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DESIGNING OF A LETTER SORTING MACHINE FOR THE REGIONAL POST OFFICES IN GHANA

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ABSTRACT

The hitherto manual sorting of 1,200 letters per hour in the post offices is laborious, labour-intensive and time-consuming. This paper seeks to design a letter sorting machine (LSM) based on the conveyor belt transportation and letter sorting principle to replace the manual method of sorting letters. This machine is designed to make sorting of letters very effective and efficient thus, minimizing sorting into wrong destination bins and increasing the number of well-sorted letters per hour to over 30,000. A programmable logic controller (PLC) installed in-between the sensors and actuators effects programming flexibility by way of the control program in its memory. Optical character recognition (OCR) technology and barcode sorter (BCS) systems are employed to read handwritten and printed addresses as well as barcodes. Coding of the regions and a proposed addressing format is resolved thereby enhancing compatibility with the postal optical character reading system. This paper therefore seeks to design a letter sorting machine for the regional post offices in Ghana to increase effectiveness and efficiency of letter delivery.

Keywords: letters, barcode sorter system, sorting machine, optical character recognition, post office, programmable logic controller.

INTRODUCTION

Many years ago, communication in Ghana used channels such as drumming, smoking, horns or trumpet blowing and sending messengers which most often carried not the actual thoughts of the sender. But today, there are various channels which include telephones or cell phones, letters (mails), electronic mails (e-mails) by way of the internet, televisions, radios, bill boards, magazines, journals etc. These medium of communication may be faster and more reliable, letter is one of the oldest media of communication which cannot be abolished since there are some things which can only be relayed properly and efficiently through the post.

Letters (mails) are still sorted by hand in the 21st century. When sorting by hand, postal staffs stand at large and long tables on which the letters are sorted into rows with the addresses all facing the same way enable the sorting of letters into areas and cities to be done. The mail is then bagged up and dispatched to the appropriate regional and district post offices for further sorting and delivery. In the local sorting office, staff distributes the mail into a 'sorting frame' of pigeonholes. About 1200 letters can be sorted per hour. This method mostly delays the time by which clients should have received their letters thereby halting many transactions. Some letters get lost through missorting. That is, punctual delivery cannot be assured. The present method is not so bad but if better is possible then good is not enough.

Ghana Post company

When talking or writing something on mailing of letter(s), Ghana Post Company should not be left out. Development of the postal services took off in 1854 as part of the colonial administration. In 1995, the Ghana Postal Service was established as the Ghana Postal Services Corporation (GPSC). Since 1998, the company has been known as the Ghana Post Company Limited. GPSC makes a very significant contribution to the national development of Ghana in areas of business and trade, employment, support for government organizations and revenue for the government. New corporations are currently investing in Ghana due partly to the company's business facilitation through on time delivery of business mail. The Expedited Mail Services (EMS) commenced in 1990 to supplement the universal mail delivery and to deliver business mail with great efficiency on an ad hoc and contract basis. It is the company's mission to provide prompt, efficient, reliable and secure communication and financial services and products to domestic and foreign customers at competitive rates. Indeed, Ghana Post is becoming the distribution center for mail to the sub-region. As of January 2003, the company has 318 Post Office and 370 Postal Agencies.

Present state of letter sorting in Ghana Post Company Limited

Letter is sorted by hand (manually) by staff around an open table. The standard number of letters sorted per minute is twenty. Thus, about a thousand and two hundred letters are sorted per hour. The letter boxes are grouped into frames or sections. Each section or frame contains one hundred letter boxes for easy segregation. Segregation is the term used to describe the sorting of letters into frames or sections without necessarily considering the final letter boxes. This method is also known as rearrangement or primary sorting. The stamp cancellation machines which were used for defacing (cancelling to prevent reuse of stamps) are no more in use due to the rapid price changes of stamps. This is because the cancellation machines are set or coded with a standard

price tag and the changes in prices cannot be effected by the workers due to less available people who are endowed in such fields. Hence, stamp cancellation is predominantly done manually. Mail canceling or defacing involves putting a postmark that contains the post office name, state, region, month, day and year that the mail matter was canceled.

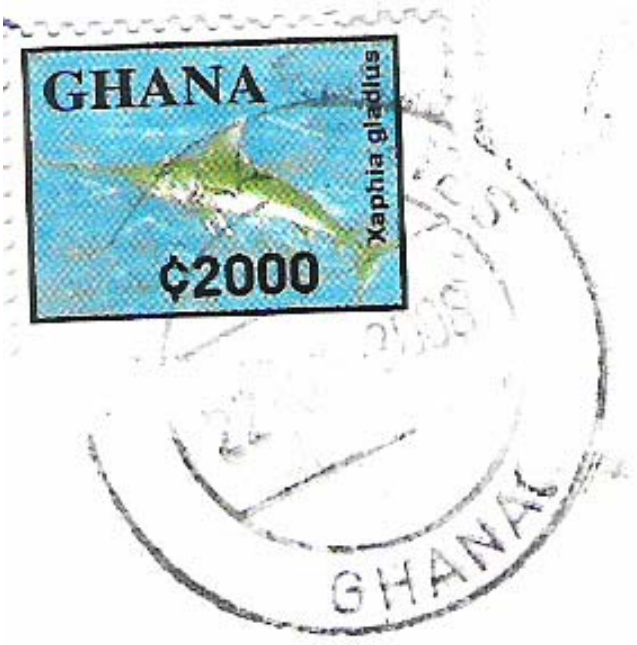

Figure-1. Relevant zones on an OCR-BCS compatible mail piece.

Figure-2. Stamp selling machine.

The stamp selling machine was used in the post offices during the colonial rule. This machine was used to sell stamps when the post office is formally closed. Stamps came out of the machine after money was put into it. This machine is not used again because it only operated when a coin denoting a certain amount was put into it. Thus, the machine is not sensitive to note currencies. As a result, these machines have become useless. Hence, stamps can only be sold and bought during working hours.

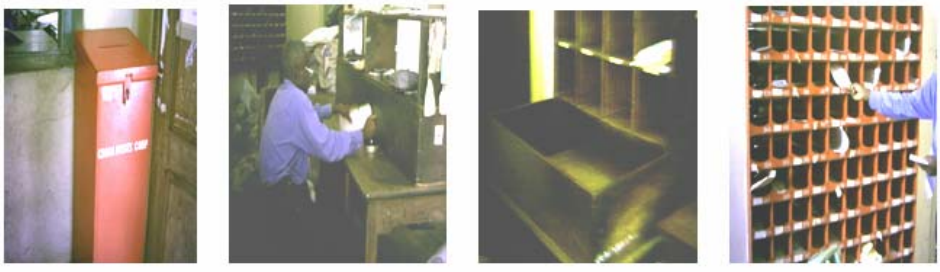

Figure-3. Letter sorting cycle of activities at the Tarkwa post office

Journey of letters

The processes a letter goes through before the recipient receives it are captured under the journey of letters (Figure-4). Letters move from the senders in the form of outgoing mails and are delivered to recipients in the form of incoming mails. Letters are qualified to go through the mail stream after the right amount of stamp has been purchased and put on them. The letters are then put into the post boxes. These letters are later brought to the stamping table where the stamps are defaced. Segregation of the letters into various towns is performed. Next, the letters are put into labeled bags and then into the mail van. When the mail van gets to its destination, the letters are debagged onto an open table. Primary sorting is done to rearrange the letters into frames. Secondary sorting is then performed to catalog the letters into letter boxes. Thus, the journey of a letter starts from the posting box and ends in the letter box.

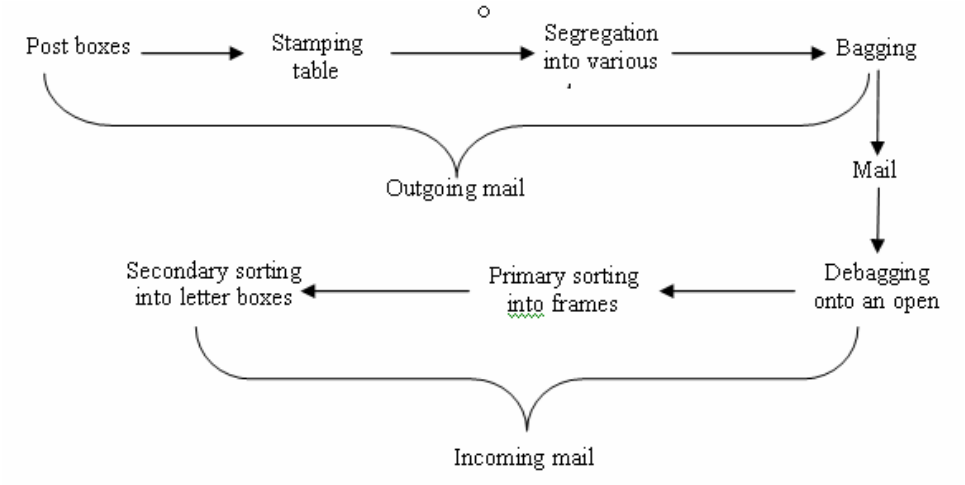

Figure-4. Manual cycle of sorting and delivery of letters.

Figure-5. Sorting room at Tarkwa post office, Ghana.

The objectives of this paper were firstly to design a letter sorting machine for the regional post offices in Ghana to enhance the number of properly sorted letters and improve upon the efficiency and effectiveness of letter delivery. Secondly, to provide a design that will lead to a prototype for scrutiny by the general public. In this design, an optical character reader (OCR) was employed to read and code both handwritten and printed addresses into barcodes. The barcodes are read by a high speed barcode sorter (BCS) which communicates with a programmable logic controller (PLC) for the right sorting gate to be opened. Sorting of over thirty thousand letters per hour is achievable as against a thousand and two hundred letters sorted manually.

MATERIALS AND METHODS

Study area of consideration

The research study area is Ghana; Ghana is a resourceful country in the western part of Africa, sharing borders with Togo in the east, Burkina Faso in the North, Cote D'Voire in the west and the Gulf of Guinea in the south. It has a population of 18.8 million, according to the last population census taken in the year 2000 and a land area of 238,537 sq. km. The country got independence in the year 1957 and had since undergone a lot of political, social and economic transformation.

A letter sorting machine (LSM) is a machine that can sort letters into bins or any other container capable of holding letters.

System development criteria

The letter sorting machine system must be able to satisfy the following criteria:

- It must be powered from a 240 V, 50 Hz supply source
- It should have a continuous mode of operation
- It must be amenable to Programmable Logic Controller programming via a computer
- It must sort over 30,000 letters per hour
- It must detect stamps, reject non-honoured letters, transport and align letters, collect and sort letters into bins, count the sorted letters
- It should read and code the address based on a control program sorting scheme loaded into the machine's memory either by hardware or computer software
- It should have a vision system which is made of optical character recognition (OCR) reader, barcode sorter (BCS) and stamp detector which work on the principle of retro-reflective photoelectric sensors.
- Sensors should communicate with appropriate actuators through the PLC
- It must be mechatronic and at least semi-autonomous.

Machine components and their configuration

A letter sorting machine is essentially mechatronic in nature consisting of mechanical, electrical, electronic, optical, sensors, software and electromechanical drive components. Whilst the conveyor belt, idlers, pulleys and shaft constitute the mechanical components, the control transformer, motor and switches form the electrical components. The PLC and counters are electronic whilst the optical character recognition and bar code sorter are optical. There are also photoelectric sensors and proximity switches. Electromechanical drive components constitute the electric motor and pneumatic linear actuators.

Mechanical components

Belt conveyor, idlers, pulleys, shaft and alignment mechanism constitute the mechanical components of the letter sorting machine.

Conveyor belt selection

The mechanical or gravity-operated belt or rollers for transferring mail between car or vehicle and platform, or from one location to another in a post office. Surge conveyor is a part of the mail conveying system that holds back surges and meters out an even flow, keeping all mail in sequence. However, the letter sorter is a conveyer consisting of letter-carrying carts equipped with escort memories that determine where each letter is to be dropped.

There are very important considerations to make when selecting a belt conveyor for a particular task. These are economic consideration, troughability, pulley diameter and pulley face, load support, impact resistance, cover

Selection of Idlers

Knowing the belt width and speed, the following should be considered: type of service i.e. operational environment, overall life expectancy of the conveyor system, hours of operation per day; characteristics of materials to be handled thus weight of material, type of material; belt speed whether high, medium, or low; type of idler i.e. troughing, carrying, flat belt, return belt, troughing carrying or impact idlers and finally, the actual idler load (IL) given by:

$$(IL) = \left(W_b + W_m\right)S_i \quad (1)$$

Where,
W_b = Belt weight, kg/m
W_m = Material weight kg/m
S_i = Idlers spacing, m

Selection of pulleys

Pulleys are selected with the following parameters in mind: lagging, weights**.** Lagged welded steel pulley, spin-end crown pulley, slide-lagged pulley, lagged wing pulley etc. are examples.

Shaft selection

The diameter of the shaft should be calculated in proportion with the load. Thus the equation for the diameter of solid circular shaft loaded in combined torsion and bending of drive pulley is:

$$d = \sqrt[3]{\left[\frac{16}{\pi P_t} \times \sqrt{\left[\left(K_b + M_b\right) + \left(K_t + M_t\right)^2\right]}\right]} \quad (2)$$

Where

K_t = Service factor for torsion
D = Shaft diameter, m
P_t = Allowable shear stress of shaft material, Pa
K_b = Service factor for bending
M_b = Bending moment, kgm
M_t = Torsion moment, kgm
But the equation for the diameter of a solid circular shaft in bending only (non-drive pulley) is:

$$d = \sqrt[3]{\left[\frac{32 M_b K_b}{\pi P_b}\right]} \quad (3)$$

Where P_b is twice the allowable stress of shaft material (P_t), Pa
The power (P) required at the drive of a belt conveyor, is given as:

$$P(W) = \frac{T_e \times V}{0.02297} \quad (4)$$

Where Te is the effective belt tension, N

$$T_{min} = \frac{4.2 \times 9.81}{1000} S_i \left(W_b + W_m \right) \quad kN \tag{5}$$

Where the constant number 4.2 is the factor based on 3% belt sag and S_i is Idler spacing, m

The effective belt tension is the sum of the belt tensions produced by forces such as: the frictional resistance of conveyor components, drive and all accessories while operating at designed capacity; the frictional resistance of the material as it is fed continuously unto the conveyor by a chute or a feeder; the gravitational load to lift or lower the materials being transported.

Selection of Drive Elements

Knowledge on such parameters as motor selection, drive selection, classification, DC drive characteristics and AC drive characteristics will help in the selection of drive equipments.

a. Motor selection

Parameters such as starting characteristics, types of power supply voltage, torque-speed variations, reversibility, duty cycle, starting torque, power required, ambient and atmospheric conditions, special service conditions such as whether the conveyor is inclined or otherwise affect the selection of motors for conveyor belt drives.

The following should be considered in selecting a motor;

i Starting torque

It is the torque at zero speed. For the system to be self-starting, the motor must generate torque sufficient to overcome friction and any load torque. The series configuration provides the greatest torque at low speeds for dc motors.

The acceleration of the motor and load at any instant is given by:

$$\alpha = \frac{\left(T_{motor} - T_{load} \right)}{J} \tag{6}$$

Where

α = the angular acceleration in rad/s^2
T_{motor} = the torque produced by the motor,
T_{load} = the torque dissipated by the load
J = the total polar moment of inertia of the motor and the load.
The difference between the motor and load torques determines the acceleration of the system. When the motor torque is equal to the load torque, the system has reached a steady operating speed state.

To ensure adequate starting capabilities;

- The locked rotor torque must be approximately twice the torque required to lift the material and overcome the total configuration respectively despite any voltage deficiencies during the acceleration period.
- The motor speed-torque curve should not fall below a line drawn from the locked rotor torque requirement to the torque running power requirement at full speed.
- The power rating of the motor to be selected should be at least equal to the power required by the conveyor, divided by the efficiency of all the drive components.

ii Maximum speed

The zero load point on the torque-speed curve determines the maximum speed a motor can reach. This is also the speed at no torque. When the motor is loaded, the maximum no-load speed cannot be achieved. Load is driven at a constant speed by using an ac synchronous motor or dc shunt motor that runs at constant speed over a significant range of load torques.

iii Duty cycle

It is the ratio of the time the motor is on with respect to the total elapsed time. The duty cycle is proportional to the power of the motor required. Thus, for a low duty cycle, a lower power motor may be selected that can operate above rated levels but will still perform adequately without overheating during repeated on-off cycles.

iv Power required by load

The power rating of load is a very important specification for motor selection. When the power requirements of the load are known, a motor can be selected with adequate power based on the duty cycle.

v Load inertia

For fast dynamic response, it is desirable to have a low motor rotor and load inertia J. When the load inertia is large, then high acceleration can only be achieved by sizing the motor so that it can produce much larger torques than the load requires. Printed circuit rotor pancake motors have low rotor inertia allowing for extremely fast response.

vi Position and speed control

In the cases of angular positioning at discrete locations and incremental motion, a stepper motor is a good choice. A stepper motor is easily rotated to and held at discrete positions.

It can rotate at a wide range of speeds by controlling the step rate. The stepper motor can be operated with open loop control, where no sensor feedback is required. However, if a stepper motor is driven too fast a step rate or if the load torque is too large, the stepper motor may slip and not execute the number of steps required. Therefore a feedback sensor such as an encoder may be included with a stepper motor to check if the motor has achieved the desired motion.

For some complex motion requirements where precise positioning or speed profiles are required, (e.g., in automated systems where machines need to perform prescribed programmed motions) servomotors may be

used. The servomotor is driven by a programmable controller that processes the sensor input signal and generates amplified voltages and currents to the motor to achieve specified motion profiles.

vii Torque-speed curve

If the load has a well defined torque-speed relation, called loading characteristic, a motor with similar torque-speed characteristic should be selected. Often, loads operate at low speeds and require large torque. Since motors function at high speed and low torque, a speed reducing transmission mechanism which may be a gear box or belt drive is needed to match the motor output to the load requirements. When a mechanism is used, the effective inertia of the load on the motor changes according to:

$$J_{eff} = J_{load}\left(\frac{\omega_{load}}{\omega_{motor}}\right) \quad (7)$$

Where J_{eff} is the effective polar moment of inertia.

The operating speed can be actively changed by adjusting the voltage supplied to the motor, which in turn changes the torque-speed characteristics of the motor.

viii Reversibility

Some motors are not reversible due to their construction and control electronics, and care must be exercised in selecting a motor for an application requiring rotation in two directions.

ix Size and weight

Motors can be large and heavy, or small and less heavy. Hence space and restriction should be considered.

x Special requirements

Larger frames may be necessary to keep the motor insulation safe and to retain normal life if the ambient temperature is more than 40°C. Larger frames should be used at high altitudes so as to promote better dissipation of heat. Special-purpose motors should be considered for a particular working environment. Totally enclosed motors, explosive-proof motors, drip-proof motors are example.

Electric Drive selection

Selecting a drive for an application calls for a major consideration as to whether to use an individual or group, AC or DC drive. Individual drives are compact and reliable but exhibit poorer efficiency due to transmission requirements in each unit. It is less reliable as the entire system depends on one motor. Multi stepped pulleys and belts are used which make the system occupy more space, be unsafe, noisy and less efficient. The group drive uses multiple motors to drive the machine's mechanisms.

DC drives utilize a preferably thyristor-based converter to transform alternating current into direct current. This is fed to the DC motor which is designed for adjustable speed operation. Speed regulation is effected by increasing or decreasing the amount of DC voltage fed to the motor from the output of converter. Speed control is realized by varying the firing angle of the thyristors. Besides, they usually offer the lowest cost for medium and high power applications. AC drives utilize a solid-state adjustable frequency inverter which adjusts the frequency and voltage in order to vary the speed of an otherwise, conventional fixed speed AC motor. This is achieved through pulse-width modulation (PWM) of the controller output signal to the motors. Voltage and frequency are maintained at a constant relationship for any motor speed so as to maintain a constant torque. This is known as the volts per hertz ratio.

Both AC and DC drives practically give a wide speed range and high speed regulation capabilities.

Pneumatic Linear Actuators

Pneumatic systems use compressed air as the working medium and the actuator is a cylinder. A compressor is used to provide pressurized air, usually on the order of 70 to 150 psi (482 kPa to 1.03 MPa), which is of much lower force than hydraulic systems. After the inlet air is compressed, excess moisture and heat are removed from the air by a treatment unit. Compressors cannot provide high volumes of pressurized air responsively; therefore, a large volume of compressed air is stored in a reservoir or tank. The reservoir is equipped with a pressure-sensitive switch that activates the compressor when the pressure starts to fall below the desired level. The control valves and actuators exhaust air into the atmosphere. That is, pneumatic systems are open systems, always processing new air.

Hence the need for a network of return lines is eliminated in this system. Double-acting or single-acting pneumatic cylinders are ideal for providing low-force linear motion between two well-defined end points. Since air is compressible, pneumatic systems are not typically used for applications requiring accurate motion between the end points especially in the presence of varying load. The infrastructure can be replaced with a high pressure storage tank. The tank serves an analogous function to a battery in an electrical system, making a light, mobile pneumatic system possible. In these applications the capacity of the tank limits the range of the system.

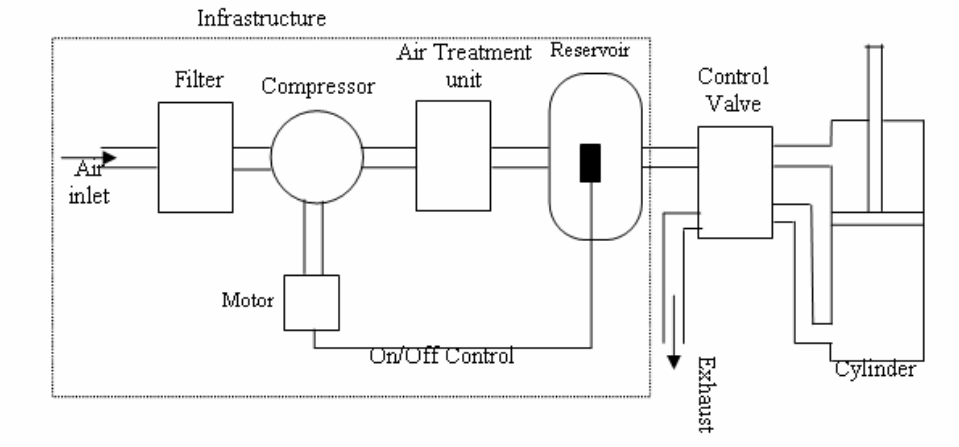

Figure-6. Pneumatic system components.

Hydraulic and pneumatic cylinders are used to produce a linear motion with a definite maximum distance of travel. Cylinders may be single acting or double acting. Cylinders produce large forces for linear motion of load or final control element. Single-acting cylinders allow fluid flow into only one side of the cylinder. The piston is returned to the starting position by gravity or by a return spring. Double-acting cylinders allow fluid on both sides of the cylinder, providing a power return of the piston.

The selection of a cylinder depends on the following: force required to move the load, speed required by the choice of system application (hydraulic and pneumatic), working fluid pressure, flow rate, valve size and oversize factor. Pneumatic cylinders have less force than hydraulic cylinders however, pneumatic cylinders are capable of greater speed than hydraulic cylinders. Air cylinder speed depends on the force available to accelerate the load and the rate at which air can be vented ahead of the advancing piston. An adjustable valve in the cylinder bent port is one method of regulating the speed of a pneumatic cylinder. The force F, produced by the cylinder is given as:

$$F = AP \quad (8)$$

where P is the working pressure and A is the cross-sectional area

Selection of working pressure is interrelated with the size and cost of the cylinders and operating considerations such as leakage and pump cost. Thus a higher working pressure would permit a smaller cylinder and a lower flow rate to achieve a specified force and speed.

Electrical and electronic components

The electrical and electronic components of a letter sorting machine are mainly made of programmable logic controller (PLC), optical character recognition (OCR), barcode sorter (BCS), pneumatic linear actuators and photoelectric sensors.

Programmable logic controller (PLC)

A programmable logic controller (PLC) is the main device installed in-between the sensors and actuators to effect programming flexibility by way of the control program in its memory. A PLC is a digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions for implementing specific functions such as logic, sequencing, timing, counting, and arithmetic to control, through digital or analog input and output modules various types of machines or processes (Groover, 1989). The PLC is used to control equipments such as conveyor systems, food processing machinery, auto assembly lines and so on. The PLC software is the control program made up of instructions stored in the memory. Depending on I/O and memory capacity, a PLC could be considered as small, medium or large.

The program is entered via a programming device that could be a personal computer or a miniprogrammer connected to the PLC's programming port. A PLC program could be written in ladder logic, Boolean or Grafcet languages. The ladder logic diagram program is easy to use and implement, it provides a powerful programming tool used in the IEC 1131 environment (Bryan and Bryan, 1997). All PLC ladder logic diagrams use two basic types of instructions: contacts and coils. Contacts are instructions that more or less mimic the conditions of turn-on or turn-off of input field devices thus monitoring them. The functioning of output devices or actuators is dependent on instructions from these coils. However, unlike a contact, a coil monitors the PLC control program and then tells the field output device whether to change state or not.

A PLC scan is a three-step process of monitoring the inputs, executing the PLC control program, and changing the status of the outputs accordingly. Scan time is roughly defined as the time it takes for the programmable controller to interrogate the input devices, execute the application program and provide updated signals to the output devices. Scan times can vary from 0.1 milliseconds per 1K (1024) words of logic to more than 50 milliseconds per 1K of logic. To keep track of all

information, it uses a system called addressing. An address is a label or number that indicates where a certain piece of information is located in a PLC's memory.

The generic PLC block diagram is illustrated in Figure-7 (Groover, 1989). It consists of power supply, input/output (I/O) modules, central processor unit (CPU), memory and detachable programming device. Inputs are defined as real-world signals giving the controller real-time status of process variables. The outputs are actuator field devices etc. Inputs and outputs can be digital or analog. The detachable programming device is essentially not part of the PLC. However, it provides interface or liaison between what the PLC understands and what the user desires to occur during program development, start-up, control sequence and trouble shooting. Programming could be off-line or on-line and instructions to be performed during each scan are coded and inserted into memory.

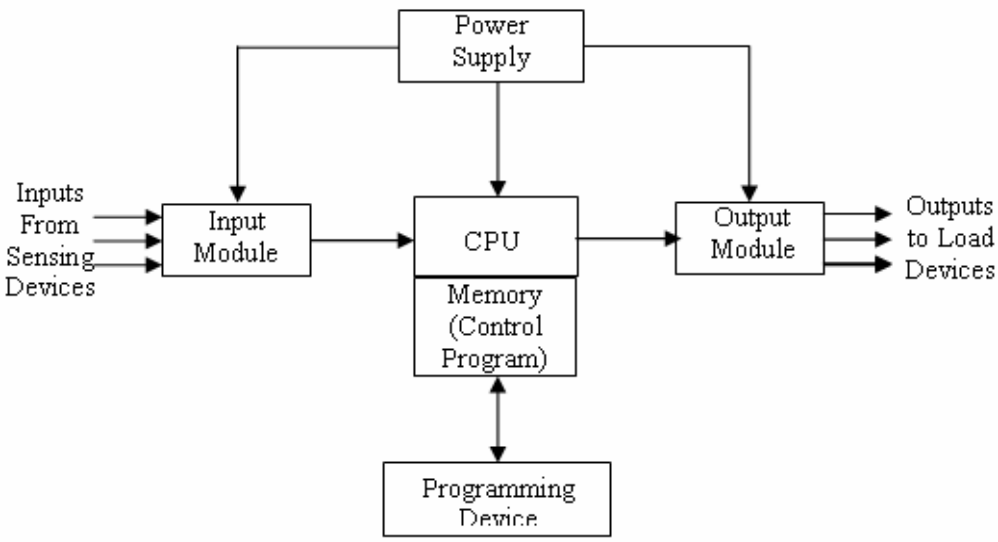

Figure-7. Block diagram of a PLC.

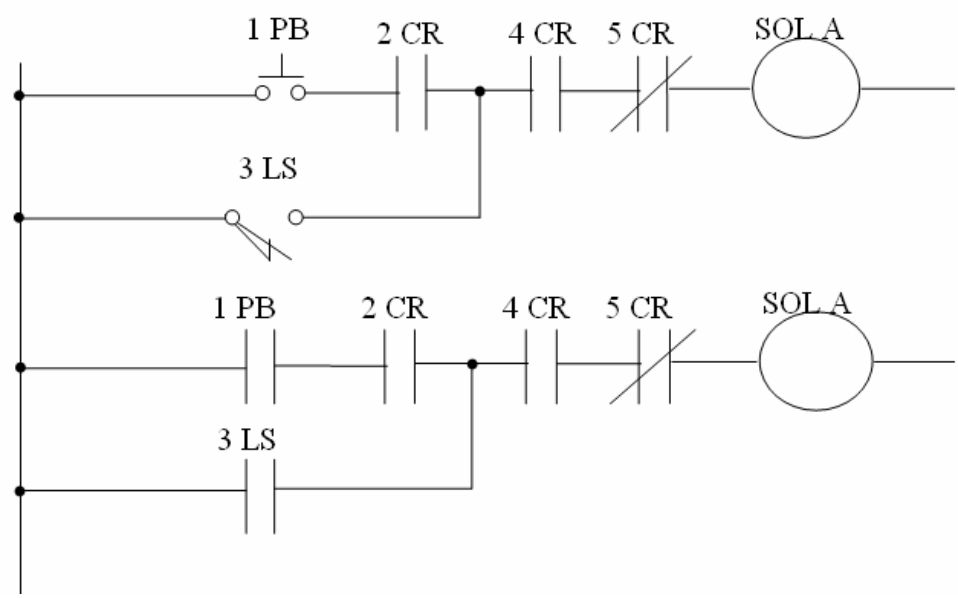

Figure-8. A typical PLC ladder logic diagram.

In selecting a PLC, consideration is given to I/O capability, type/sophistication of control, type and amount of memory, software capability, programming ease and flexibility, scan time, operating conditions, packaging requirements (dustproof, drip proof, ruggedness, type of connections), physical and environmental characteristics (temperature, humidity, dust level, corrosion, vibration, EMI/RFI, available physical space), complexity and cost, system diagnosis, proven controller reliability, vendor support, PLC equipment standardization and above all a good knowledge of the process to be controlled.

Automatic identification technology

Automatic identification as regards letter sorting involves optical character recognition, bar coding and subsequent sorting. The term optical character recognition is used to describe all data entry methods that involve the use of a light source and detector to interpret a pattern including bar codes, optical marks, and more usually the automatic recognition of human readable characters, sorting and tracking mail packages, parcels and letters.

The postal OCRs are used to read handwritten and printed addresses. An optical character reader (OCR) scans addresses on letter-size mail and converts that information into a postal numeric encoding technique (POSTNET) barcode. The OCR then prints a delivery-point barcode in the lower right portion known as barcode clear zone of the mail piece. The postal OCRs verify the address information against an internal database.

After locating the address, the OCR must be able to see all elements clearly. Hence, a complete address and 'good' print quality are so important. The OCR then does an initial sorting of the mail piece, based on the barcode. From that point on, the mailpiece is sorted by reading and interpreting the barcode using high-speed barcode sorters (BCSs). These machines are capable of reading, bar-coding, and sorting of mail at a rate of over 30,000 pieces per hour.

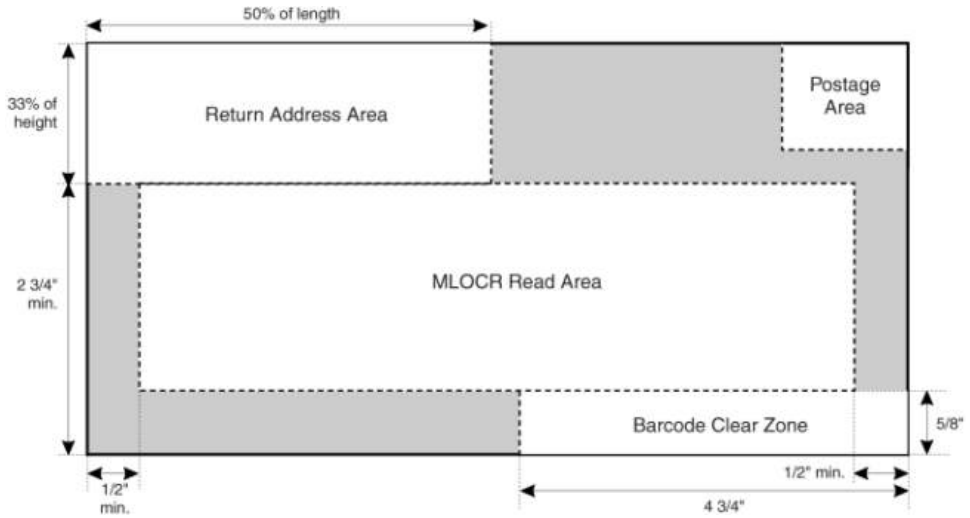

Figure-9. Relevant zones on an OCR-BCS compatible mail piece.

A barcode is a machine readable code consisting of a series of bars and spaces printed in defined ratios. Bar code symbologies are essentially alphabets in which different widths of bars and spaces are combined to form characters, and ultimately, a message (Bhaskar Raj, 2001). The message is encoded using the width of printed bars, the width of spaces between bars, and the relative positions of wide or narrow bars and spaces.

A postal service barcode sorter (BCS) 'reads' POSTNET barcodes on any portion of a letter-size mail piece and sorts the mail accordingly. These machines do not read addresses, so an incorrect barcode resulting from incorrect addressing by a customer will cause the piece to be missorted. The unsorted mail piece finds its way into an 'unread 'bin. The benefits of preprinting accurate, reliable, qualifying barcodes on mail pieces include faster mail processing, rate stability and more consistent delivery times and a decrease in misdeliveries. Overall, an appropriate automatic identification technology offers greater accuracy, reduced cost, high speed and convenience.

Addressing of letters

An address is the location to which the postal service is to deliver or return a mail piece. It consists of certain elements such as recipient's name, street name and house number, and city, state, and zone improvement plan (ZIP) or region code as required by the mail class. An addressee is the person or organization to whom a mail piece is addressed. Mail pieces with complete and properly formatted addresses definitely enhance consistent, on-time delivery by the postal service. For the sake of compatibility with the postal optical character reader, there should be an acceptable way of addressing which entails coding the regions and establishing an addressing format. The Table-1 and Figure-10 illustrate the regional coding system and proposed addressing format, respectively.

Non-address data such as accounting numbers, subscription codes, presort codes, advertising, or logos, if used, should appear above the name of recipient line as shown in Figure-10. The name of the recipient (a business or an individual) should appear on the first line above the delivery address line. The postal service should designate the line immediately above the post office, city, regional code and country as the delivery address. The regional code should always be the last but one line of the address. The standard two-letter regional abbreviations and four digits should be used.

Table-1. Coding the regions.

Region	Code
Ashanti	AS 0001
Brong-Ahafo	BA 0002
Central	CR 0003
Eastern	ER 0004
Greater Accra	GR 0005
Northern	NR 0006
Upper East	UE 0007
Upper West	UW 0008
Volta	VR 0009
Western	WR 0010

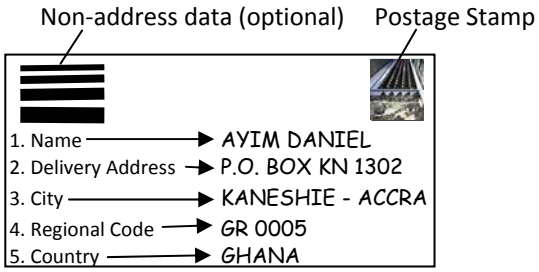

Figure-10. Proposed addressing format.

RESULTS AND DISCUSSIONS

Design configuration

Presented in Figure-11 is the functional diagram of the designed letter sorting machine.

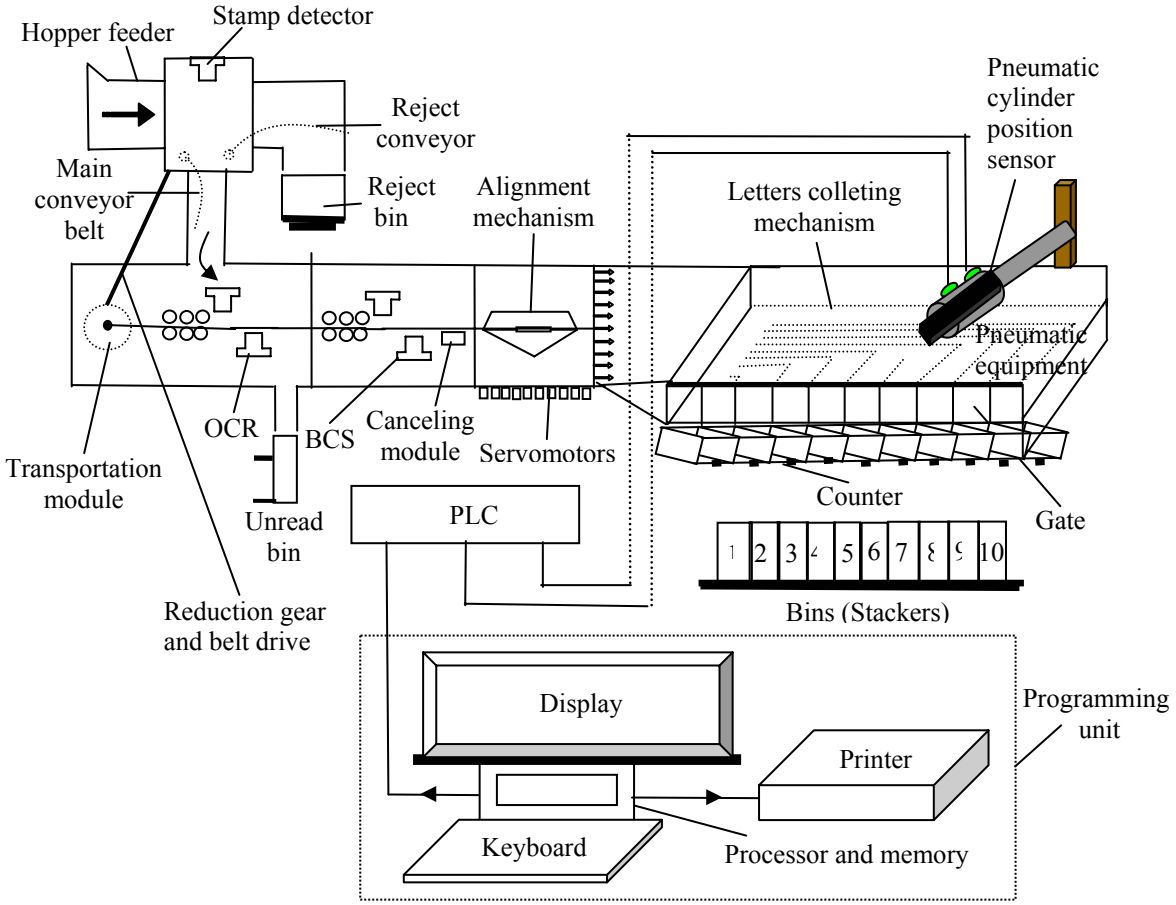

Figure-11. Functional diagram of the letter sorting machine.

Letter sorting principle and mode of operation

Mail loaded onto the detachable hopper feeder is picked-up by the air-suction mail feeding mechanism, in a manner to prevent damage to the mail during feeding. The letters are subjected to a stamp detector and undergo preliminary sorting. The 'qualified' letters are dropped onto the main conveyor to undergo a process of dedicated sorting into bins.'Unqualified' letters are rejected and positioned in the reject bin.

Stamp detector

Photoelectric sensors use a beam of light to detect the presence or absence of an object during sensing. This technology is an ideal alternative to inductive proximity sensors when the required sensing distances are longer or when the item to be sensed is non-metallic. This device consists of an infrared emitting diode and phototransistor (PNP or NPN) mounted side by side on parallel axes in a black plastic housing. Both emitting diode and

phototransistor are infrared transmissive plastic, which reduces ambient light noise. The phototransistor responds to radiation from the light emitting diode (LED) only when a reflective beam/ray passes within its field of view.

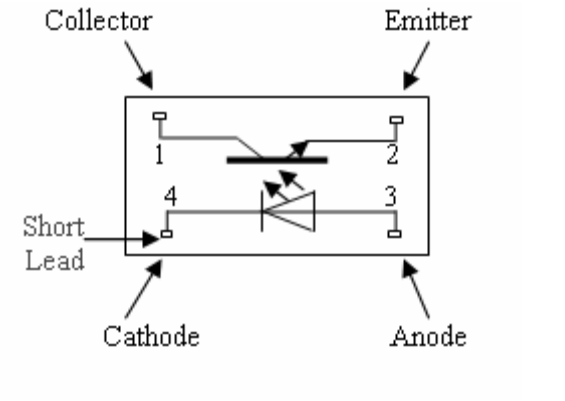

Figure-12. Photoelectric sensor.

The available photoelectric sensing modes are polarized retro reflective, standard diffuse, transmitted beam, fiber optic, background suppression and clear object. The postage stamp

Is a gummed or self-adhesive stamp affixed to mail as payment for postal services. Types of stamps include definitive stamp (regular-issue stamp), special-issue stamp, and commemorative stamp.

The scanner emits side light onto the letters passing by. This makes the serrations visible which appears as a light/shadow pattern. The scan line is projected by an objective lens on a photoelectric sensor. The analogue output signal of the sensor is conditioned by reduction and digitization into a bit stream pattern. This pattern is compared with adjustable reference patterns. At the end of the scan window the decision "stamp detected/rejected" is made and the proper information is put out on the machine interface for external data processing. Instead of stamps, printed codes can be detected too if placed in the postage zone.

Preliminary sorting, reject conveyor and bin

The letters are transported on a main conveyor which passes under a stamp detector (retro-reflective type of photoelectric switch). The stamp detector is positioned at a height within its tolerance above the conveyor. 'Qualified' letters pass underneath the stamp detector and no signal is generated. But the contrary happens for "unqualified" letters. When an "unqualified" letter is detected, a solenoid is energized and the pneumatic blower, actuated by the solenoid, is activated to blow the letter onto the reject conveyor which transports the letter into a reject bin. A reject bin is a separation (such as a pigeonhole) on the sweep side of a letter sorting machine or similar mechanized or automated mail distribution equipment which houses "unqualified" letters. The reject control action is stored in the memory of the PLC. An alternative way to realize the rejection is to use a magnetized ferrous flat belt.

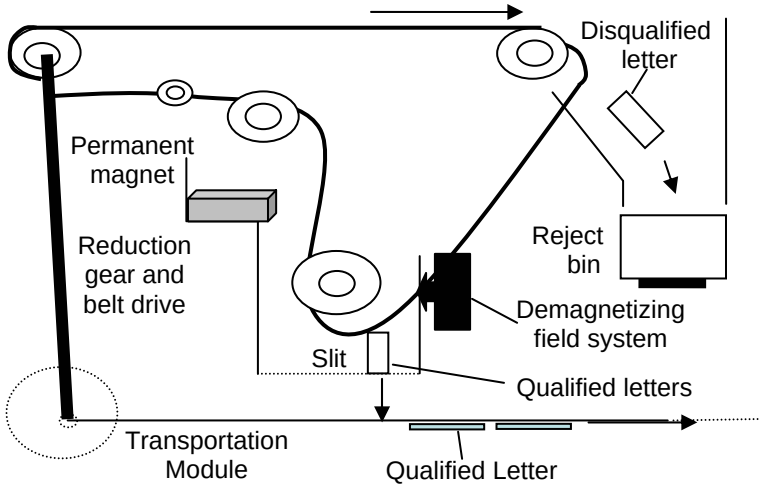

Figure-13. Use of a ferrous flat belt to effect the preliminary sorting of letters.

The stamps put on the letters are made of ferromagnetic material. For each letter sorting cycle the ferrous flat belt is respectively magnetized and demagnetized. During the preliminary sorting of letters, the letters containing the right stamps are attracted to the magnetized ferrous flat belt whilst those without stamps or fake stamps are not attracted and hence they get deposited into the reject bin as 'disqualified' letters. When the "qualified" letters get to the slit, they are demagnetized by a demagnetizing system so that the letters drop onto the main conveyor for the main sorting process to begin.

An optical character reader (OCR) scans addresses on the letter-size mail, determines the regional code, converts that information into a postal numeric encoding technique (POSTNET) barcode. The OCR then prints a delivery-point barcode in the lower right portion known as the

barcode clear zone of the mail piece. From that point on, the mail piece is sorted by reading and interpreting the barcode using high-speed barcode sorters (BCSs). The outputs of the BCSs are sent to the PLC which communicates with the pneumatic equipment to operate, thus, opening the appropriate gates. Feedback signal to the PLC of the appropriate gate-opening by the pneumatic equipment is achieved by means of the pneumatic cylinder position sensor.

Mail is routed to one of the destination bins according to recognized bar code information, based on the sorting program selected. Each of the destination bins indicates that it is filled to the number set on the counter by means of visible indicators.

System configuration and function analysis

Looking at Figure-11, the letter sorting machine could be sytemised into five blocks as presented in Figure-14. The blocks are input, transportation, connecting, output and the display and recorder modules.

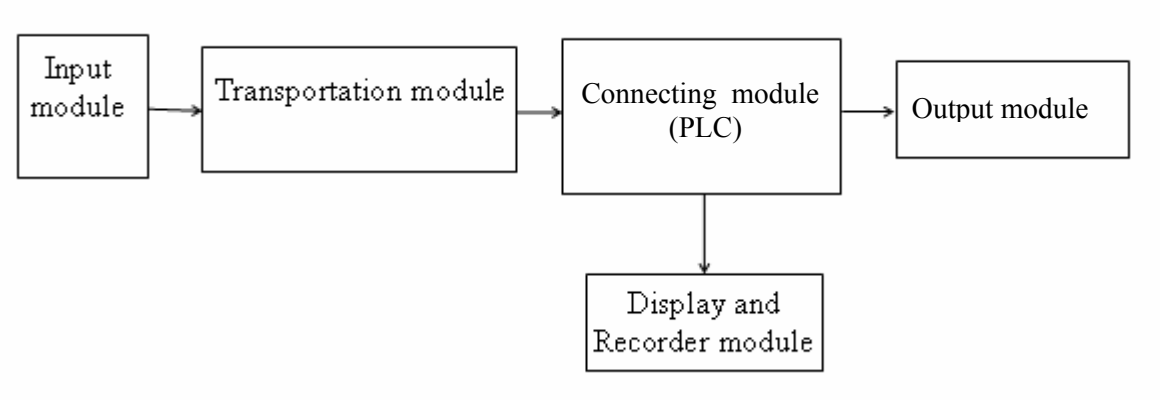

Figure-14. System configuration or function analysis of the letter sorting machine.

The input module consists of an input unit, stamp detector, alignment positioner, primary sorting conveyor belt, reject conveyor and bin. The input unit is the detachable hopper feeder into which mail is loaded and picked-up by the air-suction mail feeding mechanism in a manner to prevent damage to the mail during feeding. The primary sorting conveyor is used to separate the 'qualified' letters from the 'unqualified' ones via transportation during the preliminary letter sorting process. When an idler or pulley misaligns during the letter sorting processes, an error (difference between the desired displacement and feedback) is produced. This error is used to effect adjustment accordingly in a closed loop position control.

The transport module encapsulates the main conveyor belt system, alignment mechanism and deflectors. The letters are carried on the main conveyor belt for the other activities of sorting to be effected. The alignment mechanism determines that the mail is orientated correctly for address recognition. An unaligned letter is deflected accordingly in order to align it.

The output module is made up of letters collecting mechanism, pneumatic equipment, gates, counter and bins or stackers. Execution of tasks is displayed on the monitor and this information is printed out at the end of a number of cycles of letter sorting. The counter tells the number of letters sorted into a bin. Letters drop into the bin after the appropriate gate has opened. Gates are opened by pneumatic equipment amalgamated with sensors.

The connecting module consists of the programmable logic controller (PLC) including its programming device, protection and control circuits. The PLC receives information from the sensors and interprets the data according to the control program in its memory. It then communicates with the appropriate actuator to be operated. The PLC is programmed using the personal computer (PC). The PC comprises of a display, CPU, keyboard and a printer.

The main switch and the indicator lamps for the line voltage, power distribution, auxiliary power supplies, power-on control, counter for the hours worked by the machine, smoke detectors (fire risk) and motor control make up the protection circuits.

The control circuits serve as further link between the three main modules and the PLC.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Designing of a letter sorting machine for the regional Post offices in Ghana had been developed, the machine will help to guide against the present state of letter sorting in the country which is time consuming, labour intensive and affects the prompt delivery of letters to recipients.

Moreover, the sorting machine will enable more letters to be sorted efficiently and effectively than the manual system.

RECOMMENDATIONS

Based on the above concluding remarks and future the following recommendations could be tabled:

- This design should be introduced officially to the Ghana Post Company Limited for scrutiny so that in the long run, the lost glory of the company gets restored.
- A prototype of this letter sorting machine needs to be built.
- A stamp selling machine compatible with easily codable currency notes should be designed in order to reflect price changes. This machine should be available at all times of the day.
- The citizenry should be educated on the use of the designed letter sorting machine.
- A miniature type of this letter sorting machine should be designed for the district post offices.

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