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"NOTES ON THE FEASIBILITY OF AUTOMATIC WAREHOUSING"

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1. INTRODUCTION

There is now sufficient information and experience available on the subject of automatic warehousing to make it possible for an organisation with major storage problems to assess the advantages and disadvantages of investing in one of these highly sophisticated systems provided it examines its requirements systematically and in detail. Additionally, it is becoming possible to compute the relative cost advantages of this kind of storage pattern as against the conventional one (i.e. Fork Lift Trucks and Pallet Handling).

We believe that the present position regarding the feasibility of automatic warehousing is untenable to most organisations. There is, so far as we know, no detailed guide available or published which enables any organisations to make even a preliminary examination of the possible advantages of fully automated storage.

From the theoretical work carried out at the Materials Handling Research Unit* we can now derive rules by which the various factors influencing feasibility can be measured and valid comparisons be made. The detailed application of these rules is likely to vary from case to case, and it would be impossible to comprehensively describe their use in a short and non-technical publication.

The notes which follow are not to be regarded as rigid guide lines, but attempt to set out the criteria by which an organisation may judge its own readiness to accept a change to mechanised storage.

2. TERMINOLOGY:

There are a number of special terms in use in the field of warehousing, and their meanings are not universally agreed. In order to avoid confusion, the following terms will be understood to have the meanings shown below, whenever they occur.

"Semi-manual" storage refers to these situations where work is done by humans using powered equipment as tools, i.e. Fork lift trucks, pallet trucks, conveyors etc.

*ref.1.

"Semi-automatic" implies decisions and/or control by human intervention, but the majority of the work being accomplished by mechanical means (i.e. some form of push button controls.)

"Automatic operation" means machine controlled but normally following an invariable pre-set programme. (There may be safeguards which require human intervention to reset in case of error or failure.)

"Automated operation" implies automatic control which is in some way adaptive to changing circumstances, usually by means of a control feedback loop.

"Highbay warehousing" refers to any type of installation in which loads are placed in and removed from cellular static racking by means of stacking cranes running in narrow aisles.

A "line" (of stock) means any item which is separately accountable in stock records, and may even be one colour or size of item in a range of such items.

FLT is used throughout as an abbreviation for Fork Lift Truck.

EDP is used throughout as an abbreviation for Electronic Data Processing Equipment.

3. RECOGNITION OF THE MERITS OF HIGHBAY STORAGE

It must be appreciated that the concept of automated warehousing using highbay storage is not simply a rather sophisticated substitute for an existing system which operates with fork lift trucks and pallets or pallet racking. Unfortunately many installations have been sold and put into operation without either buyer or seller being fully aware of this fact, with varying degrees of success. The fundamental requirement for a change of system must be that because of changing circumstances the existing system can no longer meet the demands made upon it, either by reason of service, or cost, or both.

The next point which should be recognised is that most existing forms of automatic storage are designed to accept unit loads, and at the present time (1968) the cost of designing a large scale system to store individual discrete packages (e.g. cartons)

seems to be so high that there is unlikely to be any economic gain. So any items to be stored must be capable of being formed into unit loads; either before or immediately after receipt.

4. FACTORS INFLUENCING CHOICE OF METHOD

Thus the stimulus to increased mechanisation is given either by increasing demand rates or by a change in the cost emphasis. In a period when costs and wages are continually rising, which seems to be a permanent feature of life in technologically advanced countries, wage rates always increase more rapidly than equipment costs. And the more sophisticated the equipment, the lower its relative rate of increase (for example, T.V. sets have remained almost unchanged in cash price over the last ten years, in spite of vast improvements in technology and continually rising material costs). This is reflected in the handling field by the relation between driver's wages and first cost of FLT's. Ten years ago the driver's annual wage cost was a third of the initial cost of a truck, today the figure is over a half. Since this trend is likely to continue, the cost emphasis in certain fields, including handling, will pass from labour intensive installations to capital intensive ones, where actual running costs are low, and the taxation system offers benefits rather than penalties. This can already be seen in operation in the field of EDP, and since control here can be achieved by machines, it is an obvious and short step to controlling a complex handling system by means of a computer, both reducing labour costs of human controllers and increasing the degree of control.

Another and perhaps simpler factor at work which may influence thinking towards mechanisation is caused, paradoxically, by improvements in stock control. As methods of forecasting improve, less relative stock is required to be held in the warehouse, although the rate of stock turnaround continually increases. (One of the features of success in the retail food business is the reduction in amount of stock held, with its consequences in reducing capital investment, and lowering the spoilage rate). This high rate of activity with relatively low stock levels can frequently lead to congestion in the semi-manual type of warehouse, which is sometimes given as the reason for duplication or decentralisation of warehouses, rather than being the starting point for new thinking about the problem.

Thus the various factors which should induce consideration of automated warehousing are:-

- (i) High rates of throughput, but coupled with the possibility of handling in unit loads.
- (ii) High volume of material handled in shorter times.
- (iii) Low relative stock levels, combined with the above, implying greatly increased activity within the stores.

NOTE: that variety of lines held in stock does not influence any of these headings: it is the volume of transactions under each variety which is important.

5. STARTING THE INVESTIGATION

The initial investigation must therefore start with an enquiry into the rates of throughput, volume of throughput and take into account both existing and proposed stock levels. This can start with an examination of the stock profile, and this must be prepared to cover all items which are required to be stored. An analysis of sales by value and volume in terms of unit loads (which may not necessarily be the same) is a first requirement and should be made over as long a period as necessary to include normal fluctuations, seasonal trends etc. This is usually six months or a year, and it is advisable to use as recent data as possible, particularly if no reliable forecasting system is in use.

The total period sales of all lines carried in stock are then listed in descending order of throughput rate, stating throughput rate, average, maximum and minimum stocks for each line. In some organisations, this may entail a considerable amount of data gathering, as the required information may not be in a form which makes it readily available. Nevertheless, all this information can always be extracted from past records and no attempt should be made to 'guesstimate' or take short cuts at this point.

If this list is now plotted against sales value, a curve will generally result which will show that some 20% of the lines are responsible for about 80% of the firm's business. Only exceptionally is this more than 10% different, and then usually in firms manufacturing for a narrow specialised market of customers, such as subsidiary firms to the motor industry.

If the products handled vary very greatly in size to such an

extent that it is not possible to take an average physical volume over all the items and turnover quantities, then the profile must be recalculated in terms of physical volume.

Examination of these lists will often confirm the existence of known handling problems; for example at the top of the list may be some item which is handled with such frequency and in such volume that it may be questionable whether it is necessary to place it formally into a store in the first place. Fruit and vegetables often occupy this position in retail food chains, whilst high volume common parts may have similar characteristics in engineering.

6. RANDOM AND SEPARATE STORAGE

The average time it takes for any handling equipment to extract or store a single unit of a variety of items is a function of the average space occupied by that variety, which in turn is proportional to the average stock holding of the variety and the position of the line in the store layout. Now there are only two basic methods of storing items, either randomly, that is having no particular place for an individual item, but assigning space as it becomes available or separate storage for each item. The latter method tends to be used for all storage situations which are controlled by humans, because it is simpler to remember where things are, although it can be shown mathematically* (and in physical fact in many installations) that this method is expensive in terms of storage space, if only because space has to be 'reserved' for occasions of maximum stock level for all lines. With random allocation a lesser amount of the total vacant space can provide for high stock levels. There is mathematical proof for this statement.*

7. MANIPULATION OF THE DATA

Since the maximum and average stocks are known, and the physical sizes of all items to be stored are available, it is relatively simple to calculate the amount of storage space which will be required for all items to be held in stock. However, highbay warehouses are costly structures, and it is necessary to know what proportion, if any, of the total stocks to be held will be most economically handled in this way. For instance, at the 'tail' of the stock profile may well be some items which are already known to cost almost as much to stock as they bring in as profit, whilst at the head of the curve things may move so fast

*ref.1.

as to be a large fraction of the total storage and retrieval cycle time.

The speed characteristics of the equipment available together with the physical volume referred to above enable us to compute an average handling time, and thence the average 'service' rate for both random and separate modes of layout.

These calculations are started with the first two items on the list, and repeated, adding one more item at each stage. After each stage of the calculation, an 'average service rate' is obtained for the total of items included for each of the two possible layouts. If the service rate is technically feasible, i.e. smaller than the total throughput rate for the items included, one calculates the economic feasibility. Sooner or later as one goes through the list the inclusion of an additional item will prove infeasible either on technical or more likely, economic grounds. Note that firstly, infeasibility arises from the inclusion of a low throughput item within a group of faster moving items, and secondly that variety, as such, does not matter.

Items for which the relative throughput rate is greater than or equal to the relative space requirement are usually candidates for inclusion in the mechanisable group, whilst when this relationship reverses the likelihood of inclusion decreases rapidly, as the difference between relative space requirement and relation throughput rate increases.

8. APPLICATION OF EDP METHODS TO CONTROL

High variety of course makes control more difficult, as does random storage - but only for human beings. These facts enforce the argument that if a high rate of mechanisation is feasible, then automation must be better, because control by electronic means is ideally suited to the complexities involved. Although one refers to this as a 'complex' situation, it must be recognised that this is only so because of the relatively finite capacity of the average human brain for storing facts and figures: the individual operations to be carried out are very simple indeed. It is only their number and apparent disorder that makes them appear complicated to us.

9. DIFFERENT STORAGE REQUIREMENTS

As a result of this study it will be seen that not all items stocked

will be candidates for automated highbay storage. At the highest turnover rate, some form of live storage may be more suitable, whilst at the lower end, even manual arrangements might prove economic. But only a complete and thorough study will expose this information; and too often the decisions to install equipment are made on the flimsiest of evidence. We can see now why so many of the original so-called automatic warehouses constructed in the USA are now tacitly admitted by their users to be uneconomic, though perhaps without their courage progress today might be much slower.

With the assumption that some portion of the stockholding might be more economically and rapidly handled by means of an automated highbay warehouse, we will look more closely at the overall control and operation of such a complex and its implications.

At this stage, one further assumption must be made: that all items into and out of the highbay portion of the warehouse are to be in unit loads. (This assumption will be dealt with and questioned later, under the heading of Order Picking).

10. CONTROL OF THE OVERALL SYSTEM

In considering the total handling system we must first look at the problems of overall control. Any production storage or distribution chain depends for its operation on a rapid flow of information as well as the physical movement of material. In the larger organisations where major changes in storage pattern are likely to be considered much of this information is provided and controlled by the use of EDP equipment. But at present, particularly on the storage side, much of the information is still in the form of human-interpreted paper work. Invoices, advice notes, stores requisitions, stock bin records, inventory sheets, withdrawal dockets, picking and loading lists, despatch notes etc. are all usually required before an item can be despatched to a customer. In most cases, this involves a long chain of people, anyone of whom is liable to error in accordance with our knowledge of human falliability. In addition there are a number of man/machine interfaces, where information in one form or another is transcribed, re-entered, interpreted and/or punched into cards, every instance of which introduces further chances of error.

11. EXISTING MECHANISED STORAGE METHODS

In most present day highbay storage installations, which are at best automatic, and most commonly semi-automatic, control of the

storage equipment is usually by means of punched cards (and often not the standard universally used punched card, but a 'special' derivative). These cards, one of which exists for every cell in the racking structure, form a species of 'memory'. Those for cells which are empty are normally kept in one file, to be transferred to a second or 'full' file when goods are put into store. The usual routine is as follows:

Items entering the highbay warehouse are normally accompanied by a document which may be part of the production control system, or suppliers' advice). This document is 'paired' with a card, or as many 'empty' cards as required, to place the item into store. These 'empty' cards are placed in a reader, and when the items are passed into the handling complex, cause the material to be stored in the selected position. This position may of course, be randomly selected, or chosen according to some agreed priority rule. The document accompanying the items is then filed with the 'memory' card, but this time under the item reference, to facilitate withdrawal. Note that all this takes place under local control, at the point of entry into store, and usually no information about the location of a particular item is available anywhere than at this point. Consequently, when withdrawal from stock is ordered, the choice of priority of item is left largely to local control, and may rest on efficiency of filing rather than need.

Some of the possibilities of error at this point are:-

- (i) The documents can be 'paired' wrongly.
- (ii) The selected cell can be wrongly chosen according to the selection rules.
- (iii) The card (and or documents) can be wrongly filed
- (iv) The card can be lost, damaged, mutilated.
- (v) Any or all of the data can be misread or misunderstood.

These possibilities exist for both storage and withdrawal.

12. IMPROVING CONTROL

If we are to postulate an efficient system of storage and

recovery it is essential that we bypass these sources of error, arising from the purely mechanistic approach which has hitherto governed the installation of highbay storage. Reference has already been made to the ease with which EDP equipment can handle apparently complex data, and it is therefore logical to expect that no difficulties will arise from controlling a highbay warehouse in this way.

13. RECEIPT OF ITEMS

The first requirement is to replace the punched card 'memory' by an electronic analogue, either locally or in the main computer system. Access to this memory will normally be through the main EDP complex or locally, if required, by keyboard.

Items entering the system for storage will be identified either by an accompanying document which will be machine-read, or by means of a previously applied or impressed code, which will be similarly recognised. On receipt of this information, the main complex (possibly using a special sub-routine on its normal stock control programme) will order the highbay mechanism to place the item(s) into store and record its position.) On demand, items will be withdrawn in accordance with the stock control rules operating the main system - 'First in, First out,' 'Last in, First out,' etc. as required, and to a delivery programme agreed with either customer or internal transport routines.

The necessary machinery for presenting and removing unit loads from a highbay complex already exists, and is able to function just as readily under automatic control as by human intervention. Since the main EDP system now has complete control over stock entry and withdrawal, it may be only necessary to provide for local control by keyboard for emergency use, and thus no human personnel would be required at this part of the warehouse, other than anyone required in the event of breakdown or malfunction.

14. ISSUE OF ITEMS

If it is accepted, as it must be, that the above controls are both possible and available, it is only a short step to making withdrawals against customer demands part of the automated function. For the EDP system is aware of the present stock position, as well as the individual locations of all items, and is thus able to initiate physically any demands entering the system. Obviously, when this position is reached, most of the paperwork which has now to be generated will be unnecessary, and the documentation may well be limited to invoices and despatch notes. The latter could either be generated at the point of withdrawal by using remote printers, or could be sent by pneumatic tube or other means to the despatch bay.

The above series of events covers all cases where complete unit loads are required for withdrawal and despatch, as was stated in the assumption made at the beginning of the section. However, very many organisations have situations where although incoming goods almost invariably arrive as or can be made into unit loads, the demands made by individual customers are such that only infrequently can their order be satisfied by complete unit loads, and more commonly, each customer requires only a fraction of a unit load of a particular item or line. Thus we find ourselves with a problem of Order Picking.

15. ORDER PICKING

There are two basic methods of order picking for a large number of customers and stock lines. These are usually known as 'serial' and 'parallel' methods, and in some cases a combination of both can be of advantage.

16. SERIAL PICKING

The serial picking method is the one most commonly used, and is largely a 'common-sense' method, in that the storekeeper is provided with a list of items required for a particular customer, and tours the storage area systematically accumulating the items on the way. These may be put in boxes, trolleys, on conveyors etc. but the essential point is that the order is collected and travels to packing or despatch as a complete entity from picking onwards. Although this is the oldest method in existence, it is still justifiable in many situations, but can only be used in automated highbay warehouses where all quantities demanded are complete unit loads. Attempts to serial pick part loads in these circumstances have been made, but it can readily be seen that if a pallet has to be withdrawn many times before it can be emptied, a situation may arise in which the handling capacity of the system is exceeded. The economics of the total operation may also be adversely affected by the accumulation of part loads and their repeated handling. It is worthwhile remembering that the preparation and assembly of multiple-item orders in location order for serial picking by human operators from printed lists has only become a practical proposition since the introduction of EDP systems.

17. PARALLEL PICKING

Parallel picking systems are on the other hand rather less obvious, but in many circumstances can be a much more efficient way of assembling orders. The customers to be dealt with are

first grouped into batches of convenient size usually in terms of daily or shorter periods, and all items for customers in these groups are then totalled up. The bulk demand for one item for this customer-group is then withdrawn from store and broken down to individual customer quantities. The next bulked up item is then withdrawn and distributed until all items required by all customers in the group have been so treated, and all orders are completed. Then the next customer group is introduced and the process repeats.

Two things are apparent already:

- (i) that the documentation to control such an operation can only be quickly and accurately carried out by using EDP equipment.
- (ii) Such a method is ideally suited for automated highbay warehouses, where the minimum withdrawal unit should be a unit load.

Whether it is necessary or desirable to break the unit load at the point of removal from store, or convey the total items to a separate order picking area is a matter for individual circumstances, but in either event, such picking will have to be carried out semi-automatically at best, and at the worst, manually.

Since the bulking and withdrawal operation would both be under computer control in an automated warehouse, the machine can be programmed to make bulked totals to the nearest unit load quantity either within the collecting group, by marginally altering demand quantities, or by taking following groups into account, thus avoiding the situation inherent to serial picking, of having to put back into store a part empty pallet. The customer will be aware of the marginal quantity alterations. There need be no 'political' problems here, if the customers are 'internal' i.e. such as retail branches. In any case, rules about bulking up will be laid down in the appropriate programme, and will probably contain a maximum and minimum permissible percentage variation for each item.

13. IMPROVEMENT OF ORDER-PICKING METHODS

It will be noted that the weakest link in the chain of handling

through an automated warehouse is the human-controlled operation of order picking. Information to the human operator about the item to be picked and the quantities for each customer has somehow to be presented to these operators at exactly the right point in time. In some cases, no doubt, this could be done by means of a machine printed list to which the operator works, and for relatively slow demands this might be the most economic. In other situations, the pick order could be displayed on an illuminated panel before the operator at the time the goods are to hand. In any event, some thought will have to be given to the checking of picked quantities, which again presents difficulties. One way to overcome this could be for the items to bear a machine recognisable code, which would be read after the pick point and checked against demand before despatch. Such coding might again only be possible on items of regular form and above a stated minimum size.

The problems of order picking, with its attendant inevitably high labour cost, will be one of the first matters to receive attention when detailed examination and research is being done into automated warehousing. At the moment, it may well be the most expensive part of the whole operation, and the one most liable to error.

The means by which a human operator recognises an item as an individual are quite complex, and it is worthwhile looking at this problem a little more closely, in order to see what steps could be taken to make order picking a machine function.

If the items are rectangular and regularly stacked, the selection of one item from a group by machine methods may not be too difficult, provided that selection is made from a known group which are all of similar type; checking by means of identi-codes would follow as confirmation.

If the item for selection is not regular in form, or in irregular stacks or layers it is not at present, possible (or economic) to make a quantity-specific selection by machine. A human accomplishes this task by recognising the objects visually by form, colour, and distance from grasp. The second piece of information received gives the location of the objects in relation to each other, and as a result of this input, the hands grasp the item in the manner best suited (as learned from experience) to gain control. Actual counting may be done visually or by touch, or most likely by a combination of both. Selecting one or more irregular items from a batch of similar items where these are randomly oriented is thus quite a complex task, particularly with regard to the information required to carry it out.

Further, the human can adapt immediately to different sized or shaped items, or different degrees of fragility. It is almost impossible at the moment to design a machine to these standards, although this may only be a present-day restriction.

One way in which these difficulties may be overcome for small or irregularly shaped items is to enclose them in some outer package which does lend itself to machine selection, say rectangular or cylindrical forms, or by placing items such as sacks in large tote boxes which are then readily machine-handable. But any such action, unless accompanied by a gain in other directions, will inevitably result in an increase in the cost of packaging and handling. If this cost is such that the introduction of it, plus the cost of the 'selection machine' makes the method cheaper than the employment of human labour- for at least the same level of accuracy of operation - then it must be considered.

19. ADVANTAGES OF AUTOMATED CONTROL

The advantages of having a highbay type warehouse completely controlled by computer now begin to emerge:-

- (i) No order can be placed on the warehouse for items not in stock (Stockouts are unlikely under full control anyway.
- (ii) Orders can be assembled to any given 'best' (i.e. optimised for some factor) method of withdrawal.
- (iii) In the case of parallel picking, items can be 'rounded up' and drawn to ensure the withdrawal only of complete pallet loads.
- (iv) Picking lists, invoices, and advice notes can be produced simultaneously, since stock records are reviewed at each order.
- (v) Human error due to paperwork can be almost completely eliminated.
- (vi) A great reduction in the number of clerks, storekeepers and stores accounting staff can be made.

- (vii) Better overall control of stock can be achieved with immediate notification of errors or inefficiencies.
- (viii) The highbay controlled warehouse section may be unlit or unheated if the product is unaffected, since neither condition is required by the machinery.
- (ix) Security is greater than under manual control.

REF.1. A Mathematical Model for Handling in a Warehouse
by E. KAY Published by Pergamon Press Limited.