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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
Fort Collins, Colorado 80522

Clair H. Iverson
Glenn E. Coury

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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 recompression 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, Oreya, 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

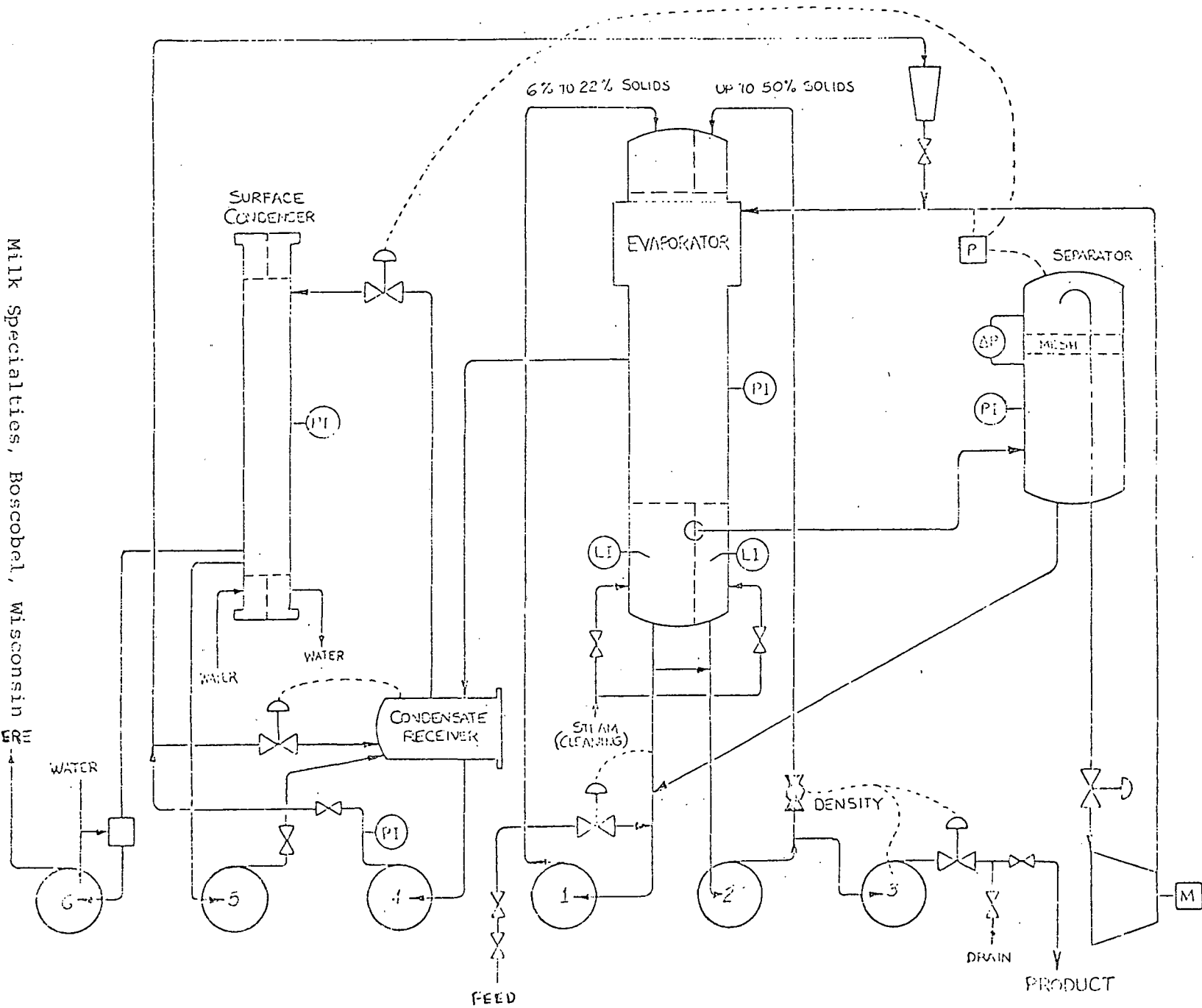
1. Milk Specialties, Boscobel, Wisconsin

- 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

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/FFE 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 Sucrierie 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
Alimentación
Agricultural and Biological Chemistry
AICHE Journal (American Institute of Chemical Engineers)
AICHE (American Institute of Chemical Engineers), Symposium Series
Aichi-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 Zootechnie
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
Australasian Sugar Journal
Azúcar y Productividad

Bakers' Digest
Belgisch Instituut tot Verbetering van de Biet; Driemaandelijksche 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)
Boletín de la Estación Experimental Agrícola de Tucumán
Boletim Instituto de Tecnologia de Alimentos, São Paulo
Boletín de la Sociedad Química del Perú
Boletim Técnico Copersucar (São Paulo)
Brasil Açucareiro
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 Azúcar (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)
Chimie Ingenieur Technik
Chemistry Letters
Chemical Processing (London). See : Processing
Chemický Průmysl
Chemical Senses and Flavor
Chemical Society Reviews
Chemia Spożywcza. See : Zeszyty Naukowe Politechniki Łódzkiej Chemia Spożywcza
Chemia Stosowana
Chimie Technik (Heidelberg)
Chemische Technik (Leipzig)
Chemtech (Chemical Technology) (Washington)
Chromatographia
Circular de la Estación Experimental Agrícola de Tucumán
Collection of Czechoslovak Chemical Communications
Communications de la Faculté des Sciences de l'Université d'Ankara, Ser. B, Chimie
Confectionery Production
Control Cibernética y Automatización
Cooperative Sugar (New Delhi)
Comptes Rendus de l'Assemblée Générale de la Commission Internationale Technique de Sucrierie (C.I.T.S.)
Critical Reviews in Food Science and Nutrition
Crystallizer (Los Banos, Philippines)
CSM Informatie

Cuba Azucar
Cuban Journal of Agricultural Science
Cukoripar
Czechoslovak Heavy Industry

Dai-ichi Kogyo Selyaku K.K. Shoho
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
Eiyo To Shokuryo (Journal of the Japanese Society of Food and Nutrition)
Elelmzési Ipar
Elelmiszervizsgálati Közlemények
Ellenike Biomechania Zahareos Trimeniaion Deltion (Hellenic Sugar Industry Quarterly Bulletin)
Energy Conversion
Ernährung/Nutrition
Ernährungswirtschaft
Estación Experimental Agrícola de Tucuman. Boletín. See : Boletín de la Estación Experimental Agrícola de Tucuman
Estación Experimental Agrícola de Tucuman. Circular. See : Circular de la Estación Experimental Agrícola de Tucuman
European Chemical News
European Journal of Applied Microbiology and Biotechnology
Experimental Agriculture

Faraday Discussions of the Chemical Society
Fermentnaya i Spirtovaya 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 Zuckervirtschaftliches Jahrbuch und Adressbuch
F.O. Licht's Internationales Zuckervirtschaftliches Jahrbuch 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 Hrniskog Drustva (Belograd)

Hakkokogaku Kaishi
Hautes Etudes Dettteravières et Agricoles

Hawaalian Planter's Record
Hellenic Sugar Industry Quarterly Bulletin. See : 'Ellenike Biomechania 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
IIRD (Revue de l'Institut International de Recherches Dettteravières)
Industries Alimentaires et Agricoles
Industrie Alimentari (Pinerolo, Italy)
Industria Azucarera
Industrie 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 Saccarifera Italiana
Informativo do Instituto Nacional de Tecnologia (N.S.)
Institut Belge pour l'Amélioration de la Dettterave, Publication trimestrielle
Institut International de Recherches Dettteravières. See : IIRD
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 Saiensu. 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 (Taipei, 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 : IIRD
Journal of the Japanese Society of Food and Nutrition. See : Eiyo 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-Vyrobniolii Zbirnik
Khranitel'skaya i Konditerskaya Promyshlennost'
Khranitel'skaya Promyshlennost'

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

Leatherhead Food R.A. Scientific and Technical Surveys
 Lebensmittel und Ernährung
 Die Lebensmittel-Industrie
 Lebensmittel Technik
 Lebensmittel-Wissenschaft + Technologie
 Licht. See : F.O. Licht
 Listy Cukrovarnické

Mandblad Suiker Unie
 Macromolecules
 Majalah Perusahaan Gula
 Malaysian Agricultural Journal
 Manufacturing Chemist and Aerosol News
 Manufacturing Confectioner
 Mauritius Sugar Industry Research Institute Annual Report
 Memoria de la Conferencia Anual de la ATAC (Asociación de Técnicos Azucareros de Cuba)
 Memoirs of the Faculty of Science, Kyushu University, Series C, Chemistry
 Milchwissenschaft
 Milling Feed and Fertiliser
 Mitteilungen aus dem Gebiete der Lebensmitteluntersuchung und Hygiene
 Mlekarske Listy (Supplement in Prumysl Potraviny)

Die Nahrung
 Nature
 Nauchni Trudove Vissh Institut po Khranitelna i Vkusova Promishlenost, Plovdiv
 Netherlands Journal of Agricultural Science
 New Food Industry (Tokyo). See : Shokuhin Shisei Kenkyukai
 New Scientist
 Nigerian Journal of Science
 Nihon Eiyo Shokuryo Gakkai. See : Eiyo To Shokuryo
 Nippon Kagaku Kaishi (Journal of the Chemical Society of Japan)
 Nutrition and Food Science
 Nutrition Reviews

Obshchestvennoe Pitanie

Philippine Journal of Science
 Philsuccap Crystal
 Phytochemistry
 Pishchevaya Promyshlennost' Mezhdovostvennyi Respublikanskii Nauchno-Tekhnicheskii Sbornik (Tekhnika, Kiev)
 Pishchevaya Promyshlennost' Nauchno-Proizvodstvennyi Sbornik (Tekhnika, Kiev)
 Potravinárska a Chladicí Technika (Supplement in Prumysl Potraviny)
 Prace Instytutów i Laboratoriów Badawczych Przemysłu Spożywczego
 Proceedings, American Society of Sugar Cane Technologists
 Proceedings of Analytical Division of the Chemical Society
 Proceedings of the Annual Congress of the South African Sugar Technologists' Association

Proceedings of the Annual Convention of the Sugar Technologists Association of India
 Proceedings of the Convention of the Deccan Sugar Technologists' Association (India)
 Process Biochemistry
 Process and Chemical Engineering
 Process Engineering
 Processing
 Proceedings of the Indian Academy of Sciences, Section A and B
 Proceedings of the Indian National Science Academy, Part B.
 Proceedings of the International Society of Sugar Cane Technologists
 Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series C
 Proceedings of the Meeting of the West Indies Sugar Technologists
 Proceedings of the Philippines Sugar Technologists Annual Convention
 Proceedings of the Queensland Society of Sugar Cane Technologists
 Proceedings of the Research Society of Japan Sugar Refineries' Technologists. See : Seito Gijutsu Kenkyukai
 Proceedings of the Technical Session on Cane Sugar Refining Research
 Prumysl Potraviny
 Przemysl Chemiczny
 Przemysl Spozywczy
 Publication Trimestrielle Institut Belge pour l'Amélioration de la Betterave. See : Institut Belge pour l'Amélioration de la Betterave. Publication Trimestrielle

Quaderni dell'Ingegnere Chimico Italiano (Supplement to La Chimica e l'Industria (Milan))
 Quimica e Industria (Bilbao)

Rassegna Chimica
 Report of the Hawaiian Sugar Technologists Annual Conference
 Report of National Food Research Institute (Tokyo). See : Shokuhin Sogo Kenkyujo Kenkyu Hokoku
 Report of the Taiwan Sugar Research Institute. See : Tai-Wan Tang Yeh Yen Chiu So Yen Chiu Hui Pao
 Research Bulletin of the Panjab University
 Revista de Agroquímica y Tecnología de Alimentos
 Revista Brasileira de Química
 Revista Brasileira de Tecnologia
 Revista de Chimie (Bucharest)
 Revista Cubana de Ciencia Agrícola. See : Cuban Journal of Agricultural Science
 Revista ICIDCA (Instituto Cubano de Investigaciones de los Derivados de la Cana de Azúcar). See : Sobre los Derivados de la Cana de Azúcar
 Revista Industrial y Agrícola de Tucuman
 Revue de l'Institut International de Recherches Betteravières. See : IIRB

Revista Latinoamericana de Ingeniería Química y Química Aplicada (Latin American Journal of Chemical Engineering and Applied Chemistry)
 Revista Latinoamericana de Microbiología
 Revista de la Real Academia de Ciencias Exactas, Físicas y Naturales
 Revue Agricole et Sucrière de l'Île Maurice
 Revue des Fermentations et des Industries Alimentaires
 Revue Roumaine de Chimie
 Rhodesia Agricultural Journal
 La Ricerca Scientifica Rendiconti

South African Journal of Chemistry
 South African Journal of Dairy Technology
 South African Sugar Journal
 Sakharnaya Promyshlennost'
 Sakharnaya Svekla
 Sbornik Nauchnykh Trudov, Kachestvo i Khranenie Pishchevykh Produktov
 Sbornik Vysoké Školy Chemicko-Technologicke v Praze (Prague)
 Potraviny
 Science
 Science and Culture
 The Sciences
 Scientia Sinica
 Science + Technologie Alimentaire (Zürich). See : Lebensmittel Wissenschaft + Technologie
 Seito Gijutsu Kenkyukai (Proceedings of the Research Society of Japan Sugar Refineries' Technologists)
 Seker
 Sharkara
 Shipin Gongye (Food Industry)
 Shokuhin Shisei Kenkyukai (New Food Industry (Tokyo))
 Shokuhin Sogo Kenkyujo Kenkyu Hokoku (Report of National Food Research Institute (Tokyo))
 Shokuryo
 Shokuryo Gijutsu Fukyu Shirizu
 Skoda Review
 Sobre los Derivados de la Cana de Azúcar
 Zucker Handlingar
 Starch/Stärke
 Stord Bartz Review
 La Sucrerie Belge
 Sucrerie Française
 Sucrerie Maghrébine
 Sugar y Azúcar
 Sugar y Azúcar Yearbook
 Sugar Journal
 Sugar Milling Research Institute (Durban). Annual Report
 Sugar News (Bombay)
 Sugar News (Manila)
 Sugar Research Institute, Mackay. Annual Review
 Sugar Technology Reviews
 Süßwaren

Taiwan Sugar
 Tai-Wan Tang Yeh Yen Chiu So Yen Chiu Hui Pao (Report of the Taiwan Sugar Research Institute)
 Tate & Lyle Times
 Tätigkeitsbericht, Zuckerforschungsinstitut (Wien)
 Technical Papers and Proceedings of the Annual Meeting of Sugar Industry Technologists Inc.

Tecnologia de Alimentos (Mexico City)
 Tecnologia. Serie 6. Ingenieria Quimica
 Tehnika (Belgrade)
 Transactions of the Institution of Chemical Engineers
 Tropical Agriculture (Guildford, England)
 Tropical Science
 Trudy, Ukrainskii Nauchno-Issledovatel'skii Institut Spirtovoi i Likero-Vodochnoi Promyshlennosti
 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 Zywnosci
 Zeszyty Naukowe Akademii Rolniczej w Warszawie, Technologia Rolno-Spozywcza
 Zeszyty Naukowe Politechniki Lodzkiej Chemia
 Zeszyty Naukowe Politechniki Lodzkiej Chemia Spozywcza
 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

Packaging Abstracts

Referativnyi Zhurnal, Khimiya
 Referativnyi Zhurnal, Oborudovanie Pishchevoi Promyshlennosti

Waste Management Information Bulletin
 WRC Information

Appendix 2

LIST OF PAPERS

- S.I.A. 78-133. Utilization of the Thermal Energy of Compressed Secondary Vapor. A.F. Deryouko - "Sakharnaya Promyshlennost", 1977, (7), 35-36. R
- S.I.A. 78-487. Heat Economy in Beet Sugar Factory Evaporation. S. Zagrodzki and A. Kubasiewicz - "Sugar Technology Reviews", 1978, S (1-2, Jan.), 1-154. E, S.
- S.I.A. 78-1234. Study of a Cane Sugar Factory with Pressure Evaporation. T. Wardhana - "Zuckerindustrie", 1978, 103(8), 467-476. D, e, f, s.
- S.I.A. 77-139. Ways to Reduce the Energy Requirements of Beet Sugar Factories. V. Sprung - "F.O. Licht's Int. Zuckerwirt". Jahradressb., 1976, FS-F14. E.
- S.I.A. 77-1513P Installation for Supplying Heating Steam to an Evaporation Station and Low Pressure Heat Exchangers. Kievskii Tekhnologicheskii Institut Pishchevoi Promyshlennosti. Invs. K.A. Utkina and V.D. Popov - U.S.S.R. P. 452346. Appl. 23 Feb. 70. Publ. 3 Apr. 75. 3PP.
- S.I.A. 76-408. Method of Saving Fuel in Sugar Factories. P. Christodoulou (P. Hristodoulou) - Ellen. Biomehania Sakh. Trimen. Delt. (Hellenic Sugar Ind. Quart. Bull.), 1975, No. 20, (Jan-Mar.), 239-259. Gr, e.
- S.I.A. 76-700. Heat Pump in the Evaporation System of a Sugar Factory. A. Fenyes - Cukoripar, 1975, 28 (6, Nov.-Dec.), 222-227. Hu, r, e, d.
- S.I.A. 76-721. Vortex Thermocompressor. A.F. Deryavko - Sakh. Prom., 1975, (10), 36-37. R.
- S.I.A. 76-868. Use of a Compressor-Accumulator Assembly in the Heat Scheme of a Sugar Factory. V.I. Chastukhin and Yu. D. Palamarchuk - Kharchova Prom., Nauk.-Vyrob. Zb., 1976, (2, Mar.-Apr.), 35-38. Uk, r.
- S.I.A. 76-1522. Heat Economy in the Concentration of Technical Sugar Solutions. P. Christodoulou - Dissertation, Technical University of Athens; 1976. 230 pp. Gr, e.
- S.I.A. 75-1304. Heat Pumps in the Sugar Industry. G. Vernois - Z. Zuckerind., 1975, 25 (3), 134-135. D,e,f,s.
- S.I.A. 73-796. Steam Consumption in a Multistage Evaporator Station and an Evaporator Station with Ejector Condensers. S. Zagrodzki - Z. Zuckerind., 1973, 23(3), 192-131. G.

List of Papers (continued)

- S.I.A. 72-690. Steam Economy Measures in the Danish Sugar Industry. P.V.L. Marasimham - Proc. 37th Ann. Conv. Sugar Tech. Assoc. India, 1970 299-302, 305
- S.I.A. 72-1237. Falling-Film Evaporators and their Applications in the Food Industry. J. Wiegand - J. Appl. Chem. 1971, 21 (12), 351-358.
- S.I.A. 71 1203. Effect of the Scheme of the Evaporator Station on the Size of the Heating Surface, and Steam and Coal Consumption. S. Zagrodski - Gaz. Cukr., 1970, 78(8), 181-185. P.
- S.I.A. 71-1538. Extension of the Heating Equipment at Bruhl Sugar Factory, and General References to the Installation of Falling Film Evaporators. P. Valentin and R. Spandau-Zucker, 1971, 24(11), 321-329. G.
- S.I.A. 70-489. Application of the Falling Film Evaporator in the Sugar Industry. Anon. - Buckau-Wolf Technik, 1969, (4), 19-24. G and E.
- S.I.A. 69-848. Evaporators Saves \$150,000/year. G.S. Fairhurst and A. Maylott. (Food Process (Chicago), 1969, 30, 42-43)
- S.I.A. 67-439. Adaptation of Steam Accumulators to the Sugar Industry. R. Raffray. (Rev. Agric. Sucri. Le Maurice, 1966, 45, 203-208. F)
- S.I.A. 65-292. Modern Evaporation in the Food Industry. J. Brault. (Ind. Alim. Agric., 1964, 81, 883-891. F.)
- S.I.A. 65-1028. Determination of the Live Steam Consumption of Steam Jet Compressors for Planning Purposes. H. Tonn. (Z. Zuckerind., 1965, 15, 383-387. G.)
- S.I.A. 65-1107. Determination of the Live Steam Consumption of Steam Jet Compressors. V. Sazavsky. (Z. Zuckerind, 1965, 15, 585. Cf. S.I.A., 1965, 1028. G.)
- S.I.A. 65-1103. Cost Equations for Vapour Compression. H. Tonn. (Z. Zuckerind, 1965, 15, 509-513. G.)
- S.I.A. 65-1118. Process for Automatic Control of an Evaporator, and Evaporator Functioning by this Process. A.E.J. Choquet. (Fr. P. 1,387,120. Appl. 19.11.63. Gr. 21.12.64. 5 PP.)

List of Papers (continued)

- S.I.A. 64-198. Mixed Dynamic-Static Evaporating Station. A.J. Chocquet. (Ind. Alim. Agric., 1963, 80, 737-750. Cf. S.I.A., 1953, 456).
- S.I.A. 64-1091. Installation for Concentrating Dilute Juice in the Sugar Industry by Evaporation. Suddeutsche Zucker A.-G. (Fr. P. 1,360,083. Appl. 6.6.63, Gr. 23.3.64. Ger. 22.6.62. 6 PP).
- S.I.A. 63-56. Mechanical Compression of Vapours in Sugar Factories. G. Vernois. (Zuckererzeugung, 1962, 6, 286-289).
- S.I.A. 61-845. Proposals for Future Heat Economy. N.M. Adams and N.R. Twaite. (Brit. Sugar Corp. 14th Tech. Conf. 1962, 40 pp + 8 pp of appendixes.)

Appendix 3

BIBLIOGRAPHY OF VR/FFE ARTICLES

1. Beale, H.J., 1972, Recompression Evaporation, Chem. Engr. Prog., 68 (10), 79-82 (October 1972).
2. Mallinson, J.H., 1963, Chemical Process Applications for Compression Evaporation, Chem. Eng. (N.Y.), 70(18) 75(82), September 2, 1963.
3. Aqua-Chem., Inc., Vapor Compression Evaporation for the Chemical Process Industries, Technical Bulletin 750-3522.
4. Aqua-Chem., Inc., Vapor Compression Evaporation of Kraft Liquor, Technical Bulletin 750-3521.
5. Evaporation/A Prime Target for Industrial Energy Conservation, ERDA Report C00/2870-1.
6. Upgrading Existing Evaporators to Reduce Energy Consumption, ERDA Report C00/2870-2.
7. Casten, J.W., Mechanical Recompression Evaporators, Chem. Engr. Prog., 61-67 (July 1978).
8. Bennett, R.C., Recompression Evaporation, Chem. Engr. Prog., 67-70 (July 1978).
9. Danziger, R., Distillation Columns with Vapor Recompression, Chem. Engr. Prog., 58-64 (September 1979).

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 Macek (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

1. Corn Product Corporation, Peakin, Illinois Corn Sugar Plant
Aqua-Chem:
Add-on effect to existing single-effect dextrose evaporator
31% solids in/50% solids out 9,900#/hr. evaporation
2. A.E. Staley Co., Lafayette, Indiana (317) 474-5474
John Holman, Plant Manager
Dedert:
3-stage evaporator with mechanical vapor recompression
on all stages and rising/falling film evaporators
100,000#/hr. evaporation.
6% solids in/22% solids out
3. Grain Processing Corp., Muscatine, Iowa Corn Wet-Milling Plant
Dick Kohl, V.P. Operations & Engineering (319) 264-4211
Dedert:
3-stage evaporator with mechanical vapor recompression
on all stages and rising/falling film evaporators
100,000#/hr. evaporation.
6% solids in/22% solids out
4. Milk Specialties Co., Boscobel, Wisconsin Whey Processing Plant
Jim Pierce, Plant Manager; Dick Janita (608) 375-4187
Dedert:
2-stage evaporator with mechanical vapor recompression
on both stages.
6% solids in/50% solids out
5. Northland Food, Shawano, Wisconsin Whey Processing Plant
Brad Bradtke (715) 524-2191
Ecodyne:
Multi-stage evaporation with mechanical vapor recom-
pression on first stage.
30% solids in/58% solids out.