKE MOIST	72%
WHE LOAD	67,065
DRYER LOAD	72,769

	TOTAL WEIGHT #/HR	RATIO PERCENT %	WATER PERCENT %	WATER WEIGHT #/HR	DEG BRIX o	SOLUBLE SOLIDS #/HR	INSOLUBLE SOLIDS #/HR	TOTAL SOLIDS #/HR
INBOUND PEEL	145,455		79.0%	114,909	12.0	15,669	14,876	30,545
WATER, OTHER SOURCES	29,091	---	100.0%	29,091	0.0	0	0	0
MOLASSES IN	40,415		55.0%	22,228	45.0	18,187	0	18,187
INPUT REACTION CONV	214,960	---	77.3%	166,228	16.9	33,856	14,876	48,732
INPUT to PRESS	214,960		77.3%	166,228	16.9	33,856	14,876	48,732
PRESS LIQUOR	107,480	50%	83.1%	89,293	16.9	18,187	0	18,187
PRESS CAKE	107,480	50%	71.6%	76,935	16.9	15,669	14,876	30,545
EVAPORATOR INPUT	107,480	---	83.1%	89,293	16.9	18,187	0	18,187
EVAP. WATER OUT	67,065	---		67,065				
MOLASSES OUT	40,415	---	55.0%	22,228	45.0	18,187	0	18,187
MOL TO REACTION	40,415	100%	55.0%	22,228	45.0	18,187	0	18,187
MOLASSES TO DRYER	0	0%	55.0%	0	45.0	0	0	0
DRYER INPUT	107,480	---	71.6%	76,935		15,669	14,876	30,545
DRYER WATER OUT	72,769	---		72,769				
PRODUCT OUT	34,711	---	12.0%	4,165		15,669	14,876	30,545
TOTAL OUT	174,545	---	82.5%	144,000		15,669	14,876	30,545
TONS/FEED/HR	17.4							

RATIO: EVAPORATOR LOAD TO DRYER LOAD = 0.92

DRYER BTU/# WTR	1,500
FUEL OIL COST/GAL	$0.35
BTU/GAL OIL	135,000
FUEL COST $/TON	$16.31

FIGURE II
SINGLE PRESSING

FILE: SINGLE.B
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BOXES PER DAY	80,000	BOXES
BOXES PER HOUR	3,636	BOXES
POUNDS of PEEL/BOX	40.0	LBS
PEEL THROUGHPUT	145,455	LBS/HR
WATER, OTHER SOURCES	8	LBS/BOX
TOTAL PEEL MOISTURE	79%	%
PEEL SOLUBLE SOLIDS	12.0	BRIX
PRODUCT MOISTURE	12%	%
MOLASSES SOLIDS	45.0	BRIX

KEY FIGURES FROM BELOW:

PRESS CAKE MOIST	65%
WHE LOAD	88,352
DRYER LOAD	51,483

	TOTAL WEIGHT #/HR	RATIO PERCENT %	WATER PERCENT %	WATER WEIGHT #/HR	DEG BRIX o	SOLUBLE SOLIDS #/HR	INSOLUBLE SOLIDS #/HR	TOTAL SOLIDS #/HR
INBOUND PEEL	145,455		79.0%	114,909	12.0	15,669	14,876	30,545
WATER, OTHER SOURCES	29,091	---	100.0%	29,091	0.0	0	0	0
MOLASSES IN	84,295		55.0%	46,362	45.0	37,933	0	37,933
INPUT REACTION CONV	258,840	---	73.5%	190,362	22.0	53,602	14,876	68,478
INPUT to PRESS	258,840		73.5%	190,362	22.0	53,602	14,876	68,478
PRESS LIQUOR	172,646	67%	78.0%	134,714	22.0	37,933	0	37,933
PRESS CAKE	86,194	33%	64.6%	55,648	22.0	15,669	14,876	30,545
EVAPORATOR INPUT	172,646	---	78.0%	134,714	22.0	37,933	0	37,933
EVAP. WATER OUT	88,352	---		88,352				
MOLASSES OUT	84,295	---	55.0%	46,362	45.0	37,933	0	37,933
MOL TO REACTION	84,295	100%	55.0%	46,362	45.0	37,933	0	37,933
MOLASSES TO DRYER	0	0%	55.0%	0	45.0	0	0	0
DRYER INPUT	86,194	---	64.6%	55,648		15,669	14,876	30,545
DRYER WATER OUT	51,483	---		51,483				
PRODUCT OUT	34,711	---	12.0%	4,165		15,669	14,876	30,545
TOTAL OUT	174,545	---	82.5%	144,000		15,669	14,876	30,545

TONS/FEED/HR 17.4 RATIO: EVAPORATOR LOAD TO DRYER LOAD = 1.72

DRYER BTU/# WTR	1,500
FUEL OIL COST/GAL	$0.35
BTU/GAL OIL	135,000
FUEL COST $/TON	$11.54

FIGURE III
DOUBLE PRESSING

FILE: DOUBLE
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BOXES PER DAY	80,000	
BOXES PER HOUR	3,636	
POUNDS of PEEL/BOX	40.0	
INBOUND PEEL	145,455	LBS/HR
WATER, OTHER SOURCES	8	LBS/BOX
TOTAL PEEL SOLIDS	79%	%
PEEL SOLUBLE SOLIDS	12.0	BRIX
PRODUCT MOISTURE	12%	%
MOLASSES SOLIDS	45.0	BRIX

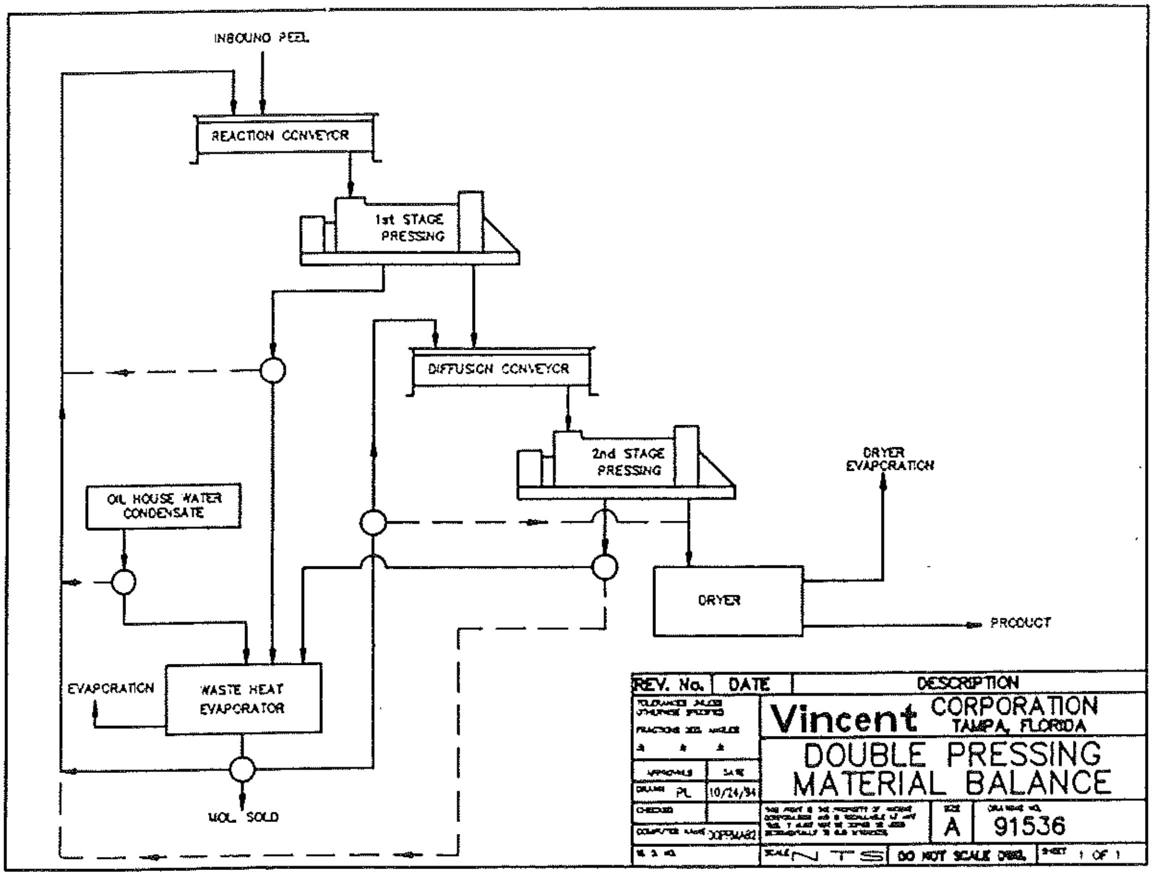
KEY FIGURES FROM BELOW:

PRESS CAKE MOIST	63%
WHE LOAD	91,833
DRYER LOAD	48,001

	TOTAL WEIGHT #/HR	RATIO PERCENT %	WATER PERCENT %	WATER WEIGHT #/HR	DEG BRIX o	DISSOLVED SOLIDS #/HR	SUSPENDED SOLIDS #/HR	TOTAL SOLIDS #/HR
INBOUND PEEL	145,455	---	79.0%	114,909	12.0	15,669	14,876	30,545
WATER, OTHER SOURC	29,091	---	100.0%	29,091	0.0	0	0	0
MOL to REACTION CONV	50,381	---	55.0%	27,710	45.0	22,672	0	22,672
INPUT REACTION CONV	224,927	---	76.3%	171,710	18.3	38,341	14,876	53,217
INPUT 1st PRESS	224,927	---	76.3%	171,710	18.3	38,341	14,876	53,217
1st PRESS LIQUOR	112,463	50%	81.7%	91,935	18.3	20,528	0	20,528
1st PRESS CAKE	112,463	50%	70.9%	79,774	18.3	17,813	14,876	32,689
INPUT DIFFUSION CONV	134,055	---	68.4%	91,650	23.1	27,529	14,876	42,405
INPUT 2nd PRESS	134,055	---	68.4%	91,650	23.1	27,529	14,876	42,405
2nd PRESS LIQUOR	51,343	38%	76.9%	39,483	23.1	11,860	0	11,860
2nd PRESS CAKE	82,712	62%	63.1%	52,167	23.1	15,669	14,876	30,545
EVAPORATOR INPUT	163,806	---	80.2%	131,419	19.8	32,388	0	32,388
EVAP WATER OUT	91,833	---		91,833			0	
EVAP MOLASSES OUT	71,973	---	55.0%	39,585	45.0	32,388	0	32,388
MOL to DIFFUSION	21,592	30%	55.0%	11,876	45.0	9,716	0	9,716
MOL to REACTION	50,381	70%	55.0%	27,710	45.0	22,672	0	22,672
DRYER INPUT	82,712	---	63.1%	52,167		15,669	14,876	30,545
DRYER WATER OUT	48,001	---		48,001			0	
DRYER PRODUCT OUT	34,711	---	12.0%	4,165		15,669	14,876	30,545
TOTAL OUT	174,545	---	82.5%	144,000		15,669	14,876	30,545

TONS/FEED/HR 17.4 RATIO: EVAPORATOR LOAD TO DRYER LOAD = 1.91
FUEL COST $/TON $10.76

FIGURE IV



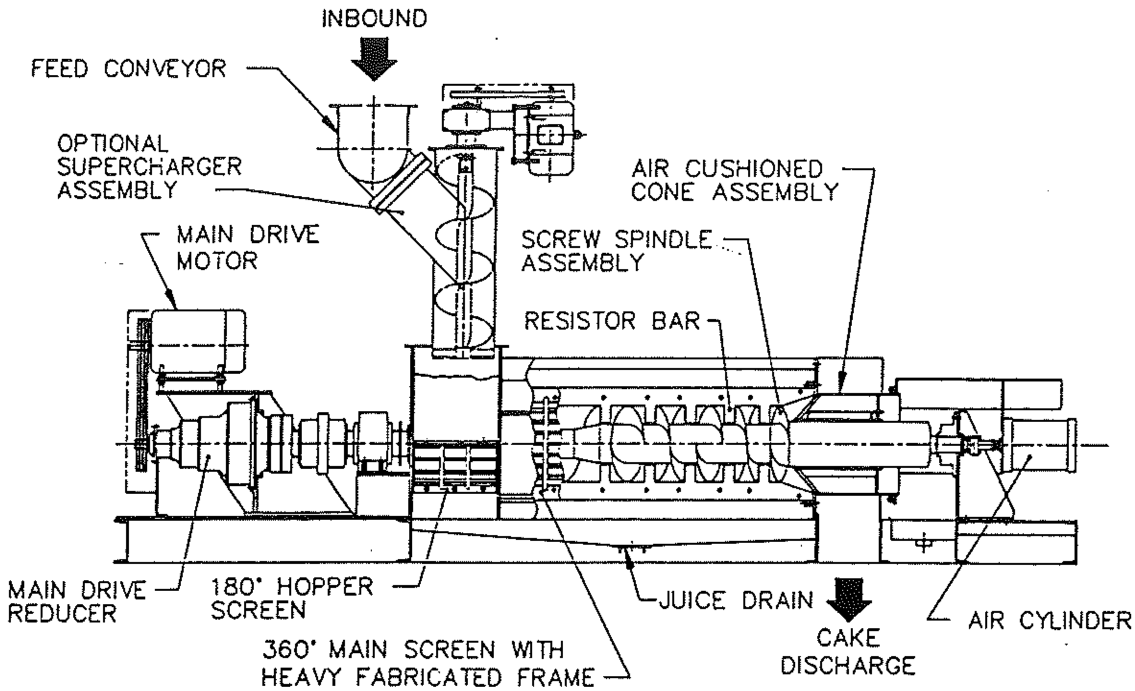
Plants frequently find that they do not have enough WHE capacity to do the job. It is a problem of undersized and overloaded evaporators. This problem has been getting worse as more and more waste waters are being diverted to the feedmill for disposal. And the advent of higher performance presses is accentuating the problem.

This problem is put in perspective with a key figure on the Material Balance, the ratio of WHE load to dryer load. Most plants are designed for a 2:1 ratio. Notable exceptions are Winter Garden Citrus and Cambuhy of Brazil that have WHE's designed for 2.5:1. The higher the ratio, the more investment required in WHE surface.

The Material Balance also reflects pressing performance. In the 1940's and 1950's feedmill pressing technology evolved rapidly. Initially belt, roller and drum presses were installed. These fell from favor because of low capacity and weak pressing characteristics. The technology settled on the use of screw presses that featured an interrupted flight screw with an auto-adjusting discharge cone. This design has remained the norm until this day.

Figure V illustrates these features. The press is a dewatering machine with a conveying screw rotating inside a perforated cylinder. As incoming material is forced the length of the machine, liquid ("press liquor") is expelled through the cylinder wall. The remaining solids ("press cake") are discharged at the far end.

FIGURE V



In operation, the peel enters through the inlet hopper where it is grabbed by the feeder portion of the screw. This pushes the peel into the tighter pitch compression stages of the screw. Notice that there is a gap between each stage of compression. Stationary resistor bars are mounted to the frame of the press, and they hold resistor teeth in the gaps between each succeeding screw flight. The main reason for having these gaps with stationary teeth is that it was found that they prevented the peel from turning with the screw (co-rotating) and not feeding through the press. Also, they cause the peel to be stirred within the press so that fresh material is exposed to the screen surface for improved dewatering.

The press cake encounters resistance at the discharge of the screen cylinder in the form of a cone mounted on a pneumatic ram. As the material reaches the discharge point, the cone exerts final pressing action to achieve maximum dewatering. More importantly, the design allows the cone to pinch tight against the screen discharge. This facilitates forming a "plug" when a press is first put in operation or when adverse conditions (distressed or dilute peel) are encountered. The plug is what starts the press working, and it will form automatically without need for operator attention.

This is the standard pressing technology. It is the same whether the press is mounted in a horizontal, inclined or vertical position.

NEW TECHNOLOGY

In the 1990's the citrus industry has seen the advent of new pressing technology.

One event has been the successful operation of presses that use continuous screws rather than the interrupted flight design. Both Tropicana and Procter and Gamble, as an industry newcomer, ran relatively successful tests with the Dupps screw press. These machines feature a single, continuous screw. These presses avoid plugging by having the capacity to exert high internal pressure. To achieve this they employ larger motors and feature much thicker metal with more robust gear boxes, frames and reinforcements. For example, the screens are made by drilling individual holes through steel plate, as compared to the use of rolled perforated sheetmetal in the interrupted flight machines.

Almost simultaneously, Caulkins Indiantown installed a pair of presses made by a Norwegian company, Stord. These machines are best known for pressing sugar beet pulp in the sugar industry. The presses feature not one, but two parallel continuous screws. As with the Dupps press, the Stord is a much heavier, higher powered machine.

What Stord achieved at Caulkins is remarkable. After severe start-up difficulties, they are able, throughout the season, to achieve 60% to 65% press cake moisture. When first installed, these presses generated far more press liquor than the existing waste heat evaporator could handle. The press cake was going into the dryer so dry that there was not enough exhaust gas to drive the WHE. For a fact, it was necessary to add a portion of the press liquor back to the press cake in order to keep the system balanced. (This condition has been improved by the recent installation of WHE and dryer capacity by Cook Machinery Company, plus the conversion of the previous WHE to steam operation.)

Another event that had an impact on pressing technology was the construction of the new Southern Gardens citrus processing plant. Stuart Salter's stated goal was for it to be the most energy efficient plant in the state, and this challenge was laid down to the screw press manufacturers.

At the same time, Cargill placed a Brazilian, Francisco Gomes, over their Frostproof plant. Mr. Gomes summarized some testing done in his Brazilian plant by stating, "The goal is 60% press cake moisture."

The success of Stord and challenges by Southern Gardens and Brazilian citrus processors led to a reexamination of the traditional interrupted flight design. The situation came to a head at Cargill Frostproof because a large Vincent VP-22 press was not meeting its guarantee conditions.

The press in question was originally built in 1978 for pressing alfalfa. It had a 100 hp DC drive at a time when 40 hp was standard on that model. In 1992 it was acquired by P&G who then owned the Frostproof plant. They had the press converted to pressing orange peel with a 75 hp motor and gear reducer.

In operation the horsepower drawn was under 40, and capacity was below expectations because an oversize screw shaft prevented sufficient peel from entering the screen area. Furthermore, press cake moisture was over 68%. A variety of speed changes had little impact on the operation.

Fortunately the press was fed by a (horizontal) variable speed feed screw with a

7-1/2 hp drive motor. One night during the 1992-93 season, in desperation, the cover to this feeder screw was bolted tight and the drive was over-sped. Peel and molasses squirted through every joint and the Supercharger was born.

By force feeding the press in this manner the horsepower went up to 50 and press cake moisture came down to 65%. At the same time, throughput capacity increased measurably. The guarantee was met.

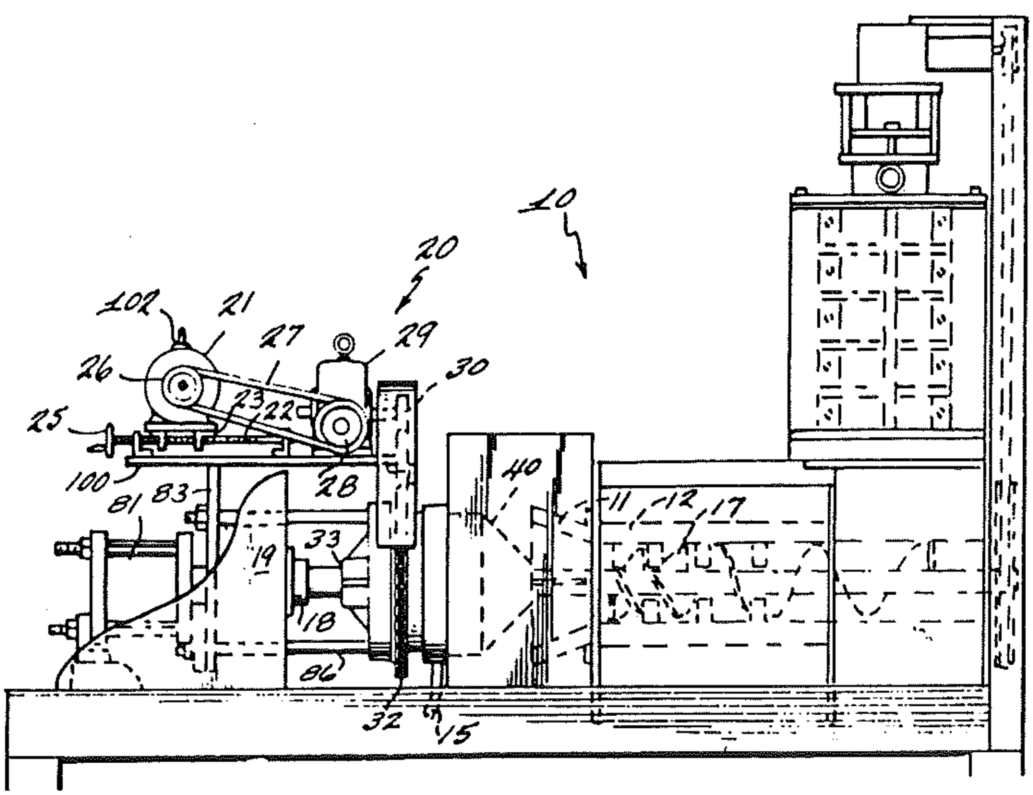
It was thought that something new had been invented – until someone pointed out a 1968 patent (Figure VI). Dan Vincent had the right idea, but it was ahead of its time.

FIGURE VI

Sept. 10, 1968 D. B. VINCENT 3,400,654

DEWATERING PRESS

Filed Oct. 20, 1966 2 Sheets-Sheet 1



During the break in the summer of 1993, Joe Wolfer and Tom Shier at Silver Springs Citrus decided to take a chance on the Supercharger technology. They already had a horizontal feeder screw in place on one of their presses, so the modifications were minor. One important step they took was to add a pressure sensing element in the inlet hopper of the press, downstream of the Supercharger, but ahead of the main screw. This senses the pressure, 0 to 10 psig, as the peel is forced into the press. The signal from this pressure transducer allowed controls to be calibrated so that the Supercharger automatically speeds up when the pressure in the inlet hopper drops, and vise versa. While the installation is far from ideal, it has meant that the press can be set to hold optimum pressing efficiency, without operator attention, as peel conditions vary through the day and season.

A notable impact of the Supercharger modification at Silver Springs Citrus was that press throughput capacity increased by as much as 30%. This is attributed to the facts that the Supercharger (a) forces out air that is entrained in the peel; (b) improves the slippage factor significantly; and (c) causes press liquor to be removed by the screen in the inlet hopper, prior to entering the main barrel of the press.

During that summer of 1993 a major Florida citrus processor purchased a VP-22 press complete with a vertical, factory built Supercharger. This Supercharger was supplied with a hydraulic drive that is controlled so as to supply constant torque (rather than speed). This feature has worked well in allowing the press to be set so that optimum performance is achieved, throughout the season, without operator attention.

Another feature of this press was that it had a new, high performance screw. Originally designed in conjunction with Southern Gardens, this screw incorporated many changes. Internal shaft and tube diameters and transitions were changed, along with increasing the pitch reduction, so as to achieve tighter pressing. Larger bearings and double seals had to be incorporated, along with a much stiffer structure.

Performance of the press exceeded expectations. During the 1993-94 season, in second pressing duty, the press consistently achieved 60% to 64% moisture in the press cake. Also, all time records for the daily tonnage of peel being processed were set.

Notably, the installation was approaching the low moisture performance of the Stord press at Caulkins Indiantown. At the same time the traditional strengths of the interrupted flight design had been retained: low initial cost, satisfactory operation under widely varying conditions, and low maintenance requirements.

While this was going on, still another pioneering effort was under way. Ron Grigsby at Florida Juice elected to build a new feedmill using the Brazilian pumped peel system. The technology of this system had been presented here, at this ASME conference, in 1993, by Carlos Odio of Gumaco.

This system presented new challenges to screw press designers. It was expected that the peel was going to be very soupy. It was also recognized that this condition would make it hard for the Supercharger screw conveyor to force the peel into the press, and it was expected that it would make it hard for the main screw of the press to get a "bite" on the peel. Also, the plug forming capability of the discharge cone was clearly going to be taxed. Despite these challenges, it was felt that 62% press cake moisture could be achieved.

Figures VII and VIII show the presses installed at Florida Juice. Note the vertical Superchargers installed above the inlet hoppers.

FIGURE VII

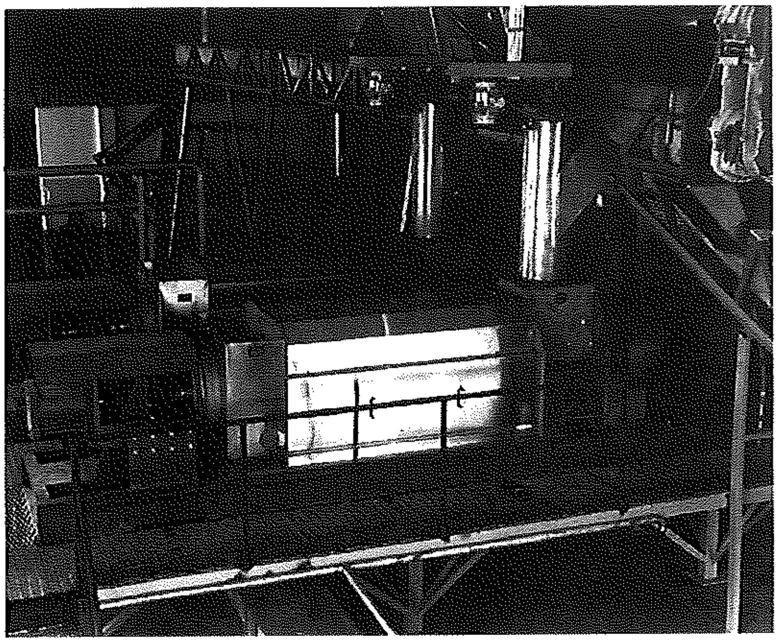
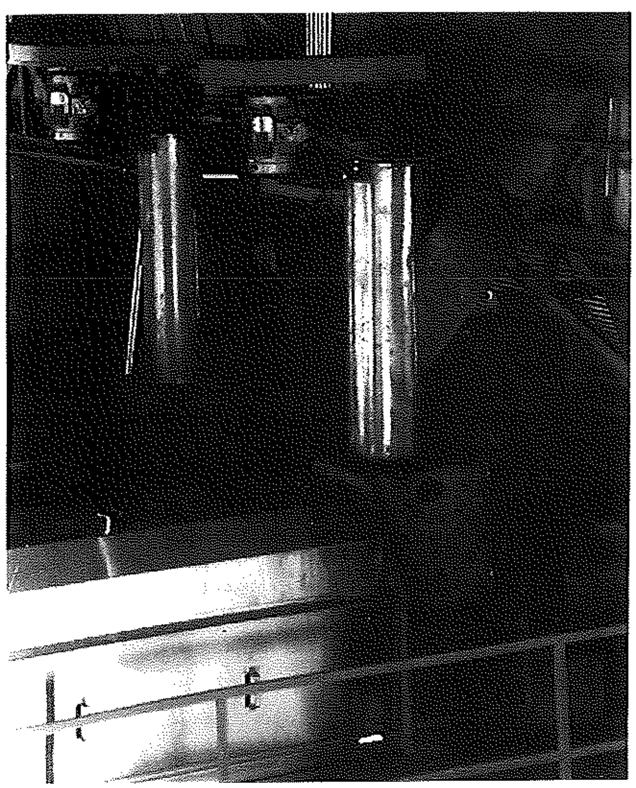


FIGURE VIII



It was never imagined just how fluid the peel would be until it poured out. When the system overflowed during trials and the peel fell to the floor, it ran like very loose slurry. This condition was compounded by pH excursions, erratic operating levels, along with a dryer too large for the WHE capacity, all of which resulted in very weak molasses being produced. Frequently the molasses Brix were 30° or less.

A comment relative to molasses Brix is appropriate at this point. We know orange peel comes in at 82% moisture and we want to press it down to 62% moisture. Think of the reverse: the peel comes in at 18% solids and in pressing we need to get it up to 38% solids. Clearly, if we can add molasses at 50° Brix, which is 50% solids, to the 18% peel, then it is easy to raise the output to 38%. In fact, if you could add enough molasses, it would not be necessary to press the peel at all!

Thus, if we look only at the press operation, the higher the Brix of the molasses added to the peel, the lower the press cake moisture is apt to be. The limits are that the peel must be able to absorb and diffuse the molasses, and the dryer/WHE combination must be able to sustain production of sufficient molasses for steady level operation.

Returning to the Florida Juice feedmill... While operation last season was limited to only a few weeks, a very wide range of conditions were encountered and managed. In this process a great deal of technology was proven. During the trial period the feedmill operated only twelve hours each day, and one of the two WHE's was not yet in service.

The rigidity of the press proved adequate to handle extreme forces. This was demonstrated during a period of very high pH peel. With high pH the pectins are hardened and the peel becomes very fibrous and tough. The press rumbled and the platform quivered. The press cake looked like ground wood, and the press almost tripped out on overload. But operations continued without interruption.

Machine rigidity has become more important with the advent of low moisture pressing. Tests were run in four different citrus plants using a transit to measure the deflection of various frame members. This lead to design changes and, in three cases, adding gussets to existing frames.

The discharge cone of the press is another important component. It was successful at Florida Juice in forming a plug under a wide range of conditions, performing marginally only when it was necessary to process spoiled and under-limed peel. On these occasions the press screens blinded with mat, and press throughput capacity fell off by at least 50%. Nevertheless, it was possible to continue operation, slowly delivering pressed peel to the dryer. (Both adding caustic wash and adding dried but not pelleted peel are remedies used in cleaning mat from press screens.)

There was one more innovation of interest at Florida Juice. Provisions were made to recirculate approximately 20% of the press cake and blend it with the peel going into the presses. This variation was triggered by a paper entitled "Multiple Stage Pressing" that was presented to this group by Ralph W. Cook in 1983. Limited testing was performed, but it was clear that use of recirculated peel drove up the horsepower drawn by the press and presumably reduced the final moisture content of the peel going to the dryer. The concept is appropriate when a plant has excess press capacity, along with

WHE capacity to take care of the additional press liquor that results. Further testing is being conducted during this present operating season.

(We should note that press cake recirculation, as we have just described, had been tried previously at Tropicana. The results were inconclusive.)

As if there were not enough irons already in the fire, Bryce Kelly and Joe Dalton at Cargill decided to push the technology one more step. They ordered a screw and set of resistor bars for their 75 hp press designed so as to achieve 62% or less moisture content with single pressing.

It was an all-or-nothing shot, so changes affecting seven different design parameters were made simultaneously. This included obvious things like tightening the pitch reduction, speeding up the Supercharger, and reducing the shaft diameter in the inlet hopper. It also went into more esoteric details of resistor tooth profile, helicoid contours, and diameter transitions. For example, one detail of resistor tooth cross section which had never been altered since the early 1950's was changed with successful results.

Operation with the Ultra High Performance screw took place sporadically in April through June of 1994. On one hand, it was a remarkable success: throughput was increased and press cake moisture (on Valencias) held in the range of 59% to 63%. The performance of the interrupted flight press design had finally matched the heavy duty continuous screw machine.

Despite many start-up problems, a very important mode of operation was proven out. Placing the Supercharger on manual control, the operator was able to select speed increases and watch resultant increases in the amperage of the press' main drive motor. It was possible to raise the motor loading up to the maximum rated 75 hp without reaching the highest possible output from the Supercharger. Thus it was possible to sit in the control room and dial in the amount of work to be done by the press.

This press was rebuilt last summer, primarily to repair damaged drive components. While it has been performing without incident this season, press cake moisture on early fruit was considerably higher than expected. This was possibly related to the unusually high ratio fruit being harvested. Testing is continuing.

One phenomena worthy of mention is the appearance of frit in the press liquor. Frit is being defined as tiny pieces of citrus peel where the moisture and solids have not been separated. It looks like orange peel that has been grated, and it appears in the press liquor when extremely tight pressing is taking place. It can be produced in the laboratory by placing a sample of peel in a cylinder with a perforated screen at one end. When a high pressure hydraulic piston is used to extrude the peel through the screen, frit is produced. Both Caulkins Indiantown and Cargill have noted minor amounts of frit in their press liquor. There has been no problem screening out this material ahead of the WHE.

At the time that this paper is being presented, the technology to be watching is the new SunPure feedmill in Avon Park. This is a greenfield installation, designed and built by Cook Machinery Company. Because the peel must be transported five hundred feet from the processing operation, a pumped peel system is employed.

PEEL PREPARATION

Pressing of citrus peel will never be successful without proper preparation of the peel. This must be kept in mind as changes and options in press design are studied.

Early theory held that for proper pressing to occur, prior to the addition of lime, the peel must first be ground and "sufficient liquids should be added until it is a freely flowing mass, thin enough to be handled by a centrifugal pump" (Dan Vincent US Patent 2,215,944, Food Product and Process of Making, 1940). This step was followed by addition of lime and agitation in a delay conveyor for three to five minutes. Later this was modified to first mixing peel, lime and water (or press liquor) prior to cutting the peel into thin slices. Quoting Dan Vincent's US Patent 22536240, Citrus Pulp Foodstuff, 1951, "The long shreds with cut smooth surfaces permit better contact with the liquid during the chemical treatment and present a more open mass to the gasses during the drying stages..." In any case, the idea was to expose the lime to the cells of the peel and allow it to break down to cell walls, thus making it easy to press out the moisture.

One important consideration at the time was that, since the peel was not pelleted, the dried peel was more desirable if it was bulky, with large pieces and a minimum of fines.

For a while thin bladed slicers were used. And the lime reaction was optimized by depositing the sliced peel and lime in a pit with water or press liquor.

This gradually gave way to the current practice. Thin bladed slicers were found to be very susceptible to damage by tramp iron, and the use of vertical shaft Rietz Disintegrators was adapted by several major processors. The Disintegrator has the advantage of being able to pass tramp metal with a minimum of damage to the screen, while still producing relatively well sliced peel.

At the same time, horizontal shaft hammermills became commonplace because of their lower capital cost. This led to the presence of larger pieces of peel, which extended the reaction time. At the same time liming pits were gradually replaced with continuous delay conveyors (also called reaction conveyors and pug mills).

Probably the biggest change was a result of the use of waste heat evaporators. Some plants felt that using press liquor to help the lime react the peel adversely affected d-limonene recovery. This is because, theoretically, mixing press liquor with fresh peel allows the essential oils a chance to be absorbed back into peel that may be destined for the dryer. Since essential oils are consumed in the dryer, it is desirable to send press liquor directly to the WHE. This led to the use of molasses as a medium for putting the lime in contact with the fresh shredded peel.

It is clear that the liming reaction is improved by the presence of a liquid to improve the contact between the lime and peel. Unfortunately it appears that this reaction process goes a little slower when molasses is used in place of water or press liquor. It is as if the acidity of the molasses acts to buffer the reaction. Little research has been done in this area.

These many changes have made it advisable to increase the time in the delay conveyor from the original three to five minutes up to eighteen minutes.

Another consideration in selecting a shredder has been that the horizontal hammermills mash the peel a little more than a Disintegrator. The mashed peel reacts with lime faster than the more uniformly shredded pieces from a vertical shaft machine. However, these fines have a tendency to either burn in the dryer or to be blown through to the WHE. Their presence in the WHE leads to excessively dirty "black water". The advent of better cyclone dust collectors has reduced this black water problem. It is evident that there are many factors to consider.

In practice, most plants achieve satisfactory pressing most of the time. However, there are occasions when poorly shredded peel and unduly short reaction times will cause pressing to become nearly impossible. It is a matter of which varieties of fruit are being run, the age of the peel, and even the weather conditions in the weeks prior to picking and the temperature at the time of pressing. The most common condition found is that the peel remains too slimy to press. A mat layer gets deposited on the screens of the press, effectively blinding the press. This reduces press capacity, and both dryer and WHE operations get out of balance.

ESSENTIAL OIL RECOVERY

Essential oil recovery is an important part of the economic operation of a citrus processing plant. Roughly half is recovered in cold pressing, and the d-limonene half is recovered in the feedmilling operation. Without getting into the technology involved, it is worth defining the financial parameters.

d-Limonene recovery varies widely. With earlies and mids, it will range from .06 to .10 pounds per box, while with Valencias one can expect .18 to .30 pounds per box. It depends on the cold press operation, the loading on the WHE, and if a steam stripper is in use.

To keep this in perspective, it should be compared to the revenue stream arising from the sale of peel as animal feed. Normally nine and a half pounds of peel are sold per box of fruit. The price of d-limonene varies widely, but a representative recent figure is US$ 0.60 per pound, as compared to US$ 70.00 per ton of pelleted citrus peel. So if one considers a plant processing 6,000,000 boxes a season, the sale of pelleted peel will generate $2,000,000, while the sale of d-limonene will add some place in the neighborhood of $500,000.

These economics can assist in selecting the investments that are appropriate for feedmill operations.

PRESS MAINTENANCE

At the same time that presses have been designed for improved pressing performance, there has been a continuing effort to improve the maintenance characteristics of these same screw presses.

Probably the most fundamental change has been the greater use of stainless steel. In the early 1960's a pound of carbon steel cost $0.10, while a pound of stainless cost $1.00. Today this 10:1 ratio has changed to 5:1. A pound of carbon steel costs $0.25, while stainless steel goes for $1.25 a pound. The result is most citrus peel presses are now being specified with all contact parts made of stainless steel.

Another change has been the greater use of catalog components in manufacturing peel presses. At one time press manufacturers made their own air cylinders and the use of specialty bearings was common. Today the use of standard OEM components has greatly reduced the cost of press maintenance.

The advent of tighter pressing has led to other changes that reduce maintenance. Double shaft seals are now standard. Split screens are made to be easily removed. Chain and sprocket drives have given way to in-line planetary gear drives which eliminate overhung shaft loads. Support and guiding of the discharge cone has been improved. And hardfacing of the compression flights on screws is becoming more common.

Many changes have been made to simplify disassembly of the press and accessibility to various components. One consequence of this is that the standard citrus press has grown from 18' to over 22' in length.

DOUBLE PRESSING

No discussion of press technology would be complete without addressing the issue of double pressing vs: single pressing.

In single pressing, the peel is shredded and reacted with lime. The lime reaction, occurring in the delay conveyor, is improved by the addition of molasses. The pressing operation follows, and the press liquor is screened and pumped to the WHE, while the press cake, possibly with some surplus molasses added to it, goes to the dryer.

In double pressing this process is modified by adding a diffusion conveyor. In this conveyor some molasses is allowed to blend into the press cake from the first pressing. After a few minutes of diffusion time, the press cake is pressed once again. After this second pressing the press cake is sent to the dryer, while the additional press liquor is merely combined with the liquor from the first pressing.

The results of single and double pressing are seen in Material Balances Figures II and III. It has been generally accepted that about one and a half percentage points reduction in press cake moisture can be achieved, as shown. An improvement in plant thermal efficiency results from this reduction in press cake moisture. This is reflected in the cost of fuel required per ton of pelleted feed that is being produced. This cost reduction is generally sufficient to make an attractive investment of the addition of a diffusion conveyor and additional pressing stage.

However, the fuel savings, in general, are not sufficient to justify the cost of additional WHE capacity. This need appears in the WHE load figures on the Material Balances.

The fact that double pressing increases WHE load is probably the main reason that several plants have switched from double pressing back to single pressing. As the amount of fruit being processed increased, a point was reached where the WHE could no longer handle the load. Switching back to single pressing reduces WHE load and allows a plant to process more fruit than before.

Another consideration is the advent of the high performance screw presses. If it is possible to achieve 60% to 62% press cake moisture with single pressing, why make the additional investment required for double pressing? The answer is similar to the issue of converting to a pumped peel system: In the case of a greenfield installation, the investment analysis of the alternatives is direct and easy. But in the case of an existing installation, analysis based on incremental investment can lead to an entirely different answer.

OVERVIEW

It is clear that a great many technical changes are taking place that affect feedmill operations. These changes allow the achievement of plant efficiencies that have not been possible in the past.

At the same time the interdependence of the main components (the press, the dryer, and the WHE) mean that what is best for one feedmill will not necessarily be best for another.

The following steps are suggested for analysis:

1. The biggest single investment in the feedmill is the WHE. Therefore, the plant should be run so that every bit of available WHE capacity is being used.

2. The dryer must provide the quantity of high wet bulb gases that are needed to drive the WHE. This is a matter of matching the burner and dryer capacities to the WHE. (It has been noted that many dryers in Florida are operating with significant unburned hydrocarbons in the exhaust gasses; this represents a major opportunity to improve thermal efficiency.)

3. The liming, shredding, and reacting of the peel must each be adequate and proper so that the screw press can do its job.

4. The screw press should be set up to generate enough press liquor to keep the WHE loaded to its full capacity.

It is my hope that the information that has been presented will assist you in optimizing the performance of your own operation.