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EVAPORATION BY MECHANICAL VAPOR RECOMPRESSION

Technical Progress Report for September 1—December 31, 1979

By
Clair H. Iverson
Glenn E. Coury

Work Performed Under Contract No. AC03-79CS40208

Beet Sugar Development Foundation
Fort Collins, Colorado

U. S. DEPARTMENT OF ENERGY

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TECHNICAL PROGRESS REPORT

SEPTEMBER 1, 1979 - DECEMBER 31, 1979

Beet Sugar Development Foundation
P.O. Box 1546
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I. SCOPE OF REPORT

This report covers the technical progress to January 1, 1980, under Phase I, Feasibility Study, of a Mechanical Vapor Recompression/Falling Film Evaporator demonstration plant to be installed at a beet sugar factory in the continental United States.

1. Technology Review

- a) Technical literature search.
- b) Visitations to selected operating installations of subject technology.
- c) "State of art" study of U.S. industry's utilization of steam and vapors in the process.

2. Demonstration Project Study

- a) Study to determine site or sites for demonstration project.
- b) Make energy balance study on selected plant or plants.
- c) Predict results of demonstration project with synthetic energy balance.
- d) Expected capital cost and energy cost savings will be projected.

In this study, Silver Engineering Works, Inc. (S.E.W.) is restricting its efforts to the experience and application of these technologies to the Beet Sugar Industry. Coury & Associates, subcontractors to S.E.W., are reviewing the technologies as applied to industries other than sugar. Because of this separation by industries, this report is presented in two parts - one for the Beet Sugar Industry, and one for other industries.

Since this is an interim report, it will cover only those activities accomplished up to January 1, 1980. A more detailed report covering factory visitations will be submitted with the next Technical Progress Report.

II. ABSTRACT OF REPORT

This report addresses the progress to date by Silver Engineering Works, Inc. and their consultants, Coury & Associates, in the development of a study of the application of the technologies of mechanical vapor recompresion and falling film evaporators as applied to the Beet Sugar Industry.

Areas of progress are reported in the following areas:

1. Technical Literature Search.
2. Plant visitations of existing applications of VR/FFE.

III. TECHNICAL LITERATURE SEARCH

A. Sugar Industry

The abstracts published in the "Sugar Industry Abstracts" (S.I.A.) were reviewed back to 1959 which identified all technical articles published relative to these technologies. A list of the publications reviewed by S.I.A. is enclosed as Appendix #1. From this review 86 publications were identified as germane to the heat balance and evaporation technologies of sugar manufacture.

A critical review of the abstracts reduced the number of papers to 28. This list is enclosed as Appendix #2. La Sucrerie Belge was contacted to provide all those papers listed for which an English translation was available, and the cost of translating those which are not available in English. Since we have access to German and French translators, we have asked that those papers also be forwarded. To date our file is incomplete.

Certain papers are now in the process of being translated.

The content of the papers obtained will be reviewed and pertinent information used in the conduct of the preliminary engineering involved in Phase I & II of this project.

B. Industries Other than Sugar

A literature search in non-sugar areas yielded nine significant papers which are enclosed as Appendix #3. Also a list of manufacturers of VR/FFE systems is included as Appendix #4. Five companies utilizing these technologies were identified and included as Appendix #5.

IV. SELECTED FACTORY VISITATIONS

A. Sugar Industry

1. The European sugar industry has for many years been forced to pay from two to four times the U.S. price for energy. As a result, capital expenditures for equipment and processes to reduce energy consumption have been much easier to justify. Most European factories produce sugar for half, or less, energy than does the average American factory. For this reason, this study would be derelict if it did not take a close look at European practices for the conservation of fuel. Therefore, a visit to European factories was scheduled.

During the period from November 24, 1979, through December 11, 1979, the S.E.W. Project Manager toured several beet sugar factories in Europe for the purpose of reviewing with factory operators their actual experience in operating and maintaining the subject equipment. Where possible, operating data was provided by the factory so that the performance of the equipment could be evaluated.

The factories visited and the focus of each visit follows:

a. Raffinerie Tirlemontoise SA, Hoegaarden Factory, Belgium.

- (1) Steam turbine driven centrifugal compressor recompressing first effect vapor back to steam chest pressure.
- (2) Beet Pulp drying apparatus utilizing waste condensates as heat source.

b. Raffinerie Tirlemontoise SA, Tienen Refinery, Belgium.

- (1) Two double-effect falling film evaporator stations under construction. These stations used to concentrate pan feed liquors from 68° to 73° Brix. Stations

totally automated with digital control, cathode ray display, automated hard copy logging and alarms.

- c. Raffinerie Tirlemontoise SA, Wanze Factory, Belgium.
 - (1) Two-steam turbine driven centrifugal compressors recompressing first effect vapor back to steam chest pressure.
- d. Raffinerie Tirlemontoise SA, Oreye, Belgium.
 - (1) Cursory look at evaporator station consisting of falling film evaporators used as second and third effects of a four effect station.
 - (2) A continuous crystallizing pan used for second boiling. Operating personnel were not available for interview at the time of this visit.
- e. Raffinerie Tirlemontoise SA, Genappe Factory, Belgium.
 - (1) A five effect evaporator station, all bodies of which are falling film type.
- f. Fabrique de Sucre de Frasnes-lez-Buissenal SA, Belgium.
 - (1) Process by which diffusion juice was cooled by cossettes to make practical the utilization of heat from previously wasted hot condensates.
- g. Hellenic Sugar Industry SA, Platy Factory, Greece.
 - (1) Visit with Dr. P. Christodoulou, author of a significant paper on steam balance and fuel economy.
- h. Zuckerfabrik & Raffinerie Aarberg AG, Aarberg Factory, Switzerland.
 - (1) The first and perhaps most successful utilization of mechanical vapor recompression in the beet sugar industry as applied to both the evaporation and sugar crys-

tallization stations.

(2) One falling film juice concentrator raising pan feed liquor from 69° to 74° Brix.

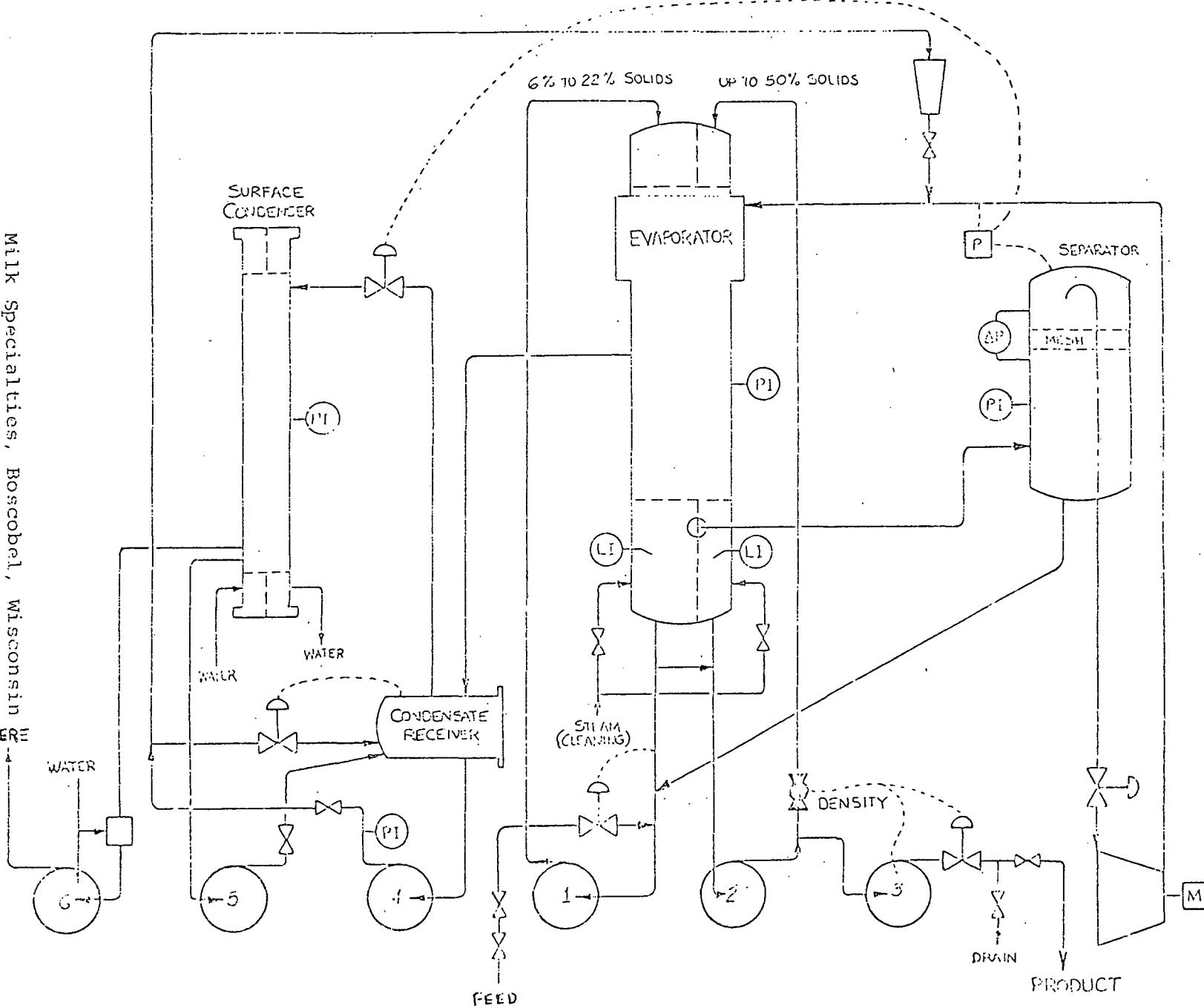
B. Industries Other than Sugar

1. Milk Specialties, Boscobel, Wisconsin

a. Milk Specialties is a whey processing plant that concentrates whey to produce a milk substitute used in feeding cattle. Whey, a byproduct of cheese manufacture, is delivered to Milk Specialties containing about 6% dissolved solids. The whey is preheated to 168°F. and pumped into one side of the evaporator. The whey circulates through one stage of the "split" evaporator at 168°F. and through the other stage at 150°F. Crossover piping connects the two product loops, allowing the product to transfer from one stage of the evaporator to the other stage.

Vapor evaporated from the product in both stages of the evaporator is collected and passed through a separator where a wire mesh removes any mist from the vapor and returns the liquid to the evaporator product line. The vapor from the separator is compressed by an electric, motor driven, centrifugal blower that increases the vapor pressure 2 psi with a flow rate of 16, 250 acfm. This compressed vapor is returned to the evaporator to evaporate more water from the product.

Condensate produced in the evaporator is removed to a condensate receiving tank and the vapor in tank is processed through a condenser to remove the non-condensable gases, while condensed liquid is returned to the tank. Liquid from the condensate receiving tank is pumped, under pressure, to



the condensed vapor line where the liquid is flashed and mixed with the vapor going into the evaporator.

During plant operation, the whey is continuously flowing through the evaporator stages. A gamma densitometer senses the density of the product stream and actuates a pump and valve to remove the product when its density reaches a level corresponding to 50% dissolved solids.

The current process has been in continuous operation for two years with no serious operational problems. Every ten days the process is stopped and the evaporator is cleaned out with steam before continuing the process.

2. Grain Processing Corporation, Muscatine, Iowa.

a. The Grain Processing Corporation plant is a corn wet-milling plant that converts corn into cornstarch and alcohol.

The solution entering the evaporation process consists of 8% dissolved solids, mostly cornstarch. A heat exchanger using evaporator condensate heats the solution to 190°F.

The solution is then pumped through three rising/falling film evaporators in series where the concentration of the product is raised to 30% dissolved solids. Vapor evaporated from the solution in each evaporator is collected in one large separator where vapors are removed and condensate is returned to the product streams. Liquid is removed from the vapor by first passing the vapor through a bubble-cap tray and then through a mesh scrubber.

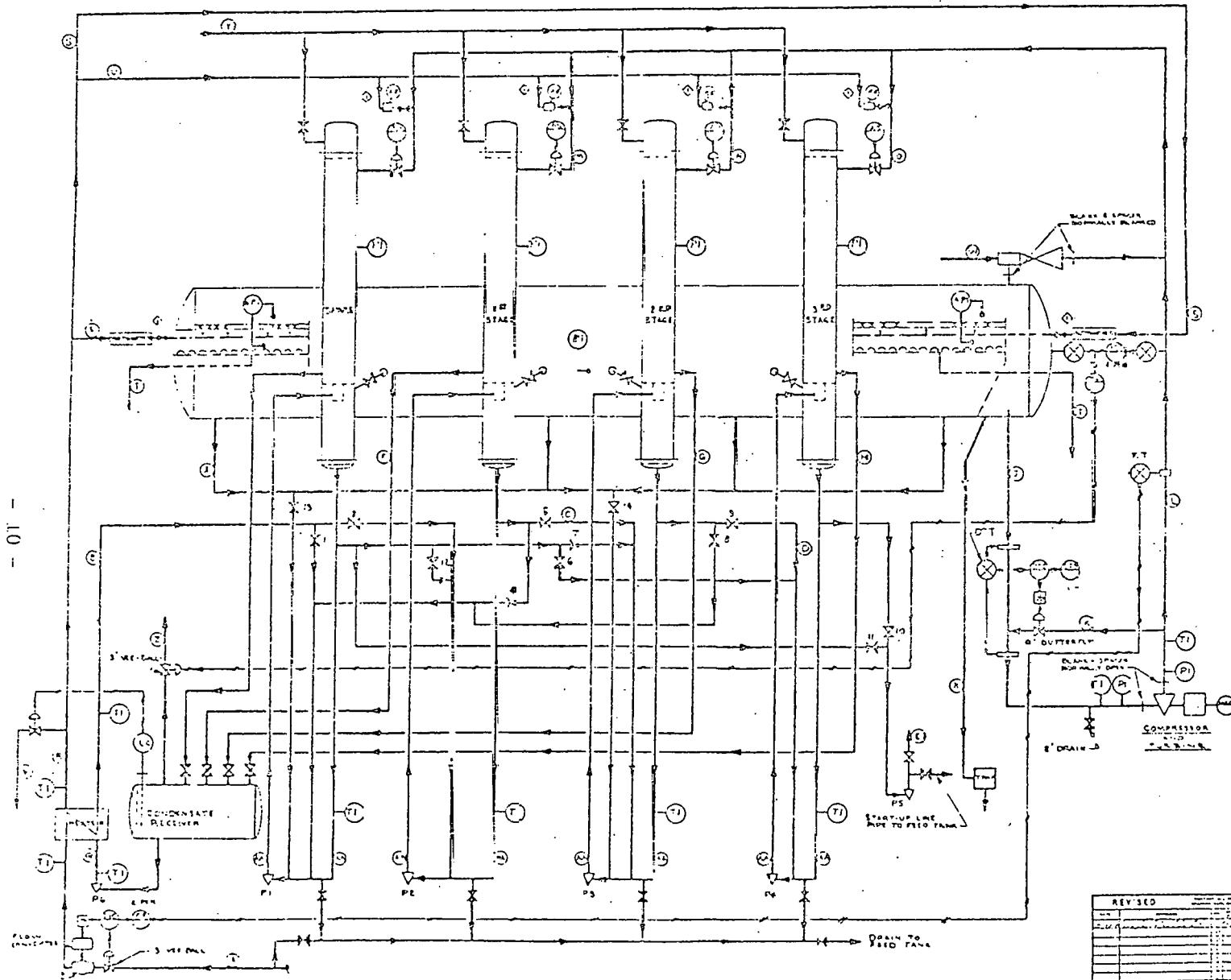
Vapor from the separator is compressed in a steam turbine driven Allis-Chalmers centrifugal blower producing an increase of 6 psi with a flow rate of 100,000#/hr. The original automatic control on turbine operation has been over-

ridden by manual control. A feedback loop across the compressor uses some of the compressed vapor to preheat the vapor entering the compressor. The compressed vapor is sent to all the evaporators to evaporate more water from the circulating product solution. Before the compressed vapor enters the evaporators it is desuperheated with the addition of some of the condensate that was used to preheat the product solution.

Condensate produced in the evaporators is collected in a tank where the non-condensable vapors are vented and the condensate is collected for use in preheating the product solution.

The evaporator process removed 100,000#/hr water from the product solution, using 10,000#/hr steam, and the product output is 40,000#/hr. At the time of the plant visit, all four evaporators were being used, but the total flows and evaporation were unchanged. In four years of operation the blower wheel has been replaced once due to pitting by liquid impingement. Superheating the inlet vapors has solved this problem and there have been no other serious operational problems as long as the prescribed routine maintenance is performed.

The cornstarch solution flowing through the evaporators leads to a problem of fouling by various protein compounds. Because of this, the evaporators are cleaned out after every ten days of service, and the separator mesh is cleaned every six months. An individual evaporator can be cleaned without stopping the total process. The evaporator to be cleaned is isolated from the process and a caustic solution is used to remove the



NOTES:

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2	3	4

Grain Processing Corp., Muscatine, Iowa

protein deposits. Cleaning the separator mesh with a caustic solution involves shutting down the process because of the lack of a spare separator.

V. PRELIMINARY CONCLUSIONS FROM FACTORY VISITATIONS

A. Sugar Industry

All technical data and its presentation must be submitted to the individual factory management for review, editing, and approval before publication. Such a submission has not been made at this time. Therefore, the conclusions enumerated below are preliminary, tentative, and non-specific as it related to any particular factory or installation.

1. Mechanical recompression equipment has proved to be extremely reliable and relatively maintenance free. There are no physical reasons that would suggest that the type of equipment observed in service is not well suited for the service.
2. A very efficient entrainment separator must be used to remove carryover of contamination from the evaporated juice so that:
 - a. Condensates will not be contaminated so as to preclude use as boiler feedwater.
 - b. To minimize the deposits of carbonized sugar in the compressor and piping system.
3. All mechanical compression units were being run at constant speed. Some installations had originally been installed to run at variable speed under automatic control, but because of operating problems have been converted to constant speed.
4. The most "normal" application of mechanical recompression was for the recompression of first effect vapor to its steam chest pressure.

5. The application of vapor recompression most often involved the use of two bodies operated in parallel as first effect. One of the bodies was operated as a "base loaded" unit, essentially a constant load. The recompression unit favored that body. The other body, conventionally piped, took the load swings which were accommodated by steam make-up through a pressure reducing station on "live" steam.
6. A falling film evaporator is essentially a "constant capacity" unit. Variations in capacity affect the color of the juice. All persons interviewed on this subject strongly recommended that this type of evaporator be used as the last body of a station, or as a concentrator where the rate of evaporation would not be materially affected by the extreme variation in vapor demands as is normally present where crystallizing pans are operated with an evaporator bleed vapor.
7. The design and maintenance of the juice distributors in a falling film evaporator is critical. Equal distribution to every tube in the body is essential to prevent dry tubes and consequent caramelization of sugar.
8. Juice distributors containing any type of orifice to distribute the juice should be avoided since the orifices are very likely to plug. V-notch weirs fed by a trough system are recommended, and precision levelling and alignment are mandatory.
9. At best, the heat transfer coefficient of a falling film evaporator is not more than 50% higher than the Roberts type evaporator which would normally be used in the same service.
10. Pumped recirculation for each falling film evaporator body is mandatory since the total feed volume must be constant regardless of station throughput. Under low throughput volumes, the

retention time increases because the recirculation rate must increase. This is detrimental to juice color.

11. All factories visited used either juice decalcification, chemical scale control (chelants), or both to limit scale formation on heat transfer surfaces.
12. To achieve maximum energy efficiency in a sugar factory it is necessary to reduce to an absolute minimum the heat losses to condensers. This involves extensive utilization of evaporator bleed vapors and of pan vapors. The most obvious use of this low grade energy is for the heating of cold, raw juice. This requires a heat exchange between cold cossettes and diffusion juice the temperature of which would normally be in the area of 25°C. provided the proper apparatus is used for cooling the raw juice. Such a temperature allows utilization of the low grade energy sources such as pan vapors.
13. The heat normally lost in excess condensates should be utilized in heating cold, raw juice, or, possibly, the drying of beet pulp.

The above conclusions will be documented to some extent by data accumulated from individual factories during the European visit.

B. Industries Other than Sugar

1. The technical literature search has come up with the following list of recommendations on VR/FEE applications.
 - a. If the proposed plant has an existing supply of high-pressure steam, a steam turbine can be used to drive the compressor.
 - b. The vapors entering the compressor should be superheated to eliminate vapor droplets that could seriously erode the compressor blades.
 - c. Entrainment of solids and liquids in the vapor within the

compressor should be kept to a minimum to avoid possible adherence of materials to the blades.

- d. Auxiliary steam is needed for start-up and cleaning of evaporators.
- e. VR/FFE applications are well suited to uses where low temperature evaporation is required.
- f. The compressor has to be matched closely to the evaporation process in terms of flow and pressure to prevent unstable operating conditions.
- g. Desuperheating the compressed vapors before returning vapors to evaporators leads to more efficient operation.
- h. Large heat transfer surfaces within the evaporators are more cost effective when allowing for evaporation at small temperature differences and keeping the required compression ratio within standard ranges (less than 1.5).
- i. VR/FFE is usually only a viable economic alternative in evaporative applications where the boiling point rise is less than 10°F.

Appendix I

SUGAR INDUSTRY ABSTRACTS

published by

La Sucrerie Belge

VOL. 40

LIST OF JOURNALS

1978

The following journals are surveyed regularly for relevant papers, from which abstracts are made. Papers from other sources are frequently included.

Abbreviated forms of journal titles are shown in **bold type**. The list is in alphabetical order of the abbreviated titles of journals.

Acta Academiae Aboensis. Series B
 Acta Agriculturae Scandinavica
 Acta Alimentaria Academiae Scientiarum Hungaricae
 Acta Alimentaria Polonica
 Acta Chemica Scandinavica. Series B
 Advances in Carbohydrate Chemistry and Biochemistry
 Advances in Food Research
 Afinidad
 Agricultural and Biological Chemistry
 AIChE Journal (American Institute of Chemical Engineers)
 AIChE (American Institute of Chemical Engineers), Symposium Series
 Alchi-Ken Shokuhin Kogyo
 Alimenta
 L'Alimentation et la Vie
 American Journal of Clinical Nutrition
 Analytical Biochemistry
 Analytical Chemistry
 The Analyst (London)
 Anales de la Asociación Química Argentina
 Animal Feed Science and Technology
 Annales de Gembloux
 Annual Report Bureau of Sugar Experiment Stations. Queensland
 Annual Report Experiment Station Hawaiian Sugar Planters' Association
 Annual Report Experiment Station South African Sugar Association
 Annual Report Mauritius Sugar Industry Research Institute. See : Mauritius Sugar Industry Research Institute. Annual Report
 Annual Report Planalsucar Estacoes Experimentais (Sao Paulo)
 Annual Report Sugar Milling Research Institute (Durban). See : Sugar Milling Research Institute (Durban). Annual Report
 Annual Report Taiwan Sugar Research Institute
 Annual Report Tate & Lyle Ltd. Group Research & Development
 Annales de Zootecnie
 Anales de Química
 Applied and Environmental Microbiology
 Archives of Biochemistry and Biophysics
 Archiv für Geflügelkunde
 Archiv für Tierernährung
 ATAC (Asociación de Técnicos Azucareros de Cuba)
 Australian Journal of Dairy Technology

Australian Journal of Experimental Agriculture and Animal Husbandry
 Australian Sugar Journal
 Azucar y Productividad

 Bakers' Digest
 Belgisch Instituut tot Verbetering van de Biet; Driemaandelijkse Publikatie. See : Institut Belge pour l'Amélioration de la Betterave, Publication Trimestrielle Le Betteravier
 Biochemical Journal
 Biochemical Society Transactions
 Biochimica et Biophysica Acta, General Subjects
 Biomedical Mass Spectrometry
 Biotechnology and Bioengineering
 BMA Information
 BNF Bulletin (British Nutrition Foundation)
 Boletin de la Estación Experimental Agrícola de Tucuman
 Boletim Instituto de Tecnologia de Alimentos, São Paulo
 Boletin de la Sociedad Química del Perú
 Boletim Técnico Copersucar (São Paulo)
 Brasil Acucareiro
 Brewing and Distilling International
 British Food Journal
 British Poultry Science
 British Sugar Beet Review
 British Sugar Corporation Technical Conference
 Bulletin of the Chemical Society of Japan
 Bulletin of the Institute of Chemistry Academia Sinica (Nankang, Taiwan)
 Bulletin Scientifique, Conseils des Académies des Sciences et des Arts de la RSF de Yougoslavie, Section A

 Cane Growers' Quarterly Bulletin
 Canadian Institute of Food Science and Technology Journal
 Canadian Journal of Chemistry
 Carbohydrate Research
 CCB, Review for Chocolate, Confectionery and Bakery
 Cellulose Chemistry and Technology
 Centro Azucar (University of Las Villas, Cuba)
 Cereal Chemistry
 Cereal Foods World

 Chemia. See : Zeszyty Naukowe Politechniki Łódzkiej Chemia.
 Chemical Age of India
 Chemia Analityczna (Warsaw)
 Chemistry in Britain
 Chemistry in Canada
 Chemika Chronika
 Chemika Chronika Genike Ekdosis
 Chemical Communications. See : Journal of the Chemical Society. Chemical Communications.
 Chemical Communications (Stockholm)
 Chemical Engineering Journal
 The Chemical Engineer (London)
 Chemical & Engineering News
 Chemical Engineering (New York)
 Chemical Engineering Progress
 Chemical Engineering Progress Symposium Series. See : AIChE (American Institute of Chemical Engineers), Symposium Series
 Chemical Engineering World
 Chemical Industry Developments
 Chemische Industrie (Duesseldorf)
 Chemische Industrie International (Duesseldorf)
 Chemistry and Industry (London)
 Chemie Ingenieur Technik
 Chemistry Letters
 Chemical Processing (London). See : Processing
 Chemicky Prumysl
 Chemical Senses and Flavor
 Chemical Society Reviews
 Chemia Spożywcza. See : Zeszyty Naukowe Politechniki Łódzkiej Chemia Spożywcza
 Chemia Stosowana
 Chemie Technik (Heidelberg)
 Chemische Technik (Leipzig)
 Chemtech (Chemical Technology) (Washington)
 Chromatographia
 Circular de la Estación Experimental Agrícola de Tucuman
 Collection of Czechoslovak Chemical Communications
 Communications de la Faculté des Sciences de l'Université d'Ankara, Ser. B, Chemie
 Confectionery Production
 Control Cibernética y Automatización
 Cooperative Sugar (New Delhi)
 Comptes Rendus de l'Assemblée Générale de la Commission Internationale Technique de Sucrerie (C.I.T.S.)
 Critical Reviews in Food Science and Nutrition
 Crystallizer (Los Baños, Philippines)
 CSM Informatie

Cuba Azucar
Cuban Journal of Agricultural Science
Cukoripar
Czechoslovak Heavy Industry

Dal-ichi Kogyo Selyaku K.K. Shaho
Dempunto Gijutsu Kenkyukai, Kaiho
Deutsche Lebensmittel-Rundschau
Dimensions/NBS (National Bureau of Standards)

East African Agricultural and Forestry Journal
Egyptian Journal of Chemistry
Egyptian Sugar and Distillation Company, Sugar Cane Department, Research Bulletin
Eijo To Shokuryo (Journal of the Japanese Society of Food and Nutrition)
Elelmezési Ipar
Elelmiszerizsgálati Közlemények
'Ellenike Biomehania Zahareos Trimeniaion Deltion (Hellenic Sugar Industry Quarterly Bulletin)
Energy Conversion
Ernährung/Nutrition
Ernährungswirtschaft
Estación Experimental Agricola de Tucuman. Boletín. See : Boletín de la Estación Experimental Agricola de Tucuman
Estación Experimental Agricola de Tucuman. Circular. See : Circular de la Estación Experimental Agricola de Tucuman
European Chemical News
European Journal of Applied Microbiology and Biotechnology
Experimental Agriculture

Faraday Discussions of the Chemical Society
Fermentnaya i Spirtnaya Promyshlennost'
Filtration & Separation
Focus (Stockholm)
F.O. Licht's International Molasses Report
F.O. Licht's International Sugar Economic Year Book and Directory. See : F.O. Licht's Internationales Zuckerwirtschaftliches Jahrrund Adressbuch
F.O. Licht's Internationales Zuckerwirtschaftliches Jahr- und Adressbuch
Food and Cosmetics Toxicology
Food Engineering International
Food Manufacture
Food Processing (Chicago)
Food Processing Industry
Food Product Development
Food Research Association. See : Leatherhead Food R.A.
Food Science + Technology (Zürich) See : Lebensmittel-Wissenschaft + Technologie
Food Technology (Chicago)
Food Trade Review

Gazeta Cukrownicza
Ghana Journal of Science
Glasnik Hemiskog Drustva (Beograd)

Hakkokogaku Kaihi
Hautes Etudes Detteravières et Agricoles

Hawaalian Planter's Record
Hellenic Sugar Industry Quarterly Bulletin. See : 'Ellenike Biomehania Zahareos Trimeniaion Deltion
Hemika Hronika. See : Chimika Chronika
Huaxue Tongbao
Hungarian Journal of Industrial Chemistry

ICIDCA. See : Sobre los Derivados de la Cana de Azucar
ICUMSA. See : International Commission for Uniform Methods of Sugar Analysis
IIRB (Revue de l'Institut International de Recherches Betteravières)
Industries Alimentaires et Agricoles
Industria Alimentari (Pinerolo, Italy)
Industria Azucarera
Industria delle Bevande
Industrial & Engineering Chemistry. Fundamentals
Industrial & Engineering Chemistry. Process Design and Development
Industrial & Engineering Chemistry. Product Research and Development
Indian Chemical Journal
The Indian Journal of Agricultural Sciences
Indian Journal of Applied Chemistry
Indian Journal of Chemistry
Indian Journal of Physics and Proceedings of the Indian Association for the Cultivation of Science
Indian Journal of Technology
Indian Sugar
L'Industria Saccharifera Italiana
Informativo do Instituto Nacional de Tecnologia (N.S.)
Institut Belge pour l'Amélioration de la Betterave, Publication Intermédiaire
Institut International de Recherches Betteravières. See : IIRB
International Commission for Uniform Methods of Sugar Analysis (ICUMSA). Reports of Proceedings of Sessions
International Flavours and Food Additives
International Review for Sugar and Confectionery. See : Zucker- und Süßwaren Wirtschaft
International Sugar Journal
Irish Journal of Agricultural Research
Irish Journal of Food Science
Izvestiya Vysshikh Uchebnykh Zavedenii, Pishchevaya Tekhnologiya

Journal of the Agricultural Association of China
Journal of Agricultural and Food Chemistry
Journal of Agricultural Science
Journal of the Agricultural Society of Trinidad and Tobago
The Journal of Agriculture of the University of Puerto Rico
Jamaican Association of Sugar Technologists. See : JAST
Journal of the American Oil Chemists' Society
Journal of the American Society of Sugar Beet Technologists
Journal of Animal Science

Japan Food Sciences
Japan Fudo Saisensu. See : Japan Food Science
Journal of Applied Bacteriology
Journal of Applied Chemistry and Biotechnology
Journal of the Association of Official Analytical Chemists
JAST (Jamaican Association of Sugar Technologists) Journal
Journal of Bacteriology
Journal of Carbohydrates, Nucleosides and Nucleotides
Journal of the Chemical Society, Chemical Communications
Journal of the Chemical Society, Faraday Transactions 1 and 2
Journal of the Chemical Society, Perkin Transactions 1
Journal of the Chemical Society of Japan. See : Nippon Kagaku Kaishi
Journal of the Chinese Chemical Society
Journal of the Chinese Institute of Chemical Engineers (Taipai, Taiwan)
Journal of Chromatography
Journal of Chromatographic Science
Journal of Dairy Research
Journal of Dairy Science
Journal of Fermentation Technology (Osaka)
Journal of Food Science
Journal of Food Science and Technology (Mysore)
Journal of Food Technology
Journal of General Microbiology
Journal of Human Nutrition
Journal of Hygiene
Journal of the Indian Chemical Society
Journal of the Indian Institute of Sciences
Journal of the Institution of Chemists (Calcutta)
Journal of the International Institute for Sugar Beet Research. See : IIRB
Journal of the Japanese Society of Food and Nutrition. See : Eijo To Shokuryo
Journal of Organic Chemistry
Journal of the Scientific Agricultural Society of Finland
Journal of the Science of Food and Agriculture
Journal of Scientific and Industrial Research (New Delhi)
Journal of the Scientific Research Council of Jamaica
Journal of Stored Products Research
Journal of Texture Studies
Journal Water Pollution Control Federation

Kemija u Industriji
Kharchova Promyslovist' Naukovo-Vyrobničii Zbirnik
Khlebopекарная и Кондитерская Промышленность
Khračicina Premishlenost'

Laboratory Practice
Le Lait
Latin American Journal of Chemical Engineering and Applied Chemistry. See : Revista Latinoamericana de Ingenieria Química y Química Aplicada

Leatherhead Food R.A. Scientific and Technical Surveys	Proceedings of the Annual Convention of the Sugar Technologists Association of India	Revista Latinoamericana de Ingenieria Quimica y Quimica Aplicada (Latin American Journal of Chemical Engineering and Applied Chemistry)
Lebensmittel und Ernährung	Proceedings of the Convention of the Deccan Sugar Technologists' Association (India)	Revista Latinoamericana de Microbiología
Die Lebensmittel-Industrie	Process Biochemistry	Revista de la Real Academia de Ciencias Exactas, Fisicas y Naturales
Lebensmittel Technik	Process and Chemical Engineering	Revue Agricole et Sucrière de l'Île Maurice
Lebensmittel-Wissenschaft + Technologie	Process Engineering	Revue des Fermentations et des Industries Alimentaires
Licht. See : F.O. Licht	Processing	Revue Roumaine de Chimie
Listy Cukrovnické	Proceedings of the Indian Academy of Sciences. Section A and B	Rhodesia Agricultural Journal
	Proceedings of the Indian National Science Academy, Part B.	La Ricerca Scientifica Rendiconti
Maandblad Suiker Unie	Proceedings of the International Society of Sugar Cane Technologists	
Macromolecules	Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen. Series C	South African Journal of Chemistry
Majalah Perusahaan Gula	Proceedings of the Meeting of the West Indies Sugar Technologists	South African Journal of Dairy Technology
Malaysian Agricultural Journal	Proceedings of the Philippines Sugar Technologists Annual Convention	South African Sugar Journal
Manufacturing Chemist and Aerosol News	Proceedings of the Queensland Society of Sugar Cane Technologists	Sakharnaya Promyshlennost'
Manufacturing Confectioner	Proceedings of the Research Society of Japan Sugar Refineries' Technologists. See : Seito Gijutsu Kenkyukaishi	Sakharnaya Svetla
Mauritius Sugar Industry Research Institute Annual Report	Proceedings of the Technical Session on Cane Sugar Refining Research	Sbornik Nauchnykh Trudov, Kachestvo i Khranenie Pishchevykh Produktov
Memoria de la Conferencia Anual de la ATAC (Asociación de Técnicos Azucareros de Cuba)	Prumysl Potravin	Sbornik Vysoké Školy Chemicko-Technologicke v Praze (Prague) Potraviny
Memoirs of the Faculty of Science, Kyushu University, Series C, Chemistry	Przemysl Chemiczny	Science
Milchwissenschaft	Przemysl Spozywczy	Science and Culture
Milling Feed and Fertiliser	Publication Trimestrielle Institut Belge pour l'Amélioration de la Betterave. See : Institut Belge pour l'Amélioration de la Betterave. Publication Trimestrielle	The Sciences
Mitteilungen aus dem Gebiete der Lebensmitteluntersuchung und Hygiene	Quaderni dell'Ingegnere Chimico Italiano (Supplement to La Chimica e l'Industria (Milan). Quimica e Industria (Bilbao)	Scientia Sinica
Miekarske Listy (Supplement in Prumysl Potravin)	Rassegna Chimica	Science + Technologie Alimentaire (Zürich). See : Lebensmittel Wissenschaft + Technologie
	Report of the Hawaiian Sugar Technologists Annual Conference	Seito Gijutsu Kenkyukaishi (Proceedings of the Research Society of Japan Sugar Refineries' Technologists)
Die Nahrung	Report of National Food Research Institute (Tokyo). See : Shokuhin Shisei Kenkyukai	Seker
Nature	Report of the Taiwan Sugar Research Institute. See : Tai-Wan Tang Yeh Yen Chiu So Yen Chiu Hui Pao	Sharkara
Nauchni Trudove Vissih Institut po Khranitelna i Vkusova Promishlenosti, Plovdiv	Research Bulletin of the Panjab University	Shipin Gongye (Food Industry)
Netherlands Journal of Agricultural Science	Revista de Agroquimica y Technologia de Alimentos	Shokuhin Shisei Kenkyukai (New Food Industry (Tokyo))
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Nigerian Journal of Science	Revista de la Chimie (Bucharest)	Shokuryo Gijutsu Fukyu Shirizu Skoda Review
Nihon Eijo Shokuryo Gakkai. See : Eijo To Shokuryo	Revista Cubana de Ciencia Agricola. See : Cuban Journal of Agricultural Science	Sobre los Derivados de la Cana de Azucar
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		Sucrerie Française
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Philissuccap Crystal		Sugar y Azucar
Phytochemistry		Sugar y Azucar Yearbook
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Trudy, Vsesoyuznyi Nauchno-Issledovatel'skii Institut Sakharnoi Promyshlennosti

Verfahrenstechnik (Mainz)
Vijnana Parishad Anusandhan Patrika
Voeding
Voedingsmiddelen Technologie
Vyziva Lidu

World Animal Review
World Crops
World Food Review
World Review of Animal Production

Zeszyty Naukowe Akademii Rolniczo-Technicznej w Olsztynie, Technologia Zywosci
Zeszyty Naukowe Akademii Rolniczej w Warszawie, Technologia Rolno-Spozywcza
Zeszyty Naukowe Politechniki Lodzkiej Chemia
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Zeitschrift für Lebensmittel-Untersuchung und -Forschung
Zeitschrift für Tierphysiologie, Tierernährung und Futtermittelkunde
Zuckerindustrie
Zucker- und Süßwaren Wirtschaft

PATENTS

Patents and published patent applications of the following countries are regularly abstracted. Equivalent patents or applications in other countries are frequently included.
Australia, Austria, Belgium, East Germany, France, Great Britain, Poland, United States, U.S.S.R., West Germany.

ABSTRACTING AND TITLE LISTING JOURNALS

Abstracts of Mycology
Abstracts on Tropical Agriculture
Analytical Abstracts
Applied Science and Technology Index

British Technology Index
Bulletin Technische Dokumentationsdienst. Service de la Documentation Technique (Tienen)

Chemical Abstracts
Computer and Control Abstracts

Current Contents Life Sciences
Current Contents Physical & Chemical Sciences

Food Science and Technology Abstracts

Leatherhead Food R.A. Abstracts from Current Scientific and Technical Literature

Microbiology Abstracts Section A

Novye Knigi
Nutrition Abstracts and Reviews A and B

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Appendix 2

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S.I.A. 65-1103. Cost Equations for Vapour Compression. H. Tonn. (Z. Zuckerind., 1965, 15, 509-513. G.)

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Appendix 3

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Appendix 4

LIST OF VENDORS CURRENTLY MANUFACTURING VR/FFE SYSTEMS

1. Aqua-Chem., Inc.; Water Technologies Division (414) 962-0100
P.O. Box 421, Milwaukee, Wisconsin 53201
2. Dedert Corporation (312) 754-4690
20200 Ashland Ave., Chicago Heights, Illinois 60411
Stan Mack (Sales)
3. Ecodyne; Unitech Division (201) 686-1181
New Jersey
Tony Disilippo (Sales)
4. Envirotech Corporation; Gosun Division (205) 324-7511
P.O. Box 398, Birmingham, Alabama 35201
5. Mechanical Equipment Co. (504) 523-7271
861 Carondelet St., New Orleans, Louisiana
Tom Willets
6. Paget Equipment Co. (715) 384-3158
Marshfield, Wisconsin
Bob Paget
7. Resources Conservation Co. (206) 575-5564
P.O. Box 936, Renton, Washington 98055
Brian Heimbigner

Appendix 5

PLANTS UTILIZING VR/FFE TECHNOLOGY