NEW ZEALAND

Engineering

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N. Z. I. E. *news section*

A supplement to " New Zealand Engineering " sent to all members of the N.Z. Institution of Engineers

President: G. K. Armstrong, D.S.O., M.C., B.E., C.Eng., F.I.C.E., F.N.Z.I.E.

Secretary: R. W. K. Stevens, C.B.E.

The Secretary's Newsletter

Taxation exemptions

MEMBERS are advised that donations to the Benevolent Association of the N.Z. Institution of Engineers will qualify as a special exemption for tax purposes, up to an overall limit of $100.00, pursuant to Section 84.B of the Land and Income Tax Act 1954.

Members are also advised that in addition to claiming for the amount of their subscription to the Institution, up to a limit of $20.00, they may also claim the cost of subscriptions to engineering or technical journals where that cost is identifiable. Receipts are not required, but each taxpayer must attach to his tax return form a statement showing the names of the journals to which he subscribes and the cost of each.

The present cost of *New Zealand Engineering* is $3.75 per member per year; members will be advised in these columns of any changes in this amount.

Acoustic symposium

The Wellington Polytechnic School of Physics and Electronics, in association with the acoustics section of the physics and engineering laboratories of the Department of Scientific and Industrial Research are sponsoring an acoustics symposium to be held in Wellington in April 1971.

The symposium will concentrate on the noise problems associated with heating and ventilating, and air conditioning plants. Further details may be obtained from:

F. A. Stephens,
Head of P.E.T.E. Department,
Wellington Polytechnic,
Private Bag,
Wellington.

Advanced training requirements

At the Professional Interviews held in October there were 65 candidates; eight of them were unsuccessful. Although it was not necessarily the case this time, it was brought to the attention of the Examinations Committee earlier this year that it is possible for graduate engineers to present their work and themselves in a poor light to the interviewers merely because they have not kept in close touch with their supervising engineers throughout the period of their advanced training, and have not taken enough advantage of the help that is available to them through their seniors to prepare themselves for the interview and for their careers as professional engineers. However, it can be said that a supervising engineer should follow the work of the trainee closely and with care; but everyone knows that it is possible for a trainee to work away quietly without reaching out for the advice and help that might be made freely available if the need for it was realised. Graduate engineers are reminded that it is very much up to them to make the best of the opportunities for training and development that are given them by the Institution's Professional Interview system.

Modern management for engineers—II

Herewith are some further names to add to the list of staff members for the above course to be held from 9 to 21 May 1971:

Professor G. J. Schmitt, who presented the major case study for the 1970 course, will be taking apart again this year, and Professor B. P. Philpott, who has just joined the Victoria University staff from Lincoln College, will also be contributing.

There was an application form for the course in the blue pages in December; if anyone requires another form, or more information about the course, write to the Secretary, N.Z.I.E., or to the Schools Lecturer, Department of University Extension, P.O. Box 2945, Wellington.

THIRD AUSTRALASIAN CONFERENCE ON THE MECHANICS OF STRUCTURES AND MATERIALS

THE Third Australasian Conference on the Mechanics of Structures and Materials will be held at Auckland in August 1971.

Papers are invited for presentation to the conference in each of the following sections:

Analysis and behaviour of structures under static and dynamic loads.

Elastic, plastic and viscoeastic material behaviour including creep and fatigue studies.

Application of computers to structural analysis and design.

Papers with a theoretical emphasis or that describe fundamental experimental studies, are encouraged. Notification of intention to submit a paper should be made to the organising secretary no later than 31 January 1971. The full text is required by 28 February 1971. Successful authors will be advised of the acceptance of their papers in May.

The conference is to be held in the School of Engineering of the University of Auckland from 23 to 25 August 1971.

Further information may be obtained from the organising secretary:

I. G. Buckle, Department of Civil Engineering, University of Auckand, Private Bag, Auckland, New Zeaand.

The Gustave Magnel Golden Medal

BY agreement between the organising committee for the Commemoration of Prof. Ir. G. Magnel and the Association of Engineers certified by Ghent University (A.I.G.), it has been decided to grant periodically a medal, to be known as the Gustave Magnel Golden Medal, to perpetuate the memory of the late civil engineer Gustave Magnel, in his lifetime Professor at Ghent University, the founder and director of the laboratory for reinforced concrete of the University, who died in Ghent on 5 July 1955.

The medal is awarded to the author responsible for the project and design of a building which has been erected and which includes a considerable and outstanding application of concrete or of the prestressed concrete methods. The medal will be awarded irrespective of the author's nationality or of the country where the building is erected.

The applications may either:

(a) Be called forth by the managing committee.

(b) Be made directly by the applicants themselves qualified to obtain the honour. Applications should be sent to the Association of Engineers, University of Ghent, St. Pietersniewstraat 41, 9000-Ghent, Belgium, before 31 July 1971.

(c) Be proposed by third persons or by any private or public authority who are desirous to cause a particularly deserving engineer to be honoured.

Every filed application should be accompanied by:

(a) A short description of the building put forward.

(b) A statement signed by the concerned person and by two witnesses, certifying that the applicant actually and personally is the author of the plan of the considered building.

(c) A letter signed by the author, and by which he declares himself willing to give the managing committee any further information and detailed explanations that may be required to enable the jury to gather an accurate opinion as to the considered building.

(d) A curriculum vitae of the concerned person.

The application and any documents entered in support will be considered confidential and will neither be divulged nor communicated should the application not be followed by an award. In such event the documents will be left at the applicant's disposal.

The successful candidate will be invited to receive the medal during a meeting which will, as a rule, take place in Ghent and performed under the patronage of the A.I.G.

A laureate not residing in Belgium may obtain the refund of his travelling and hotel expenses.

Professional Interview

October 1970

THE following candidates were successful in the Professional Interviews conducted by The New Zealand Institution of Engineers in October 1970:

CIVILS

Pass—Baldwin, W. P.; Bauld, R. G.; Bendall, G. A. F.; Berrill, J. B.; Cassey, K. B.; Cole, W. A. D.; Doar, S. W.; Fraser, I. A. N.; Gale, R. F.; Gemmill, A. D.; Gunson, B. G.; Halliday, B. L.; Hancock, B. L.; Heer, B P.; Holbrook, R. J.; James, K. J.; McGlashan, D. L.; McLennan, D. F.; Odams, R. D.; O'Halloran, C. J.; Packer, M. A.; Peacock, D. H.; Rawlings, T. J.; Reay, A. M.; Rigg, K. M.; Robertson, D. H.; Slack, S.; Steven, T. B.; Sutton, P. N.; Szabo, S.; Thorburn, R. J.; Wilshere, D. S.; Young, A.; Young, D. R.; Armitage, T. G. B.

MECHANICAL

Pass—Christan, J. B.; Grady, M. J.; Otto, I. N.

TELE COMMUNICATIONS

Pass—Baker, S. H.; Bishop, W. T.; Botting, R. E.; Ewart, J. L.; Fletcher, A. L.; Gray, B. 0.; Gudsell, D. C.; Harrison, W. J.; Moore, C. D.; Twinn, J. R.

ELECTRICAL

Pass—Clark, J. C.; Dunn, B. J. V.; Gilmour, R. M.; Gooder, S. B.; Kingsford, D. G.; Peet, J. A.; O'Sullivan, J. J.; Sorrell, L. F.

CHEMICAL

Pass—Hoult, B. D.

Candidates for Election

Any member wishing to communicate with the secretary on the subject of these elections should do so not later than the twelfth day of the month following publication.

For election as Members:

Fletcher, A. L.; Foley, B.; Gale, R. F.; Harrison, W. J.; Meyer, Prof. R. F.; O'Halloran, C. J. Stras, J. C.; Turner, B. B.; White, G. R.; Wood, W. E.

For election as Associates :

Clement, A. S.; Jones, A. E.; Levy, I. C.

For admission as Graduates:

Broome, H. S.; Bryant, P.; Dobson, H. B.; Drayton, G. W.; Knowles, B. H.; Nevill, R. G.; Nicholson, A. J.; O'Leary, A. J.; Old, R.; Reedy, J. W.; Woodfield, P. R.

For admission as Student:

Scahill, P. J.

For transfer to Fellow:

Fraser, P. E.

Associate for promotion to Member :

Crosbie, W. 0.

Students for promotion to Graduates :

Hegley, N. I.; Walker, M. J.

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The journal of
THE N.Z. INSTITUTION OF ENGINEERS, Fourth Floor, Molesworth House, 101 Molesworth Street, P.O. Box 12241, Wellington N.1.
President, G. K. ARMSTRONG, D.S.O., M.C., B.E., C.ENG., F.I.C.E., F.N.Z.I.E.
Secretary, R. W. K. STEVENS, C.B.E.

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Leading article

Articles

General

Cover picture

The new School of Engineering, Auckland University. Building designed by Kingston, Reynolds, Thom and Allardice, of Auckland.

NEW ZEALAND

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THE JOURNAL OF THE N.Z. INSTITUTION OF ENGINEERS Vol 26, No. 1, January 1971

Engineers for the 1970s

EOPLE who become engineers are doers. By definition they wish to use their ingenuity in the processes of construction and development. As a result they tend to be drawn to those parts of the world where growth and development are taking place. **In** every sort of hostile environment, men will be found accepting the challenge of construction and gaining immense personal satisfaction from difficult achievement. And among them are plenty of New Zealand-trained engineers.

For some decades development in New Zealand was virtually stationary, mainly because assured markets from the "Mother Country" for our wool, butter, cheese, and meat gave wealth enough and a glorious natural environment provided contentment. But the resulting stagnation and lack of challenge resulted in a certain smugness and insularity in the national character. One of the best things that could have happened to us was the sharp jolt in 1967 when the wool market dropped and the European Economic Community threatened traditional markets. Because it is a fact that the stimulus of adversity or danger liberates the most constructive attributes of a people.

New Zealand has entered a decade of change. It is change resulting from the response of thoughtful and intelligent New Zealanders to a new challenge to development and economic growth. This challenge found a focus in the National Development Conference and is already being reflected not only in the successful development of new industries and mineral resources, but in the enthusiasm and temper of a people. The 1970s may parallel the vigour of the corresponding decade of the last century when roads, railways, viaducts, and telegraph lines were being constructed to give communication to a new and rugged but immensely fertile and beautiful country.

Nevertheless, development of resources must not be indiscriminate, and must not happen without regard for natural environment, a concern which resulted in last year's Physical Environment Conference. This country must not fail to heed the warning of other countries where industrial develoment has caused a horrifying degradation of water, air, and landscape. The value of development must always be balanced against the possible cost to the environment.

Both the development of resources and the conservation of the environment are to be examined in special sessions at the 1971 conference next month. In both of them are to be found the challenge to those of us who are privileged to be engineers for the 1970s.

A feasibility study of irrigating land with low general grade and broken topography

The proposed Glenavy-Morven irrigation scheme is an area of low general gradient, 0.25 to 0.42%, and broken topography, where circumstances differ from those in other functioning irrigation areas in New Zealand.

A pilot farm was developed to investigate the feasibility and costs of different ways of surface irrigating this type of country.

Border-dyking was the principle means of irrigation and two flows of eight and 16 cusecs were studied. Steerage banking using eight and 16 cusec flows, and steerage ditching using a 16-cusec flow were studied.

Although border-dyking for a 16 cusec flow was slightly more expensive ($54.50/ acre irrigated) than border-dyking for an eight cusec flow ($53.45 / acre irrigated), it allowed for a 16% increase in area to be irrigated as it made more use of the limited fall available. It also gave a 100% gain in irrigation rate and a 50% increase in acres watered per man-hour. The importance of the scraper in land preparation for border-dyking is indicated.

Steerage ditches gave a 10 to 15% coverage and the cost per acre watered was slightly less than that for border-dyking a similar watered acreage.

Steerage banks gave a 60% coverage. The eight cusec flow was inefficient compared to the efficiency of the 16 cusec flow which watered 2½ acres/ h, or 50% that of the 16 cusec border-dyked area.

A. R. TAYLOR
B.AGR.SC., M.S.

ANTHONY ROBERT TAYLOR was born at Christchurch. In 1957 he was a rural field cadet on a North Island hill-country sheep farm; he then attended Lincoln College and graduated in 1962. From 1962 until 1966 he worked for the N.Z. Department of Agriculture at Winchmore irrigation research station as a scientist on the development of a surface irrigation system. He has been associated with the development of the automatic irrigation system at present used on 25,000 acres in New Zealand.

From 1966 to 1967 he attended the University of California, Davis, and graduated M.S. (Irrigation Science). Since 1967 he has been involved in the planning of irrigation systems and the supervision of their construction on farms in New Zealand.

Mr Taylor is an affiliate member of the American Society of Agricultural Engineers, a member of the N.Z. Institute of Agricultural Science, and a member of the N.Z. Association of Scientists.

D. H. RYDE
B.AGR.SC.

DAVID HOWARD RYDE has been a scientist on the staff of the Winchmore irrigation research station since 1967. He is associated with the planning and supervision of construction of the proposed Glenavy-Morven irrigation scheme demonstration farm and at present is studying the effect of wind on sprinkler distribution.

He was born at Christchurch; he obtained a rural field cadetship in 1961 and attended Lincoln College. In 1962 he gained practical experience on a North Island dairy farm and a sheep farm. He completed his degree in 1965; he then worked in Christchurch with the Department of Agriculture's farm advisory division as a farm advisory officer concerned with the planning of farm water supplies, drainage, and sprinkler irrigation design.

David Ryde is an affiliate member of the American Society of Agricultural Engineers, a member of the N.Z. Institute of Agricultural Science, and a member of the N.Z. Association of Scientists. He is a vice-president of the Y.M.C.A., Christchurch.

1. INTRODUCTION

IRRIGATION, an important feature of farming in many parts of New Zealand, is carried out mainly by sprinkling or by the surface method of border-dyking. With border-dyke irrigation the surface of the soil is used to convey and spread the water; sprinkler irrigation uses pipes to convey, and nozzles and pressure to spread the water. Where the determining factor is water availability, sprinkler irrigation can make more efficient use of the available water, but when a river diversion is being considered and ample water can be made available, quite costly farmland preparation for border dyking may be justified because of the ease and cheapness of automation of this type of irrigation. Thus, with a similar injection of capital per acre, 60 acres may be watered by border dykes with one man-hour of labour input whereas only three acres would be irrigated by sprinklers because of the necessity of manually shifting pipes.

Usually, the area to be border-dyked is surveyed to obtain a one-foot-interval contour map. The layout of the border-dyked area must suit the farmer and his management, as well as the soil type, the infiltration rate, the slope, the micro-relief, and the amount of available water. Construction is carried out with road graders and farm tractors and, recently, with motorised scrapers. For the automatic operation a constant flow of water, usually eight cusecs, is required. Headrace design involves the stepping of the headrace to supply water simultaneously to several borders over sills set at the same height at the head of each border. Usually a two cusec flow per border is used, which allows borders to be grouped in fours, although this may vary from two to six. The difference in height between groups of sills depends on the water supply and the total length of sill within a group.

Water is changed from one group to the next upstream by an automatic device timed and operated by an alarm clock (Fig. 1) . These clocks are set on concrete structures which are poured on site between each group. The release mechanism drops a metal gate into the stream at the concrete structure completing the dam; the water then builds up head and flows over the next set of sills upstream. To irrigate 30 acres a farmer will set up eight to 10 gates and release units in about 30 min; this area will irrigate unattended for the next 12 h.

2. THE PROPOSED SCHEME

The proposed Glenavy-Morven irrigation scheme commands 30,000 acres that consists of the flat portion along the north bank of the Waitaki River east of the Redcliffs irrigation scheme, and from the Waitaki River in the south to the Waihao River in the north. This area has an evenly distributed rainfall of 1.5 in/month.

The soils in this area are mostly classified as Pukeri silt loam, Steward very-stony silt loam, Paparoa and Eyre very-stony sandy loam and very-stony silt loam, and Waimakariri stony sandy loam. At least 70% of these soils are suitable for irrigation since they have a good moisture-holding capacity and an adequate depth.

Low general gradients and broken topography are characteristic of the area, the overall fall being 2 to 3 in./chain (0.25 to 0.42%) with a maximum of 4 in.

Fig. 1: Automatic irrigation dam and clock release mechanism. The metal gate is held open by a release mechanism operated by an alarm clock which is housed under the semi-circular cover at the end of the pipe. Water is introduced into the race and flows to the end, where it irrigates the lowest group of borders. Each clock is set in sequence up the race to drop a gate into the water and dam the flow. The water will then flow over a group of sills, usually four, and irrigate an area of 2.5 to 4 acres at one time.

(0.56%). These features are quite different from those in Mid-Canterbury, where slopes are 4 to 6 in./chain (0.56% to 0.83%) with little broken topography; and those of Central Otago, where soils tend to be more sandy and slopes greater. From an examination of some areas in the Orton, Rakaia, and central plains proposed schemes, it would seem that problems similar to those at Glenavy will occur.

Soil fertility appears to be low, mainly because of the large quantity of surface stones and the drought conditions. Young pastures are very open and legumes are sparse, showing an inability to combat drought conditions; old pastures are brown top-invaded and of low productivity. The carrying capacity is about two ewes per acre on the better improved farms.

After representations from the farming community to the Canterbury Interdepartmental Corntee for an irrigation scheme, it was decided that a pilot area wou'd be required to demonstrate the feasibility of irrigating the undulating land in the area at an economic cost.

In April 1965 a 270 acre block of light land, which was adjacent to the present Redcliff scheme and considered suitable for the pilot area, was made available. Winchmore irrigation research station was responsible for the experimental side of irrigation design and layout of this pilot farm which was to follow the system used in mid-Canterbury of stepped headraces and the clock-release mechanism for shifting water.

3. OBJECTS

The main aim was to demonstrate the feasibility of irrigating undulating ground with low general gradient.

The objectives were:

(1) The use of a 16 cusec supply of water to obtain data on labour input and ease of operation of this supply. This supply would also make better use of the limited fall available than an eight cusec supply.

Fig. 6: Steerage banks.

on to block C); the construction of steerage ditches (Fig. 5) on 13 acres and 19 acres of steerage banks (Figs. 6 and 7).

Steerage ditches were constructed along the ridges by a grader. Their size decreased as their length increased, thus causing water to spill out along their whole length on both sides.

The steerage banks, however, created small lakes as they were placed on contour and water was ponded inside the bank and then let into the next ponding area downstream through small gates spread around the perimeter of the bank.

The borders between the stock water race and the main gully were allowed to run into the gully to facilitate some irrigation of this area.

Most of block C was designed for border-dykes using a 16 cusec supply. One main gully had a subsidiary race taken around the edge of it to facilitate the irrigating of the higher ground surrounding it (Fig. 8). Fourteen acres were developed for steerage banks using an eight cusec supply.

For division of the experimental area see Table 1.

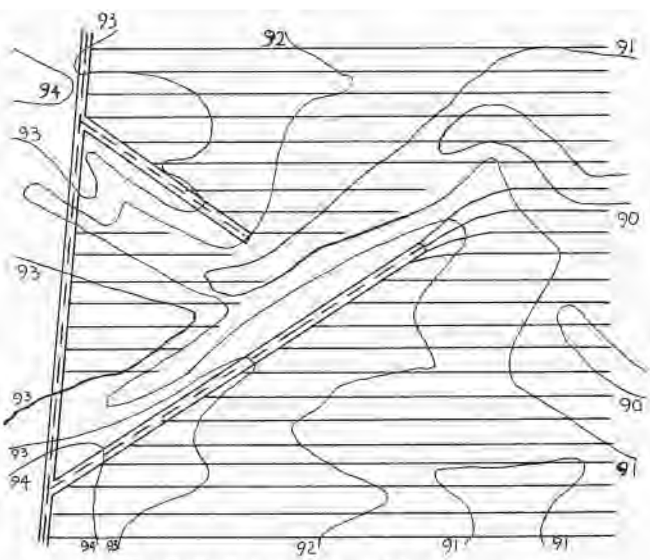


Fig. 8: Gully area irrigated by side races.

The side races were constructed as close to the gully banks as possible. Because of the fall in the side races more automated structures are needed or the race must be built up at a considerable cost. Twisting of the borders offers one alternative (see Fig. 9).

Fig. 7: Steerage banks watering,

Steerage banks were constructed approximately on a contour. The water was introduced from the headrace into the top area first. When this area was flooded the water was allowed to flow into the next area down. The top area was then drained into the second area, which in turn drained into the area below it. About 60% coverage was obtained with this method. The area prepared for an eight cusec flow had the banks at a closer interval.

TABLE 1

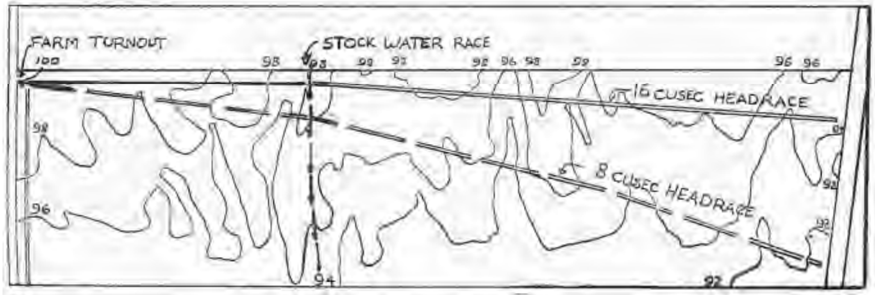
	Acres
(1) Headraces, supply races, lanes	24
(2) Border-dyking, 16 cusec flow	157
(3) Border-dyking, 8 cusec flow	19
(4) Steerage banks, 16 cusec flow	19
(5) Steerage banks, 8 cusec flow	14
(6) Steerage ditches, 16 cusec flow	13
(7) Main gullies	**16**
(8) Dry, behind top headrace	8
Total	270

Fig. 9: Twisting borders.

To follow the greatest fall some of the borders had to be twisted and angled. Here eight borders are narrowed where they meet the headrace. This eliminated either the filling of a gully, or the cutting of a side race around the side of the gully. (See Fig. 8.)

Fig. 10: Comparison of an eight- and 16 cusec headrace along the top boundary.

With a 16 cusec supply only eight acres are left unirrigated. With an eight cusec supply 50 acres would be left unirrigated unless water could be brought to the farm at more than one place. Another method of overcoming this problem would involve compensatory boundary changes.



5. DISCUSSION

5.1. Border-dyking

Road graders were the main construction equipment used but an 11 yd scraper pulled by a Caterpillar D4 tractor was employed initially for headrace construction, and to a limited extent for border-dyking. Later a self-elevating 11 yd scraper was used; this was the first use of these scrapers for the preparation of land for irrigation in New Zealand. Where considerable earthmoving was required, such as in headrace construction and in some borders, the scraper was of considerable value and in fact where headraces were required to cross many hollows and gullies, construction solely with graders would have been impracticable.

Border length was kept to about 12 chains and the width was generally 40 ft, although in some places —e.g. when a terrace was encountered—it was necessary to reduce the width to avoid excessive side cutting. Border direction was generally at right angles to the headrace, but in many places good use was made of the available fall by twisting and angling the borders to allow them to follow the steepest fall thus reducing the amount of expensive side cutting required (Fig. 9). The cost of border-dyke construction was identical for eight and 16 cusec supplies and on this property was $34.20 per acre.

5.2. Headraces

In mid-Canterbury a border-dyke with the above dimensions requires a flow of two cusecs to make optimum use of water and labour. Therefore, an eight cusec supply may irrigate four borders simultaneously; a 16 cusec supply may irrigate eight borders simultaneously. All headraces were designed with a minimum drop of 0.24 ft between groups giving an average grade of 0.05 ft/chain for a 16 cusec supply and 0.10 ft/chain for an eight cusec supply.

These falls were the minimum which could be used; 0.33 ft drops should normally be used as these increase the allowable tolerance on headrace construction and simplify its future management. Thus the 16 cusec supply enabled more use to be made of the available fall since headraces did not have to be turned down country as much as for an eight cusec supply. This enabled the amount of land left unirrigated above the top headrace to be kept at a minimum (Fig. 10).

Even with a small fall this 16 cusec headrace had to be turned slightly down country leaving eight acres between it and the boundary fence unirrigated. However, an eight cusec headrace starting from the same intake point would be turned considerably further down country leaving 50 acres dry behind it. To avoid this situation water would have to be brought on to the farm at more than one point, considerably raising the off-farm cost, or, on a district basis compensatory boundary changes could be made.

As is the general practice in mid-Canterbury a 40 ft irrigated lane was left behind all headraces.

The cost of construction of an eight and a 16 cusec headrace ranged from $9 to $11 /chain and $10 to $14/chain, or on an average $7.70 and $10.50/acre irrigated respectively.

Although the number of in-race structures required in a 16 cusec race is only half that for an eight cusec headrace their larger size makes their construction cost of $18 each almost twice as much as that for an eight cusec headrace at $10 each. This results in costs of $2.90 and $3.20/acre irrigated respectively.

However, the size of the 16 cusec headrace was larger than necessary, and in future its costs could be reduced and not be greatly in excess of an eight cusec headrace.

The number of sills required is governed by the number of borders. Each sill cost $1.20 and was installed by farm labour.

The 16 cusec headraces have a lower labour requirement. Setting up for 12 hours of irrigation takes approximately one hour, which is slightly longer than the three-quarters of an hour needed to set up for eight cusecs (obtained from a survey conducted in the present Redcliffs scheme). The distance between dams is twice as far, although the number of gates required is the same, which results in longer travelling time. However, the irrigation rate at 5 acres/h is twice as fast as that for eight cusecs at 2½ acres/h. This results in 60 acres/man-hour being watered using a 16 cusec supply, and 40 acres/man-hour with an eight cusec supply, which gives a 50% increase in acres watered per man-hour.

Although a 16 cusec flow has these two big advantages over an eight cusec flow, the larger that the flow of water is, the better must its control be if costly damage from erosion is to be avoided. Thus, as on all erodable soils, correct headrace construction, grassing down, and maintenance is of considerable importance.

5.3. Steering ditches and banks

The coverage obtained with the steerage ditches was very low—about 10 to 15%. Because of the broken nature of the country the water tended immediately to track, going to the gullies. This method was expensive since the cost/acre irrigated was only slight'y cheaper than for border-dyking a similar watered acreage.

Steerage banks gave a good coverage at about 60% because of the ponding effect of the water. With this system the efficiency of the 16 cusec supply was much superior to that of the eight cusec supply as the ponds filled in one-third the time, and reduced the loss through drainage. However, the watering efficiency of the 16-cusec supply at 2½ acres/h was low, 50% of that for a 16 cusec border-dyked area. Unfortunately these banks were rather unstable and liable to erosion, and the action of 16 cusecs on them was devastating, but by proper construction and grassing down this effect would be minimised.

An attempt to automate the steerage banks was considered but this was not undertaken as there was insufficient time and the system was not straightforward.

As the headrace had already been constructed for ultimate use by border-dykes these areas were developed to get early benefit from the available water at a low cost—about $2.50/acre excluding the cost of the headrace. It was intended that, eventually, they be turned into border-dyking for automatic irrigation. This can he done at a later stage in the development.

More development work should be done on this system of irrigation since the design and position of the steerage banks could be altered to reduce the cost. More time spent by the farmer on constructing banks and removing high spots would increase coverage, and the efficiency of the system.

5.4. Gullies

On the property used for this study small gullies were filled by the scraper and then border-dyked. There were, however, several main gullies and these, together with the area immediately alongside them, presented difficulties for irrigation.

One gully was dammed across the downstream end in the wipeoff area and was filled with water. This resulted in 2½ ft of water accumulating in the gully and, although 100% coverage was achieved, the resulting inefficiency of this method would preclude its use. Alongside this gully was a fan-shaped area bounded on the other side by a stock water race (Fig. 4). This area was irrigated by taking 16 cusecs down a grassed waterway and splitting it into four borders. The relative rate of flow into these borders was controlled by the use of small levees at their entrances. This method of irrigating a fan-shaped area proved satisfactory.

These main gullies represented less than 5% of the total area, and as obtaining good coverage and efficiency would be extremely expensive, they would be better left dry or partially irrigated by running a border of varying width along their bottoms and allowing water from borders alongside to flow into them. Furrows could be drawn along their sides to achieve better spread of this water.

Subsidiary headraces were taken along the top side of some gullies (Fig. 8) to irrigate irregular-shaped areas created by the gully and border direction. It is important to keep these races as small as practicable and on grade so that construction costs be kept to a minimum otherwise the cost/acre watered can reach $70.

5.5. Comparative costs

The following costs are based on irrigating the 270 acre farm with either an eight or a 16 cusec supply'

These may be divided into:

(1) Contour surveying.
(2) Land preparation.
(3) Automatic control structures.

The farm was contour surveyed for $944. When designed for an eight cusec supply 208 acres could be irrigated giving a surveying cost of $4.50/acre irrigated. A 16 cusec supply would enable 250 acres to be irrigated giving a surveying cost of $3.80/acre irrigated.

Although the number of sills required is the same for either flow, the cost would be $3.10/acre irrigated for an eight cusec supply; it would cost $3.00 for a 16 cusec supply.

The cost of $100 for the irrigation aids (gates and clock release units) is spread over the acres irrigated since the number of units required is the same for either flow. This results in $0.40 for a 16 cusec layout and $0.50 for an eight cusec flow.

A comparison of costs for irrigating the 270 acre farm with an eight or 16 cusec supply is given in Table 2.

TABLE 2
Cost/acre irrigated

	Supply	
	8 cusecs	*16 cusecs*
Area irrigated (acres)	208	250
Contouring	4.50	3.80
Bordering	34.20	34.20
Headraces	7.70	10.50
Sills	3.10	3.00
Dams	3.45	2.60
Gates and clocks	0.50	0.40
	$53.45	$54.00

6. CONCLUSIONS

This country was border-dyked for use with an eight and a 16 cusec supply with similar costs.

Border width should be varied to suit the ground conditions, because the amount of side cutting required can be reduced and the filling of small gullies eliminated by border widths as low as 15 ft. The twisting of borders to cut at right angles to the contours also avoids much expensive side cutting, and this along with the border width recommendation and the better machine rates now being achieved will do much to reduce the cost of border-dyking this country below the figures obtained in this study.

Little money need be spent on major gullies since these represent only a small proportion of the total area. Also small areas of unirrigated pasture in an irrigated area do not suffer from over-grazing as they do on dry-dry areas during a drought.

The 16 cusec flow has two advantages over an eight cusec flow:

(1) The headrace gradient is only half that required for an eight cusec supply. Because of this greater use of the available fall 16% more of the area could be irrigated than when using an eight cusec supply.

(2) This supply gives a 100% gain in irrigation rate and a 50% increase in area watered per manhour.

The headrace is the backbone of the method of automation. On erodable soils correct construction techniques and consequential management are of considerable importance as all precautions must be taken to lessen the chances of handling hazards.

With a 16 cusec supply the off-farm costs will be slightly increased since this flow requires larger ditches at the tail-ends of the scheme than that for an eight cusec supply. This could be more than offset by the extra reticulation costs required to increase the area irrigated on a farm by an eight cusec supply.

Without a scraper, border-dyking some of this country would be impracticable and more use should be made of the scraper both in headrace construction and border work. As a result of the work carried out on this area construction is being undertaken with a scraper in the Redcliffs and Lower Waitaki schemes. This allows for the irrigation of more land and helps reduce costs.

The use of steerage banks should receive more attention and a system of suitable headraces and banks devised as this type of irrigation has a relatively unexplored potential.

7. ACKNOWLEDGMENTS

The authors gratefully acknowledge the co-operation of R. E. J. Corbett on whose property this study was carried out; the Ministry of Works for technical assistance and land preparation, in particular D. S. McCormick for his assistance with the steerage work; and the staff of Winchmore irrigation research station for technical assistance.

The feasibility of establishing a chlorine, caustic soda, and salt plant in N.Z.

D. A. PERHAM
(MEMBER)

This paper studies the feasibility of establishing a plant to manufacture chlorine and caustic soda from a brine obtained by the electrodialysis of seawater. Hydrochloric acid, sodium hypochlorite, hydrogen and salt of high quality would be produced for sale also. The study is based on the production of these chemicals in a plant of initial cell capacity of 4,000 tons/year of chlorine.

1. INTRODUCTION

THERE are two chlorine-caustic soda plants in New Zealand; these are captive plants at the two large pulp and paper mills at Kawerau and Kinleith. The Kinleith plant also supplies most of the hydrochloric acid and some of the sodium hypochlorate solution requirements of the country.

Liquid chlorine is at present imported from Australia and solid or flake caustic soda is imported from various sources.

2. ELECTRODIALYSIS

Electrodialysis is a process which uses ion-exchange membranes. These membranes are made by milling an ion-exchange resin and calendaring with an inert binder, such as polyethylene. The ion-exchange resin is hydrophylic, conductive and permselective and is embedded in a hydrophobic insulating medium that gives flexibility and mechanical strength to the composite material. The membrane properties of high electrical conductivity and ion selectivity are utilised, by the application of Faraday's and Ohm's Laws, in the design and operation of electrodialysis equipment.

When used, as in this application, for the dilution and concentration of two streams, a multimembrane electrodialysis stack consists of many alternating anion transfer and cation transfer membranes separated from one another by electrically-nonconductive spacers. At the end of each stack direct-current electrodes are placed. To allow the electric current to flow perpendicularly to the membranes and solution passages and to allow the solutions to flow parallel to the faces of the membranes in the cells, a flow path is cut in the spacers.

DONALD ALAN PERHAM was born at Rotorua and graduated from Canterbury University. After a period as factory superintendent at the Gracefield works of I.C.I. (N.Z.) Ltd., he became a development engineer for Fisons Ltd. at their Immingham works in Lincolnshire. This was followed by a period as divisional chemist, Gair Company Canada Ltd. in Toronto, Ontario. He returned to New Zealand as training officer, and was then both personal assistant to the director of operations and in charge of the chlorine plant of Tasman Pulp and Paper Co. Ltd., Kawerau. He returned to Canada as the area supervisor of the Cornwall works of Canadian Industries Ltd., Cornwall, Ontario, and later became assistant superintendent of the Marathon Corporation Canada Ltd., Marathon, Ontario.

He then acted as resident consultant for Associated Industrial Consultants Ltd. in the United Kingdom and New Zealand. Before his present position as a consultant in the United Kingdom he was with U.E.B. Industries Ltd., first in Upper Hutt as factory manager of U.E.B. Plastics, and latterly at U.E.B.'s head office in Auckland as production, chief methods, and chemical engineer.

His activities as a consultant include personnel selection from the U.K. and technical investigation work for New Zealand companies.

D. A. Perham was a member of the technical training committee, Plastics Institute of New Zealand, 1963-5, when the first plastics N.Z.C.E. course was established at the Central Institute of Technology in 1965. He was a member of the committee of the Wellington Work Study Society from 1963 to 1964. He holds two patents on Manool extraction from pink pine.

When the flows are started and the current applied to the stack, the Na+ cations in all cells migrate towards the cathode and the Cl^{-} anions migrate towards the anode (see Fig. 1). In a concentrating cell, cations are prevented from migration by an anion transfer membrane and anions are prevented from migration by a cation transfer membrane. In a diluting cell, the cations pass through the cation transfer membrane into the adjacent concentrating cell and the anions migrate in the opposite direction through the anion-transfer membrane into the other adjacent concentration cell.

The usual electrode reactions take place in the electrode compartments:

anode:— ½ H_2O H+ +¼ O_2 (g) + e
Cl ½ Cl_2 (g) + e
cathode: H_2O + e- OH- +½|

Some water is transferred from the diluting cells into the concentrating cells from hydration of the transferring ions and from electroendoosmosis. This water imposes an upper limit on the possible concentration.

Transport numbers for cations in a cation exchange membrane and for anions in an anion exchange membrane approach unity. Some selectivity exists for different ions of like charge. Specially developed membranes exist for separating NaCl from seawater which largely exclude passage of divalent ions. These ions Ca++, Mg++, $SO_4^{=}$ and HCO_3^{-} would cause problems with blocking of the membranes and subsequently in the diaphragm cells of the chlorine-caustic soda plant owing to precipitation of insolubles.

Papers by Mason and Juda[1] and Mason and Kirkham[2] discuss the applications and design of electrodialysis equipment. The structure of ion-exchange membranes and their resulting life and performance are discussed in ref 3.

3. PROCESS DETAILS

3.1. Electrodialysis of sea water

3.1.1. General

Most impetus for the development of electrodialysis as an industrial process has come from the need for production of potable water from saline waters. More recently it has been applied to the recovery and removal of chemicals from solutions and the concentration of waste solutions.

In Japan there has been considerable commercial development of electrodialysis for the production of brine from which common salt and soda ash are made5. Electric power is the most important direct cost so that in the New Zealand situation of reasonably-priced electric power and high internal-freight costs, the electrodialysis process for producing salt from sea water is of obvious interest for a plant located at the northern end of the North Island. The cost of salt in solution has been quoted as being less than $U.S.10/ton for NaCl[5]. This compares very favourably with a price for Lake Grassmere salt delivered to Auckland of about $N.Z.28/ton NaCI.

The 15% NaCI solution produced by electrodialysis is suitable for feeding a diaphragm cell chlorine-caustic soda plant where 50% to 60% of the salt in the saturated brine feed solution (about 26%) to the cells is converted to caustic soda. By evaporation

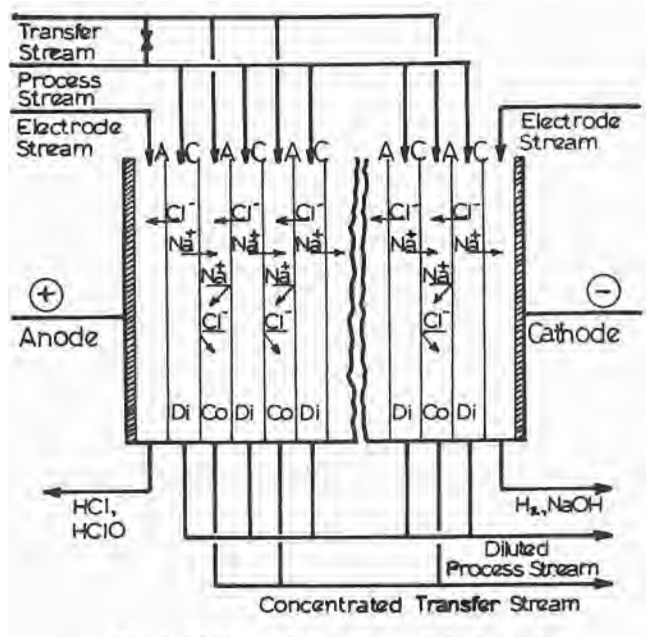


Fig. 1: Multimembrane electrodialysis stack.

of this cell effluent, 50% strength caustic soda solution is produced and most of the salt is crystallised out. This salt, which is chemically pure, can be sold as such after washing and drying, or can be dissolved to make up a fresh feed brine solution for the chlorine cells. In this case, either the recycle salt would saturate the 15% salt solution from the electrodialysis step, or, the normal double-effect caustic evaporation process would be redesigned to provide further evaporation effects purely for brine concentration.

3.1.2. Electrodialysis flowsheet

The flowsheet (see Fig. 2) outlines the electrodialysis process. Sea water is filtered and acidified with hydrochloric acid. Turbidity of treated sea water is maintained below 0.5 parts/million and the pH is held at 6.5 or slightly lower.

Sea water is passed successively in series to the two sets of electrodialysis stack at a flow rate of about 50,000 gal/h. To economise on the feed rate of sea water, the recirculation of sea water from the the second stage stack is allowed. The expected concentration of brine is about 15%.

The electricity required is about 300 kWh/ton NaCl for electrodialysis and about 50 kWh/ton NaCI for auxiliary power. Temperature of sea water varies. The total electricity required ranges from 310 kWh/ton NaCl at 22°C to 420 **kWh/ton** NaCI at 14°C.

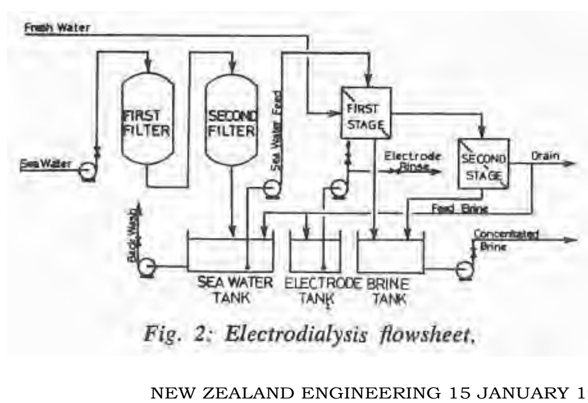


Fig. 2: Electrodialysis flowsheet.

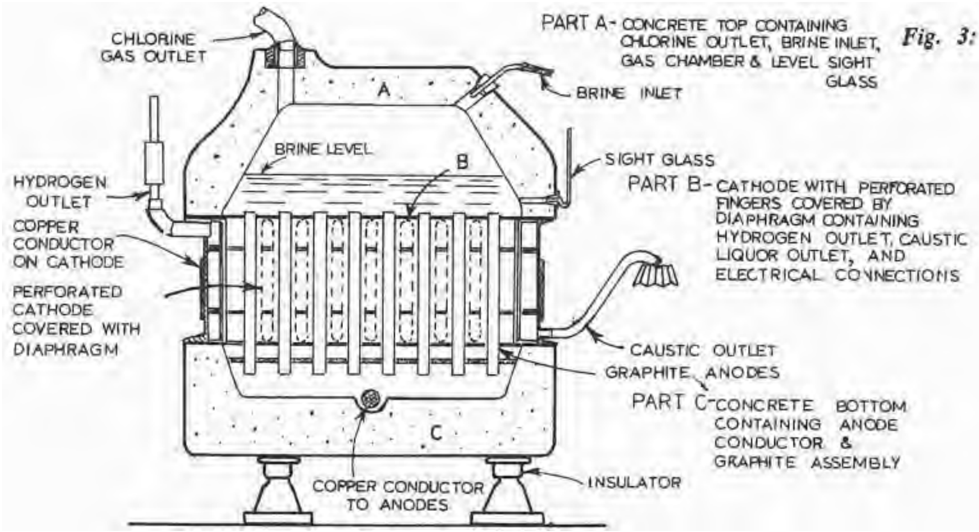


Fig. 3: Diaphragm cell.

3.2. Electrolysis of brine

The electrolysis of brine to caustic soda and chlorine is accomplished in diaphragm cells. Hooker cells are generally used and the type S, which can be loaded up to 10,000 A, is the smallest available. For this plant 10 type S cells operating at 7,000 A, would suffice and the total d.c. voltage across the bank of cells would be about 35 to 40 V. Rectification is a problem at this low voltage; it is felt that the cell should be designed and built, based on the type S, but with half the anode area. Provision of the supporting service of cell building is necessary and the concrete moulds, anode assembly jig, anode-base casting mould, galvanising pot, bitumen mastic pot, cathode washing and diaphragm preparation equipment are not complex and could readily be designed and built for a modified cell design. Indeed, several large American chemical companies make their own version of Hooker cells. A scheme of such a cell is illustrated in Fig. 3.

The flowsheet (see Fig. 4) of the brine, cell room, and chlorine sections of the plant, describes the process sufficiently.

3.3. Brine and caustic soda evaporation

This paper proposes modification of the conventional double-effect evaporation of cell effluent to 50% caustic soda. Because of the high-boiling-point elevation of caustic soda, double-effect evaporation is normal practice; triple effect is sometimes used with a high first-effect steam pressure.

It is possible to generate steam up to 4,000 lb/h or even higher at 150 lb/in^2 with a package boiler which is rated at under the 15 hp Marine Department limit. Above this limit a steam ticket is required. As this plant would run continuously it is desirable to avoid the necessity of having four-shift boiler-house operators.

The available temperature drop between 150 lb/in^2 and 26 in. Hg of vacuum is 240°F. This is sufficient to enable three brine concentration effects to be added after the second-effect caustic evaporator. Material and heat balance calculations show that such an arrangement would concentrate 15% brine up to about 25%.

A flowsheet of the proposed process is given in Fig. 5.

4. DEMAND

4.1. General

The present New Zealand demand for the main products, which would be produced by this plant, are estimated as:

Chlorine	500 tons/year
Caustic soda	5,500 tons/year
Hydrochloric acid	320 tons/year
Salt	70,000 tons/year

Fig. 4: Brine, cellroom, and chlorine flowsheet.

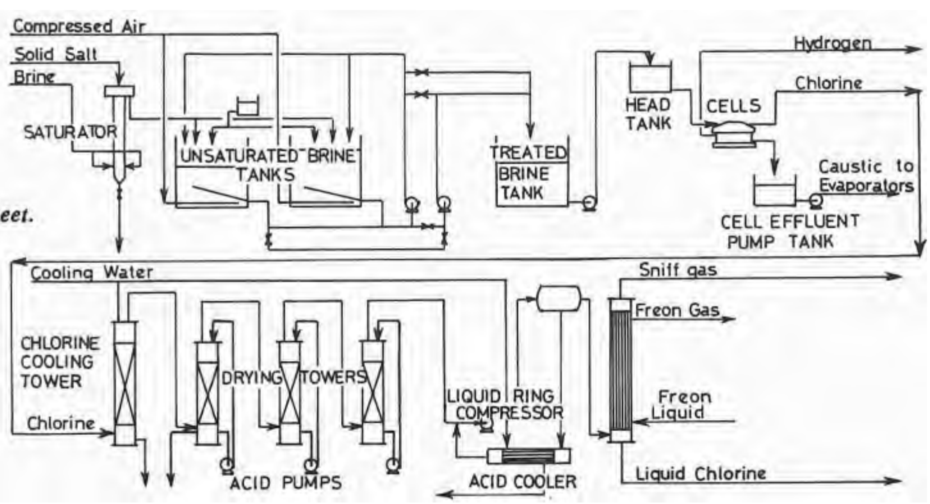
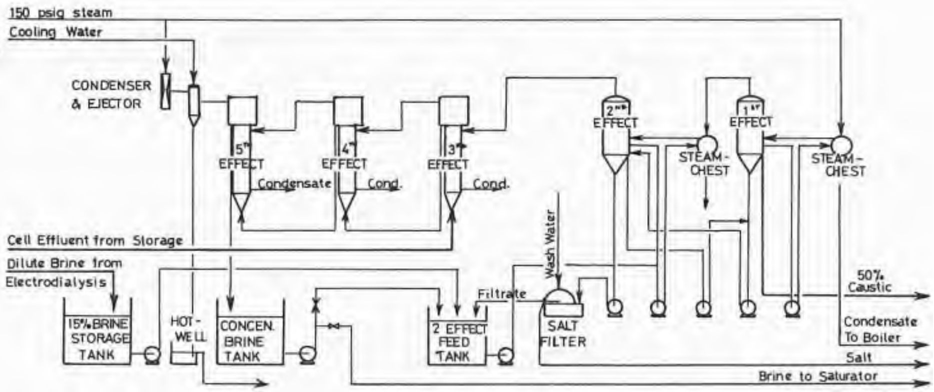


Fig. 5: Brine and caustic soda flowsheet.



Chlorine is an industrial gas with a wide variety of uses. It is a basic chemical of considerable economic importance and is an essential building block in industrial, organic, and inorganic chemistry.

Caustic soda is another basic chemical in both the organic and inorganic field.

Hydrochloric acid has many industrial uses and is finding increasing acceptance in modern steel industry, replacing sulphuric acid as a pickling agent.

Salt is used as a raw material for chemical industry and has extensive use in various branches of the food industry.

4.2. Chlorine demand

The demand for liquid chlorine and hydrochloric acid establishes the rate of output of the plant. History of liquid chlorine imports into New Zealand and the projected demands are shown in Fig. 6.

Comparison between New Zealand and Australia per-head consumptions, which in 1964 were 8.601b for Australia and 0.261b for New Zealand, cannot be used to predict demand. The New Zealand figure is largely determined by its large pulp and paper industries. A steady growth can be expected in the use of liquid chlorine for water treatment, small chemical uses as in the rubber and adhesives industries, and household bleach. If a p.v.c. plant or a titanium dioxide pigment plant were to be started in New Zealand the growth pattern would be completely upset.

However, in New Zealand per-head consumption, apart from pulp and paper, is extremely low. In 1970 the projected per-head consumption of chlorine for

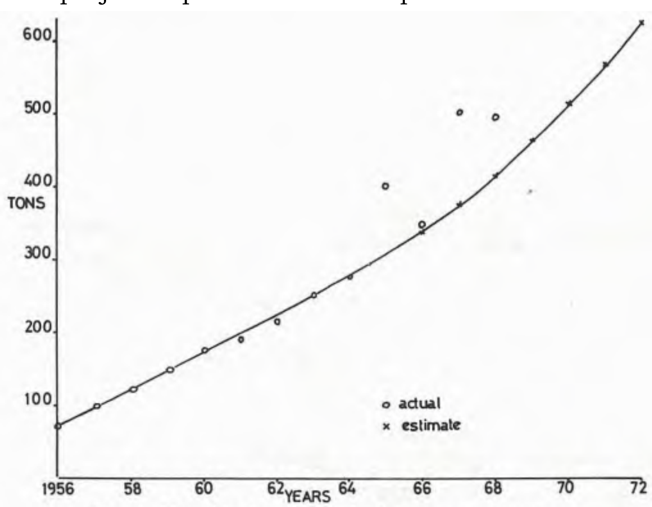


Fig. 6: New Zealand liquid chlorine consumption.

"non-paper usage" in New Zealand is approximately equal to the Australian figure for 1953. This correlation is in reasonable agreement with the time lag in industrialisation between Australia and New Zealand, as evidenced by the two countries' electric power consumption. On this basis the industrialisation time lag is 19 years; the chlorine consumption time lag is 17 years.

4.3. Caustic soda and salt demand

Both these materials are used in much greater quantities than the plant would produce; the Auckland area could readily absorb the full output.

Similarly, the salt output of the plant can be absorbed in the Auckland area for industrial purposes. However, because of the purity of the salt, it would be feasible to capture a proportion of the domestic salt market in which there would be an added margin of sales and profit..

4.4. Hydrochloric acid demand

Since 1961 very little hydrochloric acid has been imported owing to local production. Previous history showed a growth of 11% to 12%/year and by projecting at 9% /year, the same growth rate as for chlorine, a present market figure of 320 tons/year of commercial 32% HCl has been arrived at.

By selling acid at lower than the present price, say at the chlorine equivalent price, not only would most of the market be obtained, but also large user growth would be encouraged, particularly for steel pickling.

4.5. Sodium hypochlorite demand

A fair proportion of the imported liquid chlorine is used for the manufacture of sodium hypochlorate solution. The Kinleith chlorine plant supplies local bleach producers but only on an intermittent basis dependent on the pulp mill demand. Normally only unliquified chlorine would be absorbed in the proposed plant; this small quantity could be sold readily in Auckland.

4.6. Hydrogen demand

The by-product hydrogen over and above that used for the manufacture of hydrochloric acid by the burning of hydrogen and chlorine could be compressed, dried, and sold. There is a hydrogen plant in Auckland so it would be worthwhile studying this market.

5. PRICE CONSIDERATIONS

5.1. Chlorine

The prices of liquid chlorine imported from Australia are:

(i)	In 1,900 lb cylinders	\$345/ton
(ii)	**In** smaller cylinders	\$620/ton or higher

With import control, as it exists for hydrochloric acid, it would be possible to obtain all the existing market at present prices.

5.2. Caustic soda

The price of caustic soda sold as 100% solid in 750 lb drums is about $70/ton. It should be possible to obtain the same price for caustic soda sold as 50% solution.

5.3. Common salt

The North Island price for the lowest grade of Lake Grassmere salt in bags is approximately $35/ton. A special price for Lake Grassmere salt delivered in bulk to Auckland would be about $28/ton. Salt imported in bulk can be landed at lower costs than this but these would be large shipments. It is felt that for a production of 4,000 tons/year of pure salt a selling price of $30/ton is achievable.

5.4. Hydrochloric acid

The price of 32% hydrochloric acid to the repacker is not available but is estimated to be about $154/ton, half the repacker's price for large quantities. This is equivalent to $480/ton for chlorine. A price equivalent to that for chlorine in 1,900 cylinders would be $110/ton 32% HCl.

5.5. Sodium hypochlorite and hydrogen

Sales of these by-products are not considered further as the influence on sales and profit is minor.

6. PLANT LOCATION

A seaside location in the Auckland area is envisaged. Reasons for choosing Auckland are the high proportion (55%) of liquid chlorine imports into Auckland, the greater possibilities of suitable sites, the ready sale for the plant's products including salt where a considerable freight advantage exists, and the reasonable industrial power costs of the Auckland Electric Power Board.

Marsden Point would be another possible location.

7. PROFITABILITY

7.1. Capital cost estimate

The capital cost estimate is:

Total fixed capital	440,000
Working capital	60,000
Total capital	$500,000

7.2. Production cost estimate

Based on initial production of 600 tons/year of liquid chlorine, 320 tons/year of hydrochloric acid, 800 tons/year of caustic soda and 4,000 tons/year of solid salt, the production cost estimate is shown in Table 1.

7.3. Sales estimate

The sales value of the products produced at the level stated in 6.2 are shown in Table 2.

TABLE 1

	$
Electric power	45,000
Fuel, oil	25,000
Water	5,000
Membranes	50,000
Other materials	19,000
Labour, supervision and plant management	43,000
Maintenance	18,000
Amortisation at 20% of fixed capital	88,000
Total production cost	$293,000

TABLE 2

Product	*Tons*	*Price $/ ton*	$
Liquid chlorine			
(i) In 1,900 lb cylinders	480	345	165,600
(ii) In 100 lb cyinders	120	620	74,400
			240,000
Caustic soda	800	70	56,000
Hydrochloric acid	320	110	35,200
Salt	4,000	30	120,000
TOTAL			451,200

TABLE 3

Profit and return on capital

	$	$
Sales value		451,200
Production cost	293,000	
Warehousing, shipping and insurance cost	39,000	
Sales and administration cost	37,000	
Total cost		369,000
Profit before tax		82,200
Tax at 50%		41,100
Net profit after tax		41,100
Return on total capital employed	41,100 / $500,000	= 8.2%

7.4. Discussion

A profit is possible in the first year of operation. However, special depreciation would reduce this profit but would improve the cash position. Because of corrosive conditions most of the assets would be eligible for 20% depreciation. This would mean with special depreciation that the plant would be written down to below 60% of its initial value in two years.

A break-even chart (see Fig. 7) shows how the profit would improve with expanding sales and indeed, together with cash reserves from depreciation, would probably be required for expansion within five years.

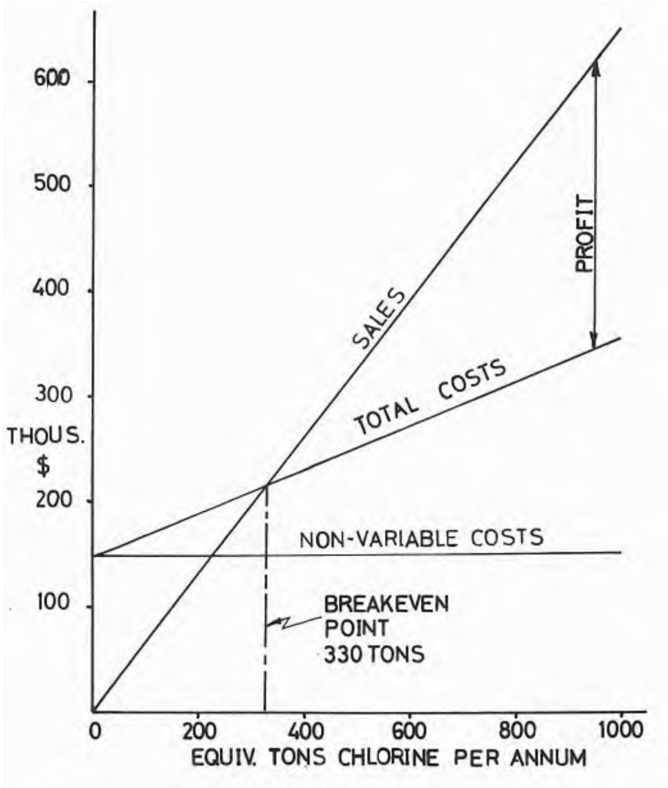


Fig. 7: Breakeven chart.

Leverage by a loan mortgage or overdraft funds obviously would improve the profit return on equity capital.

8. CONCLUSION

The approach used is based on the author's experience in chlorine-caustic soda manufacture with Hooker Chemical Company, Tasman Pulp and Paper Co. Ltd., Canadian Industries Limited and Marathon Corporation of Canada Ltd.; this includes experience with both Hooker diaphragm cells and mercury cells.

It is hoped that interest will be aroused in the possibilities of the combination of electrodialysis of sea water with chlorine-caustic soda production. If this occurs, worthwhile savings of overseas funds will be made and improve, by adequate service, the competitive position of other New Zealand industry.

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PAPERS AND ARTICLES RECEIVED

THE following have been received by the New Zealand Institution of Engineers:

P. J. Andrell—"Feilding sewage treatment plant".

R. W. H. Bracegirdle—"Mechanical handling associated with a glass batching and mixing plant".

D. W. Paddon—"Aluminium in engineering".

M. W. McLarin—"Creep of an unfired ceramic clay".

C. J. A. Nicholas—"Settlement analysis of building foundations".

B. G. Tetley—"Rotating stall or air on an axial flow compressor".

C. C. van Delden—"Expansion of water treatment plant at the Tasman Pulp and Paper Company at Kawerau".

J. A. Ince and C. E. Fenwick—"Kilmore and Madras Street bridges".

R. E. Taylor—"Industrial relations today".

R. W. Steele—"Engineering-accounting relationships in management".

J. W. Lello—"Enjoyment engineering".

O.E.C.D. - "Gaps in technology".

J. Salmcna - "Orly drinking-water-plant sludge treatment".

S. A. Vincze—"Air pollution".

The development of a communications receiver using a drift cancelling loop

R. K. PARR
B.E. (ELECT.)

This paper describes a communications receiver which was developed as far as the tunable intermediate frequency output and is basically a system for band selection. It uses a drift-cancelling loop and phase-locking techniques. Work on this system was initiated at the School of Engineering, Auckland University, as a group effort, and the unit originally developed employed a Wadley loop[1]. The author has since developed a new system which is believed to be superior to the Wadley principle. Dual-insulated gate field-effect transistors have been used exclusively in signal amplifier and mixer stages because of their inherent low cross-modulation and intermodulation properties[2] and simplicity of circuit design in these stages.

ROGER KENNETH PARR was born at Te Awamutu and is a project design engineer with Racal Pty. Ltd. in Sydney.
He began his career under the Post Office graduate engineering training scheme but decided to go abroad to gain more experience.

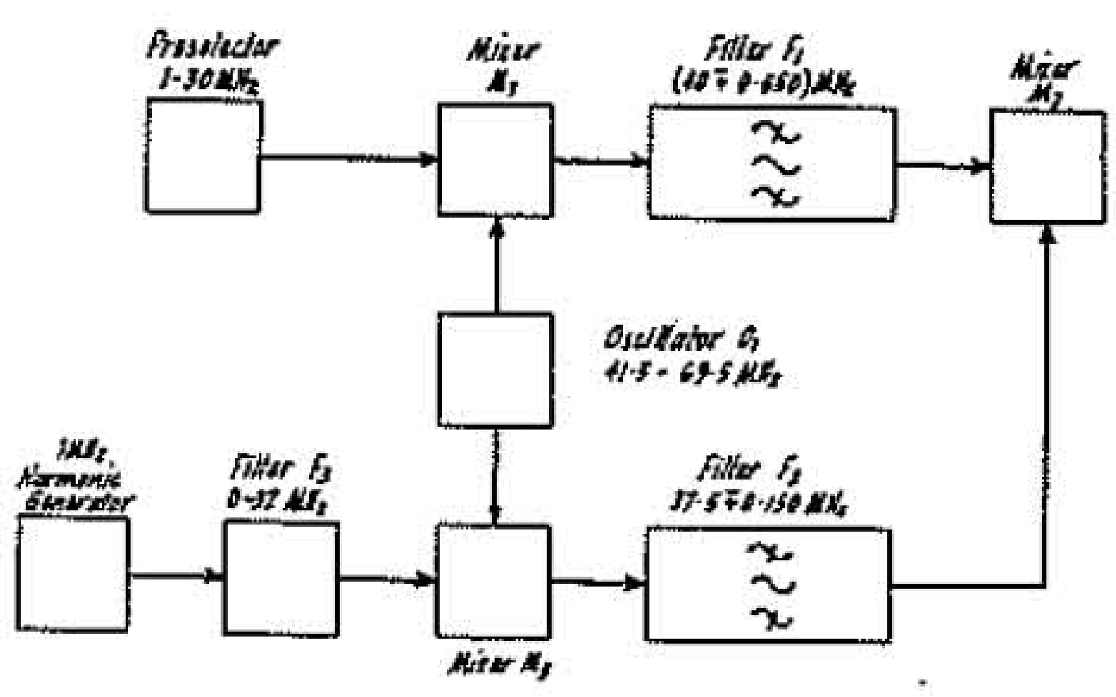

Fig. 1: The Wadley loop.

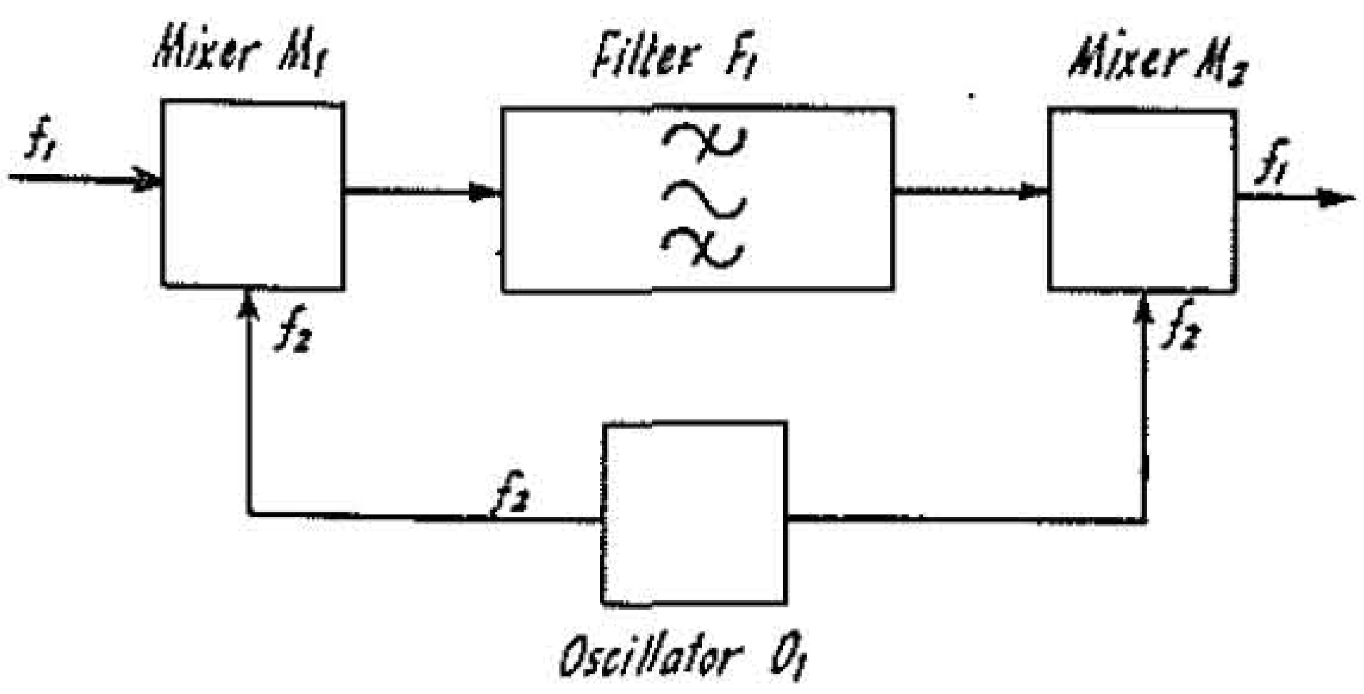

Fig. 2: Simplified Wadley loop.

This paper was first received 19 August 1968 and in this revised form 6 July 1970.

1. INTRODUCTION

THE system described accepts signals in the frequency range of 1 to 30MHz in 29 bands, each 1MHz wide, and has a tunable intermediate frequency output at 2 to 3MHz. The principle of this system is based on the Wadley concept.

1.1. The Wadley loop

The Wadley loop (see Fig. 1) is basically a drift-cancelling loop. A simplified version of it is shown in Fig. 2; the input and output frequencies are the same and not affected by the oscillator which is at frequency f_2. The Wadley loop is an extension of this principle and the injection frequencies into mixers M_1 and M_2 are displaced by introducing a 1MHz comb generator and an additional mixer with its filter, F_2, into the drift-cancelling loop.

Filter F_2 is tuned to 37.5MHz and an output from mixer M_3 will be accepted by the filter when oscillator O_1 is tuned to:

$$[N+0.5]\text{MHz where } N \text{ is an integer} \quad \ldots (1)$$

The incoming frequency range to mixer M_1 is 1 to 30MHz and the centre frequency of filter F_1 is 40MHz. To produce the correct mixing product for the filter, from the mixer, the tuning range of oscillator O_1 which also drives mixer M_1, is restricted to 41.5 to 69.1MHz. For each correct setting of oscillator O_1 an input segment of frequencies at:

$$\{\ [N+0.5]-[40\pm0.5]\ \}\text{MHz} \quad \ldots (2)$$

is heterodyned in mixer M_1 to:

$$[40 \pm 0.5]\text{MHz} \quad \ldots (3)$$

and accepted by filter F_1. Simultaneously, a harmonic at:

$$\{\ [N+0.5]-37.5\ \}\text{MHz}$$

is heterodyned to 37.5MHz and is filtered from adjacent harmonics by filter F_2, and used to drive mixer M2. At mixer M2, the output from filter F_1 is heterodyned by the 37.5MHz drive from filter F_2 to

$$\{[40 \pm 0.5] - 37.5\}\text{MHz} \qquad (5)$$

i.e. 2 to 3MHz

which is the tunable intermediate frequency output of the system.

Oscillator O1 has 29 positions between 41.5MHz and 69.5MHz which satisfies equation (1) and at each position a unique portion of the incoming signal spectrum is heterodyned in mixers M, and M_2 and appears in the tunable intermediate frequency output. As the oscillator is inside the drift cancelling loop, setting errors are cancelled out and the amount of the error is restricted by the tolerable variation of drive to mixer M_2 from filter F_2 owing to its bandwidth. Also, a setting error of the oscillator will decrease the discrimination provided by the filter against adjacent heterodyned 1MHz comb products present in the output of the mixer M3.

The Wadley loop has several defects which arise from the harmonic heterodyning and filtering process:

(1) The requirement of a reasonable setting accuracy of oscillator O, to enable maximum response from filter F^2 to the wanted heterodyned harmonic and maximum rejection of adjacent harmonics.

(2) A spurious signal at 37MHz which appears in mixer M^2. It is generated by the 1MHz harmonic generator, attenuated by filter F_3 and is accepted by filter F_2 where it is within its bandpass limits and is passed into mixer M_2. The level of this spurious response depends on the level at which it is generated and the amount of attenuation offered by filter F3.

(3) Spurious signals at [37.5 ± 1 ± 2 etc.]MHz which appear in mixer M_2. These are present because of the limitations of performance of filter F_2 in filtering the output of mixer M_3 of the heterodyned comb products from the 1MHz harmonic generator. The rejection of these spurious signals will be less if oscillator O1 is not at an exact setting.

The first defect is inherent in the system. The second and third defects are related to the design of filters F_2 and F_3 and the level of these spurious signals depends on the effectiveness of these filters. The third defect will produce signals at the 2MHz and 3MHz tuning points of the tunable intermediate frequency output and the level of these spurious signals should be of the order of microvolts for them to be below the noise level of the system. The second defect will give rise to spurious output products when strong incoming signals are present in mixer M^2.

1.2. The new system

This system (see Fig. 3) overcomes the defects of the Wadley loop and does not require high performance filters to reduce spurious signal levels at mixer M_2. The principle of operation is:

An oscillator O_2 at 37.5MHz is introduced into the drift-cancelling loop and drives mixer M^2. This oscillator is phase-locked to the 37.5MHz output of filter F_2 and does not interfere with the drift-cancelling properties of the loop. Phase locking is achieved by comparing the outputs from filter F_2 and oscillator O^2 in a phase-sensitive detector (p.s.d.) and using the output to control oscillator O_1 which is a voltage-controlled oscillator (v.c.o.) thus completing the phase-locked loop. The output of the p.s.d. is filtered with a simple low-pass filter to control the bandwidth of the phase-locked loop. When oscillator O1 is set so the system will receive a particular band and it is within the capture range of the phase-lock loop phase locking will occur—i.e. the control voltage to oscillator O, will pull its frequency to:

where *N,* is the particular integer for the band coming into the system. Drift of oscillator O_2 from its nominal frequency will, because of the phase-locked loop, pull oscillator O, from $[N_1 + 0.5]$*MHz* by an amount equal to the drift of O2.

i.e. $\Delta f_{01} =$

under phase-locked conditions. This drift cancels out in the drift-cancelling loop. A similar situation exists in the Wadley loop where mis-setting of oscillator O1 introduces an error frequency which also appears in the output of filter F_2 (and mixer MO. The basic difference between the two systems is where the error is initiated. With the system described here the error initiates in oscillator O_2 which is fixed-tuned and prealigned. Drift in this oscillator offsets the output from filter F_2 from its nominal frequency and reduces the drive level from the filter into the p.s.d. The only effect this drift can have is to reduce the filter output level to the point where phase lock cannot be maintained or to pull the loop outside its holding range, but drift as severe as this will never occur normally.

The advantages which this system has over the Wadley loop are:

(1) Mixer M^2 receives constant drive from oscillator O_2 regardless of the setting of oscillator O1, maintaining optimum mixer performance.

(2) Spurious signals present in the output of filter F_2 have no effect on the p.s.d. and do not appear in mixer M_2. Performance of filters F_2 and F_3 do not have to be as critical as those in the Wadley loop. The greater purity of oscillator drive to mixer M^2 possible with this system means that spurious-signal output products generated from spurious signals in the drive to mixer M_2 can be considerably less than those in the Wadley loop.

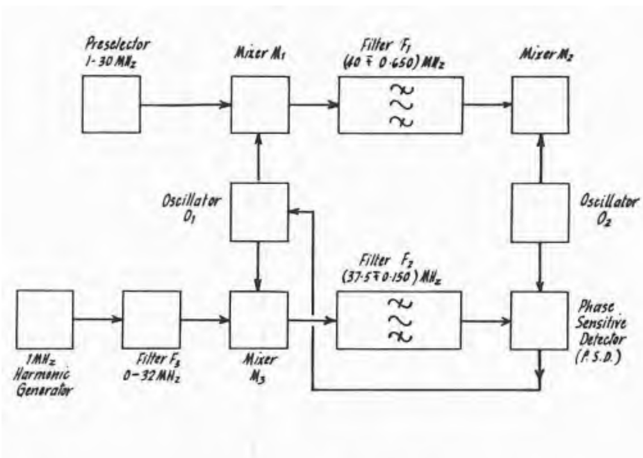

Fig. 3: The new system.

2. CIRCUIT DESCRIPTION

2.1. The preselector

The preselector (see Fig. 4) provides selectivity of the incoming signal spectrum ahead of mixer M1 and provides a small amount of amplification at the selected frequency. A dual-gate field-effect transistor is employed to provide amplification and its input gate and output drain are synchronously tuned with switchable matched coils and a dual-gang variable capacitor. Gain control is effected by applying variable bias to the second gate of the field-effect transistor (f.e.t.) and this bias is provided from the tunable intermediate frequency system. The preselector tunes the frequency range 1 to 30 MHz in four bands, 1 to 2MHz; 2 to 8MHz; 7 to 16MHz; and 15 to 30MHz. The input to the preselector has been designed for use with a general-purpose high-impedance aerial. Tuning of the system is dual control because of the difficulties of ganging the preselctor to the tunable intermediate-frequency system.

Accurate tuning of the preselector is not necessary and on the higher bands it needs only to be peaked a couple of times for each band.

2.2. Mixers M, and M_2 and filter F, (see Fig. 5)

The output of the preselector passes into the signal control gate of mixer M_1 which is a f.e.t. Mixing is achieved by driving the second control gate of the mixer with oscillator O1 and the wanted mixing product at

$$[40 \pm 0.5]\text{MHz} \qquad (3)$$

is selected by filter F_1, which has a fiat response at $[4 \pm 0.650]$MHz. It consists of two stages of back-to-back overcoupled transformer pairs, the stages being coupled with a f.e.t. The f.e.t. is used primarily to isolate the two stages of filtering and simplify alignment procedures. Some gain is provided to compensate for the filter insertion loss.

Output from the filter passes into the signal control gate of mixer M2 which is an f.e.t. Mixing is

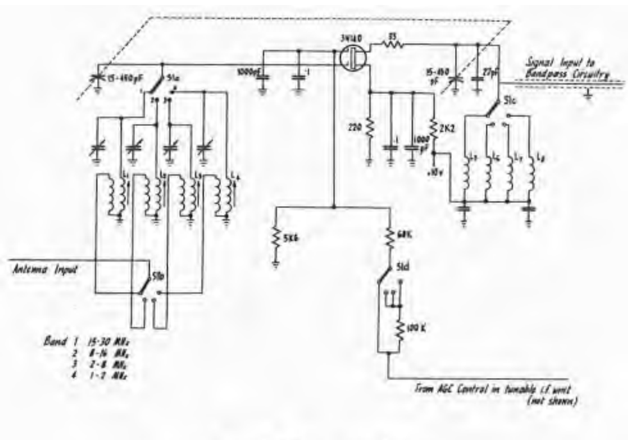

Fig. 4: The preselector.

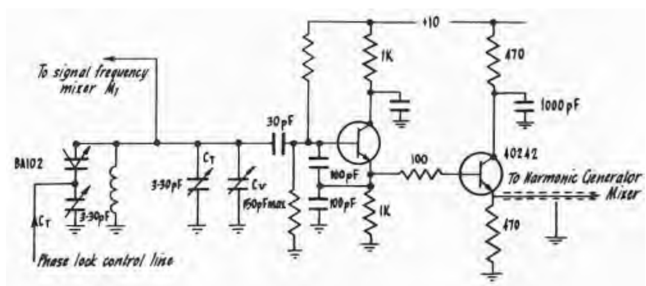

Fig. 6: Oscillator O_2.

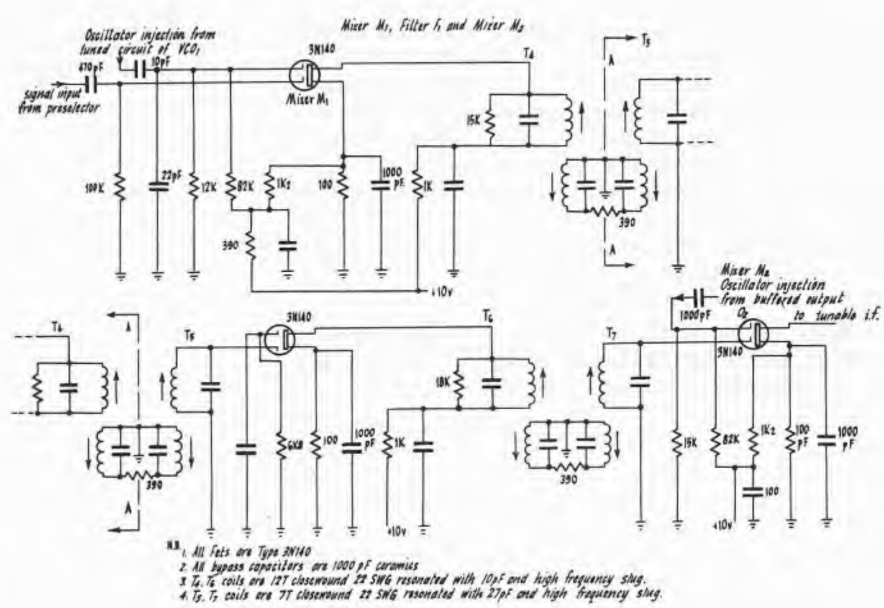

Fig. 5: Mixers and filters.

achieved by driving the second gate with oscillator 02 and the wanted mixing product is in the frequency range of 2 to 3MHz and is selected by the tunable intermediate frequency system.

Biasing and oscillator injection of each mixer is optimised for best linearity.

2.3. Oscillators O1 and O2

Oscillators 0_1 and O_2 are very similar and use a Colpitts form of circuit. Oscillator O_1 (see Fig. 6) is tunable over the range 41.5 to 69.5MHz and has a voltage-variable capacitor (varicap) across the tuned circuit to provide voltage control of the frequency as this oscillator is in the phase-locked loop. Oscillator O_2 (see Fig. 7) is fixed tuned at 37.5MHz and its inductor and tuning capacitor are identical to those in filter F_2 so that the oscillator and filter will track with temperature changes.

Both oscillators drive a signal mixer and in each case this drive is taken directly from the tuned circuit of the oscillator. Oscillator O1 also drives mixer M3 and this drive is provided from an emitter follower from the oscillator. Oscillator O_2 also drives mixer M2 and this drive is provided from an integrated-circuit isolating amplifier which has extremely small coupling between output and input and provides excellent isolation between oscillator O_2 and the phase sensitive detector.

2.4. The harmonic generator, filter F_3 and mixer M3
(see Fig. 8)

The harmonic generator has a 1MHz crystal-controlled oscillator from which is generated a harmonic comb of frequencies in a distorting amplifier. The oscillator is a crystal-controlled astable multivibrator and it drives a common emitter stage which acts as a switch to produce the harmonic comb. Harmonics above 32MHz are not required for the operation of the system and a peaking circuit in the collector of the switching stage maintains the harmonic comb level to 32MHz. The harmonic comb is then passed through a low-pass filter F_3 to attenuate comb frequencies above 32MHz. The filter output is fed to the signal control gate of mixer M_3 which is a f.e.t. The second gate of the mixer is driven from the emitter follower output of oscillator O1, and because of the good isolation between the two mixer gates, negligible energy from the harmonic generator leaks via oscillator 0, into mixer M to appear as spurious signals at each "megacycle" tuning point of the system. Output products are passed into filter F_2 which• selects the required product at 37.5MHz and will appear when oscillator O1 has been set for one of the 29 incoming bands and the phase-lock loop has pulled into lock.

2.5. Filter F2

Filter F2 (see Fig. 9) has a centre frequency of 37.5MHz and a bandwidth of 0.3MHz. It also provides amplification to raise the level present at the filter input sufficiently to drive the p.s.d. Amplification is achieved by two transistor cascaded stages and selectivity is obtained from the three transformers T_1, T_2, and T_3. A centre-tapped winding on transformer T_3 provides balanced push-pull drive to the **p.s.d.**

2.6. The phase sensitive detector (p.s.d.)
(see Fig. 10)

This is essentially a detector which works down to d.c. Both the output from filter F_2 and the reference drive to it from oscillator Q_2 are sinewaves and the resultant output from the p.s.d. will be as shown in Fig. 11. This output voltage passes through a simple low-pass filter to set the bandwidth of the phase-locked loop and into a d.c. amplifier (see Fig. 12), which has an input threshold voltage of approximately 0.6 V. The amplified voltage swing in the collector circuit is applied to the varicap oscillator O1 to complete the phase-locked loop. Once the loop is phase-locked there will be a relative phase displacement between the output from filter F_2 and oscillator Q2, so that the detector will produce an output voltage. The amount of phase displacement will depend on the manual setting of oscillator O1 The upper and lower voltage limits on the varicap are set by transistor TR1 (see Fig. 12) and the sweeper unijunction transistor and occur when TR1 saturates or the firing voltage for the unijunction transistor is reached. The loop bandwidth has been made narrow—i.e. approximately 30 Hz to reject loop response to spurious signal outputs from filter F_2. Thus the phase-locked loop exhibits considerable hysteresis and to overcome this, a sweeper circuit is connected to the loop-control line. This consists of a unijunction transistor and whenever the loop-control line voltage rise above a certain level—i.e. approximately 6 V, the unijunction sweeper will automatically start sweeping the loop-control line voltage up and down. If the phase-locked loop is within its holding range—i.e. phase lock will occur with the loop-control line voltage between its upper and lower limits, the sweeper will sweep the loop-control line through the point where phase lock will occur and the output from the p.s.d. will drive the collector of transistor TR_1 to the correct voltage. This

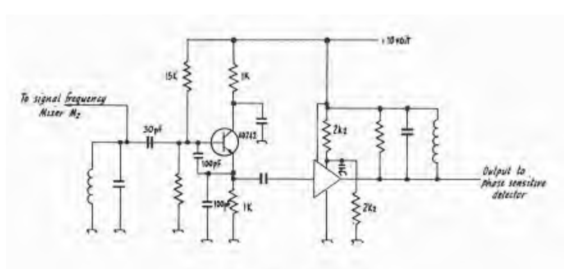

Fig. 7: Oscillator O_2

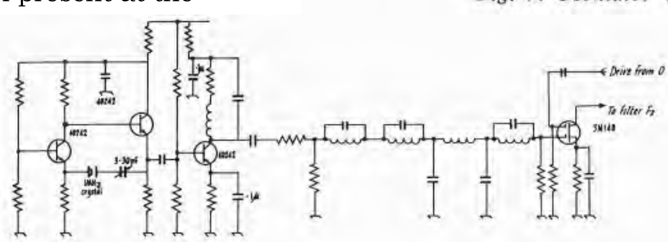

Fig. 8: Harmonic generator, filter F_3 and mixer M_3.

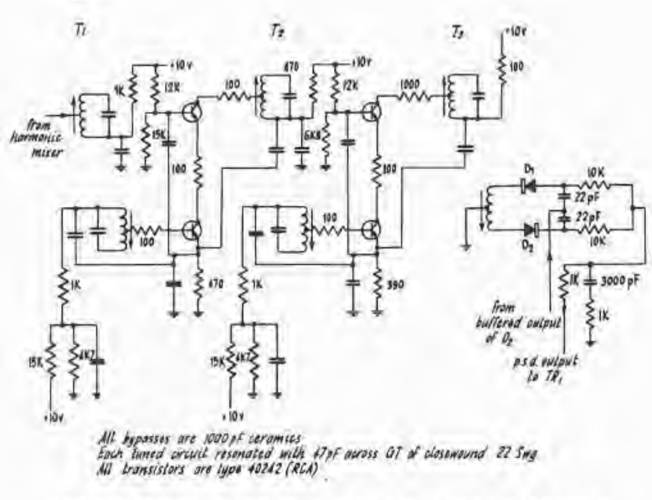

Fig. 9: Narrow-band filter and phase-sensitive detector.

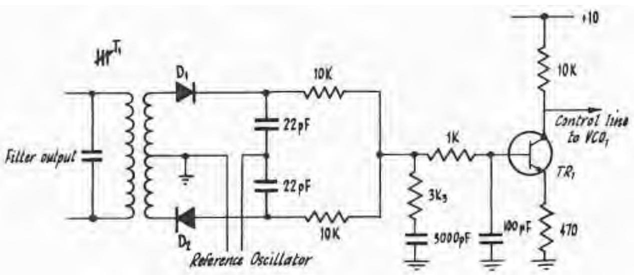

Fig. 10: Phase-sensitive detector.

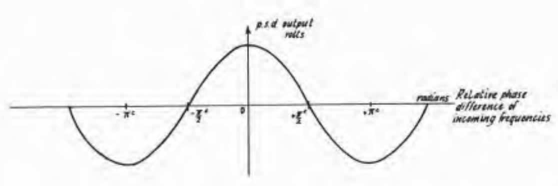

Fig. 11: Output from phase-sensitive director.

will stop the unijunction sweeper from running and phase lock will be established. To indicate phase lock, a lamp is provided and if the sweeper circuit is running, the alternating voltage is sensed in a simple detector and this will latch up a pair of transistors and the lamp will light up. With phase lock, these latching transistors are pulled into the "off" condition.

3. SPURIOUS RESPONSES

There are two forms of spurious responses which can be generated in a radio receiving system. One is due to non-linearity of the signal circuitry and the other is due to pickup, as signals, of internally-generated frequencies. A further case arises where non-linear mixing of the internally-generated frequencies, either with themselves or with incoming signals, can give rise to spurious outputs. In the system described the internally-generated frequencies are from oscillator O1 oscillator O_2 at 37.5MHz and the MHz harmonic comb. The frequencies of oscillators O1, and O_2 are above the incoming signal spectrum and do not give a direct spurious response but the 1MHz harmonic comb can be picked up directly as signals and screening of the harmonic circuitry is essential, to minimise this form of spurious pick-up. Each signal stage has some degree of non-linearity, particularly the mixer stages, and is capable of producing spurious outputs in the form of inter modulation and cross-modulation. Coupling of the output of filter F2 into mixer M_2 will give rise to spurious outputs because of the 1MHz sidebands of the 37.5MHz filter output and leakage of the 37MHz harmonic from the harmonic generator. The level of this form of spurious signal will depend on the isolation that can be achieved between the filter and mixer and with proper circuit layout and use of an effective isolation stage between oscillator O_2 and the p.s.d. the level can be reduced such that spurious output signals are reduced below the noise level of the system. Non-linearity of mixer M_1 will cause generation of harmonics of incoming signals and those which fall within the pass-band of filter F_2 will appear in the output of the system as spurious signals.

4. PERFORMANCE FIGURES

Performance figures were obtained by using a tunable intermediate frequency system with the system

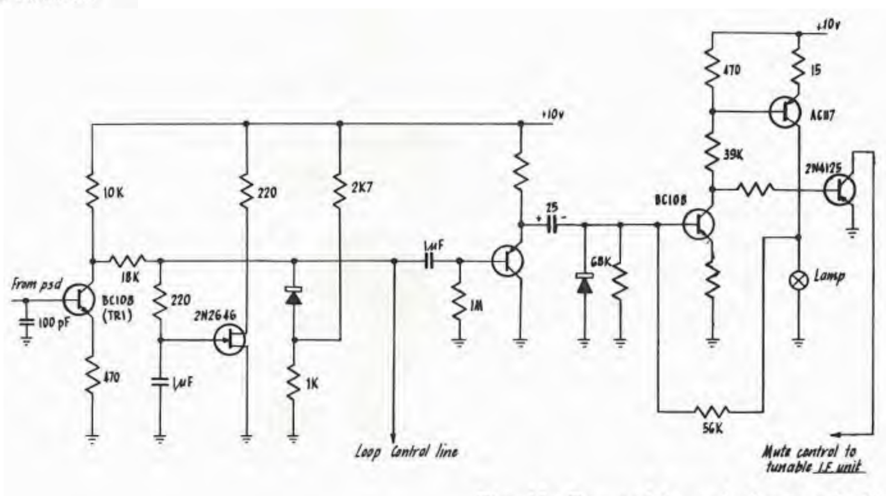

Fig. 12: TR_1 and lamp indicator circuit.

described to obtain a complete radio receiving system. Performance figures are shown in Table 1.

5. CONCLUSION

This paper has described part of a radio receiving system which accepts signals in the range of 1 to 30 MHz and produces a tunable intermediate-frequency output at 2 to 3MHz. Performance figures are acceptable on present-day standards, and the author believes that the system can be further improved to produce performance figures better than those shown.

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TABLE 1

Test	*Result*	*Remarks*
Signal input for 10dB (S+N)/N	1 to	Modulation of 30% at 400Hz
Noise figure	Not worse than 7dB	Calculated from: m2E2 = ***(s-1)KTBFR***
Intermodulation	64dB	Level above wanted signal to produce level equal to wanted signal
	80dB for 100% cross-modulation	Leve above 1μV of wanted signal
Cross-modulation	79dB for 100% cross-modulation	Level above 10μV of wanted signal
	75dB for 100% cross-modulation	Level above 100μV of wanted signal
Signal harmonic at mixer M,	42dB above	Second order non-linearity of mixer
Signal harmonic at mixer M,	46dB above	Third order non-linearity

Field measurement of self-aerated high speed open channel flow

The research programme currently being undertaken involves an experimental study of the effect of self-aeration on flow in the spillway of the Aviemore dam on the Waitaki River. This investigation represents the first known attempt to obtain detailed information from a full-scale structure.

This paper covers the laboratory developments of the field instrumentation and the subsequent trials in March 1970, the results of which are presented and discussed. The paper also summarises the aim of the main experimental programme which was proposed for late 1970, at which time, water was expected to be freely available for spilling at Aviemore.

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1. INTRODUCTION

SELF-AERATION in open channel flow is the natural phenomenon whereby atmospheric air is drawn into and mixed with the water to create a white appearance and a violently agitated and ill-defined free surface. This condition is possible only in high-speed open channel flow and can frequently be observed in spillways. Research in this field is involved with the economical design of steep channels or chutes. As air is drawn into the flow the mixture increases in volume or "bulks" and hence it has generally been assumed that aerated flow requires higher side walls than non-aerated flows. However, a complete lack of information from full-scale structures has meant that, traditionally, spillways have been designed assuming pure water flow with an over-conservative margin, to allow for air bulking, when setting wall heights.

The effect of aeration on flow velocity is of critical importance. It has been argued that the decreased mixture density of aerated flow lowers the internal friction resulting in increased velocity. This argument indicates that the effect of bulking is diminished. However, it has been suggested that the increased energy dissipation, associated with highly-turbulent aerated flow, results in reduced velocity and consequently greater bulking.

Pioneer laboratory research was carried out by Ehrenberger[1]. He published empirical equations relating air concentration, flow depth, and channel slope.

Lane[2] postulated in 1939, and it has since become generally accepted, that aeration cannot occur upstream of the critical point where the turbulent boundary layer first intersects the free surface (see Fig. 1). This is consistent with the observation that for increasing gate openings, and thus flow depths, the first appearance of white water moves downstream (see Fig. 2). Although the detailed mechanism of entrainment is not fully understood, it is evidently dependent upon turbulent fluctuations at the free surface.

A significant advance in experimental research was the development by Lamb and Killen[3], of an electronic air concentration meter.

This development facilitated a series of important laboratory experiments carried out in the late 1950s by Straub and Anderson' at St Anthony Falls Hydraulic Laboratory, Minnesota, United States. These experiments led to the clarification of the detailed structure of

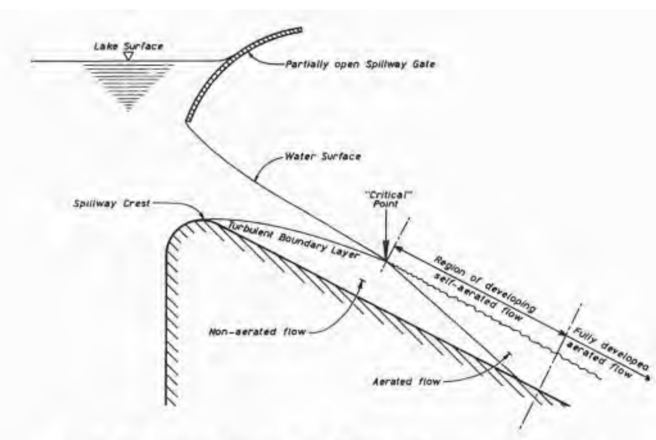

Fig. 1: Typical section of flow down a steep spillway.

Fig. 2: Flow on Aviemore spillway. Top—gate opening 1 ft.; centre—gate opening 2 ft; bottom—gate opening 3 ft.

fully developed aerated flow—i.e. flow where a terminal air concentration profile has been reached (see Fig. 1). Straud and Anderson drew a distinction between a lower region of flow consisting essentially of water impregnated with air bubbles and an upper region consisting of spray, or air, containing drops of water. For each region they developed theoretical analyses to predict the shape of air concentration profiles which showed agreement in form with their experimental results. However, flow down the face of a high spillway is not accurately represented in the hydraulic model, mainly because of disproportionate resistance effects. Consequently their conclusions cannot be applied confidently in practice lacking corroborative evidence from large spillways.

2. INSTRUMENT DESIGN

2.1. General criteria

It is the aim of this research project to obtain and analyse normal and longitudinal air concentration and velocity profiles for flow in the Aviemore spillway. This necessitated the design of instruments which would measure accurately air concentrations and velocities at points in the flow. Furthermore a pier assembly had to be developed which would be strong enough to hold the instruments under the very demanding high-speed flow conditions, yet light enough to be readily portable between stations on the spillway.

Laboratory equipment capable of simulating the spillway flow under variable and measurable conditions of turbulence, air concentration, and velocity, was a prerequisite to instrument design.

2.2. Laboratory simulator

A jet pump was constructed which proved effective as a spillway flow simulator. Air was drawn into the pump and mixed with a high-speed water stream. The resulting mixture discharged downwards through a 3 in. diameter vertical perspex tail-pipe. The pump was capable of generating air-water mixtures at speeds up to 110 ft/s and air concentrations up to 90%. The simulator was designed such that the velocity, air concentration, and degree of turbulence could be controlled.

The mean air concentration of the effluent mixture across a diameter of the tail-pipe was accurately monitored with a radiation meter. The meter comprised a radioactive source on one side of the pipe with a detector diametrically opposite. The radiation absorption capacity of the mixture was directly proportional to its density. The air concentration could thus be calculated from the ratio of emitted to detected radiation levels.

The mean velocity in the tail-pipe was indirectly obtained by calculating the mixture discharge from measurements of water discharge and mean air content.

2.3. Air concentration meter

The method adopted for the determination of local air concentrations consisted of measuring the electrical conductivity of a mixture of air and water relative to the conductivity of water alone. A comparative conductivity reading was necessitated by the continual change in concentration of minerals and other matter in the water.

Although basically similar in principle to the meter used at the St Anthony Falls Hydraulic Laboratory, the air concentration meter incorporates several features which make it unique.

To provide a continuous base for comparison a calibration cell was incorporated into the meter circuitry. Aerated water from the spillway was passed through a de-aeration unit before discharging through the cell. The electrical conductivity of this water was monitored continuously, and the system was thus self-calibrating.

The field test unit incorporated several closely spaced air-concentration probes. To minimise electrical leakage between probes a co-axial design that consisted of a centre spike electrode and an earthed outer cylindrical electrode was adopted (see Fig. 4).

As a result of exhaustive testing a design was developed which gave concentration readings within 2% over the full range of air concentrations and velocities.

2.4. Velocity meter

A satisfactory method of measuring point velocities in high-speed air-water mixtures has proved particularly elusive in the past. Previous investigators have used complicated salt velocity and conventional Pitot tube methods. Such methods, although cumbersome in a laboratory, proved completely impracticable under field conditions.

For the investigation described in this paper a velocity meter was developed from which velocities were obtained by measuring stagnation pressures with a strain gauged diaphragm. (See Fig. 3.)

Comprehensive laboratory testing confirmed that the standard relationship for a homogeneous fluid-linking velocity, stagnation pressure, and density $(P = \frac{1}{2}pV^2)$ applied for the heterogeneous mixture provided p was the equivalent mixture density. The velocity was thus dependent upon air-concentration measurements but despite the consequent compounding of experimental errors, the velocity meter gave readings within 3%.

2.5. Aviemore test rig

The test rig consists of two piers mounted side-by-side on a base plate (see Fig. 4). One pier incorporates the air concentration probes, the other incorporates the velocity meters. Velocity values are calculated from the stagnation pressure readings assuming that the air concentration at the velocity meter is the same as the measured air concentration at the same height on the air concentration pier.

The assembly may be mounted at any one of the previously established anchorage stations on the spillway face. The stations are inter-connected beneath the

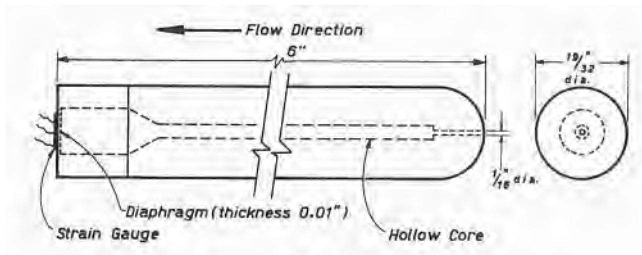

Fig. 3: Velocity meter.

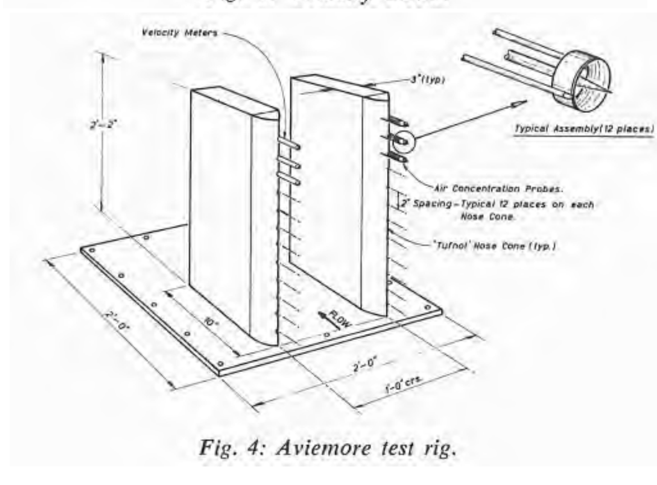

Fig. 4: Aviemore test rig.

spillway face by ducts carrying electric cables which terminate at a recording station at the side of the spillway.

Recording instruments are connected to the test rig via the cables and specially designed remote switching circuits are used to switch the recording instruments from probe to probe.

3. FIELD TRIALS

3.1. Summary

The trials were carried out with the pier assembly mounted at a station near the foot of the spillway. Normal profiles of air concentration and velocity were obtained for the spillway gate openings at 1 ft, 2 ft, and 3 ft. Figure 2 shows the spillway flow for each of these gate openings; Fig. 5 shows the pier assembly for a gate opening of 2 ft.

Although intended only as preliminary proving trials some significant results were obtained.

3.2. Procedure

The highly turbulent nature of the flow resulted in a wildly fluctuating output. For this reason a data logger was used to record automatically values of output for each air concentration probe and each velocity meter at one-second intervals for five minutes. The output thus consisted of several hundred values of the same parameter. Computer analyses yielded mean values which were used for subsequent calculations and profile plotting.

3.3. Results

The air concentration profiles for the three gate openings are shown in Fig. 6.

At the one-foot gate opening the aerated flow at the pier had become fully developed and the air concentration profile could thus be compared to that predicted by Straub and Anderson's theory. The predicted profile is shown as a dashed line on Fig. 6. However, at the present state of development, their equations are dependent on factors which must be experimentally measured.

The velocity profiles for gate openings of 1 ft and 2 ft are shown in Figs. 7 and 8. A noteworthy feature of the one-foot profile is the sharp reduction in velocity near the surface owing to the atmospheric drag on the flow, accentuated by the very disturbed nature of the surface.

The velocity profile in Fig. 8 shows a discontinuity in a region of sharply increasing air concentration. This sudden velocity increase suggests that aeration increases the mean velocity of the flow above that of a non-aerated stream.

4. CONCLUSIONS

The authors consider that the experimental techniques developed are completely successful in measuring air concentrations and velocities in air/water mixtures on full-scale structures.

Aeration has the effect of increasing the flow velocity above that for a non-aerated flow. This tends to diminish the effect of bulking though to what extent it is not yet apparent.

Fig. 5: Pier assembly for a gate opening of 2 ft.

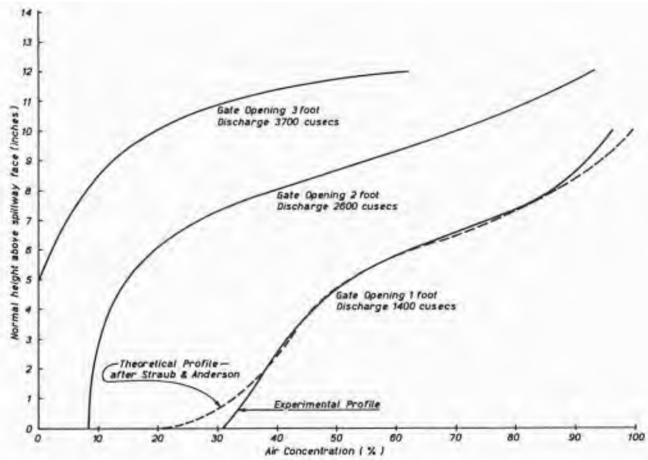

Fig. 6: Air concentration profiles.

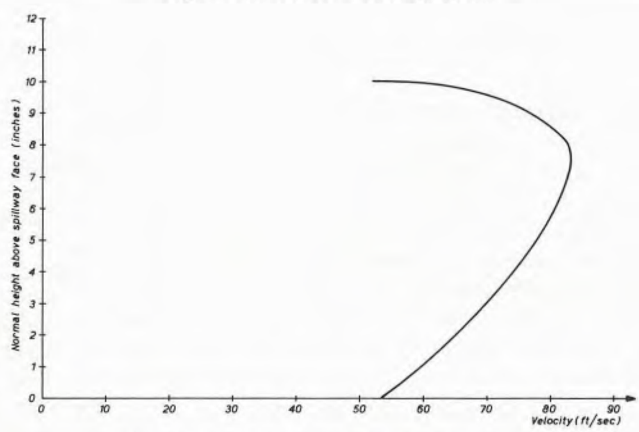

Fig. 7: Velocity profile (1-ft gate opening).

5. ACKNOWLEDGMENTS

The work described has been undertaken by **R. J.** Keller as part of his Ph.D. studies under the supervision of R. F. Hince. Computations were performed on the University of Canterbury's IBM 360/44 computer.

The authors acknowledge the assistance received from personnel of the New Zealand Electricity Department, the Ministry of Works and the University of Canterbury.

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APPENDIX

Main experimental programme

The object of the main programme is to obtain a comprehensive series of normal and longitudinal air concentration and velocity profiles for various dis-

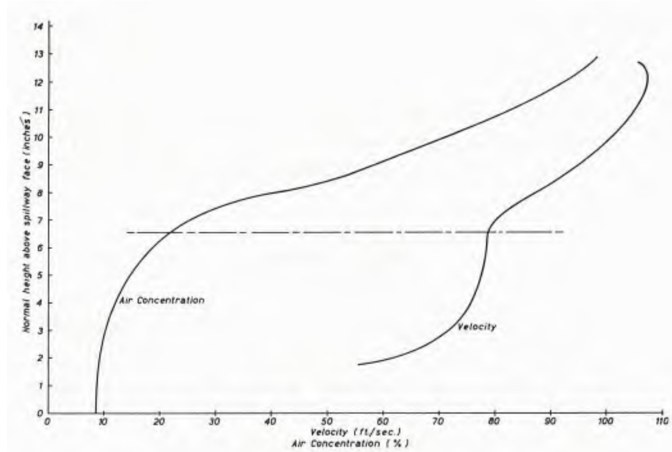

Fig. 8: Profiles 2-ft gate opening.

charges. Such profiles should enable a full analysis of self-aerated flow, including an evaluation of the effect of aeration on velocity and a study of the region of developing self-aerated flow.

Air pollution — how long can it be sustained ?

STEPHEN A. VINCZE, Dipl.Ing., C.Eng., F.I.E.E., M.N.Z.I.E.

The following "essay" by an Institution member has been widely promulgated during the past six months. It has been sent to the Secretary-General, United Nations Organisation; the Prime Minister of New Zealand; the Leader of the Opposition; the President, Council of Engineering Institutions, London; the President, World Energy Conference, London; the President, Institution of Electrical Engineers, London,

Despite the possibility that many members will have read the essay already, it is published below for the benefit of those who will read it now for the first time, as in the opinion of the N.Z.I.E. Publications Committee, the subject matter is important enough to warrant the widest possible dissemination, even at the risk of repetition.

ENVIRONMENTAL pollution, of which air pollution is but one facet, is very much in the news today. It has grown so bad that at long last it is generally agreed that something has to be done to curb it. However, it is still not generally realised that our atmosphere is by no means unlimited and how close the whole world is sailing to doomsday.

It is fair to assume that the breathable atmosphere extends only to about 3 km above sea level; and many people cannot stand even that height. Since the mean radius of the earth is approximately 6,371.2 km. the total volume of the breathable atmosphere is of the order of $1.53 \times 10^{18} m^3$, if we neglect the volume of mountains and hills, which should be deducted.

The world's energy consumption, attributable to combustible fuels only (brown and hard coal, crude oil, natural gas, peat and wood), hydro-electricity, geothermal and nuclear energy excluded, amount to the equivalent of $1,920 \times 10^9$kg UN-accepted standard fuel of 7,000cal/kg lower calorific value in 1938, to $5,520 \times 10^9$kg in 1965 and is estimated to reach $(18,625 \ldots 21,490) \times 10^9$kg by the year 2000.

The air required to burn this fuel can be estimated at $(16 \ldots 27) \times 10^{12} m^3$ for 1938, at $(46 \ldots 78) \times 10^{12} m^3$ for 1956 and at $(155 \ldots 300) \times 10^{12} m^3$ for the year 2000.

Even considering only SO_2 of the many impurities emitted with the flue gases into the atmosphere, and neglecting all other pollutants produced and emitted in wars, by the chemical industry, etc., the air pollution is already staggering. Some $2,340 \times 10^7 m^3$ SO2 have been emitted in 1938, $7,230 \times 10^7 m^3$ in 1965 and if the fuel consumption estimates are correct $(21,000 \ldots 24,000) \times 10^7 m^3$ SO2 emission may be expected in the year 2000.

Worse still, the air pollution is cumulative.

Even if the air had been crystal clear in 1938 and emission of SO_2 had started at that date only, the total volume of SO_2 emitted into the atmosphere would have reached 136,000 x 107m3 (0.89 parts per million) by 1965, and would reach $652,000 \times 10^7 m^3$ (4.26 p.p.m.) by the year 2000, if the SO, concentration could be evenly distributed in the atmosphere of the whole earth. It is well known, however, that this is not the case, and that excessive concentrations have occurred already at many places. And SO_2 is but one of the innumerable pollutants!

As a comparison, the maximum SO2 concentration permitted in factory atmospheres in the United Kingdom amounts to five parts per million.

Space forbids going into more details on pollutants, but it can be shown—again assuming the air was crystal clear in 1938—that the total amount of air used up for combustion between 1938 and 1965 was of the order of 1,340 x 1012m3 and could reach $7,500 \times 10^{12} m^3$ by the year 2000.

The 3,000,000,000 people inhabiting the earth require not less than $18 \times 10^{12} m^3$ air per year for breathing alone and no figures are available as to the oxygen requirements of wild and domestic animals, birds, fishes, reptiles and insects, which must amount to a multiple of the needs of humanity.

Remedial measures are urgently needed and the following are tentatively suggested:

(1) The burning of combustible fuel of any kind in excess of today's consumption should be stopped.

(2) No new road or rail vehicles using combustible fuel should be permitted; existing road and rail vehicles powered by internal combustion engines should be phased out and replaced by electric ones'- 3.

(3) Combustiable fuels should be reserved for shipping and for civil aviation only.

(4) Combustible-fuel-burning thermal power stations should be phased out and all future power stations should be hydro-electric., geothermal, nuclear, aeolian, and solar.

(5) The worldwide use of solar heating, cooling, water pumping and air conditioning should be promoted.

(6) The uncontrolled use of nuclear and conventional explosives and other air pollutants should be stopped.

(7) Afforestation should be encouraged all over the world and existing forests protected.

(8) Population increase should be limited.

(9) A supra national agency should be set up by the United Nations to implement and to police the above suggestions.

L'homme ne meurt pas; il se tue[4].

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PERSONAL

W. G. DRAPER, B.E., C.Eng., M.I.C.E., M.N.Z.I.E., has been admitted to the partnership of Campbell Hamman and Partners, consulting engineers, Christchurch. The partnership has opened an office at Lower Hutt and Mr Draper will be the Wellington resident partner.

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J. P. HOLLINGS, B.E., D.I.C.. C.Eng., M.I.C.E., **M.N.Z.I.E., of Beca,** Carter, Hollings and Ferner, travelled to London last November to lecture to the Institution of Civil Engineers. His subject was earthquake engineering in general, drawing on particular examples from the Inangahua earthquake. He also attended an earthquake conference in India.

* * *

I. C. SMITH, M.E., D.I.C., C.Eng., M.I.C.E., M.N.Z.I.E., was recently admitted to the partnership of Brickell, Moss, Rankine and Hill. Mr Smith will continue to direct the firm's structural engineering office at Wellington.

Gaps in technology

Analytical report

THE possible implications of recent trends in education, scientific research and development, technological innovation, and international economic exchanges, are studied in a report just pubished by the Organisation for Economic Co-operation and Development as part of its survey of gaps in technology between member countries. The report is based primarily on data collected during the survey for the decade 1957 to 1966 to provide detailed comparisons of national efforts in these four key areas related to science, technology, and the economy.

The first part of the report deals with the educational and occupational characteristics of the labour force and with the overall effort made in the educational sector. Findings emerging from the data are given in two groups showing the United States lead in overall educational effort and its secondary position in relation to the European countries studied in terms of the proportion of educational effort devoted to science and technology. Notes follow on the imbalances of the brain-drain and the brain-gain and on the available projections of enrolments and graduates in higher education to 1975-80.

Part two contains comparisons of research and development efforts between the U.S. and nine European member countries and between the level and structure of research and development efforts in those countries and in Canada and Japan. Examinations are also made of research and development in the science-based industries such as the aerospace, electrical, and chemical sectors, and of the size of firms and the concentration of research in the business enterprise sector, which in the United States performs a large part of defence, space, and nuclear research and development.

Part three of the report measures the performance of member countries in both originating and diffusing technological innovations. These include receipts and payments for patents, manufacturing licences, and technological know-how and export performance. The report examines the case of the research-intensive industries—electrical machinery, drugs, chemicals, instruments, aircraft and missiles, and non-electrical machinery—which account for from 50% to over 80% of research and development performed by industry in each of the industrially advanced member countries. An examination of the pattern of diffusion of nuclear power generating plants, computers, man-made fibres, and plastics follows to provide a portrait of recent and mature innovations likely to have a continuing impact on three key sectors—energy supply, electronics, and chemicals.

In part four, studies are made of the general characteristics of the economy in the O.E.C.D. area, and the links between scientific and technological factors and the structure and development of trade in manufactured goods. Finally, data is analysed on the flow of technology between member countries and on flows of capital, particularly dealing with direct United States' investments in Europe and Canada. The analysis points to the possibly significant influence of scientific and technological capabilities on the increasing economic interdependence of member countries.

Signalling for the Railways' marshalling yard at Te Rapa

1. Introduction

THE New Zealand Railways hump marshalling yard now nearing completion at Te Rapa will be equipped with an advanced route-setting signalling system. This will be the first time in New Zealand that extensive use has been made of remote-control equipment to control route-set interlockings.

The marshalling yard is comprised of two separate sections lying side by side; each consists of an arrival yard to store trains arriving from the main line, a hump shunting system to sort the wagons into classification sidings, and a departure yard to store trains ready for departure to the main line. Basically, movement within each section is unidirectional; however, wagons may be interchanged from one section to the other to cater for wagons moving between the Main Trunk line and the Rotorua branch or vice versa. To operate the hump shunting system, rakes of wagons to be sorted are propelled over a hump and allowed to run, by gravity, down into classification sidings. Braking is applied to each cut of wagons on the downhill section of the hump by mechanical retarders, the amount of braking being dependent on the weight and rollability of the cut and the fullness of the siding into which the cut will run, so that each cut just buffers up to the wagons already in the siding.

Train movements in to the arrival sidings, out of the departure sidings, and between the two sections are controlled by a route-setting signalling system operated from a single control panel situated in a control tower at the south end of the yard. Each hump shunting system is controlled independently from a tower beside each hump.

Under the route-setting system the signalman sits before a control panel which displays the state of signals, points, and track circuits and operates pushbuttons corresponding to the entrance and the exit or destination point of the route he requires to set.

The control panel takes the form of a track diagram with pushbuttons mounted in the line of the track, one pushbutton for each signal and one for each point of exit from the system. Most pushbuttons act jointly as an exit from and an entrance to adjoining routes. Any number of routes may be selected in series simultaneously by pushing the first entrance button and the last exit button for the routes required.

The control equipment may be considered in two parts. First, the interlocking equipment which provides the control for the individual fixed signals and points motors. The equipment consists of relays associated with each signal and each set of points electrically interlocked in such a way that a fixed signal will not clear for the movement of a train until the points in the route over which the signal reads have been correctly set and locked, and, further, that two fixed signals cannot be cleared at the same time if a collision between two trains would result. The interlocking circuits and equipment must be designed in such a manner that if a failure occurs the signal or signals concerned revert to "stop". The prime consideration in this equipment is that it be fail-safe.

Second, the route-setting equipment, which takes the commands from the control panel and translates the request for a route into a series of commands for the individual points and signals in that route. Further, the route-setting equipment interrogates the interlocking equipment and provides indications of routes set, the positions of trains, the lie of points, and whether each signal is at stop or proceed. The prime consideration in route-setting equipment is reliability of operation.

In the past route-setting equipment has been constructed using the same type of relay equipment as used in interlocking circuits and both sets of circuits grouped together into two basic modules corresponding to a set of points or a signal. A route-setting interlocking system was then built up by interconnecting points and signal modules geographically as the layout of lines. With this arrangement the control panel must be close to the interlocking equipment and remote control is very difficult.

2. The Te Rapa system

The Te Rapa marshalling yard is long and narrow and requires the interlocking equipment to be placed in two buildings 11 miles apart controlled from one control panel. Furthermore, it was felt desirable to control Horotiu and Ngaruawahia, which are the first two crossing loops on the Main Trunk line north of Te Rapa, as well as the Frankton yard, when it is rebuilt, from the same control panel, using the route-setting principle. When the scheme is complete, therefore, five interlockings will be remote-controlled and one direct-controlled.

Remote route-setting requires that most of the route-setting equipment be placed near the control panel, with the remainder near the interlocking equipment, and connection between the two achieved with remote-control equipment. These requirements are not easily met with the equipment already described and therefore a new module system was needed.

The New Zealand Railways already possessed geographic interlocking equipment without route-setting circuits so that only new route-setting and remote-control equipment needed to be developed. A pilot scheme was built to control Horotiu and Ngaruawahia from.

a temporary control panel at Frankton. The route-setting equipment uses standard off-the-shelf integrated circuits; the remote-control equipment is a transistorised centralised-train-control system using frequency-shift keyed transmission modified to suit the somewhat different requirements of route setting. This scheme was brought into use in June 1969 and has operated successfully since then.

Using the pilot scheme as a basis, a complete integrated circuit scheme has been designed for the Te Rapa yard. It includes route-setting cards, remote-control cards and indication cards, all designed to the geographic principle so that direct cr remote control may be used as desired on any yard layout with a minimum of system design. The remote-control system uses a quasi-ternary form of digital transmission giving potentially a much higher rate of data transfer than can be economically handled by frequency shift keying.

The completed scheme will result in a direct saving of 14 signalmen, relieving, to some extent, the shortage of operating staff.

Consultants' Notebook

Design award to Aurora House

THE 19-storey Aurora House on The Terrace, Wellington, has won the 1970 award of merit of the Association of Consulting Engineers, New Zealand. The award plaque was unveiled on 10 November 1970 by the Minister of Finance, the Hon. R. D. Muldoon.

The award, which is made annually to give recognition to a design project of outstanding engineering merit, was announced at the 1970 annual conference of the Association of Consulting Engineers at Wairakei in June.

Aurora House is the largest all-welded structure in high-tensile steel in the Southern Hemisphere and incorporates a five-storey parking building which holds 370 cars, and more than 20,000 ft^2 of office accommodation. The building required about 1,800 tons of high-tensile steel, which needed specialised erection and welding techniques. It was constructed for Mayfair Ltd. and was completed in 1969.

Consulting engineers for the project were W. G. Morrison and Partners, who, as principal advisers to the client, were responsible for all aspects of planning, construction, and costs. G. Cooper, of Wellington, was the engineer in charge of the project. Structon Group Architects, George Vamos and Partners, and Metlabs (N.Z.) Ltd. were retained as consulting architects, consulting mechanical engineers, and consulting metallurgists, respectively.

The decision to adopt an all-welded steel frame in high-tensile quality steel was taken in the belief that the necessary fabricating resources existed in New Zealand and despite the fact that there was no precedent for an all-welded structure of this magnitude.

The standard of welding and general workmanship achieved in both the shop and the field demonstrated that new materials can be handled satisfactorily by New Zealand fabricators who have the proper technical and physical resources.

The objective of the client was to finance a commercial building development as a profitable investment. The project was developed in several stages to ensure a quick and continuous return on the client's investment. The contracts let were: demolition of existing buildings; excavation; piling; stage one of parking building; stage two of parking building; structural steel frame; balance of superstructure and architecture.

Close co-ordination of each of these contracts both in timing and contractual responsibility was necessary to ensure continuity of construction and progressive occupation.

The windows and internal partitions are additional special structural features and have been separated from the main frame to minimise damage under earthquake loading. At the time when the details for seismic separation of both windows and partitions were under consideration there was no known precedent in this country.

The role of consulting engineers as principal adviser to the client was an aspect of particular merit.

Wellington consulting engineer, G. Cooper (right), speaking at the official unveiling of the Award of Merit plaque which this year was won by the consulting engineers of the Aurora House project, a multi-storeyed office and parking building on The Terrace, Wellington. (see page 27).

The award is issued by the Association of Consulting Engineers of New Zealand to an engineering structure of outstanding merit; Aurora House won the 1970 title from five other entries. The bronze plaque and medallion were unveiled by the Hon. R. D. Muldoon, Minister of Finance (left), at a special function in Wellington recently.

Mr Cooper designed the massive structure for Mayfair Ltd. The 19-storey building is the largest all-welded structure in high-tensile steel in the Southern Hemisphere.

AN ENGINEER'S BOOKSHELF

TWO GROUP REACTOR THEORY by J. L. Meem; 417 pp., illus. (Gordon and Breach, New York, 1965, $U.S. 20.50.)

This book is for students bginning a Masters degree in nuclear enginering. The author assumes that the student has an introductory course of atomic physics and either an introductory course of nuclear engineering or of nuclear physics. Emphasis is placed on the student attaining proficiency with design calculations of reactor criticality, reactor kinetics, and control blade worth for both the homogeneous and hetrogeneous reactor. The author seeks to draw a line between reactor physics and reactor engineering; his attempt to do so requires him—as he himself recognises—to introduce unconventional methods to obtain adequate results.

The book is purported to be for a two-semester (90 lecture hours) course at the graduate level. However, final-year undergraduate students of above average ability are capable of covering the first 250 pages (excluding chapter 6: Transport theory) in 48 lectures. This is possible even .when three lectures are spent discussing cross-sections and resonance integrals (not included in the text). A Masters degree class should be capablof absorbing, in a series of 90 lectures, considerably more material than presented in this book.

The discussion of the resonance escape probability includes a very poor introduction to the concept of the resonance integral. This criticism also applies to the discussion of the fast-group cross-sections. Surely the design engineer is not just a programmed device that turns out calculations in the same manner as a computer! He must have some understanding of the cross-sections he uses. This means that the design or operations engineer finds a knowledge of resonance absorption and group cross-section calculations useful. The job' of separating reactor physics and reactor engineering is a difficult one indeed. The brief presentation of slowing-down (or neutron moderation) theory is not a sufficient base upon which moderation and resonance absorption in hydrogeneous media can be based. The overall weakness in neutron moderation theory leads to the use of several unconventional methods to obtain adequate results. It is unfortunate that the author did not make the effort to emphasise when such methods are used and to guide the student to adequate dicussions of the more usual techniques.

The two-group approach is used as hand calculations can be carried out with the method. Although a two-page section in chapter 7 is devoted to the use of digital computers and a typical flow sheet is produced, the potential of the digital computer is neglected. A useful appendix would he one which outlined a two-group computer program (probably in Fortran IV) with the input and output data corresponding to calculations of a pool reactor, a natural uranium-graphite reactor, and a fast critical facility as presented in other appendices.

The core of the author's exposition—two-group reactor theory—is covered in considerable skill. It is applied to the calculation of the bare and reflected homogeneous reactor, and of the worth of a central control rod, to heterogeneous reactor theory, and to fast reactors. The development of the student's proficiency with design calculations is fostered by the detailed calculations of a pool-type reactor, a natural-uranium graphite reactor, and a fast critical facility. Some might say that this approach is "spoon feeding"; however, the appendices in which these are developed efficiently demonstrate for the student how the considerable quantity of data is organised and manipulated to obtain the desired results. Used as *a* reference guide, these appendices reduce the experience gap which separates a mathematical model formalism from quantitative results. In this way they are of considerable value.

Techniques and layout used in the production of this book render a pleasing appearance and one that is easy to read. This is more than can be said of other texts which may be more complete. If a potential reader bears in mind the reservations expressed above, then this book is to be recommended as an introduction to the concepts of reactor theory which arc useful in practice. The recommendation is strengthend by the presence of the accompanying appendices.

—G.K.U.

ARC PHYSICS by M. F. Hoyaux; 305 pp., illus. (Springer-Verlag, Berlin, 1969, $U.S.14.50.)

This book was published as volume 8 of the publishers applied physics and engineering series. The series has been written by American and Russian authors largely on the engineering prcblems of rocketry. The major aspects of arc discharges which are of technical importance are covered. The book discusses first the technical aspects of maintenance, extinction and ignition of arcs in relation to their power supplies, in concise practical terms. The main body of the text is then divided into three parts:

(1) Theory of the positive column: A number of mathematical models of the section of the arc column are examined in order of increasing complexity, and compared with experiment. A distinction is made between the low- and high-pressure arcs, with the simpler treatment of the low-pressure discharge preceding that for the higher pressure case. The effects of convection, radiation, magnetic self-striction, energy transfer by chemical reaction, and pressure gradients are introduced after the basic theories have been thoroughly dealt with.

(2) Wall and electrode phenomena: Three chapters deal with the properties of the layers 9f gas at the perimeter of an arc, again in order of complexity. The older theories of a neutral wall-arc interface are discussed before theories of anode-arc behaviour, and the more controversial theories of arc-cathode behaviour are broached.

(3) Diagnostic techniques widely used in arc physics: Perhaps this section is the one that will be useful for most readers. Measurements have been made on most arcs of possible technical use, but even the simplest measurement requires considerable interpretation. A critical appraisal is made cf various optical methods including optically thick and thin measurements, and methods using electric probes. A more rapid survey is made of magnetic probes, microwave techniques, and other methods.

Appendices on Langmuir's paradox, and Steenbeck's minimum voltage principle arc given.

The book is systematically laid out in short chapters, with several reviews front the literature listed at the end of each chapter. The next is clear and concise. Some background of ionisation phenomena is required of the reader, but for most aspects the text serves as an introduction itself. The emphasis is on the important engineering aspects, and the calculation of their importance. Second order effects of academic interest only are ignored. Refinements to theory without experimental basis are described very briefly, if at all. All parts of the book have been written critically, and the experience gained from the author's work at Westinghouse Electric is apparent in both theory and practical details.

The book has been found very useful by the reviewer, who is working on a technical application of the arc, and he recommends it to anyone in a similar position.

—J.A.