WASC 2218

RNCF Holton
Heath
Acetone Factory

ROYAL NAVAL CORDITE FACTORY

ACETONE FACTORY

Holton Heath

Dorset

DANGEROUS ENERGY PROJECT ARCHIVE

SURVEY REPORT

Royal Naval Cordite Factory

Acetone Factory

Holton Heath
Dorset

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SUMMARY

The Acetone Factory (SY 9455 9042) lies within the boundary of the former Royal Naval Cordite Factory (RNCF) Holton Heath. It was constructed either in late 1916 or early 1917 to manufacture acetone, using an innovative type of biotechnology known as zymotechnology or fermentation technology. This technology had been developed prior to the war on the continent and also by a team at Manchester University which included Chaim Weizmann - the future first president of Israel. He left this team and while working on his own discovered a bacterium which could ferment a starch source (initially maize) directly to ethanol, acetone and butanol. The first purpose-built plant for the manufacture of acetone using this process was the plant built at the RNCF Holton Heath. The solvent acetone was required in large quantities for the manufacture of the explosive cordite.

During the 1920s, with a reduced requirement for explosives, less acetone was needed. Also by the late 1920s the chemists at Holton Heath pioneered a new solventless process for the manufacture of cordite which dispensed with the need for acetone. The plant probably ceased work in the late 1920s and was partially demolished in 1934.

Most of the ground plan of the plant may be traced and a number of components survive. These include the footings of the granary to the rear, six out of the original eight reinforced concrete fermentation vessels and the Cooker House - converted in the 1930s into workshops, offices and stores.

HISTORY

During the Great War acetone was required in large quantities for the manufacture of the propellant explosive Cordite MD, where it was used in the incorporation process to ensure the gelatinisation of the two principal ingredients of cordite, nitroglycerine and guncotton. Prior to the war Britain had relied on imported acetone, and home produced acetone made by the destructive distillation of wood.

An alternative source for acetone lay in the infant science of biotechnology through zymotechnology or fermentation technology. In the years immediately preceding the war the Synthetic Products Company established plants at Rainham, Essex, and Kings Lynn, Norfolk, to produce acetone using a micro-organism discovered by Fernbach at the Pasteur Institute. Neither factory lived up to the expectations of backers. A team based at Manchester working on the same problem included Chaim Weizmann, the future president of Israel. When he left to work on his own, he identified a bacterium which could ferment a starch source directly to ethanol, acetone and butanol. After first approaching Nobel's, in early 1916 he was summoned to the Admiralty and directed by Winston Churchill to work the process up to an industrial scale. Research was moved to the Lister Institute in London and a pilot plant was created at J & W Nicholson's gin distillery at Bromley-at-Bow, Greater London. The first purpose-built plant to exploit the Weizmann process, using maize as a starch source, was constructed at the RNCF Holton Heath. Construction of which probably began in late 1916 or early 1917.

Later in the war pressure from German U-boats restricted the supply of maize to Britain and in 1917 experiments were made to substitute artichokes as the starch source. Even more mysterious at the time was the request by the Admiralty for school children across the country to collect acorns and horse-chestnuts for the Director of Propellant Supplies at the Ministry of Munitions, destined for this plant.

Elsewhere in Britain, two distilleries were converted to use the process and further plants established at Terre Haute in Indiana, Toronto in Canada and at Nazik in India, and were apparently modelled on the Holton Heath plant.

After the end of the Great War reduced requirements for cordite lessened the need for acetone. Also during the late 1920s the RNCF pioneered the development of solventless cordites which dispensed with the need for this expensive and volatile solvent. The plant was redundant from about the late 1920s and a series of historic photographs record its demolition in 1934. However, the Cooker House survived as it was converted to workshops, offices and stores, functions it retained when the factory was converted into a Naval Materials Laboratory in the 1960s.

DESCRIPTION

The Acetone Factory plant remains partially intact, situated between the bases of two gasometers and a railway embankment. It was roughly rectangular in plan, comprising a number of components. To the rear, adjacent to the railway embankment, was large granary 35m by 10m initially constructed to store maize. Its remains may be traced as concrete floor slab. After the demolition of the Acetone Factory, probably in the mid-1930s, the floor slab was reused for a motor transport maintenance shed. At the western end a raised vehicle inspection ramp was constructed. The slab was also roofed with a light metal structure at this date and a series of small concrete piers were constructed to secure uprights, the size of scaffold pole. This too had been removed by the time of survey.

From the granary the maize was taken to the Cooker House at the eastern end of the plant. It is a double storey steel framed structure with brick infill. A drawing, held on site, prepared in 1935 when the building was converted to a workshop shows that it had a raised central clerestory. Internally were six cookers in which the maize was reduced to a mash. From the cooker house the mash was moved, probably by sealed pipes, to the fermentation vessels. The aluminium fermentation vessels were housed in circular reinforced concrete tanks, the wooden shuttering for which is visible on the exterior of the tanks. Each vessel is 11.5m in diameter; six of the original eight of these survive. The floors of the tanks were raised off the ground on concrete pillars probably to aid heat retention, the sub-floor space apparently being a sealed area. Around the lip of a number of the tanks was a narrow groove probably to hold the lip of the tank or its lid. This groove has been lost on a number of the tanks where it appears that attempts have been made to demolish the tanks using a pick axe. The use of reinforced concrete in the fabrication of chemical plant at this date was unusual, and is even rarer as surviving field monument.

The facility was also innovative in the laboratory-like sterility which it introduced into an industrial process, as remains evident in the careful jointing and sealing in the surviving pipework. The plant was sited conveniently close to the factory boiler house for a supply of high-pressure steam necessary for sterilisation. The arrangement of pipes on the tanks followed a standard pattern comprising a large bore flanged elbow pipe connecting the exterior of the tank to the floor of the tank. This was probably used for moving the mash in and out of the tank. Above the large pipes and above the floor of the tank were four smaller pipes with flanged ends. These were perhaps used to admit superheated steam or for moving the solvents produced in the process. It is uncertain from studying the field remains if the process involved moving the mash from tank to tank.

No contemporary drawing showing the fermentation vessels has been found to confirm the original arrangements within the plant. A series of photographs taken in 1934, when the plant was partially demolished shows that the tanks were originally housed in a tall steel framed brick structure. Its original extent may be traced in as edges concrete flooring visible around the tanks.

During the Second World War the surviving concrete shells were modified to create refuges or air-raid shelters. This work involved breaking two openings into the sealed basements, to create an entrance and emergency exit. The openings appear to have usually been made where the large bore elbow pipes were positioned. Other

modifications included the installation of steam heating pipes and electric lighting. The interiors of the tanks were also partly filled with earth to improve the overhead protection.

Site archive

A small number of plans and elevations of the Cooker House, dating from the 1930s, were held on site in July 1996. Copies of photographs showing the demolition of the Acetone Factory are deposited with the National Monuments Record.

This report is the result of a field investigation by Wayne Cocroft and Bernard Thomason in July 1996. Photographs were taken by Mike Hesketh-Roberts in September 1994, Job No.94/1976.

SOURCES

Primary

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Factory drawings held on site by DERA Holton Heath July 1996

Drawing C-531 Proposed conversion of Cooker House to carpenters shop, work proposed 1930-1

Drawing No C-781 Conversion of Cooker House to work shops, office, stores etc. January 1935

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APPENDIX 1 List of RCHME Photography - September 1994 Job No.94/1976

BB94/16939	Acetone Fermentation tanks, view from south
BB94/16940	Acetone Fermentation tanks, view from south (colour)
BB94/16941	Acetone Fermentation tanks, northeast tank
BB94/16942	Acetone Fermentation tanks, north east tank (colour)
BB94/16943	Acetone Fermentation tanks, location view
BB94/16944	Acetone Fermentation tanks, detail of entrance
BB94/16945	Acetone Fermentation tanks, interior showing concrete supports
BB94/16946	Acetone Fermentation tanks, narrow gauge pipe beneath tank
BB94/16947	Acetone Fermentation tanks, narrow gauge pipe beneath tank
BB94/16948	Acetone Fermentation tanks, detail of large bore pipe
BB94/16949	Acetone Fermentation tanks, view into tank from above
BB94/16950	Acetone Fermentation tanks, detail of top rim
BB94/16951	Acetone Cooker House, interior from east
BB94/16952	Acetone Cooker House, view from east

for a great number of years, and only in recent years had been taken off. He had been in America at the time when chrome leather had been put on the free list. The removal of the tariff had adversely affected the American industry, and the German leather was coming in in large quantities. The English tanner had had a real difficulty in having to compete with the cheap labour of Germany on the one hand, and the highly organised production of America on the other. These had been severe difficulties to face in an open market.

Dr. KEANE said that many interesting points had been raised in the discussion, including the problem as to whether it was best for a man to go to his college before he entered the works, or *vice versâ*. There were great advantages in both directions, and it seemed that with the right man it did not matter very much which way he went. Another point had been as to the lack of appreciation of the chemist by the manufacturer, and the lack of appreciation of the manufacturer by the chemist, and the lack of encouragement of research on all sides. It was the same in other industries. He thought everybody was pretty much to blame. We must all make up our minds to pull together better in the future than in the past. The war had shown what could be effected by co-operation; in a National reconstruction we had to carry into science and industry the co-operation we had followed during the war.

CONFERENCE ON RECENT DEVELOPMENTS IN THE FERMENTATION INDUSTRIES.

In the afternoon of Thursday, July 17th, a Conference on Recent Developments in the Fermentation Industries was held at the Goldsmiths' Hall, the chair being taken by Sir James J. Dobbie.

The CHAIRMAN, after touching upon the early history of fermented beverages, recalled the statement, which was probably substantially true, that no nation or tribe had been discovered which did not use a fermented beverage of some kind. China and Japan produced saké from rice, India and tropical Africa had fermented palm juice, the Zulu and other South African tribes made beer from maize and millet, while in Central Asia and the Russian steppes fermented milk or koumiss was in general use. The vast extent of the fermentation industry engaged in the manufacture of these alcoholic beverages might be gathered by a perusal of the official returns of our own and other European countries, the United States, and the principal British dependencies. From these it appeared that the average annual production of wine was about 4500 million gallons, requiring for its manufacture over 30 million tons of grapes. Of beer over 6000 million gallons was produced, requiring from five to six million tons of grain. Spirit amounting to over 450 million gallons of pure alcohol consumed about 5,000,000 tons of potatoes, over 4,000,000 tons of grain, and about 2,000,000 tons of molasses, syrups, and grapes. These figures referred only to the fermented liquors subject to fiscal control in the countries mentioned, and if those produced in other countries, such as India, China, and Japan, were included, the totals would be greatly increased. Notwithstanding the enormous production of these fermented liquors it was curious that their manufacture, even in the most civilised countries, still largely followed the empirical methods of thousands of years ago. It was only in quite recent times, mainly owing to the work of Pasteur and his successors, that the chemical and biological factors involved in the processes employed had begun to be understood, and, as yet, only a small portion of the wine and beer produced was manufactured under efficient scientific control. It was more than a thousand years since the alchemists had succeeded in extracting spirit or alcohol in a comparatively dilute form from wine, and the use of alcohol except for medicinal or drinking purposes was quite a recent development. The invention of the Coffey still and similar fractionating apparatus had made possible the production on a commercial scale of alcohol of sufficient concentration to permit of its use for lighting, heating, solvent, and many other important industrial purposes. The yeast industry was naturally closely bound up with the production of alcohol, which, indeed, was in many cases only a by-product of yeast manufacture. During the war the quantity of yeast produced from a given quantity of grain had been doubled without any considerable loss in the amount of alcohol produced. Incidentally it might be noted that the cost of industrial alcohol had been reduced by about one half owing to the concurrent production of yeast. Ethyl alcohol might now be produced from such compounds as ethylene and acetylene or even from its elements; but so far these processes had not proved successful on a manufacturing scale, and the time still seemed far distant when the production of alcohol would cease to be the principal fermentation industry. The manufacture of other important commercial products, such as acetic acid, dependent on fermentation methods, had only quite recently been subjected to control on scientific principles, and the range of the "fermentation industries" would be extended as the result of research. Before the war the manufacture of butyl alcohol had excited much interest in connection with the production of artificial rubber, and, under the stimulus of war, the manufacture of acetone had become a national concern of the first importance.

THE MANUFACTURE OF ACETONE.

BY COL. SIR FREDERIC NATHAN.

Professor Louis in his presidential address referred to the work done during the war in connection with the production of acetone, and I propose to give a very brief historical retrospect and to mention one of the new processes which realised considerable supplies. I will leave Mr. Amos Gill, who is much better qualified than I am, to deal with the bacteriological aspects of the manufacture of acetone by fermentation.

The British Service explosive, cordite, is a gelatinised mixture of nitrocellulose and nitroglycerin with a percentage of mineral jelly; the solvent used for gelatinising the earlier varieties of cordite is acetone.

Before the war the main sources of acetone were the United States and Austria, in which countries it was produced from acetate of lime made by treating acetic acid with lime. Acetic acid itself is obtained by the destructive distillation of hard woods in iron retorts.

Austria ceased to be a source of acetone when war broke out and the United States became the only source of supply, the quantity produced in this country being practically negligible as compared with the large and rapidly increasing requirements of this solvent for the manufacture of cordite, and later on for aeroplane dope.

Steps were therefore taken to augment the American output from acetate of lime, and in addition a contract was placed with a firm who adopted a process for making acetone from vinegar, but although the process proved a success up to a point the yield was poor and the price was very high, and it was eventually abandoned.

Two other methods of producing acetone formed the subject of much experimental work. Both were catalytic processes; in one alcohol and in the other

calcium carbide were the raw materials employed. The former process, suggested by Dr. Perkin, was worked out by Messrs. Joseph Crosfield & Sons, of Warrington; the latter process was the result of experiments conducted at the McGill University of Montreal, and was worked by the Canada Electro Products Co., of Montreal, the calcium carbide being supplied by the Shawinigan Water and Power Co. Acetone was successfully produced by both these firms, but when the requirements of acetic acid for aeronautical purposes became very large it was necessary to stop the process, which was a three-stage one, at the second or acetic acid stage to provide the necessary quantities.

Yet another process for the manufacture of acetone is that known as the Weizmann process. In the spring of 1915 Dr. C. Weizmann, of Manchester University, brought to the notice of the Admiralty his laboratory experiments on the production of acetone by bacterial fermentation from maize or other substances containing starch. The process was generally similar to one which had been in operation on a small scale at the factory of the Synthetic Products Co. at King's Lynn since early in 1912, but in this case potatoes were the raw material employed and the bacteria were those of Prof. Fernbach. Unfortunately many difficulties were encountered in working the process at King's Lynn on a manufacturing scale and very little acetone was produced.

Steps were taken to carry out large-scale experiments on the Weizmann process, for which purpose semi-manufacturing scale plant was fitted up at Messrs. J. & W. Nicholson's Distillery at Bromley-at-Bow, and at the same time arrangements were made to carry on research work under Dr. Weizmann at the Lister Institute.

The Lister Institute research work and the experiments at Messrs. Nicholson's Distillery, which were conducted on a gradually increasing scale, proved that the process, if carried on under proper conditions, would produce acetone on a manufacturing scale, and it was decided by the Admiralty to erect a plant at the Royal Naval Cordite Factory for the production of acetone by this process. The factory was duly completed and acetone was made very satisfactorily so long as raw materials were available; damaged rice was mainly used.

It was also decided by the Ministry of Munitions to adapt some of the spirit distilleries for the process, and three in London and three in Scotland were selected. The distilleries at Bromley-at-Bow and at Ardgowan, near Greenock, were the first to be completed, and the difficulties encountered at the start were being successfully overcome when it became necessary, owing to the shortage of grain, to abandon the manufacture of acetone by this process at the distilleries.

The failure of the Synthetic Products Co. to produce acetone in any quantity from potatoes resulted in their King's Lynn factory being taken over by the Ministry of Munitions and led to the substitution of grain for potatoes and to the use of the Weizmann bacteria. These changes had good results and a satisfactory output was obtained. The factory, however, was a small one and manufacture from grain was stopped early in 1918 as by that time the acetone requirements were of less importance than the conservation of grain for food purposes.

The use of horse chestnuts having been suggested as a source of acetone in view of the fact that they contain a considerable proportion of starch, experiments were carried out at the Lister Institute which indicated the probability of horse chestnuts being suitable for the purpose. Arrangements were therefore made to collect horse chestnuts during the autumn of 1917. When a start was made with them at King's Lynn on a factory scale, the difficulties attendant on their use became apparent, but these difficulties were in a fair way of being got over when it was decided to close down the factory.

It was, however, established that for the successful fermentation of horse chestnuts the following conditions are essential:—(1) The nuts must be of good quality; (2) they should be dried to a moisture content of not less than 1%; (3) they should be ground to as fine a meal as possible; (4) the meal should be as free from husk as possible

The manufacture of acetone by the Weizmann process attained the greatest success at the factory of British Acetones, Toronto, Ltd., in Canada.

During the early part of 1916 the directors of Messrs. Gooderham and Worts' Distillery and of the General Distilling Co., of Toronto, generously offered to place their plants at the disposal of the Ministry of Munitions for the production of chemicals during the war. The plants were inspected by officials of the Imperial Munitions Board of Canada, and seemed to offer most of the necessary apparatus for the successful carrying out of the Weizmann process on a large scale. An engineer, a chemist, and a bacteriologist, who was specially trained at the Lister Institute, were sent out from England to organise and carry out the work from the technical side. Colonel Gooderham and his son placed their services at the disposal of the Ministry and acted throughout as manager and assistant manager respectively; the success which was attained was in great measure due to them. The plant started to work in January 1917 and continued in operation until the signing of the armistice. At the start there were nine fermenting vessels, each of 30,000 gallons capacity; seven more were added in the early part of 1917 and six more in 1918, making 22 in all, and an output of nearly 200 long tons a month was reached.

In view of the large requirements of solvents generally, due to the increase in the output of aeroplanes, steps were taken towards the end of 1917 to provide additional supplies of acetone in the United States. With this object Colonel Gooderham visited America, and in due course reported to the British War Mission on the advantages of the plant of the Commercial Distilling Co. at Terre Haute, Indiana, for conversion for the manufacture of acetone by the Weizmann process. As a result the plant was purchased early in 1918 and converted into an acetone factory. In the spring of 1918 it was decided by the United States authorities to acquire another distillery for the same purpose, and that of the Majestic Distilling Co., also at Terre Haute, was purchased and its conversion started. The Commercial Distilling Co.'s plant commenced production in May 1918, that of the Majestic Distilling Co. in November 1918.

In the fermentation of maize or other substances containing starch by the Weizmann process, acetone and butyl alcohol are produced in the proportions of approximately one part of acetone to two of butyl alcohol.

As butyl alcohol had only a restricted use both for war and industrial purposes, experiments were started by Dr. Weizmann in order to develop a process for converting normal butyl alcohol into methyl-ethyl-ketone which, in the pure state, is equally suitable as acetone for the manufacture of cordite. The process, which was a catalytic one, was worked out on a laboratory scale and promised to give good yields. An experimental plant was erected at Toronto early in 1917, and as a result of the operation of this plant a suitable type of large scale catalyser was evolved. Samples

of methyl-ethyl-ketone were made to enable tests to be carried out with it in the manufacture of cordite. The results of these tests being quite satisfactory it was decided to erect a large scale plant at Toronto which, however, only commenced successful operation just before the signing of the armistice.

The results obtained during the war, especially in Canada and the United States, have proved that acetone can be produced successfully on a large manufacturing scale by the fermentation of substances containing starch. The process cannot, however, be considered as a commercial one likely of being capable of competing with the production of acetone by the destructive distillation of wood, because of the relatively high cost of the raw material and the fact that the production of every part of acetone involves the production of two parts of butyl alcohol having very little value for industrial purposes, at all events at the present time.

THE ACETONE FERMENTATION PROCESS AND ITS TECHNICAL APPLICATION.

BY AMOS GILL, B.SC., A.I.C.

The micro-organism used by Dr. C. Weizmann for the production of acetone and butyl alcohol from cereals containing starch is a bacillus of the long rod type, which is stained readily with carbol fuchsin, but only lightly with methylene blue.

Spore formation takes place by slight expansion of the organism in the centre and consequent transparency, the final spore being oval in shape, with only the envelope taking the stain. Spore formation takes place at an early stage when conditions are unsuitable, and in a young culture the presence of a considerable number of sporing forms is regarded as a bad sign. In a vigorous culture spore formation will not take place much before the lapse of 20—24 hours.

The cultivation of the bacillus in the laboratory does not entail any special conditions other than those usual to bacteriological work. Growth occurs readily in various liquid media, that which was used most frequently being 5% maize mash. Many attempts have been made to produce a suitable solid medium. It was possible to rear colonies on a solid medium made up by adding 2% of agar to partially fermented maize mash. This, however, was not always successful, a good deal depending upon the condition of the maize mash, especially with regard to acidity. The most suitable mash for this purpose was one which had been fermenting about 10 or 12 hours and had reached such an acidity that 1·0—1·2 c.c. *N*/10 sodium hydroxide was required to neutralise 10 c.c. of the mash. At the factory in Toronto, A. E. Gooderham has produced a medium which he says gives excellent results with the Weizmann culture. The recipe is as follows: To 1000 c.c. of wort of sp. gr. 1·008 add 1% of gelatin, 1% of calcium carbonate, and 2% agar. Heat gently, filter, sterilise, and make up into tubes. Use for shake cultures, and in making dilutions use an old culture containing spores. Vegetative forms will not grow on this medium, but spores give rise to large colonies of healthy bacilli in 48 hours. Attempts to prepare plate cultures with this medium have been unsuccessful.

The application of the process on a factory scale presents many interesting points, and a few notes on the general methods employed may be of interest.

The first important point is the preparation of a regular supply of good culture for the factory. In practice samples of about 10 c.c. were taken from cultures which were known to be in good and vigorous condition and were put into thinner constricted tubes and allowed to sporulate. The tube was then drawn out to a capillary just above the cotton wool, evacuated, and sealed off. In case tubes of spores have to be carried from place to place it is convenient to seal off at the constriction, so that there is no cotton wool plug. This is rather inconvenient when opening the tubes. An alternative method of keeping spores is to put them down on to the sterilised sand (freed from lime, iron, and carbonates by boiling with hydrochloric acid and washing till neutral). About 2 c.c. of liquor containing spores is dropped on to the sand in a sterile test tube and the plug replaced. The sand is then dried *in vacuo*, the tube being sealed when the sand is completely dry. This method has the advantage of preserving the spores in a dry state and thus eliminating the possibility of decay of the cell wall through contact with the acetone and butyl alcohol in the liquor. Spores are supposed to keep indefinitely on sand; but this statement must be taken with a certain amount of reserve, since it is not more than 3 years since the method was introduced. With reference to the preservation of spores in their own liquid, I have raised a culture which gave satisfactory results, both in the laboratory and in the factory, from a tube which had been kept for eighteen months.

In starting up a culture for the factory, 2—5 c.c. of liquor containing spores was inoculated after pasteurisation into about 100 c.c. of sterilised 5% maize mash. In case of sand cultures, the whole contents of one small tube were used. The tube was placed in a desiccator, which was evacuated and then put into an incubator kept at 37° C. The preparation of the sterile maize mash required considerable care owing to the tendency to form cakes or balls of maize meal, which might contain an unsterile core. The most reliable method was to mash the maize with warm water until there were no lumps, bring to the boil in an open vessel, and then "tube out" and sterilise for 2 hours at 2 atmospheres pressure. The mash must be well stirred during the "tubing out" operation in order to secure an even distribution of the maize skin, which contains the proteins and is necessary for fermentation. With glass apparatus and comparatively small amounts, 2 hours at 1 atmosphere, or 1 hour at 20 lb. will probably yield a sterile mash, but on the large scale 2 hours at 30 lb. was found to give the best results and this was adopted throughout the process for the sake of uniformity.

The object of pasteurising the liquid containing the spores is to kill the vegetative forms, which would immediately germinate but give rise to a weak culture. Vegetative forms have been known to persist for as long as six months, although at the end of that time they were very unhealthy in appearance.

Signs of germination usually appear after about 24 hours and the mash is generally fermenting vigorously by the end of 48 hours from the time of inoculation with spores. At this stage the culture generally has an irregular appearance and contains many "involution" forms, which, however, disappear on carrying over the culture.

The method used for "carrying over" was to remove about 1 c.c. from a vigorously fermenting culture tube and inoculate this into another tube containing about 100 c.c. of sterile mash, the inoculant being introduced at the bottom of the tube. The contents of the tube are then incubated, preferably in a vacuum, since the B.Y. is essentially an anaërobic bacillus. After a further 24 hours have elapsed the culture is again ready for carrying over.

After 24 hours the organisms should be uniform in length and staining power, and will have arranged themselves in groups of four or five,

parallel lengthwise. These groups are formed by the organisms dividing and slipping past each other. In the earlier stages of the fermentation many chains of organisms, end to end, are found. The presence of chains after about 24 hours is a sign of a sluggish fermentation, caused by lack of motility on the part of the bacilli. In a 24-hour culture there should also be a few spores, or sporulating forms, but the presence of a large number is a sign of bad physical conditions, and this will probably be confirmed by determination of the acidity of the mash. A normal culture at 24 hours should require about 4·0—4·5 c.c. of *N*/10 sodium hydroxide to neutralise 10 c.c. of the mash. I shall refer to this acidity later.

The presence of organisms which differ in thickness from the normal bacillus is to be regarded with suspicion. We have found that in many cases the normal organisms show great variation in length, but only in rare cases do they vary in thickness. Incubation at higher than normal temperatures produces swollen forms, but in these cases the whole culture is affected. In the first generation or two from the spore-tube, it is common to find "involution" forms—swollen and distorted in shape, but these usually disappear after the culture has been carried over two or three times. If not, the culture is rejected.

Assuming a culture to be normal in general and microscopic appearance and acidity, one tube containing a hundred c.c. of this is used for the inoculation of a 3-gallon pail. The design of a suitable pail for anaërobic culture work under sterile conditions is a difficult matter, and one which would prove perfectly satisfactory in use has not yet appeared. The pails in use at King's Lynn were easily handled, but had several disadvantages. The pails were made of aluminium and the mash was introduced through an opening in the top, which was closed by a 2-inch screw plug. One tube reached to the bottom of the pail, and the other ended just below the surface. A rubber tube closed by a screw clip was affixed to the longer tube during the sterilisation, while an open rubber tube on the shorter served to let out the steam. An air filter was inserted in this rubber tube when the pail was taken out of the autoclave, and as it cooled down sterile air was drawn into the space at the top of the pail. In inoculating a seed tank from the pail the culture was drawn into the former by reason of the diminished pressure above the mash. There were several disadvantages with this pail. (1) There was no thermometer pocket, so that the temperature of the mash in the middle of the pail was never known definitely. (2) In inoculating the pail from a tube, the 2-inch plug had to be removed and the inoculant poured in. The pail was then shaken in order to mix the inoculant with the mash. This was open to two objections, *viz.*, that there was considerable risk of infection in inoculating the pail, and that on shaking the mash and inoculant together, some aeration of the mash took place, which has been shown to be detrimental to the fermentation. (3) The 2-inch plug-hole, while large enough to permit of infection entering during inoculation, sometimes prevented the thorough cleaning of the pail. (4) The inlet tube was liable to become choked during the inoculation of the seed tank and often caused trouble.

In spite of these objections the pail gave more satisfactory results than others which were tried. At the distilleries a 1-gallon pail was in use. The whole top of this lifted off, and there was considerable difficulty in keeping the joint air-tight and so avoiding infection.

A. Appleyard, of King's Lynn, designed a pail which was very good from a theoretical point of view, but in practice it was most difficult to manipulate. It was spherical in shape, was fitted with a pressure gauge, gas outlet, an outlet to be used for inoculation. A thermometer pocket was also provided. The advantages claimed for this pail were (1) being spherical could be cleaned easily and there would be corners in which pieces of maize might lodge perhaps cause infection; (2) the inoculant could be drawn in under vacuum, and as the fermentation proceeded a certain pressure could be maintained on the pail. This would be a decided help in the inoculation of the seed pot. (3) Anaërobic conditions would be maintained.

The main difficulty was on account of the narrow bore of the inoculating tube, and in practice this invariably became choked. It should be possible to make alterations to the tubes so as to overcome this difficulty and the advantage of maintaining anaërobic conditions would be a decided one.

In the technical application of the process the question of the pail culture is one which needs careful consideration—as this is the last stage of laboratory development. In all factories in which the process has been worked special care has been taken in securing sterility in the pails, as infection at this point is most serious. As a matter of factory routine it is useful to blow steam at intervals through the pails (after cleaning them). This is not absolutely necessary, but it is an extra precaution, which costs very little, and certainly does no harm.

A 24-hour pail culture is used for the inoculation of a seed tank. At the King's Lynn factory the seed tanks were steel vessels, with no enamel lining. The use of these vessels successfully exploded the idea that the organism would not work satisfactorily in contact with iron. The Bub vessels introduced into some of the factories were made of aluminium, and were certainly easy to clean and keep clean, but a 900-gallon aluminium vessel, unless made of very stout material, cannot be sterilised at high pressure, and in any case is costly. Steel vessels which would withstand 15 or 20 lb. pressure could be thoroughly sterilised and also had the advantage of withstanding a vacuum, so that when the mash entered it was not necessary to provide elaborate arrangements for filtering air into the tanks. Even though the air were thoroughly filtered in such cases, there was the disadvantage of aeration of the mash, which was proved to be detrimental to the fermentation. Again, the charging of a seed tank under vacuum makes the inoculation from a pail an easy matter, all that is necessary being to connect the tube and open the valve.

The preparation of the mash for the seed tanks was carried out as follows: 56 stones of finely ground maize was mashed with warm water and run into a cooker and the volume made up to 1300 gallons. The mash was stirred all the time and steam was passed in until the boiling point was reached, a tap being open at the top to allow air to escape. This mash was kept at the boiling point for an hour, to ensure that all the starch granules were broken and also that all air had been driven out of the vessel. The pressure was then raised to 30 lb. and this was maintained for 2 hours. The final volume of the mash was approximately 1600 gallons; it was divided equally between two seed tanks, being blown into them by steam pressure, and cooled to 37° C. on the way. The cooler is an important part of the system, and from the point of view of fermentation must satisfy three conditions. (1) The sterility of the mash must be preserved. (2) The temperature required by the organism must be easily attained. (3) The cooler must respond quickly when slight changes in the temperature of the stream of mash are desired.

The cooling system in use at King's Lynn was

simple in design, but very effective and had the great advantage of being easily sterilised. The coolers were upright coils of copper pipe 2 inches in diameter. Mash was blown in at the bottom of these and passed out at the top, and a stream of water flowed over them. Steam at high pressure could be blown through the whole length of pipe line and cooler. This was always done before the coolers were used, and if at any time they were to be in continuous use, it was done at intervals of about 4 hours. In this case it had the advantage of clearing the cooler of mash which might be clinging to the sides; the time taken for this was soon regained owing to the increased cooling power. The coolers for the large fermentation tanks were exactly similar.

Before charging a seed tank with mash it was sterilised by steam at 15—20 lb. pressure for 2 hours, and a current of steam passed through all valves and cocks. All valves and cocks should be examined carefully after each fermentation, as slight leaks in these, especially at the seed tank stage of the process, may cause much trouble through the entrance of infecting organisms.

The contents of a seed tank were inoculated with one pail of culture—this having been previously examined for acidity and for infection and general state of the culture. At various factories different amounts of inoculant were used. We found that 3 gallons was sufficient to use on an 800-gallon seed tank, and that the seed would be fit for use about 16 hours afterwards.

The mash for the fermenting tanks was made in the same way as that for the seed tanks, but was usually prepared so as to contain about 6% of maize. The fermenting vessels were of 3000 gallons charge capacity, and the cookers used supplied two tanks with mash at one charging. The cooking and sterilisation of this 6000 gallons of mash was a problem requiring careful handling.

There are three essentials for a good cooker: (1) the stirring arrangement must be good; (2) the steam inlets must be well distributed; (3) an accurate pressure gauge or thermometer should be fitted. With these conditions satisfied, the mash can be thoroughly cooked and sterilised, but with any one of them missing the result is uncertain.

The mash was blown over from the cookers to the fermenting tanks, through coolers similar to those in use for the seed tanks.

The question of the amount of inoculant to be used has been the cause of much argument. Some workers assert that a system could be evolved whereby seed is fed by the mash rather than the mash fed by seed, and by this means claim to effect economy in time by effecting quicker fermentations. Others say that the smaller the amount of inoculant the better, arguing that, by introducing large quantities of inoculant, considerable amounts of acetone and butyl alcohol are introduced, and these have a retarding action on the fermentation. My experience at King's Lynn went to show that the best results were obtained by the use of 200 gallons of seed on a 3000-gallon fermenting vessel—or about 6⅔% of inoculant. A normal fermentation was completed in 30 to 36 hours, the end of the fermentation being decided by the cessation of gas evolution. At King's Lynn fermentations were rarely complete in less than 28 hours, but the Canadian workers claim to have completed large numbers in 24 to 27 hours.

The maize mash before inoculation usually has an acidity such that 0·3—0·5 c.c. of *N*/10 sodium hydroxide is required to neutralise 10 c.c. of the mash. After the fermentation begins the acidity of the mash rises gradually to a maximum of 4·0—4·5 c.c. and then begins to fall, the final acidity usually being in the region of 2 c.c. During the fermentation a mixture of approximately equal volumes of carbon dioxide and hydrogen is evolved; the maximum gas evolution is reached some time after the maximum acidity. A sign of a good fermentation is the sudden fall in gas evolution. From a 3000-gallon fermentation tank the total amount of gas evolved during one fermentation is about 9000 cub. ft., and at its maximum about 800 cub. ft. per hour would be evolved. This corresponds roughly with the results of the Canadian workers, who calculate on about 5 cub. ft. per lb. of maize used.

On completion of the fermentation the liquor was immediately sent over to the still—a double column continuous still by Blair, Campbell, and McLean of Glasgow. The still was fed from a wash storage tank. The object was to get the wash out of this tank fairly quickly, as experiment has shown that after transference to the storage tank there was a loss of acetone—partly due to evaporation, but more particularly owing to the decomposition of the acetone and the increase of the acidity of the wash.

So much may be said to be a general description of the process work, without much reference to the difficulties which arose during the working. These I propose to deal with now.

A great source of trouble and anxiety in the earlier days of the process was the repeated sluggishness of the fermentation. This phenomenon appears after 4 or 5 generations in culture tubes, even when using perfectly pure cultures and growing under anaërobic conditions. Many disintegrating forms but very few spores are visible in the slides, and in the factory the fermentations require almost twice the normal time. Several methods were tried to avoid this difficulty. Different media were employed at intervals of one or two generations. The one which I found to give the best results as regards re-invigoration of the culture was a mash made up to the strength of 5% total solids, consisting of a mixture of 90% of flaked or ground rice and 10% of oatmeal. Cultures grown on this medium had a very pleasing appearance, the organisms being straight, sharply defined, and in typical groups, and by carrying over for one or two generations on this medium the culture was certainly improved. Chiefly, however, it was possible to preserve strongly fermenting cultures by discarding tubes at intervals and starting from an old culture containing spores, usually from three to six weeks old. This was done about twice a week. In two generations, starting from such a spore culture, a vigorous, rapidly fermenting culture is obtained.

The question of suitable pails for this type of work was discussed earlier. Aluminium pails were used in most of the factories, but in Canada satisfactory results were obtained with copper vessels. A distinct advantage in a pail would be a suitable arrangement for withdrawing a sample of the culture without exposing the rest of the contents to infection. In factory work a slide of the pail culture, with a record of the acidity, should be kept until the completion of the fermentations for which that pail is responsible. As a rule the purity of the culture is always maintained up to this stage, because everything has been done in the laboratory under more or less ideal conditions, and it was only on very rare occasions that infection was found before the seed tank stage.

Throughout the account of the process I have tried to emphasise the necessity for working under sterile conditions. This is admitted by all workers on the process to be a most important point, and experience shows that the success of the process depends almost entirely on the sterility of the conditions under which it is worked.

In factory working the infecting organisms fall into two classes: (1) Those which enter with air through leaky glands, valves, or cocks; (2) those which are present in the raw material and are not

exterminated during the sterilisation process. With regard to the first class, it may be said that after being used two or three times all valves and cocks can be regarded as leaky, even though it only be to a slight extent, and it seems to be impossible to erect a large-scale plant which can be guaranteed absolutely gas-tight, so that the danger of air infection is always with us. The best guard against this is to work the positive system. When not in use all pipe lines are kept under a positive steam pressure. This ensures the pipe line being kept sterile, and if there is any leak steam will come out and so prevent the entrance of infection. For the first two or three hours of the fermentation in the tanks at King's Lynn there was a possibility of air entering, because the inoculation was carried out under vacuum. All valves and cocks connecting to the open were covered with cotton wool soaked in formalin, so that any air which entered would be cleared of bacteria in the passage through this filter. After the fermentation begins a slight gas pressure is kept on the tanks, and this effectively guards against any leaks.

Air infection may also occur when the tank is opened for cleaning. Theoretically speaking, as long as the culture is kept pure any number of fermentations may follow each other in one tank, without opening for cleaning, but in practice it is found that after two or three successive fermentations the solid matter which remains clogs up the outlet pipes, and time is lost. It is therefore advisable to have the tanks opened and thoroughly cleaned after every second fermentation. This opportunity is also taken for a thorough examination of all the valves and cocks, which are repacked or replaced as required. Particular care must be taken to keep the manhole joint in good condition. We found that vulcanised asbestos joints gave the best results, the manhole being finally tightened when the tank was under steam pressure. After being opened the tank was sterilised for 2 hours with steam at 15 to 20 lb. pressure. Some workers are inclined to consider this excessive, but I think it is as well to regard the extra sterilisation as a matter of insurance, and if there is an error it is best to err on the safe side.

With regard to the second class of infection, namely, organisms present in the raw material, the only guard against this is efficient sterilisation of the mash, and this depends upon the state of the raw material and the type of cooker in use. To begin with the grain should be thoroughly mashed with warm water. No attempt is made at this stage to sterilise the mash, but the object is to effect a thorough mixing so as to prevent balling or caking of the meal. I mentioned earlier what I consider to be the essentials of an efficient cooker. The actual cooking of the mash, as distinct from the sterilisation, is an important point. A mash may be brought rapidly up to a high pressure and kept at that till it is perfectly sterile and yet may not yield the best results. Mash which is overcooked or burnt does not provide a suitable medium for the organism. The quick cooking of maize mash tends to increase the acidity of the mash, and high initial acidity is not favourable to good fermentation. At one time it was considered that maize mash with an acidity of more than 1·0 c.c. *N*/10 sodium hydroxide to neutralise 10 c.c. would prevent fermentation, but although I do not agree with this, I know that sluggish fermentations usually result.

For this reason the mash should be raised to the required pressure carefully, and the steam should be introduced at several points, stirring going on the whole time. In practice we found that sterilisation for 2 hours at 30 lb. was sufficient to produce a sterile mash. With other raw materials the best time and pressure must be found by experiment. For example, it would be impossible to steril wort at this pressure without caramelising sugars. Again, in the sterilisation of a mash mad from horse-chestnut meal it was not advisable use such a high pressure unless the meal coul guaranteed free from bark. In this case at hig pressures poisonous matter from the bark was tracted and taken into solution, and so produc bad physical conditions.

In practice it was found useful to take samp in sterile flasks of mash before inoculation. The were incubated and examined if any sign of fection appeared in the fermenting tank.

Usually the first sign of infection, or of an successful fermentation, was the abnormal acidi of the fermenting mash. After a little experien we could tell by the odour of the mash whether fermentation was proceeding normally or not. a sample smelt sour, the acidity was determin and a microscopical examination made. If a ves was only slightly infected there was hope that might produce some acetone and butyl alcohol, b a badly infected tank rarely recovered, and usua the acidity would rise steadily and practically " oil " was produced. An attempt was made diagnose the infection, and from the type of orga ism it could be generally settled whether the trou was caused by unsterile mash or entrance of sterile air.

Organisms present in the raw material usua gave rise to strongly acid fermentations, partic larly lactic acid fermentation. Certain coccus inf tions from the air produced no acid, but since th multiplied rapidly in the maize mash it may assumed that they were starch devourers, and the full value was not obtained from the mater by our own organism.

The diagnosis of infection in a sample from seed tank required considerable experience. It w usual, in examining a sample from a seed ta before its use as inoculant, to note the gas evo tion and acidity. These, except when cocci such those just mentioned were present, usually ga some guide. A stained slide was made, car fuchsin being used chiefly. In most cases a seco slide, stained with methylene blue, was also pr pared and examined. It was inadvisable to sta too deeply, since certain common infections to the carbol fuchsin stain very readily and, on e amination, these showed up as deeply stained orga isms, while the normal were stained ordinarily In a 16-hour culture it is usual to find a larg number of short organisms. These were regarde suspiciously at first, but we found that usuall they were young B.Y.

A seed tank culture was rejected if there was an definite infection present, or if in the opinion the man who examined it the culture did not appe vigorous enough to carry through a successful fe mentation. Thus it will be seen that in a proper organised factory the supply of seed should alway be greater than the maximum requirement, so as allow of the choice of the best and the rejectio of seed which, although not definitely unhealthy infected, might break down in the fermentatio tank.

When infection is discovered in any seed vessel fermentation tank it must be got rid of at th earliest moment, according to the circumstance Its cause should be investigated and steps taken prevent a recurrence of the trouble. Vessels whi have contained infected mash should be thorough cleaned and given extra sterilisation.

In the technical application of a bacteriologic process such as this efficient scientific contr throughout is necessary. The raw material shou be examined for bacteria, and chemically for star and nitrogen. The latter is most importa

Several of the early failures at the distilleries were due to the fact that the grains were not put into the wort, and as a result the organism suffered from nitrogen starvation. A similar state was arrived at upon one occasion at King's Lynn. Upon investigation it was found that the millers, in order to produce a fine meal, were extracting the maize skin containing the proteins. The fact that the organism can only assimilate the nitrogen in the form of protein was demonstrated at Bromley by Dr. H. B. Hutchinson and P. K. Standring. A method had been tried by which the wort was to be neutralised by lime after sterilisation. The lime was added by error before sterilisation, and in the boiling with lime the proteins were broken down, and although nitrogen was still present in the peptones formed the organism could not assimilate it, and would not ferment the wort. Examination of slides showed no infection, but the appearance of the organism was exactly similar to that noticed in cases of proved nitrogen starvation.

From the general examination of the raw material the method of cooking must be decided upon. For example, Egyptian maize is very easily cooked and very good results are obtained owing to complete extraction of the starch in cooking. On the other hand River Plate maize requires very careful cooking. The sudden change from White African maize to Plate maize was the cause of several failures. It was finally discovered that in order to use River Plate maize successfully it must be very finely ground and carefully cooked with a longer boiling period than ordinary maize, and if possible a slightly larger amount of inoculant should be given. With horse-chestnut meal a good many experimental cookings were carried out. As mentioned earlier, sterilisation of the mash at high pressure extracted tannin and acid matter from the bark, which to a certain extent poisoned the medium. In the laboratory sterility could be attained by cooking at 10 lb. pressure for 2 hours, but in the factory we had to raise the pressure to 15 lb. Later, great difficulty was experienced because many of the nuts were in bad and decayed condition, and moulds were growing upon the exposed parts. To a certain extent these difficulties were anticipated after examination of the nuts as they arrived.

Since the raw material may vary considerably, both in the whole and ground state, it is most desirable in a process of this type to have the milling done under control of the factory staff. If not, the meal supplies should conform to a given standard of fineness, and each batch should be analysed before being used.

With regard to the scientific control of the process work, the first part, namely, the inoculation of culture tubes and pails was always carried out by a qualified chemist, who also supervised the preparation of the mash for these vessels. He also inoculated the seed tanks, and examined and passed all cultures before they were used. There was always a chemist in charge of the process, and apart from the definite routine work he made arrangements at his own discretion in case of difficulties arising.

For example, the fermentation tanks were charged in a definite rotation and emptied in the same order as a rule. Sometimes, however, there would be sluggish fermentations, which did not finish according to the scheduled time. In this case it was a question whether to hold up the following tanks and preserve the rotation, or to wait until they finished. A microscopical examination of a slide and determination of the acidity of the mash or distillation of a small sample for acetone and butyl alcohol content would give a fair indication of whether the fermentation was nearing completion or not. Also the amount of fermented liquor in the still storage tank was taken into consideration, because with a continuous still it was inadvisable to stop it and re-start frequently. Such questions as this also involve the consideration of cost—whether it will be cheaper to lose the extra amount of product, or to keep the factory waiting for it. This question of cost also arises in connection with the large scale distillation of liquor with a low content of "oil." If a fermentation has been unsuccessful, and has only produced a small quantity of acetone and butyl alcohol, it is probably more economical to send the whole lot to waste, since attempts at distillation usually upset the temperature regulation of the still, and at best can only produce a small amount of the required product.

So far I have not dealt with the question of a suitable arrangement of plant for this process except to mention that it must be one in which sterile conditions can be maintained. At H.M. Factory, King's Lynn, we were fortunate in having a plant which was, in many respects, ideal—but during the working many improvements suggested themselves. Probably the weakest point was the battery of cookers which were not designed for the raw materials used by us. In setting up a battery of cookers for this process four main points must be considered: (1) the charging of the cookers, (2) the actual cooking and sterilisation process, (3) the discharging arrangement, (4) the fermentation capacity of the factory.

(1) The best method of getting the mash into the cookers is to mash it on the floor above and allow it to run into the cooker. Methods of mashing and pumping into the cooker have met with little success, since most pumps do not seem to work well with uncooked maize. It is advisable to use open pipes as far as possible because at this stage there is no attempt to sterilise, and in case of any stoppage or block it can be easily rectified.

(2) The fittings on the cooker should be such as to enable the operator to have complete and accurate control throughout the cooking. In making up the volume of mash, due allowance must be made for condensation of steam during the cooking, so that the final volume of mash is of the required strength. The cooker should be made of material capable of withstanding a normal working pressure of 30 lb. per square inch, and should be fitted with a safety valve. It is advisable to have this as high above the mash as possible, since particles of maize are apt to get into it and cause steam leakage or premature blowing off. This remark also applies to the pipe leading to the pressure gauge; a small tap in this pipe is an advantage, so that any mash which may have been carried up into the pipe may be let out. The gauge itself should be fitted to a rigid standard, in order to be free from the effects of vibration. The steam inlets should be well distributed at the base of the cooker, and for the cooking I think it is best to use saturated steam at a somewhat higher pressure than that required. Above all, a good stirring arrangement must be fitted; it must be carefully designed so as to carry the weight continuously for fairly long periods. If the steam inlets are sloped, the stirrer should drive in the opposite direction, or there will be a tendency to form a core of undisturbed mash. An additional safeguard is a thermometer, so that the actual temperature of the mash may be recorded, as well as the pressure. A sample cock is also a necessity, since it is advisable to incubate sterile samples of the mash as control experiments.

(3) The best method of discharging the contents of the cooker is by the introduction of top steam so as to keep up the pressure. The use of pumps for this part of the process would involve extra risk of infection, and there is also a tendency for the grains to stop the action of the pump. The actual discharge pipe would lead from the bottom of the cooker to the coolers. An arrangement must be

provided a pipe connection from this on to the inoculators and then on to the seed tanks. Every pipe in their works, from the time it was empty until it was used again, was under steam pressure. They had found that it did not increase the yield or give any advantage to cook the grain at anything between 15 lb. and 60 lb., but with pressures above 60 lb. better results were obtained. What the reason of this was he could not say. Four fermenters were used and each was filled in turn; that only took a few hours, but it gave the ferment in the first fermenter a chance to start; after that, they did not have to reject any batches. Of course some fermenters were contaminated to a certain extent, but they did not run the product into the sewer unless the yield of acetone was below 60% of the normal.

Dr. REILLY said that during several fermentations at the Royal Naval College Factory they had attempted to separate the acids which were formed. Butyric and acetic acids were not the only acids produced; there was also a small quantity of another organic acid which they had not succeeded in identifying. The acids were formed at first in the proportion of four parts of acetic acid to one of butyric acid. After a few hours the proportion of butyric to acetic acid increased, until more butyric acid than acetic acid was produced. Then, as fermentation proceeded, the proportion of acetic acid again rose. There was a rising curve of acidity for a certain number of hours, and afterwards it fell off; as it fell off, acetic acid was added to bring it up to the maximum again. It appeared that the bacteria or enzymes were actually able to reduce the acetic acidity in considerable quantities. The percentage of acetone was increased by the addition of acetic acid. If acetic acid were made by an ordinary fermentation process, for example, by souring cheap wines, the dilute solution could be pumped directly into the fermentation vat for conversion into acetone. In that way the yield of acetone was increased about 10½% and the butyric acid production was normal. He doubted whether in peace time such a process would have an economic value.

Sir FREDERIC NATHAN said he would like to endorse the statement made by Mr. Grant Hooper that they all knew perfectly well that Prof. Fernbach had been the first to produce a mixture of acetone and butyl alcohol from potatoes. But in the brief sketch he (Sir Frederic Nathan) had put before the Conference, he had tried to avoid anything of a controversial nature. He had stated as briefly as he could certain facts as far as they concerned the production of acetone in this country, Canada, and the United States during the war. That acetone had been produced by means of bacteria given to the Department by Dr. Weizmann. The bacteria had been used in this country, in Canada, and the U.S., and in every case with some form of grain and not with potatoes.

THE EMPLOYMENT OF MICRO-ORGANISMS IN THE SERVICE OF INDUSTRIAL CHEMISTRY. A PLEA FOR A NATIONAL INSTITUTE OF INDUSTRIAL MICRO-BIOLOGY.

BY A. CHASTON CHAPMAN.

When I was invited to contribute to this Conference a paper dealing with the employment of micro-organisms in the service of chemical industry, my first impulse was to decline, on the ground that it would be quite impossible to deal adequately with even a small branch of so wide and complex a subject within the limits of an ordinary scientific communication.

A little reflection, however, sufficed to show that if the temptation to wander too far afield were resolutely resisted, there were one or two aspects of the matter of special importance at the present moment which might very usefully be brought before an audience such as this.

It is, I think, abundantly clear that, during the period of reconstruction on which we are now entering, it will be necessary for this country to strain every nerve to meet foreign competition, and to become as far as possible self-supporting.

It is a truism that the wealth of a country depends on its productiveness and, for far too many years and in far too many cases, we have been content to act merely as agents when we should have been manufacturers. The war has, I think, brought home to us the folly of such a course, and it behoves us to see that we never again become as dependent as we have been on other countries for so many of our vital necessities.

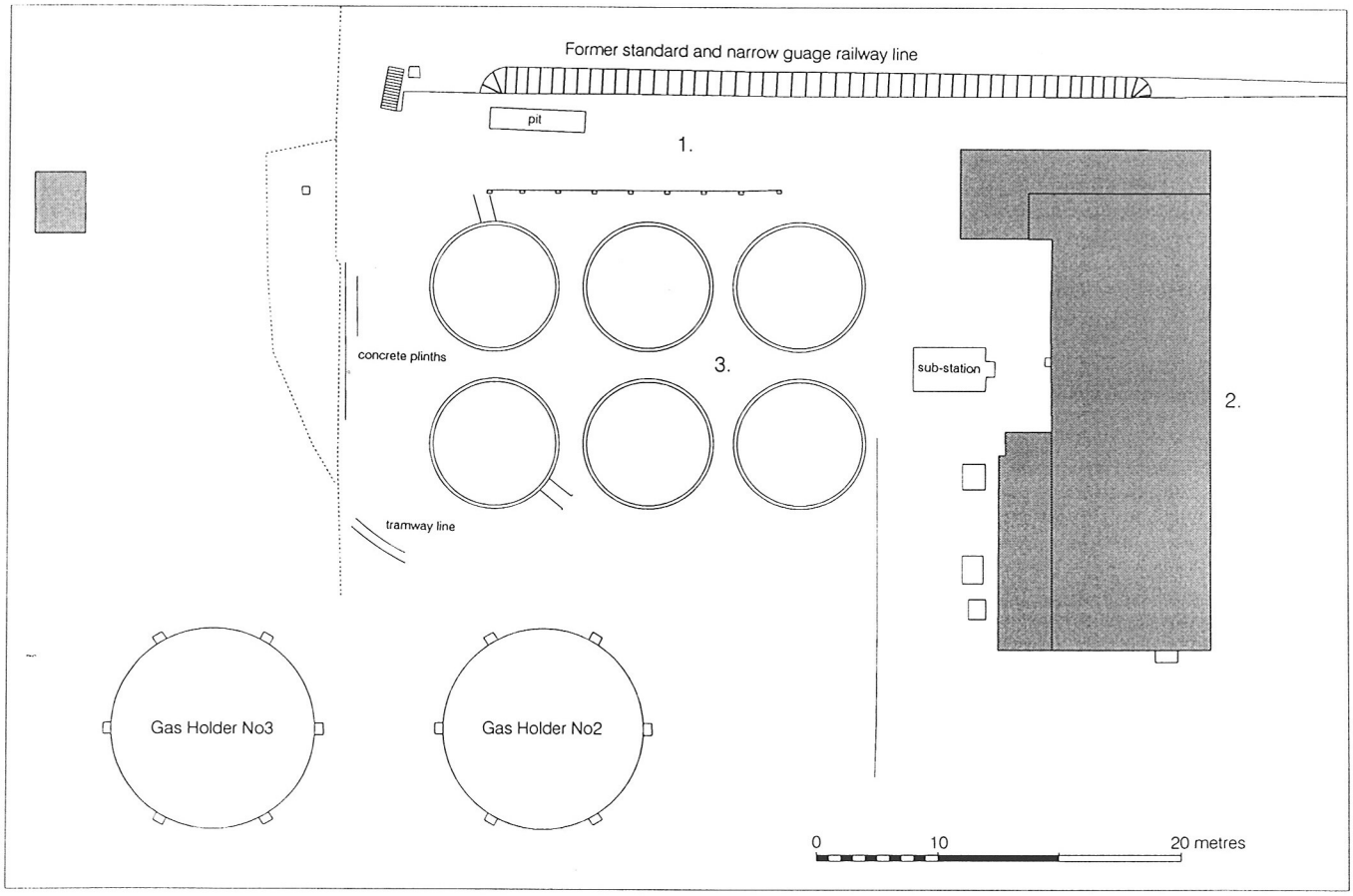
As a branch of chemical industry, industrial micro-biology has not received, in this country, the amount of attention to which its importance entitles it; and in this paper I propose to refer merely by way of example to one or two of what may be called (for want of a better term) the fermentation industries, which have been very seriously neglected in this country, and which it should now be our duty to establish firmly on British soil.

Of all branches of chemical science none, perhaps, has made greater progress during comparatively recent years than that sub-division of organic chemistry to which the term *biochemistry* is now generally applied. Including, as it does, within its purview a study of the chemical constitution of a vast number of naturally occurring compounds, their genetic relationships, their modes of production, and the various transformations which they undergo in the living organism, it will be obvious that the problems concerned are not merely of intense interest, but are frequently of the very highest importance in their relation to chemical industry.

Whilst any attempt to divide chemical processes and chemical products into *vital* and *non-vital*—that is, to assume some special "vital force" operating in living organisms—would be without scientific justification and could scarcely fail to act as a serious obstacle to progress, yet it cannot be denied that, in the great majority of biochemical syntheses and transformations, we are confronted with chemical modes of activity of which, at present, we have but the dimmest conception. When we consider the wonderful synthetic processes accomplished by the leaves of plants under the stimulus of light, the formation of starch or of protein in the growing plant, the conversion of carbohydrates into fat in the animal organism or by some of the microscopic fungi, or any of the numerous instances of enzyme action, and compare the ease and completeness with which these complex transformations are effected at ordinary temperatures with the drastic, clumsy and often wasteful syntheses of the organic laboratory, we must realise how far we are still from understanding nature's methods, and how much we have to learn before we can hope to imitate them.

To quote from the late Professor Meldola: "When we can transform sugar into alcohol in the laboratory at ordinary temperatures by the action of a synthesised nitrogenous organic compound; when we can convert glucose into citric acid in the same way that *Citromyces* can effect this transformation; when we can build up heptane, or cymene, or styrene, or when we can produce the naphthalene or anthracene complex in the laboratory by the interaction of organic compounds at ordinary temperatures, then may the chemist proclaim with confidence that there is no longer any mystery in vital chemistry."

It is true that we are beginning to understand something of the nature of enzyme action and that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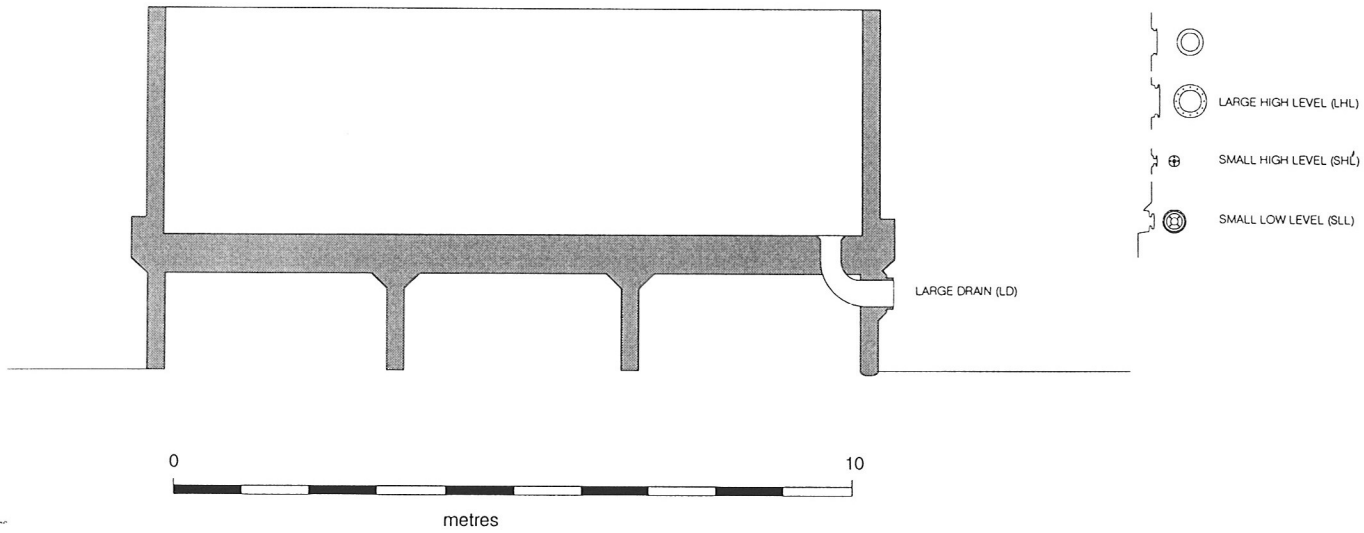
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