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AN EDIBLE BLOOD PROCESSING PLANT

A report to the Australian Meat and Live-stock Corporation on a Project supported by the Australian Meat Research Committee.

August 1979

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PREFACE

In April 1977 the A.M.R.C. agreed to support through the A.M.L.C. a development project that was to test the feasibility of producing on a commercial scale, high quality protein products from cattle blood suitable for human consumption.

The project was part of a wider quest for ways of reducing "off-farm" costs and increasing returns from slaughtered cattle.

The development work started in September 1977 and was carried out by Technical and Research Services Australia Pty. Ltd. (TRSA).

Aims

The aims declared at the start of the project were:

(1) To assemble or to design and build commercial scale units to process cattle blood to edible products.

(2) To evaluate the functional and nutritional properties of the products.

(3) To run the plant on a continuous or semi-continuous basis for up to a year to:

   a. further prove the operation of the equipment and the effectiveness of the processes.

   b. Provide more detailed information on the capital and operating costs and define the minimum size of an economic venture.

   c. Explore market acceptance of the products.

These aims were to be achieved over a three-year period ending in June 1980. However, in April 1979 the A.M.R.C. decided to terminate financial support for the project on August 31, 1979.

Achievements

Partly because of the early termination and partly because of difficulties in arranging in-works installation of the whole system, all the aims have not been met.

- Full scale plant to carry out all the major processes has been built, tested, modified and run for short periods.
- Two types of high protein powders have been produced in sufficient quantities to allow characterization of chemical, bacteriological and nutritional properties and more limited studies of functional properties in typical protein powder uses.
- Despite attempts, at Blayney and Casino, it has not been possible to set up the plant as an integral part of an abattoir production line. As a result, it has not been possible to:

    1. Collect sufficient data to reliably predict performance under continuous operation.
    2. Produce enough powder to thoroughly test market acceptance.
    3. Make reliable estimates of installed costs, running costs or likely returns.

This report attempts an objective assessment of what has been done and, by implication, of what remains to be done.

The main body of the report is descriptive. It is supported by a series of appendices and functional illustrations giving more detailed information on the main production modules. It does not include detailed engineering drawings.

1. INTRODUCTION

1.1 Background

Throughout the ten years from 1965 to 1975, there was claimed to be a world shortage of protein, and particularly of animal protein. Although the shortage was not always reflected in the prices paid for the main animal proteins such as meat, eggs and skim milk powder, interest in alternate sources of proteins grew steadily. Production of milk powders and vegetable proteins increased. Research on single cell protein from yeasts and bacteria was stepped up. While meat prices were high, vegetable proteins infiltrated into traditional meat markets. They were used as fillers and binders in smallgoods and as extenders in hamburger meats. They were spun into textured proteins that were sold in some countries as "synthetic meats".

After the collapse of meat prices in 1973-74, the Australian cattle and meat industries became more conscious of the need to obtain the greatest possible return from every carcase. Interest was focussed on all aspects of processing costs, on selling waste products, and on upgrading previously low priced by-products.

One outcome of these two trends was an interest in the possibility of upgrading cattle blood, which was largely wasted or sold at rock bottom prices. The hopes of bigger returns were based on three clearly established facts:

* There was a lot of cattle blood. The most quoted national figure was 125,000 tonnes a year.
* The protein content was high — about 17 per cent of the liquid blood and nearly 90 per cent of the solids in the blood.

* It was all high quality protein. In its amino acid profile and solubility - two of the most common measures of protein quality - it was equal to or better than any of the protein powders and meals that were bringing from $500 to over $5000 a tonne (Footnote 1).

Most Australian cattle blood went into stock feeds and fertilizers and returned, after processing costs, less than $50 a tonne for the liquid blood (see Footnote 2). Some was thrown away and at times incurred a disposal cost.

A small amount of frozen liquid plasma was produced and used in smallgoods where it raised the protein content and also acted as a binder and emulsifier, increasing the cohesion of the product and ensuring a more even dispersal of far and meat fragments.

The calculations about what would happen if all the blood was turned into edible proteins and sold for human consumption produced beguiling answers. At $50 a tonne, the whole 125,000 tonnes would return $6 million. As edible powders or flakes, it would, at the lowest prices offering, bring in $20 million and at the top prices over $50 million.

Note 1: All prices quoted here and throughout this report are in 1979 dollars.

Note 2: For comparative purposes and preliminary calculations, it can be assumed that 100 kilograms (or litres) of blood will produce 20 kg of dried blood powders made up of 15 kg of corpuscle powder and 5 kg of plasma powder. When it comes to detailed assessment of performance, these figures must be made more precise, for small differences in the total and relative yield of the two fractions can make the difference between profit and loss (see Figure 1).

1.2 The Problems of Producing Edible Blood Products

There are several reasons why the calculations just quoted have remained as predictions rather than become deposits in the bank. The most important is that blood as it is now collected is inedible and that nothing that is done after collection will make it edible. This does not mean that we could not eat it or that we might not thrive on it. It is inedible because health regulations will not allow it to be sold for human consumption. To qualify as "edible" the blood would have to be collected, processed, and stored in ways that would comply with these regulations, which basically are designed to keep bacterial contamination and spoilage to a minimum. Meeting these regulations and ensuring such hygiene is likely to be costly and to intrude upon the existing operations of an abattoir.

A second problem is that of colour. Haemoglobin, the main protein in the red blood cells, is a very intense pigment. Dried whole blood is black and if much of it is used, it turns smallgoods, breads or cakes a dark brown or black. Until people's prejudices can be changed or the haemoglobin pigment can be removed or greatly reduced, this colouring will continue to provide a powerful advantage to the rival egg, milk and vegetable protein powders. It is also the main reason for separating the corpuscles, which contain all the haemoglobin, from the colourless plasma. Even after separation, the pigment plagues the process. If the higher valued plasma powders are to be kept colourless, separate equipment or frequent, costly, and time-consuming cleaning are needed to avoid colour contamination of the plasma.

The third problem is that most of the common methods of producing a stable, storable product from blood involve drying and this usually means the application of heat at moderate to high temperatures. These temperatures affect several properties of the proteins and reduce their "quality". The technical name for the change is denaturing. The change from fresh egg white to the hard boiled egg white is the classical example of

denaturing. The most important changes are a rapid and large decline in solubility and changes in some of the amino acids that make up the proteins. The outcome is some loss in nutritional value and a large loss in the physical ability to bind, to emulsify, and to disperse through the mixture.

1.3 The Nature of Cattle Blood

Chemically, cattle blood like that of all other mammals is a complex mixture of water, small molecules (salts), middle size molecules (sugars and other carbohydrates) and very large molecules (proteins).

Physically, there are two quite distinct fractions. These are the corpuscles or blood cells and the plasma or blood liquid. Most of the corpuscles are red blood cells, rich in haemoglobin, but there is also a small proportion of other types of cells. The cells are three fifths water but they also contain a high percentage of protein and some salts, sugars and carbohydrates. The plasma is a pale clear liquid, almost all water, but with some sugars, salts and proteins dissolved in or dispersed through it. The three main plasma proteins are fibrinogen, which is responsible for blood clotting, albumin, which is very similar to egg white protein, and globulins, which are responsible for most immune reactions.

The approximate average composition of fresh cattle blood and the two fractions is:

	Whole Blood	Corpuscles	Plasma
Water	81%	59%	91%
Solids	19%	41%	9%
Proteins +	17 (90) %	38 (93) %+	7 (78) %
Haemoglobin	10%	32%	0
Other proteins	7%	6%	7%
Other solids	1.3%	1.4%	1.3%

+ Proteins as a per cent of the total solids.

It is fairly easy to separate plasma and corpuscles with a centrifuge, which spins off the corpuscles in the same way as a milk separator spins off cream.

The two fractions that are produced have different properties and processing problems. In relative terms, the corpuscle fraction is low in water, high in protein and very high in colour. In contrast, the plasma fraction is high in water, low in protein and colourless. The plasma proteins are generally of higher quality than the corpuscle proteins.

Even with perfect separation, the corpuscle fraction will contain some plasma (it is really a corpuscle slurry) but the plasma fraction should not contain any corpuscles.

The fact that plasma products are naturally colourless or white is the main reason why they have been more widely used and have commanded higher prices.

There are several other potentially valuable constituents in cattle blood that could be extracted and sold. They are mainly biochemicals that would be used in veterinary and medical pharmaceutical products. They are present only in very small concentrations but the prices expected for them are of the order of ten to fifty times the prices expected for protein products. However, it is most unlikely that a profitable scheme could be built on extracting biochemicals alone. With present technology, it seems that they could only be produced as extras to a scheme that started with and stood profitably upon the production of edible proteins.

1.4 The Quantity of Cattle Blood

As mentioned earlier, the most frequently quoted figure is 125,000 tonnes of cattle blood a year. It was calculated from the record slaughtering of 1977 and is probably an

overestimate. Best current estimates are around 90-95,000 tonnes but vary down to 75,000 tonnes. However, the true national figure is not very relevant to this study. The important thing is the quantity of blood that can be collected from the animals that are available to any proposed processing scheme. Some blood will always remain in the carcase, some will always be spilt, and some will be condemned. In addition to these unavoidables, the quantity of blood available will depend on the number of cattle slaughtered, their size, and the method used to collect the blood.

The best information on blood yields from Australian cattle comes from a study by CSIRO's Cannon Hill Meat Laboratory (see Footnote 3). As expected, this work showed the effects of size and method of collection. It also showed, unexpectantly, that the quantity varied quite a lot between animals of the same size.

The maximum yields from any group of 10 to 30 animals with standard sticking and 60 second bleeding was 10.5 kg or, near enough not to matter, 10.5 litres. The minimum was 8 kg. When these figures were converted to kg of blood per 100 kg of dressed carcase, to remove the effect of size, the maximum and minimum figures were 5.1 and 4.1 kg/100 kg for groups and 7.0 and 2.0 kg/100 kg for individual animals. Moreover, the blood to carcase ratio changed with size, declining from an average 6.0 kg/100 at 100 kg dressed carcase weight to under 3 kg/100 at 400 kg dressed carcase weight.

As would be expected, the yield increased with the time allowed for bleeding. Approximately 75 per cent of the 60-second yield was collected in 10 seconds and over 90 per cent in 20 seconds.

Note 3: "Blood — Collection and Processing for Edible Purposes" CSIRO Meat Research Report No. 4/74.

Also, in the one small comparison done, the quantity of blood collected was greater with standard sticking (4.16 kg/100 kg) than with either of the two methods envisaged for hygienic collection of blood (3.89 kg/100 with cone and tube and 3.22 with the hollow knife).

Although all the differences reported are small in kilograms, they are quite large in percentages. They are large enough to affect prospective budget calculations and to make any skimping on collection procedures a threat to the profitability of the whole scheme.

2. BLOOD PROCESSING

2.1 General Requirements

Some of the general conditions that must be met in producing edible blood products have been mentioned or implied. To repeat, bring them together, and include those not yet mentioned, the full list is:

1. The blood must be collected in a way that will keep initial bacterial contamination to a minimum (see Footnote 4).
2. It must be handled in a way that will minimize further contamination and subsequent growth of any bacteria that are present.

In practice, these two conditions mean thorough cleaning procedures, rapid treatment, and chilling to near freezing point whenever liquids are stored for more than an hour or two.

Note 4: This condition might seem almost impossible to meet given the known bacterial loads in yards and races and on soiled hides. However, blood is completely isolated from external contamination up to the moment of slaughter and it leaves the artery virtually free of bacteria — it may contain viruses and protozoa. As a result, it does not have to be decontaminated, only protected from contamination. Moreover, blood has a built-in defence that helps to keep bacterial growth down. The globulin proteins in the serum are the key molecules in the body's immune defence system and they can continue to inactivate bacteria and viruses for some time after the animal is killed and the blood is extracted.

3. The handling and processing must be designed and performed in ways that will cause minimum impairment of the desirable properties of the final products. This means maintaining maximum solubility, and causing minimum loss or damage to amino acids and minimum rupturing of the red corpuscles or contamination of the plasma fraction with red cells. In practical terms, it means rapid and thorough separation and the use of the lowest possible processing temperatures for the shortest possible times.
4. The final products must be easy to handle by prospective users, e.g., free running powders, flakes or liquids are easy to package, mix and divide, but caked powders and syrups are not.
5. The processes, particularly collecting the blood, must fit in with existing or acceptably modified procedures and structures in the abattoir.
6. The processes and products must comply with all health regulations imposed by local authorities or, in the case of exports, by importing countries.

2.2 Products and Processes

Edible blood products could be prepared from whole blood or from the separate corpuscle and plasma fractions. They could be prepared to meet the general requirements listed in the previous section in three forms. These are liquids with added preservatives, frozen flakes from entire or partially concentrated liquids, and dry powders.

Inconvenience in handling and health regulations about additives have ruled out liquids in all but special, local, quick-use situations. Frozen products are generally of better quality but powders are easier and cheaper to handle and cheaper to produce.

The specific processes involved in any system will be

determined by the end products. Only one of the three basic processes is common to all products. These processes are:

1. Collection of the blood.
2. Separation into plasma and corpuscle fractions.
3. Preservation by
    a. adding preservatives
    b. freezing
    c. removing the moisture by raised temperature evaporation, lowered pressure (vacuum) evaporation, or some form of settling and filtering.

    Moisture may be removed from a low-solids liquid like whole blood or plasma in two stages which are commonly termed concentration and drying.

2.3 Existing Practices

The most common practice in the few edible blood operations in Australia has been: Standard sticking -- Individual collection in buckets -- Separation in milk separators -- Chilling the plasma fraction followed by early use in smallgoods in the same or nearby works -- Return of the corpuscle fraction to inedible blood use. The procedure has been satisfactory for the small quantities involved but the collection method would be impractical on a larger scale and the liquid plasma could not be stored for any lengthy period nor transported easily or economically. Also, process derives no benefit from the corpuscle fraction.

In contrast, Australian inedible blood powder has most commonly been produced by the sequence of: Standard sticking -- Collection in drains -- Concentration by heat coagulation -- Drying in ring or drum dryers at temperatures around 25^{o}C.

Overseas, particularly in Germany, edible blood industries have operated on a larger scale for some years and more advanced technologies have been developed. Although details vary, the most common sequence has been: Collection by cone and tube

or hollow sticking knife (see section 3.2)-- Separation by centrifuge -- Evaporative concentration of the plasma -- Drying the plasma concentrate in a spray dryer (the most commonly used dryer for milk powders) -- Drying of some or all of the corpuscle fraction in a similar dryer.

3. THE TRSA SYSTEM

The primary aim and first task of the project was to design a system and to purchase, adapt, or design and build the components on a commercial scale. The second was to operate and prove the unit or modules (see Footnote 5).

The plant that has been assembled is a mixture of existing commercial units and completely designed and fabricated units. It derived partly from theory and experience about what was best and partly from expediency of what was available. There are other units and other ways of performing some of the functions. The chosen modules and units are not proposed as the only ones or as the best way. Each unit has not been tested against all the alternatives. It was a case of putting together a system that worked and that seemed on theoretical grounds to have some advantages, or at least no disadvantages, when compared with the alternatives.

The overall system and the separate modules are described in general terms in this section and the modules are illustrated in Figures 2-6. More detailed specifications of each installed module and its main units are given in Appendix 1. The proposed modules are dealt with in a similar though less specific way in Appendix 2.

Note 5: For consistency of description, the collection of equipment that performs one task (e.g., separation, drying, etc.) is referred to as a module. The modules that have been built and operated are described as installed modules. The two modules that have not been built in full (collection and packaging) are described as proposed modules. Individual pieces in a module that perform an identifiable function are described as units (e.g., the heating, drying, cyclone and bag filter units in the drying module). Other pieces such as pumps, pipes, valves, etc. are described as other or ancillary equipment.

The underlying plan was to build, test and prove commercial scale modules that could be increased in number rather than scaled up in size to meet any production target. The plan has not been entirely met — the separation module is probably too large and the drying units too small — and some scaling up or down may be necessary.

Partly because of this expedient choice of module size and partly because of different requirements for efficiency in different modules, the total installed system is not matched for capacity of all its modules; e.g., the separator could keep five driers going.

3.1 The Overall System

The proposed system is designed to produce two products — corpuscle powder and plasma powder. It consists of five modules, three of which are installed and two are proposed. They are, in sequence and with their functions:

Collection module: Collection of blood, anti-coagulation treatment, isolation and diversion of condemned blood.
Separation module: Separation of blood into plasma and corpuscle slurry, chilling of both fractions.
Ultra-filtration module: Removing over half of the moisture and almost all of the salts from the plasma.
Drying module: Drying both plasma concentrate and corpuscle slurry to a powder with 5-10 per cent moisture; separation of powder and air and filtering the moist air. In a real situation there would be separate drying modules for plasma and corpuscle powders.
Bagging or packaging unit: Cooling the powders, packaging, exhausting air and sealing the packages.
Ancillary systems: (These do not alter the form or properties of the material).
Transport: Where liquids are to be transported from the collection point at satellite abattoirs to a central processing plant.

Cleaning systems: All tanks, pipes, valves and units in all the modules need thorough and regular cleaning and those in the collection module may need sterilizing when condemned blood has passed through them. Most of the units in the installed modules are cleaned by hand. A few are cleaned in place (c.i.p.) by pumping steam, water and chemicals through the normal flow lines. In a complete commercial system, a separate c.i.p. system with its own holding tanks for cleaning and waste fluids and its own pumps, piping and steam supply will be necessary.

3.2 The Collection Module (Proposed)

3.2.1 Collecting the Blood

Two systems of collecting blood were tested. In the first, a cone (see Figure 6) is placed against the stick wound with the rim of the cone inside the slit. The blood drains through the cone to a bucket or, in a larger system, to a tube connecting to the storage tanks. Bleeding is fast but the possibility of spillage and the risk of contamination of the blood are higher than with the second system. However, the few comparative bacterial counts that have been done do not reflect this risk.

The hollow knife system that is proposed is shown in Figure 6. The knife, which has a hollow handle, is inserted into the large blood vessels near the heart and the blood passes through the knife handle and connecting tube to the storage tank without contacting the skin or air. Depending on the configuration of the killing line, the blood may flow to the tanks by gravity or be pumped. The extraction rate is slower than with the cone or open bleeding. The recommended collection time is 60 seconds. In this time, up to 95 per cent of the maximum possible extraction is achieved. To avoid delays or over quick collection on a busy line, a holding rail system (see Figure 6) could be included in the line to hold up to four carcases while they bleed out.

With both cone and hollow knife systems, contamination can be further reduced by slicing off a disc of skin at the incision site.

To prevent clotting of the blood, an anti-coagulant is introduced through the knife handle into the blood flow. There are several effective anti-coagulants on the market. Overseas sodium citrate is used. In USA it is the only one that is allowed. It was chosen for this reason and other anti-coagulants were not tested. At 0.2 per cent and 0.16 per cent of total blood weight (these are the maximum US and German levels) it prevented coagulation though it was most effective at higher concentrations — up to 0.6 per cent.

3.2.2 Holding and Inspection

The ideal system would feed the blood straight from the knife to the separator (see section 3.3). There are two reasons why this cannot be done. The first and less important is that efficient operation of the centrifuge depends on a steady input. Some form of storage is needed to ensure constant supply.

The more serious complication is that blood from animals that are condemned for human consumption cannot be processed into edible products. Because most condemnation takes place down the line, the blood will have to be held until the health clearance arrives. The numbers condemned are low — from three to less than one per thousand — and the risk can be reduced even further by segregating suspect animals and not collecting from them. Even with this precaution, the risk of contaminating and losing the whole bulk tank is unacceptable. The solution developed is to collect into a series of smaller holding tanks and wait for veterinary approval before releasing into the main storage tank. If one of the carcases that has fed any holding tank is condemned, the blood in that tank will be diverted to inedible processing and the tank and its lines will be sterilized.

There is a trade-off to be made in this system between many small holding tanks with a high cost (particularly for the installation and the interconnecting plumbing) but small losses on the one hand and several larger tanks with lower costs and higher blood losses at the same condemnation rate on the other hand (see Footnote 6). The best solution will depend on throughput, expected condemnation rates, operating capacity, variability in shift tallies, etc. Current thinking is for four tanks each holding one hour's collection. The size of each tank would vary with the kill being as high as 1200 litres or as small as 200.

A very recently reported Canadian system may break the contradiction. In this system each animal is stuck with a knife with its own plastic bag attached. The animal bleeds out as the carcase passes along the line, avoiding any holding problems. Further down the line, the knife is removed and sterilized while the bag is detached, closed, identified, and put onto a holding line until the carcase is cleared by the inspectors. Blood from the healthy animals is then spilt, by slitting the bag, into a single bulk tank and that from the condemned animals is returned to the inedible storage tank.

The increased cost of the extra knives and bags and the holding line seem likely to be far less than the savings in isolation tanks and their plumbing.

Note 6: The percentage of blood expected to be lost through condemnation can be calculated fairly closely by the formula $\underline{a} \times \underline{b}/10$ where $\underline{a}$ is the expected condemnation rate per per thousand animals and $\underline{b}$ is the capacity of the holding tanks in numbers of animals.

3.3 Transport (Optional Ancillary System)

Collection must be at the point of slaughter. Separation is best done there. The later processes could be done at a central abattoir or at a specialized processing plant. With these options, the corpuscle and plasma fractions must be transported from the collecting abattoir. Limiting deterioration on the way involves cooling to under 4°C and transporting in sterile insulated and/or refrigerated containers. Standard milk tankers have proved quite satisfactory for trips up to 100 km.

At 4°C both corpuscle slurry and plasma will last for about 24 hours without undue deterioration. Daily delivery seems to be necessary.

Thorough sterilization of the tankers would be needed after each load to minimize bacterial contamination and the plasma and corpuscles should be kept in separate tanks to reduce colour contamination.

3.4 The separation module

The separator used in the installed system is a commercial Alpha Laval blood centrifuge. Under optimum operating conditions, it has a capacity of 600-700 litres of blood an hour. The optimum temperature for the incoming blood is 20°C. This means that cooling or heating of the blood is not necessary when it can be separated within two hours of sticking.

The centrifuge provides near complete separation of the corpuscles from the plasma but not vice versa; i.e., under optimum conditions no corpuscle should be left in the plasma but some plasma is left in the corpuscle fraction.

Typical separation figures are:

	Plasma Fraction	Corpuscle Fraction
% of total volume	58-63%	37-42%
Total solids	9%	36%
Moisture	91%	64%
Protein content of solids	70%	92%

Operating conditions can be critical and sensitive. With inadequate speeds, temperatures, and pressures, red cells may remain in the plasma fraction or, worse, may rupture and release their pigment and stain the whole plasma fraction.

Before passing to the untrafiltration and drying modules, the fractions must be chilled. This may involve separate chilled storage tanks or recirculation to the collecting tanks.

3.5 The Concentration (Ultra-filtration) Module

The plasma and corpuscle fractions coming from the centrifuge are quite different in protein and moisture contents (see Section 3.4 and Figure 1). The difference is best illustrated by the quantities of moisture that have to be removed for each kilogram of powder produced: approximately 1.5 kg from the corpuscle slurry and 9.0 kg from the plasma.

Traditionally all moisture has been removed from blood and milk powders by the application of heat. The heat required to evaporate the moisture is one of the largest inputs into the whole system.

In an attempt to reduce the heat input and the time that the plasma is exposed to raised, protein denaturing temperatures, a novel technology has been adapted by TRSA to remove over half the moisture from the plasma before sending the resulting concentrate to the drying module (Section 3.6).

The corpuscle slurry goes straight from the separator to the drying module.

The first phase of de-watering the plasma is based on the principle of ultra-filtration. The principle and the functioning of the UF unit are described in more detail in Appendix 3 and the specification of the module are set out in Appendix 1.2. Only a broad, simplified description is given here.

When a liquid solution is passed under pressure over a special type of membrane, known as ultra-film, which has myriads of small holes in it, some of the small molecules will pass through the holes to the other side of the membrane while all the large molecules will stay behind. In the blood context, the small molecules are water and the inorganic salts and the large molecules are the proteins.

As the small molecules are drawn off, the concentration of the larger molecules in the remaining solution gradually increases. A single passage over a very large film or repeated passages over a smaller film can increase the concentration several fold. An upper limit is reached when the concentrated liquid becomes too thick to flow readily over the membrane.

In practice, the filtering unit is a small pack and batteries are made up by bolting up to 40 packs together (see Appendix 3). The concentrating plasma can be pumped through the same battery several times or, in a larger module, through several batteries arranged in a cascading sequence.

In the installed unit, repeated passage through the same battery of 40 packs reduces the moisture content from 90-91 per cent to about 80 per cent. This involves removal of 60-70 per cent of the moisture in the dilute plasma. The unit can remove 30 litres of water, equivalent to 44 litres of dilute plasma per hour.

Because the inorganic salts and some other small molecules pass through the membrane with the water (the mixture is known as permeate), the concentrate that remains behind and the powder that is produced from it have a higher proportion of protein and a lower proportion of other solids than unconcentrated plasma and totally evaporated plasma and totally evaporated plasma powders. This fact and the shorter exposure to heat in the dryer result in a higher quality powder.

In absolute energy terms, ultra-filtration is more efficient in removing the first half of the moisture than evaporation. There is, however, a large power input, for the whole unit operates under very high pressures (see Appendix 3). In many abattoir situations where "free" heat for the dryer could be obtained from waste steam, this energetic efficiency may not translate into cheaper operating costs.

The membranes that are being used in the installed unit were developed at the University of New South Wales and have been patented by "Unisearch", the University's commercial research organization. The filter packs and associated equipment was developed by TRSA.

3.6 The drying module (Figure 3)

The function of the drying module is to take the moisture content of the corpuscle slurry or the concentrated plasma down from around 65 and 80 per cent to about 6 per cent. The traditional drying methods used for inedible blood products have been ring and flash dryers. The temperatures involved are over 200°C and too high for quality edible powders. For edible blood proteins overseas and for milk powders here and overseas, the most used method has been the spray dryer. The principle of this unit is that the liquid is introduced as a fine spray in a blast of hot air. The air and droplets circulate around a large tank until the fluid has dried and

falls to the base of the unit as a powder. The powder then passes off with the air to a cyclone separator.

A spray dryer could be used to dry whole blood, corpuscle slurry, plasma or plasma concentrate. The theoretical disadvantages of the unit for drying blood proteins are:

1. The high temperatures — up to 200°C
2. The space taken — it is very large.
3. The energy consumption — much of the added heat passes out in the air draft.

The original TRSA intention was to adapt a commercial spray dryer. However, long delivery times led to the development and production of a completely different type of dryer which now seems to be more desirable on several counts. The unit is a spouted bed, thin film dryer. The essential feature is that a draft of hot air is forced up through a mass, or "bed", of small plastic beads. The velocity of the draft lifts the whole bed of beads into what is virtually an air-bead emulsion and at the same time sets up a violent circulation in the whole mass and heats the beads to about 60°C. The blood is introduced as a spray through nozzles at the side of the tank. It settles as a fine film around the warm beads. This film is dried almost instantaneously by the heat of the beads and is then shattered and dislodged as a powder by the shocks of vibration and impact. The powder is carried upwards and out of the chamber in the now moist air draft (see Figure 4). Air and powder pass to a cyclone separator (see Figure 5) where the powder settles and the air which still contains about 1 per cent of the powder is sent to a final cleaning unit — the bag filter — before being released. In the installed module, the powder is packaged direct from the base of the cyclone. In a commercial system, a packaging module would be installed (see Appendix 2.2).

The theoretical advantages of the spouted bed dryer over the spray dryer are:

1. Exposure to lower temperatures ($60^{o}C$ v. $200^{o}C$) for shorter periods (less than 1 second v. 30 seconds).
2. Lower energy requirements — much of the heat is retained in the bed of beads.
3. Smaller space requirements — approximately one tenth of the volume required by a spray dryer of the same capacity.
4. More uniform heating — because the film of liquid on the bead is dried from both the inside and the outside.

The installed unit has the capacity to remove 50 kg of moisture an hour.

The same unit could produce both plasma and corpuscle powders and it could, if needed, dry whole blood. It would, however, need very thorough cleaning to prevent colour contamination when switching from corpuscles or whole blood to plasma.

4. THE PRODUCT

4.1 Nutritional Qualities

Assessing the quality or value of any protein concentrate is a complicated task. At the simplest level, the product can be categorized by the proportions of crude protein, fat, minerals and other desirable constituents. But "crude protein" is a collective description for a lot of different types of protein molecules made up of different sequences and proportions of the amino acid.

Not all crude protein is digestible. Digestibility generally increases as solubility increases. Some amino acids are essential for human nutrition whereas others are not. Some are regarded as more valuable than others for the very practical reason that they are normally in short supply in average diets. Together these things mean that solubility and the levels of the various amino acids or the "amino acid profile" are useful indicators of protein quality.

Beyond anything that is revealed by chemical analyses, there is an elusive biological value, which, in simplest terms, is a measure of how well animals or people perform when fed the protein source - how fast rats or pigs or chickens grow, how well hens lay and so on.

Enough samples of the TRSA plasma and corpuscle powders have been analysed to allow a confident claim that they compare favourably with the traditional protein powders. Not enough feeding trials have yet been done with animals to allow any reliable statement about their biological value.

There are, also, other properties of protein powders that are important, but for non-nutritional reasons. A low moisture content prevents clogging and caking of the powder and

reduces the rate of bacterial growth. The cohesion of the protein is important where the powder is to be used as a binder in smallgoods and also plays a part in producing the stable foam that is an important attribute of breads and cakes.

The information available on the various nutritional properties is summarised in the tables on pages 27 and 28, where possible, is compared with the accepted figures for rival protein powders. It should be recognized that some of the many analyses for protein content and moisture were done on less than optimum samples. These were samples from runs where processing temperature, time, or pressure were deliberately varied to test their effects. As a result, the lower values in the ranges quoted are not a true reflection of what could be expected under optimum operating conditions.

4.2 Bacterial Loads: Keeping Quality

All protein liquids and powders will contain some bacteria. The hygiene problem is to keep the numbers within tolerable levels. The standard test involves mixing a minute amount of blood or powder with a mixture of agar, which is a bacterially nutritious jelly, incubating the mixture for several days, and counting the number of bacterial colonies that develop. The standard measure is the number of colony forming units (c.f.u.) per gram of product. The accepted upper limit for blood products in Europe is 100,000 or 10^5 colony forming units per gram (c.f.u./g.). Above this limit, the product is condemned . Australian levels may, of course, be set higher or lower.

The factors that affect the final count are the number of bacteria that are present in the raw blood as it is collected or that get in during processing and the rate at which they multiply.

Some measures of nutritional attributes of TRSA corpuscle and plasma powders and, for comparison, typical values of other protein powders

Product	Crude	Fat	Ash	Moisture	Solubility
Corpuscle powder					
Average	90.5%	1.0%	1.85%	5.7%	93.6%
Range	82-94$		1.5-2.2%	3.3-7.9%	91-98%
Number of estimates	12		2	20	3
Plasma powder					
Average	80.0%	2.0%	9.6%	7.1%	77.8%
Range	71-87%		6.0-13.5%	4.2-9.0%	64.-86%
Number of estimates	22		6	33	6
Whole egg powder	45-50%	44%	3.7%	4.5%	6.6%
Egg albumin powder	81	under 1	5.7	8.0	3.6
Skim milk powder	28-40	26	5.3	6.1	7.7
Whey protein powder	39	2.2	2.1	3.5	6.6

Amino Acid profiles of TRSA corpuscle and protein powders (analysed by CSIRO) and, for comparison, the FAO/WHO suggested levels in proteins for adults

Amino Acid	Corpuscle powder	Plasma powder	FAO/WHO standard
Essential		grams/100 grams protein	
Lysine	9.1	7.3	4.2
Threonine	4.5	5.5	2.8
Methionine	0.9	1.0	2.2
Valine	8.3	5.6	4.2
Phenylalanine	7.5	4.4	2.8
Leucine	12.7	8.0	4.8
Isoleucine	0.3	2.7	4.2
Tryptophan	1.5	1.0	1.4
Histidine	6.2	2.3	--
Non Essential			
Arginine	3.6	4.6	
Aspartic acid	9.7	8.4	
Serine	5.1	5.3	
Glutamic acid	7.3	11.9	
Proline	2.3	4.2	
Glycine	3.6	2.5	
Alanine	8.0	3.8	
Cystine	0.2	2.4	
Tyrosine	1.5	4.1	

With careful collection, the loads in the fresh blood as it entered the isolation tanks have been kep down to 100 (10^2) c.f.u./g. They have been much higher when dirty knives were used or where care during collection lapsed.

The results of over 100 analyses of raw blood from the collection tank, corpuscle and plasma fractions after separation, and corpuscle and plasma powders within a week of packaging are summarized below. As with the protein content and moisture levels in the previous section, some of these determinations were made on sub-optimum specimens. Good practice could be expected to produce fewer high counts.

Fraction	Number of samples with counts in the range shown					
	Under 10^3	10^3-10^4	10^4-10^5	E.L.*	10^5-10^6	Over 10^6
Whole blood	5	9	20		2	1
Corpuscle slurry	0	2	7		4	1
Liquid plasma	3	7	2		2	0
Corpuscle powder	0	10	12		8	4
Plasma powder	4	12	16		5	0

* The European limit for blood powders.

The conclusion to be drawn from these figures is that there should be little difficulty in keeping counts below the safety limit in plasma powders but that extra precautions may be needed with corpuscle powders.

The figures quoted for powders are a result of the combined effect of contamination and growth during processing. Growth in storage after processing is equally important. All counts that have been done have shown a steady, and at times very rapid, decline in the bacterial counts in both powders during storage.

The results of five of these counts are shown below. The interpretation to be placed on these figures is that the powders are unsuitable media for further bacterial growth — probably because they are too dry.

Product	Count after storage for						
	0	1	2	3	4	8	12 weeks
Plasma powder	$5x10^4$	$1.0x10^4$	$1.5x10^4$				
	$4x10^3$		$6.4x10^3$			$6.3x10^4$	$2.0x10^2$
	$2x10^3$		$6.4x10^2$		$6.0x10^2$	$6.3x10^2$	$6.1x10^1$
Corpuscle powder	$8x10^4$			$3.5x10^4$			
	$8x10^{5*}$		$6.0x10^4$		$6.0x10^4$		$4.2x10^3$

*In this the only sample above the European limit, the count had dropped below the limit after two weeks and stayed below.

4.3 Other Storage Qualities

The declines in bacterial counts in storage described in the previous section were all achieved in light and moisture proof, plastic lined, paper bags that have been adopted as standard package. When the corpuscle powders were stored in transparent plastic bags, they changed quite markedly in colour - though not for the better. They also had a hint of off-flavour. So far it has not been possible to put a limit on storage life but it is clear that the powders will deteriorate quite rapidly, in taste and bacterial counts, once the sealed package is opened.

4.4 Functional Properties

Many functional properties of both powders have been investigated in a semi-systematic way. "Exploration" rather than "exhaustive testing" is probably the best description

of this work. Some of the findings are described below.

Taste: The plasma powder is bland and imparts no specific taste, although some tasters have preferred it to whole eggs and egg powders used in comparative baking tests. The corpuscle powder seems (though different tasters have different reactions) to impart a slightly sweet taste when used at low levels (4 per cent or less of total weight) in bread and a "blood" or "liver" taste when used at higher levels in smallgoods.

Colour: As reported earlier, the corpuscle powder imparts a dark brown to black colour to all cakes, breads and smallgoods. The plasma powder has no colouring effect, although some plasma powders have a slight cream to yellowish colour.

Foaming and binding: The overall conclusions from a number of comparisons with egg whites in cakes were that the plasma gave as good a height, freshness, and taste as the egg white, whereas the corpuscle powder was not quite as good in height, as good or better in freshness, and, depending on the taster, imparted a taste that was better, no different, or slightly less acceptable.

5. COSTS, PRICES & POSSIBILITIES

5.1 The problems of costing

The most important question about the whole scheme is whether the conversion of blood to edible powders will be profitable. A lot of calculations have been made. Some have been published. The answers from these calculations range from bonanza profits to quick bankruptcy. The truth is that at present it is not possible to answer the question this side of fantasy. There are too many uncertainties. Too many assumptions have to be made in the absence of hard evidence. The most important areas of ignorance are:

1. The capital cost of a total installed unit.
2. The running costs - labour, materials, repairs.
3. The prices likely to be received for both products.
4. The efficiency of the system under continuous operation — the likely down time and the associated cost of stand-by units.
5. The ability to keep cattle supplies up to the plant so that it can operate near capacity.
6. The consequences of any regulations that may apply.
7. The scope of the system that is installed.
8. External financial factors deriving from government regulations or company structure.

Some of these uncertainties are and always were outside the scope of the project. Others could only be removed or reduced by reasonably long-term production runs of the whole system in an abattoir. Such runs, for up to a year, were envisaged in the original proposal but it has not been possible to carry them out.

All that can be done here is to list the limited information that is available and cite the variables that may affect the financial outcome so that individual assessments or calculations will at least be made on a realistic basis and with recognition of the genuine uncertainties.

5.2 Capital costs

The only figures that can be taken with any confidence are the estimated costs for manufactured units and ancillary equipment of the installed modules (see Section 3 and Appendix 1). Even these estimates are questionable on three counts.

1. The general inflation rate that will prevail.
2. The fact that the price of stainless steel - the main construction material - is rising much faster than any of the indicators of inflation. It has risen 100 per cent in the past 12 months.
3. There will be economies of unknown size if multiple orders allow mass production of any one unit.

The costs of the units and ancillary equipment listed in Appendix 1 do not include installation, insulation, electrical and control systems. They make up only a fraction of the total cost of installed modules or systems. Whether the fraction is as high as one half or as low as one sixth will depend on:

1. the type of system that is installed (see Section 5.7). Simpler systems will have proportionately lower extra costs.
2. the nature of the site - what extra buildings, structures or modifications will be needed to accommodate the equipment.
3. the proportions of the installation done by outside contractors and by the works engineering staff.

At the upper limit, is an estimate by TRSA for a single complete system to process the blood from 500 cattle a day that is completely built by outside contractors. The estimate was derived from the assumption of standard percentage mark-ups for many of the services.

Total Cost	$ 1,343,000
Purchase of units and ancillary equipment	27%
Transport of equipment	0.8%
Installation of equipment and piping	9.6%
Insulation of equipment and piping	0.5%
Electrical	4.1%
Control instrumentation	3.4%
Services (production of steam, cooling, etc)	2.9%
Civil (buildings, land and modifications to line)	17.1%
Engineering supervision	13.2%
Contingency	11.8%
Contractors mark up	9.1%

The total cost cited seems on sober assumptions about prices and throughput to be too high for profit. On the other hand, large reductions in this cost seem possible.

5.3 Recurring Costs

Replacement and repair costs are unknown. Materials costs, apart from heat and power, are small. Heating costs for the dryer are one of the biggest items in a fully independent system but in most abattoirs it would be possible to devise integrated systems that would use abattoir waste steam to heat the air to the dryer.

Labour costs could vary widely with the system installed. There will be a trade off between increased automation, with its higher capital costs, and the labour required (e.g., the pumped hollow knife v. the cone and bucket collecting system, or manual v.c.i.p. cleaning).

Labour costs will also depend on rates and conditions that are negotiated or awarded.

5.4 Prices

Although the guideline limits for expected prices are more precise than those for costs, the actual expectations are even less certain. The contributing factors are:

1. Protein prices have fluctuated rapidly and widely on world and local markets in recent years.
2. There may not be a market as edible protein for all the corpuscle powder that could be produced[+] (see Footnote 7).
3. The price of inedible blood powder has been moving generally, though unsteadily, upwards. If the trend continues, the shrinking gap between inedible whole blood powder and edible corpuscle powder may not cover the costs of edible processing.

The production ratios of approximately four parts corpuscle powder to one part of plasma powder mean that total returns and profits will respond more to unit changes in the price of the cheaper corpuscle powder.

Quotes and estimates obtained by TRSA from prospective buyers in the past 18 months range from $500 to $1500 a tonne for corpuscle powders and from $2000 to $3500 a tonne for plasma powders.

Note 7: This is mainly because of its colour. A successful decolouring process could remove this problem and also, possibly, could raise the price of corpuscle powder closer to that of plasma powder. CSIRO has patented and licensed a decolouring process but it has still to be used commercially.

For comparison, the prices ruling during the past year for some of the other edible protein powders were:

Whole egg powder	(40-50% protein)	$3300-6200/tonne
Skim milk powder	(28-40% protein)	$ 450-525 /tonne
Whey protein	(35-40% protein)	$ 235-300 /tonne
Soya bean protein	(25-35% protein)	$ 175-220 /tonne

The price trend for all products was upwards.

Any comparison with blood powders must take account of both the protein content, and the less easily measured protein quality (see Section 4.1).

5.5 Maintenance of Throughput

Because the fixed cost of servicing capital and the inflexible costs of labour will be much higher than the variable costs of power and materials, maintenance of throughput close to the capacity of the system will be a very important determinant of profitability. There are three important aspects.

1. Down time for equipment failure, servicing and sterilizing after contamination with condemned blood are not known. Routine cleaning should be a shift's end procedure.

   Lengthy storage of the intermediate liquid products, while repairs or servicing are done, is not possible. The price of lost output will have to be weighed against the capital cost of spare units.

2. The variability of daily throughput of cattle will determine the optimum size of the system and its shortfall from the theoretical maximum capacity. For example: with a maximum capacity of 500 head a day (5000 litres), an average of 300, and a

minimum of zero, a blood processing system that could handle 5000 litres would be over capitalized. A 3000 litre system would still be idle on some days and incapable of handling the full tally on others.

3. To minimize spoilage, collection and separation must be done at the same time (shift for shift) and the separation module must match the maximum desired collection rate. In the later stages of the process, it is possible to chill and store the plasma and corpuscle fractions for up to 24 hours so that concentration and drying could be spread over two or three shifts each day. The advantage in reduced capital costs of the smaller UF and drying modules would have to be set off against higher storage and labour costs and increased chilling and reheating capacity.

In theory, a straight through system of units of matched capacity would need very little storage or chilling or heating. In practice, it would have no buffering against breakdowns and other delays.

5.6 Regulatory Demands

Health regulations will specify that certain grades of material and finish be used in units and equipment. A decision for plastic in place of stainless steel in some or all of the equipment could have a very large effect on capital costs. So could regulations about the sit enclosure, and separation of the modules from the rest of the abattoir. The regulations could also demand a level of quality control that necessitated laboratory facilities and services.

5.7 The System Installed

Although the system that has been built and that is described in Section 3 has all the elements for complete processing to powders of all the blood collected at a single abattoir, there are many other possible variations. The three major options are:

1. Collecting the blood at satellite abattoirs, separating it and transporting the plasma or the plasma and corpuscle fractions to a central abattoir, or a separate protein processing plant for concentration and drying.

2. The possibility of processing all the plasma to an edible powder but returning all or part of the corpuscles to inedible blood or meat meal production.

3. The possibility of starting with a minimal plant and increasing in size and complexity of function if and when profits warrant the expansion.

5.8 External Economic Factors

In times when economic incentives and restraints change rapidly, today's calculations may become inoperative in a very short time. Investment allowances, depreciation rates, decentralization incentives, etc. could all be as important and as unpredictable as capital costs and prices.

Similarly, the availability of production factors such as capital, credit, under utilized labour, suitable buildings, a competent engineering section, or a favourable tax situation may make a system far more profitable in one works than in another with similar physical resources.

APPENDIX I

SPECIFICATIONS OF THE INSTALLED MODULES

- In the following three sections, some of the specifications of the installed modules (separation, concentration, and drying) are listed.

- Functional diagrams of the overall structure and some of the workings of the separation and drying modules are in Figures 2, 3, 4 and 5.

- The principle of the concentration module is explained and illustrated in Appendix 3.

- The figures are not faithfully to scale and are simplified representations in that the units have been rearranged to present a straight through flow from left to right and because many of the valves, gauges, cleaning and recirculating pipes, and inspection ports have been omitted.

- The actual requirements and configuration of any module will be determined by work's capacity and space. Detailed engineering drawings (which have been prepared by TRSA) would not fit most situations without modifications and would confuse rather than clarify the current explanation.

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A1.1 THE SEPARATION MODULE (Figure 2)

The Elements

Units (in sequence)

Supply tank: This is the final unit (bulk storage tank) of the collection module.

Starter or feed tank.

Centrifuge.

Storage tanks (2): For corpuscle and plasma fractions.

Heat exchange (chillers) (2) : For corpuscle and plasma fractions. The pipe and valve arrangement allows the chilled fractions to pass on to the next modules or to be returned to the storage tanks for chilled storage.

Equipment: Pipes, valves, pumps, electrical and control gear, C.I.P. equipment.

Dimensions+

Supply tank: 1500 litres

Starter tank: 250 litres

Centrifuge with motor: 2 x 1 x 1 m.

Storage tanks: 500 litres

Chillers: 1 x ½ x ½ m.

Total module: 2 x 6 x 3 m.

Construction

Tanks: Stainless steel (see Footnote A1).

Centrifuge: Alfa Laval blood centrifuge BPM 209-70H-11 with modified associated system for automatic control.

+ Where three dimensions are listed, they are in order: height x length x width. Where only two are quoted they are length x width.

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Operating Characteristics

Centrifuge: Capacity 500 litres per hour blood input

Optimum temperature of incoming blood 10-20°C

" speed 7000 r.p.m.

" inlet pressure 30 psi

" outlet pressure 22 psi

Inputs

Power: Centrifuge 5 kw, Pumps (3) 2, 1, and 1 kw.

Heat: Glycol refrigeration would normally be supplied by abattoir. Required refrigeration tonnage 15 T.I.R.

Estimated costs

These are the purchase price of manufactured units. The total does not include controls, electrical service or installation.

Supply pump	$ 2500
Starter tank	900
Centrifuge	22000
Chillers (2)	2000
Insulated storage tanks (2)	3600
Minor equipment (Pipes valves etc.)	9000

Servicing

Centrifuge: To be stripped and cleaned at the end of each shift.

Tanks and piping: C.I.P. each shift; complete pull down and soak and clean each week.

Options and possibilities

. Have tried float controlled top feed separators. They have the advantage of reducing operator error.

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. Larger and/or smaller centrifuges that could be matched to abattoir capacity would be an advantage. Alfa Laval, the main supplier, only make one model of blood separator -- the model installed.

Note AI:

All tanks in this and the following modules are constructed of welded stainless steel with rounded (coved) internal corners and polished to food grade finish.

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A1.2 THE CONCENTRATION (ULTRA-FILTRATION) MODULE

(see also Appendix 3)

The Elements

Units (in sequences)

Supply tank: This is the plasma storage tank at the end of the separation module.

Heat exchange: To warm chilled plasma to operating temperature.

High pressure UF storage vessel.

High pressure UF pump.

High pressure circulating pipe.

Battery of UF packs (see Appendix 3).

Permeate collecting tray and tank.

Recirculating chilling system: In practice this can be combined with the incoming heat exchanger.

Concentrate plasma storage tank.

Equipment: Pipes, valves, gauges, pumps, electrical and control gear, C.I.P. equipment.

Dimensions

UF pressure unit (vessel, pump, pipe and battery)	2 x 3 x 3 m
Concentrate tank 500 litres	500 litres
Permeate collection tank	500 litres
Total module	2 x 5 x 3 m.

Construction

Filter packs: as developed by TRSA (commercial units may be different): Milled perspex with type 316 SS mesh.

UF pump: Lobe gear type.

UF pressure vessel: welded steel plate.

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Tanks: Stainless steel.

Membranes: Unisearch patent -- each 0.05 m^2.

Operating characteristics

Optimum temperature of feedstock: 30-40°C

Optimum operating pressure: 150 - 250 k pa.

Capacity (see also Appendix 3 and Section 3.5) The basic calculation is that 1 m^2 of filter membrane can remove 15 litres of permeate from 22 litres of dilute plasma in one hour at optimum temperature and pressure. The installed battery of 40 filter packs has a total membrane area of $2m^2$ and can remove 30 litres per hour. The UF pressure pump has a maximum capacity of 540 litres per hour allowing about fifteen recirculations of the concentrating plasma.

Average composition of the concentrate, and range for all normal runs:

Protein	22.5%	(21-23)
Salts	0.5%	(0.4-1.0)
Moisture	77%	(76-78)

Inputs

Power: UF pump 6 kw, plasma pump 1 kw.

Heat: Heat to warm incoming plasma and chilling to cool recycling plasma would normally be supplied by abattoir.

Materials: Unisearch membranes ($200 / m^2). Under careful use, the membranes will require replacement after approximately six months operation.

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Estimated costs

See Appendix 1.1 for qualifications.

UF battery (membranes, supporting pack, enclosing gear)	$1000/m^2
UF pressure pump	5500
Pressure vessel	2000
Heat exchanger (chiller)	1000
Permeate storage tank	750
Permeate collection vessel	700
Concentrate storage tank	750
Minor equipment (pipes, valves, fittings, gauges)	5000

Servicing

The UF battery: C.I.P. after each shift with permeate followed by enzyme based alkali detergent followed by sterilizing solution of chlorine based bactericide. Occasional caustic clean.
Pipes, valves etc: C.I.P. each shift, pull down, soak and clean each week.

Precautions

Excessive pressure can rupture the membranes.
Excessive temperature can coagulate the proteins and clog the membranes.

Options and possibilities

- The module could be operated to produce a higher moisture concentrate if there was, temporarily or permanently, excess capacity in the drying module.

- Cascade operation through several batteries arranged in sequence is envisaged for commercial installations.

A1.3 THE DRYING MODULE (Figures 3, 4, 5)

The Elements

Units (in sequence)

Supply tanks: These are the storage tanks at the end of the separation module (for corpuscle slurry) or the concentration module (for plasma concentrate).

Air intake filter

Air fan

Air heating unit

Spouted bed dryer

Cyclone separator

Bag filter (installed to clean exhaust air rather than to extract the 1 per cent of powders remaining)

Equipment: Pipes, ducting, valves, electrical and control gear, cleaning systems.

Dimensions

	Height	Lateral
Air supply+	1.5 m	4 x 1.5 m
Dryer	3 m	1.5 x 1.5 m
Cyclone	4 m	0.5 x 0.5 m
Bag filter	6 m	3 x 2 m
Total module	6 m	8 x 4 m

Construction

The dryer, cyclone, and interconnecting ducting in the installed unit are of galvanized mild steel coated with a special food grade paint. Stainless steel may be demanded in commercial units and costs (below)are based on s.s. construction .

Air heating unit: Gas fired in the installed unit -- see possibilities.

+ The installed unit is fitted with a delivery fan and an exhaust fan beyond the bag filter. A single larger delivery fan now seems more desirable.

APPENDIX I

Operating characteristics

Air intake: 1500-3000 s.c.f.m.

Air temperatures:

At heater and dryer inlet	100-150°C
Bead bed	50- 65°C
Blood inlet and air exit	50- 65°C

Maximum moisture extraction rate 50- 60 kg (litres)/hour equivalent to

80 litres/hour of 36% solids corpuscle

65 litres/hour of 22% solids plasma concentrate

Moisture content of powders: Average 6%, range 4-9%.

Inputs (with unit operating at capacity)

Power: Supply fan 20 kw
Exhaust fan 10 kw
Compressor 5 kw
Pumps 2 kw

Heat: Approx 500,000 BTU/hour.

Materials: Beads -- ½ tonne of 5mm. diameter beads of food quality plastic. Expected life at least one year.

Estimated costs

See Appendix A1 for qualifications. Costs listed here are for a single module capable of extracting 50 kg/hour.

Air supply fan and filter	$4000
Heating unit	6000
Dryer	4000
Cyclone	2000
Bag filter and compressor	5500
Exhaust fan	2000
Bead extraction and cleaning gear	2000
Minor equipment (piping, ducts valves insulation)	1000

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Servicing: Dryer, cyclone and bag filter are self cleaning with clean water - steam - air flows in place of the product flows.

Problems: Careful start up procedures with air then water are necessary to prevent the liquid blood fraction clogging up the cold beads.

Options and Possibilities

- The installed module has a separate gas fired air heater. In any abattoir, this would be replaced with a heat exchanger drawing on waste steam. A heat extractor at the end of the air flow and insulation of all units would also increase thermal efficiency.

- The moisture extraction rate could be increased by first chilling the incoming air to reduce its moisture content. Note: The drying rate is a function of the moisture content of the air entering the dryer. In hot, moist (tropical) conditions, the rate could be seriously impaired unless the air was pre-dried.

- Replacement of the bag filter with a second cyclone would probably increase efficiency and save space.

APPENDIX 2

SPECIFICATIONS OF THE PROPOSED U MODULES

Two modules -- the collection module and the bagging or packaging module -- have not been completed, but for quite different reasons.

The bagging module was not installed because there was never sufficient output of powders to justify the expense and because there were no features in the process and no properties of the powders that demanded any important modifications to the standard bagging unit that is used in many industries.

Most of the components of the collection module have been assembled and some of them have been thoroughly tested. They were never put together as a total module because that could only be done on line in an abattoir -- and this could not be arranged.

The details of any installed collection module will depend very much upon the configuration of the abattoir where it is installed.

The essential equipment (knives, cones, and even complete collection units) are available commercially. The problem is not whether they will function mechanically but how and where they can be fitted in.

The consequence of all these factors is that specifications and illustrations of the collection module must, of necessity, be less precise than those of the installed modules.

APPENDIX 2

(ii)

A2.1 THE COLLECTION MODULE (Figure 6)

The Elements (in sequence)

Collecting knives or cones.
Citrate (anti-coagulant) dispensing system.
Holding rails or carousel -- to allow adequate bleeding time in high capacity lines.
Isolation tanks
Bulk storage tank.

The module illustrated in Figure 6 shows a single collection point (with options for three more), a hollow knife with automatic citrate dispenser, four isolation tanks, and a raised killing line with gravity feed to the tanks. Many other arrangements are possible or may be decided by the works layout. Some of the options have been mentioned in section 3.2.1 or are raised under "Options and possibilities" below.

Dimensions (lateral space required)

Single knife	1 x 1 m
Carousel for 4 carcases	4 x 4 m
Isolation tanks (4) each 100 litres/500/day kill.	3 x 3 m for the four.
Bulk storage tank	300 litres/500/day kill.

Construction

Knives: Alfal Laval or Bemeg (Swedish).
Collecting tube: Flexible food quality plastic.
Tanks: Stainless steel.

Note: Complete collecting units are available from Bemeg.

Operating Characteristics

Suggested bleeding time: 30 - 60 seconds.

Estimated recovery of blood: 75 - 90 per cent of total possible.

Citrate feed: 10 ml of 2% solution per litre of blood collected.

Inputs

Citrate: 25 kg sodium citrate crystals/500 head.

Ancillary equipment

Ancillary equipment: C.I.P. and sterilizing systems.

Estimated costs

Knife, dispenser and collection tubing	$ 8000
Bemeg collection unit	12000
Isolation tanks (each)	250
Bulk storage tank	700
Pumps, valves, piping:	Depends on individual installation.

Servicing

C.I.P. cleaning with hot water each shift. Some piping will need to be dismantled at the end of each shift and soaked overnight. Knives to be disinfected regularly in caustic and bactericide. Sterilization of all potentially contaminated knives, tubing, pipes, and tanks after condemnation of any carcase: with steam, caustic, and bactericide.

Options and possibilities

- The Canadian plastic bag system (see section 3.2.2) is the most valuable development.
- In small works or at times of interruption or breakdown a manual cone and bucket system could be used.
- With vacuum pumping, the isolation tanks and/or the bulk storage tank could be situated well away from the killing line and close to the separation module.

A2.2 THE BAGGING OR PACKAGING MODULE

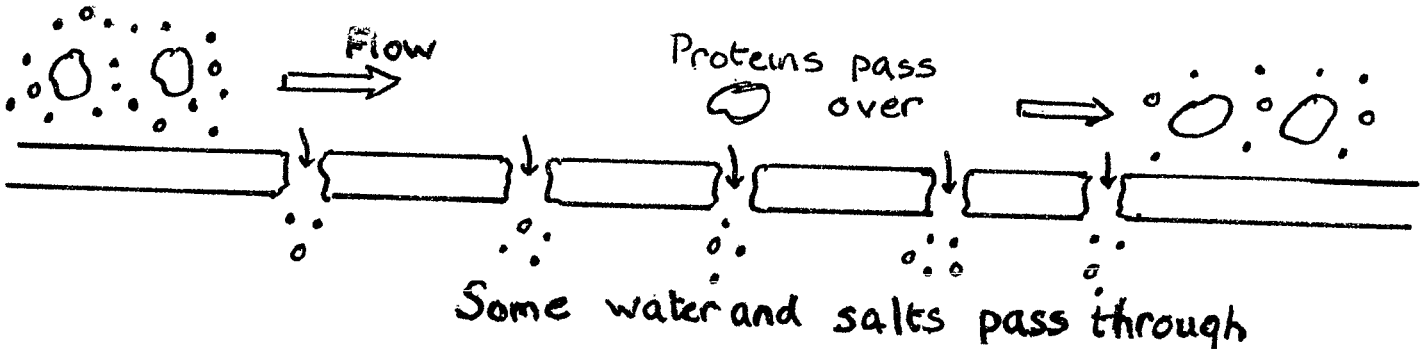
In the installed system, the powders have been bagged direct from the chutes on the cyclone separator or the bag filter. In a large system operating continuously, this would be unwieldy, and could be delaying and unhygienic. The proposal is that the powders would be ducted from the chutes to a bagging module in a separate enclosure. Most standard commercial powder bagging machines should prove satisfactory. Ancillary equipment would include scales, vibrators, pallets and exhaust fans.

The TRSA estimate of purchase costs of the units and equipment needed to handle the output from a 500 head/day operation is $20,000 each for separate plasma and corpuscle powder modules.

APPENDIX 3

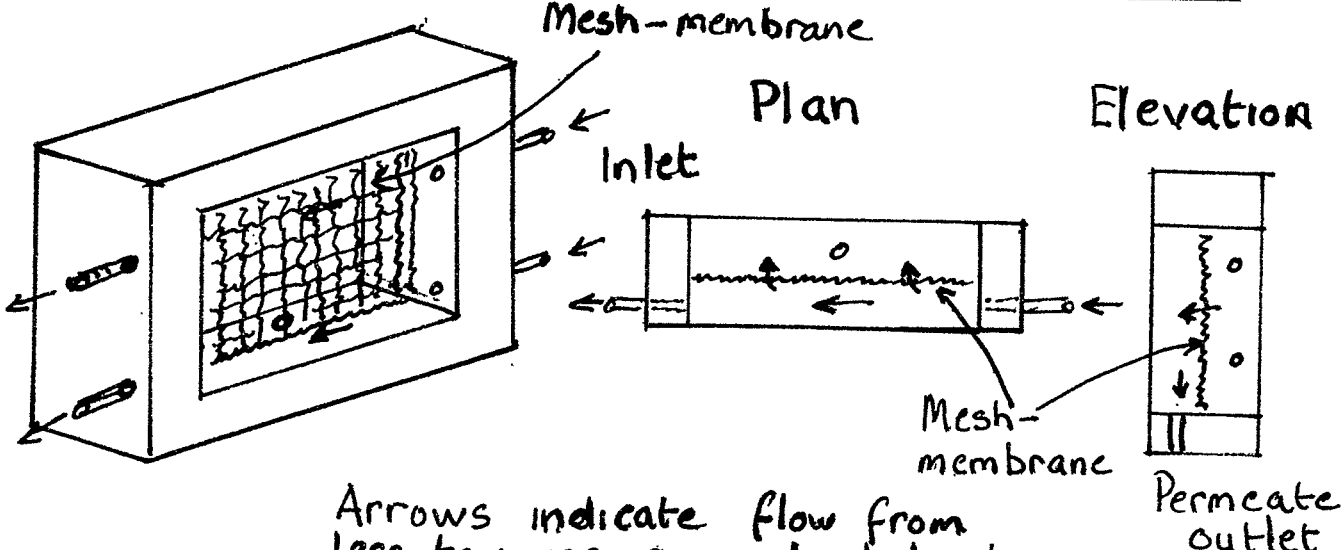
HOW THE ULTRA-FILTRATION UNIT WORKS

Ultra film, the filtering membrane in the ultra-filtration unit, is a very thin sheet of white plastic. It is perforated by thousands of minute holes which are invisible to the naked eye. The basic principle, as explained in Section 3.5, is that small molecules can pass through these holes but large molecules cannot. In practice, the rate of passage (filtering) increases as the pressure increases and as the rate of flow across the membrane increases. There is no point in simply forcing the plasma against the membrane -- the large molecules would only block up the holes.

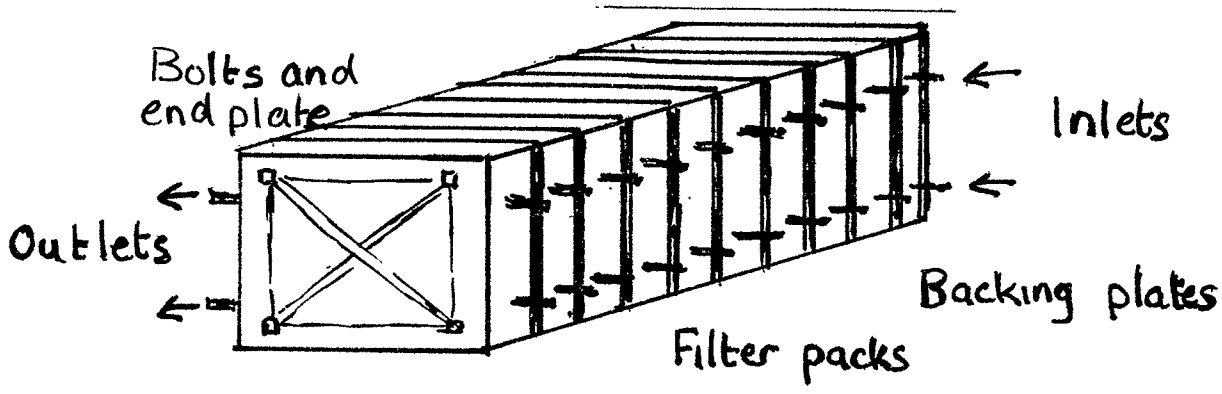


The pressure and velocity requirements virtually determine the configuration of the UF unit. To prevent rupturing, the membrane has to be supported -- by a stainless steel mesh. To allow the plasma in and the concentrate and permeate out the membrane -- S.S. mesh has to be arranged in an appropriate frame with inlets and outlets. To maintain pressure, the space has to be sealed.

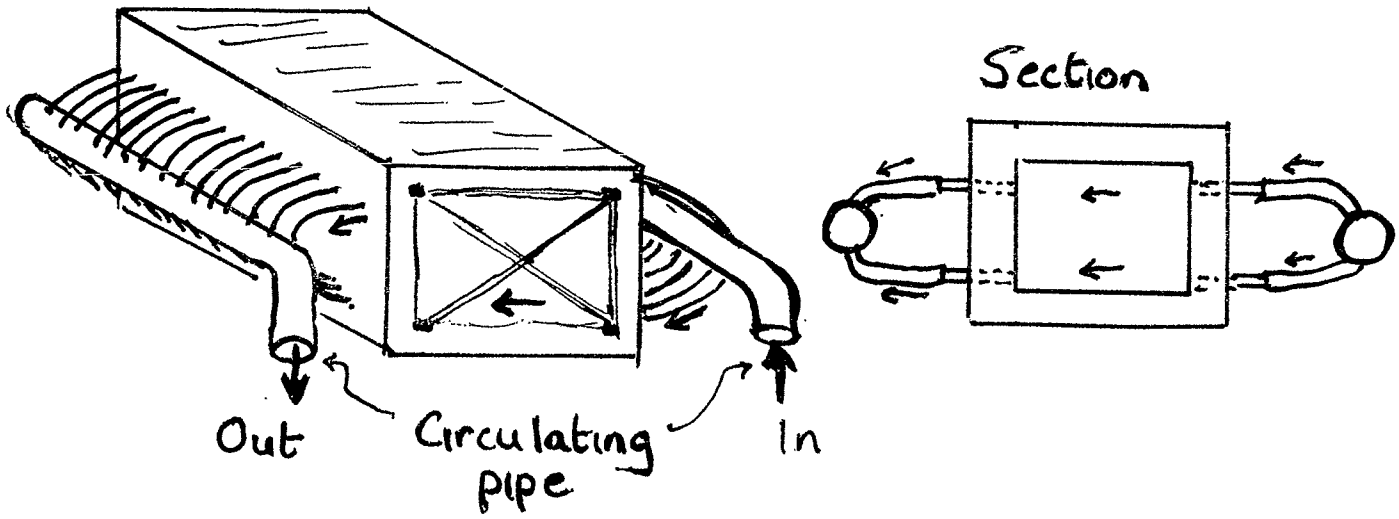
The filter pack developed by TRSA to meet these needs is illustrated below. It is milled from 2 cm perspex sheet.



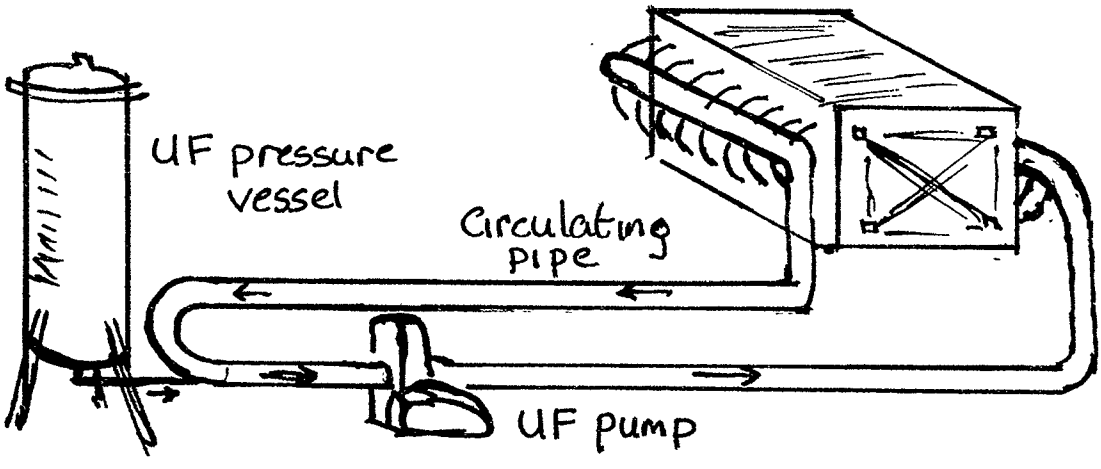
A plain perspex sheet (backing plate) is placed on each side of the filter pack to seal the filtering chamber. Up to 40 filter packs and backing plates are bolted together to form a battery.



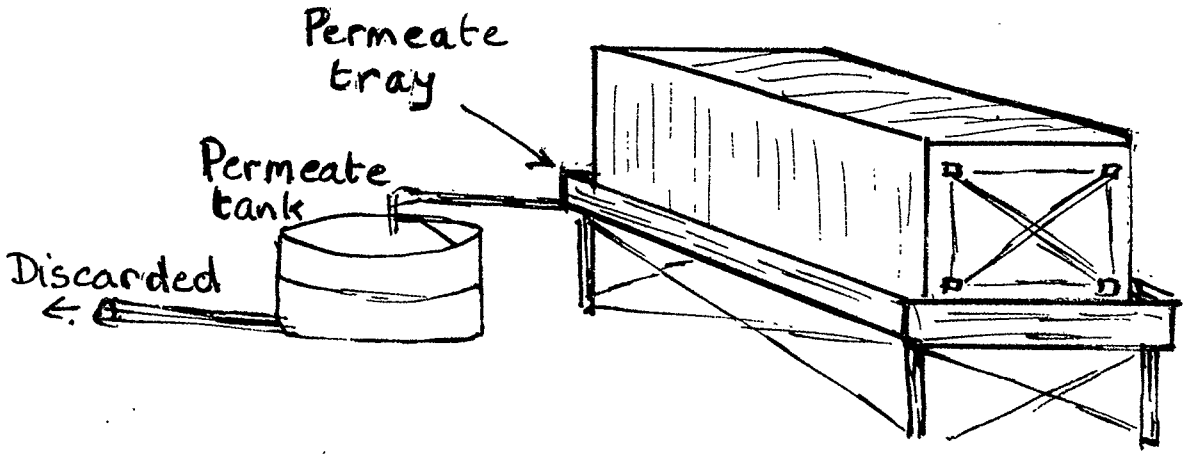
The plasma is circulated through a closed pressure pipe with small plastic feed pipes leading to the inlet and outlet pipes on the filter packs.



Pressure in the circulating pipes is maintained by the UF pump and the supply to it by the UF pressure vessel.



The permeate coming out of the packs is collected in a tray, passes to the permeate collecting tank and is then discarded.



The dilute plasma is fed into the pressure vessel which in turn feeds the circulating pipe and battery of filter packs. The pump keeps the plasma circulating until the required concentration is reached. Then, intermittently, the concentrated plasma is led off and the vessel is recharged.

The high pressures generated by the plasma pump are accompanied by increased temperatures. With repeated passages through the pump, the temperature of the concentrating plasma would be raised to unacceptably high levels. To overcome this, a secondary circulation through a chiller is incorporated.

Schematically, the whole system can be represented thus:

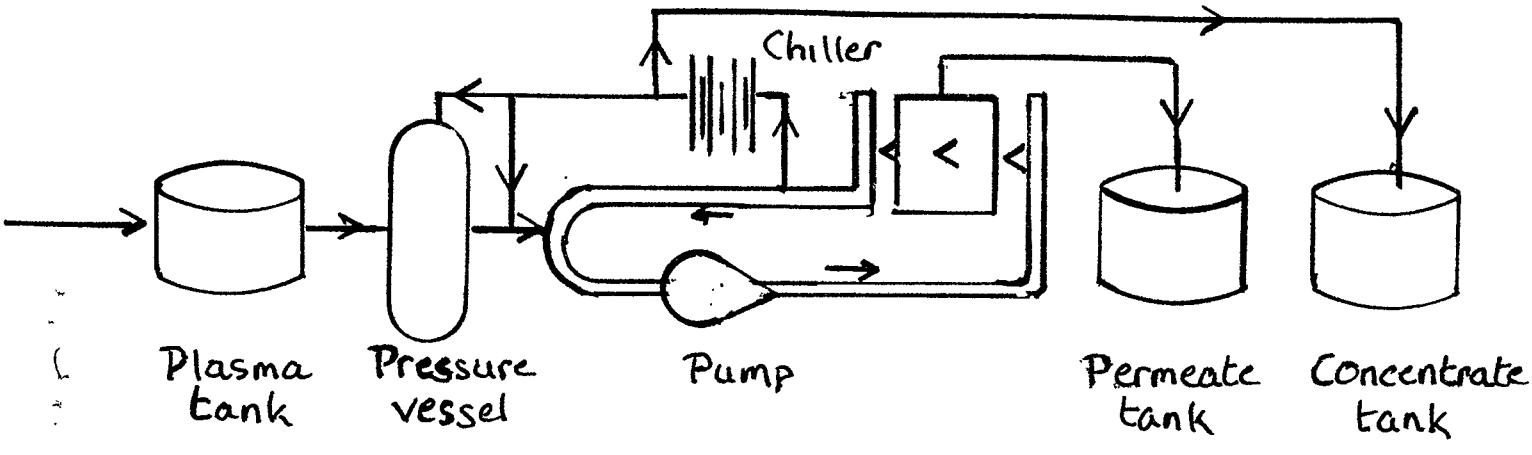


FIGURE 1: TYPICAL PRODUCT AND CONCENTRATION CHART FOR ONE TONNE OF RAW BLOOD PROCESSED IN THE TSRA SYSTEM.

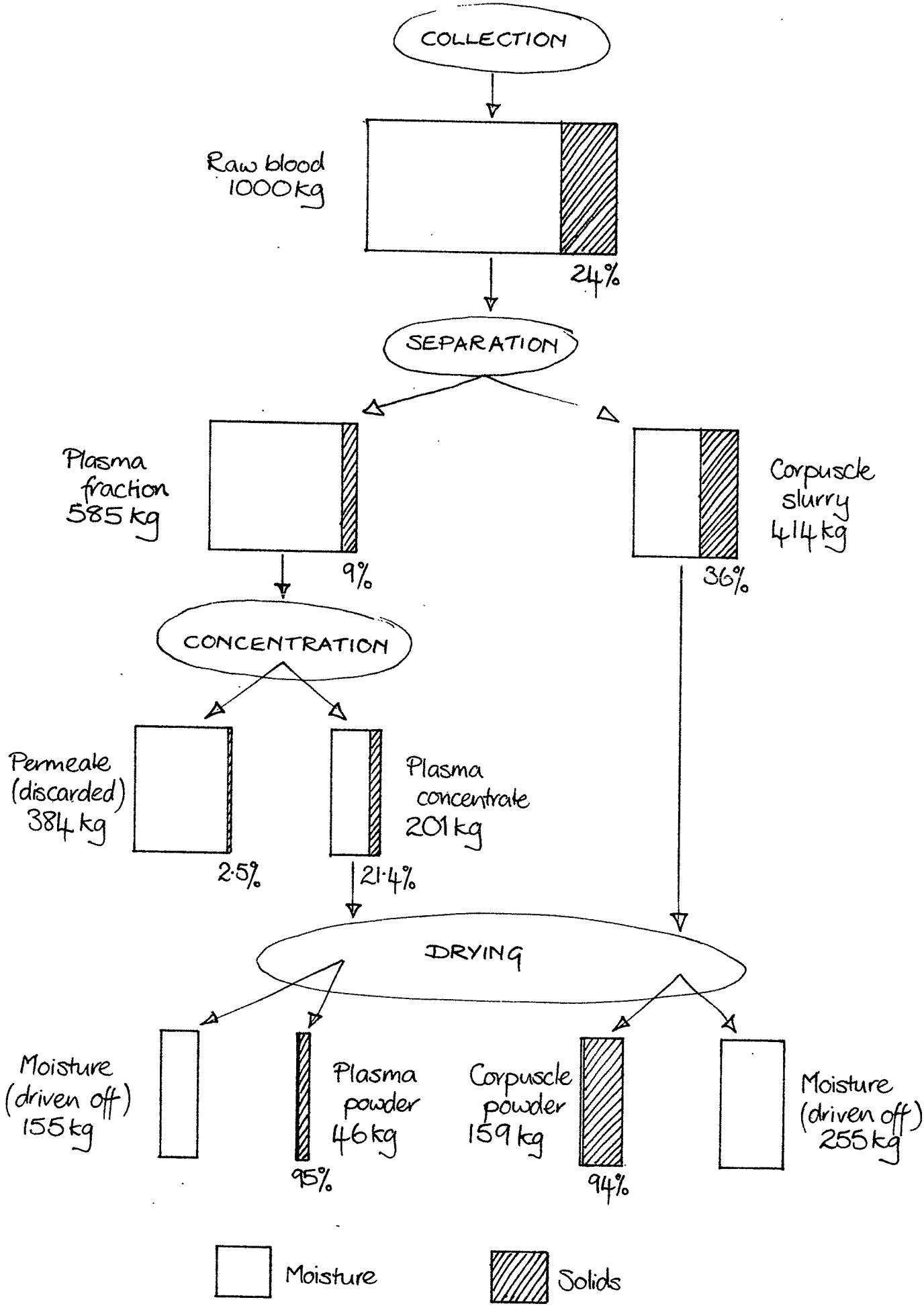


FIGURE 2: SEPARATION MODULE

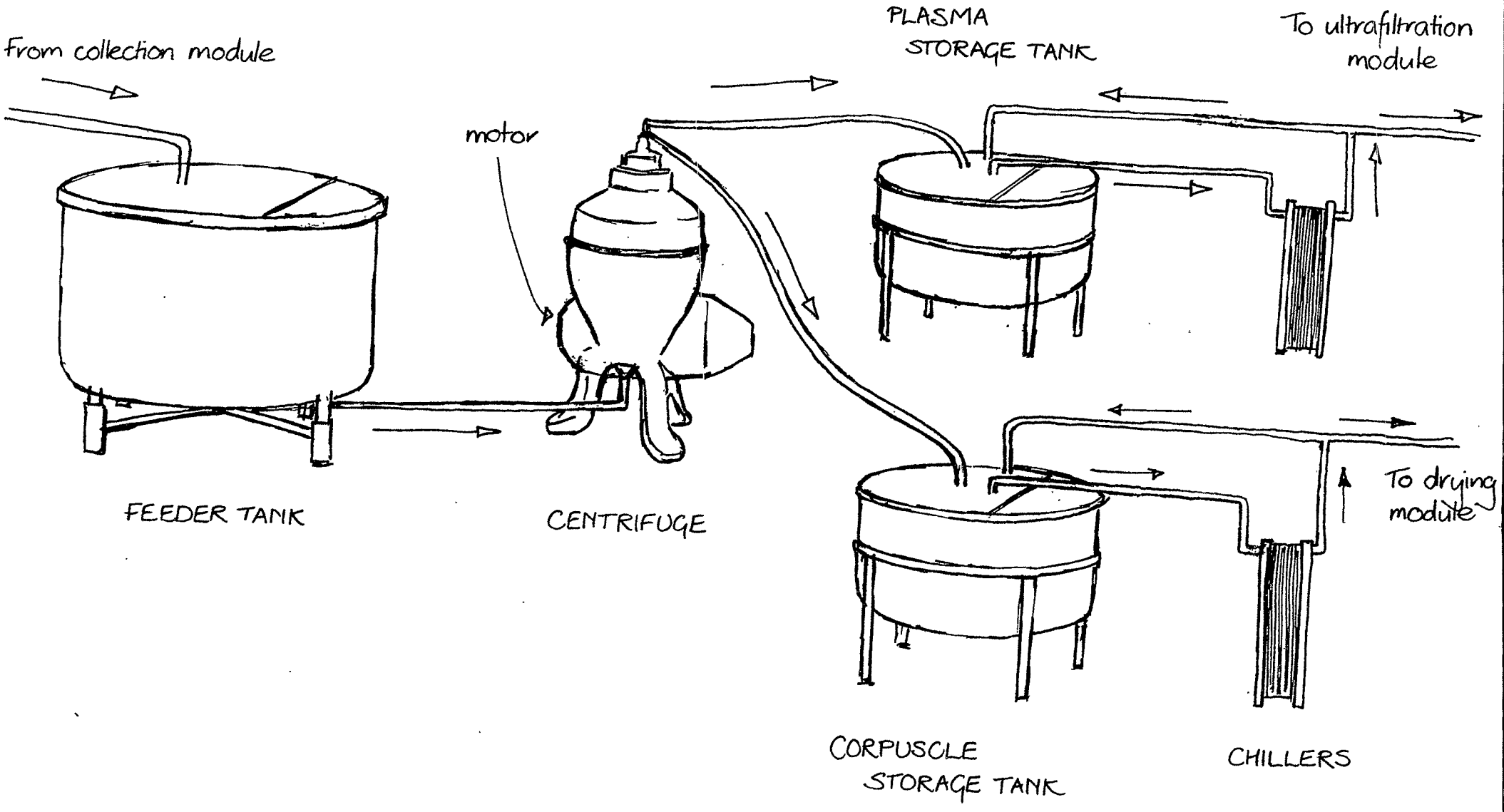
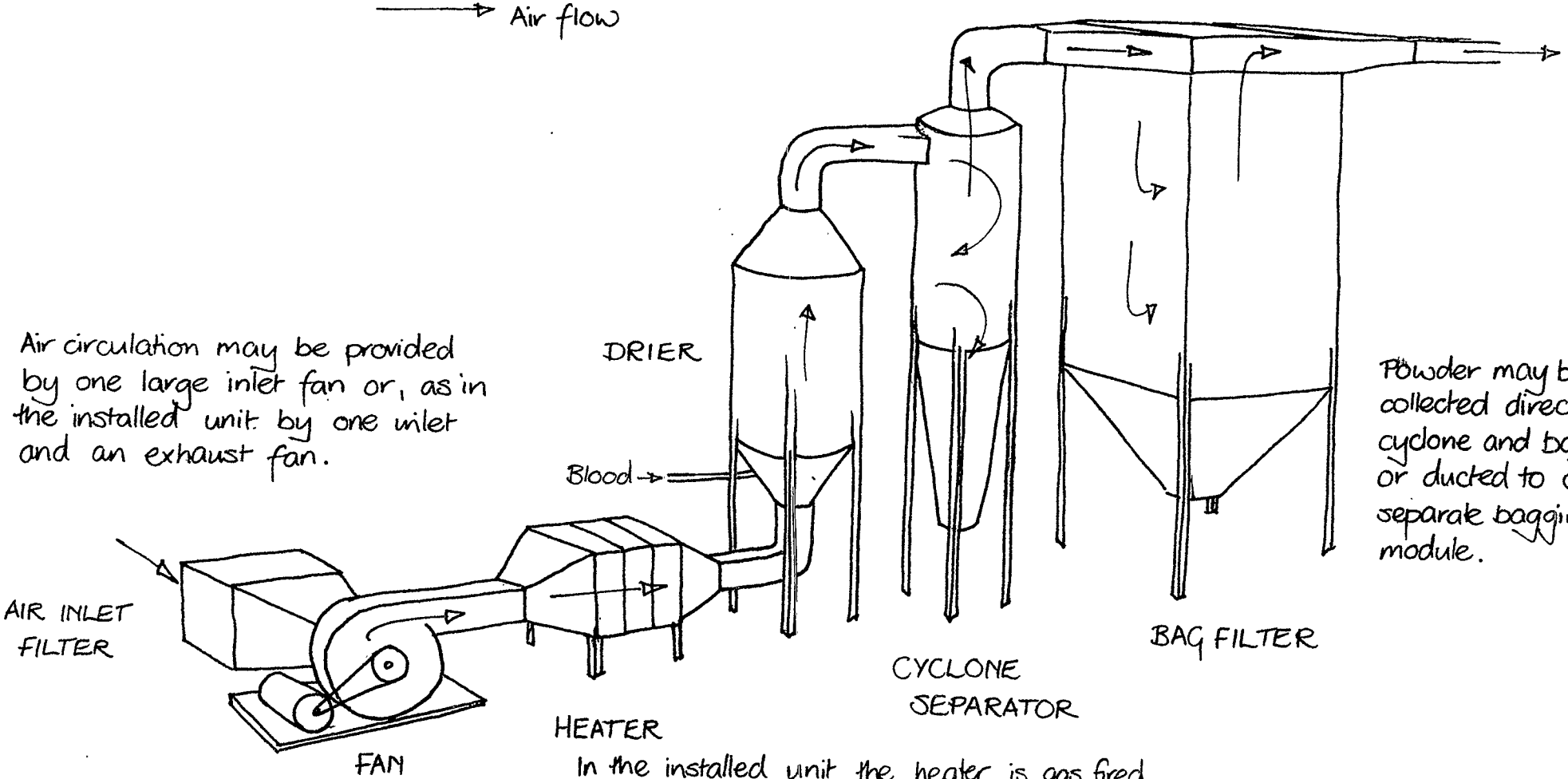
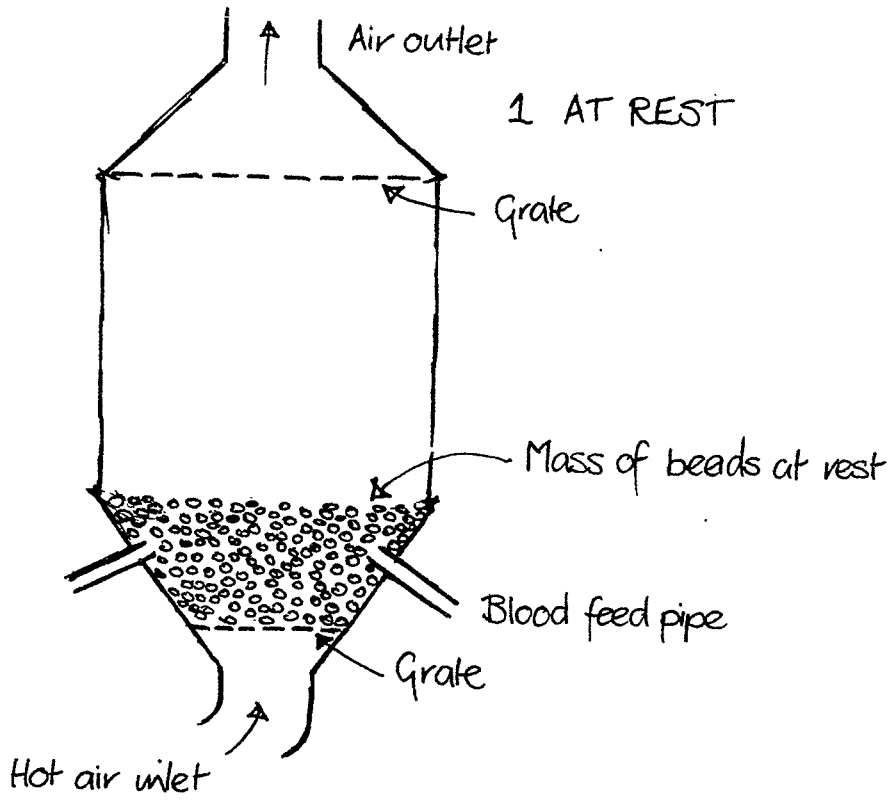


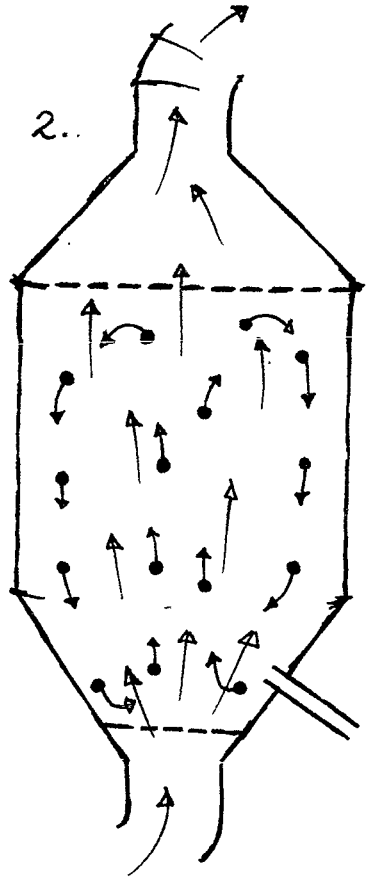
FIGURE 3: DRYING MODULE



In the installed unit the heater is gas fired, in an abattoir heat could be provided by waste steam and recovery from exhaust gases.

FIGURE 4: HOW THE DRIER WORKS

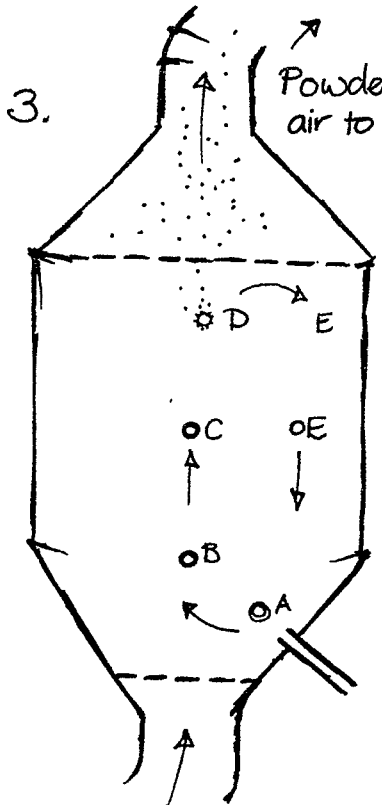




2. AIR FLOW ON

Air flow

Bead circulation
In operation collisions with other beads and walls make circulation much less regular



3. BLOOD INTRODUCED

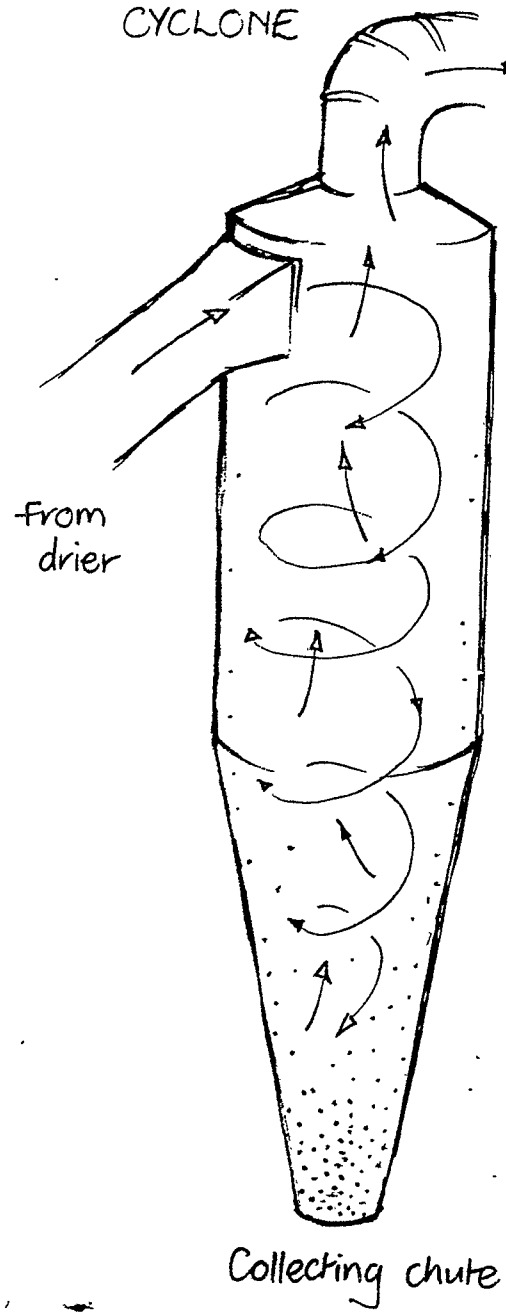
A ◎ Film of liquid settles on bead passing through spray.

B-C ● Blood liquids dry in under one second to a solid skin. Heat comes from bead and surrounding air.

D ☼ Skin broken by impact and vibration, powder passes out at top.

E ○ Clean bead returns to bottom of unit and is resprayed.

FIGURE 5: HOW THE SEPARATORS WORK



Air and powder enter at a tangent, setting up rotary cyclone movement with lower pressure "eye" in the centre. Powder is spun to the outside by centrifugal force, falls and collects at the base of the unit. The air moves to the eye, rises and passes (with some powder) over to the bag filter.

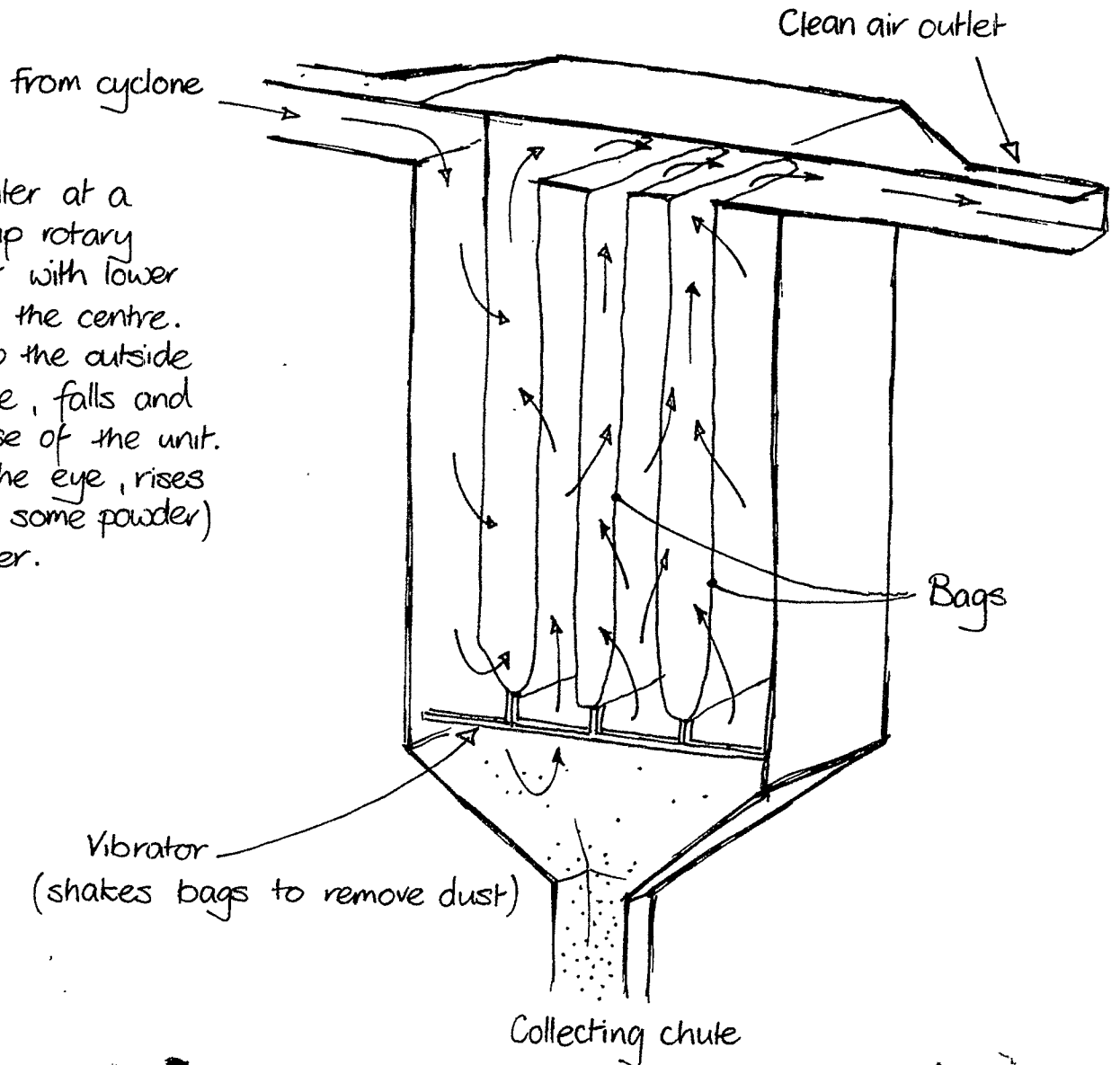


FIGURE 6 COLLECTION MODULE