普通高等教育“十一五”规划教材
PUTONG GAODENG JIAOYU SHIYIWU GUIHUA JIAOCAI

Thermal Energy & Power

RENENG YU DONGLI GONGCHENG
ZHUANYE YINGYU

热能与动力工程专业英语

（第二版）

阎维平 主 编
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内 容 提 要

本书包含了热能与动力工程专业的基础知识和专业知识的主要内容，介绍了近年来该领域的新发展和新技术。书中正文和阅读材料来源广泛，涉及的专业英语词汇量多，专业特点突出，内容丰富。

全书共分十二章，除第一章为热能与动力工程专业的基础知识外，其余十一章分别介绍了锅炉、汽轮机、火力发电厂、热工自动化、发电厂集控运行、内燃机、燃气轮机与联合循环、水力工程、制冷与空调、核能与新能源、环境工程等内容。各章后的阅读材料包括科技写作、专利申请、技术转让、技术规范、投标程序、国际行业标准与规范介绍、项目经营与管理、签证申请、国外大学研究生入学申请、专业人员简历、招聘、单位及转换和常用电力网址等。

本书可作为高等学校热能与动力工程及相关专业本科生的专业英语教材，还可供工作在这一专业领域内的工程技术人员和管理人员阅读参考。

图书在版编目（CIP）数据

热能与动力工程专业英语/阎维平主编．—2版．北京：中国电力出版社，2006

普通高等教育“十一五”规划教材

ISBN 7－5083－4627－0

Ⅰ．热…　Ⅱ．阎…　Ⅲ．①热能－英语－高等学校－教材②动力工程－英语－高等学校－教材　Ⅳ．H31

中国版本图书馆 CIP 数据核字（2006）第 093006 号

中国电力出版社出版、发行
（北京三里河路6号　100044　http://jc.cepp.com.cn）
航远印刷有限公司印刷
各地新华书店经售
*
2004年8月第一版
2006年8月第二版　2006年8月北京第四次印刷
787毫米×1092毫米　16开本　14.5印张　350千字
印数9001—12000册　定价**26.00**元

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订了普通高等教育“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。本书为修订教材。

根据本书第一版在若干高校相关专业使用的反馈意见，本书第二版除纠正若干编排错误之外，对各章后的专业词汇进行了补充。

本书第二版仍由华北电力大学阎维平任主编，山西大学工程学院冯跃武为副主编。书中第一章由张天孙编写，第二、七章由梁秀俊编写，第三、四章由崔映红编写，第五、六章由周俊霞编写，第八章由冯跃武编写，第九、十章由柳成文编写，第十一章由阎维平编写，第十二章由邢德山编写。

浙江大学程乐鸣教授对本书进行了认真审阅，提出了宝贵意见，在此表示感谢。

由于编者水平所限，再版书中仍难免存在缺点和不足，敬请读者批评指正。

编　者
2006 年 7 月

第一版前言

近年来，我国国民经济增长迅速，对能源与电力的需求增长更快。该行业具有首选应用全世界最先进的技术和全球采购最先进设备的特点，因此，对外交流与技术设备的引进频繁，迫切需要对本专业的本专科学生和工程技术人员加强专业英语阅读和交流信息能力的训练。

本书内容基本涵盖了热能与动力工程专业及相关专业领域，以介绍工程热力学、传热学和流体力学的基本知识为基础，主要内容包括：锅炉、汽轮机、火力发电厂、热工自动化、发电厂集控运行、内燃机、燃气轮机与联合循环、水力工程、制冷与空调、核能与新能源、环境工程等，还包括了与本专业领域有关的实用阅读材料。

专业英语不仅在专业术语上与大众英语不同，而且在表述和交流等方面也有显著的差别。本书编者在多年从事高等学校热能与动力工程专业英语教学工作的基础上，参考了大量的国外文献并总结了以往的教学经验编写成了这本《热能与动力工程专业英语》。本书力求选用不同内容和风格的科技英文原始资料，做到专业特点突出，内容新，知识面宽，概念性强，难度适中，尽量减少繁琐的描述和复杂的理论推导。

本书由华北电力大学阎维平担任主编，山西大学工程学院冯跃武为副主编。书中第一章由张天孙编写，第二章、第七章由梁秀俊编写，第三章、第四章由崔映红编写，第五章、第六章由周俊霞编写，第八章、第十二章由冯跃武编写，第九章、第十章由柳成文编写，第十一章由阎维平编写。阎维平策划并对全书进行统稿。

浙江大学程乐鸣教授审阅了全书，提出许多宝贵意见，在此表示感谢。

除了书末所列的参考文献外，作者在编写时还参阅了近年来一些非正式出版资料与专业英语教材，恕难一一详列。

由于编者水平所限，书中难免存在缺点和不足，敬请读者批评指正。

编　者

2004 年 1 月

目 录

Chapter 1 Thermal and Fluids Engineering

1.1 Fundamentals of Engineering Thermodynamics

You are about to begin the study of one of the most general and fascinating subjects in science - thermodynamics, the science that deals with energy and its relation to matter. Thermodynamics is most general because every technological system involves the utilization of energy and matter. In fact, since engineering thermodynamics plays such a vital role in the design of so many processes, devices, and systems for use in the home as well as in industry, it is no exaggeration to say that it touches our daily life. Engineering thermodynamics is also very important in our search for solutions to problems in connection with energy crises, shortages of fresh water, air pollution, and garbage disposal in the cities. In short, engineering thermodynamics is most relevant in our search for a better quality of life.

1.1.1 Definition of engineering thermodynamics

Engineering thermodynamics is the subject that deals with the study of the science of thermodynamics and the usefulness of this science in the engineering design of processes, devices, and systems involving the effective utilization of energy and matter for the benefit of mankind.

1.1.2 Thermodynamics systems

In thermodynamics, a system is defined as any collection of matter or any region in space bounded by a closed surface or wall. The wall may be a real one, like that of a tank enclosing a certain amount of fluid. The wall may also be imaginary, like the boundary of a certain amount of fluid flowing along a pipe. All other systems outside the wall that interact with the system in question are known as the surroundings.

Depending on the nature of the wall involved, we can classify a thermodynamic system as a closed system, an open system, or an isolated system. In a closed system, the wall involved is impermeable to matter. That is, a closed system can have no material exchange with its surroundings, and consequently its mass must remain constant. On the other hand, a closed system can exchange energy with its surroundings in terms of heat and work. In an open system, there will be material flow across the boundary. In addition, there could also be heat flow and work flow across the boundary. In an isolated system, there can be absolutely no interaction with its surroundings. The wall involved is not only impermeable to matter; it is also impermeable to any form of energy. An isolated system may therefore be defined as an assembly of subsystems with any possible interaction between matter and energy restricted to the subsystems within the assembly. Any system plus its surroundings taken together would constitute an isolated system.

1. 1. 3 Thermodynamic properties

The distinguishing characteristics of a system are called the properties of the system. They are quantities that we must specify to give a macroscopic description of system. Many such quantities are familiar to us in other branches of science, such as mass, energy, pressure, volume, density, electric field, magnetic field, and magnetization of matter. Two other properties - temperature and entropy are unique to thermodynamics. Together with energy, they play a most important role in the structure of thermodynamics.

A property is either a directly observable or an indirectly observable characteristic of a system. Any combination of such characteristics, for example, the product of pressure and volume, is also a property. That is, we can obtain new properties by defining them in terms of other properties. We shall find that among the many possible derived properties, three of them—enthalpy, Gibbs function, and Helmholz function—are particularly useful.

All properties of a system may be divided into two types: intensive and extensive. Those properties which are independent of the amount of material in the system are called intensive properties. They are not additive. Pressure, temperature, and density are examples of intensive properties. Those properties which are proportional to the mass of a system are called extensive properties. They are additive. Volume, energy, and entropy are examples of extensive properties.

1. 1. 4 Thermodynamic equilibrium and equilibrium states

The concept of equilibrium in classical thermodynamics is an important and primitive one. It is really an abstraction, as real systems are never strictly in equilibrium. However, we postulate that any thermodynamic system can be in equilibrium and that any isolated system will reach a state of thermodynamic equilibrium after it has been left to itself long enough. An important implication of this postulate is that eventually there can be no more tendencies for any macroscopic change in an isolated system. When a collection of matter experiences no more changes in all its properties, we say that it is at a state of thermodynamic equilibrium.

When a system has no unbalanced force within it and when the force it exerts on its boundary is balanced by external force, the system is said to be in mechanical equilibrium. When the temperature of a system is uniform throughout and is equal to the temperature of the surroundings, the system is said to be in thermal equilibrium. When the chemical composition of a system will remain unchanged, the system is said to be in chemical equilibrium. In order to have thermodynamic equilibrium, we must satisfy the conditions of mechanical equilibrium, thermal equilibrium, and chemical equilibrium.

1. 1. 5 Thermodynamic processes

When a collection of matter experiences a change from one equilibrium state to another equilibrium state, it is said to have undergone a process. The special features of certain processes may be recognized from the names given to them. For examples, an isothermal process is a constant - temperature process, an isobaric process is a constant - pressure process, and an isometric process is a constant - volume process. On the other hand, the significance of some processes may be recognized only if we fully understand the definitions involved. Examples of this kind are adiabatic process, cyclic process, quasi-static process, and reversible process.

Adiabatic process

A process in which no heat crosses the system boundary in either direction is called an adiabatic process.

Cyclic process or cycle

A cycle is simply a sequence of processes that a system undergoes in such a manner that its initial state and its final state are identical. In other words, the net change in any property of the system is zero for a cycle. Mathematically, this is

$$\oint \mathrm{d}x = 0 \tag{1-1}$$

where x is any property and the symbol $\oint$ indicates integration around a cycle.

Quasi-static process

If a process is carried out in such a manner that at every instant the system departs only infinitesimally from an equilibrium state, the process is called quasi-static (sometimes called quasi-equilibrium) . For such a process, the path followed by the system may be represented by a succession of equilibrium states. If there are finite departures from equilibrium, the process is non-quasi-static. Besides, a quasi-static process is reversible, or more correctly, internally reversible.

A quasi-static process is an ideal process. It is approximately realized by making the change very slowly. All real processes are not quasi-static because they take place with finite differences of pressure, temperature, and so on, between system and surroundings.

Reversible process

A reversible process is such that, after it has occurred, the initial states of the system and the surroundings taking part in the process can be restored without any changes in the rest of the universe. Thus a reversible process must be internally reversible (quasi-static) as well as externally reversible. Owing to our inability to eliminate all dissipative effects, all real processes are irreversible processes.

1.1.6 Energy and the First Law of Thermodynamics

The nature of energy may be summarized as follows:

(1) Energy is a primitive concept.

(2) Every system has energy.

(3) Energy is an extensive property. That is, it is additive.

(4) The quality of energy in a system is measured by its potential capacity to do work.

(5) Energy is something that can be neither destroyed nor created. That is, the energy content of a system is conserved if we isolate the system from its surroundings.

Expressed in words, we have, for any system.

$$\text{Energy input} - \text{energy output} = \text{change in stored energy} \tag{1-2}$$

Equation (1 - 2) is the general statement of the first law of the thermodynamics.

1.1.7 Entropy and the Second Law of Thermodynamics.

The nature of entropy may be summarized as follows:

(1) Entropy is a primitive concept.

(2) Every system has entropy. That is, with the exception of a work reservoir, entropy change is always possible for any system.

(3) Entropy is an extensive property.

(4) One interpretation of entropy is that it is an index of that portion of the energy content in a system that is not available to do work.

(5) Entropy content of an isolated system is not conserved. In fact, the entropy of an isolated system is a monotonically increasing function of time. In this respect, entropy differs fundamentally from energy: energy is a conservative property, entropy is not.

Expressed in words, we have for any system,

$$\text{Entropy creation in universe} = \text{entropy change in system} + \text{entropy change in surroundings} \geqslant 0 \qquad (1-3)$$

Equation (1 - 3) is the general statement of the second law of thermodynamics. The equality sign is for the case when the process is carried out reversibly.

1.1.8 Heat and work

Heat is interaction between a system and its surroundings. It is one of three mechanisms (the other two being work interaction and mass interaction) through which energy may be transferred across the boundary of a system. The driving force for heat transfer is temperature. When two bodies at different temperatures are brought into thermal contact, heat interaction will occur. Heat interaction is possible only when there is a change of state in a system. Thus we cannot speak of a system having a certain amount of heat energy at a given state. That is, heat is not a thermodynamic property.

For a closed system undergoing a change of state quasi - statically, the heat - transfer quantity is related to its entropy change according to

$$\delta Q_{\text{rev}} = T \cdot \mathrm{d}s \qquad (1-4)$$

There are many similarities between heat and work. As in the case of heat, work is an interaction through which energy may be transferred across the boundary of a system. Work interaction is also possible only when there is a change of state in a system. Consequently, work is not a thermodynamic property.

To determine whether there is work interaction, we observe or measure the effect of such interaction on the surroundings. Work is said to be done by a system on its surroundings if the sole effect external to the system could be the raising of a weight. Work may or may not be involved, depending on the way the boundary of system is drawn.

For a closed system undergoing a change of state quasi - statically, the work - transfer quantity, using the convention that work done by a system is positive, is given by

$$\delta \mathrm{w} = p\mathrm{d}v - \tau \mathrm{d}l - \varepsilon \mathrm{d}z - \gamma \mathrm{d}\mu + \cdots \qquad (1-5)$$

The number of terms that we can have on the right-hand side of Eq. (1-5) depends on the number of relevant work modes.

1.2 Fundamentals of Heat Transfer

From the study of thermodynamics, you have learned that energy can be transferred by interactions of a system with its surroundings. These interactions are called work and heat. However, thermodynamics deals with the end states of the process during which an interaction occurs and provides no information concerning the nature of the interaction or the time rate at which it occurs. The objective of this section is to extend thermodynamic analysis through study of the modes of heat transfer and through development of relations to calculate heat transfer rates.

We do so by raising several questions. What is heat transfer? How is heat transferred? Why is it important to study it? In answering these questions, we will begin to appreciate the physical mechanisms that underlie heat transfer processes and the relevance of these processes to our industrial and environmental problems.

1.2.1 Introduction

A simple, yet general, definition provides sufficient response to the question: What is heat transfer?

Heat transfer (or heat) is energy in transit due to a temperature difference.

Whenever there exists a temperature difference in a medium or between media, heat transfer must occur.

We refer to different types of heat transfer processes as modes. When a temperature gradient exists in a stationary medium, which may be a solid or a fluid, we use the term conduction to refer to the heat transfer that will occur across the medium. In contrast, the term convection refers to heat transfer that will occur between a surface and a moving fluid when they are at different temperatures. The third mode of heat transfer is termed thermal radiation. All surface of finite temperature emit energy in the form of electromagnetic waves. Hence, in the absence of an intervening medium, there is net heat transfer by radiation between two surfaces at different temperatures.

1.2.2 Conduction

Examples of conduction heat transfer are legion. The exposed end of a metal spoon suddenly immersed in a cup of hot coffee will eventually be warmed due to the conduction of energy through the spoon. On a winter day there is significant energy loss from a heated room to the outside air. This loss is principally due to conduction heat transfer through the wall that separates the room air from the outside air.

It is possible to quantify heat transfer processes in terms of appropriate rate equations. These equations may be used to compute the amount of energy being transferred per unit time. For heat conduction, the rate equation is known as Fourier's law. For the one-dimensional plane wall shown in Fig. 1 - 1, having a temperature distribution $T(x)$, the rate equation is expressed as

$$q_x = -k\frac{\mathrm{d}T}{\mathrm{d}x} \qquad (1-6)$$

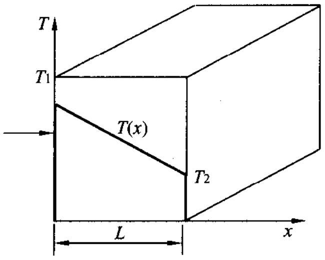

Fig. 1 - 1 One - dimensional heat transfer by conduction (diffusion of energy)

The heat flux q_x (W/m^2) is the heat transfer rate in the x direction per unit area perpendicular to the direction of transfer, and it is proportional to the temperature gradient, $\mathrm{d}T/\mathrm{d}x$, in this direction. The proportionality constant k is a transport property known as the thermal conductivity [W/ (m · K)] and is a characteristic of the wall material. The minus sign is a consequence of the fact that heat is transferred in the direction of decreasing temperature. Under the steady - state conditions shown in Fig. 1 - 1 where the temperature distribution is linear, the temperature gradient may be expressed as

$$\frac{\mathrm{d}T}{\mathrm{d}x} = \frac{T_2 - T_1}{l} \qquad (1-7)$$

and the heat flux is then

$$q_x = k\frac{\Delta T}{l} \qquad (1-8)$$

1.2.3 Convection

The convection heat transfer mode is sustained both by random molecular motion and by the bulk motion of the fluid within the boundary layer. The contribution due to random molecular motion (diffusion) generally dominates near the surface where the fluid velocity is low. In fact, at the interface between the surface and the fluid ($y=0$), heat is transferred by this mechanism only. The contribution due to bulk fluid motion originates from the fact that the boundary layers grow as the flow progresses in the x direction.

Convection heat transfer may be categorized according to the nature of the flow. We speak of forced convection when the flow is caused by some external means, such as by a fan, a pump, or atmospheric winds. In contrast, for free (or natural) convection the flow is induced by buoyancy forces in the fluid. These forces arise from density variations caused by temperature variations in the fluid. An example is the free convection heat transfer that occurs from a hot pavement to the atmosphere on a still day. Air that is in contact with the hot pavement has a lower density than that of the cooler air above the pavement. Hence, a circulation pattern exists in which the warm air moves up from the pavement and the cooler air moves downward. However, in the presence of atmospheric winds, heat transfer from the pavement to the air is likely to be dominated by forced convection, even though the free convection mode still exists.

We have described the convection heat transfer mode as energy transfer occurring within a fluid due to the combined effects of conduction and bulk fluid motion. In general, the energy that is being transferred is the sensible, or internal thermal, energy of the fluid. However, there are convection processes for which there is, in addition, latent heat exchange. This latent heat exchange is generally associated with a phase change between the liquid and vapor states of the fluid. Two special cases of interest in this text are boiling and condensation.

Regardless of the particular nature of the convection heat transfer mode, the appropriate rate equation is of the form

$$q = h(T_s - T_\infty) \tag{1 - 9}$$

where q, the convective heat flux (W/m^2), is proportional to the difference between the surface and fluid temperatures, T_s and T_∞, respectively. This expression is known as Newton's Law of Cooling, and the proportionality constant h [$W/(m^2 \cdot K)$] is referred to as the convection heat transfer coefficient, the film conductance, or the film coefficient. It encompasses all the effects that influence the convection mode. It depends on conditions in the boundary layer, which are influenced by surface geometry, the nature of the fluid motion, and a number of the fluid thermodynamic and transport properties. Moreover, any study of convection ultimately reduces to a study of the means by which h may be determined.

1.2.4 Radiation

Thermal radiation is energy emitted by matter that is at a finite temperature. Although we focus primarily on radiation from solid surfaces, emission may also occur from liquids and gases. Regardless of the form of matter, the emission may be attributed to changes in the electron configurations of the constituent atoms or molecules. The energy of the radiation field is transported by electromagnetic waves (or alternatively, photons). While the transfer of energy by conduction or convection requires the presence of a material medium, radiation does not. In fact, radiation transfer occurs most efficiently in a vacuum.

The maximum flux (W/m^2) at which radiation may be emitted from a surface is given by the Stefan - Boltzmann Law:

$$q = \sigma T_s^4 \tag{1 - 10}$$

where T_s is the absolute temperature (K) of the surface and σ is the Stefan—Boltzmann constant [$\sigma=5.67\times10^{-8} W/(m^2 \cdot K^4)$]. Such a surface is called an ideal radiator or blackbody. The heat flux emitted by a real surface is less than that of the ideal radiator and is given by

$$q = \varepsilon\sigma T_s^4 \tag{1 - 11}$$

where ε is a radiative property of the surface called the emissivity. This property indicates how efficiently the surface emits compared to an ideal radiator.

Equation (1 - 11) determines the rate at which energy is emitted by a surface. Determination of the net rate at which radiation is exchanged between surfaces is generally a good deal complicated. However, a special case that occurs very frequently in practice involves the net exchange between a small surface and a much larger surface that completely surrounds the smaller one. The surface and the surroundings are separated by a gas that has no effect on the radiation transfer. The net rate of radiation heat exchange between the surface and its surroundings, expressed per unit area of the surface, is

$$q \doteq \varepsilon\sigma(T_s^4 - T_{sur}^4) \qquad (1-12)$$

In this expression, ε is the emissivity of the surface, while T_{sur} is the temperature of the surroundings. For this special case, the area and emissivity of the surroundings do not influence the net heat exchange rate.

1.3 Introduction to Fluid Mechanics

1.3.1 Historical development of fluid mechanics

The science of fluid mechanics began with the need to control water for irrigation and navigation purposes in ancient China, Egypt, Mesopotamia, and India. Although these civilizations understood the nature of channel flow, there is no evidence that any quantitative relationships had been developed to guide them in their work. It was not until 250 B. C. that Archimedes discovered and recorded the principles of hydrostatics and buoyancy. In spite of the fact that the empirical understanding of hydrodynamics continued to improve with the development of fluid machinery, better sailing vessels, and more intricate cannal systems, the fundamental principles of classical hydrodynamics were not founded until the seventeenth and eighteenth centuries. Newton, Daniel Bernoulli, and Leonard Euler made the greatest contributions to the founding of these principles.

In the nineteenth century, two schools of thought arose in the treatment of fluid mechanics, one dealing with the theoretical and the other with practical aspects of fluid flow. Classical hydrodynamics, though a fascinating subject that appealed to mathematicians, was not applicable to many practical problems because the theory was based on inviscid fluids. The practicing engineers at that time needed design procedures that involved the flow of viscous fluids; consequently, they developed empirical equations that were usable but narrow in scope. Thus, on the one hand, the mathematicians and physicists developed theories that in many cases could not be used by the engineers, and on the other hand, engineers used empirical equations that could not be used outside the limited range of application from which they were derived. In a sense, these two schools of thought have persisted to the present day, resulting in the mathematical field of hydrodynamics and the practical science of hydraulics.

Near the beginning of the twentieth century, however, it was necessary to merge the general approach of the physicists and mathematicians with the experimental approach of the engineer to bring about significant advances in the understanding of flow processes. Osborne Reynolds' paper in 1883 on turbulence and later papers on the basic equations of liquid motion contributed immeasurably to the development of fluid mechanics. After the turn of the century, in 1904, Ludwig Prandtl proposed the concept of the boundary layer. In this short, convincing paper Prandtl, at a stroke, provided an essential link between ideal and real fluid motion for fluids with a small viscosity and provided the basis for much of modern fluid mechanics.

1.3.2 Scope and significance of fluid mechanics

Fluid mechanics, as the name indicates, is that branch of applied mechanics which is concerned with the static and dynamics of liquids and gases. Dynamics, the study of motion of matter, may be divided into two parts—dynamics of rigid bodies and dynamics of non-rigid bodies. The latter is usually further divided into two general classifications - elasticity (solid elastic body) and fluid mechanics.

The subject of fluid mechanics can be subdivided into two broad categories: hydrodynamics and gas dynamics. Hydrodynamics deals primarily with the flow of fluids for which there is virtually no density change, such as liquid flow or the flow of gas at low speeds. Hydraulics, for example, the study of liquid flows in pipes or open channels, falls within this category. The study of fluid forces on bodies immersed in flowing liquids or in low-speed gas flows can also be classified as hydrodynamics.

Gas dynamics, on the other hand, deals with fluids that undergo significant density changes. High-speed gas flowing through a nozzle or over a body, the flow of chemically reacting gases, or the movement of a body through the low density air of the upper atmosphere falls within the general category of gas dynamics.

An area of fluid mechanics not classified as either hydrodynamics or gas dynamics is aerodynamics, which deals with the flow of air past aircraft or rockets, whether it be low-speed incompressible flow or high-speed compressible flow.

There are, however, two major aspects of fluid mechanics which differ from solid-body mechanics. The first is the nature and properties of the fluid itself, which are very different from those of a solid. The second is that, instead of dealing with individual bodies or elements of known mass, we are frequently concerned with the behavior of a continuous stream of fluid, without beginning or end.

Knowledge and understanding of the basic principles and concepts of fluid mechanics are essential in the analysis and design of any system in which a fluid is the working medium. Many applications of fluid mechanics make it one of the most vital and fundamental of all engineering and applied scientific studies. The flow of fluids in pipe and channels makes fluid mechanics importance to civil engineers. The study of fluid machinery such as pumps, fans, blowers, compressors turbines, heat exchangers, jet and rocket engines, and the like, makes fluid mechanics of importance to mechanical engineers. Lubrication is an area of considerable importance in fluid mechanics. The flow of air over objects, aerodynamics, is of fundamental interest to aeronautical and space engineers in the design of aircraft, missiles and rockets. In meteorology, hydrology and oceanography the study of fluids is basic since the atmosphere and the ocean are fluids. And today in modern engineering many new disciplines combine fluid mechanics with classical disciplines: For example, fluid mechanics and electromagnetic theory are studied together as magnetogasdynamics. In new types of energy conversion devices and in the study of stellar and ionospheric phenomena, magnetogasdynainics is vital.

On the contrary, the collapse of the Tacoma Narrows Bridge in U. S. A. is evidence of