AGRICULTURAL ADJUSTMENT UNIT · UNIVERSITY OF NEWCASTLE UPON TYNE

The Role of Ergonomics in the Efficient Utilization of Agricultural Labour

by J. Matthews

TP11

THE AGRICULTURAL ADJUSTMENT UNIT
THE UNIVERSITY OF NEWCASTLE UPON TYNE

In recent years the forces of change have been reshaping the whole economy and, in the process, the economic framework of our society has been subject to pressures from which the agricultural sector of the economy is not insulated. The rate of technical advance and innovation in agriculture has increased, generating inescapable economic forces. The organisation of production and marketing, as well as the social structure, come inevitably under stress.

In February 1966 the Agricultural Adjustment Unit was established within the Department of Agricultural Economics at the University of Newcastle upon Tyne. This was facilitated by a grant from the W. K. Kellogg Foundation at Battle Creek, Michigan, U.S.A. The purpose of the Unit is to collect and disseminate information concerning the changing role of agriculture in the British and Irish economies, in the belief that a better understanding of the problems and processes of change can lead to a smoother, less painful and more efficient adaptation to new conditions.

Publications

To achieve its major aim of disseminating information the Unit will be publishing a series of pamphlets, bulletins and books covering various aspects of agricultural adjustment. These publications will arise in a number of ways. They may report on special studies carried out by individuals; they may be the result of joint studies; they may be the reproduction of papers prepared in a particular context, but thought to be of more general interest.

The Unit would welcome comments on its publications and suggestions for future work. The Unit would also welcome approaches from other organisations and groups interested in the subject of agricultural adjustment. All such enquiries should be addressed to the Director of the Unit.

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PREFACE

The Agricultural Development Association and the Agricultural Adjustment Unit are running a series of courses on various aspects of farm business management.

Several of the papers, prepared by specialists in their fields, deal with technical, legal and financial subjects in an authoritative way and are being issued as Technical Papers so that a wider audience than those attending these well-booked courses can benefit from the information which has been assembled.

February, 1970

EDITOR'S NOTE

There are two publications in the series dealing with ergonomics. TP. 11. is written from an engineers viewpoint, its author being Mr. J. Matthews who is Head of the Tractor and Ergonomics Department at the National Institute of Agricultural Engineering. TP. 10 deals with the medical aspects of the problem, the author being a lecturer in the Royal Free Hospital School of Medicine, University of London.

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Introduction

In common with many other industries, the labour costs in wages and overheads in agriculture are increasing rapidly. Added to this, the greater sophistication and output, and consequently the greater cost of machinery, is making it doubly important that maximum efficiency of work is obtained from the labour force whether it be on an essentially manual task or on a job involving the operation of field machinery or farmstead plant.

The main foundations of the technology of ergonomics were established during the last war when there was obviously also a very strong pressure to extract maximum efficiency from men and their equipment both on the battlefield and in the factories. At that stage there were also considerable physical and mental stresses associated with the dangers and privations of war. Although these are not with us now agricultural work frequently has to contend with more difficult environments than in many urban industrial situations exemplified by poor climatic conditions, dust, fumes and smell and, more recently, from machinery, unsatisfactory levels of noise and vibration. It is possible to separate ergonomics aims into two types: the study of problems representing a health or accident hazard to the workers - generally thought of in industry as occupational hygiene - and the study of working or machine operational efficiency which has close relations with, but a different approach to, work study.

Increasing awareness of the part that can be played by ergonomics in improving the usage of agricultural labour and equipment has resulted in the last few years in the establishment of research programmes, the inclusion of departments of universities and colleges, increased utilisation of ergonomics handbook data, particularly by the larger manufacturing companies, and the framing of official recommendations and regulations to help ensure the application of good ergonomic principles. In this paper an attempt is made to show by example how these ergonomics principles may be applied to different areas of farm activity. Objective data and principles are not listed in handbook fashion since these exist in many good textbooks, but an attempt is made to outline the background and philosophy of ergonomics study and application in the hope that this will indicate where the large amount of existing information might be applied.

Field tasks

In view of its ubiquity the tractor has obviously attracted a relatively large amount of ergonomics attention. Nevertheless many problems still exist and in an attempt to define these the N.I.A.E. have recently completed a survey of tractor operation. This survey consisted of observation and questioning of some 1200 tractor drivers involved in a complete spectrum of tractor tasks. The questions and recordings were designed to show to what extent design and ergonomic features of the tractor affect performance, were considered by the driver to be objectionable or unsatisfactory, or might have contributed to ill-health. Significantly as far as efficiency is concerned, in more than 10% of cases the speed chosen for the task in hand was determined not by the power capabilities or the tractor of the performance of the implement but by the discomfort level of the operator. In certain cultivation tasks the percentage was much higher. The response to questioning on some features of the tractor design (Table 1) shows a high level of dissatisfaction with many of the environmental features.

Noise is one feature frequently blamed for discomfort and it is an aspect which has received much attention by researchers over the last year or two. A survey of the hearing of tractor operators carried out in 1967 by the N.I.A.E. and Loughborough University of Technology indicated that approximately 50% of the survey sample had detectable noise induced hearing loss whilst 25% of the sample had sufficient hearing damage to affect their hearing of speech (Table 2). In addition to this the adoption of cabs on tractors, although undoubtedly justified as a weather protection and as a safety feature to prevent crushing of operators in overturning, has led to generally higher noise levels with a resulting increase in the proportion of operators finding the noise level seriously objectionable. In the future with more cabs in use, this could clearly lead to greater operational inefficiency than shown in the N.I.A.E. survey unless steps can be taken to reduce the noise levels.

N.I.A.E. noise reduction studies suggest that large benefits are not likely to be attainable in the immediate future from improvements to diesel engines, improved exhaust silencing or the incorporation of noise reducing hoods to the sides of the engine. However, our work has shown (Table 3) that a safety cab designed with acoustic properties in mind can afford a considerable reduction in noise level at the driver's position. Such a cab would probably require anti-vibration mounts where it is attached to the tractor to prevent it acting as a loudspeaker excited by the engine and transmission vibration. In addition substantial bulkheads between engine and operator's position, the incorporation of noise absorbent materials inside the cab and the inclusion of a separate floor or covering over the transmission all help to reduce the noise. In Sweden national regulations have already been set to limit tractor operator noise levels. These are based mainly on the protection of hearing, whereas much more information is required on the effects of noise on performance either by reducing the speed of work, affecting operator capabilities, or hastening the onset of fatigue. With this information objectives can be set to ensure not only to preserve hearing but also to ensure that noise will not contribute to uneconomic tractor operation.

In addition to being a likely hazard to spinal and stomach health, ride vibration from tractor travel over uneven farm surfaces is also a factor frequently limiting the speed at which a tractor operator will work. In the future, where it is likely that tractor development will be in the direction of higher speeds in order to convert greater powers into work without requiring large increases in tractor size and weight associated with wider implements and higher draught forces, the problem of achieving a satisfactory ride will obviously increase in importance. The adoption of well designed suspension seats has led to some reduction in ride vibration, demonstrated by the results of N.I.A.E. tests on the seats (Table 4), and indeed, again in Sweden, national regulations will require all new tractors to be fitted with an approved type of suspension seat later this year. However, the improvement attainable by a seat suspension alone is limited and there are other objections to their use, particularly with respect to relative movement between the operator and his controls, so that for the future alternative means of improving ride are likely to be adopted. Suspension cabins or platforms are being studied at many centres including the N.I.A.E. These avoid the adoption of a motor car type suspension to carry the complete vehicle and to transmit the draught and control forces but provide the operator with a cabin or platform which is spring mounted to the rest of the tractor. Computer calculations have shown that such a platform should achieve a much better ride than a suspension seat and it may even be worth eventually considering the adoption of a hydraulic stabilising system to reduce the platform movement still further.

Other environmental factors which might be guilty of reducing a tractor's usefulness are dust, exhaust fumes, climatic conditions and, possibly, lighting. With each of these factors, it is not sufficient to know that the operator is willing to continue working since the efficiency of this work may be low or its value subsequently reduced by him requiring time off to cure the complaints which have resulted from the exposure.

In addition to the prevailing environment tractor operability would be affected by the design of the operator's platform and driving controls. For both efficiency and safety reasons a British Standard has been established recommending the arrangement of controls on a tractor and more recently consideration has been given to the standardisation of identification symbols for the controls of agricultural machines. Although conventional steering wheel and foot pedals controls have many benefits, not the least being their familiarity, there may be scope for further improvement of the layout, operating dynamics, and identification of controls particularly with higher vehicle speeds and more frequent control operation. One way that such developments could come is by the utilisation by researchers or the development departments of manufacturing companies, of tractor simulators on which alternative arrangements may be accurately compared and tested under simulated conditions of environment and vision.

To the best of my knowledge this approach has yet to be tried with tractors although a laboratory simulator for studies of combine harvester design and operation has been developed at the Agricultural University at Wageningen, Holland.

The combine harvester is generally considered to present a more difficult operational task to the driver, particularly in that many more functions of the machine must be observed and controlled simultaneously and possibly also that all of this work is done under the added stress of the relatively short harvesting season, threatening weather and the need to work very long days. In addition combine harvester grain losses represent a very real loss in money.

On the Wageningen simulator the control platform of existing or experimental combine harvesters may be reconstructed and the operator required to operate the principal controls in response to visual signals given to him either as a continuously varying indication of error requiring correction by control adjustment (steering, for example), or the random lighting of indicator lamps for each of which a particular control should be adjusted. His ability to deal rapidly and accurately with these requirements can be considered to be related to the correctness in the arrangement of the controls. Added to this the necessary manual movements to grasp controls and operate them in a sequence which is typical of normal field use can be estimated and calculated as a proportion of the total time available during operation. Again any reduction in the time required for operation is obviously beneficial.

On the combine harvester and, possibly later, on the tractor automatic controls will remove some of the task from the operator. In these cases ergonomists have a part to play in indicating how far the operator's task should be eased and in which preferred way. Both on the tractor and combine harvester one step which can be taken towards further automation is to provide for the operator, instrument indication of performance of appropriate aspects of the vehicle or implement. An existing example is the adoption of electronic grain loss monitoring on the combine harvester whilst on the tractor one can visualise the development of instruments to be placed in front ofthe operator indicating, for example, ploughing depth, width of first furrow, or satisfactory operation of all rows of the grain drill. The employment of these devices initially as operating aids will minimise the ultimate step of including them in completely driverless systems.

The sources of inefficiency I have listed are not limited to the more sophisticated machinery like tractors or combine harvesters but can exist on relatively simple field machines such as transplanters. Studies were made at N.I.A.E. of the posture required of workers during brassica planting on a typical commercial transplanter and it was shown by recording the electrical activity in the operator's lumbar muscles andhence the level of stress induced in these muscles by the posture, that the posture provided by the manufacturers siting of seats and footrests could be significantly improved. Subsequently we operated an original (unmodified) version of this machine alongside one on which seat and footrest had been moved to improve the posture and showed in recorded field work that the number of errors made by the operators, resulting in the plant failing to be properly embedded, were significantly reduced by the improved posture. Although with certain highly experienced workers on the machine the amount of improvement was reduced, this experiment clearly indicated that improved work could be obtained as a result of more careful ergonomics design of equipment which incidentally implied no addition to its constructional cost. Although this study was limited to the transplanter a similar situation could clearly exist on many other types of equipment.

Dairy work

Mechanisation of milking parlours has reduced very considerably the amount of physical effort required in dealing with large numbers of cows. The adoption of a pit from which the worker may milk has reduced the amount of stooping and has resulted from earlier ergonomics experiments showing a clear reduction in physical effort and an increase in the rate of work with such a facility. There is still some inevitable argument about the optimum depth of a pit and apart from the variation in depth requirement linked with the stature of the workers it seems probable that depth of pit should not be considered alone but may be affected by, for example, the presence and position of rump rails and other features. Further studies are being directed to attempting to discover optimum layout of pit equipment and arrangement of milking task in order principally to reduce the level of mental activity and stress imposed on milkers by the very high throughput rates they are required to maintain, sometimes for periods of several hours. This stress arises in part from the inevitable difficulties in maintaining a strict routine where cows require different times to milk dry and are, in any case, animate objects with a reluctance to always perform in exactly the way required by the objective routine. Mental workload can at this stage only be assessed with limited precision but currently attempts are being made to do this either by imposing an additional mental task on the worker to be carried out with a measured accuracy at the same time as the primary task (milking parlour work) - the accuracy being a measure of the spare mental capacity available - or by making physiological measurements such as some characteristics of the heartbeat, which are related to mental activity. Fatigue, as represented by a drop in performance throughout the milking shift, will also be studied and, in addition to being related to the milking routine, may be dependent on the prevailing environment and other features of the parlour. Parlour heating has been studied scientifically in relation to staff comfort in the U.S.A. where it was shown that the most satisfactory arrangement was overhead infrared radiators coupled with tubular heaters within the pit.

Even more so than on field machinery it seems likely that automation will play an increasing part in the near future on milking parlour work. Currently the milker must carry out the following tasks:-

1. Identify the cow and the amount of concentrate feed required.
2. Operate a mechanism to feed accordingly.
3. Wash and dry the udder.
4. Foremilk and inspect the milk for mastitis.
5. Add the teat cups to the udder.
6. Inspect the cow for general health and the presence of oestrus.
7. Observe the end of milking.
8. Remove the machine.
9. Despatch the cow from the parlour and replace with the next beast.

Although much work remains to be done, particularly with respect to the automatic monitoring of health and oestrus, there appears to be no basic reason why the majority of these tasks should not be taken over by computer-controlled automatic equipment. The probable exception in the early stages would be the placing of the teat cups on the cow and some of the health inspection. Therefore one visualises a situation in which the milking work is shared between the man and a computer-based automatic system. In this case again it is important that the two be correctly integrated in order to perform the task most effectively. Man and machine exhibit different characteristics and any division of functions should take these into account. Table 5 lists some of the differences.

Work with fatstock

Work in connection with this area of husbandry has probably received the least attention by ergonomists. The problems currently reported as deserving of most effort are those of environment - principally dust, smell or temperature and humidity. The climatic problems and, to a lesser extent, problems of smell have become more critical with the increased incidence of large-scale housing of pigs and cattle and elevated temperatures for calves. Mechanisation of feeding is, of course, already common practice and automation can be employed in the future for animal welfare and weight gain progress checks. However, even with the possibility of some manual supervision with the aid of closed circuit television, it seems probable that regular entry to the animal's housing will be necessary. Some thought should be given to the design of special clothing for this purpose. It may at this stage appear to be rather 'far-fetched' to consider fresh-air ventilated and cooled plastic suits, but if, as is possible, the staff are ultimately completely unwilling to go home smelling of pigs, measures of this nature could be justifiable.

The need for further automation to replace unavailable labour has led to a requirement to know in more specific terms far more of the skills and information employed by a good stockman in supervising his herd. These skills are often superficially thought of as a heritage from past generations of farmers or farm workers or of an art which comes naturally to many countrymen. There is, of course, a need to have a great deal of knowledge to be a successful stockman and undoubtedly an experienced man develops intuition in the detection of ill-health among his charges. Nevertheless, the knowledge required and the characteristics of an animal to be judged in assessing its well-being, its environmental and diet needs or its incidence of oestrus, for example, can be catalogued so that ultimately they can be incorporated in the memory and monitoring functions of a computer-based automatic supervision and control system for feeding, environment and market selection. Work is in progress at Reading University on an analysis of the skills of stockmanship.

Barn machinery and plant

Although there are many environmental problems in relation to the design, housing and operation of bulk processing plant such as grain and grass driers, feed milling and mixing plant and storage silos, in relation to operational efficiency more immediate attention should probably be paid to manned processing lines for the inspection, grading and packing of farm, orchard and glasshouse produce.

The repetitive manual tasks associated with these enterprises, although frequently requiring quite a high level of skill, have in general received little specific attention, although there is obviously a large quantity of information from more generally-aimed studies of inspection and other cyclic repetitive tasks which can be applied to the farm or packhouse situation. In the majority of these tasks one must consider the following ergonomics aspects:-

Posture and work layout.
Vision of the produce.
Hand, arm and body movements.
Pacing of the task.
Environment.
Organisation of teamwork.

Postural errors are likely to reduce work efficiency by a reduction of either speed or accuracy, in the same way as for the transplanter example described earlier. Data on correct heights for work benches and for seating, which should always be available if it is practicable to sit, as well as information on optimum and acceptable reach in respect of either men or women is generally available in handbook form. Some factors in visual arrangement are interconnected with posture - particularly the restriction of the task to optimum angles of viewing. However, in addition to this, one must arrange - particularly in inspection and grading - adequate time for eye fixation on each item or even part of item and for eye movements between items (Table 6) as well as being sure that all parts of the items are at some time visible to the operator. Even if an approximately spherical body is rotated continuously by rollers, in our experience there is still every likelihood that some parts will be always obscured to the viewer. Good vision requires adequate lighting - not only in terms of intensity, but in absence of glare, adequacy of source size to give multi-directional illumination and, combined with colouring of background parts of the equipment or surrounding walls, the optimum colour of lighting to give contrast between the produce being inspected and the background.

Where produce items must be handled, the task should be arranged so that necessary hand movements are consistent with the principles of motion economy, which have been postulated to ensure that limb motions may be made with a minimum of effort and maximum speed. The rate of carrying out repeated tasks may be governed by the rate of the machinery, by the rate of the whole team engaged, or by the capability or willingness of the operator alone. For maximum output, whatever is governing the rate should allow each operator to perform at near his, or her, maximum rate. Thus, if a team is involved in such a way that each worker must deal with produce that has been processed by a previous one, an adequate pool of items should be maintained between each member of the team to avoid the rate of work being always that of the slowest member at that time. This is made more important by the known - and relatively well understood - variability in workrate (cycle time), which as well as varying randomly from cycle to cycle, is also subject to gradual performance decline (increased cycle time) throughout working periods as a result of fatigue. In this connection, the incidence of breaks in the work and their length is critical. It has many times been demonstrated that breaks at an opportune time can greatly minimise if not eliminate the fatigue effects with a resulting increase in overall output, inclusive of the breaks. In some circumstances it may be equally effective to substitute a change in the work for a complete rest.

In addition to lighting, other aspects of environment are liable to affect performance. In different contexts noise, vibration and ambient temperature have all been shown to significantly influence the rate or accuracy of repetitive work. Space prohibits a more complete account here of these influences.

On grading equipment we have no evidence of noise levels likely to produce a hearing loss risk, in contrast to drying and milling plant, for example, where unsatisfactorily high levels are commonly met (Table 7). Added to the hearing damage risk to workers, noise from grain or grass driers can annoy nearby residents. The frequency with which this happens would also appear to be increasing from reports we have received at the N.I.A.E. This is possibly partly due to the recent adoption of large-scale grass drying plants and partly due to an increased sensitivity of the community to noise nuisance, engendered by the great publicity given to aircraft and other noise encroachments. The effect of this community objection can be to force a farmer to restrict operation of his plant to five days per week and then only use it during the normal industrial day, with a consequent loss of output and generation of severe problems during critical weather periods. For these reasons we are carrying out at N.I.A.E. some investigations of this problem and its possible solutions. The farmer who is establishing such plant can help himself by a careful siting of buildings brick-built types - and by siting fan or air outlets, conveyors and doors on the side away from any nearby houses.

The other large environmental problem associated with drying, conveying and feed preparation plant is dust. The sensitivity of persons to dust varies tremendously and once exposed, a person may exhibit painful symptoms which last far longer than the actual period of exposure. The most effective solution of potential dust problems is normally the treatment of parts nearest to the source of dust - that is if the original source can be treated by local enclosure or positive extraction, or better still be eliminated, by using appropriate conveyors for example, the solution is likely to be much more satisfactory than general building ventilation or the provision of facemasks.

As an example of yet another environmental hazard, silos - and particularly tower silos for silage - almost inevitably during the filling process contain gaseous atmospheres which are highly lethal to man. At the moment, the only advice ergonomists and engineers can give on this problem is for no-one to enter the silos at any stage during and within some weeks of the filling period.

Conclusions

These few examples have demonstrated the two facets to ergonomics application in agriculture. There is scope for study of many mahcines and manual tasks to improve directly the efficiency with which work may be done - generally to increase output per machine or per man. Alongside this are the many health and welfare hazards - most of them connected with agriculture's many highly unsatisfactory environments - which can lead to sickness or accident with consequent time away from work or can certainly be a persuasive feature in deciding a man to turn away from farm work altogether and go to work in a factory where in most cases nowadays conditions are far superior. Agriculture may never be able to supply such good conditions in which to work, but it is surely possible to do much better than at present.

Summarising, the following should be among the progressive farmer's aims:-

(1) Consider the actual operational efficiency of machinery and plant and not the ultimate output achievable by an operator unaffected by the equipment limitations and his own inevitable limitations due to fatigue, etc.
(2) Provide an environment or, if this is dependent on the equipment manufacturers, exert pressure on them to provide an environment in which high task performance efficiency can be expected.
(3) Ensure as far as possible that health and accident hazards are removed. Again this must frequently be done with the co-operation of the agricultural engineering industry.
(4) Be careful to arrange tasks - particularly those involving a team - in such a way that human characteristics are considered and catered for.

(5) Where partial automation becomes feasible, ensure that it is arranged in such a way that associated manual work - whether this be control of the equipment or sharing the task with it, is satisfying and economically sensible.

<u>Recommended for further information</u>

Murrel, F.K.H.	Ergonomics - Man in his working environment. Chapman and Hall, 1965.
McCormick, E.J.	Human Factors Engineering. McGraw-Hill, 1957.
Woodson, W.E.	Conover, D.W. Human Engineering Guide for Equipment Designers, University of California Press, 1964.

Table 1

Extract data from N.I.A.E. Tractor Operation Survey

Proportion of operators	Percentage
Choosing speed of work by implement performance requirements (A)	47
Choosing speed of work by tractor power limitation (B)	21
Choosing speed of work to be an acceptable level of comfort (C)	9
Choosing speed of work by a reason other than (A), (B) or (C)	22
Finding noise objectional (with cab fitted)	25 (35)
Finding ride vibration objectionable	19
Finding dust objectionable	12
Finding vision restricted	23
Considering controls to be in some way unsatisfactory	44

Table 2

Summary of Tractor Driver Hearing from Loughborough University/N.I.A.E. Survey in Bedfordshire

Age Group	18-24	25-34	35-44	45-54	55-64	Total
Proportion unaffected	6/11	8/14	12/26	6/11	2/8	34/70
Proportion with defective hearing	5/11	6/14	14/26	5/11	6/8	36/70
Proportion with speech frequencies affected.	0/11	3/14	7/26	2/11	4/8	16/70

Table 3

Summary of Tractor Noise Reduction Studies by N.I.A.E.

Vehicle details	Noise level, dBA	Loudness, Sones
Tractor only	99	140
Tractor with normal cab	103	140
Cab fitted with anti-vibration mounts	102	155
Bulkhead between cab and engine	97	115
Rubber mat flooring	92	80
Improve tractor silencing	87	70

Table 4

Selection of Measured Performance Data on Tractor Suspension Seats

Seat	Reduction in ride vibration, %		
	Heavy man	Average weight man	Light man
A	60	50	60
B	55	45	50
C	45	30	25
D	40	35	20
E	25	20	10
F	5	5	-15*
G	-15*	-25*	-30*

*Amplification of vibration by seat

Table 5

Comparison of Some Characteristics of Man and Machine

Characteristic	Man	Machine
Power	2.0 hp for 10 secs. O.5 hp for 2 mins. 0.2 hp continuous.	Consistent at any level. Large constant forces.
Consistency	Not reliable: should be monitored by machine.	Ideal for routine repetition, precision.
Complex activity	Single channel.	Multi-channel.
Memory	Large store, multiple access. Better for printiples and strategies.	Best for literal reproduction and short-term storage.
Computation	Slow; subject to error. Good at error correction.	Fast; accurate. Poor at error correction.
Intelligence	Can deal with unpredictable; can anticipate	None
Overhead reliability	Graceful degradation.	Sudden breakdown.

Table 6

Some Characteristics of Eyes and Vision

Characteristic	Data
Binocular angle of vision	188^{o}
Time for 10^{o} eye movement	40 millisec.
Time for 40^{o} eye movement	100 millisec.
Visual acuity (separation of small objects)	1 minute of arc at average lighting intensities.
Fusion frequency for flicker	50-60 cycles/sec.

Table 7

Typical Noise Levels on Farm Plant

Machine	Sound level, dBA	Loudness, Sones
Rolling Mill	98	100
Grain Drier (tower type)	94	115
Grinding Mill	82	45
Hammer Mill	94	100
Feed Mixer	71	20
Manure Drying Plant (Poultry)	87	60

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March 1970