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08730

Distr.
LIMITED

ID/WG.293/2
9 March 1979

ENGLISH

United Nations Industrial Development Organization

Workshop on Fermentation Alcohol for Use as
Fuel and Chemical Feedstock in Developing Countries

Vienna, Austria, 26 - 30 March 1979

DIRECT HYDROLYSIS OF WET MILLED CASSAVA ROOTS*

by

C. Bos**

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DIRECT HYDROLYSIS OF WET MILLED CASSAVA ROOTS*

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Fresh Cassava Roots are washed and peeled and wet milled to a certain particle size.
After adding bacterial Alfa-Amylase and chemicals, the slurry is pumped continuously through a steam jet system, where the starch is liquified.
After adjusting the pH of the slurry, reducing the temperature and adding Amyloglucosidase, the slurry is saccharified and is suitable to be pumped to the fermenters.

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SUMMARY

This paper describes the principles involved in converting and saccharifying raw manioca roots into an easily fermentable substrate suitable for ethyl alcohol manufacture.

Introduction

The raw material for this process is the roots of the manioca or cassava plant (Manihot utilissima). These roots grow in many tropical parts of the world and are processed to food products used by people living in these areas and a large proportion of these roots are processed into starch, manioca chips, i.e. products used mainly in the developed world.

The roots used in this process are of the bitter variety; the bitter content is a cyanogenic glycoside, which decomposes during processing and produces small quantities of hydrocyanic acid.

A. THE PROCESS

The process consists of the following parts:

1. Washing, peeling and milling of the roots;
2. Enzymatic liquifaction of the milled roots slurry;
3. Saccharification of the liquified roots slurry.

1. Washing, peeling and milling of the roots

1.1 Washing and peeling

The harvested roots arriving at the factory contain normally sand and small stones, which will have to be removed before the milling operation. Efficient washing is required and two possibilities are standard practice, i.e. paddle washing and/or perforated drum washing. Normally in large factories a prewashing is included consisting of a sump/elevator conveying system. The washwater is used countercurrently. The washer system also removes the peels from the roots effectively. The roots are rubbing together and the rubbing and tumbling action removes 90-95 % of the skins. These scales do not contain starch and only provide unwanted bulk in the subsequent process steps if they are not removed.

In order to obtian maximum alcohol yield, the roots arriving at the factory should not be older than 48 hrs. If they are older, the starch yield will diminish and reduce the overall yield because of decaying processes. In mature roots i.e. 12-16 months old, the starch content lies between 25 and 30 % on roots. This starch is 100 % available for the alcohol fermentation process by means of the DDS-KRØYER A/S process. It also contains often small quantities of sugar which are available for fermentation if the process is properly handled. (see Fig. 1).

1.2 Milling

The milling operation is very important for this process. To prevent losses of any solubles, which are fermentable, it is important that the roots are not damaged before milling.

Manioca roots come in many shapes and sizes, and for a good technological operation the root supply should and must be of high quality and as uniform as possible. This can be achieved in a correctly run agricultural operation. Very large roots i.e. over 3 feet in length are undesirable as they need precutting before going into the washing/

peeling operation. Starch losses can increase and subsequently reduce alcohol yield in the fermentation.

The milled roots must be fed to the liquifying section at about 15 % w/w starch in the slurry. The average starch content in the roots will be about 25 %. Therefore water is added during the milling to bring the starch content to 15 % w/w in the slurry.

The milling operation is a 2 step process:

a) precrushing step;
b) fine milling step.

The washed and peeled roots are crushed in a hammermill type of machine, the roots are broken into smaller pieces before the fine milling step. No water is added.

The crushed roots together with the correct amount of water are conveyed to the fine milling step.

The fine mills are of the sawtooth drum type, i.e. rasp type. The design is so that only one pass is necessary to produce the required milled fineness of the slurry particles.

To have efficient starch liquifaction, the maximum particle size should not be larger than 2 mm. This is easily achieved in a rasp type mill. It is also important not to use too much water during the milling operation. Optimum starch concentration in the liquifaction section is 15 % w/w to yield a 9 volume percent alcohol after fermentation. (see Fig. 1).

2. Enzyme liquifaction step

Two types of enzymes can be used in this step:

a) normal bacterial alpha amylase, or
b) heat stable bacterial alpha amylase (see Fig. 2).

In order to liquify the slurry various conditions are necessary to operate the system efficiently: i.e.

a) Temperature

This should be as high as possible, so that any manioca starch which is still bound in the plant cell structure is gelatinised and available for enzyme attack.

b) High mechanical sheer forces

These should also be as high as possible to be able to destroy the cell structures to gelatinise the starch and make it available to enzyme attack.

c) Inorganic ions concentration

This is mainly the free Ca^{++}ion which improves the heat stability of the enzyme. The Ca^{++}ion is dosed continuously into the system as a 10 % w/w solution of calcium chloride.

d) pH control

The optimum pH before licuifaction for both enzyme systems is 6.5. It is important to monitor this pH to make certain that maximum available activity of the enzyme is utilised. pH correction of the slurry can be achieved by means of continuous dosing of sodium carbonate solution, lime water or ammonia solution (see Fig.2).

2.1 Liquifaction with normal bacterial alpha amylase

Normal bacterial alpha amylase has a limited heat stability, optimum activity is at about 85°C. To improve the heat stability, calcium chloride solution is added so that the slurry has a free Ca^{++} content of about 200 ppm.

To utilise efficiently the activity of the liquifying enzyme, a strict temperature profile is necessary over the process stages.

As explained previously, the optimum operating temperature of bacterial alpha amylase is 85°C at which temperature the activity is slowly declining.

At higher temperatures the activity of the enzyme declines rapidly and the life time of the enzyme is reduced; however, a high temperature is required in the first step of the process to have maximum thermal energy input compatible with reasonable enzyme activity.

During the subsequent stages the temperature is dropped to 85°C, to be able to use the maximum activity of the enzyme available.

At the very high temperature i.e. 92-95°C, the enzyme activity is rapidly reduced and therefore we have three places in the process where the enzyme is dosed.

The system is as follows:

a) jet cooker, temperature 92-95°C
very short retention time

b) flash cooling to 85-86°C, followed by a transfer to the stirred reactor, where the retention time is about 10 mins.

c) stirred reactors in cascade where the retention time is one hour.

In fact the small enzyme dosage before the jet is really used to reduce the viscosity peak resulting in the slurry because of the gelatinised starch particles, making process control easier.

The process runs as follows:

The pH of the slurry is adjusted to 6.5 with a suitable alkali as previously described and 1/5 of the total alpha amylase is dosed continuously into the slurry before the jet.

The slurry is pumped through the steam jet which runs at a

temperature of 92-95°C, the partly liquified slurry is flash-cooled to 85-86°C by means of a vacuum system and another 1/5 of the total alpha amylase is dosed into flash-cooler, to control the viscosity, i.e. reduce it further.

The retention time in this reactor is about 10 mins. Finally, the remaining 3/5 of the enzyme is dosed just before the stirred reactors, where the retention is 1 hour. After this time, liquifaction is complete and no free starch is detectable in the slurry.

As explained previously, traces of hydrocyanic acid are freed during the liquifaction process, this acid is steam volatile and is flashed off with the steam from the partly liquified slurry and vented to free atmosphere.

2.2 Liquifaction with heat stable alpha maylase

The liquifaction with the high temperature stable alpha amylase is similar to the normal bacterial alpha amylase; however, the temperature profile across the process steps is different, i.e.:

a) steam jet temperature - 115°C;
b) stirred reactor temperature - 100°C;
c) cascade stirred reactors temperature - 90°C.

The final liquified product obtained by means of the high temperature stable enzyme is identical to the product obtained with normal alpha amylase liquifaction.

An important advantage using high temperature stable alpha amylase is the wider temperature limits allowed for the process and therefore easier process control (see Fig. 2A).

3. Saccharification of the liquified product

The product after liquifaction passes via a flash cooling system to a series of stirred reactors.

The flash system reduces the product temperature to 60°C necessary for the saccharification step. The pH of the slurry is adjusted to 4.5 with hydrochloric acid and amyloglucosidase is dosed into the slurry. After passing through the stirred reactors, where the retention time is about 1 hour, the saccharified product is continuously pumped to the alcohol fermenters. (see Fig.3).

The flash condensate system is shown in Fig. 4.

Energy saving possibility:

Steam energy can be saved by utilising the expansion condensate produced in the flash condensate system. This condensate is mixed with cooling water and is used as part water supply for the fine milling step, the temperature of the milled goods can be raised considerably before the liquifaction step (see Fig. 5).

B. PROJECT "BRAZIL"

Fig. 6 shows a mass balance of an actual project being realized in Brazil.

The plant is expected to produce 200 tons of alcohol per day. The slurry volume per hour is 70 m^3. Total roots consumption is 1226 tons per 24 hours.

Fig. 1

I

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ROOTS RECEPTION, WASHING, PEELING AND MILLING

① Peeles / Washes
② Precrushing
③ Fine Milling
④ Slurry Buffer

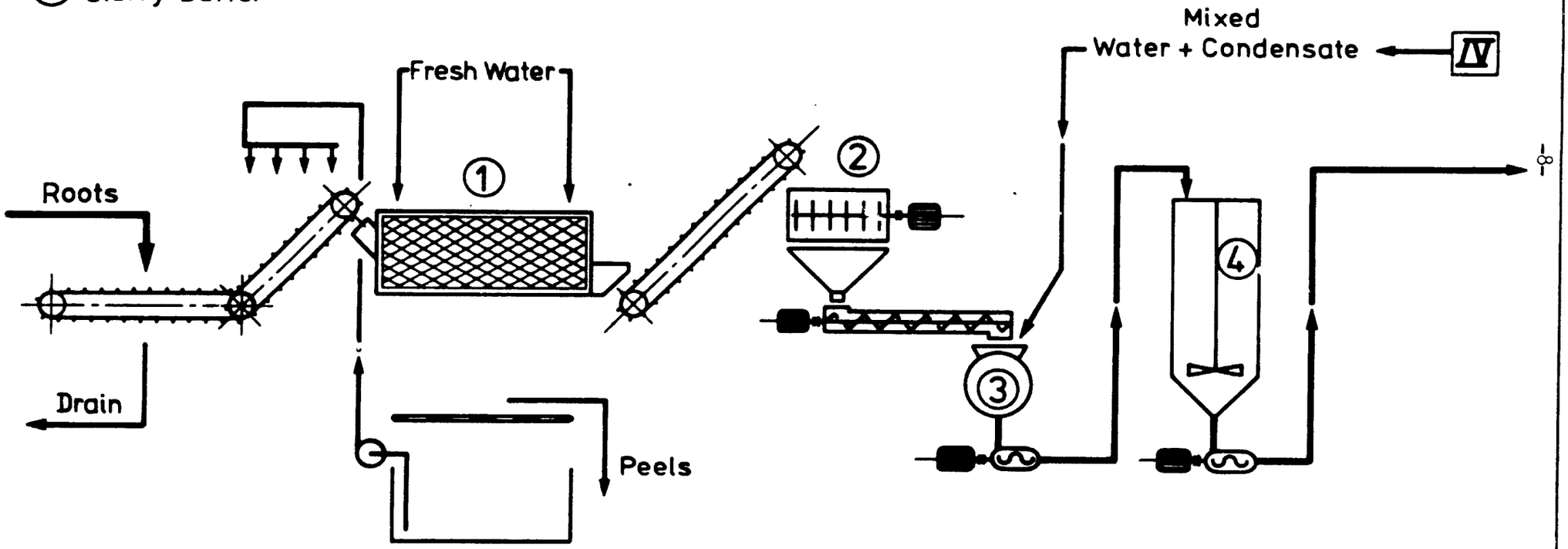
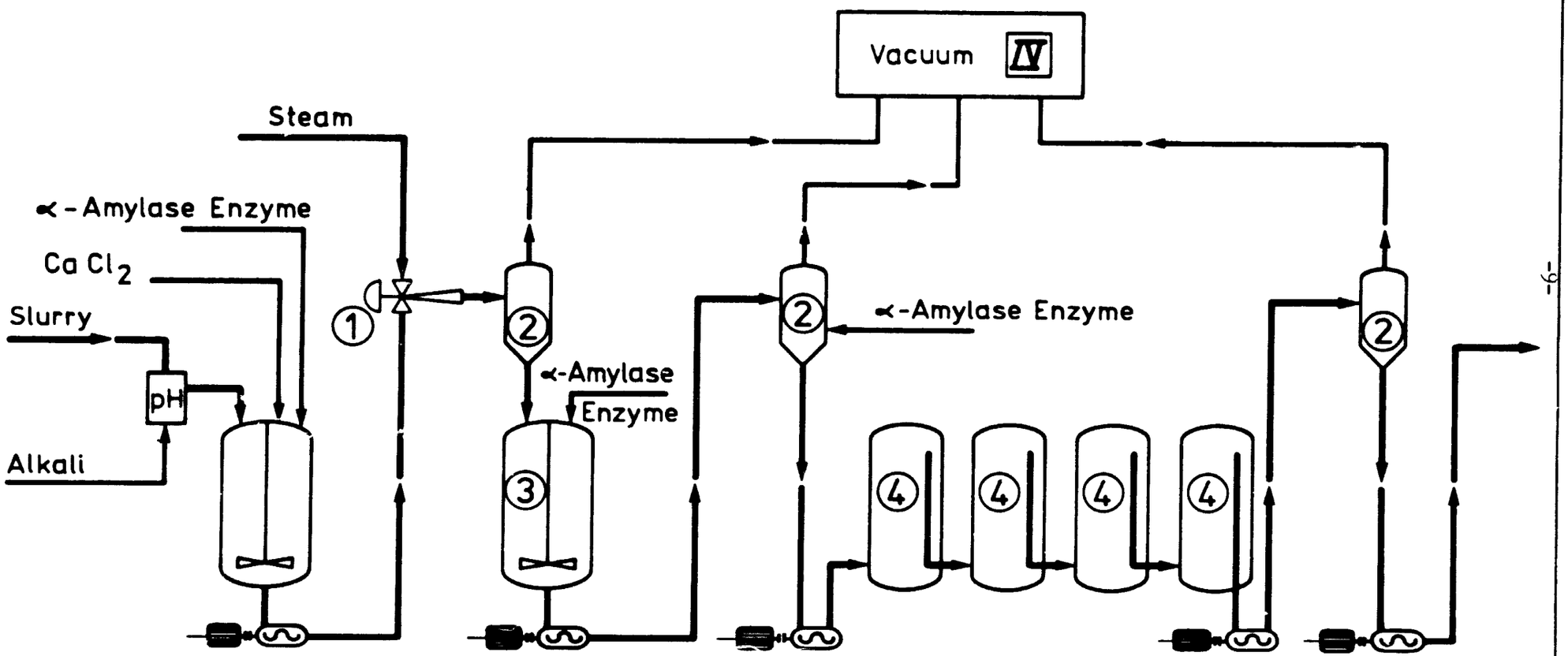


Fig. 2

II

DDS-KRØYER A/S

SLURRY LIQUIFACTION



① Steam Jet ② Flash Cyclones ③ Stirred Reactor ④ Backmix Stirred Reactors

Fig. 2 a

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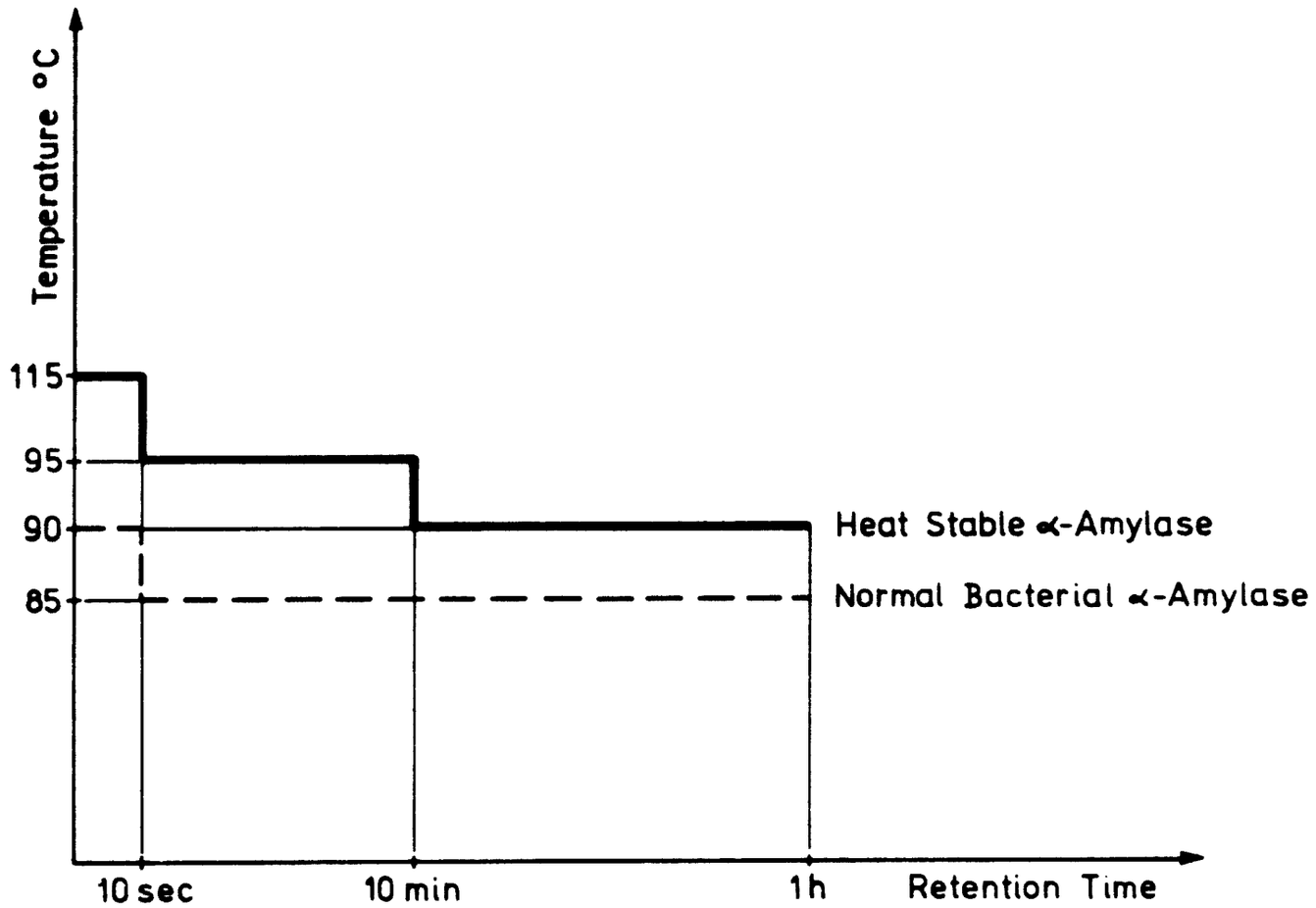
Fig. II A

TEMPERATURE PROFILE OF ∝-AMYLASE SYSTEM

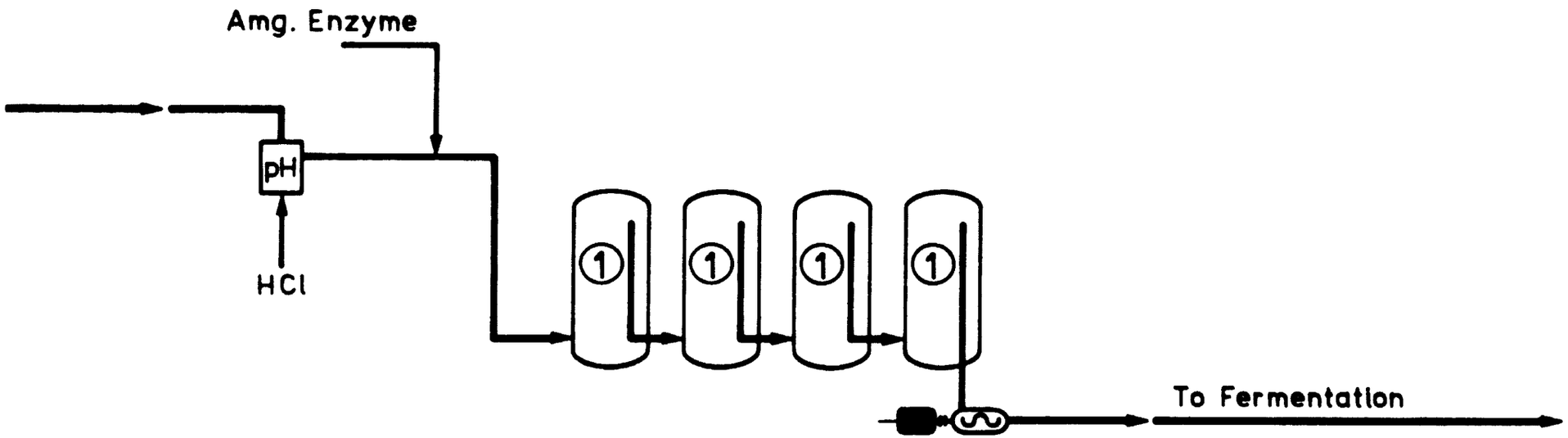


(Not to Scala)

Fig. 3

DDS-KRØYER A/S

SLURRY SACCHARIFICATION



① Backmix Stirred Reactors

Fig. 4

VACUUM SYSTEM

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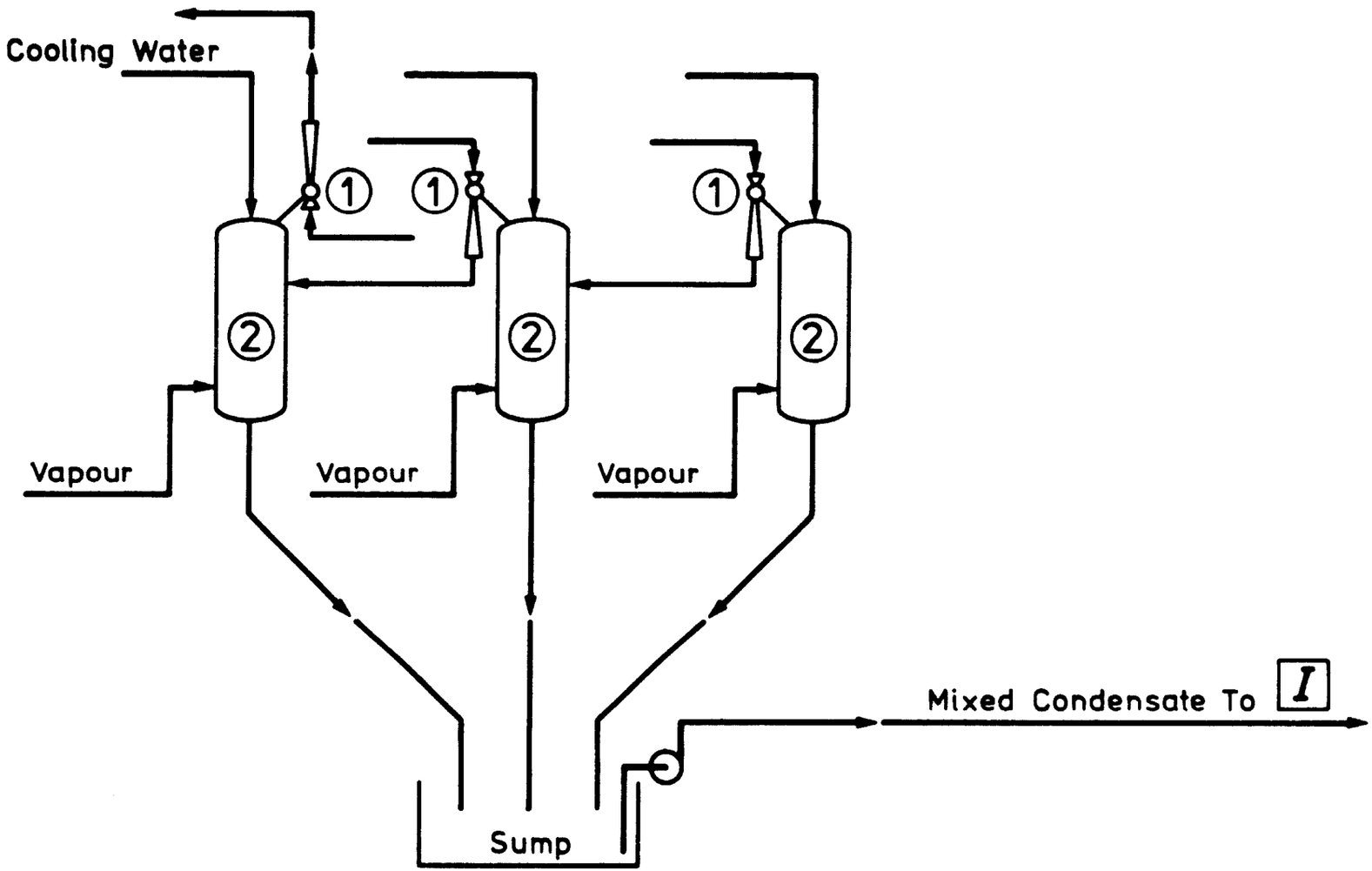
IV



① Steam Jets
② Mixing Condenser

Fig. 5

ENERGY SAVING POSSIBILITY

DDS-KRØYER A/S

		MIXING CONDENSATE RETURN TO MILLING I	WITHOUT II
BACTERIAL ALPHA-AMYLASE	Roots 25% Starch	1225t/24h	1225t/24h
	Temperature	30°C	30°C
	Water	817t/24h	817t/24h
	Water Temperature	60°C	30°C
	Roots Slurry to Liquefaction 15% w/w Starch	2042t/24h	2042t/24h
	Roots Slurry Temperature	43,5°C	30°C
	Steam Cons. in Tons Steam/Tons Roots	0,180T/T	0,216T/T
	Steam Saving	16,5%	
HEAT STABLE BACTERIAL ALPHA-AMYLASE	Roots 25% Starch	1225t/24h	1225t/24h
	Roots Temperature	30°C	30°C
	Water	817t/24h	817t/24h
	Water Temperature	60°C	30°C
	Roots Slurry to Liquefaction 15% w/w Starch	2042t/24h	2042t/24h
	Roots Slurry Temperature	43,5°C	30°C
	Steam Cons. in Tons Steam/Tons Roots	0,207T/T	0,243T/T
	Steam Saving	15%	

	Enzyme	1	2	3	4	5	6	7	8	9					
Capacity kg/h	① ∝-Amylase	73 740	74 200	83 800	83 000	80 850	80 850	77 400	77 450	77 450					
	② Heat Stable ∝-Amylase	73 740	73 950	84 700	82 250	80 700	80 700	76 650	76 700	76 700					
Temperatur °C	∝-Amylase	30	30	105	100	86	85	60	60	60					
	Heat Stable ∝-Amylase	30	30	115	100	90	89	60	60	60					
Starch Hydrolysate % DS	∝-Amylase	14,6	14,6	12,8	12,9	13,3									
							13,5	14,1	14,1	14,3					

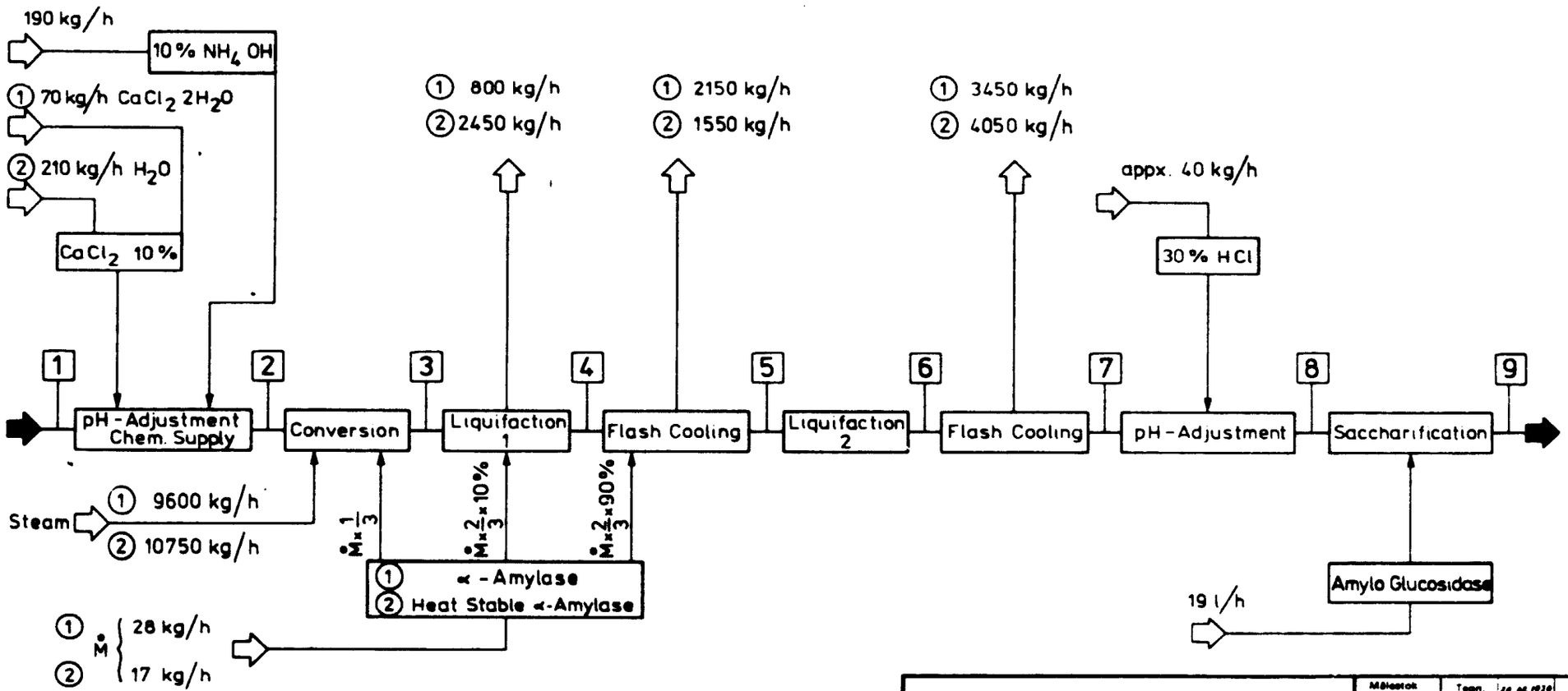


Fig. 6

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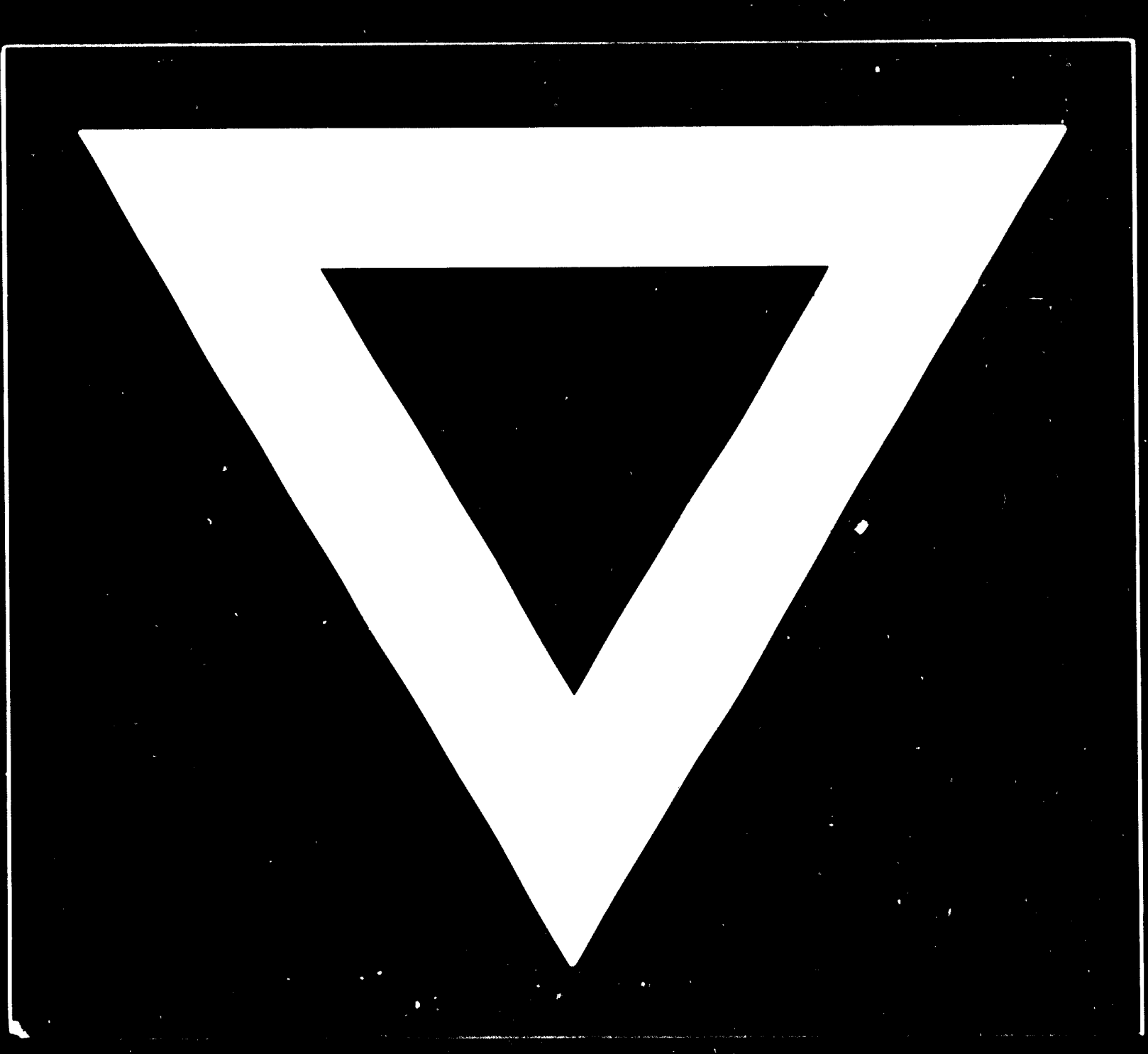
PANDGADE 16 DK 2100 COPENHAGEN Ø DENMARK

MASS BALANCE
PROJFCT BRASIL

Erstatning for
811 G 1137

B-83



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