ACP CANE SUGAR REFINING

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Introduction

Some idea of the complexity of the process of converting raw sugar into marketable refined products can be gained by studying the process and chemical control system employed at Thames Refinery which is illustrated in Appendix I. The operation at Westburn Refinery in Scotland is similar but on a smaller scale. This is by no means the complete picture, for linked to the two refineries are two speciality liquid blending stations where some eighty different liquid blends, syrups, treacles and speciality products are made for the retail and industrial sectors. If judged in terms of input and output balance the process should be relatively straightforward.

Input	Output
Raw Sugar	Refined Sugar Products
	Molasses
Water	Effluent
Lime	Chalk
Bone Char	Bone Char

The complexity arises from the need to satisfy the market with so many products, although this happens to be one of the major strengths of a cane refiner, to extract the maximum amount of saleable sucrose from the raw sugar, minimising both the sucrose content of the molasses and the quantity sold, and to restrict process losses to an absolute minimum.

The fundamental aims of the refinery are listed in Appendix II with various factors, such as raw sugar quality, plant capacity and operational efficiency, which could limit the achievement of the objectives.

The main product groups sold on the retail and industrial markets are shown in Appendices III and IV. There are so many products because obviously there is a need in the market, which Tate & Lyle Refineries have developed by capitalizing on the acceptable and often desirable properties of the cane flavour impurities entering the refinery with the basic raw sugar. To secure that market and to meet the objectives, the refineries need a steady supply of uniform quality raw sugar throughout the year.

The Refining Process

The refining process, if limited strictly to the conversion of raw cane sugar to a high quality white product, as defined in Table 1, is undertaken in four main stages.

Table 1.

AVERAGE ANALYSIS OF RAW AND REFINED SUGAR
THAMES REFINERY

PERCENTAGE	RAW SUGAR	REFINED SUGAR
SUCROSE	97.73	99.950
INVERT	0.56	0.006
ASH	0.45	0.007
ORGANIC	0.62	0.014
MOISTURE	0.64	0.023

1. Affination: is designed to separate the outer layer of impure syrup from the purer crystal.

2. Defecation: the affined crystal is dissolved or melted and subjected to clarification or filtration designed to remove any solid material imported with the raw cane sugar together with bulk inorganic and organic impurities.

3. Decolourization: the clarified liquor requires to be decolourized further if the desired yield of high purity white sugar is to be achieved. This is accomplished by passing the liquor over beds of active adsorbent.

4. Crystallization: where pure white sucrose is extracted from the decolourized liquor.

The sequence for the removal of impurities is shown in Table 2.

TABLE 2.

REMOVAL PATTERN

% Removed

Analysis	AFFINATION	DEFECATION	DECOLOURISATION	CRYSTALLISATION
INVERT	66	18	7	93
ASH	67	20	9	91
ORGANIC	73	13	14	87
COLOUR	66	50	85	85

1. AFFINATION

Raw sugar is composed of a layer of impure syrup surrounding a fairly pure crystal. Not all impurities are contained within the syrup layer. Some are occluded within the basic crystal and some are trapped between agglomerated crystals. Affination is designed to separate the syrup from the crystal as effectively as possible with minimum dissolution of the underlying crystal. The objective can be defined as impurity removal and is illustrated in Table 3 which shows typical analyses of raw and affined sugar.

TABLE 3.

IMPURITY BALANCE ACROSS THE AFFINATION PROCESS

ANALYSIS	RAW SUGAR	AFFINED SUGAR	PURIFICATION %	AFFINATION SYRUP
% SUCROSE	98.45	99.52		87.5
% INVERT	0.50	0.17	66	5.0
% ASH	0.45	0.15	67	3.5
% ORGANIC	0.60	0.16	73	4.0
COLOUR,ICU'S	2000-6000	700-1500	66	24000

The process is shown in Appendix V. Raw sugar is mixed with raw syrup at a controlled temperature and brix, in the ratio of two parts sugar to one part syrup, to produce a fluid magma. The magma is mixed for 15 to 20 minutes to loosen the syrup layer before being fed into automatic batch centrifuge machines with perforated baskets which retain the sugar when spun, but allow the syrup to pass through. At the appropriate stage in the spinning cycle wash water is applied as a fine spray to the wall of sugar in the basket. The amount of water used depends on the quality of the raw sugar being processed. Raw sugars containing a high proportion of small crystals are difficult to affine because:-

(a) they blind the machine cloths
(b) more crystal is dissolved during the washing procedure
(c) the machine charge is about 25% less than for large grain sugar.

The quality of input raw sugars is very variable as can be seen in Table 4.

TABLE 4

VARIABILITY OF RAW SUGARS

	RAW SUGAR			
ANALYSIS	1	2	3	4
% SUCROSE	95.63	98.55	96.13	97.53
% INVERT	1.19	0.33	1.43	0.89
% ASH	0.79	0.35	0.51	0.46
% ORGANIC	1.63	0.45	1.08	0.60
% MOISTURE	0.76	0.32	0.95	0.52
COLOUR, ICU's	7272	2588	5450	4831

Some idea of the size of the Thames operation can be gained from the fact that the two magma mixers are each 16m long and 1 $^3/_4$m deep and have a working capacity of about 25 tonnes. The centrifuge battery consists of 20 machines each capable of producing about 400kg of affined sugar at a minimum cycle time of 160 seconds.

2. DEFECATION

The affined sugar still contains a high proportion of soluble impurities and the affination stage is ineffective in removing insoluble or solid material contained in, or imported with the raw material. Defecation or clarification is designed to remove in particular the solid impurities. Original defecation processes involved simple filtration but this proved costly and inefficient.

Modern refineries now employ either phosphatation, flotation clarification or carbonatation. In phosphatation, calcium phosphate formed in the dissolved or melted affined sugar liquor by the addition of lime and phosphoric acid, can, in the presence of suitable additives and with aeration, be floated to the top of the liquor. The scum formed traps all insoluble materials and when scraped off leaves a clear clarified liquor.

In carbonatation, lime is added to the melter liquor. It is then neutralised with carbon dioxide available in boiler flue gas. The resulting chalk formed is then filtered off to yield a bright clear liquid. Carbonatation is more efficient than phosphatation as illustrated in Table 5, and is employed at both Thames and Westburn.

TABLE 5.
REMOVAL OF IMPURITIES BY CARBONATATION AND PHOSPHATATION

% COMPOSITION	MELTER LIQUOR ANALYSIS	CARBONATATION ANALYSIS	LIQUOR % REMOVAL	PHOSPHATED ANALYSIS	LIQUOR % REMOVAL
SUCROSE	99.52	99.60		99.57	
INVERT	0.17	0.14	18	0.15	12
ASH	0.15	0.12	20	0.14	7
ORGANIC	0.16	0.14	12	0.14	12
COLOUR ICU's	1200	700	42	800	33

A typical carbonatation system is shown in Appendix VI. Raw melter liquor at 75°C and 69°Bx is dosed with milk of lime to a level of 0.4 to 0.8% CaO on liquor solids, depending on the quality of the raw sugar. The limed liquor is then passed through a series of tanks through which the washed flue gas containing carbon dioxide is passed. Using the chalk as a filter aid, the carbonated liquor is filtered through a battery of twenty Sweetland presses. Each press contains 72 x 0.9m diameter leaves giving a total press area of $95m^2$ and a station area approaching $2000m^2$. At the end of each press cycle the press mud is desweetened to minimise sugar loss before disposal.

3. DECOLOURIZATION

The liquor now free from insoluble impurities is suitable for decolourization. The objective of decolourization is simply to decrease the colour of the pressed liquor to a level whereby maximum white sugar can be crystallised from it. The performance of the existing station at Thames is shown in Table 6.

TABLE 6

DECOLOURIZATION

% COMPOSITION	BEFORE	% AFTER	REMOVAL
SUCROSE	99.60	99.64	
INVERT	0.14	0.13	7
ASH	0.12	0.11	17
ORGANIC	0.14	0.12	14
COLOUR	400-700	80-100	90

Refineries have a choice of three basic processes.

Bone charcoal and granular activated carbons are solid adsorbents which can be regenerated at high temperatures. Ion-exchange resins are gaining more widespread use and are regenerated by chemical treatment. As such, this process can be adapted to automatic operation and control. Thames still employs bone char as its decolourizing adsorbent and the process is illustrated in Appendix VII. The char is contained in 32 x 3m diameter pressure vessels each holding about 25 tonnes of material. The pressed liquor is passed through the char under pressure until the activity or capacity of the char for further colour removal is unacceptably low. At this stage the cistern is desweetened and the char transferred to a multihearth rotatory kiln where it is heated to about 550°C to pyrolise the adsorbed organic impurities. After this regeneration process it is returned to the cistern for decolourizing duty.

4. CRYSTALLIZATION

The decolourized and purified liquor is now of sufficient quality to enable three strikes of white sugar to be boiled from it. The process is illustrated in Appendix VIII and the degree of purification achieved is shown in Table 7.

TABLE 7

CRYSTALLIZATION

% COMPOSITION	BEFORE	% AFTER	REMOVAL
SUCROSE	99.64	99.967	
INVERT	0.13	0.009	93
ASH	0.11	0.009	91
ORGANIC	0.12	0.015	87
COLOUR	40 - 100	12	85

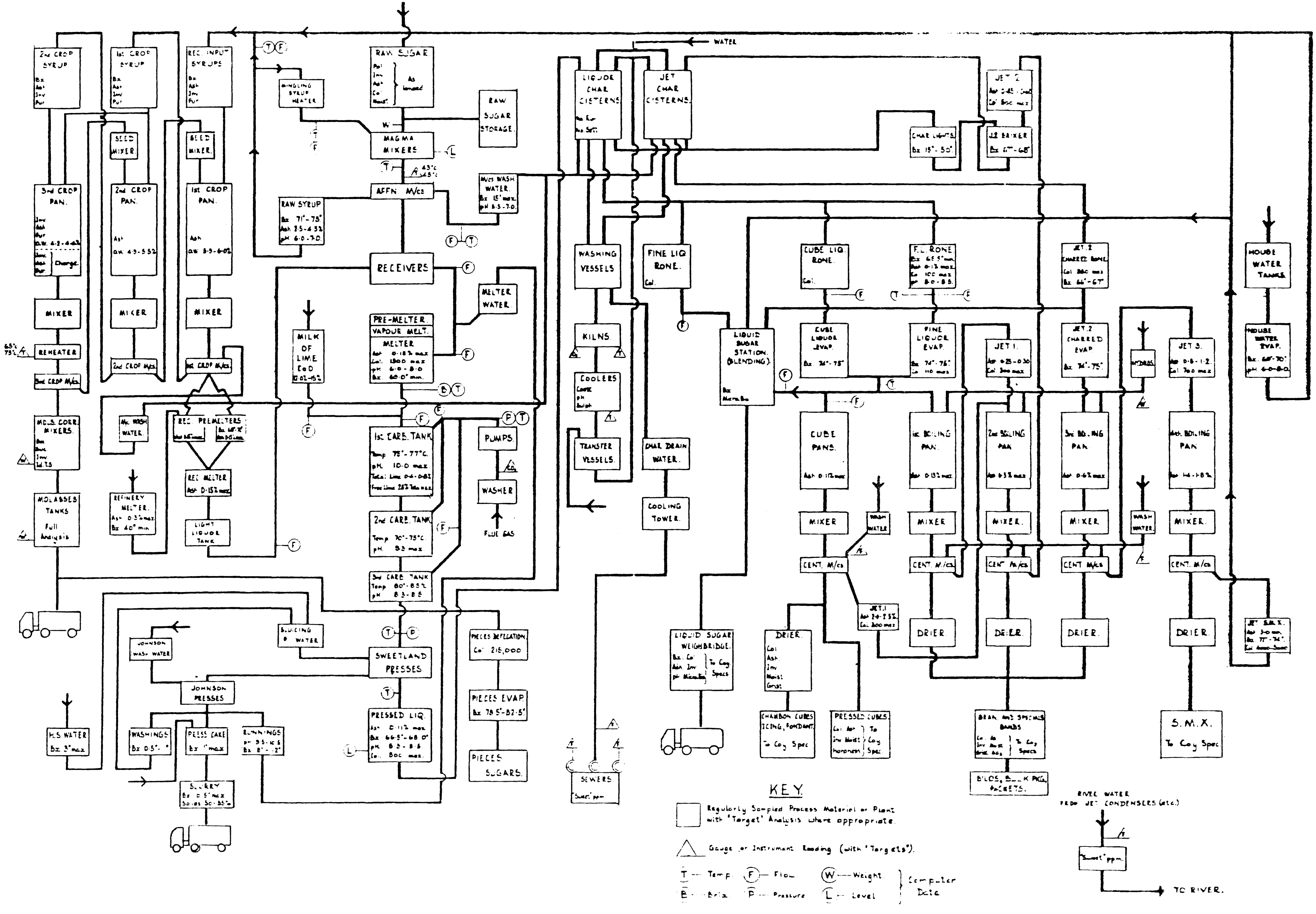
The process of crystallization is common to both cane sugar factories and refineries. At Thames a three boiling white sugar system is operated with each of the boilings from fine liquor, Jet 1 and Jet 2 respectively geared to produce the same uniform sugar quality. Thames have four main pans each capable of producing about $85m^3$ of masse. The pans are charged with a volume of $35m^3$ of evaporated fine liquor or jet. This charge is boiled or evaporated under vacuum to a 1.1 degree of supersaturation. This determines the driving force for crystallization.

The pan is then seeded with milled icing sugar, the theory being that each milled sugar particle acts as a nucleus or centre for subsequent growth to the appropriate sugar crystal size. Conditions within the pan are controlled to generate sucrose deposition whilst the pan is being fed with additional liquor, the rate being governed by the rate of water evaporation. At the end of the cycle the feed is shut off and the masse is boiled down to give a high yield sucrose. The masse is then discharged to mixers where it is lubricated with syrup to give it the necessary fluidity for centrifuging.

During centrifuging, undertaken on 16 automatic machines, the sugar is washed with hot condensate to achieve the correct crystal colour specification. The liquor spun off the first boiling is called Jet 1 and this forms the feedstock for the second boiling. The syrup from the second boiling, Jet 2, forms the input feed for a final third boiling. The jet produced from this boiling is too impure to yield a further strike of white sugar but it can be used to produce a lower grade manufacturing sugar and as an input for liquid sugar blends and syrups.

The final parts of the operation in producing white sugar involve the drying, cooling and conditioning of the sugar prior to its packing or bulk delivery to industrial customers.

THAMES REFINERY
PROCESS AND CHEMICAL CONTROL SYSTEM



APPENDIX II

REFINING AIMS

TO MAXIMISE THE YIELD OF HIGH VALUE

REFINED PRODUCTS AT MINIMUM COST

1. HIGH YIELD OF CRYSTALLINE WHITE SUGAR
   RAW SUGAR QUALITY - EFFICIENCY
   PLANT CAPACITY

2. HIGH YIELD OF "CANE IMPURITIES"

   INDUSTRIAL SUGARS
   LIQUID SUGARS
   BROWN SUGARS
   SYRUPS
   TREACLES

   PLANT CAPACITY/ABILITY - MARKETING SKILLS

3. LOW OUT-TURN OF MOLASSES

   RAW SUGAR QUALITY - EFFICIENCY -

   SALES OF LOW END PRODUCTS

4. MINIMUM SUGAR CONTENT IN MOLASSES

   RAW SUGAR QUALITY - EFFICIENCY

   CHEMICAL DEGRADATION
   MICROBIAL SPOILAGE

5. MINIMUM SOLIDS LOSS IN PROCESSING

   EFFICIENCY

   PHYSICAL LOSSES - SEWERS, PRESS MUD ETC.,

   PHYSICAL DESTRUCTION - KILNS.

APPENDIX III

T.L.R. MAIN PRODUCT GROUPS

RETAIL

WHITE	GRAN
	CASTER
	ICING
	CUBES
BROWN	DEMERARA
	LIGHT
	DARK
SYRUPS	GOLDEN
	DARK
	TREACLE

APPENDIX IV

T.L.R. MAIN PRODUCT GROUPS

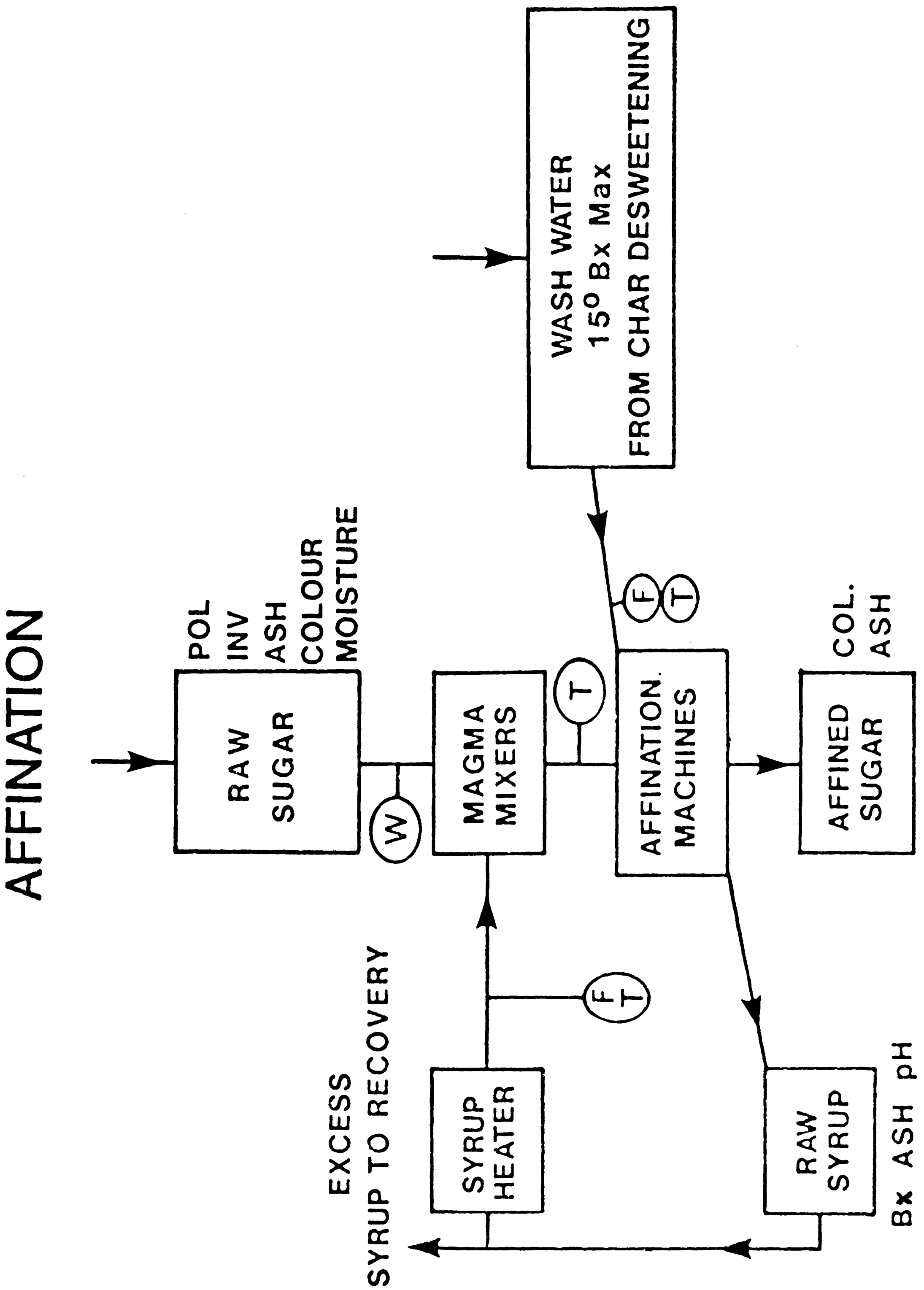
INDUSTRIAL - DRY

WHITE	GRAN
	PRESERVING
	TWO'S
	FINE
	SUPERFINE
	EXTRA FINE
	CASTER
	ICING
SEMI-WHITE	SMX
BROWNS	FOURTHS
	DEMERARA
	PRIMROSE
	DARK PIECES

INDUSTRIAL - LIQUID

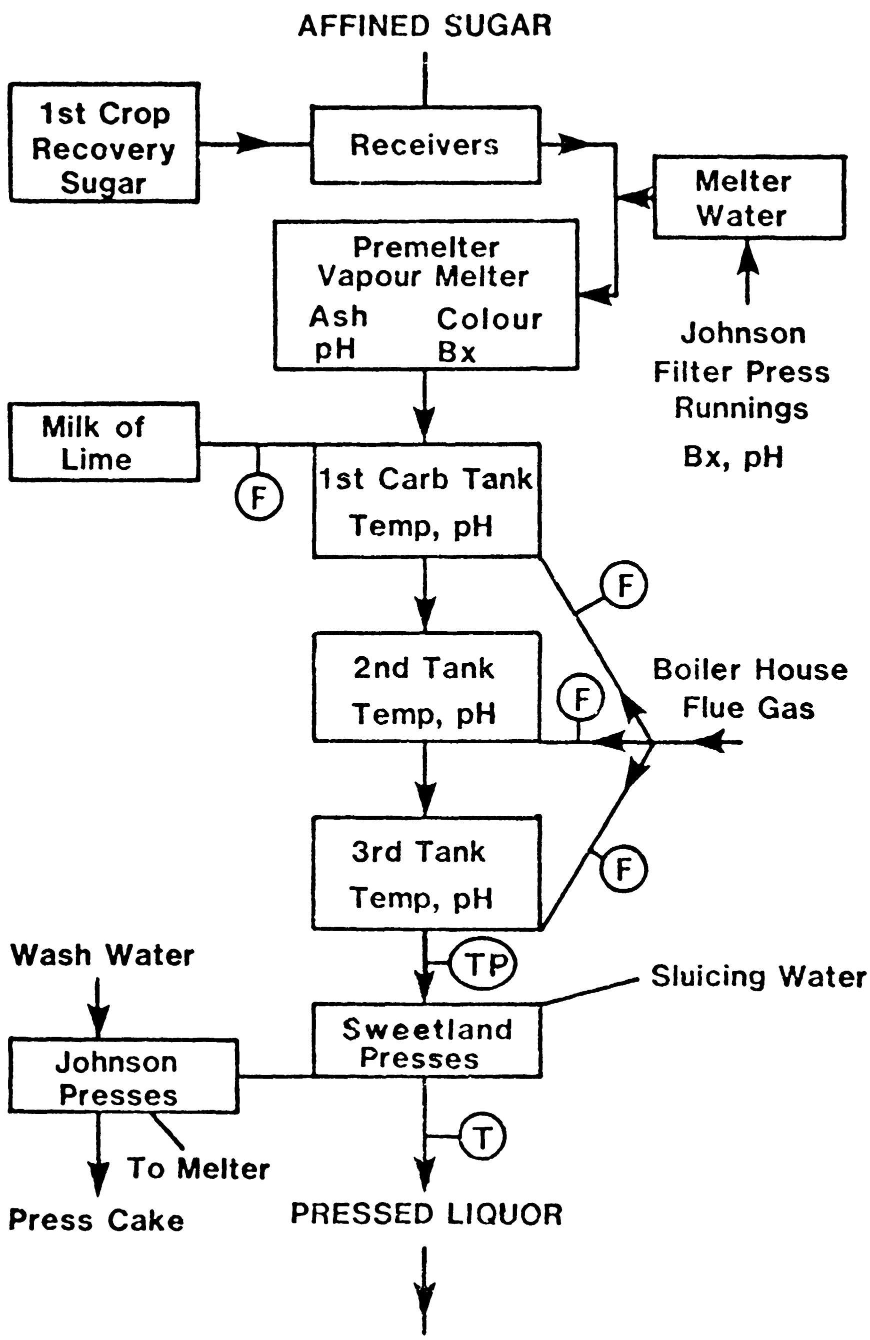
LIQUIDS	T.1000	MWS
	1001	GRAN
	2000	FINE
	2800	JET BLENDS
	3000	
	3302	
	7000	
BLENDS	80	DIFFERENT

APPENDIX V


AFFINATION
RAW SUGAR
POL
INV
ASH
COLOUR
MOISTURE
W
MAGMA MIXERS
T
AFFINATION MACHINES
F
T
WASH WATER
15° Bx Max
FROM CHAR DESWEETENING
AFFINED SUGAR
COL.
ASH
F
T
SYRUP HEATER
EXCESS
SYRUP TO RECOVERY
RAW SYRUP
Bx ASH pH

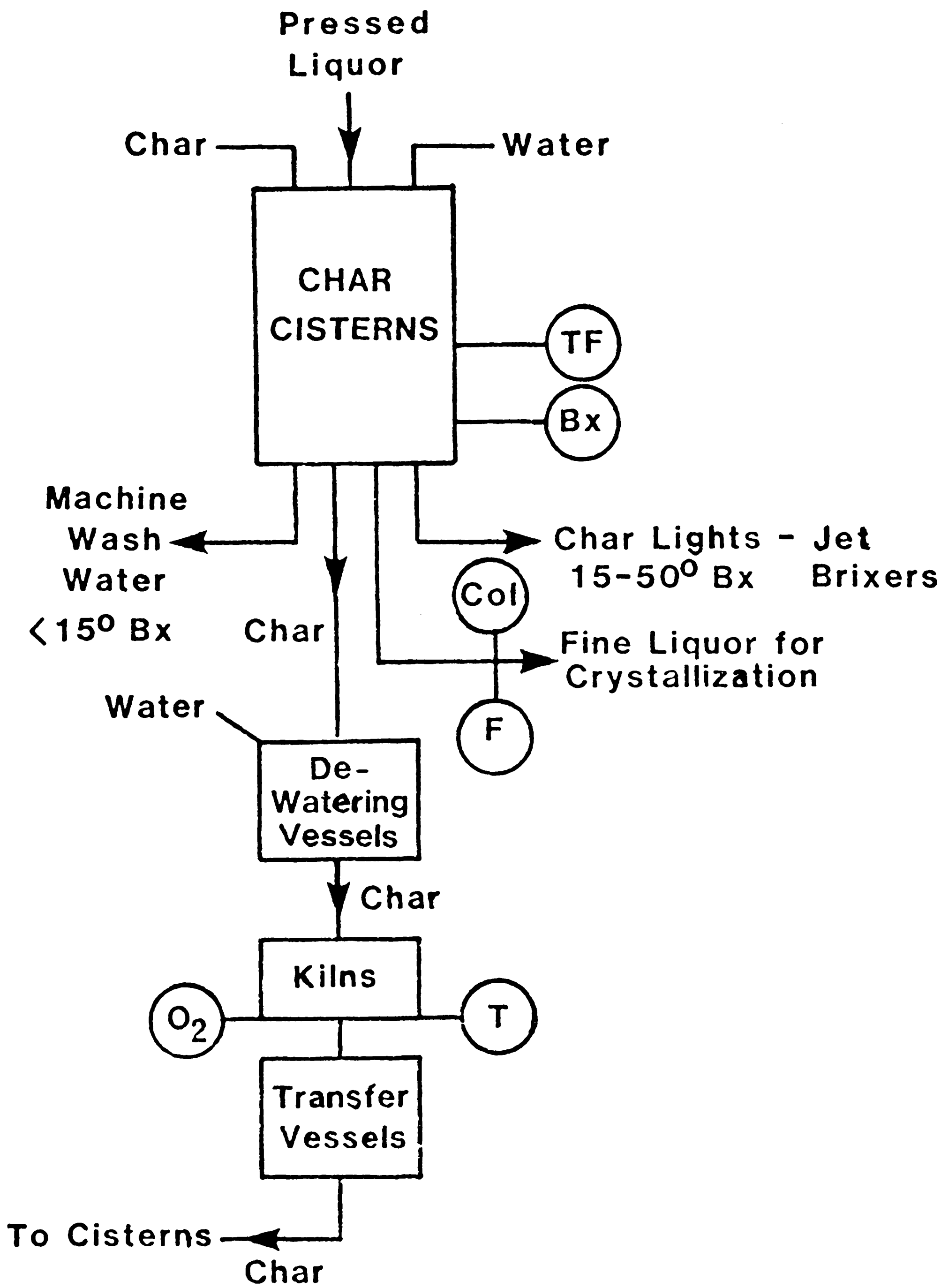
APPENDIX VI

CARBONATATION



APPENDIX VII

DECOLORISATION



APPENDIX VIII

CRYSTALLIZATION