PAPER No. 92.

SOME EXPERIENCES WITH A DRAGLINE EXCAVATOR.

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Object of the paper—General Conditions—Special Conditions—The conditions examined—Monthly Outturn—Examination of Monthly Outturn—Finishing off the work—Lessons to be learnt—Cost—Conclusion.

Object of the paper.

This paper is not intended to be a description of dragline excavators nor does it contain any advice to those about to purchase such plant; the object aimed at is to detail the actual cost of working an excavator in one particular case in order that others may be in the position of knowing what their own costs may be in such work. An attempt is made to indicate the amount of success and failure attained, and how particular conditions affect the work, in order to obviate the expensive necessity of buying this experience: in short, the object of the paper is to put in the possession of others the experience gained in order that when occasion arises they may be saved some doubtful guesses as to estimates of cost, be able to anticipate difficulties before they arise and in particular be in a position to visualize how any special conditions will affect costs, methods of working, etc. It is, therefore, assumed that the members of the Congress are acquainted with the dragline excavator and have a general idea of how it works; many must have seen them working or have read descriptive articles in technical periodicals dealing with the excavator in general.

It may be at once admitted that the costs are not given in the detail originally intended: it would no doubt have been interesting to have had full details of the staff, amounts of coal, oil, water, etc., used daily: it is, however, not possible to give these figures for reasons detailed later, and it is further doubtful whether such details would have been of very much practical use. These figures must vary greatly with the conditions of working, and experience shows that it would be unwise to generalize about them; it is probably best to indicate what conditions govern the details, and this, together with the information gleaned from the makers' figures and technical papers, will be the best information for the basis of calculations and enable the engineer to draw his own conclusions.

General conditions.

The excavator in question is a Class 24 Bucyrus dragline excavator which arrived at the end of April 1923, was erected and working at R. D. 30,000 of the Main Line of the Bikaner Canal by July and finished at R. D. 83,000 at the end of March 1924. This excavator was provided

with a bucket containing 3½ cubic yards for work with a 100 feet jib, and another bucket of 4½ cubic yards capacity for work with the jib shortened to 85 feet : the latter combination was used throughout. The canal has a bed width of 52 feet, side slopes one to one ; the digging varied from about 4½ feet to about 11 feet and is generally about 7½ feet deep ; the balancing depth varied from 6·7 feet in R. D. 30,000 to 75,000 to 5·5 feet in R. D. 75, 000 to 83,000. The earth excavated is mostly sandy and little could be called hard.

Special conditions.

As the canal is to be lined eventually, it is necessary that the bed and slopes should be dressed accurately. The water-supply was abundant and sweet in the upper reaches of the digging but became more and more difficult to obtain from surface wells : the supply obtained from tube wells was unfit for human use and for boilers, and eventually a return had to be made to good water from the original source. As a metre gauge track was being laid along the canal from the tail of the Main Line upwards, part of the track was sent round by rail and laid down along the canal from the site where the excavator started, so that connection was kept up by rail with the coal and water supply and with the workshops. A skilled erector, supplied by the makers, arrived with the excavator ; erection was done under his supervision, and he trained the operators, otherwise all the staff was obtained in India.

To any one who has had to make arrangements for dragline work, it will be evident that some of the general and special conditions make for good progress at cheap rates, whilst others influence the outturn in the opposite direction. It is proposed to go into these in some detail, because it is believed that the conditions under which the work is done have a very great influence on the success or failure of the operation and because, when the employment of an excavator for any work is under consideration, it is necessary to go carefully into the conditions under which it will work and which will be different in almost all cases. No greater mistake could be made that to assume that, because an excavator has done well or the reverse on certain work, it will do the same when conditions are entirely different.

The conditions examined.

Bearing in mind the fact that a dragline excavator gives the best outturn when the swing of the jib is reduced to a minimum, say about sixty degrees, and that the deeper the digging the cheaper the rate of excavation per unit (because the time lost in moving is less) and provided that the jib is long enough to enable the spoil to be deposited comfortably, it will be observed that the canal is small and the digging is moderate ; further, that in the reach where it worked it was sometimes above and sometimes below balancing depth, thus leading to frequent changes of section in the spoil. It follows from this that the excavator had to be moved many times a day, thus losing digging time, and that the frequent changes of section from those where there was a bank only

to those where there was a little spoil deposited at a lower level than the bank and finally to those where a drain had to be left between the bank and higher spoil, all worry the operator, who has plenty to do in digging correctly without considering the section of the spoil bank; and moreover an operator not fully trained dumps the earth so inaccurately that a considerable amount of hand labour has to be employed subsequently to correct his errors. As an example, in one reach it was found possible to tell the operators to consider only the spoil bank and to dump all the earth excavated on one side in that spoil bank only without making any patrol road; the result was more progress and a better spoil bank.

It has been stated that the lining to be laid subsequently on the bed and on the slopes to a vertical depth of nine feet needed accurate cutting of the slopes and bed; this was so much so that it was considered advisable to allow the operators under training to dig only to within one foot of the eventual bed, and later to within six inches of it, when they became more expert. The slopes were roughly removed by the bucket, and then correctly cut by hand labour when the remainder of the earth was removed from the bed; it will be evident to all that such hand work is the most expensive form of earthwork. Had the canal not to be lined, it is believed that the excavator could have dug, when the operators became more expert, with sufficient accuracy to make further handwork in the bed unnecessary, and very little to be done to the slopes. It is believed that a great amount of care and expense is generally wasted on the accurate cutting of side slopes, often to be left to be damaged by rain for years before the canal is opened and in the sure and certain knowledge that after the canal has been opened for a year the side slopes will not retain the slightest resemblance to the carefully cut slopes at the time of excavation.

An abundant supply of good water, is, of course, a necessity where steam is employed. Bad water affected the outturn of the excavator to an extraordinary extent as will be related later. It is unlikely that water will be available along any alignment without carrying in some places, and in this case it was fortunate that it was possible, without increasing the cost of excavation in any way, to lay a metre gauge track alongside the canal and thereby arrange for coal and eventually water, simply at the cost of haulage.

The expert erector was invaluable in the process of erection and in training the operators; but the process of training operators is a fairly expensive one as the outturn is comparatively small to begin with, and the digging and dumping of the spoil inaccurate. There is evidence to show that the operators were getting more outturn and doing better work as they became more expert, although this is to some extent hidden by other factors.

Summing up, it may be said that whilst the canal section suited the excavator, the digging was shallow for a maximum outturn at cheap rates; the accuracy in cutting the bed and side slopes to the correct

sections necessary for the purpose of lining told against a large outturn ; the bad water was against a good outturn and undoubtedly hard on the engine and boiler ; the existence of a metre gauge track alongside made the bringing up of coal and water as easy as possible ; and finally the training of the operators was in excellent hands. How far these advantages and disadvantages cancel each other, it is impossible to say.

Monthly outturn.

The statement below gives details of the monthly outturn :—

Month.	Outturn in cubic feet.		No. of days in month.	No. of working days.	Outturn in c.ft. per working day.	Coal consumption in tons.	Coal per lakh c.ft. outturn.
	During month.	Up to date.					
1	2	3	4	5	6	7	8
July ..	10,35,165	10,35,165	31	26	39,000	87	8·4
August ..	20,61,484	30,96,649	31	24	86,000	180	8·7
September ..	21,40,179	52,36,828	30	25	85,000	148	6·9
October ..	20,36,067	72,72,895	31	26	78,000	169	8·3
November ..	16,95,183	89,68,078	30	22½	75,000	135	8·0
December ..	17,23,341	106,91,419	31	20½	84,000	140	8·1
January ..	23,50,653	130,42,072	31	25½	92,000	234	9·9
February ..	17,30,676	147,72,748	29	21½	80,000	205	11·8
March ..	25,17,571	172,90,319	28	22½	112,000	218	8·6

Any one who reads to the end of this paper will notice that, in dealing with costs, the total output is taken as 170,54,049 cubic feet, the difference is explained by the fact that this latter figure is accurately calculated from cross-sections of the work taken before it was completed by hand, the former figure is based on daily measurements of the uncompleted work and is necessarily a little inaccurate. The difference is not material and not worth the trouble of distributing it over each month's work.

The number of working days in column 5 needs explanation. The excavator did not work on Sundays, when the engine was overhauled, the boiler washed out and petty repairs and adjustments carried out : this is treated as a non-working day and is left out of account. Similarly such holidays or religious festivals when it was necessary to give leave to the labour or operators are not counted as working days. All other days, with the particular exceptions noted below, are counted as working days, whether the excavator actually worked or not, even if heavy rain stopped work, or a break down occurred, or, as often happened at the beginning, there was a failure in coal or water-supply, as such stoppages are due to inefficiency and must be counted in to obtain a true idea of the efficiency of the working of the excavator.

There were, however, days which are not counted in when the excavator did not dig ; these were the days when the excavator was passing over parts of the canal which were purposely left undug for reasons connected with the lining to be done afterwards. This is not a normal condition and would scarcely apply elsewhere, so such days are omitted entirely from the count of working days. The number of working days so calculated is 213½ out of a possible 272.

Examination of the monthly outturn.

The monthly outturn varies from ten to twenty-five lakhs of cubic feet of earth work ; an explanation of this is desirable and interesting as showing how the various working conditions above alluded to affect the outturn.

The excavator actually commenced to work on the 25th June, but for the few days of this month the expert erector alone worked, testing all parts and getting every thing in trim for actually starting excavation : the period of working before 1st of July does not therefore appear in the statement. In July two operators were under training and the erector of necessity did a good deal of work himself. The excavator worked for eight hours a day only, and the outturn per working day is, it appears, a bit flattering owing to the fact that the erector was doing a lot of work himself. The metre gauge track, mentioned above, had not arrived and so a make-shift had to be made with tramway track, an expensive and unsatisfactory arrangement.

From 1st August, the excavator worked for 16 hours a day and almost exactly doubled the total outturn, whilst the outturn per working day is more than doubled. The number of working days is reduced by three, over and above the usual weekly over-haul, on account of the delay caused in taking the excavator across an old inundation canal, in flow at the time.

During September, when the progress was much as in August the operators were both ill at one time or another and work was carried on with difficulty during a fever epidemic. Up till the end of this month, the supply of coal and water was run up on the tramway, which, as the lead grew longer, gave a large amount of trouble and stoppages were frequent. The number of working days are normal except for one entire day due to a failure in the water-supply. The consumption of coal per lakh of cubic feet excavated shows an astonishing drop from what was seen to be the normal figures of the preceding months, and no explanation of this is forthcoming.

Early in October, a third operator was put under training and the working hours extended from 16 to 18 hours daily. The outturn showed a drop from September, although there was one more working day in the month. The water-supply was moved to a nearer source

during the month but continued to give much trouble until the metre gauge connection was made about the middle of the month. With the third operator in training and with the longer working hours it was expected that the progress would rise steadily from about 20 lakhs cubic feet upwards.

The outturn per working day in November shows much the same figure as for October, and it is to be noted that in November work was carried on for the first time without the expert, who after October only paid periodical visits. Two and a half non-working days were occupied in crossing the Sukha Nalla, where the excavator had to cross on a high "made" bank and for safety's sake work was only done in day light. Coal consumption continued to be normal, but difficulty was experienced with breakdown of pumps for the water-supply. The record day's outturn of 1,40,364 cubic feet was done during the month.

December shows a slight improvement in outturn over November, but owing to the few working days the progress is still below that of August to October. Five Sundays, two and a half days for the Christmas holidays, and moving the excavator over a length of one thousand feet undug, account for the abnormal number of non-working days. So far, progress was not altogether as satisfactory as had been hoped: circumstances, in the shape of an abnormal number of non-working days, conspired to keep the progress short of what had been obtained with shorter hours, and even the progress per working day was not what it had been, though to a certain extent the earlier figures are flattering, the expert being responsible for some of the outturn.

January with a good number of working days showed a welcome return to a good outturn: the month's progress and the outturn per working day was the best to date, showing that the operators were improving, in spite of one entire working day lost in scraping the deposit off the crown plate of the fire-box. The increase in the consumption of coal was enormous, and was directly traceable to one or two bad truck loads, for the last eight days of the month consumed an average of $10\frac{1}{2}$ tons a day, whereas the consumption of the preceding 23 days only amounted to $6\frac{1}{2}$ tons. During the month the source of water supply was moved to a tubewell put down at R. D. 63,000: it was ascertained that the water was brackish and expert advice had been obtained as to the "dope" required to make it fit for boiler consumption. This treatment was not a success, as the boiler "primed" badly. Another trouble was that if "priming" occurred or bad coal was used, causing the fire-box door to be opened frequently, the engine swinging round continuously at a high level drew in cold air and caused the boiler tubes to leak.

February had fewer working days, owing to the excavator having to move over two long lengths without digging and also to the fewer days in the month. The monthly outturn was again short of hopes and the outturn per working day showed a disappointing drop. This is almost

entirely attributable to trouble with the water from the tubewell above mentioned. The treatment was given a prolonged trial and the amount of "dope" even trebled, but it proved quite useless. The boiler "primed" so badly that it was necessary to "blow off" for 12 minutes in every hour, so that the water consumption went up from 12,000 gallons daily to 20,000 gallons : steam could not be maintained though the coal consumption went up heavily, in spite of the use of picked coal. In the end, the supply from the tubewell had to be dropped and a return made to the surface well nearly 7½ miles away. The moral needs no pointing.

March was the last month during which the excavator worked on the Bikaner Canal, and work was closed down on the 28th after 22½ working days. The digging was normal, but the operators were now trained and the water-supply good and well organized though brought from a distance of 8 miles. The daily progress was remarkably steady, rarely falling below a lakh cubic feet on a full day's work. Given reasonable conditions, this shows what the excavator can do.

The total quantity excavated was 1,72,90,319 cubic feet in 213½ working days, giving an average of 80,000 cubic feet per working day, including the month of 8 hour day and the time spent on training three operators. It would appear that the average outturn per working day of 18 hours with trained operators should be at least 90,000 cubic feet, and the average monthly outturn about 23 lakhs cubic feet.

Finishing off the work.

The excavator left the canal roughly excavated and the spoil and patrol banks roughly thrown up. How roughly this was, was not at once recognized as the dressing and completion of the canal and banks was not undertaken until about 5 miles had been dug. Detailed cross sections showed that the excavator had left 25 per cent. of the total amount still to be excavated and that the spoil and patrol banks had been *very* roughly thrown up, so that much hand work would be necessary to bring it to the true section. This was disappointing as it will be at once realized that such hand work is expensive, particularly in the bed and side slopes, where the work amounts to dressing coupled, usually, with a big lift. This result is attributable principally to inexpertness on the part of the operators, together with the frequent changes in section entailed by the digging being so much in and out of "balancing depth," and the rather natural tendency on the part of operators to go for progress in outturn without paying sufficient regard to accurate dumping of the spoil. It will always be a difficult point for any one to decide as to how far the time of the excavator should be wasted on accurate digging so as to leave as little as possible for hand labour, and it is a decision which must be made separately in each case with due regard to the quality of the dressing required.

Lessons to be learnt.

There are many lessons to be learnt from the experience gained and the more important are enumerated below :—

(*a*) The type of excavator must fit the work it is to do, due regard being paid to the height and width of spoil bank : this being fixed, the excavator will pay best in the deeper digging, where its outturn is, if anything, better than in shallower digging, whilst hand labour is more expensive.

(*b*) Trained operators are highly desirable : training operators is expensive both in lack of outturn and in indifferent work. All operators should be competent mechanics.

(*c*) Good water and coal are essential.

(*d*) A nice balance has to be struck, bearing in mind the quality of the finish desired for the excavation, between decreasing the outturn of the excavator by attempting accurate cutting of the bed and sides of the canal and leaving a large quantity of excavation to be done by hand labour on a roughly dug section.

(*e*) As corollary to (*d*), dressing of the canal and completion of the spoil and banks should follow as rapidly as possible on the excavation, so that it can be ascertained what the cost of completion is and the method of working adjusted if necessary.

(*f*) A dragline excavator cannot be planted down anywhere and expected to work efficiently without arrangements for a good and regular supply of coal, water and stores ; it is also essential that a workshop be within easy reach for repairs.

(*g*) The excavator must be worked as continuously as possible ; the working hours should not be less than sixteen, preferably eighteen hours a day. One day a week must be set aside for washout and general overhaul, but every other non-working day should be viewed as a regretable incident.

(*h*) The employment of one excavator for digging a length of a canal is a mistake ; a programme should be made out to employ a number of them and move them from canal to canal in accordance with the programme. This will prove more economical in working, in the number of operators employed, in the supply of spare parts kept and in the employment of a competent mechanical engineer to supervise the work. It should be the latter's duty to watch the accuracy of the digging and dumping, and to complete the earthwork, the entire operation being in one pair of hands.

Costs.

It was intended to give in this paper the monthly running costs in the same way as they have been reported month by month, so that the effect of the outturn or consumption of coal, etc., could be shown on the cost : but owing to a variety of reasons so many adjustments have been made subsequently and charges debited in one month which really relate to the work of another that the costs quoted in the monthly report are far from accurate. It has therefore been decided to discuss the costs of the whole work instead of the monthly cost : it is, however, possible to show with accuracy the cost of the work separately from R. D. 30,000 to R. D. 75,000 and from R. D. 75,000 to R. D. 83, 316, as it so happens that they are different estimates ; and this separation serves to show in marked relief the improvement of the working towards the end when the operators were trained and the organization running smoothly. As regards monthly costs, it is interesting to note that the running cost of the excavator in February was Rs. 6·2 per thousand cubic feet, whilst that in March was Rs. 4·1 per thousand cubic feet—the difference between a poor and a good month's work.

The general abstract for the two reaches mentioned above is :—

Detail.	R. D. 30,000 to 75,000.	R. D. 75,000 to 83,316.
Labour	17,350	2,058
Coal	32,966	5,949
Other stores	6,078	679
Spare parts	4,766	526
Water-supply	7,029	1,013
Workshop repairs	3,006	715
Non-working days	9,169	930
Warm clothing for labour	113	..
Tram line	4,681	..
Total ..	85,158	11,870

The heavy cost of non-working days shows the necessity for avoiding as much of this unproductive expenditure as is possible.

The actual outturn from careful measurements and the rate per thousand cubic feet for these two reaches is—

R. D. 30,000 to R. D. 75,000	142,67,122 c.ft. @ Rs. 6 %.
R. D. 75,000 to R. D. 83,316	27,86,927 c.ft. @ Rs. 4·2%.

Taking the work as a whole, the outturn is 170,54,049 cubic feet and the cost of excavation is Rs. 5·7 per thousand; this latter rate disguises the improvement shown at the end of the working.

This is, of course, only half the picture, it is necessary to ascertain what the completed work cost and then compare it with what hand labour would have cost in order to see how far the excavator proved an economic success. The statement below gives the cost of the completed work :—

Detail.	R. D. 30,000 to 75,000.	R. D. 75,000 to 83,316.	Total work.
Total quantity of work done, cubic feet.	194,97,964	34,46,901	229,44,865
Total cost of work done, Rs.	1,46,786	20,190	1,66,976
Cost per thousand cubic feet, Rs.	7·5	5·9	7·3

The figures sufficiently demonstrate the improvement in the working of the excavator in the second estimate as compared with the first. It is, of course, unknown what hand labour would actually have cost, and it can only be estimated in the ordinary way at the rates which have proved sufficient in similar work. For the reaches in question the rates work out to Rs. 7-11-0 and Rs. 7-10-0 per thousand cubic feet respectively for the first and second reaches or about 6 annas per thousand cubic feet more than the running costs of the excavator.

Depreciation.

The above satisfactory result is as it would appear on the books if the method of accounting at present in force in the Department be adopted.

It is not a true method of measuring the cost and the depreciation of the plant should be included to arrive at a fair comparison. The rate of depreciation tentatively laid down for these excavators is 16 per cent. per annum, which does appear to err on the low side. It is unfortunate that, at the time of writing some 15 months after arrival, the cost of the excavator in Indian currency is not known, as the debits received from the India Office are so muddled as to be obviously incorrect. The cost of the excavator in dollars has however been ascertained and converted into rupees at what appears to be about the right rate of exchange, and the freight, etc., are known, so that the figure now adopted, Rs. 2,30,000, is not likely to be far from the final one. This gives a rate of depreciation of Rs. 3,066 per mensem. Adopting this figure, and adding the depreciation for the appropriate number of months to the estimates, the following results are obtained :—

Reach.	Quantity done c.ft.	Total cost excluding depreciation.	Depreciation.	Total cost including depreciation.	Rate including depreciation.
		Rs.	Rs.	Rs.	Rs.
R. D. 30,000 to R. D. 75,000 ..	194,97,964	1,46,786	24,105	1,70,891	8·8
R. D. 75,000 to R. D. 83,316	34,46,901	20,109	3,192	23,301	6·8
Whole work R. D. 30,000 to R.D. 83,316	229,44,865	1,66,895	27,297	1,94,192	8·5

Taking depreciation into account, the unit cost of the whole earthwork done works out to be about thirteen annas per thousand cubic feet more than what it would have cost by hand labour, which goes to show that the excavation of the whole reach in question by machinery cost about Rs. 18,645 more than if it had been done by hand. Further, the results on the second estimate indicate that, with trained operators and a complete and satisfactory organization for the supply of coal and water, the cost including depreciation should have been in the neighbourhood of Rs. 7 per thousand cubic feet and the work would have exhibited a saving at eleven annas a thousand cubic feet or about Rs. 16,500.

Conclusion.

It appears that, supposing labour is sufficient to meet requirements, which it is notorious that it is not, such excavators can, if conditions are reasonably good, compete successfully with hand labour. Mechanical means have improved and the wage of the labourer has risen to such an extent that, whilst adverse conditions may make the use of mechanical means more expensive than hand labour, favourable conditions may throw the balance of cost in the opposite direction. In the case in question, lack of experience coupled with the necessity of training the staff and some other unfavourable conditions have shown that it is at least possible to compete with hand labour. If the experience so gained enables other excavators to beat hand labour in cost, the object of this paper will have been achieved.

Acknowledgment is due to the monthly reports compiled from time to time by Messrs. A. W. M. Jesson, C. E. Jefferis, and James L. Roy, Executive Engineers, from which the above figures have been taken.

DISCUSSION.

The discussions on papers No. 91 and No. 92 were taken together.

MR. HOCKNEY introducing his paper stated he wished to make it clear that the object of the paper was to give those members who were interested in excavation, and, no doubt, the majority of those present were, a general idea of the principles and method of working of the single bucket excavator. No reference had been made to the design of excavating machinery for the obvious reason that the majority of those present were civil engineers.

MR. D. J. MORRIS, in the absence of Mr. R. P. Hadow, read a written introductory note by the author who remarked that a question very often asked of those in charge of mechanical excavators was—what did the earthwork cost? It had been the author's endeavours in his paper to shew that such a question could not be answered in a few words, any more than if one were asked—how much petrol did a motor car consume? The answer to the latter question as everyone realised, depended on the car, the work it was required to do, the kind of petrol used and whether the driver was good, bad or indifferent. In a similar way, the cost per unit of outturn of an excavator depended on many conditions and the paper indicated in one particular case with one class of machine, what conditions influenced the cost, so that the cost per unit under other conditions, might be estimated with some accuracy. It was hoped also that the paper would extract from the many others who had charge of dragline excavators, details of their costs and conditions governing them, so that such figures and details might be available for general use instead of being buried in files.

Another (and more intelligent) question sometimes asked was—how did the cost of your dragline work compared with the cost of hand labour? In this paper, the comparison was drawn and the conclusions arrived at by the writer were given—that the costs were so close that good or bad conditions on either side would tip the scale for or against mechanical excavators. Some knowledge of the experience of others in this direction was highly desirable.

It was to be noted that since the paper had been written, rules had been made enabling the depreciation of certain plant in use on the Sutlej Valley Project to be written off from time to time against the works estimates, thus allowing something like true costs to be exhibited in accounts.

MR. H. W. NICHOLSON said he had five dragline machines of 3 types on the Suleimanki Weir Construction Works and preferred the largest size fitted with caterpillars.

On page 6, Mr. Hockney stated that the caterpillar machine could be turned in practically its own length. This was correct only as far as the machines fitted with two caterpillar tracks were concerned and not those fitted with four tracks. He considered the oil-driven machines

would be much more useful in the Punjab, as compared with those operated by coal fuel as coal was very expensive and difficult to handle and store, while oil fuel, on the other hand, was easily handled and stored, besides which, there was much less risk of losses by theft with oil.

Another point was that in order to get good results with draglines, good operators were essential.

The figures of cost given in Mr. Hadow's paper were very good and shewed that good supervision had been maintained. At Suleimanki, owing to the varying conditions of work, the cost figures of draglines could not be accurately fixed. One excavator, for example, had been engaged in digging a big drain for river diversion works. Before the drain was dug, water level was at ground level, whereas after its completion, water level had been lowered, to a sufficient extent to enable the whole of a channel to be excavated in the dry. The excavator had paid for itself in doing this job alone.

MR. J. P. GUNN remarked that he had in his charge two 8 cubic yard machines and one 5 cubic yard machine. The cost of the excavation varied enormously with the quality of the spoil. In sandy soil, for example, it was not possible to get a full bucket load as the sand would not stay. He considered that a slightly damp clayey soil was the best for good progress and it was possible to keep the buckets absolutely full or even overfull in such cases.

Another question which seriously affected cost of work was the depth of the cut, as when excavating comparatively shallow cuts, work was delayed by the need for continually moving forward.

He fully endorsed Mr. Nicholson's remarks as to the need of first class operators : a poor operator in his experience had very serious effects on the working costs immediately.

MR. A FERRIE said that as Islam Weir, where he had been since April 1924, the work of the dragline excavators had been carried out under difficulties. Firstly, the heat was very great and malaria prevalent so that half of the operators and firemen were always sick and the remainder not fully fit. Secondly, as at Suleimanki, the excavators were not on continuous work but digging holes here and there and dodging around spoil heaps.

There were two No. 60 Ruston machines. One of these was dismantled in October 1924 and the other was in course of dismantling. The original under-carriages were unsatisfactory and the makers had supplied new under-carriages with continuous roller bearings. This was a great improvement.

The second machine in course of dismantling had been fitted with a new under-carriage in November and had given an outturn at Islam of about 25,000 cubic feet per diem, in average soil, working four shifts of six hours, including stoppages for coaling and repairs.

A No. 6 Ruston machine had recently been obtained for use on well sinking. It had an excellent two rope grab and was very successful, wells 14 feet by 14 feet being sunk in wet sand and clay to a depth of about 15 feet at the rate of one well in seven hours' working.

He considered that all grease lubrication on caterpillars and other working parts of excavators and other mechanical plant working in sandy country should be done by the use of grease guns and Enot or similar fittings.

PUNDIT MOOL CHAND SHARMA remarked that having proceeded on leave the previous day, he was not able to say very much as to the working of the dragline excavator in the Hafizabad Drainage Sub-Division for the previous 14 months. The working costs for 1924, however, varied from Rs. 6-8 to Rs. 7 per 1,000 cubic feet and were rising gradually as the machine got older and the expenditure on repairs and renewals of spare parts was high. Subsoil water level in the area was near the surface and it had been necessary to construct a proper track about 2 feet above ground level and the rate of excavation, including cost of track approximated to Rs. 10 per 1,000 cubic feet, excluding depreciation charges, or Rs. 15, including depreciation.

He had found that the cost of excavation by manual labour in this area compared very favourably with that of the excavator. For instance, a large diversion and deepening work in connection with the Ahmadpur Kot Nikka drain carried out by manual labour had cost Rs. 8 per 1,000 cubic feet, whereas if excavators had been employed, the cost would have been Rs. 15 per 1,000 cubic feet.

MR. D. J. MORRIS remarked that he fully agreed with Mr. Nicholson that it was essential to get the best possible class of man as operator on dragline machinery, as both the cost of digging as well as depreciation charges depended on the outturn. Another vital factor was not to keep machines idle; if machines were kept idle, depreciation continued. This introduced the question of spare parts and repairs. Ample spares should be at hand at all times and a decent workshop available whereby quick repairs could be effected.

It was important to select the right machine for the right job and also to organise the job to suit the machine. This was sometimes not realised, with the result that unsuitable machines were employed to do certain work and consequently the costs of the work were seriously affected.

The payment of bonuses to operators had been recently introduced on the Sutlej Valley Project, whereby each operator was paid a bonus for excess outturn above a certain fixed limit. The effect of this new system was not known yet, but the speaker felt that it was a step in the right direction and would lead to improvement in outturn and reductions in costs and would also help to ensure that operators would take care of their machines, as unless the machinery was kept in good condition, a bonus could not be earned for any length of time,

Up to recently only comparatively large machines varying from $8\frac{1}{2}$ cubic yards to $1\frac{3}{4}$ yards bucket capacity had been employed in the Sutlej Valley Project, but now a start had been made with smaller machines, one being used for well sinking as instanced by Mr. Ferrie.

Although perhaps at present in India under certain conditions manual labour could successfully compete with machinery in regard to excavation, the time was coming when owing to rise in cost of labour, it would be essential to use machinery and the experience being gained on the Sutlej Valley Project with dragline excavators would be of great help in the future.

MR. J. B. G. SMITH said a member from Hafizabad by his criticism of working rates in the excavation of drains had unhappily left the impression that coolie labour did the work more efficiently and economically than the dragline excavator. He would like to point out that the rates for which work could be done were not the sole criterion. Time was the most important factor in some cases which had to be reckoned with. At Suleimanki, the river was flowing over the area of the Right Undersluice Pocket at the end of October 1924. At the end of November 1924 it was still under water. In February 1925 seven or eight thousand cubic feet of concrete was being laid in it and in order to do this, the excavation had to be taken down to 15 feet below the cold weather river level and at a distance of not more than a couple of chains from the water edge. This could simply not have been done at all in the time available with coolie labour and certainly not at the rate of Rs. 15 per 1,000 cubic feet which is what the excavator had cost. Again, on the Pakpattan main canal, with work going on not only all over the Sutlej Valley Project but all over the Punjab and in Sindh as well, it would have been impossible to have followed the programme which had been adopted, without the dragline excavators, unless excavation work had been closed down on the other portions of the Project, and concentrated on this one canal. He left it to the audience to judge what this would have meant in indirect losses.

MR. T. M. BOSTOCK said that when considering working expenses of draglines, it was necessary to give them an indirect credit which was lost sight of. This was that, as all agreed, the price of manual labour had been kept down by the employment of the dragline excavators all over the Sutlej Valley Project. If it had not been for this, the rates for labour must have risen. It was a very great asset when a coolie contractor demanded a higher rate, to be able to reply that the work would be done with an excavator.

Another point was that all were gaining experience with these machines and experience had to be paid for. It might have been more economical had all excavating machinery been concentrated under one engineer instead of the machines being distributed amongst many executive engineers all of whom had to learn about them, and having other duties to perform, could not always give the necessary time to work the machines to the best advantage.

MAJOR E. P. ANDERSON said that up to the time he left the Khyber Railway, just a year ago, his experience with small steam shovels practically confirmed Mr. Hadow's views as to the comparative cost of work done by them or by hand labour. He would like to know whether the dragline excavator described, worked on solid ground, excavating behind them, or in the bed of the canal, excavating in front of them. The shovels used on the Khyber Railway were similar in type to that illustrated in Fig. 1 of Mr. Hockney's paper, and it was found that their use in railway cuttings was restricted by the fact that the back of the frame fouled the side of the cutting when the shovel swung round.

This greatly increased the difficulty of getting the material away, than which there was probably no more potent factor in increasing the cost of work. He considered that for this kind of work the American type of railway shovel in which the jib only swings through about 180° instead of a full circle and is supported on an A frame at one end of the main frame, carrying the boiler, would have been more suitable for this kind of work.

He wished manufacturers would pay more attention to the climatic and other conditions under which such machines had to work. In the Khyber Railway shovels, for example, the water tank was situated immediately below the boiler.

In the hot weather the water got too hot for the injectors to lift and stoppages were frequent as there was no feed pump. He cured the trouble by purchasing and fitting small steam donkey pumps. The physical labour of driving a machine fitted with dog-clutches was so great that a man of even average physique could not keep it up for long in the hot weather; all clutches should be steam driven. If oil was available, he thought it would be an advantage to use it in an internal combustion engine rather than burn it under a boiler.

He also enquired whether the operators employed on Mr. Hadow's draglines, were brought out from England or engaged in India.

In the Khyber, good results had been got with a Bombay lascar as operator, who had, he believed, been a ship's donkeyman or something of that sort before. One of the speakers had referred to a new type of grab used at Islam. This was a matter of interest to all engineers who had well sinking to do, and he hoped that if anything better than the old standard patterns was now available, details of it would be published in the "Proceedings."

MR. HOCKNEY replying to the discussion stated that the method of operating the dragline was explained fully on page 2.

Mr. Nicholson's idea in favour of the biggest dragline on caterpillars was quite sound for certain classes of work but did not apply generally, such as for well sinking work.

He agreed with the remarks of various speakers concerning the need for good operators and such men were exceedingly scarce in India.

It was not only the actual operation of the machine which mattered, however, but also looking after it and keeping everything in order, and in this connection the bonus idea mentioned by Mr. Morris was good.

Major Anderson had mentioned the question of clutches. Present day machines were fitted with steam clutches and electrical machines generally were fitted with compressed air clutches of various types depending on the makers. Dog clutches were out of use. In this country owing to the low grade coal available as fuel and difficulties in getting suitable water for steaming purposes, he considered that the machines of the future would be driven by internal combustion engines. In the past there had been difficulties in designing a suitable clutch for such machines but these had been successfully overcome. It would mean, however, an entirely different design of machine from the under-frame upwards.

MR. D. J. MORRIS, replying on behalf of Mr. R. P. Hadow, said that the point raised by Mr. Bostock of putting all dragline machines in charge of one man had been under consideration and an expert excavating engineer would be put in charge of all the plant shortly. The executive engineers would thus be relieved of a good deal of work which they did not have time to attend to properly. Major Anderson's remarks on the difficulties experienced with a steam shovel in the cuttings of the Khyber Railway exemplified the speaker's previous remarks that it was essential to organise the work to suit the machine.

He fully agreed with what had been said by a number of speakers regarding the importance of the personal factor, which, in this case, meant the operators.

The practice on the Sutlej Valley Project had been to get a trained erector and operator sent out by the manufacturers with the machine, who erected the machine and trained operators employed in India.

They had tried to attract a good type of man for this work by offering good pay and had found that the best class of operators were men armed with a second or third class Board of Trade Marine Engineer's Certificate, who had a good practical knowledge of mechanical work and the stamina to carry on during the severe hot weather months of the year.

THE PRESIDENT in closing the discussion said that earlier speakers had left the matter in doubt whether they condemned dragline excavators, but he was glad that later speakers had drawn attention to the fact that it was not only actual cost of excavation which mattered, but also the effect of the employment of the machines in keeping down the rates of manual labour and in releasing the available manual labour for other works.