CHAPTER II

LITERATURE REVIEW

2.1 Controlled Cycling

Controlled cycling has been applied to various types of mass transfer processes, heat transfer processes, and others. Its soundness and practical usefullness have been proved by experimental work especially in the fields of distillation and liquid-liquid extraction. Schrodt (1965) has summarized some of the experimental results concerning the following processes: extraction, distillation, adsorption, screening crystallization, chemical reaction in a fluidized bed, heat transfer and electrolysis. The results indicated that the magnitude of the improvement in the performance of process equipment due to controlled cycling was much more than a few percent. One hundred percent increases in column efficiency were possible, and order-of-magnitude increases in throughput were observed.

The experimental work concerning the application of controlled cycling is mainly in the fields of extraction and distillation. Because these fields are related and more similar to the present work than others, only the literature concerning these fields is discussed in detail here.

2.2 Controlled Cycling in Extraction

Controlled cycling was applied for the first time to liquid-liquid extractor by Cannon (1956). The extractor was filled with light and heavy phases. When the two phases existed on every plate the controlled cycling was begun. Cannon divided the cycle of operation into four different parts:

1. A light-phase flow period during which an amount of light phase was introduced through the bottom of the column. This displaced the less dense phase (which was just below each plate) upward through each sieve plate in a stream of high velocity droplets, and these struck screens which were located between plates to assist coalescence.

2. A coalescing period during which all valved closed, there was no flow at all and the phases separated at each plate.

3. A heavy-phase flow period during which an amount of heavy phase was introduced through the top of the column. This displaced the more dense phase (which was just above each plate) downward through each plate in a stream of high velocity droplets which struck the screens again, but in the opposite direction to aid in rapid coalescence of the dispersed phase.

4. Another coalescing period to permit phase separation before the cycle was repeated.

In this type of column each phase was continuous for a part of cycle and discontinuous for another part of the cycle. Each phase dispersed into streams of droplets between plates and coalescenced into a continuous phase between plates.

Szabo, Lloyd, Cannon, and Speaker (1964) applied controlled cycling to stainless-steel sieve and screen plates column and packed column. The columns were 2 inches in diameter, and their heights were varied between 31 and 122 inches. The results of experiments were concluded as follow.

a) For the perforated or sieve plate column the magnitude of throughput did not affect the column efficiency, but for the packed column the column efficiency decreased with increasing throughput.

b) In comparision to the conventional column, the capacity of the perforated or sieve plate column was increased greatly and the column efficiency was some what improved.

c) The efficiency of both columns increased linearly with the ratio of raffinate flow to extract flow.

d) The phase input flow period and jet velocity through the plates had on effect on the column performance. The column efficiency increased with decrease of the phase input flow period or increase of the jet velocity.

e) When the number of plates was doubled while the plate spacing was held constant the column efficiency decreased.

Darsi and Feick (1971) experimented on column 110 mm. O.D. standard wall pyrex tubing and two set of perforated plates or sieve plate $\frac{1}{8}$ in. thick stainless steel plates, with $\frac{1}{16}$ in. diameter holes, the holes provide a free area of 10.5% of the column, tray spacing 5 in. An eight-tray column was used. Total height of column was 65 in.

The parameters of these experiments were physical properties of the system, duration of flow periods, duration of delay periods, flow ratios, nozzle Renolds numbers, column pressure drop, tray spacing, direction of mass transfer, and type of trays.

By using the principles of controlled cycling and equipment described above Darsi and Feick (1971) found that the column efficiency and capacity were obvious over conventional mode of operation for the same column.

2.3 Economic Consideration

Darsi and Feick (1971) studied the relative costs of a controlled cycling extractor and a conventional sieve tray extractor to process 2 million pound per year of an end product. The conditions assumed for this hypothetical extractor are based on the results obtained from their experimental work and industrial practices. The minimum saving that could be expected were thus 32.7% of the cost of conventional extractor system.

Itemized data for two extractors

	Conventional Extractor	C.C.Extractor
Overall column efficiency	25%	45%
Operating throughput rate	600 gal/hr.ft^2	1,200 gal/hr.ft^2
Material of construction	316 ss	316 ss
Optimum solvent to feed ratio	1.0	1.0
Feed	20% aq.soln.	20% aq.soln.
No.of theoretical stage	20	20

	Conventional Extractor		C.C.Extractor
	Two 2'Ø×70' high Tower,316 ss	One 2'Ø×138' high Tower,316 ss	One 18'Ø×64' high Tower,316 ss
Tower (insulated,installed)	\$133,900	\$111,900	\$61,100
Pumps	6,000	3,300	3,300
Piping (insulated)	24,000	16,000	15,300
Instrumentation(pneumatic)	27,000	15,500	19,000
Total	\$190,900	\$146,700	\$98,700

The costs are in Canadian dollars (1968)

Table for operation of various extractors using MIBK-acetic acid-water system.

Type of Column	Column Dia. in.	HETS(in) (HTU)	Max.Total.flow (gal/hr.ft^2)
Sieve plate controlled cycling	2.0	8.5-19	2,270
Packed columns	3.6	7.2-48	820
Spray	3.6	10.8-36	970
Pulsed spray	1.5	11.4	620
Rotating disc	8.0	4.3-14	980
Pulsed sieve plate	1.5	4.7-12	262
Pulsed packed	1.6	3.2-10	135

2.4 Controlled Cycling in Distillation

Gaska and Cannon (1961) applied controlled cycling to sieve and screen plate columns. The cycle of operation consisted of two distint parts: a liquid flow period and a vapor flow period. The process was controlled by a solenoid valve installed on the vapor out-let line of the reboiler. When the valve was opened vapor flowed up the column at a high velocity preventing liquid from flowing down. When the valve was closed, the liquid was not hindered by vapor flow, so it drained by gravity from one plate to another. Liquid down-comers were not necessary since both phases flowed through the same passages during their separate parts of the cycle. The rate of boilup in the reboiler was controlled automatically by the use of column pressure drop. A simple manometer circuit contained one fixed electrode immersed in the manometer liquid and one movable electrode that could be best for any desired column pressure drop. When the set pressure drop was reached a small electric current flowed through the manometer curcuit to a simple electric relay which operated the electric valve in the steam line to the reboiler. Total reflux was used.

Using the principles above, Gaska and Cannon (1961) found that the column capacity was increased by approximately 50% over the capacity for conventional operation of the same column operated at the same pressure drop across each plate, but the column efficiency was slightly lower and neary constant with varying vapor velocity or column capacity. Increasing the liquid flow period for a fixed vapor-flow period decreased the column efficiency but markedly increased the capacity. When the number of plates was doubled while the height of the column was held constant, the plate efficiency and the capacity of the column decreased. It was also found that increasing the free area of plate increasing the capacity but decreased the efficiency of the column.

Controlled cycling in a packed-plate distillation column was done by McWhirter and Cannon (1961). The column was made of 2-inch diameter glass pipe. It had 8 packed plates spaced 9½ inches apart. The packed plate was made of 1.81 inch inside diameter. Three different types of packed plates 1-inch, 2-inch and 3-inch depth, were tested. The method of operation was the same as that employed by Gaska and Cannon (1961).

McWhirter and Cannon (1961) found that controlled cycling was more flexible than conventional operation. It was possible to operate a column for either maximum efficiency or maximum capacity by changing the ratio of liquid to vapor-flow periods. Increasing the ratio decreased the efficiency but increased the capacity of the column. However, when the ratio was greater that unity, the capacity of the column was nearly constant with change of the ratio.

McWhiter and Lloy(1963) have done some experiments in a 5-stage, 6 inch diameter, packed-plate distillation column operated in both the cyclic manner and the conventional manner. They compared the results of the two methods and found that the efficiency and capacity of the column were increased by controlled cycling as much as two times over conventional operation.

Schrodt (1965) applied controlled cycling to distillation columns, and found that the increase in throughput over conventional operation for a five-stage batch vaccumm-still column was five times and for a packed column was three times.

In conclusion, controlled cycling has the following advantages over conventional operation:

1. High capacity and/or higer over-all efficiency of the column.

2. Simpler and cheaper plant design.

3. Higher flexibility due to a choice of operating conditions dependent upon the cycle time and ratio of the two phases flow periods.

2.5 Controlled Cycling in Particle Size Separation

The application of controlled cycling to particle size separation in screening was studied by Robertson (1956). In this apparatus the pressure of the gas (usually air) on the down stream and upstream side of the screen is varied in such a way that the bed of mixed particles is blown off the screen into the space between screens, where upon, the pressure is changed so that the cloud of mixed particles is sucked or forced against the screen. The cycle consists of two parts, a low pressure period followed by a higher pressure period on each side of the screen. The cycle is easily imposed on the equipment by means of a timer, electric valves and two surge tanks maintained at different pressure.