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I. **"Some Aspects of Alluvial Dredge Design"**

by

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and

II. **"The Prevention of Corrosion of Pontoons"**

by

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SOME ASPECTS OF ALLUVIAL DREDGE DESIGN.

By

A. G. FABER.

It will be appreciated by all persons who are intimately connected with alluvial dredging—whether it be for tin, gold or platinum—that the "perfect dredge" has not yet been built.

From the commencement of alluvial tin dredging in 1910 until about 1920, the general design of dredging plants installed in various parts of the world did not advance as might have been expected.

During the last decade, however, these dredges have improved out of all recognition, due, almost entirely, to the large number operating within the comparatively limited area of the F.M S. This fact has enabled Mine Managers and Engineers to get together and discuss problems as they arise. It has also been the means of creating a direct link between the builders and operators; data has been collected, while machine shops and foundries have sprung up enabling experiments to be tried out at but little cost.

My personal opinion, however, is that although such strides have been made, they have not been made along the soundest lines. Alluvial dredges can be divided into certain definite classes as regards design, and although each class has advanced upon its own clearly demarcated lines, but little has been done to select the best points of each class and combine these in such a way as to materially improve the general design.

For this reason, I consider that Dredging Association Southern Malaya is to be congratulated upon its present enterprise, as open minded discussion is bound to go a long way towards solving many outstanding questions regarding the most suitable designs for various important component parts of dredges, and should also materially assist independent mines in running as economically as possible during the present unwelcome depression.

This paper may appear to be somewhat disjointed, but I would like to mention that after reading Mr. J. S. Whittaker's excellent paper entitled "The Digging End of a Bucket Dredge," I have attempted to select some further portions of a dredge which lend themselves to discussion, and which for the most part cover new ground. At the same time, I have intentionally refrained from touching on "Tin Saving Equipment," as I hope to see this made the subject matter for future papers.

PONTOON: During the last few years, a number of tin dredges operating in Malaya and Siam have capsized and sunk. This fact has caused the Government to institute enquiries, and also the Insurance Companies to be stricter with regard to the issuing of Policies, and therefore a few notes in this connection may be of interest.

(*a*) *Construction*: When considering hull construction, two main points must be kept in view, namely lightness and strength. Examples exist where the difference between these two factors does not seem to have been duly appreciated, as some tin dredges, judging by their appearance, might almost have been designed and built by a Steel Rolling Mill. Weight in the wrong place is a snare and delusion, as through it we lose range of stability and minimise the reserve buoyancy—points which will be considered later.

A simple construction is the most suitable for re-erection, embodied in a design employing as few sizes of rolled sections as possible, and with the number of pieces reduced to a minimum.

A reliable and simple form is that with the well sides carried aft to the stern with the cross beams and floors cut in way of same. No other fore and aft bracing is required. Transverse bracing is taken care of by the watertight bulkheads, and the partial bulkheads under the machinery;—also large beam and floor brackets. The bottom plating should preferably be stiffened by flanged plate floors with bottom frames joggled to suit the plating. This is stiffer and lighter than channel floors with joggled plating.

The deck beams should be angles joggled to suit the deck plating, and supported by light angle stanchions from the floors. Channel beams are, for the greater part of the deck, unnecessarily heavy, and, as they cause the deck plating to be joggled, they leave a deck which holds water and accelerates corrosion.

There seems to be a prevalent idea that longitudinal and transverse internal bracing is required in addition to the longitudinal and transverse bulkheads. This is unnecessary as the vessel is not a girder supported at its extremities only, but is water-borne along its entire length and breadth. Such bracing is an instance of unnecessary deadweight, as the bulkheads are amply sufficient to prevent any tripping.

As the bulkheads play such an important part in the stiffening and bracing of the hull, it may be useful to say something about their position.

There should be one, which may be called the "collision bulkhead," about 1/10 the vessel's length from the fore end of the pontoon,—that is, half will be on the port and half on the starboard side of the well.

A second one should be at the end of the well, and another about half way between it and the collision bulkhead. In an average sized dredge, a further two or three would divide the pontoon abaft the well.

Although it entails additional expense, a dredge designed to work where snags are likely to be encountered, should have a cofferdam bulkhead fitted on each side of the well and distant about 2 ft. 6 ins. from it, extending along the whole length of the well. If the pontoon is holed in the well, this will prevent the vessel from sinking.

A pontoon structurally designed in this manner will give no cause for anxiety, but the questions of Stability and Trim must also be carefully considered, as these factors largely govern the dimensions of the pontoon.

(*b*) *Stability*: It is of the utmost importance that a tin dredge should have ample stability, not only for safety, but to enable it to work efficiently. When the shape of a typical pontoon is considered, it will be realized that nearly all have sufficient stability, but what they lack is range of stability. In other words, it is not sufficient for the static stability to be good, but the dynamical stability must also be above the average—the latter for two reasons: Firstly—because the common centre of gravity of a tin dredge is very much higher above the centre of buoyancy than it is in an ordinary vessel, and secondly—because, after the deck edge is immersed, the range of stability of a flat-bottomed pontoon is not only limited but drops off very quickly.

From this it will be seen that the beam of a tin dredge should be in proportion to the height of the common C. G. above the deck so that the dynamical stability will be sufficient to prevent the deck edge being forced under water even when the maximum wind pressure is encountered broadside on.

Obviously, if this condition is met with, it is not only the external pressure that is acting upon the vessel. Other agents—such as side line pull, bilge water, spoil, etc., are all helping the upsetting effort, and have no doubt often contributed to disaster. Naturally, the effect of these heeling agents is much more serious in a flat bottomed pontoon than in a 'shipshape' vessel.

It will readily be seen that freeboard is a very important factor in connection with stability, as on its amount, the range of stability practically depends. With a freeboard of 12″, the deck edge of a dredge may be forced under water when the angle of inclination is less than 5 degrees, and from that moment her dynamical stability declines owing to the loss of water plane area. An increase of 12″ in freeboard would mean that double the pressure would be required to heel her deck edge to the water level, and would thus double her range of stability.

The loss of freeboard sometimes experienced with tin dredges in Malaya may perhaps be accounted for as follows:

Assuming an insufficient study of the problem before the construction is proceeded with, it may be found that the dredge has quite a considerable heel to one side when complete in working order. With a view to counter-balancing this, ballast is added on the opposite side. This, of course, increases the draft of the vessel and diminishes her freeboard. It may be argued that it also increases her stability by the addition of weight low down in the hull, but this does not compensate sufficiently for those valuable lost inches of freeboard with the consequent decrease in the range of stability.

In a well-designed vessel calculations are carefully gone into before commencing the construction to see that the port and starboard leverages of the machinery etc. balance, or to see that the hull is so constructed as to counter-balance any excess moment to one side or the other. At the same time the weight of every part of the dredge is calculated to ensure that the displacement provided is sufficient to float the hull, machinery, fuel, water and spoil and still give the desired freeboard, with something to spare for bilge water and sludge.

(*c*) *Trim*: What applies to stability applies also to trim, which is, after all, stability in a fore and aft direction.

Again, there is the same need for careful calculation of weights and leverages, not forgetting that the vessel trims about the longitudinal centre of water-plane area. If the design is faulty and the vessel trims a foot by the head when she should trim that much by the stern, again ballast may have to be resorted to and again a certain amount of surplus buoyancy and freeboard is lost. Sometimes it would appear that the effect of the water in the well has been overlooked when the trim of some dredges is considered. This should be taken account of in the trim calculations, as a weight equal to the weight of water enclosed in the well up to the designed waterline with a leverage from its centre of volume to the centre of the solid water-plane area.

If not possible by means of manipulating the weights, in order to avoid the use of ballast it may be necessary to taper the hull to shift the longitudinal centre of buoyancy and thus get the dredge to the required trim.

(*d*) *General*: From the above it will be seen that the only practical way of increasing the range of stability of a tin dredge is to increase the freeboard, but for obvious reasons there is a practical limit to this. Thus the designed freeboard should not be less than that necessary to keep any part of the deck above water when the dredge is inclined at an angle of 6 degrees, although possibly this might be reduced to 5 degrees when in loaded condition. It may be of interest to remark that a normal heel for a dredge when slinging the top tumbler over the side is anything from 2 to 2½ degrees. This is assuming the dredge to be upright at the start, and makes an allowance for bilge water etc.

As the freeboard on many existing dredges is insufficient, it is advisable for them to be fitted with automatic alarms which operate if the freeboard at any point becomes less than a predetermined figure, or if the bilge water in any compartment is allowed to accumulate to too great an extent.

BOTTOM TUMBLER: Although this subject was dealt with in a previous paper, I propose to make some brief observations on a somewhat unusual type of bottom tumbler, *i.e.* the Lobnitz Patent Lubricated variety.

This differs from the majority in that the shaft is fixed in the ladder horns forming a very efficient tie between them, while the tumbler body, which is fitted with a heavy cast iron sleeve, revolves freely on the shaft. Owing to the length of the sleeve, the bearing pressure is naturally very low, and thus, if grit is excluded and the tumbler kept efficiently lubricated, the resultant wear is almost negligible.

The shaft is pierced from end to end, and the ends are fitted with special screwed plugs enabling grease to be introduced under pressure between the shaft and the sleeve. After the first initial filling, the grease is introduced by means of a high pressure pump situated on the ladder above the water line, this enabling the pressure, as shown on a gauge, to be kept constant.

To retain the grease and exclude grit, side wearing plates of hard steel are fitted on the tumbler. Rings of hard rubber fitted in the ladder end castings bear against these side wearing plates, while the rings are kept in place against the wearing plates by means of springs assisted by the pressure of the grease.

This type of tumbler has been in use since about 1904, and the following instance will serve as an example of how long it can be run without requiring attention:—A new shaft was fitted to a 54 cubic foot harbour dredge in 1912, and at the end of 1929 it was described by the Chief Engineer to the London & North Eastern Railway Co. as being "in good order and condition."

This tumbler is slightly more expensive to manufacture than the more common varieties, and its success is largely dependent upon great care being exercised when being fitted in the first instance. Once installed, it is essential that the grease pressure is never allowed to drop or grit will penetrate into the bearing past the hard rubber sealing rings.

There is a small point of interest which arises in connection with the maintenance of these tumblers, and that is the difficulty of estimating what the grease pressure should be at the pump gauge in order to give the correct pressure within the tumbler. The frictional resistance of grease within a restricted area is almost impossible to estimate accurately, and we have found that this can only be ascertained by practical experiment;—too low a pressure will allow grit to get in, while too high a pressure will destroy the hard rubber sealing rings by forcing them sideways into the clearance space left for end play. The pressure within the tumbler should slightly exceed the water pressure at the maximum digging depth of the dredge.

A drawing of this tumbler will be available at the meeting for anyone who may care to examine the design more closely. From this drawing it can be seen that a turning mark is made on the tumbler and a gauge provided for making periodical tests. Such tests should be made weekly and a record kept;—should wear suddenly become appreciable, it is obvious that the device is not working efficiently, which in nine cases out of ten denotes neglect in regard to lubrication. Obviously, only grease which will not attack rubber must be used to lubricate these tumblers, such as stauffer or petroleum jelly.

The body of these tumblers is usually made in a one piece casting from high tensile carbon steel with a thick tread, while renewable manganese steel wearing plates are bolted on to the side flanges.

For dredges fitted with large capacity buckets the body can be made from manganese steel, but owing to the difficulties attendant upon the casting and finishing of large manganese castings, this becomes more expensive in the first instance.

As this variety of bottom tumbler has achieved such success on large capacity harbour dredges, it is surprising that it is not more generally found on alluvial dredges. It naturally requires a certain amount of attention, but this is amply repaid if stoppages for repair can be obviated.

MANGANESE STEEL: In view of the extensive use of what is commonly known as "manganese steel" in the dredging industry, I do not think it will be out of place to make rather more than passing comment on this remarkable alloy.

The results of alloying manganese with steel are extremely variable and conflicting. If you add 1.5% manganese to steel the resulting alloy is relatively brittle; increase the percentage to 5.5 and the brittleness becomes greater, but raise the percentage still higher and the result is contrary to what would be supposed, namely great ductility combined with toughness.

Manganese steel is an iron-carbon alloy which has a manganese content of between 11 and 13%, and 1.2% carbon. The carbon being in solution renders the steel non-magnetic. It has an austenitic molecular structure which breaks down under pressure into Martensite, which is an intensely hard substance. Consequently, although toughened manganese steel will give a Brinell number between 170 and 200, the same casting after being in work for a few months becomes "work hardened" and will give anything up to a Brinell number of 321 and even higher.

The effects of heat treatment are also extremely interesting. Untreated castings give a Brinell of between 200 and 250 and are often quite brittle, but when quenched in water from a temperature of 950 to 1,000 degrees Centigrade, they give a Brinell of 170 to 200 and become extremely ductile and tough. This is, of course, quite contrary to the action of ordinary steel but similar to copper. With manganese steel sudden cooling makes the metal ductile, slow cooling makes it brittle.

Forging should be carried out at a bright red heat and never continued when the work has become dull red, and it is essential that after forging it should be re-heated to a bright cherry red and quenched in water.

Manganese steel has a comparatively low elastic ratio, which means there is a great disparity between the point at which, under load, the steel first takes a permanent set, and the point at which it eventually breaks. It usually has an ultimate breaking strain of 55 tons per square inch, elongation 40% in 4 inches, Brinell 200.

Owing to the tremendous hardness resultant from deformation of molecular structure when subjected to cutting or abrasions, it has been impossible to drill or machine manganese steel as a commercial practice until recent years, when Messrs. Edgar Allen & Co. of Sheffield produced a super-high speed steel which has enabled them to carry out both these operations as a usual procedure in their machine shops, thus obviating the very expensive processes of punching and grinding. To do this type of work a special technique has of necessity been developed, involving specially designed drills and lathe tools. This recent development is extremely interesting, and much could be written about it, but it must suffice to remark that the first essential before machining can be commenced is the obviation of "chatter." The machine carrying the tool and holding the casting must be absolutely rigid, enabling a steady and progressive cut to be made;—the slightest "chatter" immediately alters the molecular structure of the metal in the vicinity of the tool, making it so hard that even the special tools quickly become blunt.

Manganese steel cannot be employed for parts which are subjected to heat which exceeds 345 degrees C. as once the temperature rises above this point the steel will become brittle.

As will be readily realized from the foregoing, Manganese Steel is a difficult metal to handle and considerable knowledge of the temperature points at which the molecular structure changes is necessary before satisfactory casting or heat treatment can be carried out. One of the many difficulties encountered when producing castings of this material is the considerable shrinkage which takes place when solidifying from the molten state. Special patterns in which the proper shrinkage allowance of 5/16" to the foot has been made, must be used, and considerable difficulty is experienced obtaining sound castings where heavy masses of metal occur in the design. It is also very essential to relieve the casting of all hard cores immediately after being cast, otherwise the casting pulls itself to pieces during the cooling, by contraction onto the cores.

I have perhaps gone into this question in greater detail than the title of the paper warrants, but my reason for doing so is because Manganese Steel is being used to a greater extent in dredge work almost every day, but owing to the difficulties attendant upon its casting, new experiments are not always satisfactory. Many of the failures could be obviated if engineers and dredge designers would collaborate with foundry experts when actually designing the component parts. The designs put forward would then lend themselves better to the casting peculiarities of this very useful alloy.

POWER: (*a*) *General*: It is obvious that a whole paper could be written on the subject of Power, but it is not my intention to deal with more than a very few aspects.

At the present time the most usual forms of power as applied to tin dredges in this part of the world are as follows:—

(1) Straight Steam.
(2) Straight Electric (outside supply).
(3) Combined Steam and Electric.
(4) Diesel-Electric.
(5) Suction Gas Electric (If not in actual use at present this form of power would appear well worth considering).

Naturally, the type of power installed on a dredge depends largely on local conditions, but at the same time there are many instances when any, if not all, of the various types could be satisfactorily utilized. For this reason it may be of interest to compare the initial costs of the different types, average running costs, and any apparent advantages and disadvantages connected therewith.

Until a few years ago, apart from isolated cases, nearly all tin dredges were "straight steam." The boilers were designed to burn either coal or wood fuel, while the main engines were generally of the Marshall horizontal variety. The result was a simple and reliable combination, but not necessarily a very economical one.

When other types of power began to threaten the popularity of the steam driven dredge, designers turned their attention to ways and means whereby both the efficiency and economy of the steam plants could be improved. The latest arrivals use higher boiler pressures, super-heaters, and triple expansion engines, and as a result the power costs of these dredges are quite as low, if not lower than electrically operated plants which purchase their power from outside supplies.

In the following notes, any remarks in connection with steam plants refer to "recent models," as it is only in this way that a fair comparison can be made.

(*b*) *Initial cost*: Assuming that dredge material of the straight steam and combined steam-electric varieties can be landed c.i.f. Malayan ports for £40 per ton, (this figure is fairly accurate for an averaged sized dredge) a similar sized straight-electric dredge will cost about 5% less, while diesel-electric and suction gas electric will cost about 25 to 30% more.

The foregoing shows that as far as initial outlay is concerned, Straight Steam, Straight-Electric, and Combined Steam-Electric have a strong pull over the Diesel-Electric and Suction Gas Electric types.

(*c*) *Running costs and future tendencies*: It is not easy to collect a sufficient amount of reliable data regarding running costs to form a fair comparison, especially during the present time when restriction of output is in force. I consider the following can, however, be taken as a typical comparison of the average power costs of each class of dredger (with the exception of Suction Gas) taken over a given period of time and brought down as nearly as possible to a common basis:—

The power costs of Steam driven dredges average about 85% of those of Straight-electric dredges which purchase their power from outside sources of supply, while the power costs of Diesel-electric plants are about 75% of those of Straight-electric.

Unfortunately it is not possible to give comparative figures for Suction Gas driven dredges, but I think experience with this form of power in other spheres indicates that it should prove to be the cheapest power of all.

When considering the above remarks regarding comparative power costs it must be clearly remembered that in my opinion they form a fair average, but they must not be taken as referring to any isolated examples. Also, owing to the fact that the figures, on which the foregoing statement is based, have been collected over a period of fully two years, it is possible that the statement is not a fair representation of the position to-day. A great deal of knowledge has been acquired recently regarding the practical application of electric power on tin dredges, which has enabled their power costs to be considerably reduced. Furthermore, I understand that alterations have been made quite recently in connection with the prevailing systems of tariffs, which in certain cases have proved most advantageous to consumers. Lastly, to consider power costs alone is unfair to dredging Companies which run a fleet of more than two dredges, as in such cases, the use of electric power enables economies to be effected both as regards European and native labour.

From this it would appear that the Diesel-Electric and Suction Gas Electric forms of power will always supply a limited demand for dredges which are intended for working deposits off the beaten track, but the position regarding the comparative merits of steam and straight-electric dredges is not so clear.

In most forms of Industry, steam has been forced to give precedence to electricity, so is it not highly possible that the same will occur regarding the tin dredging Industry of Malaya ? In the not far distant future, we may see considerable areas of the F.M.S. covered by a grid system, which would mean a cheap and handy form of power available to a large majority of tin dredges. Furthermore, the present tendency in the local tin mining Industry would appear to be the absorbing of the smaller independent Companies by the larger and more powerful groups. This tendency, together with the fact that the capacities of dredges being installed is undoubtedly increasing, will popularize electrical power to the detriment of steam. I would not like to prophecy regarding the monthly cubic yardages which tin dredges will be treating in ten years time, but no doubt what we consider abnormal yardages to-day will then be considered very average;—harbour dredges were fitted with 54 cubic foot buckets many years ago, so why should not tin dredges reach, and even exceed this mark ? In the case of a mechanical plant such as a tin dredge, which is in reality a concentrated mass of machinery, it would seem probable that a size will be reached when it will no longer be economical to manufacture power aboard when this can be done outside and delivered on board by means of nothing more elaborate than a cable.

There is a further matter I would like to touch upon regarding electrically operated dredges of the future. Present day examples using this form of power are actually nothing more than steam driven plants on which the engines have been replaced by motors and the boilers by transformers.

If a comparison is made between a steam and an electrically driven locomotive, it will be seen that there is no similarity whatsoever, and the same can be noticed in other examples.

The practical application of electrical energy is so entirely different to that of steam, that in future, instead of following the "steam pattern," we may see electrically operated tin dredges treating huge yardages and bearing only a remote resemblance to those we have before us to-day.

(*d*) *Summary*: The advantages and disadvantages of the different kinds of power are largely a matter of opinion, but should prove a subject which will form the basis of a most interesting discussion. Let us examine each type separately:—

(1) STRAIGHT STEAM. Comparatively cheap initially,—capable of being extremely economical,—understood by native labour—no expenditure on fuel if temporarily closed down, and very flexible to handle.

(2) STRAIGHT ELECTRIC. Cheapest of all initially,—power costs of an efficiently designed machine are about the same as those of an economical steam driven plant provided the cost of the power does not exceed 2 cents per unit. In most cases dependent upon an agreement with the Power Supply Company, which may necessitate the incurring of expenditure when the dredge is temporarily closed down. More difficult than steam to manœuvre over an uneven bottom and liable to be cantankerous in contingencies such as the face falling in on the ladder.

(3) COMBINED STEAM AND ELECTRIC. Is in reality only a variation of Straight Steam which lends itself well to incorporating in the designs of alluvial dredges.

(4) DIESEL ELECTRIC. Although the fuel costs of this type are very low, (there is normally a saving over steam, provided the

cost of oil is less than about six times the cost of coal delivered on board) nevertheless the extra initial cost must be taken into consideration. In the case of these dredges, it is almost essential to arrange for a stand-by unit, by either installing two sets of engines each capable of developing 100 per cent., or three sets developing 50 per cent. of the required B.H.P.

(5) SUCTION GAS ELECTRIC. This makes a suitable arrangement for incorporating into an alluvial dredge design, and has the added advantage that it can be changed over to oil in a comparatively cheap and simple manner. The unit essentially consists of a generator which produces the gas, which must then be cooled and thoroughly filtered before going to the engine. The normal procedure is to use coke in the generator, but wood fuel can equally well be used provided the plant is made proportionately larger, a more efficient filtering device fitted, and a tar extractor added. This form of power would appear well suited to mines in out-of-the way localities, where transport is difficult but jungle firewood plentiful and cheap.

(*e*) *Sub-division of Power—Complete dredge*: Having very briefly touched upon the usual forms of power as applied to alluvial dredges, it may be of interest to consider the sub-division of power on an average plant, although this will vary somewhat with the size of the dredge, dredging depth, etc. An average, however, may be taken approximately as follows:—Pumps, 36 per cent., Dredging 27 per cent., Screen 6 per cent., Ladder Winch 18 per cent., Manœuvring Winch 5 per cent., Extras 8 per cent. These figures refer to distribution of the total power over the various motors or engines, and may not represent the actual distribution of power used.

(*f*) *Sub-division of Power—Dredging engine*: The sub-division of the power of the dredging engine or motor is a matter of considerable interest. One can take so many tons of spoil lifted through so many feet in a given time (making due allowance for the difference due to lifting through water for part of the height) which will give the power required for lifting the spoil. The remainder of the power is available for digging and overcoming friction, and will vary in different cases. In an average case, and for 45 feet of water, the percentages will be about 40 to 50 for friction, 20 for elevating the spoil, and 30 for digging. Assuming 350 H.P. applied to a bucket chain at 100 feet per minute (it is appreciated that this is an excessive speed, 70 to 80 feet per minute being the normal) this will equal, say, 50 tons pull applied to the top tumbler, of which 15 tons is available for digging. This is further reduced at the cutting lip owing to the leverage. The ratio of the radius of the circle described by the cutting edge in passing the bottom tumbler to the radius of the circle described by the links is about 5.7 to 2.3, so that an effective pull of 15 tons on the links at the bottom tumbler becomes only 8.7 at the cutting edge, and this may be divided up between two or more buckets digging at the same time, of 3 to 5 tons each. These figures may, of course, vary for different examples, but roughly, they show that the greatest loss of power is in the friction of parts, and that only a small remainder is available for actual digging.

(*g*) *Tension of Bucket Band*: The above leads to the consideration of two further facts which have a direct bearing on the subject. The first of these is the tension of the bucket band.

A usual formula for ascertaining the correct number of buckets in a band is

$$\frac{2.08L}{P} + 6$$

when L = the length between tumbler centres
and P = the pitch of the buckets.

As an example, I will take a mythical case, and assume a ladder with 77 feet centres and no idler. The figures are for the ladder horizontal and therefore, although they are not quite practical, they are comparative.

Consider three things:—

Extra buckets in chain (on sagging side).
Sag at centre in feet.
Tension in chain, assuming unity as standard.

Extra buckets.	Approximate Sag at centre.	Approximate Bucket Tension.
3 off	13 feet	1
2 off	11 feet	1.3
1 off	8 feet	1.7
0 off	0	0.0
(impossible case)		

From this it will be seen that by cutting down the extra buckets in the chain, the sag is reduced by only 5 feet, while the chain tension is increased by 70 per cent. This increase in chain tension naturally occurs only when digging at water level, as if the ladder could be dropped until vertical, the tension would again become unity.

Thus, if for practical reasons it is found necessary to run with a tighter band than normal, the power consumed will be very considerably increased.

The effect of adding an idler is to support the sag and thus reduce chain tension.

Applying the conditions of the previous case, but with an idler at the centre, we get the following results:—

Extra Buckets.	Approximate Sag each side of idler.	Approximate Bucket Tension.
3 off	7 feet	.4
2 off	6 feet	.5
1 off	4 feet	.7

This shows that an idler is of considerable assistance in reducing the amount of power required for digging.

(*h*) *The Problem of Friction*: The second point which arises in connection with the sub-division of the usage of the power of the dredging engine or motor is regarding friction.

As friction consumes such a high percentage of this power, cannot some means be discovered which will overcome it ?

Obviously, the majority of this friction occurs between the buckets and pins, these bearing surfaces being unlubricated and open to sand and grit.

Most of the moving parts of a dredger which have to work under similar conditions are carefully lubricated and fitted with grit excluding devices, and thus if the same system could be applied to bucket pins, it is not difficult to see what far reaching effects this would have on the tin dredging industry;—the brake horse power of the digging engine or motor could be considerably curtailed, the strain on the buckets decreased and the wear on bucket eyes, pins and tumblers reduced to a minimum.

I understand that an experiment on these lines is being tried out at present, and no doubt the results of this will be carefully watched by the Dredging Industry. It is only to be expected that the cost of equipping a dredge with lubricated and grit excluding bearings between the bucket eyes and pins would be considerably higher than the present system, but if the arrangement can be developed satisfactorily, I suggest that all dredging Companies would find it an economical proposition to incur the additional expenditure.

In conclusion I would like to mention that in preparing this paper I have attempted to choose subject matter which does not crop up every day in the course of practical dredging, and which at the same time lends itself to open discussion.

Subjects such as Power, upon some aspects of which I have touched, cover so much ground that I hope they will be dealt with more fully in future papers compiled by members of Dredging Association Southern Malaya, or others connected with the Tin Dredging Industry.