普通高等教育“十一五”规划教材
PUTONG GAODENG JIAOYU SHIYIWU GUIHUA JIAOCAI （高职高专教育）

JIDIAN ZHUANYE YINGYU

机电专业英语

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内 容 提 要

本书为普通高等教育“十一五”规划教材（高职高专教育）。

本书所选材料紧密结合相关专业知识，不拘泥于传统的机械和电气专业的要求，而侧重于现代机电技术发展的特点，即各专业交叉发展。全书共13个单元，每个单元包括专业相关的英文材料、词汇表、注释、译文、练习等内容。本书编排注重对英文专业资料的阅读理解，以达到开拓专业视野的目的。

本书可作为高职高专机电类专业的教材，也可供其他专业师生和工程技术人员参考。

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前　言

为贯彻落实教育部《关于进一步加强高等学校本科教学工作的若干意见》和《教育部关于以就业为导向深化高等职业教育改革的若干意见》的精神，加强教材建设，确保教材质量，中国电力教育协会组织制定了普通高等教育“十一五”教材规划。该规划强调适应不同层次、不同类型院校，满足学科发展和人才培养的需求，坚持专业基础课教材与教学急需的专业教材并重、新编与修订相结合。本书为新编教材。

本书所选材料紧密结合相关专业知识，不拘泥于传统的机械和电气专业的要求，而侧重于现代机电技术发展的特点，即各专业交叉发展。全书共13个单元，每个单元包括专业相关的英文材料、词汇表、注释、译文、练习等内容。本书编排注重对英文专业资料的阅读理解，以达到开拓专业视野的目的。

本书由焦作大学侯继红主编。参与编写的老师还有河南理工大学的李涛、张洪良，太原理工大学阳泉学院刘振山，河南机电高等专科学校的田长留，焦作大学的孟超、宋芳、梁超，中原工学院的武超，河南经贸职业技术学院的于光许等。具体编写分工为：第一章和第十一章由孟超编写，第二章、第四章及第十三章由刘振山编写，第三章由李涛编写，第五章和第九章由于光许编写，第六章由田长留编写，第七章由张洪良编写，第八章由宋芳编写，第十章由武超编写，第十二章由梁超编写。

焦作师范高等专科学校的张新海教授担任本书的主审，对本书提出了许多宝贵的意见和建议，在此表示感谢。

由于编者水平有限，加上时间仓促，书中错漏难免，敬请读者批评指正。

编　者

2008年5月

目　录

Unit 1 Automation

1.1 Mechanization and Automation

Processes of mechanization have been developing and becoming more complex ever since the beginning of the Industrial Revolution at the end of the 18th century. The current developments of automatic processes are, however, different from the old ones. The "automation" of the 20th century is distinct from the mechanization of the 18th and 19th centuries in as much as mechanization was applied to individual operations, whereas "automation" is concerned with the operation and control of a complete producing unit①. And in many, though not all, instances the element of control is so great that whereas mechanization displaces muscle, "automation" displaces brain as well②.

The distinction between the mechanization of the past and what is happening now is, however, not a sharp one. At one extreme we have the electronic computer with its quite remarkable capacity for discrimination and control, while at the other end of the scale are "transfer machines", as they are now called, which may be as simple as a convey or belt to another. An automatic mechanism is one which has a capacity for self-regulate, that is, it can regulate or control the system or process without the need for constant human attention or adjustment③. Now people often talk about "feedback" as being an essential factor of the new industrial techniques, upon which is based an automatic self-regulating system and by virtue of which any deviation in the system from desired conditions can be detected, measured, reported and corrected. When "feedback" is applied to the process by which a large digital computer runs at the immense speed through a long facts that have been put to machines. This is perhaps very different with the familiar machines. But "feedback", as such, is a familiar mechanical conception. The old-fashioned steam engine was fitted with a centrifugal governor, two balls on levers spinning round and round an upright shaft. If the steam pressure rose and the engine started to go too fast, the increased speed of the spinning governor caused it to rise up the vertical rod and shut down a valve. This cut off some of the steam and thus the engine brought itself back to its proper speed.

The mechanization, which was introduced with the Industrial Revolution, because it was limited to individual processes, required the employment of human labor to control each machine as well as to load and unload materials and transfer them from one place to another. Only in a few instances were processes automatically linked together and was

production organized as a continuous flow.

In general, however, although modern industry has been highly mechanized ever since the 1920s, the mechanized parts have not as a rule been linked together. Electric-light bulbs, bottles and the components of innumerable mass-produced articles are make in mechanized factories in which a degree of automatic control has gradually been building up④. The development of the electronic computer in the 1940s suggested that there were a number of other devices less complicated and expensive than the computer which could share the field of mechanical control⑤. These devices mechanical, pneumatic and hydraulic have been considerably developed in recent years and will continue to advance now that the common opinion is favoring the extension of "automation". Electronic devices, of course, although not the sole cause of what is happening, are nevertheless in a key position. They are gaining in importance and unquestionably hold out exceptional promise for development in the future.

New Words

mechanization [ˌmekənaiˈzeiʃən] n. 机械化
discrimination [disˌcrimiˈneiʃən] n. 辨别，鉴于，识别
feedback [ˈfi:dbæk] n. 反馈，回馈
deviation [di:viˈeiʃən] n. 偏差，偏移
spinning [ˈspiniŋ] adj. 旋转的
pneumatic [nju(:)ˈmætik] adj. 空气的，气动的
hydraulic [haiˈdrɔ:lik] adj. 液压的
remarkable [riˈmɑ:kəbl] adj. 显著的，非凡的，值得注意的
old-fashioned [ˈəudˈfeʃənd] adj. 老式的，旧的

Phrases and Expressions

in as much as 因为，由于，鉴于

Notes

① The "automation" of the 20th century is distinct from the mechanization of the 18th and 19th centuries in as much as mechanization was applied to individual operations, whereas "automation" is concerned with the operation and control of a complete producing unit.

20 世纪的工业自动化之所以有别于十八九世纪的机械化，是因为机械化仅应用于操纵（执行）机构，而自动化则涉及整个生产单元中的执行和控制两个（核心）部分。be distinct from（与……有显著的区别），in as much as（因为……）引导一个原因状语从句，相当于 because，whereas 表示转折关系，相当于 while 表示相反的、但是、反之的意思，be

concerned with (与……有关)。

② And in many, though not all, instances the element of control is so great that whereas mechanization displaces muscle, "automation" displaces brain as well.

在大多数情况下，控制元件依然发挥着强大的力量，机械化已经代替了手工劳动，而自动化也代替了脑力劳动。muscle (肌肉) 在这里是暗喻，表示体力劳动，brain (脑) 同样也是暗喻，表示脑力劳动，as well (as) 相当于 and。

③ An automatic mechanism is one which has a capacity for self-regulate, that is, it can regulate or control the system or process without the need for constant human attention or adjustment.

自动调整机构能够自动调节系统，也就是说，它能在没有人干预和调整的情况下，自动对系统或生产过程进行控制和调节。which 引导后面的定语从句，修饰 one，self regulate (自我调节控制)，without the need... (在不需要……的情况下)。

④ In general, however, although modern industry has been highly mechanized ever since the 1920s, the mechanized parts have not as a rule been linked together. Electric-light bulbs, bottles and the components of innumerable mass-produced articles are make in mechanized factories in which a degree of automatic control has gradually been building up.

一般而言，从 20 世纪 20 年代以来，尽管现代工业已经实现了高度机械化，然而通常机械化的部分还没有联系在一起。机械化的工厂生产了光电灯泡、瓶子和大量生产的产品元件，这些机械化工厂的自动化程度日益得到了加强。in general (通常，大体，一般而言)，ever since (自从……)，主句要用完成时被动语态 has been highly mechanized，as a rule (通常)，in which=where 引导地点状语从句，修饰 factories，building up (加强)。

⑤ The development of the electronic computer in the 1940s suggested that there were a number of other devices less complicated and expensive than the computer which could share the field of mechanical control.

20 世纪 40 年代电子计算机的发展，意味着在机械控制领域内将出现大量比计算机更简单、更廉价的产品。

Questions

一、英译汉

(1) Industrial Revolution, mechanization and automatization, self-regulating system, feedback, mass-produced articles, hydraulic control, component, load and unload.

(2) Now people often talk about "feedback" as being an essential factor of the new industrial techniques, upon which is based an automatic self-regulating system and by virtue of which any deviation in the system from desired conditions can be detected, measured, reported and corrected.

(3) The mechanization, which was introduced with the Industrial Revolution, because it was limited to individual processes, required the employment of human labor to

control each machine as well as to load and unload materials and transfer them from one place to another.

二、汉译英

(1) 一般来说，自从20世纪80年代，计算机技术和信息技术就已经发展得很快。

(2) 借助自动调节系统，这个生产线生产的产品质量已经越来越高，而生产成本越来越低。

(3) 自动机械装置是一个能够自行调节，不需要人工调整的系统。

译 文

1.1 机械化和自动化

自从18世纪末工业革命开始，工业机械化进程一直在不断地发展，并且变得越来越复杂。但目前的工业自动化过程较以前的工业自动化过程有很大的不同。20世纪的工业自动化之所以有别于十八九世纪的机械化，是因为机械化仅应用于操纵（执行）机构，而自动化则涉及整个生产单元中的执行和控制两个（核心）部分。在大多数情况下，控制元件依然发挥着强大的力量，机械化已经代替了手工劳动，而自动化代替了脑力劳动。

机械化程度的发展在过去和现在的区别不是很明显。在一端是具有强大辨别和控制功能的电子计算机，另一端是我们目前所说的“转换机构”，正如传输带一样与其他设备简单地连接起来。自动调整机构能够自动调节系统，也就是说，它能在没有人干预和调整的情况下，自动对系统或生产过程进行控制和调节。现代工业技术的核心因素就是当前人们经常提起的反馈（控制），它是以自动调节系统为基础，借助于系统偏差与期望值之间的偏差来控制，可由自动检测、测量、显示和校正方法得到。反馈控制应用于高速运转的大型数字计算机进行复杂运算时，对于输入的复杂问题，计算机通常会一直运行，直到求出与问题匹配的结果。这或许与我们以前熟知的机器有很大的差别。但是，反馈同样是我们所熟悉的机械概念。旧式的蒸汽机安装有离心传感器，控制杆上的两个球不停地绕立轴旋转，气压升高，发动机转速变快，旋转控制器速度增加，使立杆上升，关闭阀门，切断蒸汽，从而发动机恢复到合适的速度。

随着工业革命的出现，机械化也随之产生，由于这时的机械化仅局限于单个生产过程，因此，需要使用人工控制每部机器及装卸材料，并把材料从一个地方运到另一个地方。仅仅在极少的情况下，这些生产过程才能够自动地衔接起来，形成连续的产品生产线。

一般而言，从20世纪20年代以来，尽管现代工业已经实现了高度机械化，但是通常机械化的部分还没有联系在一起。机械化的工厂生产了光电灯泡、瓶子和大量生产的产品的元件，这些机械化工厂的自动化程度日益得到了加强。20世纪40年代电子计算机的发展，意味着在机械控制领域内将出现大量比计算机更简单、更廉价的产品。机械装置、气动装置、液压装置，在近些年来已有了很大的发展，并将持续发展下去，普通的观点认为这有利于自动控制的发展。当然不仅仅电子设备对目前自动控制的发展举足轻重，无疑在今后自动控制发展方面还继续会发挥不可估量的作用。

参考答案

一、英译汉

(1) 工业革命，机械化和自动化，自我调节系统，反馈，大量生产的产品，液压控制，元件（部件），装载和卸载。

(2) 现代工业技术的核心因素就是当前人们经常提起的反馈（控制），它是以自动调节系统为基础，借助于系统偏差与期望值之间的偏差来控制，可由自动检测、测量、显示和校正方法得到。

(3) 随着工业革命的出现，机械化也随之产生，由于这时的机械化仅局限于单个生产过程，需要人工控制每部机器，并装卸和运送材料。

二、汉译英

(1) In general, computer technology and information technology have rapidly developed ever since the 1980s.

(2) By virtue of the automatic self-regulating system, the quality of products made by this mass-produced line has been greatly improved, and lower and lower in the productive cost.

(3) An automatic mechanism is a system which has a capacity for self-regulate without the need for human adjustment.

1.2 Industrial Robots

There are a variety of definitions of the term "robot". Depending on the definition used, the number of robot installations worldwide varies widely. Numerous single-purpose machines are used in manufacturing plants that might appear to be robots①. These machines are hardwired to perform a single function and can not be reprogrammed to perform a different function. Such single purpose machines do not fit the definition for industrial robots that is becoming widely accepted. This definition was developed by the Robot Institute of America.

A robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.

Note that this definition contains the words "reprogrammable" and "multifunctional"②. The term "reprogrammable" implies two things: The robot operates according to a written program, and this program can be rewritten to accommodate a variety of manufacturing tasks.

The term "multifunctional" means that the robot can, through reprogramming and the use of different end-effectors, perform a number of different manufacturing tasks.

Definitions written around these two critical characteristics are becoming the accepted definitions among manufacturing professionals.

The first articulated arm came about in 1951 and was used by the U. S. Atomic Energy Commission. In 1954, the first programmable robot was designed by George Devol. It was based on two important technologies:

(1) Numerical Control (NC) technology.

(2) Remote manipulation technology.

Numerical Control technology provided a form of machine control ideally suited to robots. It allowed for the control of motion by stored programs③. It allowed for the control of motion by stored programs. These programs contain data points to which the robot sequentially moves, timing signals to initiate action and to stop movement, and logic statements to allow for decision making.

Remote manipulation technology allowed a machine to be more than just another NC machine. It allowed such machines to become robots that can perform a variety of manufacturing tasks in both inaccessible and unsafe environments. By merging these two technologies, Devol developed the first industrial robot, an unsophisticated programmable materials handling machine.

The first commercially produced robot was developed in 1959. In 1962, the first industrial robot to be used on a production line was installed by General Motors Corporation. This robot was produced by Unimation. A major step forward in robot control occurred in 1973 the development of the T-3 industrial robot by Cincinnati Milacron. The T-3 robot was the first commercially produced industrial robot controlled by a minicomputer.

Numerical control and remote manipulation technology prompted the wide-scale development and use of industrial robots. But major technological developments do not place simply because of such new capabilities. Something must provide the impetus for taking advantage of these capabilities. In the case of industrial robots, the impetus was economics. The rapid inflation of wages experienced in the 1970s tremendously increased the personnel costs of manufacturing firms. At the same time, foreign competition became a serious problem for U. S. manufacturers. Foreign manufacturers who had undertaken automation on a wide-scale basis, such as those in Japan, began to gain an increasingly large share of the U. S. and world market for manufactured goods, particularly automobiles.

Through a variety of automation techniques, including robots, Japanese manufacturers, beginning in the 1970s, were able to produce better automobiles more cheaply than nonautomated U. S. manufacturers. Consequently, in order to survive, U. S. manufacturers were forced to consider any technological developments that could help improve productivity.

It became imperative to produce better products at lower costs in order to be competitive with foreign manufacturers. Other factors such as the need to find better ways of performing dangerous manufacturing tasks contributed to the development of industrial robots. However, the principal rationale has always been, and is still, improved productivity.

One of the principal advantages of robots is that they can be used in settings that are dangerous to humans. Welding and parting are examples of applications where robots can be used more safely than humans④. Even though robots are closely associated with safety in the workplace, they can, in themselves, be dangerous.

Robots and robot cells must be carefully designed and configured so that they do not endanger human workers and other machines. Robot work envelopes should be accurately calculated and a danger zone surrounding the envelope clearly marked off. Red flooring strips and barriers can be used to keep human workers out of a robot's work envelope.

Even with such precautions it is still a good idea to have an automatic shutdown system in situations where robots are used. Such a system should have the capacity to sense the need for an autocratic shutdown of operations. Fault-tolerant computers and redundant systems can be installed to ensure proper shutdown of robotics systems to ensure a safe environment.

New Words

manipulator [mə'nipjuleitə] n. 操作者，操纵者，操纵器
accommodate [ə'kɔ:mədeit] vt. 供应，调节，和解，容纳，调和；vi. 适应
end-effector [endi'fektə] 末端执行器，末端器
articulated [ɑ:'tikjulitid] adj. 有关节的，铰接的
remote [ri'məut] adj. 遥远的，细微的
merge [mə:dʒ] v. 合并，结合，融合

Phrases and Expressions

remote manipulation 遥控
T-3 industrial robot T-3 机器人（一种六轴连续路径活动关节臂型机器人）
work envelopes 工作包迹，加工包迹（表示机器人可达到的最大工作范围和作用距离的一些点的集合）

Notes

① Numerous single-purpose machines are used in manufacturing plants that might appear to be robots.

在制造工厂中使用的许多单用途机器可能会看起来像机器人。

② Note that this definition contains the words "reprogrammable" and "multifunctional".

注意在这个定义中包含"可以改变程序"和"多功能"这两个词。

③ Numerical Control technology provided a form of machine control ideally suited to robots. It allowed for the control of motion by stored programs.

数字控制技术提供了一种非常适合机器人的机器控制技术。它通过存储的程序对运动进行控制。

④ One of the principal advantages of robots is that they can be used in settings that are dangerous to humans. Welding and parting are examples of applications where robots can be used more safely than humans.

机器人的一个主要优点是它们可以在对人类来说是危险的环境中工作。例如，焊接和切割工作，由机器人来完成会比由人来完成更安全些。

Questions

英译汉

(1) Robots, we read about them, applaud their heroism at the movies and secretly fear we may make them too smart for our own good.

(2) Instead, they are more apt to be just a mechanized arm with a metal gripper at the end that forms "a hand".

(3) When plugged into an electrical outlet, this assembly of microprocessors, much like the human brain, transmits electrical impulses along pathways which run from the computer itself down the robot's arm and into its hand.

译 文

1.2 工业机器人

对于"机器人"这个词有各种各样的定义形式。根据曾使用过的定义，机器人装置的数量在全世界大相径庭。在制造工厂中使用的许多单用途机器可能会看起来像机器人。这些机器通过硬线连接实现某单一功能，同时不能通过重新编程来执行不同的功能。这种单一用途的机器不符合当前正被广泛接受的工业机器人定义。这个定义是由美国机器人研究所提出的。

机器人是一种可改变编程的多功能机械装置，这些装置被设计用来运送材料、零件、工具，或通过可变程序来完成各种任务的特殊装置。

注意在这个定义中包含"可以改变程序"和"多功能"这两个词。"可以改变程序"这个词意味着两件事：机器人是根据设计好的程序动作的；这个程序是可以根据不同的生产任务来重新编写的。

"多功能"这个词意味着机器人通过重新编程和安装不同末端执行器来完成许多不同的任务。围绕着这两个核心功能所写出的定义正在成为制造业中所广泛接受的机器人定义。

第一个关节臂大约出现在 1951 年，被美国原子能委员会采用。1954 年，第一个可编程机器人是由 George Devol 所设计的。这个机器人基于两个重要的技术：

(1) 数字控制 (NC) 技术；

(2) 遥控技术。

数字控制技术提供了一种非常适合机器人的机器控制技术。它通过存储的程序对运动进行控制。它使得对根据存储的程序进行动作的控制成为可能。这些程序包含了机器人连续动作所依据的数据点，采取行动和停止运动的定时信号，以及允许做出决策的逻辑语句。

微控制技术使机器不仅仅是另一台数控机床。它使得这些机器成为能够在人们难以接近和不安全环境中完成各种任务的机器人。通过这两种技术的融合，Devol 设计了第一个工业机器人，一种可编程的材料运送机器。

1959 年设计出了第一个商业生产的机器人。1962 年，用于生产线的第一个工业机器人是由美国通用汽车公司安装的。这个机器人是由 Unimation 设计。在 1973 年由 Cincinnati Milacron 开发的 T-3 工业机器人使机器人控制技术向前迈进了一大步。T-3 型机器人是第一个商业化生产的由微机控制的工业机器人。

数字控制技术和遥控技术促进了工业机器人的大规模的发展和应用。但是，某些新功能使得主要技术的发展并非一帆风顺。为了充分利用这些功能，必须提供推动力。以工业机器人为例，这一推动力就是经济学。在 20 世纪 70 年代，迅速膨胀的工资大大增加了制造业公司的人员成本。与此同时，国外的竞争成为美国制造商的一个严重的问题。已经取得大规模自动化基础的外国厂商，如日本，开始在美国和世界工业品市场中占据越来越大的份额，特别是汽车行业。

通过包括机器人在内的多种自动控制技术，在 20 世纪 70 年代日本生产厂商能够生产出比没有采用自动控制技术的美国制造商生产的更好、更便宜的汽车。因此，为了生存美国生产商被迫采用可以提高生产力的任何新技术。

为了用较低的成本生产出更好的产品以保持对国外制造商的竞争力，工业机器人的使用已经是势在必行。其他因素也对工业机器人的发展做出了贡献，如需要找到更好的办法来完成危险的制造任务。然而，无论是在现在和将来，提高生产力一直是工业机器人发展的主要原因。

机器人的一个主要优点是它们可以在对人类危险的环境中工作。例如，焊接和切割工作，由机器人来完成会比由人来完成更安全些。尽管机器人是与工作场所的安全密切相关的，但他们本身也可能成为一种危险。

机器人和机器人单元必须经过精心设计和配置，使他们不会危害工作人员和其他机器。应当准确地计算出机器人的工作包迹，并将这一包迹周围明确标明为危险地带。红色地板条和障碍，可以使人类远离机器人的工作包迹。红色地板条和栅栏可以用来将人类和机器人的工作线路隔离。

尽管采取了这样的预防措施，在使用机器人的场所设置一个自动停车系统仍然是一个好办法。这样的系统应该有感知一个自动关闭操作需求的能力。可以通过安装容错计算机和冗余系统来确保适当地关闭机器人系统，以确保环境的安全。

参考答案

英译汉

(1) 机器人——我们在书本上读到过，并为它们在电影里的英雄行为而喝彩；同时也暗自担心，是否把它们造得太精巧了，以至于不利于人类自己的发展。

(2) 实际上，机器人往往只是一只机械臂，在其末端有金属夹，形成一只“手”。

(3) 接通电源后，这个微处理器集成电路就像人脑一样，沿着通道将电脉冲从计算机本身传送到机器人的手臂，再传到手。

1.3 Numerical Control

One of the most fundamental concepts in the area of advanced manufacturing technologies is Numerical Control (NC). Prior to the advent of NC, all machine tools were manually operated and controlled. Among the many limitations associated with manual control machine tools. Perhaps none is more prominent than the limitation of operator skills. With manual control, the quality of the product are directly related to and limited to the skills of the operator. Numerical Control represented the first major step away from human control of machine tools.

Numerical Control means the control of machine tools and other manufacturing systems through the use of prerecorded, written symbolic instructions. Rather than operating a machine tool, an NC technician writes a program that issues operational instructions to the machine tool①. For a machine tool to be numerically controlled, it must be interfaced with a device for accepting and decoding the programmed instructions, known as a reader.

Numerical Control was developed to overcome the limitation of human operators, and it has done so. Numerical Control machines are more accurate than manually operated machines, they can produce parts more uniformly, they are faster, and the long-run tooling costs are lower②. The development of NC led to the development of several other innovations in manufacturing technology:

(1) Electrical discharge machining.

(2) Laser cutting.

(3) Electron beam welding.

Numerical Control has also made machine tools more versatile than their manually operated predecessors. An NC machine tool can automatically produce a wide variety of parts, each involving an assortment of widely varied and complex machining processes. Numerical Control has allowed manufacturers to undertake the production of products that would not have been feasible from an economic perspective using manually controlled machine tools and processes.

Like so many advanced technologies, NC was born in the laboratories of the Massachusetts Institute of Technology. The concept of NC was developed in the early 1950s with funding provided by the U. S. Air Force. In its earliest stages, NC machines were able to make straight cuts efficiently and effectively.

However, curved paths were a problem because the machine tool had to be programmed to undertake a series of horizontal and vertical steps to produce a curve. The shorter the straight lines making up the steps had to be calculated.

This problem led to the development in 1959 of the Automatically Programmed Tools (APT) language. This is a special programming language for NC that uses statements similar to English language to define the part geometry; describe the cutting similar to English language to define the part geometry, describe the cutting tool configuration, and specify the necessary motions. The development of the APT language was a major step forward in the further development of NC technology. The original NC systems were vastly different from those used today. The machines had hardwired logic circuits. The instructional programs were written on punched paper, which was later to be replaced by magnetic plastic tape. A tape reader was used to interpret the instructions written on the tape for the machine. Together, all of this represented a giant step forward in the control of machine tools. However, there were a number of problems with NC at this point in its development.

A major problem was the fragility of the punched paper tape medium. It was common for the paper tape containing the programmed instructions to break or tear during a machining process. This problem was exacerbated by the fact that each successive time a part was produced on a machine tool, the paper tape carrying the programmed instructions had to be rerun through the reader. If it was necessary to produce 100 separate times. Fragile paper tapes simply could not withstand the rigors of a shop floor environment and this kind of repeated use.

This led to the development of a special magnetic plastic tape. Whereas the paper tape carried the programmed instructions as a series of holes punched in the tape. The plastic tape carried the instructions as a series of magnetic dots. The plastic tape was much stronger than the paper tape, which solved the problem of frequent tearing and breakage. However, it still left two other problems.

The most important of these was that it was difficult or impossible to change the instructions entered on the tape. To make even the most minor adjustments in a program of instructions, it was necessary to interrupt machining operations and make a new tape. It was also still necessary to run the tape through the reader as many times as there were parts to be produced③. Fortunately, computer technology became a reality and soon solved the problems of NC associated with punched paper and plastic tape.