™CCE-MultiContactor Technology- a new process intensification tool with major applications in the cleaning of biomass with energy recovery

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Foreword

Process intensification – two or more unit operations carried out simultaneously in the same equipment.
The primary objectives of process intensification are the reduction of the size and cost of process plants, and possibly improved or new processing opportunities..
This paper describes the ™CCE-MultiContactor Technology that provides opportunities for several simultaneous unit operations within a single piece of relatively simple, low cost equipment. The technology is being developed on a large scale for the removal of soluble and insoluble contaminants from biomass with energy recovery and additional processing advantages for the pulp and paper mill host.
Additional pilot testing has been carried out in applications for the oil and nuclear industries.

Description

The CCE-MultiContactor™ is a development of Counter Current Diffusion Extraction (CCE) Technology that was developed in Australia for the extraction of juices from fruits and vegetables. The CCE is well developed and used in large-scale commercial applications in a number of juice extraction plants in Australia, New Zealand, USA, and Mexico.

The CCE consists of a rotor made with ribbons or slots working inside an inclined trough or closed casing. The casing may be equipped with a jacket for heating or cooling.
The screw is driven in a forward and reversing motion that sets up pulsating action within the equipment, to achieve a counter-current contact between the feed material and the solvent. The equipment works by diffusion of soluble materials from the solid phase into the liquid solvent phase

The objectives of developing the CCE Technology were to extract the soluble materials from fruit, vegetables, at a higher efficiency than conventional presses, with minimum damage to the fruit fibre. The equipment works at low shear, by diffusion in contrast to the normal method of obtaining juice with presses that destroy the fruit fibre.
In comparison with the pomace produced as a waste by presses, the fibre leaving the CCE is undamaged, and looks similar to the original fruit feed. The resulting fruit pieces contain dietary fibre that can form a valuable additional product, whilst avoiding waste.

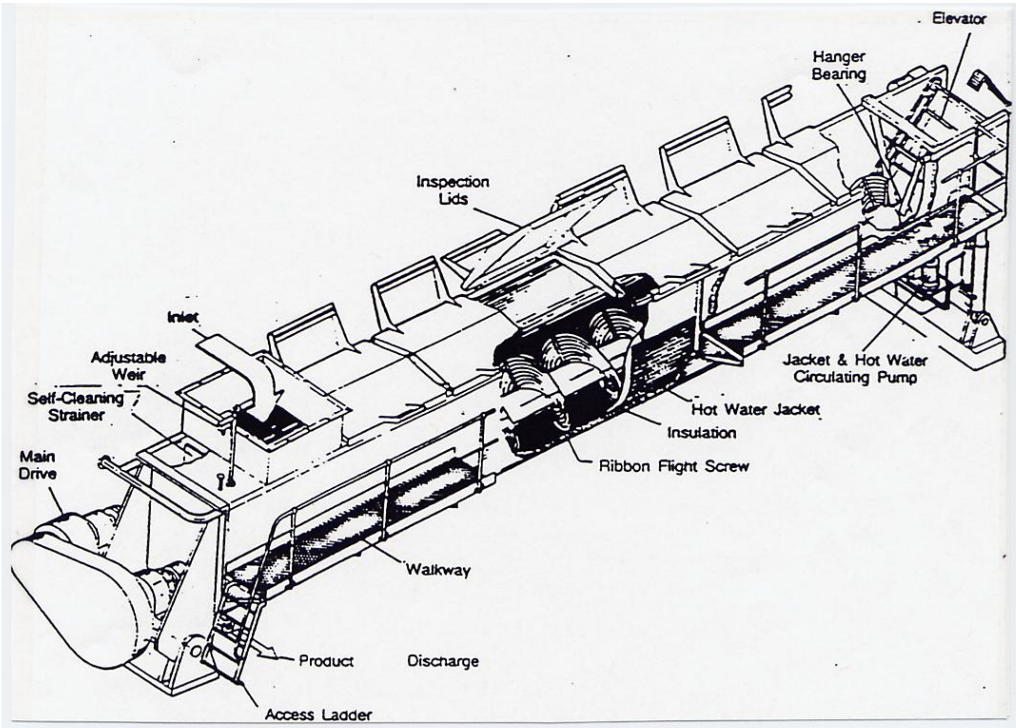

Fig 1 Typical Food Type Counter Current Diffusion Extractor

The feed material, normally fruit slices, enters the lower end of the casing and is propelled in a pulsating flow by the reversing action of the rotor up the inclined casing. (Fig 2)
Water solvent enters at the top end and meets the oncoming feed in pulsating counter-flow. The juice is removed from the fruit by the solvent in Counter-Current Diffusion Extraction.
The extracted fruit pieces leave the unit virtually undamaged at its top end, with the extract (juice) leaving the CCE at its lower end.
Conversely, the equipment can be used to diffuse a liquid into the solid phase.

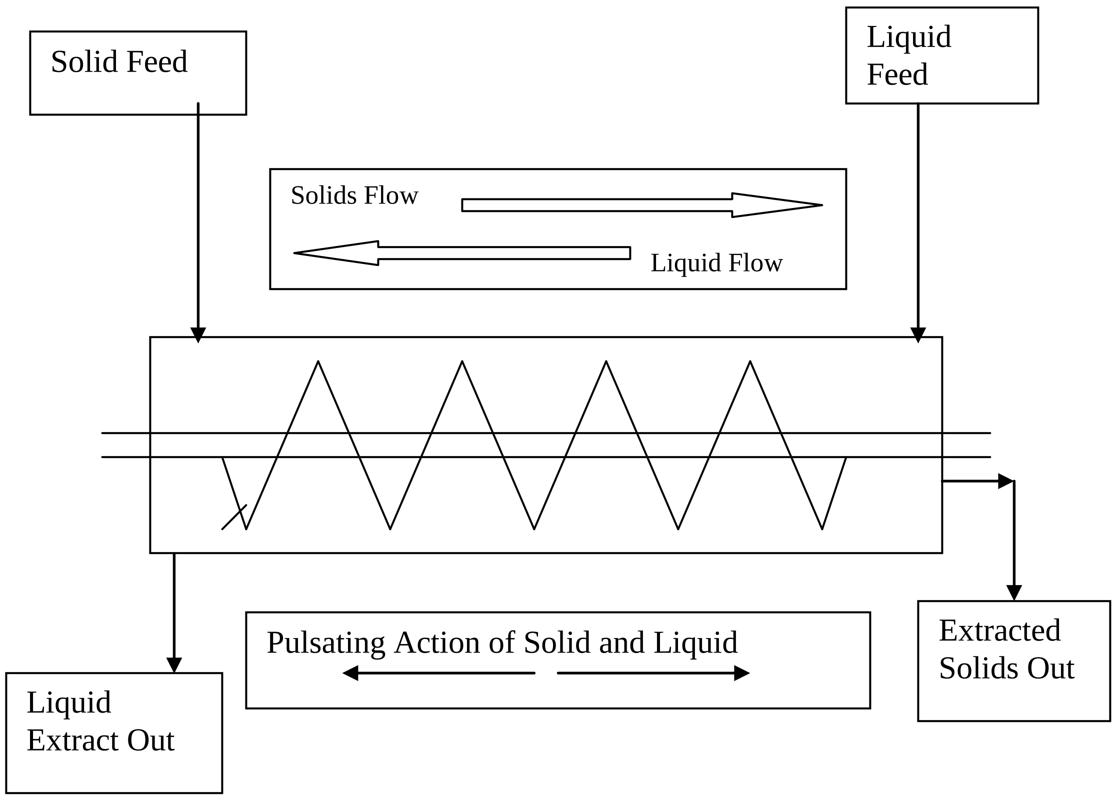

Fig 2

Heavy Industrial Applications
CCE Technology has been highly developed and commercially exploited in fruit juice extraction applications and has features that can be applied to large scale "Heavy Industrial" processes, especially in the cleaning and processing of bio-mass.

A number of attractive features may be exploited in large-scale applications:

1. Mechanically simple
2. Pulsating operation
3. Plug Flow
4. Low Shear
5. Design for high or low pressure operation
6. Diffusion extraction
7. Infusion
8. Direct-contact heat exchange
9. Use of solid bed in unit to act as a filter

10. Assisted gravity separation from pulsating action.
11. Optimize diameter and length for desired service.
12. Multiple feed and exit points possible

Design Approach

A basic chemical engineering/custom process design approach has been used to identify and apply the various unit operations possibilities inherent in the basic CCE solid-liquid contactor.

To distinguish this new way of using the equipment to provide simultaneous unit operations, the new name ™CCE-MultiContactor" is being used.
The ™MultiContactor provides several simultaneous unit operations that may or may not include the original diffusion extraction capability provided by the CCE.

Pulsating Action

The rotor drive system sets up both forward and reverse motion.
This provides a pulsating action within the contactor, with a net forward progression of solids up the slope of the unit until they are discharged at the top. (See Fig 2)
The pulsating counter-flow of liquid travels down the contactor by gravity flow, exiting at the lower end.
Adjustment of the rotation speed of the rotor shaft, the time in forward and reverse motion and the depth of material in the contactor provides a wide range of possible operating conditions and residence times within the contactor.

The pulsating action provides increased efficiency of contact, illustrated by Lo and Prochazka (Perry, Chemical Engineers Handbook 7th Ed 5-15 (Fig 4)
This work was carried out on liquid-liquid systems, but indicates the lowering of HETS (Height of a theoretical stage) with increase pulsating action.

The usual geometry of CCE equipment, with about 8:1 Length to diameter ratio, together with pulsations creates about 14 theoretical mass transfer stages in one casing.

Pulsations mean performance!

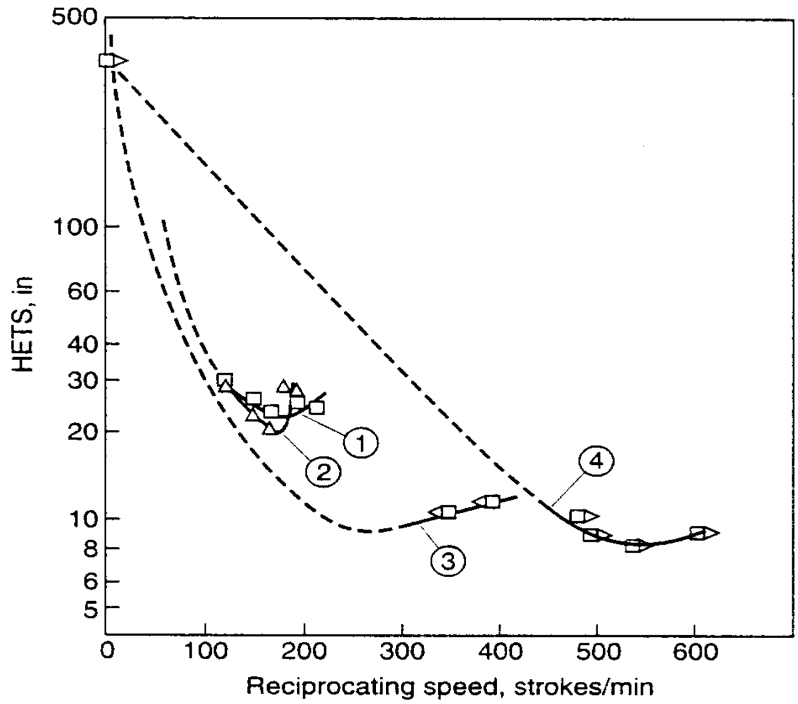

FIG. 15-51 Effect of reciprocating speed on HETS, *o*-xylene-acetic acid-water system. (*Lo and Prochazka in Lo et al., p. 377.*)

Fig 4 Reduction in Height of Theoretical Stage Effect with pulsations

™CCE-MultiContactor Applications

Applications for the heavy oil, nuclear and biomass industries have been pilot tested. The capability of the original CCE technology to handle fruit fibres makes it particularly well suited to biomass cleaning.

There is considerable interest in renewable resources, for use as fuel or as a feedstock to bio-oil or other processes, as an alternative to fossil fuels that create greenhouse gases when burned.
However, biomass will collect contaminants such as fertilizer residues, solid contaminants picked up during harvesting and handling, and other adsorbed or absorbed compounds from exposure to the environment.
One example of a large scale application of ™CCE-MultiContactor Technology in cleaning of biomass is described below.

One such biomass resource is "Hog Fuel" that is produced in large quantities and burned for power generation.

"Hog Fuel" is the outer layer of trees, primarily bark that is stripped off before the log is converted into lumber or chips.

On the West Coast of Canada, there is a large Forest Products Industry that harvests trees along the coast . The majority of the trees are transported by sea to sawmills, where the hog fuel is removed prior to cutting the logs into chips or lumber.
The hog fuel is transported by barge to pulp and paper mills, where it is burned in the boilers for power generation.
The hog fuel will come from a variety of wood species and may also contain waste sawdust and shavings. It this has a wide particle size range and no consistency.
Hog from certain types of wood, especially Western Red Cedar, is stringy, tends to bind up equipment and is generally very difficult to handle .

The hog fuel also arrives at the mill site with a considerable amount of contaminants:

- Salt – 1-2% from immersion in sea water
- Sand and gravel – picked up during harvesting and transport
- Metallic and other debris – from equipment failures.

Chlorine in the salt (NaCl)combines with organics from the hog fuel under combustion conditions to form a variety of long-lived poly chlorinated compounds, including dioxins and furans.
There are international efforts to eliminate dioxin emissions as they are long-lived poisons that have impacts on living organisms , including cancer and birth defects.
Dioxins have been described by the US Environmental Protection Agency as a serious public health threat. The International Agency for Research on Cancer considers one dioxin as a Class 1 carcinogen. The Canadian Environmental Protection Act[1] has an objective of virtual elimination of dioxin and furan emissions.
Whilst there are many sources of dioxin emissions, the combustion of salty hog fuel by coastal mills contributes 60% of the dioxin emissions load in BC, and 4.3% of the Canada-wide dioxins total [2].

The chlorine also forms hydrochloric acid that causes considerable corrosion in boiler parts.
A considerable amount of salt also passes through the boiler , clogging tube banks and emissions control equipment. Salt is also emitted as small particles that may be hazardous when inhaled.

The sand and gravel passes through the hog fuel handling system and ends up in the boiler where they cause fouling and erosion.

The metallic debris is removed in part with a magnetic separator, but stainless steel and some other materials pass through into the boiler.

There are large volumes of hog fuel consumed on a typical mill, in the order of 185m3/hr, and the volume and its random particle size and nature make any efforts to clean the material difficult and expensive. Previous attempts have been focused on the capture of emissions or their partial control with combustion conditions.

Cleaning the hog fuel before it is burned avoids the problems and pollution caused by salt and sand.

In addition, in the ™CCE-MultiContactor the hog fuel becomes a valuable resource, a filter aid and heat transfer medium!

The ™Hogwash Process

A method of cleaning hog fuel economically, exploiting the unique features of ™CCE-MultiContactor Technology has been developed and is described in US patent 6,792,881.

The process works as follows:

- Salt – Removed from hog fuel by diffusion extraction into a mill effluent stream.
- Sand , gravel and other debris – dropped to the bottom of the contactor and removed using the pulsations of the equipment to provide assisted gravity separation.
- Heat recovery – the salt is removed by counter current washing with a warm mill effluent stream that heats the hog.
- Additional fibre recovery – The filtration action of the large bed of hog fuel in the contactor provides efficient filtration of waste fibre contained in the wash stream.
- Waste treatment – mill sludge may be piped into the contactor where the solids are separated by filtration from the contained water, saving flocculation chemicals and equipment.

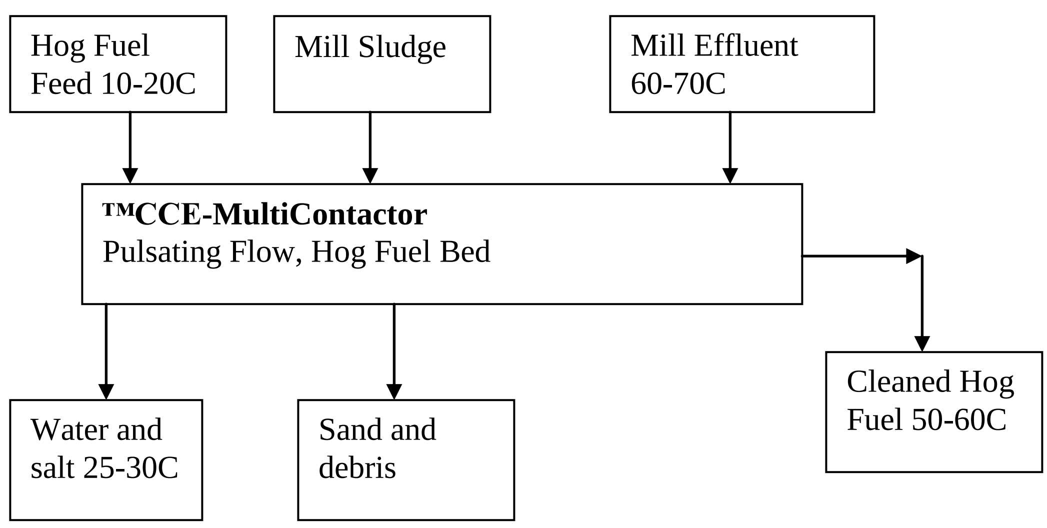

Fig 5

The ™Hogwash Process was tested during 2004 on the NorskeCanada Elk Falls, BC Pulp and paper Mill, under a Joint Technical Development Agreement between PWS Technology Ltd and NorskeCanada, with PAPRICAN (Pulp and Paper Research Institute of Canada) and substantial funding from Natural Resources Canada.

The process produced sufficient desalted hog fuel for a full scale test run of the mill power boiler with complete emissions testing.

Fig 6 Hog Desalting 5m3/hr Pilot Plant May 04

The test program produced very satisfactory results, with all process capabilities being confirmed. A summary is given below as the test results are too extensive to be repeated here, but details may be obtained from the author:

- Extraction of salt from all kinds of hog in the range 87-95%
- Filtration of Effluent achieved
- Heat Recovery from Effluent
- Gravity separation of sand

The effects of the salt removal on air emissions from the power boiler are indicated below in Fig 7

Parameter		Dioxin	Salt Emissions	Particulate Emissions
Units		TEQ ng/dSm^3	mg/dSm^3	mg/dSm^3
Average	August 2003 to present	0.090	42.6	76.8
Boiler Trial	August 18, 2004	**0.027**	**18.6**	**38.2**
Regulation	Existing boiler	0.5	N/A	115
	New boiler	0.1	N/A	115

Fig 7 Boiler Air Emissions from burning desalted hog fuel produced with ™CCE-MultiContactor data Courtesy NorskeCanada Elk Falls Mill

Summary

The test of the ™Hogwash Technology has confirmed that the system performs well with simultaneous unit operations

– Mass Transfer -diffusion extraction removes salt.
– Heat Transfer – warms hog fuel, also cools effluent going to treatment.
– Filtration recovery of waste fibre from effluent
– Gravity separation of sand and debris
– Lower greenhouse gases from elimination of fossil fuels
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There are considerable environmental and economic implications from the use of this intense process on hog cleaning.
In particular the virtual elimination of salt from the boiler that leads to – avoidance of dioxin and furan formation, greatly improved particulate emissions, lower maintenance costs, lower fuel consumption, greater boiler reliability from reduced outages.

General Cleaning of Biomass

The process should also have application in cleaning biomass going to bio-oil fast pyrolysis plants. In this application, compounds in the biomass can cause fouling of the fast pyrolysis reactors.
The ™CCE-MultiContactor could be used with a chemical wash in place of the mill effluent used in the hog fuel application.

It is anticipated that most processes have an excess of low level energy that is currently un-economic to recover. The ™CCE-MultiContactor offers a simultaneous low cost way to address such energy conservation.

References

1. www.CCME.ca, Website maintained by the Canadian Council of Ministers of the Environment.
2. www.ec.gc.ca Website maintained by Environment Canada
3. Canadian patent application No. 2,433,507 Filed June 26, 2003.
4. US Patent No 6,792,881 "A Method for Cleaning Salt Impregnated Hog Fuel and other Bio-mass, and for Recovery of Waste Energy".
5 Desalination of Salt Laden Hog Fuel Using ™CCE-MultiContactor Technology. B.McGuffie, P.Smith, Conference on Biomass Conversion Science in Thermal and Chemical Biomass Conversion Conference in Victoria 30 August – 2 September 2004 .