DESIGN OF HYDROCYCLONE FOR SALT CONTROL IN CONTINUOUS BUTTER MAKING MACHINE

THESIS
SUBMITTED TO THE KURUKSHETRA UNIVERSITY, KURUKSHETRA
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE
IN
DAIRYING
(DAIRY ENGINEERING)

BY
JITENDRA BALLAV MAHAPATRA
B.Sc. (Dairy Tech.)

DIVISION OF DAIRY TECHNOLOGY AND ENGINEERING
NATIONAL DAIRY RESEARCH INSTITUTE
(I. C. A. R.)
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Dedicated to
my beloved Parents

DR. S.C.SARMA

Senior Scientist (Engineering),
Division of Dairy Technology & Engineering,
Principal, Dairy Science College,
NATIONAL DAIRY RESEARCH INSTITUTE,
KARNAL.

Dated the 2nd June, 1984.

This is to certify that Mr.Jitendra Ballav Mahapatra of the National Dairy Research Institute, Karnal participated in planning of this study, executing the experiment work, analysing the data and preparing this report on:

" DESIGN OF HYDROCYCLONE FOR SALT CONTROL IN CONTINUOUS BUTTER MAKING MACHINE "

He did this work under my supervision in partial fulfilment of the requirements for the degree of Master of Science in Dairying (Dairy Engineering) of the Kurukshetra University, Kurukshetra. The help and assistance given by the individuals have been suitably acknowledged in the report.

(S.C. SARMA)

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Words can't express my deepest feelings of gratitude that I owe to my most precious and loving parents who have continuously struggled and borne innumerable hardships with dauntless courage, in their endeavour to provide me the best of everything in this life.

Last but not the least, my sincere acknowledgements are due to United Nation's Development Programme for awarding me Junior Research Fellowship for conducting this study.

(JITENDRA BALLAV MAHAPATRA)

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NOMENCLATURE

Dc = Hydrocyclone diameter.

Di = Hydrocyclone inlet diameter.

Do = Hydrocyclone overflow diameter.

Du = Hydrocyclone underflow diameter.

d_{50} = 50% separation size.

d_{max} = Maximum particle size in hydrocyclone overflow.

g = Gravitational acceleration.

V_i = Liquid inlet velocity.

Xf = Solid concentration $\frac{\text{Kg. of solids}}{\text{100 kg. of water}}$

μ = Liquid absolute viscosity.

ν = Liquid kinematic viscosity.

ρ = Liquid density

L = Length of cylindrical portion.

I = Length of projection of vortex finder into the cylindrical portion.

gc = Gravitational constant.

CHAPTER 1.

INTRODUCTION

1. INTRODUCTION

Butter, a fat rich dairy product is manufactured from cream. Among various methods for its production the basic principle of operation has remained as "churning of cream" to achieve fat separation, using mechanical means. Large scale manufacture of butter with (stainless steel butter churns of large capacities) has been in extensive use for over three to four decades. This design is still very popular and churns continues to be economical with many dairy plants. While the butter produced through churn continues to receive the acceptability as to it's quality, however its usage suffers from the following disadvantages.

- Batch operation and hence limited capacity.
- Labour intensive.
- System not being very convenient to rework and stored butter.
- Manual handling of product which limits the hygienic quality of product.
- Large floor space involved.
- High dynamic and impact loads during butter manufacture, which calls for precision and heavy duty components reflecting in equipment cost.

Besides with the improvement in milk collection, the production of butter should increase tremendously in future which also calls for its continuous production. Inception of continuous machines has helped to a great extent in overcoming the problems associated with batch production or seasonal variation in product quality, reduced shelf life etc. Due to the above limitations the manufacturing process for butter has undergone quite a few changes compared to its earlier methods of production.

Continuous butter making is a process which gives uninterrupted production for a given run. It involves a set of new processes and equipments. In this the butter making stages are arranged in mechanical saquence rather than in time sequence.

On the basis of the working principles the modern continuous butter making process can be divided into three main groups.

(a) The churning process or Fritz process:

The machine working on continuous churning principle include -

(i) Buttermatic (West Falia).
(ii) HCT-Type butter maker (Silkeborg).
(iii) Contimab (Simon Frere's).

(b) The concentration and phase reversal process:

This process is of two types and they are:

(i) Alfa type

(ii) Maleshin

(c) The emulsification process:

Two kinds of process exist and they are:

(i) Gold'n flow process

(ii) Creamery package process

For manufacturing table butter, salt is added. The advantages of adding sale to the butter are to increase its keeping quality, improve its flavour and to satisfy the requirements of the trade. In countries where legal standards are confined to a maximum moisture limit and have no limit on minimum fat, the salting of butter may serve as a means to increase the over run.

Mostly in European countries continuous butter making machines are designed with little regard to the manufacture table butter/salted butter. So in existing continuous butter making machine (CBM) which are imported to this country, none of the methods for adding salt is entirely satisfactory as reported by the Dairy plants. In our country demand for salted butter is high, it is, therefore, essential to modify the salt injection system in CBMs in order to obtain butter having uniformly distributed salt. It has been observed that when size of salt particles are in the range of 50 to 100 microns, they get dispersed in the butter phase easily.

The present study aims at evolving a suitable device namely hydrocyclone which can yield slurry having very fine particles of salt. Such a slurry can be directly injected into the mixing section of CBM. A salt mixing device was also developed to examine the efficiency of hydrocyclone.

CHAPTER 2.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study necessitated search for literature on the following aspects:

- (i) Effect of salt on keeping quality of butter.
- (ii) Salting in continuous butter making machines.
- (iii) Hydrocyclone.

A brief review of the published work is presented below:

2.1 EFFECT OF SALT ON KEEPING QUALITY OF BUTTER

It was established that a salt content of 1.5 to 2.5 per cent is a quite suitable for butter storage. The salt influences the keeping quality both bacteriologically and chemically. There is sufficient experimental evidence to show that higher salt contents stimulate chemical changes in butter during storage and is therefore detrimental to its keeping quality. Gray and Mckay (1906) found that lightly salted butter had superior keeping quality. Washburn and Dahlberg (1918) found that salt exclusive of its antiseptic properties, has tened the deterioration of butter in storage except at temperatures below 0°C. Both chemical and biological changes were arrested at lower temperatures and little difference in scores was noted.

Sommer and Smit (1923) observed that salt is one of the factors which contribute to the development of fishy flavour in butter. Lecithin dissolves in salt solutions and salt accelerates the change of lecithin into trimethlamine which is the fishy-flavoured substance. However, several other factors also contribute to the development of fishy flavour. In fact, fishiness is not a common flavour defect of butter. Factors favouring the development of fishy flavour are:

(i) Raw cream

(ii) High acid cream

(iii) High salt

(iv) Over working

(v) Presence of iron and copper salts.

Macy *et.al*. (1932) found that salt checked the growth of yeasts and bacteria. Its inhibitive effects on mold were less marked. Higher percentages of salt were more effective in reducing the number of organisms.

Thornton and Wood (1935) also concluded that salt is an important inhibitory factor in the growth of microorganisms in butter. Guthrie et.al. (1936) stated that, their results confirmed previous experimental work which showed the inhibitory action on microorganisms of lactic acid and salt in butter. The presence of either lactic acid or salt in butter without containing other spoilage factors considered in their study resulted, after storage, in a poorer quality of butter. The combined effect of salt and acid was shown by lower scores after 36 days storage at 10°C.

2.2 SALTING IN CONTINUOUS BUTTER MAKING MACHINE

Muller (1949) found that if salt crystals remain undissolved at the end of working, they will attract water from the sorrounding area of butter, giving area of reduced water content deeper yellow colour than the rest of the body of the butter. This leads to an yellow spot against a paler back ground, thus, giving rise to the defect known as spotted colour.

Dolby, K. (1955) reported that if the salt is not uniformly distributed, then, also it would cause spotted colour. He suggested that it would be better if the salt was added immediately after the point at which the last part of the butter milk was drained from the granules while making non washed butter or as early as possible in the working section, while making washed butter. According to this author if salt is added at these points, there would be free moisture available to dissolve it and a longer working time to disperse it evenly and throughout the butter.

Dolby (1956) reported that in conventional churning the salt is added to granules when they are fairly small and have sufficient free moisture on their surfaces. Dolby (1961) showed that salt particles in the size range of 18-25 mesh when mechanically stirred in water, took 40 seconds to dissolve. As this condition is very much different from that exists during the working of butter, he suggested that very fine salt is required when dissolving times are short.

Rusell (1971) showed that salt for use in continuous butter making machine should be filtered through a fine mesh sieve to remove extraneous matter and the size of salt particles pumped into the machine should be less than 100 microns. The salt which should be stored in a clean dry room at an ambient temperature of 10°C or above is added in form of a slurry to Fritz type continuous butter making machine. A change from 60:40 to 40:60 slurry will increase the moisture by approximately 1 per cent and vice versa. Bardely (1971) suggested that salt used should be very finely divided preferably to a maximum particle size of 80 microns. Mccartney (1972) showed that the working time should be at least 45 seconds in continuous process. Failure to maintain this time results in loose moisture and discoloration with a subsequent reduction in keeping quality. Rusell (1972) found that since the working period in continuous process is less than 1 minute it requires a special technique of salting to obtain satisfactory results. Ideally it would be best to add the 50 per cent salt in form of brine. But saturated brine solution contains only 25 per cent salt. A relatively small amount of brine is required to be added to the butter and this would increase the moisture content to 3 per cent. To achieve 2 per cent salt content in the final product it is necessary to use a salt slurry with the grains so fine in size that they do not affect the distribution of moisture while the butter is under storage. He also found that it is always advantageous to use as low concentration of salt as possible, because the amount of undissolved salt will not only be less with low concentration but the size of the salt grain will also be less. Practical experiments indicate that for a salt content of 2 per cent in the finished butter, a slurry of 60 per cent water and 40 per cent salt would be appropriate.

Mccartney (1972) tried the method of salting the butter by adding salt directly into the cream. The disadvantage of this method was the loss of salt through the butter milk. Jebson (1974) found that the fine salt (particle size approximately 100 microns) for use in continuous butter making machine could be obtained economically and efficiently by wet grinding process comprising a colloid mill and classifying and concentrating cyclones. The proportion of fines in the feed to the mill was recommended to be kept at minimum for obtaining high efficiency good quality butter.

2.3 HYDROCYCLONE

The hydrocyclone uses liquid, generally water, instead of gas. A swirling motion is imparted to the fluid by a tangential entry near the top of hydrocyclone. The rotational energy of the fluid is utilized in various separation techniques. Its potential for multiple applications combined with its superior performance and overall economy have placed the hydrocyclones in a position of greater advantage over the conventional equipments like centrifuges and gravitational thickners, etc.

Though the equipment is small, simple and cheap having no moving parts yet its design is quite controversial and difficult. Different schools of thought have put forward their own methods of design. Almost all designs are based on d_{50} the particle size present in the feed which has statistically 50 per cent chances either to be recovered in over flow or under flow. This is often a very good index for the study of the separation efficiency of the hydrocyclone. However, its utility in design has been proved to be limited (Panesar (1966). In the first place, it becomes rather difficult to estimate the exact fineness of the product from the d_{50} concept. Dahl strom (1954) suggested 1.5 per cent recovery size as the mesh size separation while Rietema and Verver (1961) suggested the use of 80 per cent point as a measure of separation efficiency. Secondly the particles used by earlier workers had a negligible friability.

Bradley (1964) reviewed in detail various aspects of velocity distribution, flow pattern, areas of application, performance, design and operating variables and categories of hydrocyclones. Normally, the amount of fluid head available is either fixed by the process or is restricted by the capacity of the available pump. Various equations have been put forward for pressure drop in hydrocyclone (Braley, 1965). The most recent one is reproduced below Gazder (1966).

$$V_i\sqrt{\frac{\rho}{\Delta P g_c}} = 0.148\left[\frac{D_o^{0.55}\,D_u^{0.1}\,D_c^{0.85}}{D_i^{1.5}}\right]\left[\frac{\nu^2}{g\,D_c^3}\right]^{0.03}\left[1-\left(\frac{X_f}{100}\right)\right]^{0.44} \quad \ldots\ \ldots\ \ldots(1)$$

In actual practice it has been established that additional fines are formed during separation because of a high shear field. This effect has been shown to be more predominant for high concentration of solids (Panesar, 1966).

It is, therefore, better to base the design of hydrocyclone for classification on the basis of the maximum particle size that can be present in the overflow, d max, so that a hydrocyclone can be designed to give definite cut point accepted for the process. Study of the effect of various design parameters gave the following dimensionless correlation for calcium carbonate slurries (Panesar, 1966).

$$\frac{d_{max}}{D_c} = 4.5\times 10^{-4}\left[\frac{D_o^{0.8}\cdot D_c^{1.0}}{D_i\cdot D_u^{0.7}}\right]\left[\frac{d_{max}\times V_i}{\nu}\right]^{-0.4}\left[\frac{V_i}{g\cdot D_c}\right]^{-0.4} X_f^{0.4} \ldots$$

This equation has to be corrected if the density of the solids is appreciably different from that of calcium carbonate. Optimum ratios of D_c/D_1, D_c / D_0, D_c / D_u have been worked out and most generally accepted ratios are; (Bradley, 1965).

$$D_i = D_c /7$$

$$D_0 = D_c /5$$

$$D_u = Dc /15 \qquad - (3)$$

Substituting these values in equation (1) and (2)

$$\frac{d_{max}}{D_c} = 7 \times 10^{-3} \left[\frac{d_{max} \cdot V_i}{\nu}\right]^{-0.4} \left[\frac{V_i}{g \cdot D_c}\right]^{-0.4} \cdot X_f^{0.4} \quad —(4)$$

$$V_i \sqrt{\frac{\rho}{\Delta P g_c}} = 0.86 \left[\frac{\nu^{2}}{g \cdot D_c^{3}}\right]^{0.03} \left[1 - \frac{X_f}{150}\right]^{0.44} \quad —(5)$$

These two simultaneous equations may now be solved for two unknowns that is V_1 and D_c for efficient and economic separation, it is, suggested that value of the hydrocyclone Reynold's Number $D_c V_1/\nu$ should be of the order of 10^5. A cone angle of 20°, length of the cylindrical portion, $L = 1.5$ to 2.0 times D_c and projection of vortex finder into the cylindrical portion $l = 0.4 D_c$ have generally been

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$$V_i \sqrt{\frac{\rho}{\Delta \rho g_c}} = 0.86 \left[\frac{\nu^2}{g \cdot D_c^3} \right]^{5.03} \left[1 - \frac{X_f}{150} \right]^{0.44} \quad —(5)$$

These two simultaneous equations may now be solved for two unknowns that is V_1 and D_c for efficient and economic separation, it is, suggested that value of the hydrocyclone Reynold's Number $D_c \ V_1/\nu$ should be of the order of 10^5. A cone angle of 20°, length of the cylindrical portion, L = 1.5 to 2.0 times D_c and projection of vortex finder into the cylindrical portion l = 0.4 D_c have generally been accepted from considerations of operation and fabrication of the equipment. Lynch and Rao (1968) studied the operating characteristics of hydrocyclone classifier.

Panesar _et.al._ (1970) carried out experimental investigations to find (i) the plane of equilibrium of a particle rotating at the cone wall of a hydrocyclone (ii) the radius of maximum tangential velocity of hydrocyclone, and (iii) the maximum particle size in the overflow stream of a hydrocyclone and developed equations. Kumar _et.al._ (1974) worked on verification of Mussorie Rock phosphate by hydrocyclone. Row and Row (1975) analysed concept of reduced efficiency curve of a hydrocyclone and developed an expression relating percentage of feed solid, to under flow and size of particles having corrected efficiency of 50 per cent of operation. Sastry _et.al._ (1976) carried out pressure drop studies on two phase flow through a hydrocyclone. Gupta and Grover (1976) developed correlation for critical feed inlet velocity for maximum collection efficiency in hydrocyclone.

Mahajan and Pai (1977) carried out studies on liquid - liquid separation efficiency and volume split in hydrocyclone.

CHAPTER 3.

OBJECTIVES SCOPE AND PLAN OF WORK

3. OBJECTIVES, SCOPE AND PLAN OF WORK

3.1 OBJECTIVES

The main objectives of this study were as follows:

(i) To design a hydrocyclone which will give 80 micron size salt particles when the feed is in the temperature range of 6, 12 and 20°C.

(ii) To test the performance of the hydrocyclone by various operating parameters.

(iii) Employing the hydrocyclone for injecting solution with desired size of solution crystals into butter to achieve uniform distribution of salt.

3.2 SCOPE

Various investigations have been carried out on salting by the Dairy Plants in India using the continuous butter making machines but none of the methods has been found entirely satisfactory. This work has been directed to achieve fine particles of salt in the solution thereby rectifying few defects caused by the coarse salt crystals in manufacture by the contimab process.

3.3 PLAN OF WORK

The present study has been catagorised as under:

3.3.1 Design of Hydrocyclone

A hydrocyclone was designed for a pressure drop of 2.5 $\frac{kg}{cm^2}$ and a discharge of 2,200 $\frac{kg}{hr}$. This hydrocyclone was fabricated from stainless steel. It was devided into three portions viz:

(i) Cylindrical
(ii) Top cone
(iii) Bottom cone

These three parts were joined by threading. This method of joining was employed with a view to dismantle the device completely when necessary.

3.3.2 Performance of hydrocyclone

For performance testing of hydrocyclone, trials were conducted at different temperatures mainly at 6, 12 and 20°C. The effect of temperature on overflow concentration was studied. Particle size distribution was measured both by microscopic as well as wet screening method.

3.3.3 Salt injection

For salting, a mixing device was developed. The samples were tested for uniformity in salt distribution.

CHAPTER 4.

MATERIAL AND METHODS

4. MATERIALS AND METHODS

4.1 DESIGN OF HYDROCYCLONE

The pressure energy of the fluid is utilised in creating a swirling flow inside the hydrocyclone. When swirling flow is fully established, the feed gets split into under flow and overflow. The ratio of split depends upon the physical and dynamic parameters.

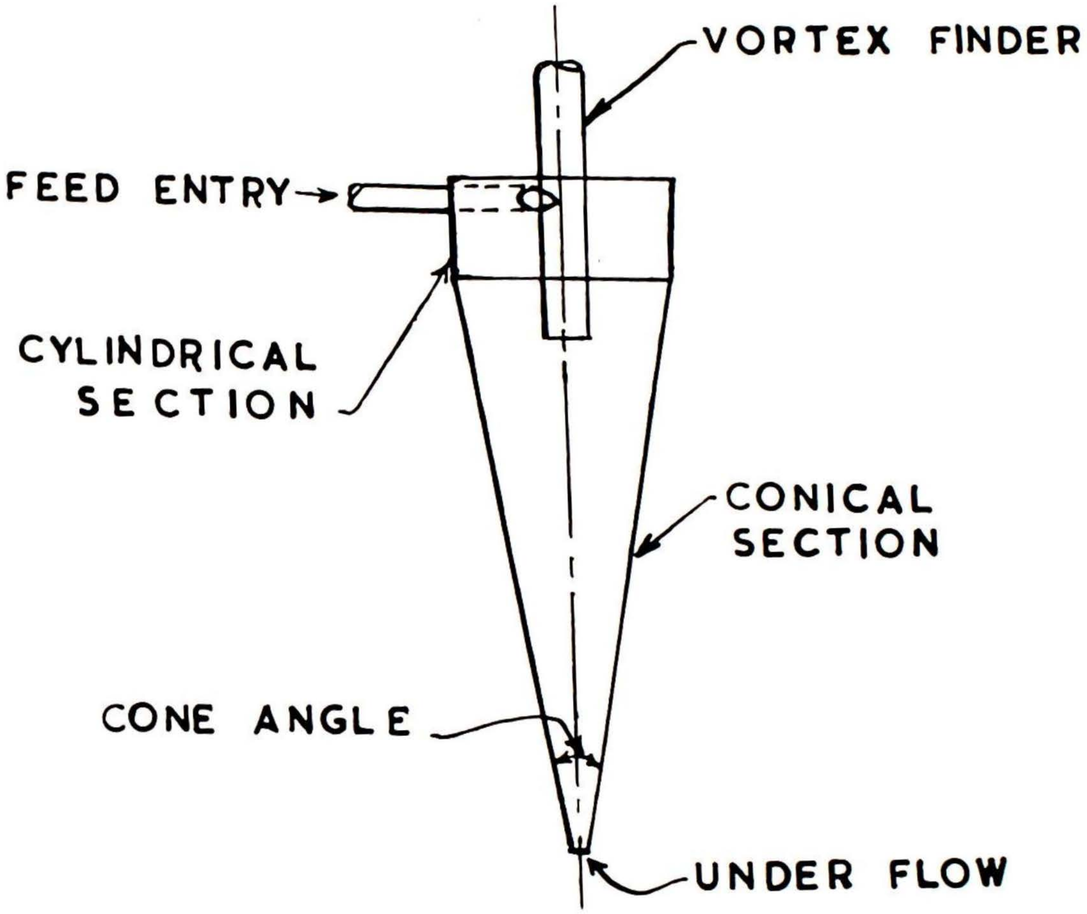
Δp = Pressure drop = $2.5 \frac{kg}{cm^2} = 2500 \frac{gm}{cm^2}$

ρ = Density of Brine = $1.1894 \frac{gm}{cm^3}$ at 20°C (unit operation of chemical Engg. McCabbe & Smith p.p. 998).

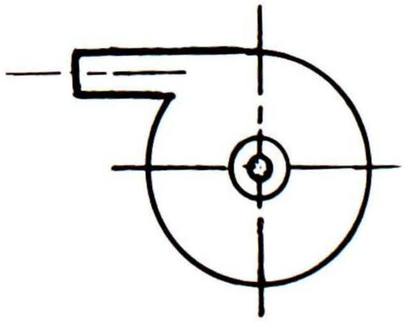
Viscosity of Brine = 1.889863 cp = 1.8898×10^2 at 20°C concentration of Brine = 33.33 per cent at 20°C (unit operation of chemical Engg. McCabbe & Smith p.p. 998).

ν = Liquid Kinematic Viscosity

= $0.0158892 \frac{cm^2}{Sec.}$



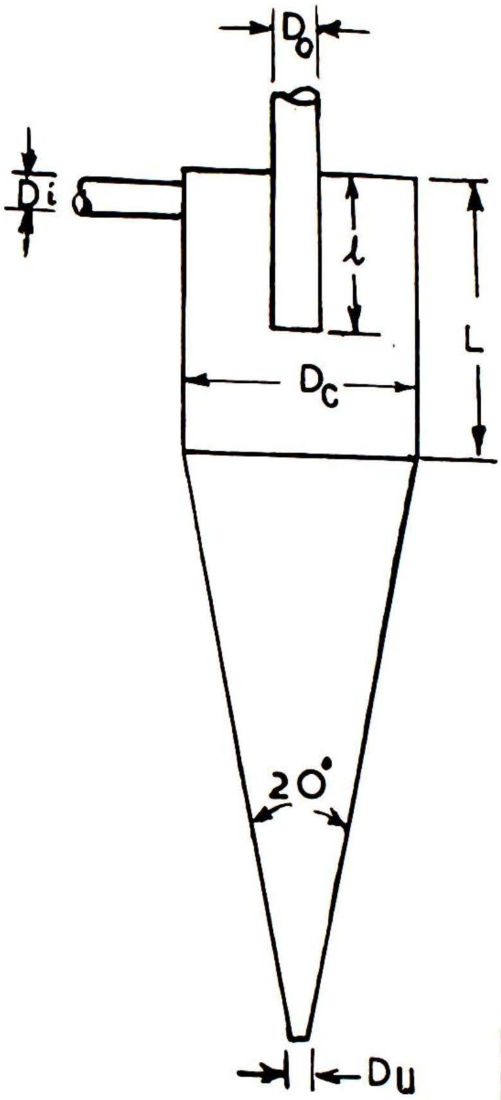
Front View



Top View

FIG. 1 (a)

HYDROCYCLONE.



ITEMS.	SPECIFICATION.
D_c	7 cm
D_i	1 cm
D_o	1.4 cm
D_u	0.466 cm
L	14 cm
l	2.8 cm

FIG. 1 (b)

DIMENSIONAL SKETCH OF HYDROCYCLONE.

$$\frac{dmax}{D_c} = 7 \times 10^{-3} \left[\frac{dmax \times V_i}{\nu}\right]^{-.4} \left[\frac{V_i}{g.D_c}\right]^{-.4} \left[x\ f\right]^{.4} \quad (1)$$

$$dmax = 80 \text{ microns} = 8 \times 10^{-3} \text{ cms}$$

$$\frac{8 \times 10^{-3}}{D_c} = 7 \times 10^{-3} \left[\frac{8 \times 10^{-3} \times V_i}{0.0158892}\right]^{-.4} \left[\frac{V_i}{980 \times D_c}\right]^{-.4} \left[0.33\right]^{.4}$$

$$\frac{8}{D_c} = 7 \times 1.315842 \times V_i^{-.4} \times 15.72 \times \frac{V_i}{D_c}^{-.4} \times .6418$$

$$\frac{8}{D_c} = 92.929594 \times V_i^{-.8} \times D_c^{1.4}$$

$$0.0860866 = V_i^{-.8} \times D_c^{1.4} \times \text{----} \quad (1)$$

$$V_i \sqrt{\frac{\rho}{4 P \times g_c}} = 0.86 \left[\frac{\nu^{2}}{g\ D_c^{.3}}\right]^{.03} \left[1 - \frac{x_f}{100}\right]^{.44} - (2)$$

$$V_i \frac{1.1894}{2500 \times 980} = 0.86 \times \left[\frac{2.52466 \times 10^{-4}}{980 \times D_c^{3}}\right] \left[1 - \frac{.33}{100}\right]^{.44}$$

$$V_i\ 6.96756 \times 10^{-4} = 0.96 \times .6343505 \times .9988 \times D_c^{-.09}$$

$$V_i\ 6.96756 \times 10^{-4} = 0.5449165 \times D_c^{-.09}$$

$$V_i = \frac{0.5449165}{6.8756 \times 10^{-4}} \times \frac{1}{D_c^{.09}}$$

$$V_i = \frac{782.07614}{D_c^{.09}}$$

Putting the value of V_i (1)

$$0.0860816 = \frac{782.07614^{-.8}}{D_c^{.9}} \qquad D_c^{1.4}$$

$$0.0860866 = 4.84619 \times 10^{-3} \qquad \frac{D_c^{1.4}}{D_c^{-0.072}}$$

$$17.763769 = D_c^{1.472}$$

$$D_c = (17.763769)^{1/1.472} = 7.06104477 \text{ cms.}$$

Putting the value of 'D_c' in equation (2)

$$V_i = \frac{782.07614}{(7.06104477)^{.09}} = 655.9199 \frac{\text{cm}}{\text{sec.}}$$

$$V_i = 655.9199 \frac{\text{cm}}{\text{sec.}}$$

Verification of Discharge:

D_c = 7 cm

D_i = 7/7 = 1 cm

D_0 = 7/5 = 1.4 cm

D_u = 7/15 = 0.466 cm

$$A_i = \frac{\pi}{4} d_i^2 = 0.7855 \text{ cm}^2$$

$$V_i = 655.92 \frac{\text{cm}}{\text{sec.}}$$

$$Q = A_i \times V_i = 0.7855 \times 655.92 = 515.22516 \frac{\text{cm}^3}{\text{sec.}}$$

$$515.22516 \times 1.1899 = 612.81 \frac{gm}{sec.}$$

$$\frac{612.8 \times 3600}{1000} = 2201.11 \frac{Kg}{hr.}$$

The dimensioned sketch of the Hydrocyclone is shown in Fig.1(b).

4.2 DESCRIPTION OF THE EXPERIMENTAL SETUP

The schematic diagram of the experimental setup is shown in Fig 2. It consisted of a tank (1) connected to the inlet of centrifugal pump (2). The discharge line of the centrifugal pump (2) was provided with a bypass line to control the feed rate. The feed line was connected to hydrocyclone inlet (3). A Bourden type pressure gauge (4) was provided to measure the feed pressure. The feed pressure could be controlled by a control valve (5) and also by a by-pass valve (6). During recirculation the under flow was directed to feed tank (1) through a hose pipe. The over flow line was bifurcated into two parts: the feed line and the by-pass line. The feed line was provided with a control valve (7) and connected to the salt injecter (8). The salting chamber consisted of two components:

(i) Butter moulding machine (9)

(ii) Mixing device (10)

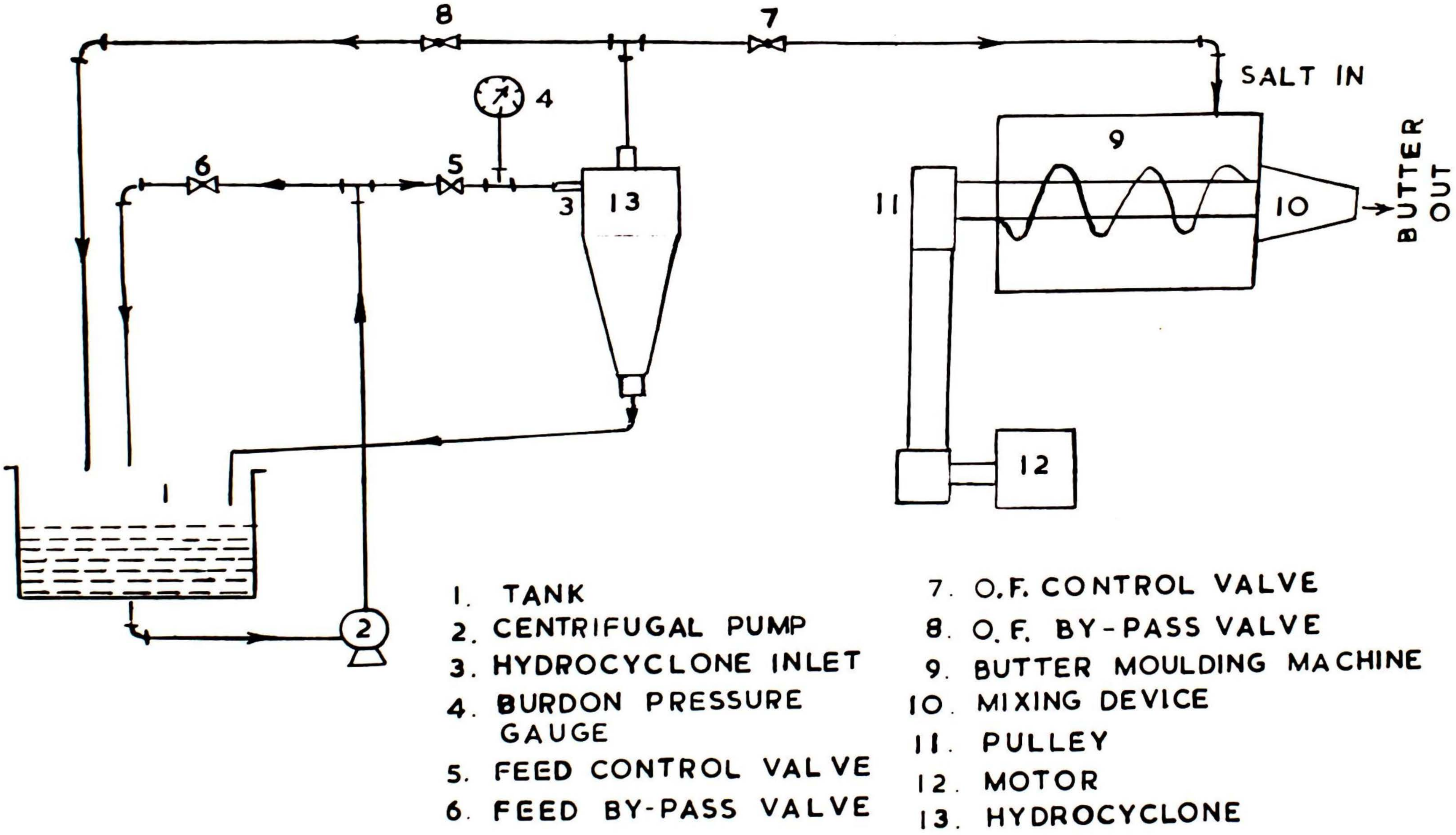


FIG. 2

SCHEMATIC LINE DIAGRAM OF EXPERIMENTAL SET-UP.

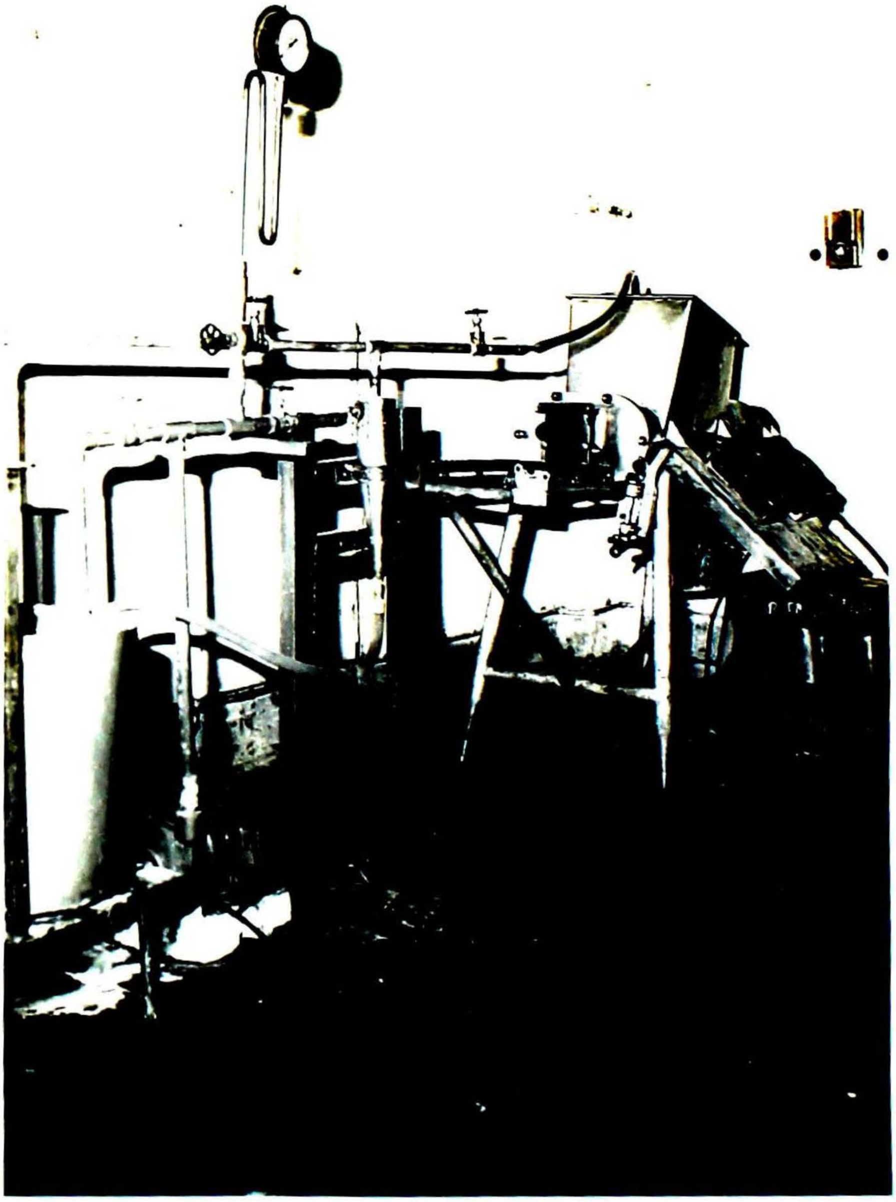


PHOTO SHOWING THE EXPERIMENTAL SET-UP

Butter moulding machine has two augers. The augers were driven by a motor and pulley arrangement. The exploded view of mixing device is shown in Fig 3. It consisted of one perforated plate (P) and a cone (C). This device was fixed to the outlet of the butter moulding machine.

Salt was injected through a line connected from the over flow straight way into the chamber of the butter moulding machine.

Sr. No.	Item	Specification
1.	Tank	18:8 stainless steel ø = 30.5 cm Height = 3 cm Capacity = 30 litres
2.	Hydrocyclone	18:8 stainless steel
3.	Pump	Centrifugal A.C. Industion Motor, H.P. = 1 Phase = 3 Head = 2.2 M. Discharge = 5,000 lit/hr.
4.	Pipe fittings	Galvanized iron ø = 1.3 cm
5.	Butter moulding machine	Make : -Laval Capacity 15 kg/hr.

6. Mixing device:

i) Perforated plate 15.2 cm x 10.2 cm
1.3 cm drill
Mild Steel

ii) Cone
ϕ_1 = 1 cm
ϕ_2 = 2 cm
L = 3 cm

4.3 PERFORMANCE TESTING OF HYDROCYCLONE

Predetermined quantity of brine slurry was prepared by taking 40 parts by weight of common salt with 60 parts by weight of water. Then all the valves of the setup were closed except valve No.(6) to achieve proper mixing. Then valve number (6) was closed and all the control valves for under flow and over flow were opened. The mass flow rate was calculated for both over flow and underflow and the samples were collected from under flow, over flow and feed for testing of concentration and particle size distribution. The outlet temperature of over flow was also measured. The trials were conducted at 6, 12 and 20°C.

4.3.1 <u>Collection and preservation of sample</u>

Samples for checking of concentration were collected from overflow. But for the determination of particle size distribution, the samples were collected from feed, under flow and over flow. The samples were preserved in mixture of diethyl ether and petroleium ether (50:50) in which brine is completely insoluble to prevent salt crystal growth.

4.3.2 Particle size distribution

4.3.2.1 Microscopic analysis: Microscopic analysis was done to determine range of the salt particles.

A thin smear was made on a glass slide and to it Nigrosine was added to obtain coloured back ground. This was observed under low power microscope and simultaneously the size was measured by an occular micrometer.

4.3.2.2 Wet screening: The wet screening method was adopted to determine the size distribution of salt particles in the entire sample.

In this process, three screens of mesh sizes 120, 200 and 240 were chosen which correspond to 115, 74 and 63 microns respectively. All these screens were placed one above the other in an assending order of mesh size and at the bottom, a vessel was kept. This arrangement was fixed to a mechanical shaker. Total amount of slurry fed through the top screen the amounts retained over each screen and at the bottom, were determined. This procedure was adopted for feed, under flow and over flow.

4.4 PROCEDURE FOR INJECTING SALT INTO BUTTER

Brine slurry (40:60) was prepared and kept in the brine tank. All the valves were closed except valve (6) to achieve proper mixing. Then valve (6) was closed and all the valves were opened. Valve (7) was adjusted in such a way that it exactly delivered 2 per cent brine. This method was standardized prior to starting of the operation. Then the brine pump and butter moulding machine were switched on.

4.4.1 Collection of samples

The butter ejected out from mixing device in the form of a continuous cylindrical roll. The samples were collected at various section along the length of the butter roll.

4.5 ANALYTICAL PROCEDURE

4.5.1 Concentration

An aluminium dish was cleaned, dried and then weighed empty. The sample was taken into the dish and weighed. The sample was kept in hot air oven and weighed

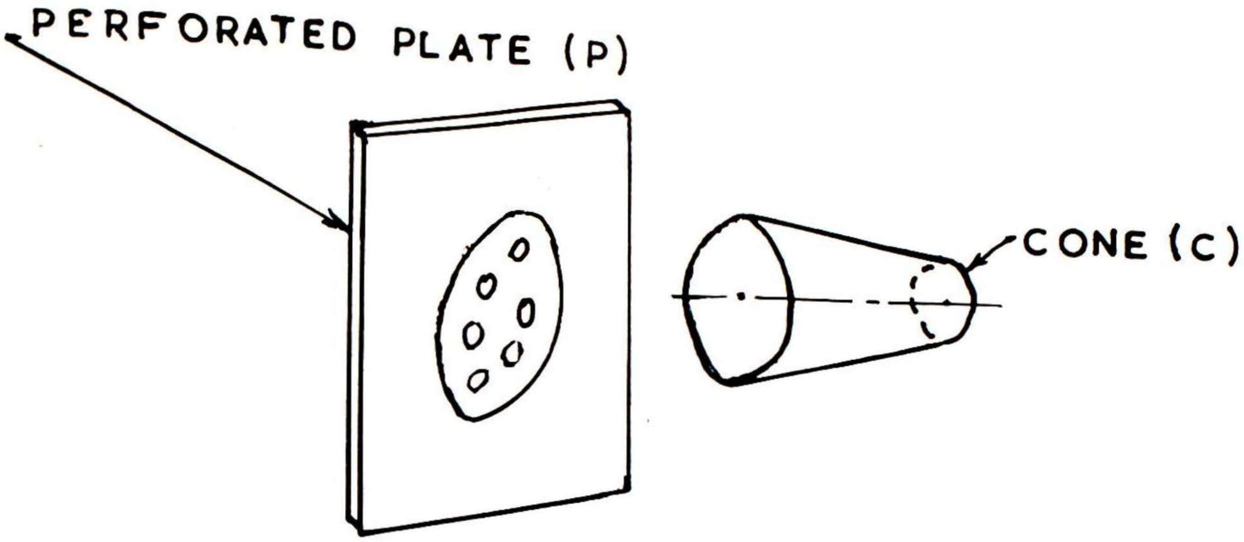


FIG. 3 (a)

EXPLODED VIEW OF MIXING DEVICE.

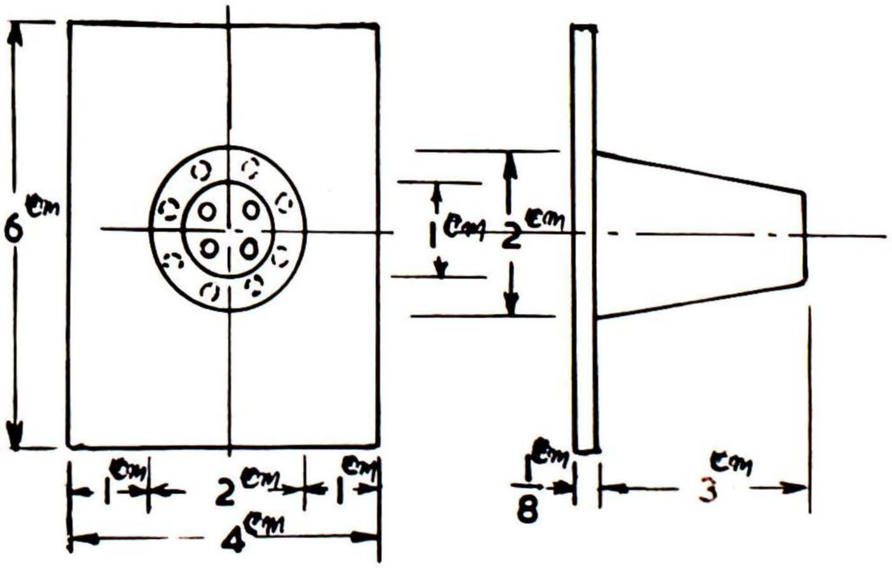


FIG. 3 (b)

SCHEMATIC DIAGRAM OF MIXING DEVICE.

intermittantly till the weight was constant.

4.5.1.1 Calculation:

A = weight of the emply dish in g

B = weight of dish + sample in g

C = weight of dish + salt in g

B-A = weight of sample in g

C-A = weight of salt in g

B-C = weight of moisture in g

$$\text{Parts of salt} = Y = \frac{C-A}{B-A} \times 100$$

$$\text{Parts of water} = Z = 100 - Y$$

$$\text{Concentration} = Y:Z$$

4.5.2 Salt content in butter

The butter was melted in hot water and chloride in the mixture was titrated with a solution of silver nitrate using potassium chromate as indicator.

5 gram of the sample was accurately weighed in a conical flask. 100 ml of boiling distilled water was carefully added. It was allowed to stand with occasional swirling for 5 to 10 minutes. It was cooled to 50-55°C (titration temperature) 2 ml of potassium chromate was added. Again it was mixed by swirling.

0.25 gm of calcium carbonate was added and again mixed by swirling. This mixture was titrated at 50-55°C with standard silver nitrate solution with continuously swirling until the brownish colour persists for half a minute. A blank test was carried out with all the reagents in the same quantity except the sample material.

$$\text{Sodium chloride per cent by weight} = \frac{5.85\ N\ (V_1 - V_2)}{W}$$

where

N = Normality of silver nitrate 50 per cent

V_1 = Volume of silver nitrate in the sample titration.

V_2 = Volume of silver nitrate in the blank titration and

W = Weight in g of the sample.

CHAPTER 5.

RESULTS AND DISCUSSION

5. RESULTS AND DISCUSSION

In accordance with the objectives of the study earlier stated the investigations were conducted. Based on these, the necessary data was recorded and analysed.

5.1 ANALYSIS OF TRIALS

The studies involved the following steps:

A. Performance testing of hydrocyclone
   - (i) Effect of temperature on mass flow rate and concentration.
   - (ii) Salt particle size distribution.

B. Mixing of salt in butter.

5.1.1 Thirty trials, 10 each at temperatures of 6, 12 and 20°C were conducted and the results were recorded in tables 5.1 to 5.3. In all the trials the feed slurry concentration was kept at 40:60 level.

5.1.1.1 When the feed temperature was maintained at 6°C, the discharge rate ranged from 1238 to 1280 kg/hr and as such, the over-flow discharge rates were in the range of 860 to 812 kg/hr and under flow ranged from 398 to 468 kg/hr respectively. The average brine concentration in over-flow was 39.5 : 60.5.

When the feed temperature was maintained at 12°C, the discharge rate ranged from 1614 to 1618 kg/hr and as such, the over-flow discharge rates were in the range of 1100 to 1105 kg/hr and underflow 508 to 518 kg/hr respectively. The average brine concentration in over-flow was 38.4:61.6.

When the feed temperature was maintained at 20°C, the discharge rate ranged from 2174 to 2191 kg/hr and as such, the over-flow discharge rates were in the range of 1504 to 1518 kg/hr and under flow 668 to 680 kg/hr respectively. The average brine concentration in over-flow was 37.6 : 62.4.

From the above mentioned observations it can be inferred that mass flow rate is a function of temperature. As the temperature increased from 6 to 20°C the mass flow rate increased. This could be attributed to lowering of viscosity of the brine slurry with increasing temperature. At lower temperature the solubility of sodium chloride also decreases resulting in large number salt particles remaining in suspended form in the solution and hence forming a viscous slurry.

It was also observed that as the feed temperature increased from 6°C to 20°C the salt concentration in in over-flow decreased from 98.75 per cent to 94 per cent.

The reason could be that at lower temperature the slurry becomes highly viscous and large number of the salt particles remain in suspended form. This might enhance collection of more solids in the over-flow.

5.1.1.2 Particle size distribution: The particle size distribution was investigated through microscopy and wet-screening method.

The microscopic examination revealed that the particle size in the main feed, over-flow and under-flow ranged as 40-120, 40-90 and 40-120 microns respectively.

These figures seem to over lap each other. However, to estimate the quantity in each range wet screening method was adopted. The results obtained are shown in table 5.4. It was observed that the large percentage of fines in the range of 63 and 74 microns, were obtained in over-flow as compared to that in under flow. The salt particles in this range are easily dispersible in butter.

Since almost all designs of hydrocyclone are based on d_{50} concept, the particle size present in the feed which has stastically 50 per cent chances either to be recovered in overflow or underflow.

To achieve higher separation efficiency micropulverized salt should be used. The salt should be wet grounded followed by separation of over size particles in a hydrocyclone system. The most successful method would be using two hydrocyclones in such a way that the under-flow of the first hydrocyclone will be the feed for the second hydrocyclone and finally the over-flow of the second hydrocyclone should be injected in continuous butter making machine.

5.1.2 Though salt mixing section could not be exactly simulated as that exists in the continuous butter making machine, somewhat a similar system was developed. The samples collected from the mixing device were analysed for salt distribution and the results were recorded in table 5.5. It could be observed that out of ten samples, six had uniform salt content. The amount of salt content in the final product was less than the amount injected because some portion of salt was lost in butter milk.

Considering the imperfections in mixing device, the salt distribution in samples can be regarded as satisfactory. This result can be attributed to the hydrocyclones performance in yielding fine salt particles in the over-flow which could be distributed in the butter easily.

5.2 CALCULATIONS

5.2.1 Concentration

$A = 30.20$ grams

$B = 40.30$ grams

$C = 34.139$ grams

$B-A = 40.30 - 30.20 = 10.1$ grams

$C-A = 34.139 - 30.20 = 3.939$ grams

$B-C = 40.30 - 34.139 = 6.161$ grams

$$\text{Parts of salt} = Y = \frac{C-A}{B-A} \times 100$$

$$= \frac{3.939}{10.1} \times 100$$

$$= 39$$

Parts of water = $Z = 100-39 = 61$

Concentration = 39:61

5.2.2 Salt content

$W = 5$ grams

$N = 0.1$

$V_1 = 30.6$ ml

$V_2 = 15.4$ ml

$$\text{Sodium chloride per cent by weight} = \frac{5.85\ N\ (V_1 - V_2)}{W}$$

$$= \frac{5.85 \times 0.1\ (30.6 - 15.4)}{5}$$

$$= \frac{5.85 \times 0.1\ (15.2)}{5} = 1.775\%$$

TABLE 5.1 : FLOW RATE, CONCENTRATION AND PARTICLE SIZE CONCENTRATION OF FEED = 40:60

Sr. No.	Inlet Temp. feed °C	Outlet Temp. over flow °C.	FLOW RATE (Kg/hr)			Concentration of overflow	PARTICLE SIZE DISTRIBUTION IN MICRONS (MICROSCOPIC ANALYSIS)		
			Over flow	Under flow	Total flow		Over flow	Under flow	Feed
1.	6	8	810	468	1278	39:61	40–90	40–120	40–120
2.	6	9	860	398	1258	39.2 : 60.8	40–90	40–110	40–120
3.	6	8	812	468	1280	39 : 61	40–78	40–120	40–120
4.	6	8	803	471	1274	39.8 : 60.2	40–90	40–120	40–120
5.	6	8	832	445	1277	39.5 : 60.5	40–90	40–120	40–125
6.	6	8.5	890	385	1275	39.4 : 60.6	40–80	40–110	40–110
7.	6	8	830	444	1244	39.8 : 60.2	40–78	40–110	40–110
8.	6	9	832	447	1279	39.2 : 60.8	40–90	40–105	40–110
9.	6	8.5	840	431	1271	39.7 : 60.3	40–80	40–110	40–110
10.	6	8	813	464	1277	39.7 : 60.3	40–90	40–120	40–120

TABLE 5.2 : FLOW RATE, CONCENTRATION AND PARTICLE SIZE CONCENTRATION OF FEED 40:60

Sr. No.	Inlet Temp. °C feed	Outlet Temp. over flow °C	FLOW RATE $\frac{Kg}{hr}$			Concentration of overflow	PARTICLE SIZE DISTRIBUTION IN MICRONS (MICROSCOPIC ANALYSIS)		
			Over flow	Under flow	Total flow (observed)		Over flow	Under flow	Feed
1.	12	15	1100	518	1618	38.1 : 61.9	40–110	40–110	40–110
2.	12	19	1104	514	1618	38.1 : 61.9	40–80	40–110	40–120
3.	12	18	1102	515	1617	38.8 : 61.2	40–80	40–110	40–110
4.	12	15	1104	512	1616	38.1 : 61.9	40–90	40–120	40–120
5.	12	16	1105	512	1617	38.1 : 61.9	40–80	40–120	40–120
6.	12	15	1104	512	1616	38.2 : 61.8	40–80	40–110	40–110
7.	12	18	1103	511	1614	38.1 : 61.9	40–80	40–105	40–110
8.	12	17	1105	511	1616	38.6 : 61.4	40–80	40–120	40–120
9.	12	18	1105	508	1613	38.6 : 61.4	40–80	40–110	40–110
10.	12	15	1104	514	1618	38.2 : 61.8	40–80	40–110	40–120

TABLE 5.3 : FLOW RATE, CONCENTRATION AND PARTICLE SIZE CONCENTRATION OF FEED 40:60

Sr. No.	Inlet Temp. ^{o}C feed	Outlet Temp. ^{o}C Flow	FLOW RATE $\frac{Kg}{hr}$			Concentration of Overflow	PARTICLE SIZE DISTRIBUTION IN MICRONS (MICROSCOPIC ANALYSIS)		
			Over Flow	Under Flow	Total Flow (observed)		Over Flow	Under Flow	Feed
1.	20	27	1511	668	2179	37.9 : 61.1	40-90	40-110	40-110
2.	20	27	1518	672	2190	37.8 : 62.2	40-90	40-110	40-110
3.	20	27.5	1509	672	2181	37.1 : 62.9	40-80	40-110	40-110
4.	20	29	1504	670	2174	37.9 : 62.1	40-110	40-120	40-120
5.	20	27	1507	678	2185	37.9 : 62.1	40-80	40-120	40-120
6.	20	27.5	1516	675	2191	37.6 : 62.4	40-90	40-110	40-120
7.	20	28	1508	673	2181	38.0 : 62.0	40-90	40-110	40-110
8.	20	27	1508	672	2180	38.1 : 61.9	40-90	40-110	40-120
9.	20	27	1509	668	2177	37.9 : 62.1	40-80	40-110	40-120
10.	20	27	1504	680	2184	37.6 : 62.4	40-90	40-110	40-120

TABLE 5.4 : WET SCREENING ANALYSIS

Sr. No.	OVER FLOW Particles Retained (%)			UNDER FLOW Particles Retained (%)			FEED Particles Retained (%)		
	120 Mesh size (115 Microns)	200 Mesh size (74 Microns)	240 Mesh size (63 Microns)	120 Mesh size (115 Microns)	200 Mesh size (74 Microns)	240 Mesh size (63 Microns)	120Mesh size (115 Microns	200 Mesh size (74 Microns	240 Mesh size (63 Microns)
1.	30	24	15	99	12	6	91.7	3.9	2.0
2.	28	24	15	79	12	6	91.0	3.0	2.0
3.	28	23	15	79	11	7	91.0	4.0	1.0
4.	31	24	15	79	11	6	91.0	3.0	2.0
AV	29.25	23.75	15	79	11.5	6.25	91	3.25	1.75

TABLE 5.5 : SALT DISTRIBUTION

Amount of salt injected (%)	Amount of salt obtained in final product %				
	1	2	3	4	5
2	1.875	1.775	1.775	1.90	1.775
2	1.775	1.775	1.875	1.775	1.825

CHAPTER 6.

SUMMARY

6. SUMMARY

A hydrocyclone to handle salt slurry was designed on d_{50} concept and its performance was tested. Discharge rate and concentration of slurry from over-flow and underflow were found to be temperature dependent. As the temperature was increased, discharge rate increased but the concentration decreased. The particle size measurement and distribution were determined by microscopic and wet screening techniques.

A salt mixing device was also developed. Fine salt slurry in 80 micron range particle size, obtained from over-flow of hydrocyclone, was injected into butter moulding machine. The butter samples were tested for uniform salt distribution. Out of ten samples, six had salt content of 1.775 per cent while the remaining four had 1.855 respectively. In overflow large proportion of particles were in the range of 40-80 microns.

Considering the imperfections in salt mixing device salt distribution in sample was satisfactory. This was also attributed to the hydrocyclone performance in yielding fine salt particles in the over-flow.

BIBLIOGRAPHY

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Bardely, K. 1971. Salting in butter making. Aust. Jl. Dairy Tech. 26:321.

Bradley, O. 1964. The hydrocyclone. Int. Series of monographs in chem. engg. 48(9):63.

Bradley, O. 1965. The hydrocyclone. Int. series of monographs in Chem. Engg. 49(10):104.

Dahlstrom, D.A. 1954. Mineral Engg. Techniques. C.E.P. monograph series 50:15(41).

Dolby, R.M. 1956. Body and structure defects in butter. Nez. Jl. of Science & Tech. 36(A):527.

Dolby, R.M. 1956. Defects in butter. Int. Dairy Congress. 2(1):433.

Dolby, R.M. 1955. Defects in butter. Int. Dairy Congr. 2(1):87.

Gazder, H.J. 1966. M. Tech. Thesis, I.I.T. Kharagpur.

Gray, C.E., and G.L. Mckay. 1906. Investigations in the manufacture of storage of butter. U.S.D.A., B.A.I. Bull. 34.

Gupta, J.P. and P.D.Grover. 1976. Correlation for critical feed inlet velocity for maximum collection efficiency in hydrocyclone. Chemical Engg. World. 11(12):71.

Guthrie, E.S.; B.J. Scheib and C.N. Stark. 1936. "The effect of certain factors upon the keeping quality of butter". Jl. of Dairy Sci. 29:887.

Jebson, R.S. 1967. Preparation of salt for continuous butter making machine. Nz.Jl. of Dairy Tech.2.

Jebson, R.S. 1974. Salt crystal control in continuous butter making. NZ. Dairy Research Institute, Annual Report. 47.

Kumar, S.; B.D.Sharma, and P.S. Panesar. 1974. Benefication of Mussoorie Rock phosphate by hydrocyclone. Jl. Institute of Engrs. (India). 55:1.

Lynch, A.J., and T.C.Rao. 1968. Studies on the operating characteristics of hydrocyclone classifiers. Indian Jl. of Tech. 6(4):106.

Mahajan, S.P. and V.J. Pai. 1977. Liquid - Liquid separation efficiency and volume split in hydrocyclone. Indian chemical Engr. (Incorporating the transactions). 19(3):3.

Macy, H.; S.T.Coulter, and W.B. Combs. 1932. Observations on the quantitative changes in the microflora during the manufacture and storage of butter. Minn. Tech. Bull. 82.

Mccartney, A.S. 1972. Continuous butter making. J. of Society of Dairying Tech. 25:4.

Muller, L.L. 1949. Storage defects of butter. Aust. J. Dairy Tech. 4:7.

Mccabe and Smith.Third Edition. unit operation of chemical Engg. Mc Graw Hill. 98.

Panesar, P.S. 1966. Ph.D. thesis. I.I.T., Kharagpur.

Panesar, P.S.; N.K.Roy and M.N.Rao. 1970. Plane of equilibrium of a particle rotating at the conewall of a hydrocyclone. Indian Chem. Engr. (Incorporation of the transactions). 12(2):57.

Panesar, P.S., V.S.Rajan and H.Z. Gazdar (1970). Study of maximum particle size in the over-flow stream of a hydrocyclone. Indian Chemical Engr. (Incorporation the transactions. 12(3):12.

Panesar, P.S.; N.K.Roy and M.N.Rao. 1970. Determination of the radium of maximum tangential velocity in a hydrocyclove. Indian Chemical Engr. (Incorporation the transactions) 12(3):20.

Rao, K.N. and T.C.Rao. 1975. Analysis of reduced efficiency curve of a hydrocyclove. Indian Jl. of Tech. 13(10):446.

Rietema, K. and C.G. Verver. 1961. Cyclone in Industry. C.E.P. Monograph series. 57(22):83.

Russel, R.W. 1972. Provision for fine salting in continuous butter making. Nez. Dairy Research Inst. Annual Report 45.

Russel, R.W. 1971. Salt for continuous butter making machine. Nz.J. D. Sci. & Tech. 6:54

Sommer, H., and H.C.Smit. 1923. Flavour defects in butter. Jl. of Dairy Research. 5:46.

Thorntor, H.R., and F.W. Wood. 1935. The microbiology of butter. Canadian Jl. of Research. 12:286.

Washburn, R.M.; and A.C.Dahlberg. 1981. The influence of salt in the changes taking place in storage of butter. Jl. Dairy Science. 1:114.