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Proceedings of the SYMPOSIUM ON MACHINE MILKING 1968

THE NATIONAL INSTITUTE FOR RESEARCH IN DAIRYING
SHINFIELD READING ENGLAND

Michael Cowhig
In memoriam

PROCEEDINGS

of the

SYMPOSIUM ON MACHINE MILKING 1968

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Foreword

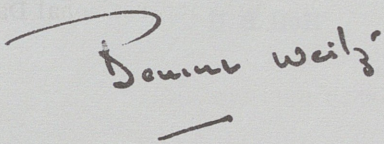
The Symposium on Machine Milking 1968 was a notable event in the history of the development of milking techniques. Experts from many different countries and from diverse disciplines gathered to discuss the problems of mechanical milking in all its technical and scientific aspects. The high standard of contributions from a wider range of participants made this Symposium a worthy successor to the Symposium organized by Alfa-Laval AB in 1963.

The problems of machine milking are as diverse as they are complex and demand a clear understanding of the biological principles of lactation and milk production, of the industrial and farming problems concerned, and of the dynamic and engineering aspects which form the basis of the system. By itself it was a great achievement to have brought together specialists from such different fields and to have overcome so successfully the problems of communication.

It is extremely gratifying that the results of these extensive deliberations are now published as a book which without doubt constitutes an authoritative document on the subject and which will be used as a basis for future studies. The book is a valuable contribution to the literature on this topic and will be regarded as the accepted standard work by authorities all over the world.

The many contributions to this book have a common objective: the improvement of the economic, agricultural, industrial and health aspects of milking to the general advantage of the animal, producer and consumer. The successful outcome is shown not only by stressing the achievements and their applications, but also by uncovering some of the more important gaps in the present-day knowledge regarding the technique of milking, and by realizing the differences which are imposed by national traditions and requirements in different countries. In this way the frontiers of knowledge have been extended beyond national limits and the book has fused the thoughts of the leaders in this field to a common purpose.

None of this could have been achieved without the hard work and exemplary organization of the convener of the Symposium. Mr. H. S. Hall long ago gained the greatest respect of his colleagues by his work on the subject and the publication of this book under his editorship is a fitting tribute to his leadership in this field.



Editor's Preface

This Symposium began with tragedy. The three participants from the Republic of Ireland, M. J. Cowhig, J. F. Nyhan and T. P. Dwane died in an aeroplane disaster on their journey to Reading. Their written contributions had preceded them and were presented by others familiar with their work, so that many of their views and opinions are recorded in these Proceedings.

Research at Moorepark on machine milking centred around this team of young scientists. It had passed beyond its formative years and was receiving world-wide recognition. The loss to the Symposium resulting from this tragic accident was unanimously acknowledged: the loss to research of the future contributions which inevitably they would have made in increasing measure cannot be replaced.

All the papers and most of the written contributions to discussion were issued to participants before the Symposium but where authors introduced additional material in presenting their papers, the text has been suitably amended. The discussions which followed each paper were recorded verbatim but in the reader's interest only the essential points and illustrations have been included in the report.

It was not to be expected that the Symposium would reach finality on definitions and terminology but the discussions emphasized the pressing need for international agreement. This difficult task was delegated to Dr. C. C. Thiel, assisted by Dr. K. Rabold and Prof. C. O. Claesson and considerable progress has been made in reconciling the views of authorities in Australiasia, Europe and North America. The results are published in the February 1969 issue of Dairy Science Abstracts.

The decision to seek the interest of the International Dairy Federation in promulgating international work on a code or standard for milking machine installations has been implemented. The postponement of the I.D.F. annual meetings which were to be held in September 1968 has delayed consideration of this matter but it is hoped that the delay will not be serious.

The help of milking machine manufacturers and many colleagues at N.I.R.D. in staging the Symposium is gratefully acknowledged. In the work of preparing the Proceedings for publication the assistance of Dr. C. C. Thiel, Dr. F. H. Dodd, Mr. P. A. Clough, Mr. C. Machin and M. N. Gruber has been invaluable.

November 1968

H. S. Hall

2. Factors affecting Milking Performance

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The optimum milking performance of a single teat-cup cluster assembly is achieved by combining a number of factors to milk the cow quickly and completely without the necessity of machine stripping. The cluster assembly should not influence milk quality and it should be largely independent of the operator and acceptable to the cow. With a milking installation optimum milking performance is achieved when the maximum quantity of milk is obtained per hour under acceptable conditions of hygiene, udder health and with the minimum of effort.

This paper discusses some of the more important factors in milking rate, machine stripping and end-of-milking determination for single cluster assemblies and for whole machines.

VACUUM LEVEL

There is a large volume of evidence in the literature to show that milking rate of cows increases with increase in vacuum level and this has been reviewed by Labussière & Richard (1965). The experiments reported on the effect of vacuum on milking rate, with the exception of those of Porter, Miller & Skaggs (1955) and of Brandsma (1963a), had one type of cluster assembly used with different vacuum levels. Furthermore the milking clusters with the exception of those used by Brandsma (1963a) were designed to milk cows at a vacuum of 12 to 15 inHg and when these were used in experiments with a vacuum greater than 16 inHg, teat-cup crawl occurred early in milking and this gave rise to excess machine stripping with a resultant small increase in total milking time.

Increases in milk yield with increase in milking rate have been reported by Dodd & Clough (1955) and Brandsma (1963a). Thr former workers obtained an increase of 5% using a half-udder technique. However, when they repeated the experiment using twins (Clough & Dodd, 1961) the difference in favour of high milking rate was smaller and non-significant. Gregoire, Mochrie, Elliott, Eaton & Spielman (1954) found that cows milked at a higher vacuum had a longer lactation but the difference in milk yield was not significant.

VACUUM FLUCTUATIONS

During milking the vacuum inside the liner fluctuates under certain circumstances and it is necessary to define the causes of these fluctuations.

Type I Vacuum fluctuation in a large part or all of the vacuum system.

This may be caused by one or a combination of the following factors: inadequate vacuum pump capacity, inefficient vacuum controller, restriction of air flow in pipeline system and excess air leaks.

Type II Vacuum fluctuations in the milk tubes and pipelines used for the dual purpose of providing vacuum at the cow's teat and for transferring milk to the releaser.

These fluctuations are caused by the hydrostatic pressure of columns of milk and flooding of pipes.

Type III Vacuum fluctuations caused inside the teat-cup liner by milk in transit impeding air flow as liners open and close.

This type of fluctuation is not discussed in this paper.

Vacuum fluctuations of types I and II can, apart from organisational problems, only affect milking performance by affecting milking vacuum within the liner and by affecting pulsation chamber pressure changes. When the level of vacuum in the teat-cups varied between 7 and 15 inHg at a rate of 53 vacuum fluctuations per minute Stanley & Kesler (1962) found that milking time was increased from 5.96 minutes to 7.64 minutes ($P < 0.01$). In an experiment with 13 sets of identical twin cows Cowhig & Nyhan (1967) found that vacuum fluctuations varying from 9 to 15 inHg at a rate of 4 fluctuations per minute reduced mean milking rate from 3.8 to 3.3 lb/min ($P < 0.05$) and mean maximum milking rate from 6.4 to 5.7 lb/min ($P < 0.01$).

Vacuum fluctuations occur whenever large volumes of air enter the vacuum system. The magnitude and duration of the fluctuations will depend on a combination of factors, namely, vacuum pump capacity, sensitivity of vacuum controller, the volume of the vacuum system and the obstruction to air flow in the system. Working with pipeline milkers Phillips (1952) found that reserve air (pump capacity in excess of machine consumption) and vacuum tank volumes had relatively little effect on the initial fall in vacuum to about 10 inHg but had a marked effect on the recovery of vacuum once air admission was stopped. He found that if the recovery time was about 3 seconds the fall in vacuum became barely noticeable at the teat-cups owing to the cushioning effect of the milk in the milk tubes. Using this as a basis he calculated reserve air figures for various sizes of pipeline milking installations (Table 1).

Table 1. Reserve air flow volumes* for various sizes of milking installations

Size of installation (Units)	Machine consumption ft³/min†	Reserve air ft³/min
2	3-4	3.5-4.5
3	4-5	3.5-4.5
4	5-6	4.0-5.0
6	7-8	4.5-5.5

* These volumes apply to milking installations milking with a 4-gallon vacuum tank and $\frac{1}{32}$ inch air admission holes.

† Cubic feet per minute free air.

These figures have been used in many milking machines both pipeline and bucket type during the past 15 years. Phillips (1965) has also measured the effects of the volume of air flow on the milking vacuum at various parts of the installation under different conditions. Results of experiments show that volume of reserve air influences the rate of milking. Clarke & Lascelles (1965) compared conventional high pipeline, conventional low pipeline and large diameter low pipeline systems with $2\frac{1}{2}$ and $8\frac{1}{2}$ ft³/min reserve air on 6 cows. They found that the milking rate was reduced in the pipeline machines operating without any reserve air. Milking rates were 6.4 and 5.5% faster with a reserve air of $8\frac{1}{2}$ and $2\frac{1}{2}$ ft³/min respectively than with no reserve air. When milking rate was not increased significantly by increasing reserve air from $2\frac{1}{2}$ to $8\frac{1}{2}$ ft³/min they concluded that optimal conditions of vacuum were achieved at a low level of reserve air with single units.

Forty-two cows paired on the basis of milk yield, milking rate and quarter infection data were used in an experiment to compare the effect of different volumes of reserve air on milking rate with a 3-unit bucket milking machine (Cowhig & Nyhan, 1966). Reducing the manual reserve air from 6 to $3\frac{1}{2}$ ft³/min reduced mean milking rate by 7%. A further reduction in the reserve air to 2 ft³/min free air reduced mean milking rate by 11% ($P < 0.05$) compared to the control machine with 6 ft³/min reserve air.

These results show that the volume of reserve air in a milking machine has an effect on the vacuum level at the cow's teats. This in turn influences the rate of milking. Vacuum fluctuations will affect pulsator rate and ratio but there is no evidence in the literature to show that this has any important effect on milking performance and it is difficult to theorise on how it could have any worthwhile effect on milking rate. Vacuum fluc-

tuations caused by inadequate reserve air and flooding of milk tubes and pipes may be responsible for teatcups falling off cows during milking. This aspect can be detrimental to the running of an efficient milking routine and has a serious effect on milking performance.

In conclusion, vacuum level is probably the most important factor controlling milking rate. Milking machines should be designed to a standard to have a minimum partial vacuum of 15 inHg at the cow's teat during milking.

The figures on reserve air requirements for pipeline milking installations (Phillips, 1952) appear to be satisfactory for bucket type milking machines. Adequate diameter air and milk pipes should be used in milking installations.

It is desirable to initiate more research work using higher vacuum levels with new design of teatcups and liners.

PULSATION

All two-chamber teatcups have a pulsation chamber where pressure alternates between atmospheric pressure and milking vacuum during milking. When the pulsation chamber is under vacuum, the teatcup liner is in its normal open position and milk flows. When the pulsation chamber is under atmospheric pressure, the liner is collapsed, stopping milk flow and massaging the cow's teats. The number of times the liner opens and closes during one minute (pulsation rate) and the proportion of the cycle during which milk flows influence milking performance. Experiments on pulsator ratio, reviewed by Labussière & Richard (1965), show that machines with wide-ratio pulsation milk faster than machines with close-ratio pulsation. Phillips (1963) has shown that the rate of change of pressure in the pulsation chamber to and from milking vacuum will influence the rate of milk flow to a small degree. When the change from air to vacuum phase was increased from 8 to 18% of the cycle time the milking time increased by approximately 2% and the yield of machine stripping increased by 18% which indicates that teatcup crawl takes place earlier when a protracted air to vacuum change is used. When the change from vacuum to air phase was increased from 7 to 23% of the cycle time the average and maximum milking rates were increased by about 2 and 10% respectively.

Experiments carried out to measure the effect of pulsator rate on milking rate have given some conflicting results—see review by Labussière & Richard (1965). Increasing pulsation rate resulted in higher milking rate in experiments carried out by Stewart & Schultz (1956), Clough, Dodd & Hughes (1953) and Andreae (1957). However, the results of experiments by Schmidt, Guthrie, Guest, Hundtoft, Kumar & Henderson (1963a), Stewart & Schultz (1956, 1958) and Voldmann (1959) were inconclusive and in two

experiments (Bratlie, Slagsvold & Tellersrud, 1959; Kaveshnikova, 1960) increase in pulsation rate reduced milking rate.

Some of the conflicting results in these experiments are probably due to the possibility that, when the pulsation rate was changed in some pulsators, there was a corresponding adverse change in pulsation ratio and this was not considered. The size of the vacuum and air ports of a pulsator can influence the pulsation ratio when the rate is changed, and it would be possible to get a reverse ratio at a high pulsation rate if the vacuum port of the pulsator is small. In some experiments (Schmidt et al. 1963a; Stewart & Schultz, 1956, 1958) an increase in machine stripping yield resulted from increases in pulsator rate and this counteracted any change in total milking time.

It is reasonable to conclude that increases in pulsation rate will increase milking rate and the explanation for this increase postulated by Clough et al. (1953) has been studied and confirmed by Thiel, Clough, Westgarth & Akam (1966).

Most of the conflicting results on experiments on pulsator characteristics are probably due to the different methods used by research workers for measuring and reporting on pulsator characteristics. It is desirable that a standard procedure should be adopted in all countries in the future. This procedure should receive attention during this symposium.

The frequency with which pulsator rate changes from day to day in pneumatic pulsators is quite variable and in a test on six makes (Cowhig & O'Flaherty, 1968) the frequency varied from none for one pulsator up to 42 for another pulsator in 29 consecutive days.

The information available suggests that higher pulsation rates and wider pulsation ratios result in higher milking rates. However, the research results indicate that any changes made in pulsator characteristics have not reduced total milking time by more that 10%. While it is desirable to standardize on pulsator mechanisms to prevent changes in pulsator rate from day to day, there is no clear case for standardizing on pulsator rate or ratio from a milking rate basis. However, it is probably important to standardize within certain limits on pulsator characteristics for the sake of cow comfort and udder disease.

CLUSTER ASSEMBLY

The weight of the cluster assembly and the design of liner has received attention from research workers for many years. Dodd & Henriques (1949) showed that increasing the weight of a cluster assembly from 7 to 11 lb gave an insignificant increase in milk yield and a highly significant reduction in machine stripping yield with one type of liner. The reduction of machine stripping time by increase of cluster weight was offset by the

rate at which clusters fell off at the heavier weights. Experiments by Brandsma (1963b), Rabold (1963) and Langeluddeke & Kloth (1964) have shown that milking rate was affected by different cluster assemblies. Clough (1964 a, b) found that cluster assembly weight was significantly and inversely related to quantity of machine stripping with 18 commercial sets of cluster assemblies weighing between 6. 2 and 7. 8 lb. He also found a highly significant difference between peak flowrates and machine milking times with different liners. In the experiment of Schmidt, Guthrie & Guest (1963b) the narrow-bore moulded liner ($^7/_8$ inch i.d.) had no advantage over the medium or wide-bore liners ($1^1/_4$ inch i.d.). Tilliole (1964) found that liner size had no effect on milking rate and Gedde-Dahl (1962) showed that the effect of pulsation ratio on maximum milking rate was four times as great as that of cluster assembly.

In a short term experiment Clough (1964a) found a difference of 13% in mean machine milking time between teatcup liners. This suggests that research in this area could be profitable. It is desirable to quantify the relative importance of bore, length, tension, elastic properties and mouthpiece dimensions of liners in any future research work.

FACTORS OF WHOLE MACHINES AFFECTING MILKING PERFORMANCE

Most of the experiments on the effect of changes in milking machine factors have been carried out with one or two different types of machines. It is reasonable to assume that an increase in milking rate will occur with an increase in vacuum level with different types of machines. However, it is interesting to measure the magnitude of this increase and find out how changes in pulsator and cluster assembly factors influence it.

Eight milking machines with different vacuum levels, pulsator rate and ratio, cluster assembly weight and design, and liner design were compared using an 8 x 8 Latin square design with 16 cows (Cowhig & O'Flaherty, 1968). Each cow was milked by one machine for 17 days and was then transferred to another machine. Cows were free from udder infection before the experiment started and remained free throughout the experiment. Details of the 8 machines are given in Tables 2 and 3. The milking performance results are presented in Tables 4 and 5.

The milking rate and stripping times were measured at the morning milking during the final 3 days of each period by milking into a pail suspended from a spring balance graduated in 0. 1 lb.

Machine stripping started when flowrate dropped to 0. 3 lb per 15 seconds and the cluster assembly was removed from the cow when flowrate dropped below 0. 1 lb per 15 seconds. The results agree with research findings in general.

Table 2. Description of clusters of eight milking machines

Machine	Weight of cluster	Type of liner	Air admission in clawpiece
	lb		ft^3min free air
A	6.6	Moulded	0.11
B	6.3	Semi-moulded	0.15
C	5.3	Moulded	0.25
D	4.5	Moulded	0.30
E	5.5	Semi-moulded	0.25
F	5.2*	Moulded	0.15
G	Not recorded†	Moulded	0
H	6.4	Semi-moulded	0

* A 3½ lb stripping weight was added to the clawpiece after 75% of machine yield was milked.

† Not possible to record weight of suspended pail-type cluster.

Increasing the milking vacuum from 13 to 15 inHg and widening the pulsation ratio from 50 : 50 to 73 : 27 significantly increased ($P < 0.05$) mean milking rates.

Cluster assembly weight was inversely related to yield of strippings and duration of machine stripping. There was no relationship between vacuum level and machine stripping. This could be due to interaction between vacuum level and liner design. The 7 machines working at 15 inHg vacuum produced more milk, milk fat and total solids than the working at 13 inHg vacuum.

The milking performance of cluster assemblies at farm level depends on the accuracy of the end-of-milking indicator. Dwane (1967) has shown that on average overmilking is carried out for at least 0.5 to 0.75 minutes at each milking with bucket machines using the following types of end-of-milking indicator: transparent plastics tube; sight glass at end of teatcup shell; sight glass in long milk tube; and transparent clawpiece. It can be argued, therefore, that an efficient end-of-milking indicator is as important a factor in determining milking performance of a machine as any changes that may alter pulsator characteristics or liner design. New Zealand type end-of-milking indicators used on pipeline machines are more accurate than bucket type indicators, but they influence the level of vacuum at the cow's teats especially during peak flow. Dwane (1967) found

Table 3. Pulsation and vacuum characteristics

Machine	Pulsation rate	Pulsation* ratio	Vacuum level
	pulsations/min		in Hg
A	61	73 : 27	15
B	50	56 : 44	15
C	45	54 : 46 † / 46 : 54	15
D	48	60 : 40	15
E	44	49 : 51	15
F	42	51 : 49	15
G	60	40 : 60	15
H	60	70 : 30	13

* The graph of the pressure changes in the pulsation chamber was recorded during one pulsation cycle with the cluster assembly in the milking position. The pulsation ratio is defined as the ratio of the vacuum phase to the atmospheric pressure phase along a horizontal line drawn at a vacuum of 5 inHg below the steady vacuum phase.

† The two sides of the pulsator in Machine C had different ratios, i.e. the teatcups on one side of the cow were pulsed with a 54 : 46 ratio, and the cups on the other side with a 46 : 54 ratio.

that the Dairymaster end-of-milking indicator had a pressure drop of 0.75 inHg across it at a flow rate of 8 lb/min. This is equivalent to the pressure drop in 1.3 ft of vertical $\frac{1}{2}$ inch i.d. milk tube at the same flow-rate.

The effect of diameter of milk tube and amount of air admission on vacuum drop at the clawpiece in highline pipeline machines has been studied by Mein (1965). He suggests that a $\frac{9}{16}$ inch i.d. milk tube with a $\frac{1}{32}$ inch air admission hole is the best combination to keep vacuum fluctuations and milk lipolysis at a minimum. The vertical height the milk is lifted from the cow's udder to a pipeline or glass jar will influence the vacuum stability at the cow's teat and consequently milking performance (Mein, 1965; Clough, 1965).

The milking performance in round-the-shed pipelines and pipelines in parlours with glass jars are probably influenced more by installation and

Table 4. Mean milking rate data for machines

Machine	Mean maximum milking rate	Machine	Mean machine milking rate	Machine	Mean milking rate
	lb/min		lb/min		lb/min
A	6.11	A	4.51	A	3.84
B	5.86	B	4.35	B	3.69
D	5.82	D	4.32	D	3.59
C	5.39	E	4.02	E	3.45
E	5.31	C	3.95	F	3.44
F	5.22	F	3.77	G	3.39
H	4.73	H	3.47	C	3.38
				H	3.12
Standard error	±0.193		±0.134		±0.115

Any two means not covered by the same vertical line are significantly different ($P < 0.05$).

Table 5. Mean machine stripping time of seven machines and cluster weight of machines milking at 15 inHg vacuum

Machine	Mean machine stripping time	Machine	Weight of cluster
	min		lb
F	0.91	F	8.8
B	0.94	B	6.3
E	0.96	E	5.5
A	1.00	A	6.6
H	1.05		
C	1.39	C	5.3
D	1.45	D	4.5
Standard error	±0.129		

Any two means not covered by the same vertical line are significantly different ($P < 0.05$).

the use of adequate diameter pipelines than by the nominal vacuum recorded in the vacuum line.

SUMMARY

Some factors affecting the milking performance of single cluster assemblies and whole milking machines are reviewed.

Vacuum level is probably the most important factor controlling milking rate and it is desirable to design milking machines to have a minimum vacuum of 15 inHg at the cow's teats during milking. It also seems desirable to maintain a stable vacuum at the teat end. The figures on reserve air suggested by Phillips (1952) for pipeline installations appear to be satisfactory for bucket installations.

The information available suggests that higher pulsation rates and wider pulsation ratios result in higher milking rates. However, the results of experiments show that the use of an efficient end-of-milking indicator will influence milking performance as much as changes in pulsation. It is desirable to standardize the procedure used for measuring pulsation ratio in different countries.

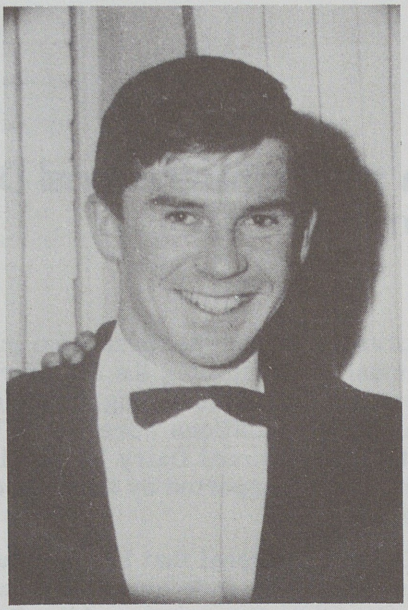
Results of experiments on liner design suggest that there is room for improvement.

The milking performance of 8 teatcup assemblies with different characteristics is reported and the importance of installation of round-the-shed and pipeline machines is discussed.

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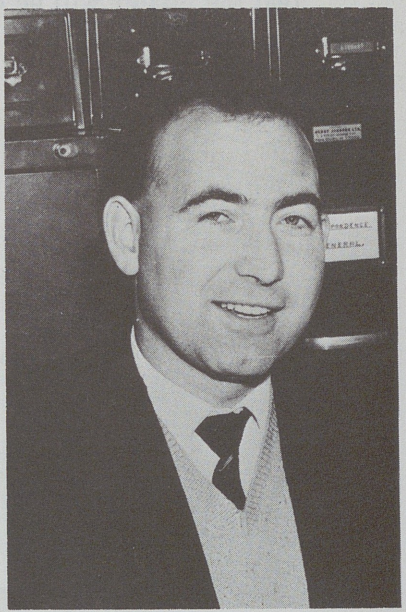
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T. P. Dwane



J. F. Nyhan



M. J. Cowhig

Obituary

Michael Cowhig, John Nyhan and Tom Dwane joined An Foras Talúntais at Moorepark, Fermoy after graduating in Dublin. Cowhig, a graduate in agriculture, was the first to be appointed joining the Dairy Husbandry department in 1960; Nyhan, a veterinary surgeon, joined the Physiology department in 1962 and Dwane, an agricultural engineer, the Engineering department in 1966. They formed an energetic and very successful research team working on machine milking and its relationship with udder disease. Their success, not only in the field of dairy science but also in the application of their results into local farming, was the more remarkable because of the short time they worked together and also because they had to create their facilities, learn new techniques and gain the confidence of farmers, milking machine manufacturers and agricultural advisers.

To the farmer their success was mainly their influence on machine milking practice in Ireland. After surveying equipment and practice they tested available milking machines and installations, laid down standards for manufacturers and encouraged farmers to adopt better milking techniques. They developed training programmes so that the results of their work could be disseminated more widely.

Through their work they made many friends in research stations throughout the world: Cowhig spent six months working at the N.I.R.D., Reading and Nyhan a year in the Bacteriology department at Manchester University. Their studies attracted many visitors and in 1967 D. S. M. Phillips of Ruakura spent a year with this enterprising team to develop further the New Zealand work on stimulation and lactational yield.

In research their most outstanding achievement was the demonstration that irregular vacuum fluctuations increased intramammary infection. This work was unique in that it provided the first good evidence that a single milking machine factor could have a major influence on udder disease. The observation is of considerable value in itself but its real importance is that it has stimulated research on the relationship between the design of milking equipment and udder disease and has provided a key to the study of the particular ways in which bacterial infection occurs during machine milking.