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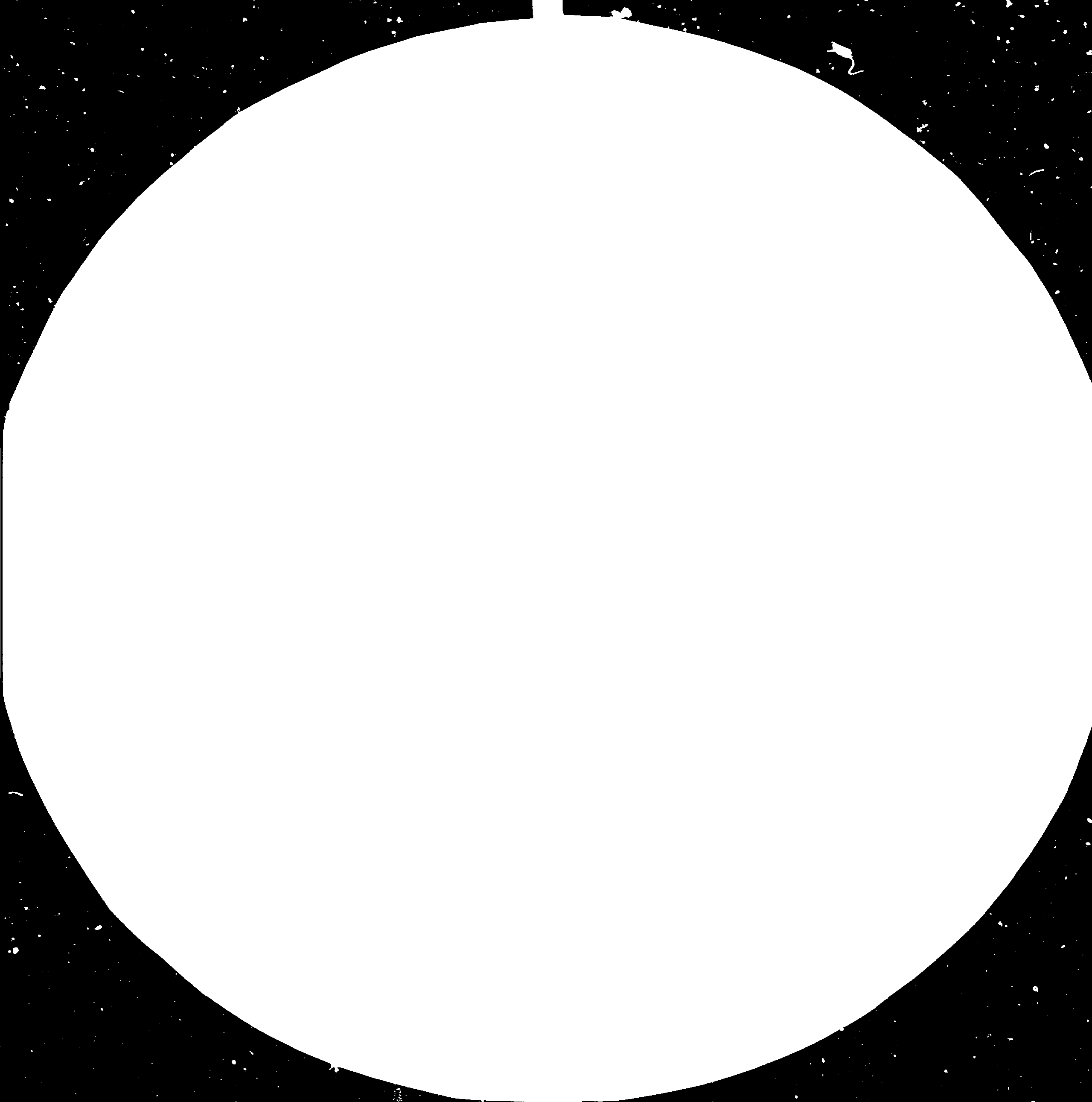

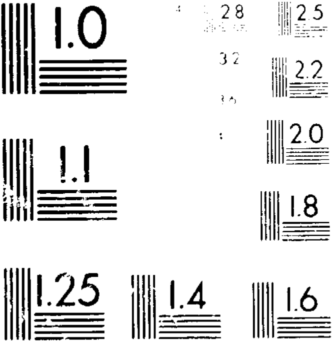

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DP/ID/SER.A/515
29 May 1984
English

NATIONAL CANE SUGAR INDUSTRY RESEARCH CENTRE

DP/CPR/82/005

CHINA

Technical Report: The National Cane Sugar Industry Research Centre
Seminar on Cane Sugar Technology *

Prepared for the Government of China
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Margaret A. Clarke,
Expert in Colourants in Cane Juice

United Nations Industrial Development Organization
Vienna

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CONTENTS

GOALS OF VISIT

The goals of the project, as outlined by UNIDO's job description, were to furnish detailed information and research activities on the new analytical methods for certain minor constituents that contribute to sugar color; to facilitate the capability in the research work of the Chinese sugar industry with respect to improvements of the quality of sugar products, and operation of the current processes of clarification and to develop new processes.

The general goals, as amplified by personnel of the Ministry of Light Industry and the Cane Sugar Research Institute after the arrival of Dr. Clarke were as follows:

1. To develop processes to make a high quality, industrial grade sugar, comparable to international standard, for a certain percentage of production.

2. To increase the yield of sugar produced from land currently in cane production, and existing factories.

3. To increase the capacity of current equipment in existing factories.

4. To propose research projects designed to achieve the above goals.

These research projects are to include work on identification of sugar colorants and non-sugar components that affect quality and yield.

ACTIVITIES DURING VISIT

The group of visitors included Dr. J.C.P. Chen, Dr. C.C. Chou and Dr. T.T. Chao (TOKTEN experts) as well as Dr. Clarke. The four visitors shared responsibilities for talks during the seminar on cane sugar. Visits to the Institute by Dr. Clarke on December 13 and 14 were spent discussing analysis by HPLC, optimization of current equipment, development of new techniques, analysis of sugar colorant and inorganic components, test procedures and control systems done by the Institute for the industry, byproducts utilization and personnel training programmes.

The First Seminar on Cane Sugar Technology in China, the focal point of the visit, was remarkable for the fine planning on the part of the organizers, and their ability to adapt plans where appropriate (e.g. to arrange additional visits to the Institute), and for the enthusiasm and preparation of the delegates, who had familiarized themselves with the publications and areas of expertise of the visitors in order to gain maximum information. Three hundred delegates were present. Delegates were top technologists from all over China, including some beet sugar technologists from the Northern Provinces. Faculty members of Institutes of Technology (e.g. the South China Institute of Technology in Guangzhou) were also delegates. This Seminar was the first national meeting of the sugar industry of China, a significant event in an industry so geographically divided, and a worthwhile achievement for progress of the industry.

OBSERVATIONS

General Observations on the Sugar Industry In China.

Total sugar production in China in 1982-83 was some 3.8 million metric tons, of which 3.1 million tons were cane sugar. Beet sugar is produced in the northern provinces of Heilongjiang, Jilin, Neimong and Xinjiang, and will not be discussed in any detail in this report. Cane Sugar is produced in nine Southern provinces: Guangdong, Guangxi, Fujian, Yunnan, Sichuan, Jiangxi, Zhejiang, Hunan and Kweizhou. The first four of these produce about 90% of the total sugar, and Guangdong province alone produces about 50% of the total: 1-49 million tons in 1982-83. Sugar production has expanded in recent years at a remarkable rate (figures from China Daily, October 16, 1982, except for 1982-83 figures):

Years	Total sugar production
1978-79	2.5 million tons
1979-80	2.5
1980-81	3.0
1981-82	3.4
1982-83	3.8

Of this total, most (over 90%) of the increase has been in cane sugar production. China consumes now almost 5 million tons of sugar per year (4 to 5 kg per capita), importing 1 million tons of raw sugar from Australia, Brazil and Thailand. This raw cane sugar is refined in cane sugar factories during off-season for cane grinding.

The general production of sugar is plantation white, directly produced from cane juice using sulfitation and settling clarification or carbonatation. Raw sugar is refined by the same processes.

In addition to the white sugar production, there is some half million tons of brown sugar (called "red" sugar) produced, most of it by rather small factories, and in slab form. This is a highly popular product.

The total number of factories proved difficult to estimate. In the entire industry, there are some forty factories that grind over 1000 tons cane per day, about half of which grind over 2000 tons per day. In Guangdong province, ten to twelve factories grind over 3000 tons per day. There are over two hundred small white sugar factories grinding less than 1000 tons per day.

Equipment for factories is generally made in China, along the lines of equipment acquired from abroad before or since the Cultural Revolution. A lot of equipment is old, but there is a large labor force for maintenance, and new equipment is required for expansion rather than replacement, as the process has not changed a great deal over the last thirty years.

The grinding season begins in late November (it began later in 1983 because of typhoons earlier in the year) and continues into March.

Most cane is grown on small plots of land, by individual farmers. Cane is a popular cash crop, because excess cane be produced over quota and sold for cash. All cane is plant cane for first ratoon, no further ratoon crops are made. Total land to cane in 1981-82 was over half a million hectares.

Fertilization is by organic matter. Essentially all cane is hand harvested.

Byproduct usage is intense: molasses goes to alcohol and yeast production; bagasse to paper, board, pulp and furfural production; filter muds and other waste go to fodder. Because of the requirement for bagasse as fiber, coal is the fuel for 50-60% usage in factories.

The production of sugar is controlled by the Ministry of Light Industry, that is, purchase of cane and raw sugar, and, production and marketing of sugar are under this Ministry. Production of cane is under an agricultural ministry.

Research for the industry is conducted at the Cane Sugar Research Institute of Guangzhou, the major research institute, for processing and agricultural research, in China. There are other sugar research institutes in Yunnan and Guangxi provinces. There has been formed, some three years ago, a national society, the Chinese Society of Sugar Cane Technologists, and provincial societies have been formed, now that communications across the nation have been resumed. The seminar held during the author's visit, sponsored by the Cane Sugar Research Institute and the Ministry of Light Industry, was the first nationwide seminar on sugar technology in China.

The major problems in the sugar industry that affect the goal of increased production (to 10 million tons by the year 2000) are as follows:

1. Development of acreage for extension of cane production. All available flat land with rich soil is in use, and varieties, agronomic and harvest practices must be developed for hilly areas with sandy soils.

2. Improvement of quality of cane delivered at mills. A cane quality sampling program, now begun in Guangdong, is imperative. Cane has been paid for on a weight basis only, and old, soaked cane, representing high sugar losses and processing difficulties (high fuel usage), is delivered. There is the possibility of 3% to 10% increase in production here.

3. Increase in production at mills, using current equipment, is inhibited by the fuel and equipment intensive (with high sugar loss) system of boiling a very large grain sugar, overwashing it, and steaming to dry. There is the possibility of 2% to 8% increase in production here.

4. Requirement for a better quality of sugar produced (about 350,000 tons) for industrial buyers e.g. soft drink industry, pharmaceutical manufacturer, with minimum capital investment or change in process.

5. Variety development program oriented toward disease resistance. Little information appeared available about field losses to disease and pests.

CANE SUGAR RESEARCH INSTITUTE, GUANGZHOU

The Cane Sugar Research Institute of Guangzhou, founded in 1958, employs a total of 700 workers, including those at three experiment farm stations as well as at the Institute itself. The stations are at Hainan Island (where cane breeding is carried out, in the more tropical climate there), Hangjiang, and at Guangzhou, near the Institute.

Departments and Personnel

The four main departments of the Institute are:

1. Sugar Processing (39 technical people)
2. Automation and Instruments (20 technical people)
3. Byproducts utilization and Environmental Protection (25 technical people)
4. Analysis, Measurement and Testing (10 technical people)

There is also an Industrial Division, for factory consultation, with 7 senior engineers. When graduates from colleges or technical training schools are assigned to the Institute by the Ministry of Light Industry, they must first spend a year at a factory to gain practical experience before beginning work at the Institute.

Director of the Institute is Prof. Tsien-Ming Wang; Associate Directors are Mr. Shi-Zhi Chen (Sugar Technology); Mme. Bao Guo-Yu (Byproducts and Environmental Protection); Mr. Kuo-Chin Deng (Engineering), and Administrative Director Chang. With regard to titles: Ph.D. degrees are not used in China, and have not been awarded for some years. The author was informed that the degree is being reinstituted in some universities. The Master's degree has been the highest degree available.

Areas of Research

The major areas of research, as outlined by Mr. Shi-Zhi Chen are as follows. Several have been indicated to be projects of national importance by the Ministry of Light Industry. Some comments are included by this author.

1. Energy saving, a national project. Currently, factories burn both coal and bagasse in about 2:1 ratio (because bagasse is valuable as a fiber source and coal is supplied under a support price). Average burn is 7% coal on cane; best is 6.05% (at Chiangmen).

The objective is to reduce burn to 5.5% coal on cane, saving some 15,000 tons of coal. Approaches are:

a) to insure that all factory boiler instruments are adjusted for accuracy and uniformity.

b) to utilize all exhaust steam, including that from the last effect. Most factories currently use five effects, with the first effect on low pressure steam. The plan is to raise steam pressure for the first effect and to cut back to a triple effect system to increase recovery of high pressure steam.

At present, exhaust vapor is used for A, B and C boilings, and because of the low pressure, a long pan time is required (see section on Factories).

2. New processes for white sugar production, to improve the quality of the product. The Blanco Directo process, about which this author informed the Institute, was of especial interest in this respect. A concomitant goal in this area is reduction of pan scale during production.

White sugar produced under the current system is suitable for household use, but not for industrial use. Other processes under investigation for production of white sugar without sulfitation include:

(1) use of flocculants, phosphoric acid and aeration. This type of syrup clarification is in current use at factories visited.
(2) clarification at high pH to remove colloids (but create heavy muds to treat)
(3) production of a high quality juice with only 0.3 to 0.4% lime on juice (technique unclear).

Removal or reduction of sulfitation will, of course, lower pan scale formation.

3. Quality control of cane entering mill, and cane payment based on sucrose content. Historically, cane had been bought on weight alone, regardless of quality. Growers would soak cane in water to bring up weight (increasing deterioration severely) and sell old, stale, wet cane. Some mills, in cooperation with the Institute, have started sampling cane and testing it for sugar. The problems in sampling so many small deliveries are complex. One approach is to remove cane from the load (selection method is a problem), grind it, and measure juice sugar. Another is to grind cane in the mill, time the interval between cane into mill and juice appearance, and measure sugar in the crusher juice. The second approach can only be used at mills with one weigh table. Two weigh tables dump cane into the mill in no fixed order, making a timing sequence impossible.

These first quality payment systems are using a single pol measurement (following an acid inversion) to measure sucrose, whereas factory control procedures use a double pol measurement on crusher and mixed juices (although this is not actually in use, and only single pol is run).

The Institute is constructing cutter-grinder machines, to be used in conjunction with a press, for extraction of juice from sample cane, and is experimenting with various cycle times to determine the point of extraction equilibrium to be used. Moisture in cane is determined by a microwave oven procedure, with measurement of weight loss. Water added to cane gives a problem here.

4. Waste stream treatment at alcohol plants, a national project. Alcohol distilleries are each connected with a sugar factory. The usual problem of stillage treatment is a problem here too. The Institute has a project on concentrating stillage up to about 60 Brix, using vapour bleeding in the distillation process. The decision then remains: to use the concentrate as feed additive or fertilizer, or to burn it. A trial on burning at Guangxi factory showed that concentrated stillage had to be mixed with coal to give a satisfactory burn.

5. Particle Board production from bagasse, a national project. A pilot plant is in operation at the Institute, which tests bagasse size separation, drying and blending with various resin combinations. There are 3 medium

density particle board plants now operating in China. In 1982, 3500 cu.m. of particle board was produced in China. The multi-plater press techniques is apparently used in all plants. Density is 0.65-0.75 g/cm^3. Bagasse is the sole fiber used, however, and requires the high percentage of 8 to 10% urea formaldehyde (expensive) resin for binding. This high level of resin lowers the strength and weather resistance of the board. It also requires that the bagasse be dried to 6 to 8% moisture. Research is in progress on blending bagasse with other fiber available in China to make stronger board with reduced resin content. Other research on manufacturing a three layer board to produce mat rial suitable for furniture is in progress.

A division of the Institute is devoted to research on particle board. A separator (for bagasse) has been developed, operating at 2t/day. Blending and pressing equipment has also been built, and testing machinery is available. The separator, an S-style, collects the 24-45 mesh fraction (87%) for board manufacture.

The lack of forest resources for wood, and of petrochemical supplies for plastics, make this byproduct use for furniture production particularly important here.

6. Dextran analysis and control in the factory. Dextran, a product of microbial infection on cane (increasing with staleness of cane) and in juice is a problem because of both sucrose loss to dextran and processing problems from dextrans. In the second half of the season, when ambient temperatures rise, dextran contamination (and sugar loss) is most severe, and "cane rice" (whitish solid masses of microorganisms) appears in factories. Dextran is also found in beet factories (unusual in the rest of the world), in limed juice at pH 6.2-6.5, because temperatures, by February, can be hot during the day, although freezing at night, so that stored beets do not remain frozen. Amounts of formaldehyde required for treatment are under investigation.

The Institute, recognizing the problem of contamination across the mill, has started a hygeine program of washing mills down with chlorine water, but has encountered difficulties with factory personnel.

Investigation into dextran analysis, using the Roberts Method developed at S.P.R.I., are examining causative factors and problem areas of dextran production.

7. High Performance Liquid Chromatography is currently in use as a technique for sugar analysis at the Institute. The Institute is finding problems with stability of the instrument, because of the requirement that electricity be shut off each night. (See Recommendations). Another instrument is required for routine sugar analysis so that the current instrument may be used for new projects e.g. organic acid analysis; colorant analysis. The Institute has good accessories for the current systems.

Sample preparation is also a problem (see Recommendations).

8. Use of molasses as feed for cattle production. Development of an optimal dairy cattle feed (for the large dairy farms at Kuamin, near Hong Kong, that supply 60% of the milk for Hong Kong) using bagasse + molasses + nitrogen source is in progress. A current problem is the nature of the equipment required to mix molasses with hydrolyzed bagasse.

9. In addition to the research program, the Institute functions as a central analytical laboratory for the factories in Guangdong, and maintains quality control for the industry. Factories themselves regularly run pol, reducing sugars and moisutre on the sugar produced. Daily samples are kept at the factory and mixed. A sample (of about 5 kilos) is submitted to the Institute for season's average analyses, for pol, reducing sugars, ash, moisture, colour, turbidity, insolubles, grain size (M.A., C.V.), and lead, arsenic, copper and sulfur dioxide. Tests are all run by ICUMSA Methods. An additional analysis on colour is reported in Stammer units; these units are now seldom used elsewhere. Lead, copper and arsenic are the inorganic elements with restricted levels specified by the Codex Alimentarius.

Results from these tests were used some three years ago to set up standards for production. These standards must be met by the factories, or the annual bonus for quality of product cannot be awarded. The standards are one incentive to monitor quality of production, but also a deterrent to change, under the current bonus system. The conflict presented by maintenance v/s improvement is difficult under current conditions of change. The maintenance of this quality may also be a factor in the factory contribution to decreasing yield of sucrose on cane observed in the last three years.

The Institute has played an important role in establishing quality standards for the various grades of sugars produced in China. These are as follows:

		Superior	Grade A	Grade B	Brown Grain
Sucrose (pol %)	>	99.75	99.65	99.45	89 (total sugar)
Reducing Sugars %	<	0.08	0.15	0.17	
Ash %	<	0.05	0.10	0.15	
Color (Stammer)	<	1.00	2.00	3.50	
	(about	80 ICUMSA)			
Insolubles, ppm	<	40	60	90	250
Water %	<	0.06	0.07	0.12	3.50

10. Additional future projects include investigation of the treatment of B-molasses with ion-exclusion: This project at first appeared unlikely to the author because ion-exclusion is an expensive (intensive use of ion exchange resin) and inefficient way to remove sucrose from cane molasses. But when the plan was explained, it appeared quite sensible. Ion-exchange resins are manufactured in China and so supply is not a problem. By returning sucrose to the B massecuite, concentrating reducing sugars in the molasses, most C-boilings (except a high C massecuite) will be eliminated, so that steam and equipment time are saved and the net effect is an increase in the capacity of the current equipment.

Extraction techniques for the smaller mills are under investigation, particularly the cane disintegration plus intense washing technique developed by Honiron (Farmer, ISSCT, 1974 pp. 1719-1935). Under consideration is a combination of Tilby separator-type apparatus, which derinds the cane, with disintegration for the center stalk. This proposal has several advantages: the longer fibers found in the rind are sepaated from the shorter pith fibers, for use in board manufacture. Although about 5-10% of the total sugar will go to the rind fraction, removal of sugar from pith is much easier (requires some 30% lessenergy), more complete (97-98% extraction) and yields a much cleaner juice than from whole cane. The major problem with derinding equipment is feeding cane to it so that blockage and/or knife breakage are infrequent. The availability of labour at Chinese factories can insure good feed. The small size of this type of equipment (10 to 20 tons per hour) is best suited to smaller factories.

Coordination and organization of projects in processing and agriculture:

Several of the research projects on processing are dependent on agricultural factors: cane quality payment systems, dextran control and stillage treatment. The overall goals of increased sugar yield, current factory capacity and development of new proceses are dependent on cane quality, solely an agricultural area.

The Institute is fortunate in that agricultural research is carried out in the same building as processing research, and that there can be exchange of information between agricultural and processing personnel. However, there appears to be no system for planning of joint research projects between agricultural and processing scientists. In areas such as variety development, disease control, agronomic practice, harvest practice, and cane deterioration, such joint planning is essential.

This problem exists not only in research, but throughout the industry. For the last three years, percent sucrose in cane as delivered at the factory has decreased, from the 14.02% figure of the top 1973/4 season.

1980-81	13.59%
1981-82	12.68%
1982-83	11.73% (yield of sugar 10.05%)

The sucrose percent cane in the field has remained the same. (The decrease in recovery at factories because of new mills with inexperienced personnel will be referred to later.) Industry and Institute personnel are aware that cane grower practices such as watering down cane, and adding trash and field soil to cane bundles to increase weight have distorted the "weight of cane delivered" factor so that the sucrose % cane figure is not a true reflection of the situation. These practices, particularly holding and wetting cane after cutting, also lower the actual level of sucrose in cane as it arrives at the factory. The diversion of authority between agriculture and industry at the factory gate, extending into research areas, makes control of these delivery problems difficult. Development of the cane payment system based on cane quality is a good solution, made very difficult by the diversity of cane delivery systems. Cane quality, and the amount of recoverable sucrose, are directly dependent on agricultural practice. Work on cane breeding, fertilizer practice, irrigation, field size and shape and cane spacing must be coordinated with processing to be meaningful.

Coordination of field and factory practice is always a problem, but here, where there are so many and various small growers and little control over cane delivered to factory, it is especially necessary. The route to coordination in research is already simplified by the adjacent physical location of agricultural and processing research. Several of the research projects proposed in this report require coordination of agricultural and factory research.

Coordination with Industry.

Coordination of Institute work with the industry appears to be very good. No doubt the requirement that Institute personnel spend a year at a factory before beginning research is helpful here, as is the constant work of the Industrial Division directly with factories. In the author's limited exposure during factory visits, there appeared to be a greater regard for research among factory personnel than is often observed in other areas.

The problems of combining research with production (always a situation that requires special planning) are particularly difficult under regulations here. Because the sugar quality standards must be met to obtain the factory workers' bonus, no factory person is willing to initiate change that may risk losing the bonus. The author met this obstacle repeatedly in discussions at factories. This situation makes experimentation on site, whether for cane testing, new analytical approaches, or even new processes, very difficult. Resistance to change will be encountered, as no-one will wish to be responsible for loss of bonus. It is this situation that has led to the recommendation (see Recommendations) that a factory engaging in a research project with the Institute be exempted from the quality-standard bonus system, or that a substitute system be devised for factories trying new systems. There are usually difficulties with new systems or procedures, and personnel resistance can enhance these problems considerably.

Personnel and Equipment

At the Institute, staffing appeared adequate, with an appropriate number of support personnel per scientist, unlike the excessive numbers of support personnel that might have been expected under Chinese conditions. Interest in the job appeared high, in all levels of personnel encountered, support as well as scientific, in such a thorough manner as to indicate a constant condition rather than response to a visitor. This interest, and the high degree of familiarity with work in the field of interest were extremely commendable.

There did not appear to be much cross-division awareness among Institute personnel below management level. Increased awareness of research in other sections, and skills of fellow scientists should be useful.

Equipment in the analytical division was adequate with regard to spectrophotometers. An atomic absorption spectrophotometer is available. A graphite furnace, or carbon arc accessory, was not observed for the atomic absorption unit, and, if not available, should be obtained for analyses of metals in sugar products. The Institute has chosen high performance liquid chromatography (HPLC) as the method of choice for sugar analysis, rather than gas liquid chromatography. This is a wise choice in view of the versatility of the analytical capabilities of HPLC, and its suitability for development of factory control. The Waters HPLC instruments available (with both refractive index and UV detection, radial compression system, and data processing module) are a good base for development. A variety of columns have been obtained. This instrument can be used for other analyses in addition to sugar (colorant, organic acids, aldehydes and alcohols) of interest to sugar factories and byproduct operations. A Waters Sugar Analyzer is a very useful planned purchase and will be used exclusively for sugar analysis, making the current system available for other research. The columns used in the Sugar Analyzer contain a type of ion exchange resin, 10-30 u in size. It is recommended that the ion-exchange resin manufacturers in China be consulted about future availability of this packing material.

The use of some of this instrumentation in development of agricultural research projects (e.g. cane breeding) should be considered, as part of the development of coordinated research.

Difficulties were reported with stability of the HPLC system and with sample preparation. The author observed a rule at the Institute (and all such institutions and buildings) that electricity be turned off each night, and pointed out that the refractometer in the HPLC system takes 2 to 3 days to stabilize, so that under the electricity use rules, the instrument could never stabilize. Institute personnel then planned to acquire a generator for use with the system. Sample preparation techniques for easier handling will be sent to the Institute as developed at S.P.R.I.

A senior technician had been sent to a Waters Associates Inc. Training Program for HPLC Users, held in Japan, upon purchase of the HPLC equipment at the Institute. This was a very useful action, as no service is available for the instrument in China. The Waters company also makes available a service and maintenance course; if possible someone from the Institute should take this course also, perhaps in connection with other training outside China.

Training

The Institute and the Ministry of Light Industry are aware of the need for training in specific areas of sugar manufacturing technology and research. Because the industry has expanded so quickly in recent years, there has been some difficulty in maintaining sufficient internal training programs for new engineers to staff factories. Time will permit training programs to catch up with the need for adequately trained engineers. A recommendation is made (see Recommendations) that internal training programs e.g. on sugar boiling techniques; maintenance programs; cane preparation; sugar chemistry; during the summer months when most factories are not operating.

External training is required for research and development personnel, both in areas related to sugar technology and to byproduct utilization. Institutes and commercial organizations suitable for training programs of variable lengths are listed under Recommendations. Because of the difficulties in sending personnel out of the country for training, it is recommended that each trainee make multiple visits during this program. This puts a load on the trainee, who may be required to deal with areas outside his own area of expertise, but will enable a wider range of contacts to be established. This development of a network of contacts for information is extremely important for the Chinese sugar industry at this rapid stage in its growth.

SUGAR FACTORIES

The cane grinding season was just beginning at the time of the seminar. Only two sugar factories were visited, as many had not begun operations at that time. The factories visited were both large for China, and near Guangzhou. The first, Dongquan, grinds some 3000 tons of cane per day (2800 to 3400) during the 120 day season (early December to mid-March) and functions as a refinery for off shore raws, processing 500 tons per day, for about three months after cane grinding has stopped. The second factory, Shitou factory, grinds over 4000 tons cane per day. Both factories had only just started at the time of our visit, and were toured on their second day of operations. Factories were well built, in good general repair, relatively clean, by world standards. The numer of personnel available for maintenance should ensure a greater degree of cleanliness, however.

Conditions, therefore, were not typical of normal operations. However, factory personnel were extremely helpful in answering questions, and Institute and Ministry personnel supplied data sheets from normal operating days in the 1982-83 season, so that an adequate picture of operations and process control was obtained. Both factories, like all sugar factories in China, produce sulfitation white (plantation white, pol > 99.3) sugars, directly from cane juice. Dongquan, in its refining mode, produces a sulfitation white from imported cane raws. Standards for white sugars are given in section 9 under "Areas of Research". Both factories also have plants for use of byproducts on site; these are small plants, servicing their own and perhaps two or three other mills, to minimize transport of bagasse and molasses. At Dongquan, there are plants to produce pulp, paper and furfural; at Shitou, there is a molasses distillery, and muds from both factories are sent to cement manufacture. There are, as far as could be determined, no refineries in China, that is, refineries only with no cane factory.

Both factories quoted a 12% yield of sucrose on cane. Factory daily sheets from early January, 1983 showed yields of 11.21% for Dongquan, and 12.85% for Shitou. The abovementioned problems concerning weight of cane into the factory, contaminated as the cane is with trash and field soil, lend question to these figures. The daily sheet at Dongquan, on the day of our visit, showed only 5.4% extraction on 2700 tons cane, but this is on only the second day of crop, and with immature cane, and so cannot be regarded as representative. The Dongquan factory has begun a program of cane sampling, which should improve the quality of its cane, at least by the end of the 83-84 season, and give support to the cane delivery figures.

Cane Delivery and Handling

Cane deliveries are determined for each factory by the agriculture department of the factory. This is always a difficult matter because each farmer wants to bring in the maximum amount of mature cane during the best weather.

Cane is all hand cut and cleaned, and is extremely clean, by general standards, upon arrival at the factory. Cane is tied in bundles (apparently 40 to 80 stalks) for shipment. The author saw many small fields but no large cane acreage, which may be the reason that no transloader stations, or central collection points, were observed. Cane was observed piled up at the edge of waterways for shipment by boat. The author was informed that farmers, in order to increase the weight of cane, will soak the cane in vats of water, or cover it, in piles, with mud and keep it wet. These practices are disastrous for keeping sucrose without deterioration.

Cane handling is by several means: large trucks, small trucks, small carts (especially for small mills in more distant areas), the usual variety of wheeled vehicles seen in Asian countries, and by boat. Boat delivery is unusual, except in a few areas in Asia. We were told that one-half to two thirds cane at each of the two mills was delivered by boat. These are very small boats, holding perhaps half a ton of cane each and create a major problem in the cane delivery system. It is necessary to use boats in this area, because many waterways are available, whereas roads and haulage equipment are not. Boat transportation is much cheaper than road (or rail) and the only transport means available to many small farmers. But the waterways are very crowded, and cane boats must give way to any larger form of transport; so, cane may spend several days on a boat, arriving at the factory in a stale condition even if it were fresh when loaded. There is a long line up of boats at the factory in part because the delivery schedules will of course not risk shortage ot cane deliveries. A boat may wait in line up to two days, and generally half a day or overnight. These factors all increase sugar losses in stale cane, but cannot be changed in the near future. Emphasis can be placed right away, however, on loading freshly cut cane.

Cane is offloaded from boats or trucks by grab cranes onto a weigh table (two tables at Dongquan and Shitou). Feed tables off the weigher are horizontal or downsloping.

Cane sampling, organized by the Institute, had begun at Dongquan Factory. Two sample boys, one at each weigh table, usually abstracted several stalks of cane from each bundle, after cutting open the fiber ties of the bundle. This is not a bad method of obtaining a sample, particularly in China where much labour is available. The major criterion is that sampling of stalks be random over all bundles, and heterogeneous (some stalks from outside, some from inside) on each bundle.

It is also important that cane deliveries be assigned anonymous labels to ensure neutrality on the part of the sampler. A program for cane sampling tests is proposed under Recommendations. At this time, the author believes that the most important endeavour is to start a widespread program of cane sampling, with what facilities are available. The program can be adapted, changed, and rescheduled with time and experimentation. The condition of cane delivered at factories at present makes the institution of any sort of cane sampling and testing imperative.

At Dongquan, the sample of stalks is ground up in a small sample hill and the juice analyzed for pol and Brix. A fiber analysis was not done at this time. The Guangzhou Institute is developing a combination cutter-grinder machine to be used for direct fiber analysis.

Weight of cane, as measured by the weighing-in scale, is used for payment to farmers only, and not for control. Cane weight for factory control is calculated from weight of mixed juice plus fiber in cane. An improved weighing-in system, or possibly a belt weigher for prepared cane, would be preferable to this. Because of the large number of boat deliveries, the usual system of weighing transportation units in and out of the factory is not possible. This and following calculations are from Dongquan mill, apparently typical of this size of cane factories in China.

Milling, juice and bagasse sampling.

Dongquan has a mill-diffuser combination: two sets of knives and a shredder are followed by four 3-roll mills, a diffuser, and a 3-roll mill for dewatering bagasse. Shitou factory had two sets of knives, a shredder, four

3-roll mills, and no diffuser. Dongquan was built, in 1935, by Skoda of Ckechoslovakia as a 1000 TCD mill, and has recently been increased by the Chinese to current capacity. Mills and most equipment obtained before 1950 came from outside China, but almost all current equipment is manufactured in China.

On factory data sheets, both sucrose % cane and pol % cane are quoted. Sucrose % cane is used for payment. The calculation is sucrose % cane = (pol in mixed juice + pol in bagasse) /cane weight. A single pol measurement is used. Pol % cane, a similar calculation, using double pol measurement and used for factory control purposes, is no longer calculated. Laboratory personnel no longer run double pol because they claim lack of time with increased factory throughput (The Institute indicated there were many new, relatively untrained, personnel.) The sucrose % cane figure is used also for control in lieu of pol % cane.

For fiber and trash, samples of 2 to 4 stalks per hour are extracted from incoming cane, and trash is cut off and weighed. Each shift, this is compiled. The cane is ground in a small mill, pol and moisture by drying are read on the bagasse, and the fiber is calculated by difference. There is also a direct fiber determination in bagasse (not on cane) by washing until wash water is Brix-free, drying and weighing. It is not clear which fiber measure is used. Presumably when the cutter-grinder under development at the Guangzhou Institute is put into service, that will replace the current system. Since this fiber measurement (confounded by questionable sampling) is the current basis for control weight of cane, it should be conducted with greater accuracy. It appears that the calculated cane weight is used for factory control, but the weighed-in weight, plus sugar yield, for factory yield.

Cane in Guangdong province is all fairly low fiber (11 to 13% on cane), which is satisfactory for the climate, since cold tolerance and wind resistance are not usually important factors. Breeding for high yield and high sucrose has led to these low fiber canes, which should be easier to mill.

Extraction is calculated per shift using the calculated sucrose % cane over the control cane weight. High average extractions of 95% to 97% are probable, as reported, with the low fiber cane, but again the calculation confuses the result.

Maceration, reported as 15% to 18% on cane, is begun on the final mill, using condenser water. Application is rather uneven, but the author considers the amount about right for the type of cane and preparation, although a little high for Dongquan factory with its diffuser, where additional water is added. Maceration water is measured in two ways: (1) in a two-tank system, with a float in one tank and (2) by moving it through a nozzle with flow meter. Mixed juice volume is also measured in a two-tank system, with density (from spindle brix) calculated in to give weight of mixed juice.

Suspended matter in juice is measured (not usual everywhere) by either a small centrifuge or paper filtration. This is a useful indication of amount of trash in cane.

Figures on pH for clarified and filtered juice were listed on data sheets as above pH 7 (7.1 to 7.5), which is unusual, especially for sulfitation process. Syrup pH, of 6.1-6.7, were more normal. It was suggested that new inexperienced workers might make an incorrect reading at the beginning of the season, but data sheets on last season showed similar readings. If these are valid pH figures, there is considerable overliming, which is adding to the serious problem with heavy scaling in the evaporators. Juice is often refractory, because of the stale cane, and perhaps excess lime is added to increase filterability and give faster crystallization.

The lime (CaO) percent cane figures listen on data sheets are high, 0.25%-0.27%. The high levels of dextran in the stale cane may have prompted this high liming. The fact that pH is measured by bromthymol blue instead of by pH electrode (preferred) also introduces error.

After milling, the juice is passed over DSM-type screens to collect fines. The back side of these screens is an area particularly prone to growth of Leuconostoc mesenteroides organisms, that produce dextrans. Contamination was observed during the factory visit, even though operations had just started and the weather was relatively cool, emphasizing the need for improved hygiene across the mill.

Juice sampling, by a drip collector, was well done for 8-hour shifts, with formalin added as a preservative agent. Bagasse sampling was by hand catch from across the mill; this type of sample requires surveying the sampler, to be sure that the sample is taken truly across the whole mill. A better method is a slide opening across the mill, activated periodically to dump bagasse into a container below. This container, also with formalin added, is mixed and sampled every 4 or 8 hours.

Bagasse fiber, moisture and pol figures are in accord with the good extraction, 96-97% reported at Dongquan, and the slightly higher moisture and pol with the slightly lower extraction at Shitou factory. At Dongquan, there appeared to this auther to be overpreparation of cane: very fine fibers going into the diffuser encourage extraction of non-sugars as well as sucrose. The soft, low-fiber cane received excessive treatment. Studies should be made in this area, on relative extraction of sucrose, especially with regard to the energy saving program, and are recommended (Recommendations).

No lost time was quoted on data sheets. The author questioned this because cane blockages at the mill are usually listed as lost time, but was told that although blockages occurred, they were not included in lost time.

Fuel

Dongquan factory burned about 1/3 bagasse, 2/3 coal, with the remainder of the bagasse going to the byproducts factories on site. About 100 lbs. bagasse per ton of cane was quoted. Shitou factory quoted about 60% bagasse to 40% coal: the bagasse byproducts have to be shipped from Shitou to Dongquan, so it is economic to burn more bagasse rather than ship it. Coal is supplied by the government at a price of U.S.$50 per ton, much below world price. Under conditions in other sugar producing countries, it is unusual to burn coal or any other fuel except bagasse (except at start-up, when there is not enough bagasse.) There have been exceptions, such as Louisiana for some years, when natural gas was priced extremely low. China has a shortage of pulpwood and other fiber sources for paper products, and so finds it worthwhile to supply coal at a low support price in order to save bagasse fiber for paper. The high degree of fiber preparation, which is energy intensive and not always good for sucrose extraction, may be useful to some factors in paper making e.g. it allows for more surface exposure for lignin removal.

Clarification

Both factories used large settling clarifiers, tray type, after sulfitation. Sulfitation is performed in an unusual system, devised at the Institute. SO_2 gas is injected into the juice stream under vacuum; the juice continues, via gravity flow, into the liming tank. In this way maximum use is made of the decolorizing ability of SO_2, by adding it before lime, but the low pH caused by SO_2 exists for only a second before the liming tank. This system requires lower capital investment than the usual sulfitation tanks and maintains low pH for less time, therefore cutting down sugar loss and equipment corrosion.

The system of sulfitation--liming, followed by carbonatation, is the usual method for direct white sugar production from cane is the tropics. The factories visited did not use carbonatation, although some factories in China do. This process, for producing a plantation white sugar according to the standards given in "Research Program", has many drawbacks: it gives high sugar loss, produces a dull greyish sugar with no sparkle which gains colour on storage, and does not work well with most other decolorizing processes. It also creates much scaling in evaporators, demanding frequent cleaning and lowering heat exchange. However, it has low capital and operating costs, is fuel efficient, and, in general, cheap. In the author's opinion, it is perfectly suitable for production of most sugar used in China, other than that required for industrial use. The excessive scaling observed here will be discussed later.

Sulfur dioxide is added to a level of 0.07%-0.09% on cane (a commendably low level for plantation white production). Lime (levels mentioned agve, 0.17%-0.27% on cane) and phosphate (0.04% to 0.05% on cane) are also added to liquor going into the settling clarifiers. Cane in China is low in phosphate, as no phosphate fertilizer is used. The added phosphate levels quoted seem high for such an expensive commodity, but it may be cheaper to add phosphate here rather than on the field, since the cane plant manages with the low levels available (low fiber cane).

The reasons for adding so much lime and phosphate to obtain filtered juice of sufficient clarity and filterability can be traced back to the condition of the cane arriving at the mill. Stale cane, having undergone a lot of deterioration, both chemical and microbiological, contains high levels of reducing sugars, organic acids, and soluble and insoluble polysaccharides, particularly dextrans. Dextrans range from very soluble, through colloidal phase, to insoluble. Other polysaccharides and protein form colloidal suspensions in juice, with levels increasing with degree of cane deterioration. The very finely prepared cane and high degree of extraction increase levels of these materials going into juice from cane. These materials are difficult to remove in clarification; colloidal material can pass through mud filters, slowing down the rate, and cause cloudy juice. The only cure is to increase levels of lime and phosphate, creating more precipitate in the clarifiers thereby presenting both more surface area for adsorption of impurities and greater chance of impurity entrapment during precipitate formation. The high levels of lime and phosphate increase processing costs and the lime increases scale formation. Clarifier retention time (1 1/4 to 2 hours) is longer than optimal, again required to produce a clear juice from poor quality cane. Long retention time creats more sugar breakdown and loss, and colour formation. Poor hygiene across the mill increases the levels of dextrans and enhances the problem. Use of settling additives has been studied.

Mud filtration is accomplishes on rotary vacuum filters, some with belts, some not. Washing appeared to be rather uneven on the filters; muds at Dongquan still retained some sugar, more than the usual 1% to 2% pol. However, a high pol of 5% was shown on the control sheets, perhaps indicating problems connected with factory start-up or reflecting the high levels of dextrans in the muds. Plate and frame filters were also used, for excess mud and for use during refinery operations. It was not asce tained if bagasse fines were added to mud to assist cake formation: the cake did not appear to contain much bagacillo.

Evaporation

At both mills visited, there were 5 effects at the evaporator station, the usual situation for factories in China, plus one initial stage for production of low pressure steam. Major problems at this station are, first, the large amount of scaling, caused by sulfitation and overliming (because of stale cane.) Scale, mostly calcium sulfate and calcium silicate, is so heavy that the last effect has to be cleaned on every shift, with soda. No alternate evaporators for use during cleaning were observed; however, if this cleaning requires down time at the mill, it is not noted on the control sheets. The clarifiers may be used as retention vessels. Some additives to prevent scaling have been tried, but without much effect. No really good anti-scaling additives are known to the author. This loss of time, heat exchange, and capacity make an inefficiently and expensive operation. The second problem is that, because so many effects are used, there is a high proportion of relatively low pressure steam. This is used on the vacuum pans, and causes extended time for boiling, thereby lowering pan capacity.

Vacuum Pans

Pans were generally about 35 cubic meter size, calandria type, insulated with wood. Pans were equipped with refractometers, built at the Research Institute. A straight three boiling system is in use at most factories, with B-sugar used as a footing for A pans. Seeding with ball-milled sugar in alcohol is the common practice. Most pans do not have circulators.

Purity drops of 85 (A massecuite) to 68 (B mass) to 53 (C mass) are usual. Purities (all apparent purities) at Shitou were about two degrees lower. Final molasses apparent purities were quoted from 26 to 35. There appeared to be ample crystallizer space at both factories, but we were informed that it is reaching capacity.

Average colours on A sugar were 1.3 to 1.5 Stammer (the unit used by the Chinese) or 105-120 ICUMSA. There is a lot of water use in the pans, because of the required high grain size and problems with conglomerates.

The grain size of these sugars is the very large (by U.S. or European standards) size boiled in this plantation white systems throughout the Asian countries. This large grain is time consuming and energy consuming to boil, particularly in pans without circulators, where water must constantly be added (as "drinks") to redissolve false grain. Because the non-sucrose level in these syrups is so high, there is a lot of false grain and conglomerate formation in spite of the excess water usage. The slow boiling with low pressure steam also increases conglomerate formation. In this white sugar production system, the large grain size is necessary because sugar in the batch centrifugals (A and B strikes) is washed by hand with hoses, instead of spray devices in the centrifuge basket. Sugar is then steamed in the centrifugals, to dry it without the use of rotary driers. Everything in this system encourages loss of sugar, capacity, and energy. White sugar is made in crystal form, at excessive steam and equipment cost, and then washed away in the centrifugals, to be recycled at further cost. This system, the general systems in use in most middle and far East countries has the sole advantage (to this author) that it does not require a rotary louvered drier. The capital and on-going costs of driers are soon covered by the savings in energy, capacity and sugar. This subject will be discussed further under "Recommendations".

The sugar produced by this system, because of its large grain size, appears darker and less white than sugar of equal colour and a smaller grain size. The system of standards for sugar in China maintains this grain size: if this sugar quality parameter is not met, the factory will lose a bonus payment. Grain size is, on average, 78% > 1.6 mm; M.A. = 1.08; CV = 18.6.

Pans are dropped into open receivers. This type of equipment, while acceptable for raw sugar factories, is somewhat unhygenic in white sugar production. Batch centrifugal gates for massecuite delivery, require improved maintenance. Several were observed leaking massecuite.

Batch centrifugals are used on A and B sugars, each with hose attached for washing. A viewport, to observe degree of washing, was installed on the outer body of some centrifugals. This is a new idea to the author and appears a good one.

Sugar is packaged by hand in jute bags of 50 kilos and weighed. There was little warehousing observed: deliveries are frequent. The jute bags were not lined with anything: this lack of lining is both wasteful (leakage, water damage) and unhygenic (contamination; pests). Personnel reported that plastic linings had been tried, but caused caking. The sugar, high in invert ash and polysaccharides, holds a lot of water and probably does cake in any case. The closed plastic bag would cause caking to appear more quickly if temperature changes were encountered. Paper linings are suggested, as perhaps more satisfactory, although since paper is so scarce in China they may be too expensive. There is no bulk storage, with facilities for conditioning that would prevent caking after packing. Hygiene and housekeeping in factories observed were not bad, by world standards, although could be improved throughout. However, at this end where the product is produced, standards of cleanliness should definitely be improved. The packaging area should have standards of hygiene of a food packaging plant.

Standards for reducing sugars, ash and water are quoted above in the "Institute" sections. Levels on Factory control sheets showed 0.04%-0.09% reducing sugars, 0.06-0.08% reducing ash, and 0.03%-0.04% water; for sugars of 99.6 to 99.7 pol. Insoluble matter averaged 40 to 50 ppm, a surprisingly low value for alcohol precipitables in these sugars.

Molasses

Molasses is used either for feed (for the growing dairy cattle industry and for beef), yeast production or alcohol production. Shitou factory has a distillery on site, which receives molasses from Dongquan and two other factories. There have been problems with molasses storage, and a storage tank at Shitou exploded several years ago. The two major causes of molasses explosion (or fires) are high levels of nitrogen compounds in molasses, and high temperature of material going into storage. Cane in China has a high level of nitrogenous compounds and amino acids naturally, because of the high nitrogen fertilizer used on the soil. This is one of the factors for high colour in sugars. Juice from the stale cane maintains high levels of dissolved and suspended nitrogenous matter through clarification and into the molasses, so that factor is present. Figures from the Institute for molasses from Shitou factory show nitrogen levels in final molasses increasing from 0.57% in 1974/75 to 1.42% in 1980/81, as farmers increase levels of nitrogenous fertilizer applied in order to increase cane yield (though not sucrose). Shitou, like most factories around the world, wants to get molasses out of the factory and into storage as quickly as possible, and so pumped in some molasses at too high a temperature. There is no recourse for this but to cool the molasses, usualy by moving it, before it goes into storage. Molasses is a good insulator, and shields the spontaneous decomposition reactions that can go on inside the tank, producing CO_2 gas, until the mass blows up from the contained gas and heat emitted by the reactions. It is recommended that molasses temperature be reduced below 45°C before storage.

Syrup Clarification

In both factories visited, syrup clarification, in round clarifiers, using lime, phosphoric acid and flotation chemicals, had been installed. The systems were not being operated at the time of these visits because of the proximity to start up. Personnel reported that sugars made using these processers were better quality, with lower colour and sparkling appearance, showed less caking problems and, important in this cane, less colour development in storage than the normal sugars. These results are to be expected, for the syrup clarification proces removes a lot of high molecular weight soluble and colloidal material as well as colour. This high molecular weight material gives crystal sugar a dull cast and, more importantly here, causes the sugar to hold moisture thereby encouraging caking and colour development in storage. This process is a good choice for improvement of sugar quality.

Byproducts

The intensive use of the entire cane plant in the Chinese sugar industry is admirable. Byproduct utilization is achieved through small, labour-intensive plants on site at the sugar factories, a very suitable system for this situation.

At Shitou, the abovementioned molasses distillery was visited. At Dongquan, there is a bagasse size separation and baling system. Longer fiber goes to the paper mill on site, which produces white magazine quality paper from 95% bagasse plus 5% pulp (cotton and/or wood). The paper has a fine appearance, but low tear strength, as is characteristic of bagasse . The factory operates 300 days per year, using some 100 tons bagasse per day. Caustic hydrolysis is used to achieve cellulose separation.

A furfural plant, also on site, uses the bagasse fines. Bagasse is trucked by hand from the factory to a storage shed to the separator. Fines from the separator (a French-type screw press leading to a rising forced air draft) plus fines from the bagacillo screens are hydrolyzed with 5% sulfuric acid. Yield by weight was reported to be about one-third, which is the approximate weight of the hemicellulose fraction. The non-hydrolyzed residue is removed from the tank by an alternating piston valve mechanism.

There are three column stills, 20 ft. to 30 ft. high, running continuously for production of the final 99% furfural of good quality and very light colour. Production is about 2 tons per day.

Muds from filters are taken in some cases to fields as fertilizer but more generally are used to make some sort of cement.

Factory Laboratories

Laboratories at the factories observed were spacious with adequate number of personnel. Methods of analysis in China, are compiled in a handbook, a copy of which was kindly given to the author but has not yet been translated. Environmental control (water) sections were observed at both mills.

Many analyses are made from the data sheets. The lab at Shitou was well equipped, with a spectrophotometer. All Brix are read as spindle brix, however, and all pol by optical polarimeters. The pH is all read by bromthymol blue. Changes in sampling are recommended above, and further changes for laboratories will be recommended under "Recommendations". Personnel for these are available.

Field Observations

Sugar cane is a popular crop in the areas where it is grown (see "General Observations") because it is a cash crop and can be grown in quantities over quota to provide extra income for farmers. Green leaves and trash provide fodder, fish feed and fuel.

Cane plots tend to be small and elongated; very few large fields were observed, although the author did not see areas far from towns or factories where there may be larger fields. many plots of less than 30 x 5 meters were observed. All cane areas are irrigated. Both factors, irrigation and the high percent of edge-of-field cane are stressful to the cane plant. Yields of canefrom 40 to 60 tons/hectare were quoted.

Most cane observed was plant cane: only one ratoon crop is taken in most areas before replanting, because most varieeties in use give poor ratoon crops. Cane observed showed little tillering, also. Cane appeared straight, with little lodging. The extensive hand labour available supports the replanting practice and may account for the clean appearance of the fields. The cane, to use a Louisiana term, looked pretty in the fields, although not in heavy yield.

Variety development takes place under the auspices of the Guangzhou Research Institute. Breeding studies are done at the Hainan Island facility, and development at the Institute farms and at agricultural colleges. The mechanism of distribution of new varieties to farmers was not clear.

The land used for cane in Guangzhou is mostly flat and relatively rich (Pearl River delta) and is flat in most current areas under production, but the only land available for acreage expansion is hilly, with sandy soils.

Fertilization practice is to use organic fertilizer (human and animal generated) only, because that is available. The soil is, therefore, overrich in nitrogen and deficient in potassium and phosphorus, and probably in calcium and iron, too. High nitrogen will increase the amino acid level in the plant and increase colour in juice and sugar. The fertilizer dosage is increasing because higher levels produce higher cane weight, and the farmer is paid on weight basis. There is a limited distribution of filter muds and distillery stillage to fields; these certainly improve the situation where supplied.

Cane was observed cut and piled up beside waterways for boat transportation. All harvesting is by hand, because labour is available, and hand harvesting is the best method for small plots.

The piles of cane belied the great appearance of field cane; piles were drying out and were watered down to bring up the weight and, incidentally, to rot the cane. The deteriorated condition of the cane as it arrives at the mill is a major problem in the Chinese industry.

Little information was obtained about cane diseases: many are known; cane smut and rust are present, as are ratoon stunting disease, chlorotic streak, red rot, and some other deficiency diseases. Borers and nematodes are major pests. Leafhopper is apparently not known. These do not seem to be extensive disease prevention measures, which are surely required to improve yield.

As a point of information, the following varieties are the main varieties planted in Guangzhou province in 1980-81 (source: T.L. Chu, Sugar y Azucar. February 1982, pp. 56-57):

Variety	Hectares planted	% of total
F 134	114,530	53.4
Kwt 57-423	29,540	13.8
Kwt 63-237	13,490	6.3
Co 997	10,320	4.8

PERSONNEL AND TRAINING

In general, senior factory personnel appeared well versed in the manufacture of sugar and familiar with factory operations. This was somewhat remarkable in view of the isolated nature of the industry for many years, and speaks well for training programs of the Ministry of Light Industry and the Cane Sugar Research Institute of Guangzhou. There was considerable awareness of the problems in sugar losses caused by stale cane, although not so much of problem in process caused by deterioration products.

Institute personnel informed the author that there were some problems with training of younger people. Production has expanded so much in the last ten, particularly the last five, years that it has been difficult for technology training programs to provide numbers of engineers and technicians required. This shows up particularly in laboratories: many young, relatively untrained workers are responsible for testing and control, and many mistakes are made. On several occasions, when unusual data was questioned, this was the reason given. The author was not able to obtain a list of training programs available in China for sugar technology workers or laboratory technicians. Some recommendations are made for short courses that might be set up by the Guangzhou Institute, in cooperation with the South China Institute of Technology and other sugar institutes, and also for training programs outside China that might be attended by senior technologists, for study as a base for Chinese programs. Other recommendations made (all under "Recommendations") are for special courses or institutions that senior technologists might attend for individual development.

A special task force, composed of representatives for the Cane Sugar Research Institute, the Ministry of Light Industry, and the South China Institute of Technology (or other such Institutes) is recommended to plan a training program.

GENERAL RELATIONSHIPS IN THE SUGAR INDUSTRY

Within the factory and production area, there appears to be good relationships between factory personnel, the Ministry of Light Industry (in whose charge are sugar factories) and the Cane Sugar Research Institute. The engineering division of the Institute cooperates closely with factories, with personnel spending most of the grinding season at the factories. Recommendations to simplify procedures for experimental work of the Institute at factories will be made in the "Recommendations" section. The cooperation of these organizations forms a good base for solving the problems that relate to factories alone: increasing capacity with current equipment, and producing some industrial grade white sugar. The growing and production of sugarcane is not, however, under control of the Ministry of Light Industry, but under an agricultural ministry. There appears to be little communication between the agricultural interests and the factory and production people. Each factory has an agricultural division, which is responsible for scheduling cane deliveries. Further responsibilities of this division, if any, were not clear.

The major problem in the cane sugar industry of China is the severe deterioration of cane as it is delivered to the factory. The institution of cane quality payments by the factory will, in time, bring improvements to the condition of the cane, as farmers observe higher payments awarded for fresher cane. There appears to be no mechanism whereby production requirements can be relayed to the agricultural sector. It is particularly important, because of the stale cane problem, that some pathways for communication be established. Agronomic and fertilizer practices, as well as harvest practices, have a strong effect on cane juice and sugar. An agency should exist to consider and communicate responsibility for both agriculture and production. The author understands that a commission has been appointed to investigate this problem, and wishes to emphasize the importance of this joint problem.

In the areas of agricultural and production research, this problem exists in the structure of the Research Institute. Although both disciplines share the same site, there is no formal program for cooperative research. Because of the dedication of the scientists involved, informal communications are well established within the Institute, and both agricultural and processing research scientists are aware of the problems in one another's areas. There is, however, no mechanism for design and operation of joint research projects, and this problem should be corrected. Under the current system, processing research is under the auspices of the Ministry of Light Industry and can, through the Ministry, obtain aid from the United Nations Development Programme. There is no similar pathway by which agricultural research, not under the auspices of the Ministry of Light Industry, can obtain aid, or receive assistance for training or expert advice. Measures should be taken to improve the resources of agricultural research.

This is actually an unusual situation, where agricultural research receives less assistance than processing research. In many cane growing countries, the income from sugar production is split roughly 60% to agriculture and 40% to processors (except where cooperatives exist) and the research funds assignment generally follows a similar distribution pattern. At this time in China, where the goal is to increase production to become independent of imports, and where a major obstacle to production increase is the deteriorated condition of cane at factory gate, it is important to continue to support processing research but to supplement this with a coordinated agricultural programme.

If cane deliveries were made within 24 hours of harvesting (less time if possible in hot weather), between the lower losses in cane and the factory savings on not having to process all the deterioration products, there could be an increase of 4% to 12% of sugar produced from current acreage and yield.

BYPRODUCTS UTILIZATION

Several areas of byproducts utilization have received comment in the "Factory" section. The extensive use of byproducts in China is probably the most intense and diverse in the world, except perhaps in Taiwan. In addition to the abovementioned production and research on alcohol, particle board, high quality paper, furfural, and cement, there are yeast foods, fodder from stillage, CO_2 and dry ice, brown wrapping paper, slag bricks (from boilers using coal) and some pharmaceuticals, presumable produced from molasses by microbiological techniques.

The distribution of small utilization and production facilities on site at many factories is a suitable arrangement for the Chinese system for several reasons. It avoids transportation of hard-to-handle bagasse and molasses, and requires only transportation of end products, important where transportation is expensive and scarce, as here. Fuel economy is improved by utilization of steams from the sugar factory for many of these plants during grinding season. Labour requirements are in this manner widely destributed.

There was great desire for further knowledge about many of these byproduct utilization facilities, but little new information is available on most of them. There has been little successful development, and what has been attained is mostly proprietary information. The situation with regard to pulp, paper and board from bagasse is that many cane growing countries have started paper or board factories, but have closed them down (Peru, South Africa, U.S.A., Mexico) because other cheaper sources of pulp and fiber were available. The only countries operating extensively in this area are Taiwan and Cuba. Cuba is particularly active, building two large paper plants. Because of the heavy reliance on sugar as the basis of their economy, Cuba is more heavily involved in byproducts utilization than most other cane-producing countries, but access to their knowledge may be a problem.

Furfural is produced in the U.S., Venezuela, Cuba, Brazil, Philippines and Taiwan. The major plants, run by Quaker Oats, are very proprietary about their process. Smaller plants, to the author's knowledge, run much the same process as that at Dongquan factory. Many areas offer cheaper sources for furfural than bagasse e.g. cottonseed mills and corn mills, and pure furfural is produced from these residues rather than from bagasse.

The Chinese might investigate production of furfuryl alcohol from furfural, if this is not already done. The alcohol is a higher value product, used for plastic resin manufacture, and some details of conversion have been published.

With regard to yeast and alcohol production from molasses, food yeast production (throughout the world) is quite proprietary, especially with regard to the yeast strains used. Alcohol production is widespread, and less proprietary, with continuous distillation, continuous fermentation processes under constant improvement. The continuous processes are generally commercial developments, rather than proprietary information. The decisive cost factor in other countries is the fate of the stillage: the former practice of sending this to the field as fertilizer now has too high distribution costs, unless farmers remove it from the factory gate. Instead, stillage is subject to (1) drying by evaporation to produce fuel or feed (condensed molasses solubles) or (2) activated sludge treatment under anearobic conditions with methane-carbon dioxide as a usuable product, biogas (operating in Cuba). (A UNDP project on biogas production, US/CPR/81/171 is listed in UNIDO material supplied to the author. Perhaps there could be cooperation.)

There is no clear best choice for all distilleries: local resources and distribution facilities determine the treatment.

One byproduct not observed in production in China is cane wax, produced from filter muds. A crude wax can be extracted with an organic solvent (e.g. ligroine) on site at the larger factories, and the crude wax transported to a central refinery. The wax product is a hard, high grade wax, similar to carnauba wax. The determining factor in economics of production of this product (in countries outside China) is the availability of a sufficient supply of crude wax to permit year round operation of a refinery.

RECOMMENDATIONS

Cane Sugar Research Institute, Guangzhou

1. The sugar industry in China is spread over an enormous geographical area. There are many different sizes of factories, most with a similar white sugar product, some with brown sugar. Plans anticipate different milling and processing procedures at different factories. During the recent rapid growth of the industry, each province has had considerable autonomy regarding its expansion and new construction. The industry requires further centralization, to coordinate future development. Both cane and beet sugar should be considered together, from the point of view of sugar manufacture and distribution. Land use and crop rotation are differend for the two systems.

The Guangzhou Research Institute, the largest and best developed research center for the sugar industry, in the major sugar producing area, is a natural center for research and development for the industry, under the auspices of the Ministry of Light Industry.

In order to achieve the goals of production of industrial quality white sugar, and of increased production with current facilities, special programs planning change must be developed through from the research stage to pilot plant, or equivalent level, into factory trials. The Institute, which already has a division that works directly with factories, is a good base of operations for such a program.

It is recommended that the Guangzhou Institute be designated the center in China for new product development and factory improvement, through coordination with the Ministry of Light Industry as suggested in Recommendation 2. A project to study production of high quality industrial grade white sugar directly from cane juice by a process such as the Blanco Directo process from Tate and Lyle Company, is a good example. Studies must be made on the quality of sugar produced (low colour, low SO_2, low turbidity) by the chemical research while the engineering division does a feasibility study on conversion of existing factories to Blanco Directo production. A study such as this should be made at one central location, with parameters of distribution and local conditions considered for each geographical area.

It is also recommended that the Institute become the center for coordination of processing research and agricultural research, and from thence to coordination of cane production in the field with processing requirements at the factory. The proximity of agricultural research to processing in the Institute, and the desire on the part of the Institute Directors, for this vital coordination support this development.

2. In order to facilitate the program for centralization of industry development at the Guangzhou Institute, it is recommended that liason officers from the Ministry of Light Industry be appointed to plan and direct this operation. The Ministry of Light Industry is in charge of both sugar factories and the Research Institute. It is suggested that both technical and administrative personnel be appointed to work together on this program.

As mentioned under Observations, there was some resistance to innovation on the part of factory personnel where there was the possibility that innovation would conflict with the standards and targets set for sugar produced, and lose the factory their bonus e.g. producing a smaller grain size sugar, at considerable energy savings. It is suggested that the team of liason officers, as part of their general goal of coordination, consider some form of special compensation for factories participating in joint research projects which could change their standards of production. This should be conceived in a fashion to favor research projects. A factory might be exempted from the target system for the term of a project (or for that grinding season) with the previous season's performance to be used for bonus purposes, plus some incentive reward for success in the research projects e.g. in production of smaller grain size, with drying, for increased sugar production and energy savings.

The liason officers should also be responsible for assigning which factories will cooperate in research projects. Under current conditions, there is resistance to change, quite understandably so, and procedure to make new developments possible without loss to factory personnel should be devised, as a vital aspect of coordination of research and production.

3. A series of specific research projects is proposed for the Cane Sugar Research Institute of Guangzhou. Projects are designed to increase sugar yield, save energy, improve product quality and storage quality, increase factory capacity with current equipment, and develop a sugarcane quality payment system. The overall goals of the Institute are the basis for these recommendations, i.e., energy saving, yield increase, capacity increase, and product quality improvement.

Many of these projects use HPLC analysis. It is recommended that the HPLC equipment at the Institute be allowed to remain turned on at all times, and not turned off each night to save electricity has been the practice. The refractive index detector in this expensive equipment requires three days to stabilize, and has not been operating properly under electricity saving conditions. A small generator might be installed for this purpose. It is also recommended that a sample preparation technique, diluting cane juice to 10% solution with water before filtration, be adopted.

A. Sugar loss through invert formation in sulfitation evaporators, and vacuum pans.

Levels of invert (glucose plus fructose) and lactic acid are determined in sulfitated and clarified juice, evaporator syrups and pan syrups by HPLC. HPLC conditions for syrup analysis must first be optimized. It may be necessary to do post column derivatization (see Wnukowski, Proc. Sugar Industry Technol., 1983) for higher purity materials. Results should be correlated with pol analyses and, as Director Chen Shi-Zhi suggested, with observations from the refractometers now being installed on evaporators in some factories. Invert forms, and decomposes, continually through the process. It should be remembered that under acid conditions the fructose moiety will decompose more quickly than the glucose and glucose levels may be higher than fructose, as is usually the case in cane factories. However, deteriorated cane has a much higher level of fructose than glucose and this may show up in juices here. Lactic acid gives an indication of microbial loss of sucrose. This study should indicate areas of sucrose loss caused by overheating, poor mixing or incorrect pH, most of which can be corrected.
Potential benefits are in sugar yield and energy saving.

B. Improvements in factory performance: a cooperative project between factories and the Institute.

Sucrose losses are studied by examining effluents: filter muds and mud filtrate, bagasse and bagasse wash water, and molasses are analyzed for sucrose, glucose and fructose by HPLC. Because of the mixtures of sugars, polysaccharides and sugar breakdown products in these materials, pol is not a good estimate of true sucrose loss.

Condenser waters (pan and evaporator) and boiler feed water should also be monitored by HPLC for sugars. If samples must be stored for any period (more than two hours) they should be frozen to prevent change. This applies to samples for any study, but dilute, low purity materials are most subject to deterioration.

Potential benefits are in energy saving and sugar yield.

C. New processes of clarification should be studied for production of industrial grade white sugar, e.g. the Blanco Directo process of the Tate and Lyle Company. This process, using juice sulfitation with flotation clarification of mud filtrate (then sent forward) and syrup, enables production of an industrial grade white sugar, color less than 100 ICUMSA, SO_2 residue less than 2 ppm. It requires very little additional equipment to that already in factories, only the addition of filtrate and syrup clarifiers. Scaling is reduced with this process. This type of process seems ideally suited to the Chinese requirement for a certain amount of production (about 10% current) of high-quality industrial grade white sugar for sale to pharmaceutical, beverage, and some food companies. The quoted process is used in Thailand, Brazil, Mexico, Cuba, Taiwan, Philippines and Indonesia, among other areas. Information on this process has been given to Institute Director Chen Shi-Zhi.

In addition, studies on polymers used in settling clarification should include a study of the effect of recirculating neutralized polymers in mud filtrate. After polymer is reacted with charged particles in the clarifier, and neutralized, some may remain soluble, go into mud filtrate and be recycled back into mixed juice where it can then inhibit good clarification.

Potential benefits are for product quality improvement, sugar yield and energy saving.

D. Colorant in cane juice and sugar: factory and field effects.

A study is proposed whereby factory juice samples are analyzed for compounds which affect color in sugar produced, and color development on storage. Analyses are for: phenolics; iron; amino acids; alcohol precipitables; molecular weight distribution (by rocking dialysis or Sephadex Separation) and pol, Brix and pH (the standard analysis). Results are to be correlated with sugar produced: its appearance, color, and storage quality. These tests should be run over several weeks period of time.

Results should also be correlated, depending on the processes in the factory, with degree of extraction, milling or diffusion factors, and any unusual circumstances (weather; equipment) at time of sampling.

With regard to field effects: the same series of tests may be run on field samples (a joint agriculture-processing project), and results correlated with field parameter: location and geography, rainfall, variety, age of cane, disease circumstances, ratoon stage, row spacing, shape or position in field.

This study will yield data to show effect of field conditions on sugar produced in areas other than cane deterioration.

Potential benefits are in the areas of sugar quality, sugar yield and energy saving.

Procedures for the recommended analyses have been given to the Institute.

E. Colorant in sugar and in storage.

Sugars from factories with different conditions (area; diffusion v/s milling) are to be analyzed for the following parameters: color, moisture, invert level, turbidity, pol, pH, amino acids, phenolics and iron. Sugars of different typical qualities should be chosen.

The sugars are then stored for one year, in containers of several materials (iron, stainless steel, plastic, jute bags, paper) at controlled temperatures (25^{o} to $40^{o}C$). Color of each sample is measured each month, and color measurements are correlated with the manufacturing and storage parameters. This is a large scale test that will require many samples. The study should point out the particular problem areas for color development in storage under conditions in China.

It is known that amino acids, iron, high moisture and heat enhance color development, for example, but this study should develop a profile that shows up especial problem conditions in China.

When these profiles have been developed, they may be used as a basis for the establishment of standards for sugar to be stored (if those can be identified) and conditions for sugar storage.

It is also recommended that a study on nature of colorant in the sugars be made, using HPLC with solvent programming, along the lines developed by Dr. P. Smith, of CSR, Ltd., Australia (Proc. Sugar Proc. Res. Conf., 1982), if there is sufficient time on the HPLC instrument at the Institute and sufficient personnel available.

The potenial benefits of the color study are for sugar quality, sugar yield and energy saving. Results of this work should be considered in conjunction with results on the polysaccharide studies in section F.

F. Polysaccharides in cane juices and sugars.

A study is proposed to examine the relationship between levels of dextran, pol, and true sucrose in cane juice and sugars.

Several varieties of cane, in different geographic areas and at different times of season (age of cane) are taken as samples. The samples are held for varying times and temperatures after cutting, ground, and then juice measured for pol, dextran (Roberts Method) and sucrose and invert (HPLC). Effect of variety, age of cane, area, length of time between cutting and grinding, and temperature are determined. Because of the farmers' practice in China of soaking the cane, or covering it with mud to bring up the weight, some samples should also be soaked in water or piled in mud. This study will show losses of sucrose, to dextran deterioration products, with various cut-to-crush times, temperatures, varieties and other conditions and enables calculation of sucrose loss from field to factory.

In crystal sugars, the levels of polysaccharide and invert affect the level of moisture held in the crystal and therefore the storage quality of the sugar. A series of sugars, from several factories at different times of the season, where process parameters are expected to give variation in invert and polysaccharide levels (the Institute should choose such factories) are analyzed upon initial sampling for dextran, total polysaccharides, invert, moisture and turbidity. The samples are stored up to one year (container material may be varied) at different temperatures, and once each month colour, moisture and invert are measured. Color development is then correlated with the initial factors.

Potential benefits are in the areas of cane quality payments, sugar quality, sugar yield and, if results improve quality of cane deliveries, in energy savings.

G. Cane deterioration.

Fresh cane samples, of selected varieties, age, soil types and locations are cut and stored up to two weeks under different local conditions (in water, in mud, and dry), at different temperatures and age of cane.

Samples are taken from each lot at least every two days (each day is preferable, but requires a large sample), ground, and the juice tested for pol, pH, dextran, sucrose and invert (HPLC), and phenolics.

This study might be conducted in different areas at various times of the season in order to achieve different ambient temperatures. Temperature has a major effect on deterioration.

Other parameters will no doubt be identified by the Institute and incorporated into this study. This work, like most of the suggested projects, requires a lot of sampling, with a carefully constructed sampling plan, and adequate sample sizes to be chosen. The information gained is very valuable and will, in time, outline the picture of deterioration and loss in the Chinese sugarcane industry.

Information gained from this deterioration study can benefit the cane payment system and thereby benefit sugar quality and yield, and energy savings.

H. The systems best available for cane testing require study for optimization.

At several mills, grab sample studies should be planned, changing the size of the sample (number of stalks) and frequency. Mills with a single weigh table should be chosen, and the time from cane onto table to crusher juice should be estimated. This can be done by putting a bucket of lime on cane on the table, measuring pH on the crusher juice and timing when the pH goes up.

The crusher juice corresponding to the grab samples is compared to the sample juice for sucrose and Brix, and a statistical comparison, using analysis of variance (ANOVA) made to give an estimate of the accuracy and effectiveness of each sampling procedure.

It is also recommended that a statistical study (using ANOVA) be made on regular factory samples: the composite mill juice samples, extraction and boiling hours efficiency.

Potential benefits are in the areas of cane sampling, sugar quality, sugar yield, and energy savings.

I. All the above projects require considerable sampling with careful planning, and extensive analyses, some on site and many at the Institute. The author believes that there are sufficient personnel (technologists) available at the Institute for these projects but that additional technicians and equipment may be required to run the tests, if several projects are run in the next two years, as is recommended.

There are also several longer term projects (over the next five years) recommended for the Institute.

One, in cooperation with the Ministry, is a study on the grain size and boiling system. Boiling a smaller grain size will give a higher yield for less time in pan and therefore increased capacity at lower steam usage. The smaller grain has lower apparent color. However, the levels of polysaccharides and invert in the current sugar make the crystal hold a lot of moisture so that excessive washing, the current practice, is necessary and this cannot be done with a smaller crystal size. Tests should be conducted on syrups from fresh cane. Further recommendations on this subject are in the Factory section.

Another long-term study, already underway, is in the area of milling vs. diffusion. The degree of cane preparation required for adequate extraction of sucrose (without excessive extraction of non-sugars) merits study, for energy saving purposes. Investigation of the disintegrator system, after Tilby separation, is already underway. These studies, for a system which seems very appropriate for small factories, should be continued. It is also recommended that the production of new products, to sell non-sucrose constituents with sucrose be investigated. In North America and Europe, brown sugars crystallized in vacuum pans are a popular product, that sells at from 50% to 100% the white sugar price and contains up to 1% water and 1% invert. While these are a possibility for China, they require special packaging and storage, and would probably not manufacture well from the stale cane. However, there are processes to make amorphous sugar, crystallized under atmospheric pressure, either batch or continuous, that are used in Brazil and Portugal, especially, that would be suitable for Chinese conditions. The product does not look like typical white sugar: it is much finer, and the brown sugars are not shiny crystals. But the product contains all the ash and invert from the syrup. The brown product stores better than the white. This type of process, which requires about half the steam of a vacuum pan for similar tonnage production, is worth investigation if it has not already been considered.

4. A joint study with the Ministry if proposed, for state-of-the-art of bagasse utilization (cellulose hydrolysis) for ethanol production, if this has not already been done. Other byproduct processes, such as the alternative uses of stillage for feed, fuel or biogas production should continue under investigation. The production of cane wax should be investigated.

5. It is recommended that there be increased training for personnel in the Institute and other research institutes, universities and field stations where possible in other parts of the world, particularly with regard to sugar quality and byproducts utilization. The possibility of setting up such courses in China should be kept in mind. It is also recommended that a series of short courses, to be held in the summer months (out of grinding season) on sugar chemistry, sugar processing, and sugar boiling be organized by the Institute for factory personnel, both new people and veterans who wish to refresh their knowledge. Such courses will not only increase training of factory personnel, but will help to develop industry unity, as factory personnel meet one another and as there develops increasing similarity in factory process handling because of similar training. These steps will aid in the centralization of the industry.

It is recommended that a joint task force from the Institute and Ministry and the South China Institute of Technology be appointed to set up training procedures, both internal and external.

The following Institutes are possible places for training of personnel. The author was told that some well known institutes, ex. Sugar Research Institute of Australia, are already cooperating with the Guangzhou Institute and so are not included.

1. Mauritius Sugar Industry Research Institute
   Reduit, Mauritius

Director: Mr. Jacques D. deR. de St. A~toine
Byproducts: paper and board production on Mauritius and Reunion. Alcohol, cattle feed, biogas.
Mr. M. Paturau, world authority on by-products is associated with this Institute.

Agriculture: cane growing and harvesting on hilly ground.
Processing: raw sugar production and interest in direct white production.

2. Berlin Sugar Research Institute
(Institut fur Zuckerindustrie)
Amrumer Strasse 32
1000 Berlin 65
Germany

Dr. Werner Mauch.
Work on beet sugar but also on cane.
Especial interest in instrumentation for laboratories and control, and energy-conservation.
Beet sugar factories in Europe have excellent control; study could be useful.

3. Sugar Technology Research Unit
Barbados Sugar Industry, Ltd.
Edgehill, St. Thomas
Barbados

Dr. Stephen Brooks and Mr. Keith Laurie
Tilby Separator Process. Fiber and particle board
Cane harvesting and milling. Raw sugar production.

4. Estacion Experimental Regional Agropecuaria
Famailla
Tucuman
Argentina
Dr. Franco Fogliata

Cane growing in subtropical climates. Production of raw and refined sugars in same factory.

5. Luis Queiroz University, Branch of University of Sao Paulo
C.P. 9
Piracicaba, S.P. Brazil
and Copersucar
Department Tecnologia,
Piracicaba

The University works in conjunction with both Copersucar and the National Institute of Sugar and Alcohol, and might serve as a good base to study the Brazilian industry.

Production of alcohol and stillage disposal. Amorphous sugar production. Various byproducts.

6. Sugar Industry Research Institute of Jamaica
   College of Arts, Science and Technology
   Kingston
   Jamaica

   Dr. Ian Sangster
   Tilby separator process. Fiber board manufacture and sugar manufacture from pith. Potable alcohol production.

7. Indian Institute of Sugarcane Research.
   Lucknow - 226002
   India

   Dr. Kishan Singh

8. Zuckerforschungs-Institut Fuchsenbigl
   2286 Haringsee
   Austria

   Dr. Gunter Pollach

9. The Sugar Institute
   Ministry of Industry
   Rama VI Road
   Bangkok 4
   Thailand

   Mrs. Choom Chai Athachinda

This Institute has a research division which works in conjunction with some universities.

The Guangzhou Institute is already aware and in contact with many other research institutions such as Sugar Research Institute and Bureau of Sugar Experiment Stations in Queensland, Australia; Hawaiian Sugar Planters' Association, Honolulu; Braunschweig Sugar Research Institute, Braunschweig, Germany; U.S.D.A. Sugar Cane Research, Houma, Louisiana; Canal Point, Florida and Weslaco, Texas; Audubon Sugar Institute, Louisiana State University, and ICINAZ (sugar) and ICIDCA (byproducts), Havana, Cuba.

Discussions have taken place with the author's organization, Sugar Processing Research, Inc., who look forward to hosting a visiting technologist from the Institute, under auspices of U.S.D.A.

Training

Courses of interest are listed as follows:

Cane Sugar Refiners Short Course, Nicholls State University, Thibodeaux, Louisiana, USA. Two weeks Information appended. Useful for large amount of information presented by several experts in various fields of refining and for meeting young technologists from around the world.

Louisiana State University. Short courses in sugar chemistry and sugar boiling are held (7-10 days) which might serve as examples for development of China's own courses.

University of Los Banos, The Philippines offers some training in sugar technology.

Luis Queiroz University, Branch of University of Sao Paulo, Piracicaba, S.P. Brazil, offers some training in sugar technology.
Dr. Henrique V. Amorim, Dept. of Chemistry, although not in sugar (coffee and peanuts interests) has spent time at the Southern Regional Research Center and might serve as a contact here.

Cameco Company, Thibodeaux, Louisiana U.S.A., a major manufacturer of cane field equipment, sometimes holds short courses on field and factory operations with good lectures. The Company has been known to offer financial assistance to interested parties.

It is also very strongly recommended that the sugar industry of China undertake membership in the following organizations:

1. International Society of Sugar Cane Technologists. The Chinese Society should be a member of this, the largest and most diverse sugar organization. Each member Society has representation on the Board. I.S.S.C.T. meets every 3 years, and each Congress is organized by the host country, which alternates from Eastern to Western Hemisphere, and is chosen by vote of the Board. The Congress, about 5 days long, has sections on the various agricultural areas, processing, by-products and energy. Proceedings are published.
The next Congress will be in Indonesia, April 25 to May 3, 1986. Information can be obtained from: R. Moeljono Hadipoero, Jalan Tanjung Karang 5, P. O. Box 3185, Jakarta, Indonesia.

2. Sugar Industry Technologists. This organization of sugar refiners, producers and suppliers to the industry is based in North America, but has international membership. It meets annually (next in Houston, May 6-8, 1984) for 2-3 days to hear papers on sugar technology and engineering. Its annual Proceedings is a very useful publication. Membership is available to companies (U.S. $350 per year) or to individuals as allied members (U.S. $50 per year). It is recommended that an official from the Ministry of Light Industry and the Head of Sugar Technology should belong to this group. When meeting attendance is possible, S.I.T. will be a most useful source of contacts with technologists and management, internationally.
The author has observed, in the S.I.T. Membership Roster, that there is a member in the P.R.C.; Dr. Yun-Men Huang, Executive Vice-President, Science and Technology Association, Neijiang, Sichuan.

3. International Commission for Uniform Methods of Sugar Analysis (ICUMSA). Technologists in China, especially at the Institute, are aware of ICUMSA and follow its progress and regulations closely. As an importing country and, more importantly, as a country interested in exporting, China should participate in ICUMSA meetings, where test procedures and standards are set. Individuals cannot belong to ICUMSA: each country that has a National Committee on Sugar Analysis is a member, and sends delegates to the Conference, held every 4 years (next in France in 1986). Formation of a Chinese National Committee on Sugar Analysis is recommended. Such a group would be instrumental in promoting industry unity and development of procedures especially suited for use in China, in accord with international standards. Organization of a Chinese National Committee, with members from

the industry and the universities, would permit membership in ICUMSA. Further information can be obtained from General Secretary Dr. Albert Emmerich, Institut fur landwirtschaftliche, Technologie und Zuckerindustrie, Postfach 5224, Langer Kamp 5, 3300 Braunschweig, West Germany.

4. Sugar Processing Research, Inc. (S.P.R.I.). The author recommends that the Ministry for Light Industry consider membership for the Sugar Research Institute in S.P.R.I., although she realizes that at this time it is unlikely that foreign exchange regulations will permit payment of the subscription fee. This is an independent, international organization, supported by sugar producers, refiners, users, and suppliers to the industry, around the world, and housed at the U.S. Department of Agriculture's Southern Regional Research Center, New Orleans, Louisiana. S.P.R.I. holds a conference every other year, and publishes Proceedings of this, plus frequent technical reports and bulletins to its member companies.

Further information may be obtained from the author.

5. Although this report is primarily concerned with cane sugar, there were personnel present at the Seminar from beet sugar factories who asked questions and presented problems. This recommendation is that a beet sugar technology expert be invited to consult with the beet industry. It is recommended that Mr. Stanley Bichsel, Vice President, American Crystal Sugar, Moorhead, Minnesota, would be an excellent expert for this purpose, as he is a general expert in beet sugar technology, energy saving, and byproducts with good knowledge of sugarbeet agriculture.

Recommendations for Factories

1. Several changes are recommended in factory laboratories, particularly with regard to instrumentation. It is expected that these changes will be gradual and that much of this instrumentation can be built in China. The reasons for the recommendations are all to improve factory control. The changes recommended will produce more accurate and more reproducible (important for inter-factory comparison) measurements. The instruments recommended can be used reliably by personnel with little technical background and minimal training. These instruments require, in general, much shorter analysis time than current procedures, for example, refractometer Brix reading requires 20-30 seconds; spindle Brix 20-30 minutes to allow settling.

It is recommended that the shift from spindle Brix to refractometer Brix be made. Refractometer Brix is a lower reading, closer to true solids, and the change can be significant with the stale cane and high non-sucrose solids often found in China. Digital readout instruments are now available and should be obtained to reduce operator error and increase reliability.

A small electronic polarimeter with digital readout should be obtained (e.g. Optical Acitivity U.K., or Rudolf (U.S.A.)) and studied for use in factories in China. These are quite rugged, very simple to use and very fast. Operator error is agian minimized. The use of these instruments will improve the accuracy of control measurements by an order of magnitude, and release considerable technician time for other work. Highly trained operators are not required. These factors are especially important in establishing a cane testing program where many more analyses will be required than those needed for control. the use of an automatic polarimeter should allow restoration of the double pol measurement to the factories.

It is also recommended that colour readings be made in ICUMSA units rather than in Stammer, a unit not used elsewhere. If it is possible to convert instrument dials so that both systems may be used for a year or so, until

ICUMSA unit conversion is complete, this system might ease the transition. It is highly recommended that pH measurement be done by electrode and pH meter rather than bromthymol blue. This inaccurate measurement makes control very difficult, and may be responsible for the apparent overliming observed, which makes scaling worse. It is expected that pH meters and electrodes are constructed in China. This is important for cane juice quality as well as clarification.

2. Investigation and trials on methods of direct industrial quality white sugar production, such as Blanco Directo, (referred to in Institute Recommendations) are recommended. This is not to be considered for all white sugar production, but only for the 10% or so required by industrial users. Several factories have already tried syrup clarification, and found this to produce significant improvement in product and storage quality. Blanco Directo adds other steps to process, as well as syrup clarification to produce an industrial grade sugar.

Further studies on new methods of clarification, such as have already begun at the Institute, are recommended.

3. Institution of a cane quality payment system, as quickly and as widespread as possible, is highly recommended. Further details on plans for future development of such a system, are included under Institute Recommendations.

4. A program for improved maintenance, good housekeeping and hygeine is recommended. Although housekeeping factories visited were not bad by world standards, their housekeeping should be better, with numbers of personnel available. Hygeine at the sugar bagging station should definitely be improved.

Hygeine on the mills is a very important consideration in view of the high dextran levels observed in mills. Dextran is not only coming in with the cane, it is being made across the mill. Trials have shown that the use of frequent sprays of chlorine water is effective at controlling microbial infection, but employees do not like to use this because of the smell. This is an effective control, and cheaper than most bactericides. It is most important to control dextran, not only because of sugar loss, but because of process slowdown and inefficiency, and recycling of syrups and molasses that cost energy.

It is recommended that at each factory an engineer be appointed to be in charge of hygeine control, with the goals of cutting losses, saving energy and improving quality. This should be recognized as an important position. With regard to mill hygeine: it is suggested that a special team of workers be appointed to spray chlorine water on the mills. The job should be made a special one, with some special status, special clothing, and extra pay, if possible, to overcome employees' resistance to this necessary procedure.

5. A study on the size and separation of sugar crystals produced is recommended. As mentioned under Observations-Factories and Recommendations-Institute, the system of boiling a very large grain (which holds a lot of water because of the high levels of invert and polysaccharides) and then washing it excessively, and steaming it, is very wasteful of sugar, plant capacity and energy.

A first step to consider is replacement of steam in the centrifuges by a double wash using superheated water. This flashes off and atomizes around the crystals, causing less sucrose loss and color formation on the crystal, and less corrosion to the centrifuges (which appeared to be carbon steel) than does steam.

White sugar made for export will require a smaller grain, for most countries except the Middle East, and when the time comes to export, conditioning systems should be considered to ensure long-term stability of the sugar. These are not necessary at this time and would be a waste with the current type of sugar.

Improvement in syrup quality and production of a smaller grain, with moderate washing, no steam, and hot and cold ambient air drying, will save sugar loss, reduce pan time, reduce recycling of syrup (and sugar loss and color buildup), reduce number of centrifuges refined, improve sugar appearance, quality and storage quality.

6. A study on the degree of cane preparation, maceration and extraction to maximize yield of sugar with minimum energy input is recommended. The relative virtues of diffusers and mills, alone or in combination (unpopular most places it's been tried) for larger factories has been discussed, in the P.R.C. and elsewhere. The unusually soft low fiber cane in China makes required conditions here unlike those in other countries, and does not appear to have been studied conclusively.

Where factories employ diffusers, it is recommended that the prepared cane is limed before going into the diffuser, to cut sugar losses. The cane observed at Dongquan was very finely prepared, and at the low pH of stale cane, diffuser losses must be considerable. Liming at this stage may make the bagasse yellow; this is because some of the lignin has been released and oxidized to form colored compounds. This is useful if the bagasse is to go to paper manufacture, where an alkali treatment will be used to release lignin anyway.

7. Additional utilization of byproducts, where possible, is recommended. There is awareness of these possibilities, e.g. distribution of distillery muds to farmers, to carry away to put on their fields, where the mud can replenish some of the potash shortage. It appears that overall organization of these approaches is desirable. The abovementioned use of filtrate muds as a source of wax is also recommended.

8. As a final, general recommendation, it is recommended that the Symposium that the author attended become a regular event, to be held every second or third year, in different areas of technology (processing and byproduct) and agriculture. Such an Institution will promote unity and coordination across the industry: the desire for these is there, and a regular Symposium will provide one means to supply it.

MISCELLANEOUS

A selection of papers and technical publications, brought to the P.R.C. by the author, was presented to the Cane Sugar Research Institute Library. Papers from various journals on subjects known to be of interest; Proceedings of technical meetings of Sugar Processing Research, Inc. and its predecessor, Cane Sugar Refining Research Project; the 1983 Sugar y Azucar Yearbook (written by this author) and the Recommendations from the 1982 Session of ICUMSA were included.

NON-TECHNICAL COMMENTS

Translation

Translation facilities in Beijung were excellent: Mr. Chen Ruquan, Ministry of Light Industry, is a most helpful and efficient interpreter.

Faciities at the Seminar in Guangzhou were very good, and much better than anticipated. Very good preparation on the part of the graduate student, Mr. Gao, who had read the author's papers, was commendable. The author attempted to present as much material as possible on slides or transparencies, and in written form. The availability of an overhead projector with blank transparencies was very helpful. Participants were requested to submit their questions in written form (those not in English were translated by Institute Librarian, Li Jinding) and answers were given during the lectures or in written form where possible. Copies of questions and answers are addended.

Cooperation from Ministry of Light Industry

Cooperation from the Ministry both technical and non-technical, was excellent. Factory personnel were well-prepared for our visits, and open and cooperative about answering questions and providing information. The author was especially impressed that Mr. Liang Chi, in charge of all sugar factories in the area, made great efforts to spend ample time with our group at that extremely busy time when grinding season was beginning and factories were just opening. This required a great deal of planning and excess travel.

The Foreign Affairs Department of the Ministry was most helpful with all arrangements, and ensured smooth and efficient visit, making best use of the time available to our group. The Foreign Affairs people were very helpful with hotel arrangements, transport, timing, acclimatizing visitors to Chinese customs and advising on etiquette. They were especially helpful to the author, who could not use the telephone without help if she did not know the number.

Cooperation from the Institute

Cooperation was excellent. The extensive planning that was required to arrange for so many delegates, and such a variety of topics for discussion, made for smooth operations of the Seminar. The ability to adapt plans e.g. to allow the author time for additional visits to the Institute, was admirable. Director Chen Shi-Zhi was especially helpful with everything from arranging meetings and rearranging schedules to acting as interpreter when necessary.

Part of the planning was to ensure that the delegates were familiar with the visitors work, and this was helpful in determining areas of greatest interest for discussion. It is always difficult to determine the technical level of an audience when the lecturer does not speak their language. Because of this, the author suggests that if a visiting lecturer is talking about material that is well-known and at too low a level, personnel should be encouraged to let the speaker know this, so that time is not wasted. This may not seem polite, but is practical. In the author's case, Professor Shun (a lady professor from the South China Institute of Technology) and Mr. Li (in charge of Analytical Department, Sugar Institute) helped her to establish levels of general interest.

Of the greatest assistance during the author's visit was Mme. Li Jinding, Librarian at the Institute, who acted as informal translator and companion. Mme. Li has very good colloquial English and a fine technical vocabulary, and is most helpful at explaining customs and traditions. Her help and support were invaluable. It is recommended that she be available for the assistance of future European and American visitors.

INTRODUCTORY REMARKS
BEFORE FIRST GENERAL SESSION OF SEMINAR

Distinguished Professors and Scholars, Technologists and Colleagues, Ladies and Gentlemen:

I am very pleased to be here with you in Guangzhou as part of the first seminar on Cane Sugar Technology in China. It is my great pleasure to meet so many leading sugar Technologists here in China.

The achievement of bringing together so many leading sugar technologists from different parts of the country is a great advance, and the discussions that will ensue are bound to be useful in the development and growth of the sugar industry in China as a whole. To encourage this growth and development, and to increase progress here at the Cane Sugar Institute of Guangzhou, is the aim and purpose of our team.

China is a mother of sugar and sugar production: In olden days, China was one of the first places where sugarcane was grown.

Today, China is already a major producer of sugar, among the top ten producers in the world, and looking toward a great future.

The plans to produce 10 million tons per year by the turn of the century will, when realized, place China in the lead as the major sugar producer in the world, and so China will become a father or grandfather of sugar production, as well as being a mother of the original sugarcane plant.

It is our desire that this seminar and our team's visit here will aid and support this growth and development of the sugar industry. I am pleased and honoured to be part of the team helping this effort.

In the talks that I will present to you, I want to discuss some foundations and basic aspects of each situation, and then some applications and ways to gain insight into problems that apply to your situation here in China. This morning, I will talk about colour in cane juice and in sugar, and colour removal, in a quite general way. Later, when we divide into small groups, there will be detailed information for those of you especially interested in colour and colour problems.

On Wednesday, we will discuss factors and materials that affect efficiency and yield in cane sugar processing, and analytical methods to examine these. These factors include dextran and other polysaccharides, inorganic compounds, organic acids, and invert sugar.

On Friday, we will discuss research projects, current and past, of my own group that can be of interest to technologists in China.

Next Monday, those people especially interested in chromatography, particularly High Performance Liquid Chromatography, will meet to talk about useful ways to use HPLC to improve sugar production efficiency, cane testing, pollution control, and special products considerations.

On the final day for talks, Thursday, Dec. 15th, we will review problems that have been presented for discussion and that have been observed, and plan future work for the institute in these areas.

Before we start the talk on colour, let me tell you a little about my own group, Sugar Processing Research, Incorporated, or "SPRI" for short.

We are an international, non-profit, research organization. Our major goals and purposes are:

1. To examine the fundamentals of sugar production and refining process to gain understanding of the chemical and physical bases of these processes in order to improve the operation of current processes and to develop new processes.
2. To develop new analytical methods for the sugar industry, as such needs are identified, and to improve and expand methods in current use.
3. To study the chemical nature of sugars, non-sugars and sugar producing plants in order to explain processing problems, and to coordinate problems in agricultural and production practices.
4. To serve as an information resource and data base on sugar production, process problems, sugar byproducts and associated areas for sponsoring companies of S.P.R.I.
5. To assist in problem solving in research-related areas for sponsoring companies of S.P.R.I.

We are supported financially by more than 30 sugar companies around the world, many in the U.S.A. and Canada, and companies in England, Australia, Brazil, South Africa, Pakistan and the Philippines.

We work in cooperation with the U.S. Department of Agriculture, and we are housed at the U.S.D.A. Southern Regional Research Centre (S.R.R.C.) in New Orleans, Louisiana. S.R.R.C. is a major research centre, for about 400 people, with major research equipment, such as mass spectrometers, x-ray fluorescence, nuclear magnetic resonance, Fourier transform infra-red, protein sequence analysis, and much chromatographic equipment. There are also pilot plant and greenhouse facilities. The Centre scientists work on utilization of crops produced in the southern United States, including cotton, cottonseed oil and protein, peanuts, rice, fish farming, grain sorghum and eggs, as well as cane sugar. Several scientists from China have spent one to two years visiting the Centre to work on cotton textiles. S.R.R.C. is the home of wash-and-wear finishing, and other textile improvements. Our group, S.P.R.I., works with some of the cotton textile research people on questions of fiber, because bagasse is partly cellulose, like cotton.

Our major areas of research at S.P.R.I., which will be discussed in detail on Friday, include colourant and color precursors, chromatographic analysis, polysaccharides, filtration efficiency, crystallization parameters and sugar losses.

One of our scientists, Tsang Wing-Sum (Dr. Charles Tsang, to us) visited the Institute here in June, 1983, and enjoyed your kind hospitality. Dr. Tsang, an organic chemist, has joined S.P.R.I. only last year, but plans to stay with us for some time, so we are fortunate to have in the group a scientist who speaks both Mandarin and Cantonese.

REMARKS AT CLOSING SESSION OF SEMINAR

Distinguished Professors and Scholars, fellow technologists and Colleagues, Ladies and Gentlemen:

I was requested by the National Cane Sugar Industry Research Centre, here in Guangzhou, through UNIDO, The United Nations Industrial Development Organization, to attend this nationwide seminar in the company of Dr. James C.P. Chen's illustrious group. The purpose of my visit was designated as two areas: One, discussion of research and analysis of cane sugar colorants; and, two, suggestions for sugar industry research for improvement of product quality, improvement of current clarification operation, and development of new processes.

OBSERVATIONS

General Observations during my visit here include the following:

1. Very impressed with keen interest of delegates to seminar, and their general knowledge of current sugar research.
2. Equipment at the Institute for HPLC and other analysis is adequate, with only slight additions for research in the areas designated. Personnel are adequately trained, with some additional training and cooperative programmes to be recommended.
3. Factories and cane producers require development of cooperation to meet goals of increase in cane production, sugar production in cane, and sugar production in factory.
4. Factories require development of cooperation between milling end and boiling house. Targets set for each part are not necessarily supportive of one another. For example, achievement of maximum extraction in the mill can increase energy demands in the boiling house.
5. The general quality of sugar produced is not suitable for industrial use, although quite suitable for household use. Production processes require excess time and energy because of poor quality of cane received at the mill.

GENERAL RECOMMENDATIONS AND SUGGESTIONS

1. Increase understanding and cooperation between factory and cane producers. Improve planned cane deliveries. I understand that a commission has already been appointed to investigate this area. A cane quality payment system will of course improve growers deliveries. The Institute can play a central role here because of the fortunate combination of processing and agricultural research facilities.
2. Increased training of Institute personnel in other cane sugar areas of the world, particularly for byproducts utilization.
3. Increased cooperation between the Institute and factories for projects on improvement of product quality and energy demands. Consideration of the possibility that a factory conducting experimental work be exempted from process targets.
4. Increased automation in factory control laboratories, especially for digital-readout refractometers for Brix measurement (already underway at the Institute), and small automatic digital-readout polarimeters.
5. Final recommendation is for a series of proposed research projects, which

are submitted in some detail to the Institute. These involve analyses for colorants and other non-sucrose components. These analyses can be performed with current Institute equipment plus some small additions. Results will give information to guide decisions on process changes and new processes.

These research projects should increase energy saving, decrease sucrose loss in factory and in cane, increase factory capacity, improve sugar quality and sugar storage quality, and help to develop a cane quality payment system.

It has certainly been my great pleasure, during our seminar's very full schedule, to meet so many of China's leading sugar technologists, and to learn more about the sugar industry in China.

Thank you all very much for your great welcome and tremendous hospitality.

I have here some publications that I wish to contribute to the library of the Cane Sugar Research Institute of Guangzhou. These include Proceedings of various meetings of our own group, Sugar Processing Research, Inc., and the Cane Sugar Refining Research Project, Inc. There is also a copy of the 1983 Sugar y Azucar Yearbook, which I was honoured to write this year, and a selection of papers on sugar colorant and other topics we have discussed. I hope these will be of use in future research and development of the industry.

Thank you all very much.

QUESTIONS FROM DELEGATES
AND ANSWERS FROM M. A. CLARKE
(given on site during the Seminar)

Question: What are the major environmental factors that affect colour substances in cane juice?

Answer: Components, that are subject to environmental conditions, that affect colour substances in cane juice: Levels of phenolic compounds (some coloured, many colour precursors which become coloured on oxidation or complex formation with metal irons) and amino acids (which enter into Browning Reactions) are the main components of cane juice that affect colour in juice and later in processing and in sugar. Levels of iron and phosphate (high iron bad; high phosphate good) are also important. Invert levels have an effect: invert decomposes into organic acids and coloured compounds during processing.

Environmental factors that affect these components are:
1. Age of cane and cane variety. The genetic makeup of the cane controls levels of flavones (complex phenolics) and amino acids, and age at which cane is optimum for harvest, with maximum sucrose and minimum colour precursors and invert.

2. Rainfall and drought. Too little rainfall (drought conditions) increases the level of amino acids in juice. These lead to formation of high molecular weight that is difficult to remove. Cane that is irrigated has a similar response, and develops increased levels of amino acids in juice.

3. Age of cane after harvest. Stale cane not only contains dextrans, from L. mesenteroides, but other byproducts of that organism, and of inversion and invert destruction. Levels of organic acids, and colour precursors and colour in juice increase with increased staleness. Dextran in sugar, and high invert levels, increase moisture in crystal, and make sugar difficult to dry. High moisture increases colour development on storage.

4. Size and shape of field. Cane from the outside of a plot or field tends to have higher levels of flavones and anthocyanins than cane from the inside, shaded by the canopy. This is a problem in cane areas I've observed here, probably insoluble.

5. Fertilizers. Excess nitrogen in fertilizer leads to an increase in amino acid levels in juice (especially asparagine) and these develop into high molecular weight colorant that is difficult to remove and is selectively occluded in the sugar crystal. Additional phosphate in soil will help the plant assimilate the excess nitrogen more efficiently, and additional phosphate in juice aids processing and improves sugar colour.

Insufficient soil levels of phosphate, potassium or copper will cause excessively high levels of amino acids (especially asparagine) even if nitrogen dose is low. Too much potassium also increases amino acid levels.

6. Proximity to equator. For any given variety, the flavone levels in juice increase at latitudes approaching the equator.

7. Disease resistance and infection. Occurance of infection can generate increase in flavours and anthocyanins (anthocyanins are not a really severe problem; amino acids are a bad problem) ex. red rot anthocyanin. The plant creates these to fight disease.

Newer cane varieties with better disease resistance show higher levels of juice flavones than older, less resistant varieties.

Question: 1) What is the mechanism of the action of SO_2, chemical and physical chemical actions, on juice materials?

Most of our sugar factories apply sulfitation process; it is quite simple and low cost, but has some shortcomings. In general, sugar produced by this process is not white enough and gets yellower during storage. In the past, this was attributed to the fact that SO_2 could only reduce the colorant temporarily, so that the original color could return after being oxidized by air.

We think this concept may not be complete. We have found that some sugar produced by sulphitation process changes its color only a little after a long period (a year) storage; even when the sugar absorbs the moisture from the air and becomes quite wet, it still remains quite white. We will give you a sample.

2) We have known from colloid chemistry, that the properties of the colloidal material are greatly dependent on their charge, and the organic colorants are like that generally. In cane juice or raw sugar, many of the colorants are charged, some are stronger and others are weaker. But what are their amount of the charge? How many molecular weight of a certain colorant carries a unit of charge? Could you tell us some concrete facts about the influence of the charge upon the properties of some certain cane (or raw sugar)colorants?

Besides these two questions, I have two others, and hope to get answers or information in the future (if they cannot be discussed this time): (1) In cane juice, are all the soluble calcium compounds able to dissociate into calcium ion? or do some of them exist in a complex compound and only dissociate very weakly? This situation will influence greatly the reaction of calcium and sulphurous ion (SO_3), as well as the calcium content in the clarified juice.

(2) There are some silica in the cane juice. What compounds does it exist in? Is this compound in a colloidal form? What are its major properties? How can the factory remove the silica from the juice?

Answer: There are two mechanisms of action known for SO decolorization (there may be others not yet known).

1. SO_2 + colorant (ex. phenolic with series of double bonds conjugated) → reduced form of colorant, or non-colored reduction product.

2. SO_2 + colorant of phenolic-amine addition product type, or reducing sugar-amine (melanoidin or melanin). → sulfite addition product (contains (NH_3 + HSO_3), non-colored.

To my knowledge, none of these individual reduction products or addition products have been isolated. This is very complex chemistry and the value of research expended on isolation and identification of simple compounds, when many are present in each class, must be questioned. Spectroscopic techniques could be used to identify groups of non-colored products--a potential area for research if you are looking for one.

The 2 types of non-colored products (there may be additional types; we don't know) remain in the sugar crystal, and may in time enter into the following series of reactions that cause colour to appear again in the crystal upon storage. The colour that reappears is not necessarily identical to the original form, especially in the case of iron-colorant compounds. All reactions are speeded up by increase in temperature, available oxygen, photo sensitivity (sunlight) and moisture. The presence of iron both creates complexes (coloured) and catalyzes color forming reactions.

A. Amino acids + reducing sugars → coloured compounds (melanoidins) + SO_2

↓

Sulfite addition products, non-colored. Reformed color by two pathways.

① Storage, heat, H_2O → Coloured compounds. Addition products break up, HSO_3 is oxidized.

② Fe in sugar or in storage container → Highly coloured complexes and also oxidized addition products, with break-down catalyzed by Fe.

B. Phenolics, with or without amino acids. Again, individual SO_2 reaction products have not been identified and so your request for specific examples cannot be fulfilled, at least to my knowledge.

Phenolics + amino acids → High molecular weight colorants. These *probably* form addition products with SO_2 and enter into the series of decomposition reactions on storage outlined above.

Phenolics without amino acids + SO_2 → reduction products, non coloured.

Oxidized form, coloured ← (1) Storage, heat, light, water

Iron complexes highly coloured; also catalysis of oxidation. ← (2) Fe

There are generalized pathways, composed of probably many individual reaction steps. These reaction steps are not known.

With regard to colour removal, and production of sugar that does not darken on storage: phosphate flotation, and carbonatation physically remove the colorant molecules from the syrup, so that they are not in the sugar crystal in either coloured or non-coloured form, and so cannot react to form colour again and cause darkening on storage.

Flotation (phosphate + polymers) also remove iron, a major cause of darkening in storage.

Sulfitation chemically, not physically, changes colorant but leaves the molecules in the crystal so that they may change on storage. Some sulfite addition or reduction products may not change back to colored products--we don't know. Again, research is needed in this area.

The sample of sugar you gave me was apparently made by syrup flotation, which had removed iron and colorants (as above), and so did not contain sulfite addition or reduction products to re-form color on storage, in spite of its very wet condition. The wetness can be due to several things. (1) Packing too hot, (2) severe temperature changes during storage, (3) high polysaccharide level holding moisture in crystal.

For colorant research, I refer you to the papers of Dr. J. A. Williams, Dr. K. J. Parker, Dr. Peter Smith and Dr. Norman H. Smith; and a series of carbohydrate research papers from Sweden by Dr. O. Theander.

(2) Your request for "concrete facts" about charge and colour may be filled by some of the publications of the above, but, again, most work has been in general terms. The following facts are known:

1. Maillard colorant (melanoidin) carries a unit charge of approximately 160 m.wt. units, with this m.wt. per charge ratio decreasing with increasing molecular size.

2. Flavones tend to become more coloured at high pH, above 8, and to become more negatively charged at pH>8, so that they can be more easily removed by anionic resins at pH>8.

3. For cane juice suspneded matter, the zeta potential (overall charge of particle, or outer layer of charge on particle) is positive at low pH and becomes negative at pH>5, so that this material can be precipitated, or removed by resin (watch out for blockage) at pH>5.

Additional References. Bennett, Int. Sugar Journal, 1959.

(3) Brief answers to your other questions:

Calcium in juice: No, all calcium solubles do not completely dissociate. Calcium tends to complex, with chloride if nothing else is available.

You can determine the level of free (uncomplex) calcium ion using the calcium ion selective electrode, and total calcium (free + complexed) by atomic absorption spectroscopy, or EDTA titration, all available at the Institute.

2. Silica exists as a series of soluble silicates (see Clarke, SIT 1976, CSRRP 1976-77). Much of it can be in colloidal form in juice--depends on soil and water. Major properties are that these are haze formers and scale formers. Most precipitates out as calcium silicate in evaporator scale. Silicates can be removed, somewhat, by settling clarification, and by anionic resin or polymer. Silicate will foul ion-exchange resins irreversibly.

Sorry not to give more details--practical answers to many of your questions are simply not available at this time.

<u>Question:</u> Dextran Analysis by the Roberts Dextran Test.

1. How long can the copper reagent be stocked at room temperature?
2. How long can the phenolic solution be kept?
3. The anhydrous sodium sulphate must be added to satuate the copper reagents when preparing it, but the sodium sulphate cannot be dissolved completely at room temperature. Can we heat to dissolve it?

<u>Answer:</u>
Copper reagent: Stock solution (3 g · $CuSO_4$, $5H_2O$, 30 g · sodium citrate in 1 litre) can be kept for 2 weeks. Reagent solution (50 ml · stock solution/50 ml H_2O + 12.5 g Na_2SO_4) <u>must</u> be made freshly every day it is to be used. Do not keep this solution after the day it is made up.

Phenol solution--Prepare fresh each week. Will keep for 1 week.

Copper reagent solution--Yes, you can heat the copper reagent solution to dissolve the sodium sulfate. Heat gently in a covered beaker, with stirring. Don't boil it. There should be a few crystals of sodium sulfate undissolved in the saturated solution at room temperature, to keep it saturated.

Question:

1. Please explain for prolonging the life of the HPLC columns, what are the requirements of sample (cane juice, molasses, etc.) treatment. Does the ash component of the sample damage the carbohydrate column? Is it correct to use lead acetate to purify the sample for the carbohydrate column?
2. Please explain the method of using SepPak C_{18} and SepPak silica cartridge for sample treatment.
3. Please explain the sample ethyl acetate extract method for the HPLC analysis of organic acid and colorant compounds.
4. Please explain how to modify a silica column with a complex amine compound dissolved in the solvent of acetonitrile and water, so that the modified column will separate sugars.
5. In earlier papers resins in HPLC columns are in potassium form and the solvent is pure water only. But in Dr. Clarke's studies, resins are in calcium form and the solvent is Milli-Q water containing 20 ppm calcium salt. I would like to know the difference between the two systems.

Answer:

Modification of silica column with complex amine compound:

Radial compression system.
Column cartridge, 10 μ silica
Solvent: acetonitrile and water, containing Tetra ethylene pentamine. The column is first treated with a solution of tetraethylene pentamine (TEPA) stronger than the solvent.

A reference is:
B. B. Wheals and P. C. White
Journal of Chromatography, 1979,
176, pp. 421-426.

Ethyl acetate extraction of sugars.

100 g. sugar made up to 40 Brix solution, or an equivalent amount of syrup, is acidified to pH 2.5 with 2 N sulfuric acid (For juice, use 150 mls.)

The solution is extracted with 100 mls. ethlyacetate (150 mls for juice) in a separatory funnel.

The extract is dried over sodium sulfate, and can be concentrated in a rotary evaporator at room temperature (do not heat--will change colorants) or by freeze drying.

The extract can be divided (to some extent) into a phenolics fraction and acidic fraction.

To the ethyl acetate fraction, add 100 mls sodium bicarbonate (3% solution). The ethyl acetate fraction will then contain mainly phenolics. The sodium bicarbonate fraction should be readjusted to pH 2.5 with 2N sulfuric acid, and another extraction with ethyl acetate performed. The acid colorant components will go into the ethyl acetate fraction.

HPLC--cleaning out with HNO_3, 6 Normal

After pumping HNO_3(6N) through, flush system out by pumping HPLC (MilliQ) water through system at 2 ml/min. for 20 min., and then 50% methanol-50% water through at 2 ml/min. for 10 minutes.

Only after this washing, replace the column in the system, and change solvent back to CH_3CN = H_2O.

When solvent is changed from CH_3CN - H_2O to CH_3OH - H_2O, or vice versa, pressure will go up as solvent interface crosses the column, so flow rate should be reduced to keep pressure down. Use 0.8 ml/min. when changing solvents and allow 2J minutes for complete change.

When you wash μ Bonda pak carbohydrate column with 50% methanol 50% water in evening, leave that on column overnight and switch back to CH_3CN - H_2O in the morning at startup.

Question:
You have shown us a figure of sucrose content in steam of about 0.008%. Is this steam from boiler or from pan or evaporator?

Answer: The sucrose in steam (from boiler) of 0.008% is not typical: it is a bad situation. This factory had a problem with sucrose loss and we were trying with HPLC to identify the source of the loss. We found that the sucrose in boiler feed water and steam from the evaporator was one source of loss.

This is a high level of sucrose in steam. The U.S. factories and refineries try for zero sucrose in boiler feed water.

When we identified the problem, the factory repaired the condensers and decreased the sucrose level in feed water.

Colorimetric Tests for boiler feed water:
The α-naphthol test analyzes for any reducing sugar, or compound that will reduce α-naphthol, in addition to sucrose. These compounds include polysaccharide end-groups (terminal glucoses on dextran, starch, and other polysaccharides) and fructose and lactic acid (a compound present in stale cane and stale cane juice and mud wash water).

An α-naphthol test does not indicate sucrose only.

The molybdate test also reacts to many polysaccharides and non-sugars, not necessarily the same ones as α-naphthol. The two tests need not, therefore, give the same results, in the case where sucrose is present, or the case where sucrose is not present.

HPLC analysis (using ion-exchange columns like HPX87C or HPX87H) will show what polysaccharides, other sugars, and lactic acid may be present in boiler feed water, as well as sucrose. HPLC is not recommended as a routine control here, but as a demonstration of the results of the colorimetric tests. Conductivity is also a good general indication of contamination by non-sugars as well as sucrose.

Question:
Our sulphitation sugar turns yellow easily during storage, and our favorite, the brown sugar, gets darker, especially after storing in iron containers for a time. I would like to know the cause of it.

Answer:
Brown sugar turning dark during storage: Darkening is caused by oxidation of phenolic compounds during storage (discussed above, with other reasons, especially in sulfitation sugars, for darkening), and reactions of amino acids.

Iron catalyzes this process and makes the colour turn darker more quickly. You need the phenolics in the sugar for colour and flavour. If possible, keep the iron away from the sugar.

Store in aluminum, or plastic-lined vessels, or plastic (even paper) bags, if possible--anything except iron--and the problem should grow less, although some darkening will still occur.

The more airtight the storage container (and cooler) the better keeping quality of the sugar.

N.B. An increase in phosphate level of syrup will give brown sugars a good reddish-brown colour and remove greenish colour caused by iron; suggested level 200 ppm P_2O_5. But this is rather expensive.