火电厂专业英语

（修摇订摇版）

English for Thermal Power Engineering

（[illegible]）

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前　　言

自从 圆园园猿年以来，全国电力供需逐年紧张，电力供需形势严峻，持续缺电地区扩大，拉闸限电时间和电量不断增加。为此，国家及时调整了电力发展规划，加快了电力建设步伐。与此同时，国家在亚临界机组方面加大了技术改造的力度，在超临界、超超临界、环保型火电机组等方面，加大了技术引进和技术开发的力度，大机组比重有所提高，引进机组、设备和技术不断增加。为了适应时代发展的要求，帮助从事火电厂建设、管理和运行的广大科技人员和工作人员，以及相关专业的在校大、中专学生和研究生利用英语这一语言工具，掌握先进的技术，我们对《火电厂专业英语》进行了修定。

修订版《火电厂专业英语》保留了原稿的专业知识系统性强、专业词汇覆盖面宽、生词重复率高等特点。全书内容仍以锅炉、汽轮机和发电机三大主机为主体，广泛涉及大型机组（猿园园酝宰 和 远园园酝宰）的设备及运行管理、火电厂的设计规划和厂址选择、自动控制、电厂化学和环境等内容，包括诸多新技术，如 :洁净煤技术、阅悦杂控制系统、燃气—蒸汽联合循环技术和烟气脱硫技术等。在原稿的基础上，修订稿增加了阅读材料部分，其内容涉及超超临界技术的发展、机组增容改造、核电等新技术和新动向等。全书的内容排列不仅保持了火电厂专业知识的系统性，而且符合英语教学的特点。为便于读者使用，每个单元均附有词汇表，全书后附有总词汇表，并配有参考译文（为了便于任课教师了解学生对专业英语的掌握程度、增加学生的阅读量，阅读材料部分没有配参考译文）。

全书由唐必光、谢诞梅担任主编。参加原稿编写的人员有 :向军（第一部分）、唐必光（第二部分）、谢诞梅（第三部分和第七部分）、李培生、史慧萍（第四部分）、袁立宏（第五部分）、于萍（第六部分）。修订稿共分八部分，共 缘远个单元，其中第二部分（锅炉）、第三部分（汽轮机）、第四部分（发电机）和第八部分（阅读材料）各设 愿个单元，其他各部分均设 远个单元。全书总阅读量由原来的 圆缘园园园园词左右增加到 猿远园园园园词左右，生词量由原来的员远苑缘个增加到 员圆缘愿个。修订工作由唐必光、谢诞梅策划和承担。全部书稿由谢诞梅审定和校阅。其中刘占辉、杨长柱和武云鹏同志参加了部分书稿的整理。

在编写过程中，得到武汉大学出版社、武汉大学动力与机械学院各级领导和同仁的大力支持。在此，一并表示衷心的感谢。由于我们水平有限，书中错误在所难免，欢迎广大同仁及读者批评指正。

编摇摇者

圆园园缘年 猿月

悦燥灶贼藻灶贼泽

Part One摇General

哉灶蚤贼员摇耘造藻糟贼则蚤糟 孕燥憎藻则 陨灶凿怎泽贼则赠 蚤灶 悦澡蚤灶葬

Present Situation

The year 圆园园缘 is the last year of the tenth Five-year Plan period in China. During the period, a remarkable result has been achieved in energy industry and electric power industry as its kernel. In 圆园园源 the total primary energy production got to 员援愿远 billion tons of standard coal with an increase of 员源援源% compared with 圆园园猿 which includes 员援愿缘 billion tons of raw coal, 员愿圆 million tons of crude oil, 猿源援园 billion cubic meters of natural gas.

In order to cope with the increasing demands of industry, agriculture and other sectors, the nation's total annual electricity generation has been going up rapidly and amounted to 员,怨员猿援员 TW·h in 圆园园源 representing a rise of 员源援缘% over 圆园园猿. The total thermal, hydro and nuclear power generation accounted for 员,缘远远援远 TW·h, 猿园猿援怨 TW·h and 源缘援怨 TW·h in the year, representing 愿圆援愿远%, 员缘援愿愿% and 圆援源远% respectively. In the aspect of capital construction, total of 员猿远援愿愿 GW (圆员援源 GW in 圆园园员; 圆猿援猿远 GW in 圆园园圆; 猿远援员员 GW in 圆园园猿; 缘员援园 GW in 圆园园源) of generating capacity was installed in the last four years, which averages an annual add-ups by 猿源援圆 GW and makes the nation's total installed capacity reach 源源圆 GW by the end of 圆园园源 representing a rise of 员源援愿% over 圆园园猿 in which thermal, hydro and nuclear power shared 苑源援园%, 圆猿援缘% and 员援愿%.

Along with the rapid growth of installed generating capacity, the construction of high voltage transmission lines and expansion of power networks have been speeding up in recent years. By the end of 圆园园源 the total length of 猿缘 kV and above level lines amounted to 苑缘园,园园园 km, of which 缘园园 kV, 猿猿园 kV and 圆圆园 kV lines accounted for 猿员,园园园 km, 怨,园园园 km and 员远愿,园园园 km respectively.

In 圆园园源 the national net coal consumption rate of thermal power plants witnessed a new record 猿苑远 g/kW·h, reduced by 员员 g/kW·h, as compared with 猿愿圆 g/kW·h in 圆园园园.

As a result of the progressive development of the electric power industry, electricity has become more and more significant for the progress of the national economy and the improvement of the living standards. The total electricity consumption of Jan—Nov in 圆园园源 amounted to 员，怨源缘愿TW·h with an increase 员缘.员猿% over 圆园园猿. The electricity consumption has stepped up in various sectors as follows: primary industry consumption accounted for 缘源愿TW·h with an increase for 圆.源源% compared with 圆园园猿, secondary industry consumption accounted for 员，源源缘源TW·h with an increase for 员远.缘园% , the tertiary industry consumption accounted for 圆怨圆TW·h with an increase for 员缘.猿园% , residential consumption accounted for 圆远源TW·h with an increase for 怨.缘源% .

Outlook and Strategy

According to the situation of energy resources and its development strategy, the policy for power industry can be outlined as follows:

员 Developing thermal power vigorously to give full play to the superiority of rich coal resources.

The thermal power based on coal-fired will still be the main power for meeting the electricity demand and the share of the thermal power in the total electric generation will keep about 苑园% in the 圆园圆园. By the year of 圆园圆园 the total thermal installed capacity will go up to 苑园缘GW, representing the share of thermal power in total installed capacity being 苑圆缘% (远缘% for coal-fired, and 苑缘% for oil and gas-fired).

In order to speed up development of thermal power and improve the generation efficiency, stress should be focused on construction of large power plants with large-sized high temperature and high pressure efficient units, e.g. sub/super-critical parameters and USC units of 猿园园MW and 远园园MW, and even 员园园园MW are mainly the options. It is the prior consideration to build a number of large and backbone thermal power plants in pit-head of huge coal mines.

圆 Speeding up hydropower on some river sections with favorable conditions.

At present, however the hydropower installed capacity is only less than 员园% of exploitable potential. This situation means that efforts should be concentrated on continuous exploitation of some rivers. The key point for hydropower exploitation in the coming years should be to develop the water resources of the upper and middle reaches of Changjiang River, upper reaches of Huanghe River as well as Hongshui River basin for speeding up hydropower expansion.

猿 Expanding power networks to bring the benefits of interconnecting networks into full play.

In the coming ten years, the following key projects have been tentatively arranged:

—The 缘园园kV transmission lines from the coal electricity base in eastern Inner Mongolia to Northeast China.

—The 缘园园kV transmission line from Shanxi, Shaanxi and western Inner Mongolia to the Beijing—Tianjin—Tangshan area.

—The 缘园园kV transmission line from the Southwest China to Guangdong province.

In addition, long distance and high voltage transmission lines will be constructed from Shanxi and Henan provinces to Jiangsu and Hubei provinces, so as to realize "sending electricity from the West to the East as well as from the North to South."

源 Mastering manufacture and construction technology of nuclear power as soon as possible to create conditions for speeding up its development after the year 圆园园园

Due to shortage of coal deposit and hydropower in the Southeast, coastal region and Northeast China, it is in urgent need to build nuclear power plants, as a supplement to thermal and hydropower, to meet the continuously increasing load-demand and to gain experience in further developing nuclear power. At present, Qinshan Nuclear Power Plant with 猿园园MW of capacity and Daya Bay Nuclear Power Plant with 圆伊怨园园MW PWR units have been put into operation.

缘 Opening new energy resources to pay great attention to rural electrification.

While making efforts to develop conventional energy resources, opening new energy resources for power generation has been encouraged. Several kinds of resources, such as small hydro, wind, tidal, solar and geothermal power, have been developed in accordance with local energy resources conditions.

The use of wind power is very promising in PR China, which tops the world league with an estimated wind potential of 圆缘园GW. Wind farms with a total capacity of over 源园园 MW have been developed so far, mainly financed by bilateral trade agreements and foreign loans. The current five-year plan covering the period up to 圆园园缘 envisages expansion of electricity generation by wind power to 员 圆GW. The declared goal of the Chinese government is to increase the wind power component to 缘% of total generating capacity by the year 圆园园缘

The use of wind power is slowly beginning to develop in China. However, the present capacity exploits only a marginal portion of the potential available. Studies show that up to 圆缘园GW of wind power capacity could be installed in the PR China, which would put the country in a leading position world-wide.

There are, however, a number of obstacles to this:

— lack of transparency in permit procedures;

— slow decision-making and approval processes;

— sub-optimal legal framework;

— high import duties;

— the "local content" requirement that at least 源园% of wind turbines must be produced in China;

— the specification that loans above US$ 猿园million must be managed by SDPC;

— major friction between the institutions (especially between SDPC and SETC).

Both the grid-coupled and the off-grid sectors are important for the use of wind power in China. The off-grid sector consists of a large number of small wind power plants (园园-猿园园园MW) with about 员园园园 installed units and a total capacity of 源园MW.

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the tenth Five-year Plan摇摇摇摇摇摇摇摇摇摇摇摇摇	第十个五年计划
kernel	核心
primary energy	一次能源
standard coal	标准煤
raw coal	原煤
crude oil	原油
cubic meter	立方米
hydro power	水电
installed/generating capacity	装机/发电容量
thermal power	火电
high voltage	高压
coal consumption rate	煤耗率
tertiary industry	第三产业
residential consumption	民用电消费量
transmission line	输电线
municipal	市政的
energy resource	能源
vigorously	大力地
coal/oil/gas fired	燃煤/油/气
electricity demand	电力需求
generation efficiency	发电效率
sub-critical parameters units	亚临界参数机组
super-critical parameters units	超临界参数机组
backbone	主干,中坚
pit-head	煤矿坑入口
coal mine	煤矿
exploitation	开发
interconnecting networks	联网
nuclear power plant	核电站
deposit	矿床,矿层
PWR (Pressurized Water Reactor)	压水堆
put into operation	投入运行
tidal power	潮汐发电
solar power	太阳能发电
geothermal power	地热发电
bilateral trade	双边贸易

源

envisage	**正视**
transparency	**透明，透明度**
SDPC （State Development Planning Commission）	**国家发展计划委员会（中国）**
SETC （State Economic and Trade Commission）	**国家经济贸易委员会（中国）**

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System Planning

The need for power stations is evaluated by many factors, such as whether there is a need for new capacity in order to maintain an adequate security of supply, or to give greater economy or to improve the security of fuel supply by allowing the types and sources of fuel or primary energy to be diversified. In addition it may be justifiable to build a new form of generating capacity in order to prepare the ground for a possible future benefit.

• Capacity Considerations

Capacity requirement is determined by the need to meet the peak demand of the year. The first step in estimating generating capacity requirement is therefore to forecast the peak demand for each future winter up to the planning years. The forecast presumes that the peak is most likely to occur on working weekdays in December to February during a spell of cold weather of average severity and is thus described as the "average cold spell" (ACS) winter peak demand. ACS conditions are determined by a statistical analysis of past weather data and the variation in demand caused by weather variations.

In order to meet the local statutory requirement to provide a continuous supply of electricity except in case of emergency, the industry has over many years aimed at providing sufficient generating capacity to meet the future demand with a high degree of security. One of the GEGB's functions is to ensure that sufficient generating capacity is provided to meet the peak demand and it achieves this by making a plan.

• Economic Considerations

The provision of new capacity to meet the forecast demand is not the only reason, which might justify the construction of new generating plant. New construction might also be justified on economic grounds and might allow the retirement of some existing capacity. In principle, a plant is retained in service until it becomes more economic to replace it with new capacity. Evaluations are made for certain economic indicators for existing stations and for the potential new stations that might be built:

(员 For existing stations, the annual avoidable cost is evaluated, on a year-by-year basis, of retaining certain stations or parts of stations in an operable condition. This cost is called the "net avoidable cost" (NAC) expressed in units of £ /kW pa.

(圆 For new generating station options for commissioning by the planning years, the CEGB calculates the net effect on total system costs of building and operating the station over its lifetime and converts this into an average annual cost, in units of £/kW pa, called the "net effective cost" (NEC).

These indicators allow two economic comparisons to be made. Firstly, the comparison of NEC for alternative new generating plant options allows, for given assumptions of input parameter values, the identification of the most economic option, namely the one with the lowest NEC. Secondly, for that option, it is possible to test whether it is economic to install the new plant and commission existing capacity.

Selection of Alternative Generating Plants

When added to the existing electricity supply system to meet increasing capacity needs, the power station would show a benefit by reducing overall system cost. The method of analysis adopted is to establish, from previous experience or by preliminary design studies, the capital cost, fuel costs, manpower and other operating costs, for each alternative type of plant. The annual costs of owning and operating a plant are then:

(I) Annual charges on capital, including repayment of the capital and interest. This charge may include the costs of raising finance during the construction phase, any government taxes related to capital, and allowances for the cost of commissioning and dismantling the station.

(圆 Annual costs of fuel for the expected hours of use, including any costs associated with disposal of waste (ash, nuclear waste).

(猿 Annual costs of maintenance, manpower, etc.

The nuclear plant, having low fuel and operating costs was predicted to have a high load factor throughout its lifetime, and these low operating costs offset the high capital charges. The implications on plant design are that the nuclear units will run, as far as they are able, at virtually constant full load output.

The coal-fired unit having a higher fuel and operating cost was predicted to have a high load factor in the early years of its life, but to operate intermittently for increasing periods in its later years. The uncertainty in predicting load patterns many years in advance results in the need to specify for these plants a combination of operating regimes, which is onerous in terms of load-cycling capability, including the ability to respond reliably to demands for rapid loading and deloading.

At the time when the oil-fired units were selected, the lifetime cost of oil was expected to be lower than that of coal, and the plants were specified to have high initial load factors, but to operate intermittently later in the lifetime. However, the abrupt rise in oil cost has meant that oil-fired units have been allocated a low lifetime load factor since they were commissioned, and they have been generally called upon to operate in a peaking role.

The pumped storage plant can be regarded in system operational terms as complementing both the nuclear and the coal-fired plant. When surplus nuclear and coal-fired capacity becomes available at nighttime, the storage of water for regeneration of electricity during the daytime is itself economic. In addition, the very rapid loading which has been possible is of considerable value in relieving some of the coal-fired plant of the need to respond to rapid changes in system demand, with a resulting saving in system operating cost.

[illegible]

CECB (Central Electricity Generating Board)	摇摇摇中心电力委员会(英国)
statutory	法定的,依照法规的
peak demand	尖峰负荷需求
severity	严寒
variation	差异
provision	供应
retirement	退役
retain	保持,保有
annual	一年一次的
avoidable	可避免的
pa 越per annum	每年
convert	使(一种形式)转变成(另一种形式)
commission	委托,代办,交付运行
preliminary design	初步设计
capital	资本,资金
manpower cost	人力费
raise finance	筹措资金
phase	阶段,时期
allowance	特别经费
dismantle	拆除…之设备
offset	抵消,弥补
implication	含意
load factor	负荷系数,满载系数
intermittently	间歇地,断续地
specify	指明,详述
regime	制度
onerous	繁重的
reliably	可靠地
abrupt	意外的,突然的
pumped storage plant	抽水蓄能电站
complement	补充物
surplus	盈余的,剩余的
relieve	援助

[illegible]

Site Selection and Evaluation

The major elements involved in the site selection and evaluation process are discussed below in greater detail.

• Client Requirements

The owner must at first determine from the load demand forecast that additional power will be required at some future time. The owner must then proceed through a management and planning process to determine how much power is required, when and where.

• Choice of Generation Type

The type of power plant (usually nuclear or fossil-fuel) to generate the required electricity must be chosen. If a nuclear fuel decision is made, the utility must determine the reactor type which is usually either a boiling water reactor (BWR) or a pressurized water reactor (PWR). If a fossil-fuel decision is made, the utility must determine whether to use coal, oil, gas, or some innovative alternatives such as magnetofluid, municipal solid waste, coke, combined cycle, etc. There is also the remote possibility that some other form of electrical generation, such as geothermal power; ocean thermal energy conversion (OTEC), hydroelectric power, or the liquid metal fast breeder reactor (LMFBR) may be considered.

• Establishment of Site Selection Criteria

Based on decisions established by the owner and as a part of the total process of site selection, the architect-engineer next establishes the basic configuration of the plant envelope as well as the site selection criteria. These criteria include:

员 Acreage;

圆 Water availability;

猿 Seismic constraints;

源 Distance constraints from power source to user centers;

缘 Socioeconomic and geopolitical factors, including zoning and community planning constraints;

远 Property acquisition conditions;

苑 Environmental factors such as biological inventories and effects;

愿 Locations of archaeological and historical sites;

怨 Population distributions;

员园 Transportation and communication limitations;

员员 Land use patterns;

员圆 Meteorological and climatological patterns.

Scaling and/or rating factors (a rating may be from 员 (good) to 员园 (bad)) must also be established for each of the above site, selection criteria.

• Identification and Screening of Candidate Sites

The owner may designate several candidate sites. An information and data acquisition plan must be developed related to these sites. Literature is searched for relevant information; government and private agencies are queried for existing background information and data; and libraries and nonprofit organizations such as hunting clubs are contacted. Survey plans are then developed to acquire data and information not already available from other sources. Large area screening, usually done on topographical maps, is performed to eliminate obvious undesirable, unusable, and impractical areas. This process results in a reduction of potential site areas to less than 员园% of the total land area under consideration. At the termination of this process, more strenuous criteria are applied to eliminate marginal sites. In the final site selection process, the site evaluation becomes even more explicit.

• Final Site Selection

A full evaluation of the remaining candidate sites is conducted in order to make a final selection. The Environmental Assessment Plan is developed at this stage in preparation for the later formulation of the Environmental Report and Environmental Impact Statement. A Community Acceptance Plan, which is designed to inform the public and at the same time reduce public apprehension, may or may not be developed depending on the potential for local objections to a power plant at the candidate site.

Location of Drax Power Station

Drax power station is located on the south bank of the River Ouse, midway between Selby and Goole in the County of North Yorkshire. The site was selected following detailed investigations of three large areas in the vicinity — two of these areas were on the south bank of the Ouse near Barlow and Newland, the third area was on the north of the river at Barmby. The investigations showed that there was little to choose between the areas on foundation conditions. The Drax site, which forms a part of the Barlow area of investigation, was selected in preference to the others primarily because of the shorter rail link required for coal haulage to the station.

A number of factors enabled a power station of large capacity to be considered, the main factors being:

员 The proximity of the site to the North Yorkshire coalfields means that transportation costs of fuel are kept to a minimum;

员园

圆 Good rail connections for fuel transportation；

猿 Comparatively short transmission connections were needed to the existing 源园园kV grid network；

源 Drax is a cooling tower station and the River Ouse is capable of supplying the make-up water requirements；

缘 Adjacent land at Barlow provides an adequate ash disposal facility；

远 Freedom from restrictions on site area and structure height.

Geologically，the site is within the Vale of York and the strata include lacustrine sandstone. The bed rock lying at a depth of 圆缘m is of sandstone，the surface of which was planed by the passage of ice during the Ice Age and overlaid by sands and laminated clays deposited in a glacial lake. Above these glacial deposits an alluvial mud was laid down by regular flooding，and this forms the flat low lying countryside. The nature of the strata made it necessary to carry all heavy buildings and installations on piles taken down to the rock and sand strata，but light or flexible structures could be carried on foundations placed on top of specially compacted or stabilized fill.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

boiling water reactor	沸水堆
fossil-fuel	化石燃料
magnetofluid	磁流体
municipal solid waste	城市固体废物，城市垃圾
coke	焦炭
combined cycle	联合循环
breeder reactor	增殖反应堆
criterion (*pl.* criteria)	标准，准则
acreage	英亩数
seismic	地震的
constrain	约束，制约
archaeological	考古学的
meteorological	气象学的
climatological	气候学的
topographical	地形的
strenuous	费力的
eliminate	除去，剔除
marginal	边际的
explicit	明确的，明白表示的
vicinity	附近，邻近地区
haulage	运输
proximity	接近

grid	高压输电线路网,网格
adjacent	毗邻的,邻近的
adequate	符合要求的,令人满意的
geologically	地质学地
vale	山谷
latchstring sandstone	湖积砂岩
overlay	覆盖,包
laminate	辗压成薄片
glacial	冰川的
alluvial	冲积
strata	(地壳的)岩层、地层
pile	(作屋基的)木、铁、水泥桩
flexible	易弯曲的,柔软的
compact	压紧的,致密的
stabilize	使坚固,使稳定

Unit Control Operating Requirements

Many power plants are designed to be capable of continuous operation over a load range as wide as possible, the design intent being that it is not necessary to shutdown the plant for overhaul, repairs or cleaning of gas passes except at statutory intervals of inspection.

Control Range

As a minimum requirement, the Drax plant is specified to be capable of operating continuously at full load on weekdays for a period of three months during which the availability exceeds 85%. The load range at other periods of continuous operation may be 50% to 100% continuous maximum rating (CMR). When operating at part load, the plant must be capable of responding to system frequency changes to raise or lower load at rates up to 5% CMR per minute in either direction in the load range 50% to 100% CMR. The periods of part load operation down to 50% CMR for system reasons could be up to 10 hours duration. The control equipment is required to ensure output regulation in response to system frequency variations at any load in the control range and to ensure rapid corrective response to sudden frequency changes due to imbalance between system load and generation.

2-Shift Operation

The plant is required to be unloaded in a period of approximately 30 minutes so as to minimize cooling of the boiler and turbine and to ensure a rapid reload after an overnight shutdown of 6 hours to 8 hours. The target rate of loading is from synchronization to full load in 30 minutes. No restraint is placed on the duration of the startup prior to synchronization. This should, however, be as short as possible to assist meeting unforeseen operational demands and to reduce the heat loss during startup. For periods of shutdown in excess of 8 hours, a lower rate of turbine generator loading can be accepted. In a multi-unit station such as Drax, the main and auxiliary plant is designed so that following an overnight or weekend shutdown all units can achieve full output within 2 hours from the first unit synchronization. Failure of one unit during the startup and loading should not prevent the other units in the station achieving full output in the programmed time.

Load Rejection

Each unit has the ability to reject load to the extent of [illegible]% CMR on sudden partial loss of demand from any load level in the range of [illegible]% to [illegible]% CMR. Additionally the plant is capable of tripping without damage on loss of grid supplies or as initiated by a plant fault.

Design life

The life span of the generation plant is anticipated to be in the order of [illegible] years when operation at a load factor is required by the system, and Table [illegible] gives the typical number of cycles of operation during this lifetime on which component design is based.

[illegible] [illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Conditions of Operation

Table [illegible] gives the specified design parameters for the steam flows, temperatures and pressures at selected loads of the Drax power plant.

[illegible] [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

intent	目的,意向
shutdown	停机,关闭
overhaul	检修,检查
statutory intervals of inspection	规定的停机检查
continuous maximum rating (CMR)	最大连续出力
duration	持续时间,期间
imbalance	不均衡
minimize	将…减至最小量或最低程度
synchronization	同时发生,同速进行,并网
auxiliary	辅助的
load rejection	甩负荷
partial	部分的
initiate	开始,着手
life span	寿命期限
component	部分,成分
warm start	温态启动
hot start	热态启动
evaporation	蒸发量
superheater	过热器
outlet	出口
reheater	再热器
flow	流量
inlet	入口
economizer	省煤器

哉擂贼云蚤藻瑶 悦燥藻造

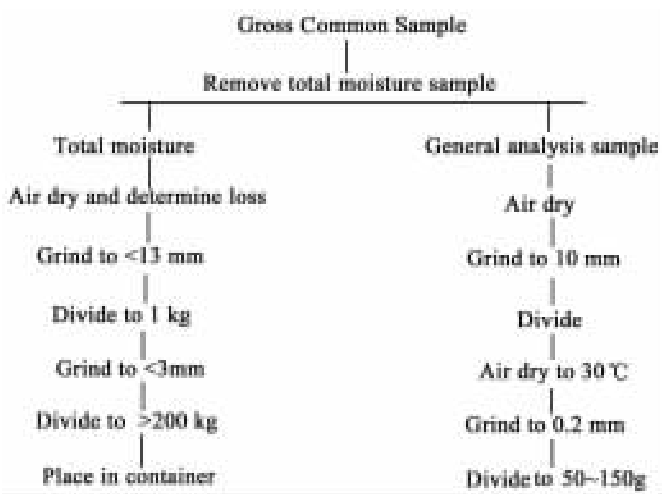
General

The basic requirement for effective coal sampling is to produce a small quantity of coal for preparation and analysis by the Chemist which is in almost every way (e. g. large and small pieces, moisture content, ash, chemical analysis, etc.) representative of the consignment in bulk. It is easy to say, but very difficult to achieve in practice because coal is such an intractable material to deal with. If it is dry it is usually dusty and some of the dust is liable to blow away; if it is wet it is sticky or, if very wet, a thick paste; if it is frozen pieces bind together to form lumps.

So the very nature of the material presents the first problem.

Preparation of the Laboratory Sample

If the sampling method is beyond reproach the gross sample will be representative of the consignment in bulk. It will have the same proportions of large and small lumps, dust, ash and so on, as are in the consignment within very small tolerances. However, the sample will still be too large for use by the Chemist as he only requires between 员kg and 缘园grams for the analysis. But, of course, these few grams must still remain a faithful representation of the original quantity. Normally the sample is required for:



(a) total moisture determination; (b) general analysis, and the stages for each are shown in the following chart:

Notice that air drying of the sample is carried out as an early step in each case.

The purpose of the initial measured air drying of the moisture sample is to ensure that it will pass through the subsequent sample reduction and grinding equipment without loss or gain of moisture to the atmosphere in the coal preparation room. The general analysis sample is dried to assist milling and to prevent blockage of the fine mill outlet screens.

Laboratory Analysis

If the sampling and preparation have been carried out carefully and in accordance with BS 员园员苑the Chemist will now have two samples of about 圆缘园grams of coal, one crushed to pass 园圆mm mesh and the other crushed to pass 猿mm mesh ready for analysis.

A proximate analysis is carried out on the first sample (园圆mm mesh), usually called the "analysis" sample. This gives:

"As-tested" moisture;

Ash;

Volatile matter;

From which the "Dry" basis analysis can be calculated.

The second sample will be derived from the bulk moisture sample or a 员园— 圆园kg portion abstracted from the main sample. The moisture sample must be placed in a sealed container immediately to prevent loss of moisture to the atmosphere. This container is then weighed with and without its contents. The contents are allowed to air-dry at ambient temperature in the sample preparation room, and then reweighed. The loss of weight (which is often referred to as the "free" moisture) is recorded.

The air-dry coal is then further ground to pass a 猿mm mesh and the bulk is reduced to about 圆缘园grams. The remainder of the moisture can then be determined and "total" moisture calculated. This is usually called the "Moisture" sample. From the "dry" basis analysis and the total moisture the Proximate analysis of the original sample can be calculated.

If a full "*Ultimate*" analysis is required, a difficult and protracted series of laboratory analyses is necessary using the "Analysis" sample as a starting point. The ultimate analysis requires the separate determination of:

Carbon, hydrogen, nitrogen, oxygen, sulphur, and chlorine, in addition to the total moisture and ash already determined in the proximate analysis.

If only hydrogen and carbon are required they can be calculated from various formulae (the most commonly used being Parr's formula, which will be discussed later), provided the proximate analysis and CV are known. The sulphur and chlorine contents are sometimes required if slagging or superheater fouling problems are encountered, electrostatic precipitator performance is being investigated, or if fireside corrosion is evident. In addition it is sometimes desirable to determine the softening and fusion temperatures of ash.

Calorific Value

The calorific value of coal is a direct indication of the energy value of the coal and this particular property is considered to be one of the most important means by which a coal can be evaluated. The calorific value is one of the many physical properties of coal and, as such, is often found in the various sections that deal with the physical properties of coal. However, in the present context, the importance of the calorific value as one of the means by which coal can be evaluated dictates that it be included in this particular sections as well as in the section describing the general thermal properties of coal.

The calorific value of coal is actually a complex function of the elemental composition and is usually reported as the gross calorific value with a correction applied if the net calorific value is of interest. For the analysis of coals, the calorific value is determined in a bomb calorimeter either by a static (isothermal) or an adiabatic method. In the isothermal method (ASTM D 猿圆愿远), the calorific value is determined by burning a weighted sample of coal in oxygen under controlled conditions and the calorific value is computed from temperature observations made before, during, and after combustion with appropriate allowances made for the heat contributed by other processes. The adiabatic method (ASTM D 圆园员缘 ISO 员怨圆愿) consists of burning the coal sample in an adiabatic bomb calorimeter under controlled conditions. The calorific value is calculated from observations made before and after the combustion.

The computed value for the calorific value of coal is usually expressed in joules per gram, British thermal units per pound, or occasionally, as calories per gram. In either form of measurement, the recorded calorific value is the gross calorific value whereas the net calorific value is calculated from the gross calorific value (at 圆园C) by making a suitable subtraction (越员园圆园Btu/lb 越缘远园cal/g 越圆援猿缘kJ/g) to allow for the water, originally present as moisture as well as moisture formed from the coal during combustion. The deduction, however, is not equal to the latent heat of vaporization of, water (圆援源缘kJ/g at 圆园C) because the calculation is made to reduce from the gross value at constant volume to a net value at constant pressure for which the appropriate factor under these conditions is 圆援猿缘kJ/g.

The experimental conditions require an initial oxygen pressure of 猿园园—远园园psi and a final temperature in the range 圆园C—猿缘C with the products in the form of ash, water, carbon dioxide, and nitrogen. Thus, once, the gross value has been determined, the net calorific value (i. e. the net heat of combustion) is calculated from the gross calorific, value (at 圆园C) by deducting 圆援猿缘kJ/g to allow for the heat of vaporization of water.

The deduction is not actually equal to the heat of vaporization of water（圆源缘 kJ/g）because the experimental conditions are different，Thus，Net calorific value（kJ/g） 越 gross calorific value 伊圆猿缘伊% Total Hydroge 伊怨 员园

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

consignment	委托，交付
intractable	难控制的，难加工的
lump	煤块
proximate analysis	工业分析
ambient	周围的
ultimate analysis	元素分析
protracted	延长的，长时间的
slagging	结渣
foul	积灰
iso thermal	恒温，等温线
adiabatic	绝热的

Introduction

Coal is well known to be a dirty fuel, so it is necessary to develop "clean coal" techniques in order to comply with more and more stringent environmental legislation.

The first approach consists in reducing emissions from existing Pulverized Coal (PC) installations by developing depolluting devices that act on combustion in the furnace (primary process) and/or that treat flue gas leaving the furnace (secondary process).

The second approach consists in designing entirely new technologies, all based on fluidized bed combustion, which enables to set coal combustion conditions favorable to simultaneous NO_x and SO_x depollution in the furnace. In addition, coal gasification is considered.

So, the Clean Coal Technologies to be considered in this study are the following:

1. Primary and Secondary Depolluting Systems for Existing Units;
2. Pulverized Coal with Flue Gas Treatment (PC + FGT);
3. Atmospheric Circulating Fluidized Bed Combustion (ACFBC);
4. Pressurized Bubbling Fluidized Bed Combustion (PBFBC);
5. Pressurized Circulating Fluidized Bed Combustion (PCFBC);
6. Integrated Gasification Combined Cycle (IGCC);
7. Hybrid Cycle Applied to Circulating Fluidized Beds (HC: HC-ACFBC and HC-PCFBC).

Clean Coal Technologies for Existing Units

• Primary Processes

Denitrification Devices. Burners are more and more designed to limit nitrogen oxide formation during combustion. These burners, known as "low-NO_x", rely on the concept of air injection staging and of fuel distribution modification. The principle is to avoid too high flame temperatures and to reduce oxygen excess in the furnace, which favors nitrogen oxide formation. Another primary process consists in staging the combustion air in the furnace and is known as Over Fire Air (OFA). An additional process consists in staging the fuel injection into the furnace and is known as "reburning".

Desulphurization Devices. The primary desulphurization processes consist in injecting lime or limestone as a fine powder into the furnace in order to absorb the generated sulphur dioxide. If necessary, slaked lime and water are injected into the flue gas in order to improve the desulphurization efficiency. These processes can be used because of their low cost even if their efficiency is moderate: about 40% to 70%.

• Secondary Processes

Denitrification Devices. The reduction of NO_x emissions can be also achieved by means of catalytic or non-catalytic chemical processes. The most used secondary process (95% of installed systems) is the Selective Catalytic Reduction. Gaseous ammonia is mixed with combustion gas at the boiler outlet before the air-heater. The mixture gets then across a reactor containing catalysts to give N_2 and water. The temperature range of operation is 350°C – 450°C.

Desulphurization Devices. For the recent installations, the SO_2 emissions are generally reduced by wet limestone/gypsum Flue Gas Desulphurization (FGD) systems. Sulphur dioxide is removed from combustion gas in the form of gypsum ($CaSO_4$), essentially through a wet process using a solution of carbonate, sulphite and sulphate of calcium in-suspension.

Atmospheric Circulating Fluidized Bed Combustion

The principle of Atmospheric Circulating Fluidized Bed Combustion (ACFBC) power plant consists in producing steam at high temperature and pressure from the heat generated by the complete coal combustion in a fluidized bed furnace. Pressure in the furnace is about atmospheric pressure and fluidizing velocity is high. Solid particles leaving therefore the furnace are collected and recirculated into the furnace. This recirculating of solid matters in the furnace enables an efficient coal combustion kept at about 850°C (in order to favour sulphur dioxide retention by limestone and to minimize nitrogen oxide formation). Electricity is delivered by an alternator associated with a steam turbine where the steam generated by the process is expanded.

Pressurized Bubbling Fluidized Bed Combustion

In a Pressurized Bubbling Fluidized Bed Combustion (PBFBC) power plant, the boiler is operating under pressure, between 10×10^5 Pa and 16×10^5 Pa, and the bed fluidizing velocity is low. So the fluidized bed presents a free solid surface distinct from the gaseous phase above. At this fluidizing velocity, gas bubbles are getting through the bed to its surface, and it is called as "Bubbling Bed". Electricity is delivered by two generators, the first one associated with a steam turbine where the steam generated by the process is expanded, the second one with a gas turbine where flue gas is expanded. The PBFBC technology involves a combined cycle.

Pressurized Circulating Fluidized Bed Combustion

In a Pressurized Circulating Fluidized Bed Combustion (PCFBC) power plant, the boiler is operating under pressure, between 员园伊员园^{缘} Pa and 员远伊员园^{缘} Pa, and the bed fluidizing velocity is high, similar to ACFBC. The PCFBC properties due to the Circulating Fluidized Bed are the same as those of ACFBC. The only difference is that the PCFBC furnace operates under pressure.

Integrated Gasification in a Combined Cycle

In IGCC, gas obtained from coal gasification is cleaned up in order to eliminate in particular dust and sulphur compounds, prior to being burnt, generally in a gas turbine, to generate electricity. A heat recovery boiler allows to recover part of the sensible heat of flue gas by producing steam. This steam is also used to drive a steam turbine to generate electricity also.

The new techniques of coal or oil residue gasification offer today the possibility to generate electricity in combined cycle with high efficiency. The IGCC technology presents many variants. They can be notably distinguished not only by the gasified type (fixed bed, fluidized bed), but also by the oxidizer used (air or oxygen) and by the gas cleaning system.

晕藻憎 宰[illegible]

Clean Coal Technology (CCT) 摇摇摇摇摇摇摇摇摇	洁净煤技术
stringent	严格的
legislation	法律
emissions	发出,排出物
Pulverized Coal (PC)	煤粉
flue gas	烟道内烟气
fluidized bed combustion	流化床燃烧
simultaneous	同时发生的
coal gasification	煤气化
Circulating Fluidized Bed (CFB)	循环流化床
Bubbling Fluidized Bed (BFB)	鼓泡流化床
Integrated Gasification Combined Cycle (IGCC)	整体煤气化(蒸汽一燃气)联合循环
Hybrid cycle	混合循环
denitrification device	除氮装置
burner	燃烧器
air injection staging	空气分段送入
nitrogen oxide	氮氧化物
Over Fire Air (OFA)	过燃风

reburning	再燃烧
desulphurization devices	除硫装置
lime	石灰
limestone	石灰石
sulphur dioxide	二氧化硫
slaked lime	熟石灰
Selective Catalytic Reduction（SCR）	选择性催化剂脱氮装置
gaseous ammonia	氨气
catalyst	催化剂
carbonate	碳酸盐
sulphite	亚硫酸盐
sulphate	硫酸盐
calcium	钙
suspension	悬浮
retention	被保留
alternator	交流发电机
deliver	释放，发出
sensible heat	显热
residue	残存
gasifier	气化床
oxidizer	氧化剂

Part Two摇Boiler

[illegible]

摇摇The steam generating system, frequently called the boiler, is a system that transfers the heat from the products of combustion to water and produces hot water or steam. The combustion is accomplished in a furnace. Heat is transferred in the furnace mainly by radiation to water-cooled walls, which constitutes the evaporation section of the steam generation system. After leaving the furnace, the gases pass through a superheater in which steam receives heat from the gases and has its temperature risen above the saturation temperature. Since the temperature of the gases leaving the superheater section is still high, modern steam generators often employ additional heat transfer surfaces to utilize the thermal energy of the gases. These include the surfaces of reheaters, economizers, and air preheaters.

Boilers may be classified into three categories according to their applications. These include industrial, marine, and central electric power station. Generally, the industrial boilers produce saturated steam or hot water. The pressure condition is frequently low. The marine boilers are much larger and usually produce superheated steam. The boilers for electric power generation stations are quite different in terms of steam conditions and generation rates. The steam pressure may be either supercritical or subcritical and the temperature is frequently around 缘愿°C.

Boilers may also be classified according to the relative positions of products of combustion. In one type boiler, called the fire-tube boiler, the products of combustion flow through tubes surrounded by water. This type of boiler is frequently used in most steam locomotives, in small factories, and sometimes in heating buildings. In another type of boiler, called the water-tube boiler, the products of combustion flow over water-filled tubes. Both ends of the water tubes are connected to the headers or the boiler drums. In the drum the steam is separated from the saturated water. Then, the saturated steam usually goes to the superheater in which the steam temperature is increased. All high-pressure and large boilers are of the water-tube type. The small tubes in the water- tube boiler can withstand high pressure better than the large drums of a fire-tube boiler.

Boilers are operated by firing various fuels. These fuels include bituminous coal, lignite, anthracite, natural gas, and oil. Different fuels result in different boiler designs and operations.

To attain high system efficiency, the steam generator usually, consists of the evaporation section, superheaters, reheaters, economizers, and air preheaters. In power plant system design one steam generator is frequently used to match one turbine unit. Because of this, steam generator unit size increases as turbine unit size increases.

Since the general introduction of pulverized coal-fired boilers in the 1950s there has been a considerable increase in unit size. The rapid increase in size at one stage resulted in some cases of excessive extrapolations from earlier designs with a consequent loss in the standard of reliability. To counter this a program of extensive testing was embarked upon on, units in stations. This program provided information, which resulted in the attainment of higher standards of plant reliability.

On-going development and improved manufacturing techniques led to the introduction of further design changes. Important changes can be summarized as follows:

(1) As a result of design and manufacturing development, steam drum internals have been modified to improve steam/water separation and to allow interchange of components between drums.

(2) Changes were made to the superheater and reheater tube thicknesses and materials to give increased design life and improve corrosion allowances. Platen designs were altered due to operational experience and constructional changes recognized improved manufacturing methods and practices. Because of the difficulty of fabrication, a change was made from reheater outlet drums to a system of headers with a steam outlet at each end of the headers. This also gave better steam distribution to the hot reheat lines.

(3) Changes to furnace internals, were made to give better heat transfer characteristics and to simplify construction procedures.

(4) Boiler tubes have been subjected to 100% ultrasonic examination to comply with more stringent specification requirements and case histories have been prepared relating to all pressure parts. A complete record of the design, manufacture and quality aspects of each component is thus provided which gives confidence in the long-term operation of pressure parts.

(5) Operational experience on a number of power stations demonstrated that a 2 speed motor on forced draught (FD) fans and induced draught (ID) fans was of limited advantage and, because of a potential trip on changeover, tended always to be operated in the high speed mode. Consequently it was decided that single speed motors should be fitted.

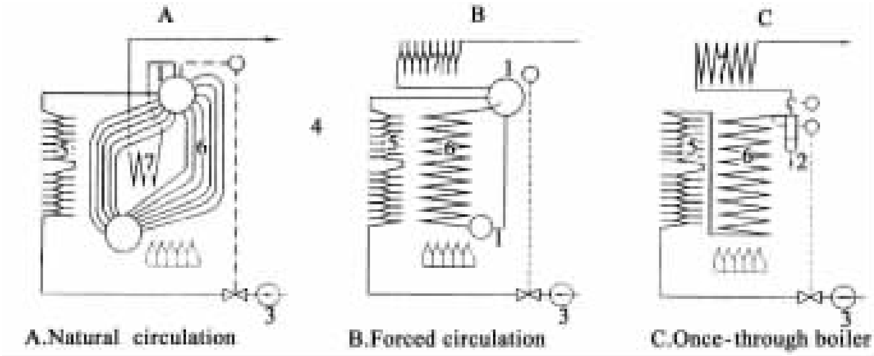
furnace	炉膛
water-cooled wall	水冷壁
category	种类,类型
marine	船舶的,海的
locomotive	机车
header	联箱,母管
drum	汽包,汽鼓
bituminous	烟煤
lignite	褐煤
anthracite	无烟煤
match	匹配,使协调
extrapolation	外推,推断
attainment	达到
internals	内部部件
modify	更改,改变
platen	屏
subject	有待…的,须经…的,受人支配的
comply with	照做
specification	说明书
history	过去事的记载,来历
aspect	样子,外表
forced draught	送风机
induced draught	引风机
trip	解扣,跳闸

[illegible]

All power station boilers are of the water-tube type. Water circulates within the tubes and partially becomes steam as it receives heat from the products of combustion. When water circulation within the boiler takes place due to its own density difference, it is called the natural circulation boiler. In this type of boiler, water from the boiler drum first flows downward to the bottom of the heated evaporative tubes through several pipes (frequently called downcomers). Then, the water reverses its flow direction and returns to the drum as it receives the heat from the furnace. Since the evaporative tubes (frequently called risers) contain a mixture of steam and water, the average density in the riser is always lower than that in the downcomer. This density difference gives rise to a driving force that will overcome all friction in the water-steam circuit. Figure 圆员 (A) shows a schematic diagram of water-tube boiler operating on the natural circulation principle. Natural circulation is a simple and efficient technique and is frequently employed in boiler designs.

As the boiler pressure becomes higher and higher, the difference in density of the fluid between the downcomers and the risers will become less and less. At a certain boiler pressure, the driving force, which is proportional to the density difference, is not sufficiently large to balance the frictional resistance. One alternative is to employ pumps to force the water through the evaporative tubes. The boiler using circulation pumps is called the forced circulation boiler. Figure 圆1 (B) shows a schematic diagram of forced circulation water-tube boiler. It is seen that the circulation pumps take the water from the drum and supply it to the headers at the bottom of the boiler. From the headers water moves upward as it receives heat from the products of combustion. Because sufficient driving force is available, smaller diameter tubes can be used in the forced-circulation boiler. Furthermore, it is possible to apply an orifice to each tube so that more uniform flow and tube temperature can be achieved. These advantages frequently offset the cost of circulation pumps and their pumping power. Similar to the forced-circulation boiler is the once-through boiler shown in Figure 圆员 (C). It is seen that there is no boiler drum. Water flows through the evaporation section without any recirculation. This arrangement is frequently employed when the steam pressure in the boiler is supercritical.

In the three boiler arrangement just introduced, each has its own economizer, evaporator section and superheater. Not shown in the diagrams are the reheater and air



[illegible]

preheater, which are usually employed in modern boiler design. The economizer is a heat exchanger used to increase feedwater temperature. The evaporation section, which usually surrounds the boiler furnace, is to produce saturated steam and supply it to the superheater. In the superheater the steam is further heated and has its temperature risen to the level above the saturation temperature. Then, the superheated steam flows to the turbine-generator throttle for power production. The reheater, when included in a steam generator, is usually installed in the location adjacent to the superheater. The reheater receives the steam from the high-pressure turbine after the steam partially expands. In the reheater, steam absorbs heat from the products of combustion and has its own temperature increased. Usually, the outlet temperature is identical to the temperature of the steam leaving the superheater. To maintain high furnace temperature and boiler efficiency, an air reheater is frequently employed in boiler design. It is usually installed in the location just before the hot gases leave the steam generation system.

The products of combustion are generated in the boiler furnace. The hot gases first transfer heat to the evaporation section by radiation and convection. Then, these gases exit the furnace and enter the superheater and the reheater zone. In these zones the gases further transfer heat away. The basic heat transfer mechanisms are still convection and radiation. Next along the gas path is the economizer. In the economizer heat is transferred to the feedwater from the gases. Because of the low temperature in the products of combustion, convective heat transfer is the prevalent mode. In the air preheater, the gas temperature is further reduced. The lower the gas temperature, the higher the boiler efficiency will be. However, the gas temperature should not be lower than the dew point of water vapor in the gases. Any water condensation will give rise to a formation of liquid acid, which results in a corrosion of the air heater surfaces.

In case of burning coal or lignite, the boiler firing equipment is either a pulverizer-burner system or a cyclone furnace. Usually the boiler is completely automatic, including combustion, steam temperature, and feedwater flow.

Once-through boiler is usually applied to a large turbine-generator unit size. Like the natural-circulation boiler, this type of boiler can burn coal, lignite, oil, and natural gas. In a once-through boiler the feedwater pump speed and turbine throttle are used to control the steam flow and steam pressure. Steam temperature is controlled by the fuel firing rate and the gas tempering. The temperature of steam leaving the reheater is also important. It is frequently controlled by gas-recirculation and/or attemperation.

Most central station boilers are equipped with air pollution control systems. These often include an efficient precipitator and sometimes an SO_2 removal system. In addition, sufficient stack height is frequently used to ensure an acceptable level of pollution concentration in the plant surroundings.

[illegible]

downcomers	下降管
risers	上升管
friction	摩擦
evaporative	蒸发的
orifice	孔板,节流板
saturation	饱和
throttle	节流阀,调速汽门
dew point	露点
condensation	凝结
acid	酸
corrosion	腐蚀
pulverizer	磨煤机
cyclone	旋风,旋风分离器
once-through boiler	直流锅炉
temper	缓和,调温,回火
attemperation	温度调节,温度控制
pollution	污染
precipitator	除尘器
stack	烟囱,冷却塔

哉拯癫栽谏磉藜摇 月燦羅藝刂坛恚藍

Energy is liberated within the boiler furnace by the chemical reaction of oxygen with the combustible elements of the fuel. For any fuel there is a minimum quantity of oxygen required for complete combustion. The amount of air that contains this minimum quantity of oxygen is termed as theoretical air. The theoretical air varies according to the nature of the fuel. Nitrogen and ash in the fuel are inert and thus do not enter into the combustion process. The theoretical air is linearly proportional to the high heating value of the fuel.

Since it is impossible to achieve a complete combustion with theoretical air, additional amount of air must be supplied. The amount of excess air depends on many factors including the fuel characteristics, the type of burner, and the design of furnace. For a coal-fired steam generator the excess air varies in the range of 员圆% to 圆缘%. The total air for combustion is the sum of the theoretical air and the excess air. When the fuel consumption is determined, the total amount of air required for combustion can be easily calculated.

The products of combustion are important in boiler design. They contain the components such as CO_2, CO, O_2, H_2O and SO_2. The amount of SO_2 is relatively small and usually neglected in measurements. The gas analyzer determines the composition of gases on a dry basis. The readings include CO_2, CO, O_2 and N_2 in a volume percentage. The total gas weight is the sum of the total air and the fuel minus the ash content. Both total air and gas weight are needed to determine boiler fan capacities.

Boiler fuel consumption is closely related to its output. In addition, it also depends on the heating value of the fuel and the boiler efficiency.

The heating value of the fuel is the amount of heat released by one unit of fuel when it is completely burned and the products of combustion are cooled to the original fuel temperature. When the water from combustion is in a vapor form, the value is called the low heating value (LHV). If there is complete water condensation in the products of combustion, the heating value thus obtained is the high heating value (HHV). The low heating value can be obtained by subtracting from the high heating value, the heat needed to vaporize the moisture of the coal and the moisture formed in combustion.

The boiler efficiency is based on the high heating value of the fuel or the low heating value. Therefore, it is important to define the boiler efficiency with a clear indication of whether HHV or LHV is used.

Boiler efficiency can be also expressed in terms of boiler heat losses. To determine these losses the fuel and flue gas analysis must be available.

The boiler efficiency depends on the boiler design parameters. In addition, it varies with boiler operating conditions such as its output. In modern boiler design, the boiler efficiency is generally around 愿苑% to 怨园% for solid fuel firing. Natural gas fired boilers have a lower efficiency of 愿源% to 愿缘% because of the higher water vapor in the products of combustion.

Coal-Oil Mixtures (COM)

COM development has a history of more than 员园园 years. The COM consisted of 猿缘% pulverized coal ground to below 苑缘μm, 远源% heavy fuel oil, and 员% stabilizer.

•COM preparation and handling

Usable COM must be stable over periods of weeks and preferably months, the theological properties must allow ready pumping and atomization, and the COM mixture must be amenable to efficient combustion with pollutant outputs that meet applicable emissions standards. Generally, stability improves at the expense of increased viscosity. Fine atomization in the boiler is required for efficient combustion. The control of slagging and the development of improved and long-lived atomizers represent major challenges. The flame stabilities achieved with COM have been excellent.

Successful introduction of COM into industrial use requires that the mixture be stable and that the theological properties be favorable. It is also desirable to increase the coal content as much as possible and to use particle sizes, which do not require excessive grinding energy for their preparation.

The relationships between these variables show that good stability and favorable theological properties have conflicting requirements. Thus, the stability improves but the viscosity of the mixture increases with increasing coal concentration, finer particle sizes and increasing oil viscosity. Additions of small amounts (up to 缘%) of water and about 员% of surfactant can produce an acceptable solution.

The mechanism of COM stabilization is poorly understood. The action of the chemical additives is explained by the effects on electrostatic, steric and flocculated networks in the fluid but the relationships between additive properties and COM stability are, at best, semi-empirical. Improved understanding in these areas is desirable.

• COM combustion and pollutant emissions

Combustion studies at several laboratories have served to emphasize the necessity of matching coal and oil combustion properties and showed wide-ranging variations in carbon combustion efficiency when different types of coals were used.

The combustion of COM in an industrial type turbulent diffusion flame is dominated in the near field (i. e., close to the burner) by characteristics of the oil flame and, in the far field, by the burn-out of the residual coal char towards the end of the flame.

Single COM droplets ignite more readily than oil drops, perhaps because of increased absorptivity of thermal radiation caused by the presence of the solid particles. If a bituminous coal is used, its thermal decomposition commences while the particles are still surrounded by the liquid phase. The high molecular weight tars, which evolve from the coal, are partially extracted by the oil, and the coal particles swell and produce an agglomerate. On termination of oil combustion, a solid carbonaceous residue is left, which encloses the partially devolatilized coal char particles. As oxygen reaches the surface, the temperature of the char agglomerate is risen, causing further evolution of coal volatiles and an increase of internal pressure; the carbon surface becomes spherical and, eventually, this cenosphere ruptures to permit the volatiles to escape through blow-holes. The char cenosphere burns out in the tail end of the flame, where the temperature is high but the oxygen concentration is low because of prior combustion of oil and coal volatiles. Flame stability may be reduced by hot combustion products at the burner. Some reduction of recirculation is highly desirable. Otherwise, the combination of resulting high temperatures close to the burner and the possibility of carbon (from unburned fuel) becoming embedded in the wall deposit can cause serious slagging problems. The atomization quality has to be high because the sizes of the char cenospheres are close to those of their parent droplets and their burning time is proportional to the square of initial particle diameter.

It is expected that NO_x emission from COM will be somewhat higher than from oil alone, mainly because of the increased fuel-nitrogen contents of COM. However, with staged combustion in COM use, coal-nitrogen evolution occurs in an atmosphere in which the O圆 has been strongly depleted. As the result, there is reduced NO_x emission. NO_x emission has been shown to respond sensitively to variations in the overall amounts of excess air used.

The emission of sulfur will depend on the total sulfur contents of coal and oil in the mixture. Sulfur reduction is an important consideration in coal preparation.

The flame emissivity is increased by coal particles and enhanced radiative heat transfer from the flame is therefore expected. However, this process does not produce increased heat transfer in the combustion chamber because of the insulating effect of the ash-slag deposit on heat-exchanger surfaces. The flue gas volume had to be increased because of higher excess air requirements for complete combustion and this, together with reduced heat transfer in the combustion chamber, resulted in a higher proportions of the enthalpy of the flue gas being carried into the convective superheater section of the boiler.

Coal-Water Mixtures (CWM)

Applications of coal-water mixtures (CWM) represent a relatively new area of coal utilization. The primary use is expected to involve CWM as replacement of oil in industrial boilers. This fuel may, also be used in gas turbines and in high-pressure gasification.

• CWM preparation and handling

The presently available studies suggest that mixtures for boiler applications will contain about 殉园% coal and 猿园% water. Coal percentages for gas-turbine applications may be lower. The blended coal particles generally cover a range from small to large sizes up to 缘园mesh. It is customary to use small percentages of additives for the control of viscosity and dispersion. Claims are made that mixtures are stable for significant periods of time (e. g. , one month).

• CWM atomization and dispersion

In the areas of atomization and dispersion, studies should be performed (a) to determine the effects of variables such as mass-flow rates, pressure levels, and nozzle configurations that control the droplet-size distributions, coal sizes and distributions and (b) to determine the relations between nozzle designs, secondary air-flow patterns, and mixing rates to achieve optimized burner designs and control coal agglomeration.

In the areas of combustion and pollutant production, a number of studies are desirable: (a) Measurements are needed of combustion rates, fouling, and pollutant-formation characteristics of CWM, including optimum coal solids levels, use of beneficiated coals with low ash contents, and effects of additives. Of particular importance are achievement of adequate flame stability, control of nozzle erosion, and high carbon conversion (跃怨愿%), as well as control of ash and NO_x levels; (b) Designs of optimum burner configurations for CWM remain to be accomplished; (c) Tests are needed of long-term operation of CWM in large-scale, oil-designed utility boilers, with emphasis on slurry mixture stability, flame stability, control of fouling, ash and nozzle erosion, high carbon conversion, and control of NO_x levels. This applied task must be performed successfully before widespread commercial applications can occur.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

high (low) heating value	高(低)位发热量
dry basis	干燥基础
ground	磨碎 基础 地
preferable	更可取的,更好的
rheological	流态的,流变的
atomization	雾化
amenable	有义务的,经得起检验的
at the expense of	以…为牺牲,在损害…的情况下
conflict	斗争,冲突
solution	溶液
surfactant	表面活性剂

additive	添加剂
electrostatic	静电的
steric	空间的,位的
flocculation	絮凝作用
network	网眼织物,网状物
decomposition	分解
commence	开始
tar	焦油
extract	蒸馏出,抽取
swell	膨胀,增长
agglomerate	烧结块,烧结
termination	结束
carbonaceous	含碳的
devolatilize	脱挥发分
rupture	破裂
blowhole	气孔,砂眼
prior	在先的,优先的
embed	埋置,把…嵌入
deplete	使耗尽,使空虚
emissivity	辐射能力,辐射系数
enhance	加强,提高
insulate	绝缘,隔离
blend	混合,掺和
dispersion	扩散,弥散,泄漏
configuration	构造,外形
droplet	小滴,飞沫
slurry	煤泥,泥浆

獭源

[illegible]

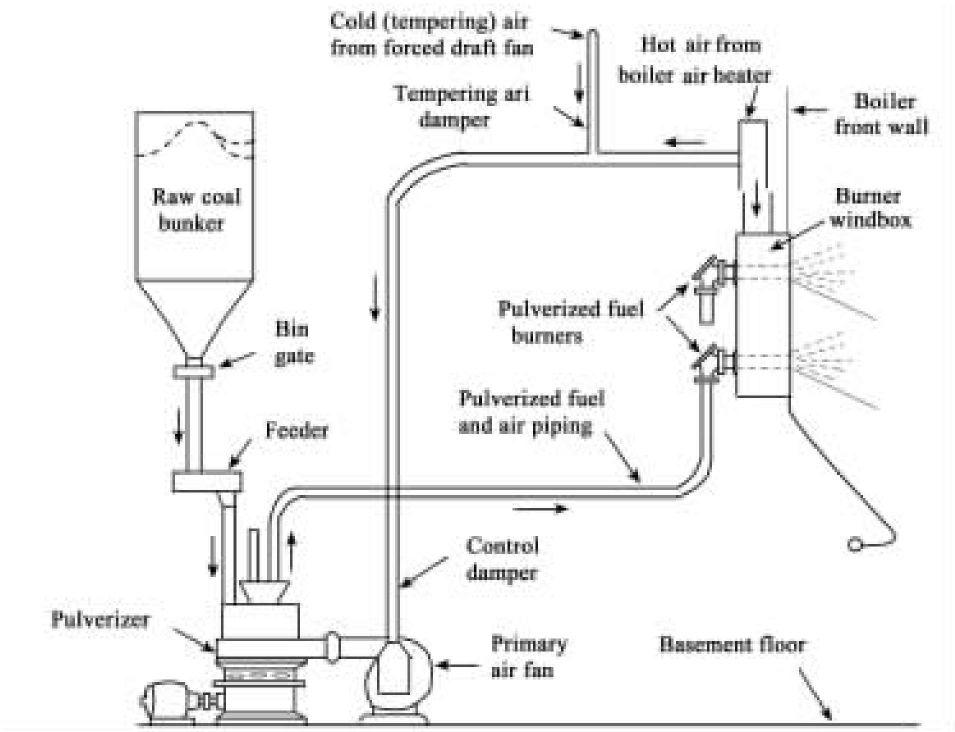
A steam generating system is large and complex. It consists of combustion equipment, furnace, and various heat transfer surfaces. In addition, the steam generating system has some auxiliary equipment needed for efficient operation. These auxiliaries include at least the boiler fans (forced-draft and induced-draft), stack, precipitator, and SO圆 removal system.

The selection of combustion equipment depends on the type of the fuel used. For solid fuels such as coal, three combustion systems (mechanical stoker, pulverizer burner and cyclone-furnace) are generally suitable. Mechanical stokers were first developed in the history of the boiler. Almost any coal can be burned on some type of stoker. Other advantages of stokers include low power requirements and large operating range. Because of the small capacity, they are seldom used for today's central electric power station.

The pulverizer-burner system was introduced in the third decade of last century. This system overcomes the size limitation of the mechanical stoker. Modern pulverizing systems are so well developed that they can burn almost any type of coal, particularly those in the higher grades and ranks. In addition, the system has improved response to the load change, higher combustion efficiency, and less manpower required in operation.

Figure 圆圆 shows a typical firing system for pulverized coal. The function of this system is to pulverize the coal, deliver the coal powder to the burners, and accomplish complete combustion in the furnace. The system must operate in continuous process and can adjust itself to the load demand in a reasonable time. There are two major equipment components, pulverizer and burner, in the system. The pulverizer receives coal from the coal bunker through the coal feeder, and produces the coal powder according to the fitness requirement. At the same time the pulverizer receives the hot air from the primary-air fan for drying and transporting the coal powder to the burners. Each pulverizer is usually connected with several burners. In operation, the coal feed is proportioned to the load demand, and the primary air supply is adjusted to the rate of coal feed. The air-coal ratio is so determined that the air-coal mixture leaving the pulverizer should have a proper temperature and moisture. Generally, the temperature and moisture are, respectfully, 逸缘℃ and 1% to 圆% for bituminous coals.

In addition to delivering a sufficient amount of air, the primary air fan is designed to maintain a high velocity of the air-coal mixture in pulverizer discharge lines. The velocity must be such that there is no settling and drifting of coal in the piping. At the burner the air-coal mixture is combined with secondary air and both injected into furnace. As indicated in Figure 圆圆 both primary air and secondary air are from the boiler air preheater. When the moisture of coal is below the maximum level, or the boiler is in a low load condition, cold air is used to temper the primary air.



[illegible]

Combustion equipment for oil and natural gas is relatively simple. There is no need for a coal pulverizer, coal crusher, or other fuel preparation facilities. Because of the high viscosity of the fuel oil, some types of heaters are usually needed in the oil storage tank to warm the oil and to facilitate pumping. Oil pumps receive the oil from the strainers and discharge it to the burners through heaters. To maintain a good combustion, the temperature of the fuel oil entering the burners should be around [illegible]C. The recirculation lines are provided in the fuel oil system. The recirculation lines are used to prevent stagnant oil from collecting in the piping system and cooling to the point of solidification. The burners for the fuel oil are similar to those for the pulverized coal.

[illegible]

forced-draft 送风机
[illegible]

induced-draft	引风机
stoker	层燃炉
capacity	容量,生产力,功率
powder	煤粉
bunker	容器,仓
feeder	给煤机
fitness	适合,恰当
discharge	排出,离开
settling	沉淀,沉降
drifting	漂移,偏差
crusher	破碎机
facilitate	使方便
strainer	过滤器,滤网
stagnant	停滞的,不流动的
solidification	凝固,浓缩

猿苑

哉擅贓云雞蘿瑶 云魍雌蘼藻

A boiler furnace is constructed to encompass the enclosure that surrounds the space needed for combustion and radiation heat transfer to the water-steam mixture. A boiler furnace also collects a portion of the coal ash at the furnace bottom and removes it. There are two types of furnace bottoms, depending whether the ash is in liquid or solid form. When the gas temperature in the furnace is higher than the ash fusion temperature, the ash is in a molten state, moving downward and eventually being trapped in the slag pool. In this arrangement, frequently called the wet-bottom furnace, about 缉% of the total ash is trapped within the furnace. The remainder of the ash will leave the furnace. When the gas temperature in the furnace is lower than the ash fusion temperature, the ash remains in a solid state, falling into the bottom of the furnace. In this dry-bottom furnace, the ash is collected in a refractory-lined hopper. The hopper surface is cooled by placing water tubes on the refractory material. The dry-bottom furnace generally collects about 圆% of the coal ash; thus comparatively more fly ash for the precipitators that are required for all boiler installations.

The furnace wall is protected by water-filled tubes, which are formed into a solid wall and are backed by refractory material. These tubes constitute almost the entire heat absorbing surfaces in the furnace. These surfaces receive heat from the products of combustion mainly by radiation. The amount of heat received depends on the quantity of energy released and the volume of the furnace. A large heat absorption means a large temperature reduction in the furnace, resulting in a low gas exit temperature. This furnace exit temperature plays an important role in boiler design. When the exit gas temperature exceeds the ash fusion, the ash becomes melted and the slag begins to build up on the boiler convective heat transfer elements such as the superheater and reheater. These slag deposits will adversely affect the performance of these elements and require periodic surface cleanings. On the other hand, low exit gas temperature will result in a large reduction of temperature differential for subsequent heat transfer elements and lead to an increase in the number of heating surfaces. In design, the temperature of the gas leaving the furnace should be a little lower than the fusion temperature of the coal fired. Regulation of this gas temperature is accomplished by controlling the amount of energy released and the size of the furnace. Experiences indicate that the heat release per unit area of heat absorbing surface is an important parameter. As the heat release increases, the gas exit temperature will increase.

獯蕙

Radiation heat transfer in the boiler furnace is complex, and accurate prediction of the gas temperature at the furnace exit is difficult. Many variables can affect the furnace radiation. These include at least the surface characteristics, and the composition of the combustion products. The surface characteristics are dependent not only on the tube material, but also the tube surface conditions such as the thickness of the slag and the ash deposits. The products of combustion contain various gases, water vapor, and solid particles. The exact composition depends on the type of fuel fired and the amount of excess air used. Some components including carbon dioxide, carbon monoxide, water vapor, and solid particles are the participating media, emitting and absorbing the radiation energy in the furnace. Other components such as oxygen and nitrogen are nonparticipating media, being transparent to thermal radiation. In addition, the furnace radiation heat transfer is affected by the furnace geometry complex and by variation in operating conditions. Evidently, a theoretical model for predicting the radiation and the furnace exit gas temperature is impossible, at the present time. We now present an approximate method to solving this complex problem.

Double-Arch FW Furnace

For a reheat unit supplied by Foster Wheeler, it is top supported, and vertical burners located on the arches are fed a fuel/air mixture by conduits issuing from ball-mill pulverizers located at ground level. The reliable FW ball-mill was selected in view of the low grind ability of the high-ash fuel, and the fineness required throughout the mill load range. Hot drying air is provided to the mills through tubular primary air heater by primary air fans. Secondary air fans, followed by regenerative secondary air heaters, supply air to the front and rear walls below the arches.

In the lower furnace, a W-shaped flames' pattern forms. Combustion continues as gases rise in the upper furnace, up to its exit vertical plane, tangent to the tip of the furnace nose. Gases cross the vestibule, then turn down and split into the two separate convection surface passes of the heat recovery area. One of these passes contains the entire reheater surface, for control of reheat steam temperature by proportioning of gases. The front pass encompasses the convection primary superheater and upper economizer. Ash is collected and extracted from the ash pit underneath the furnace, and from the hoppers below the flues and the electro-static precipitator.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

encompass	围绕,包围
enclosure	围绕,封入
bottom	底部,炉底
fusion	熔化
molten	熔化的

trap	捕捉,搜集
wet-bottom furnace	液态排渣炉膛
dry-bottom furnace	固态排渣炉膛
refractory	耐火材料;耐火的,耐热的
medium	介质,方法
arch	拱,拱顶
conduit	管道,管路
issue	排出,流出
grindability	可磨性
regenerative	再生式,回热式,蓄热式
tip	端点,端头
vestibule	前厅,通廊
pit	沟,槽
flue	烟道,风道

哉灶蚤贼摇猿摇杂怎责藻则澡藻葬贼藻则 葬灶凿 砸藻澡藻葬贼藻则

The superheater is a heat exchanger in which heat is transferred to the saturated steam to increase its temperature. Steam superheating is one of the design features accepted in central electric power stations. Superheating raises overall cycle efficiency. In addition, it reduces a moisture level in the last stages of the steam turbine and thus increases the turbine internal efficiency.

Superheaters are commonly classified as either radiant superheaters, convective superheaters, or combined superheaters, depending on how heat is transferred from the gases to steam. These superheaters have different performance characteristics. The feature that the outlet steam temperature can stay essentially constant over a wide range of unit load is the most desirable. When the outlet steam temperature becomes excessive, it may cause failures from overheating parts of the superheater.

The convective superheater is located in the furnace exit or in the zone where it can receive thermal energy from the high temperature products of combustion. The convective superheater is frequently screened from the furnace radiation by a bank of water-filled tubes. These tubes, when adequately spaced, can also intercept the slag particles and reduce slagging problems in superheaters. Convective superheaters in large steam generator systems are frequently split into two parts: the primary superheater and the secondary superheater. Saturated steam first enters the primary superheater and receives the initial superheating. The primary superheater is located in a zone of relatively low gas temperature. After the partial heating, steam moves to the secondary superheater and completes its superheating process. The main reasons for splitting the superheater are to provide space for the steam reheater and to achieve an effective heat transfer from the gases to steam.

The radiant superheater is not as commonly used as the convective superheater. When the radiant superheater is needed, it is usually placed on the furnace wall replacing a section of water-filled tubes. Another arrangement is to have the radiant superheater just behind the screen tubes. The radiant superheater is an integral part of the secondary superheater.

Central station boilers provide for steam reheating. The reheater is essentially a convective type and usually located in the space between the primary and secondary superheaters. After steam partially expands in the turbine, it returns to the boiler for reheating. The temperature of steam leaving the reheater is usually equal to the superheated steam temperature. Since the design and operation of reheaters are essentially the same as superheaters, the discussion of superheaters will be equally applicable to reheaters.

In superheater thermal design, the steam temperature is first determined. This is generally accomplished in the plant system design, balancing the plant initial cost against the lifetime operating cost. In recent years the optimum steam temperature is approximately 缘源园C for all large steam generation systems. In the second step, the amount of superheater surface required is approximated.

After the amount of superheater surface is determined, the next consideration is to select the tube length, tube diameter, and the number of tubes. Evidently, the selection is an iterative process, generating a trial solution and checking to see whether all constraints are met, from several acceptable solutions, the optimum is found. The optimum superheater should have enough heat transfer surface necessary to give the design steam temperature. The tube parameters (length and diameter) are such that the steam pressure drop and tube metal temperature will not exceed the design values. The tube metal temperature is an important parameter and has a strong influence on the tube material selection. In addition, the optimum superheater should have its tubes so spaced that minimum ash and slag deposits will result.

Modern superheaters have many tube passes, and the tubes are arranged in-line rather than staggered. The tubes are usually cylindrical and have 缘m or 远猿m outside diameter. There is no extended surface (i. e. , fins) attached to the tubes. The material selection depends on the steam temperature and pressure. Carbon steel has an allowable temperature up to 源缘园C and is frequently used for low-temperature superheaters. Chrome-moly, stainless steel, or some similar heat resistant alloy can withstand the temperature up to 远缘园C. Therefore they are selected for the superheater in a high-temperature zone.

In case that the superheater is split into the primary and secondary heaters, the procedures presented above are equally applicable. Each superheater should be individually designed, considering the constraints associated with each heater. The primary superheater may not have the same heat transfer rate as the secondary superheater. Because of different temperature encountered, these two heaters may have two different tube materials. The reheater is usually located in the zone between the primary and secondary superheaters. Design considerations given to reheaters are similar to those given to superheaters. For reheater design, particular attention must be given to the steam pressure drop. A large steam pressure drop will reduce the benefit due to the steam reheating temperature regulation and control are important for both superheaters and reheaters. Steam temperature adjustments are frequently made at the time of the commissioning of a boiler. The principal methods are an addition or reduction of heat transfer surfaces. Steam temperature can be also adjusted by regulating the hot gas temperature and mass flow rate. These are generally accomplished by changing the excess air or the effectiveness of the evaporation section.

During a boiler operation, there are many factors affecting the temperature of steam leaving the superheater and reheater. These include a boiler load, excess air, feedwater temperature, and cleanliness of heating surfaces. Control of steam temperature during operation must be done without changing the arrangement of equipment. The most effective approaches are gas bypass, burner control, attemperation, gas recirculation, excess air, and divided furnace.

A gas bypass is to control the gas flow rate to the superheater. The main disadvantages of this approach are the operating difficulties experienced by the movable dampers located in the high-temperature zone and the slow response to load change.

Burner control is used to control the flame location and combustion rate. Tilting burners can direct the flame toward or away from the superheater. These will result in a change of heat absorption in the furnace and change of gas temperature in the superheater. As the boiler load is reduced, burners are removed one by one from service. This will change the combustion rate and, thus, change the gas flow rate to the superheater.

Attemperation is one of the approaches frequently used. The attemperator is usually located at the point between the primary and the secondary superheaters. There are two basic types of attemperator. The first is the tubular type in which some of superheated steam is passed through the tubes of a heat exchanger and has heat transferred to the boiler water (either boiler feedwater or water in the boiler drum). Subsequent to attemperation, the divided streams from the primary superheater will combine and enter the secondary superheater. The second type of attemperator involves a spray of feedwater into the stream of superheated steam. The feedwater evaporates and reduces the steam temperature. Controlling the amount of feedwater will result in control of the steam temperature. Care must be exercised to ensure that the spray water has sufficient purity. The spray water should mix well with the superheated steam so that there are no water droplets in the inlet of the secondary superheater.

Gas recirculation is used to control the steam temperature by changing the heat absorption rates both in the furnace and in the superheater. When the steam temperature needs to be risen, some of the flue gas from the economizer outlet is recirculated back to the bottom of the furnace. Therefore, the furnace temperature, will become lower, resulting in a lower heat absorption in the furnace and thereby a higher flue gas temperature in the furnace exit. This high gas temperature, combined with an increase in the gas flow rate, will increase the heat transfer rate in the superheater and thus increase the steam outlet temperature.

Temperature control can be affected by using different amounts of excess air. The more the excess air, the higher the steam outlet temperature would be. The reasons for this are similar to those for the gas recirculation method. It must be pointed out, however, that too much excess air will result in a reduction of boiler combustion efficiency. A divided-furnace boiler is usually arranged with a generation of saturated steam in one section and a superheating of steam in another section. The temperature of the superheated steam is regulated by controlling the firing rates in the two furnaces. This method is not economical and is seldom applied in a central electric power station.

[illegible]

bank	组,管束
lifetime	使用时间,寿命
iterative	重复
constraint	强制,约束
in-line	顺排的,平行排列的,同轴的
staggered	错列的,叉排的
fin	肋片,鳍
chrome-moly	铬-钼
alloy	合金
approach	态度,方法

哉灶蚤贼摇耘糟燥灶燥皂蚤扎藻则摇葬灶凿摇粤蚤则摇匀藻葬贼藻则

Central station boilers are usually equipped with an economizer and air heater. Boiler efficiency rises about 员% for each 员园F increase produced by an economizer. Use of air heaters not only improve boiler efficiency by lowering the stack temperature, but also improve the combustion conditions by raising the combustion air temperature.

The economizer is generally located ahead of the air heater in the gas stream. When a high combustion air temperature is desirable, it may be necessary to divide the air heater into two sections and place the economizer between them for an effective heat transfer. In some cases, especially those large high-pressure steam generators, an additional low-temperature economizer may be included and located in the gas stream after the air heater. This economizer, frequently called stack cooler, is used to replace one of the low-pressure feedwater heaters. The temperature of water leaving the stack cooler is in the range of 苑员C to 愿园C.

The economizer is a tubular heat exchanger. The water from the last feedwater heater flows through the tubes and absorbs energy from the flue gas discharged from the superheater and the reheater. In recent designs steel tubes are usually used and have an outside diameter ranging from 源源cm to 苑cm. All these tubes are continuous from inlet to outlet headers and have several horizontal sections in the gas stream. Feedwater enters the economizer through the bottom inlet header and moves upward, while the flue gas enters on the top of the economizer and flows downward outside the heat transfer tubes. The tubes in the economizer are either bare tubes or finned tubes. The finned tubes have some advantages over bare tubes. These include a low initial cost and a small space required for installation. However, attention must be given to the draft loss and potential fouling associated with the finned tubes.

An economizer is usually justified in central station boilers, because it can absorb some heat at less cost than other heat transfer surfaces in the boiler. The exact economizer size is determined by many variables such as the temperature of incoming feedwater and the boiler pressure. The feedwater temperature varies in the range of 圆缘源C to 圆远园C, depending on the number of feedwater heaters and the extraction steam conditions. The boiler pressure usually presets the upper limit of water temperature in the economizer. Steaming or nonsteaming also affects the economizer surface. In the steaming economizer, part of water flow is evaporated and the temperature of water leaving is naturally equal to the saturation temperature corresponding to the boiler pressure. The outlet water temperature in the nonsteaming economizer is usually lower than the saturated temperature.

In a boiler system design the economizer cannot be separated from the air heater. The distribution of the flue gas energy is frequently optimized, taking into account the equipment cost and fuel cost. For a given stack temperature there is an optimum gas temperature leaving the economizer. An increase in the gas temperature will reduce the size of the economizer and increase the size of the air heater. The selection of the stack temperature is important. From the viewpoint of energy utilization, the stack temperature should be as low as possible. But attention must be given to the corrosion of the heat transfer surfaces. Corrosion can be avoided by setting the flue gas temperature (i. e., stack temperature) above the dew point. Below the dew point water vapor in the flue gas will condense on the surface and combine with the sulfur dioxide in the flue gas to generate an acid.

For tubular air heaters, flue gas usually flows inside the tubes while air moves outside. These tubes can be placed vertically as well as horizontally. In both cases the tubes are either welded or expanded into tube sheets, one of which must float to allow for tube expansion. The tube diameter ranges from 源源cm to 苑cm and the tube material is frequently steel. Because of the low overall heat transfer coefficient, the tubular air heaters are relatively bulky and therefore occupy relatively large space.

In addition to the tubular air heater, plate-type air heaters are available for preheating the air for combustion. These heaters comprise parallel plates that provide alternative passages for flue gas and air. The spacing between the plates is approximately 员猿cm. Like the tubular air heater, this heater also has a low overall heat transfer coefficient and therefore a large heat transfer surface. To provide high-temperature combustion air, steam-coil air heaters are sometimes used. In this case heat is transferred to the air from the steam that usually comes from the turbine extraction line. Steam-coil heaters are particularly suitable when the flue gas temperature is low for air preheating purposes.

Air heaters used in central station boilers may be classified as either the recuperative or regenerative type. The recuperative type is the air heaters we have just described. Generally, the flue gas is on one side of a plate or tube and air is on the other. Heat is transferred from the flue gas to air by convection and conduction. These are of static construction and there is only a nominal leakage from the air to the flue gas. In a regenerative air heater, flue gas flows through a closely packed matrix to raise its temperature and, then, air is passed through the same matrix to absorb the heat. Either the matrix or the hoods are rotated to achieve this in a continuous cycle. The regenerative air heater has several advantages over the recuperative type, including its compactness and subsequently its low initial cost. However air leakage is more serious with the regenerative air heater.

In regenerative type air heater, a rotor, mounted with a box housing, turns slowly and moves the heat transfer matrix through the separated streams of flue gas and air. The heat transfer matrix receives heat in the flue gas stream and rejects heat in the air stream. The main disadvantage is the leakage of air into the gas. Leakage occurs at the radial seals and, the annular space between the rotor and the housing. Another problem with the regenerative air heater is the entrainment of air and gas in the heat transfer matrix.

The heat transfer matrix used in regenerative air heater is usually a high performance type, producing a large heat transfer surface per unit volume and resulting in a compact structure. Because of the small space required for installation, the initial cost is usually lower than the tubular air heater.

[illegible]

feedwater	给水
bare	裸的,露出
finned	有鳍片的,有散热片的
justify	证明是正当的
extraction	(可调) 抽汽,排热
preset	预调,预置
weld	焊缝,焊接
sheet	板,板料
float	漂浮,漂移
bulky	体积大的,笨重的
comprise	由…组成,构成
coil	盘绕,成圈状
recuperative	还原的,间壁换热的
nominal	额定的,名义的,标称的
leakage	泄漏
matrix	填质,型片
hood	机壳,机罩
compactness	紧密度,坚实度
rotor	转子,旋翼
mount	机座 安装 装置
housing	齿轮箱,支架
seal	密封,封闭
annular	环形的
entrainment	带走,输送
performance	性能,特性曲线,执行

哉揿蹬醚蹂醒骣蹄据 阅赙黯罾悦悚蹑踵醚蹈罾藜趟孕蹂蹭蘖剔昉蹶赖蹑醚瞢

Steam Drum

The steam drum is an all welded cylindrical construction supported by two U slings from the steelwork. The drum was manufactured in one piece at the factory and was transported to the site by sea. It has a length of 猿园 源园m and an internal diameter of 圆怨m. Its weight with the internal fittings is 猿缘t.

Four rows of 远缘conical cyclone separators are fitted in the drum and above each separator is an inclined primary scrubber. Secondary scrubbers are fitted at a higher level close to the saturated steam takeoffs. The drum is made from high tensile steel and no welding is permitted on the drum after it has been stress relieved.

Apertures in a girth baffle allow the combined steam and water mixture to enter cyclone separators, which are arranged in pairs, in two rows along the front and the rear of the steam drum. The steam and water mixture enters each cyclone body tangentially and whirls around the inside of the cylinder producing a powerful vortex, within which a positive separation of steam and water occurs. The steam collects in the centre and passes out at the top, whilst the water moves downward in a helical path and passes back into the drum water space for recirculation through the furnace walls. The saturated steam flows upwards through the primary inclined scrubbers, which remove water residue that may be carried over by the steam after leaving the separator. The steam then passes through secondary scrubbers, fitted at the top of the drum, which provide a final separation of water from the steam before it leaves the drum and flows into the superheating circuits.

Draught System

The draught system comprises two forced draught (FD) fans, two induced draught (ID) fans, two rotary air preheaters and three electro-static precipitators. Air for combustion is supplied to the burner registers by the two FD fans by way of air preheaters where the boiler flue gases heat the incoming air. The effluent gases are drawn through three electrostatic dust precipitators by the ID fans, which then discharge the gases to the chimney. The furnace is balanced by the FD and ID fans to maintain a pressure just below atmosphere.

The FD and ID fans are mechanically similar, the ID fans having a higher maximum duty specification. The fans are electrically driven at constant speed and the air or gas volumes are controlled by radial inlet guide vanes.

Gas air heaters are used to provide a means of heating the air supplied to the furnace in order to assist combustion and provide for a more economical use of fuel. They are supported by the main boiler structural steelwork at the firing floor level, and located at the rear of the furnace enclosure, one fitted on each side of the boiler beneath the gas outlet flues.

The air heaters are of contra-flow design, the combustion air from the FD fans passing upwards through the units to the burners, via the hot air duets, whilst the furnace gases from the boiler outlet flues pass downwards through the units to the precipitators. The two streams, which flow through diametrically opposite segments of the rotor, are separated from each other by a small blanking section fitted with sealing plates, which forms a division between them.

Each of the air heaters is fitted with its own combined soot blowing and water washing gear, fire detection and fire fighting equipment and a pressure fed oil system for lubricating the rotor bearings.

The rotor, which is 员源源m in diameter, is the central part of the air heater and contains the heat transfer matrix. Each rotor has a nominal heating surface of 缘员,愿圆远 m圆. Radial plates extending from the hub divide the rotor into 圆源sectors, which in turn are sub-divided at the hot and intermediate ends by sector division plates, which strengthen the rotor and carry the hot and intermediate end element containers. At the cold end of the rotor, grids welded between the radial division plates perform the same duty as the sector division plates, but enable the cold end element containers to be radically withdrawn from the air heater. The weight of the rotor is carried on the underside by a spherical roller thrust bearing whilst at the top a spherical roller guide bearing is provided to resist radial loads.

The rotor is driven by a small electric induction motor coupled to the rotor hub through a double worm reducer and spur gearing.

Precipitator

Three electrostatic precipitators per boiler are fitted in each gas discharge line to collect dust from the boiler flue gases. The precipitators achieve a collecting efficiency of 怨愿缘% with a gas inlet temperature of 员圆园C and volume per boiler of 愿远猿圆m猿/s. Dust-laden flue gases are directed through the zones of each precipitator in which discharge and collecting electrodes are situated. A variable high voltage DC current is supplied to the electrodes.

The precipitators, which are mounted on steel support structures above ground level, comprise six rows in series of dust-collecting plates forming multiparallel gas paths and with discharge electrode wires suspended vertically within these paths. Boiler flue gases are directed by baffles in the inlet flare to flow evenly through the precipitator via gas passages formed by the spaces between the collecting plates. The cleaned gases are extracted by the ID fans and vented to atmosphere through the station chimney. The dust, which accumulates mainly on the collecting plates but also on the discharge wires, is removed at intervals by mechanically-rapping the plates and wires. The dislodged dust falls into hoppers suspended below the precipitators and supported by the steel structure. Accumulated dust in the hoppers is removed by the dust disposal plant to which the hopper outlets are connected.

The generation and control of the high voltage (HV) systems, rapping control systems and heating systems are located at ground level on the gas inlet side of the precipitators.

Sootblowers

Some of the ash formed by the combustion of the coal adheres to the external surfaces of the boiler tubes; this ash must be removed in order to maintain boiler efficiency. To achieve this end, deposits on the boiler tubes are prevented from building up by automatic, retractable soot blowers, which are located strategically around the boiler. The sootblowers are electrically operated by a control system which provides sequential and selective control of the [illegible] sootblowers fitted and has provision for the control of a further [illegible] sootblowers if experience dictates a requirement for more.

Compressed air is used as the blowing medium and this is supplied from a common manifold, which serves all boiler units. The air for the sootblowers of each boiler unit is supplied via remotely controlled, electrically operated isolating valve.

[illegible]

sing	吊环,吊索
steelwork	钢结构,钢架
fittings	零件,设备
row	行,列
conical	圆锥的
scrubber	洗汽装置,湿式除尘器
tensile	张力的,拉力的,能伸长的
aperture	孔,口,开度
girth	围梁
baffle	挡板,隔板
helical	螺旋的
register	调风器,挡板
effluent	流出的
chimney	烟囱

leaf	薄板,节流门
trunk	母管,本体
duty	功率,负荷
segment	扇形体
bearing	轴承
hub	轮毂,中枢,轴套
thrust	推力
reducer	减速器
worm	螺杆,蜗杆
spur	专用线,支线
vent	排出,出口
rap	敲击
dislodge	取出,移动
main	总管,母管
retractable	缩进的

续页

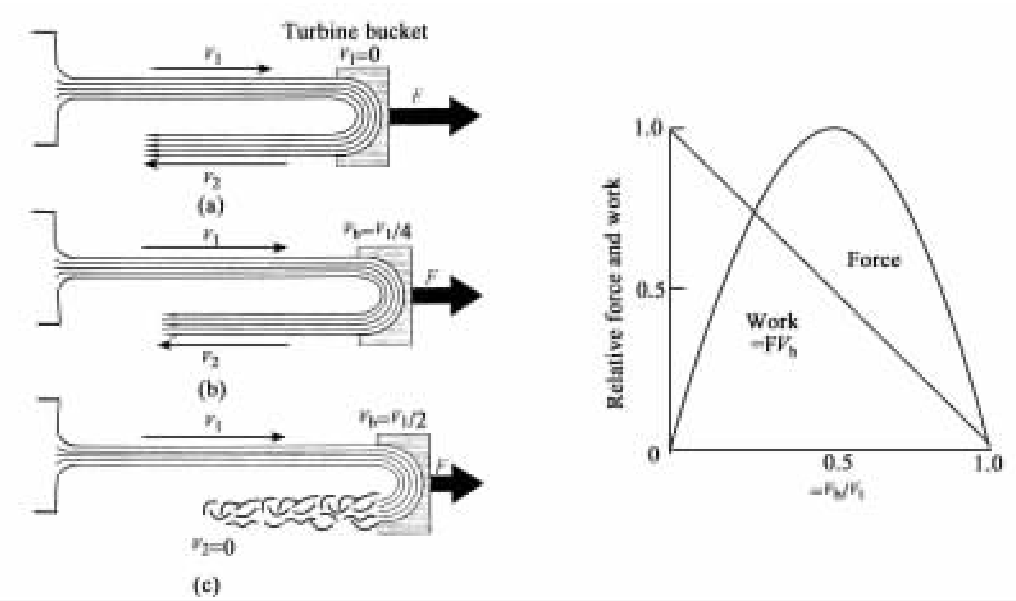
Part Three Steam Turbine

[illegible]

A heat engine is one that converts heat energy into mechanical energy. So the steam turbine is classed as a heat engine, as are the steam and internal-combustion engines. The turbine makes use of the fact that steam when issuing from a small opening attains a high velocity. The velocity attained during expansion depends upon the initial and final heat content of the steam. This difference in heat content represents the heat energy converted into kinetic energy (energy due to velocity) during the process. The kinetic energy or work available in the steam leaving a nozzle is equal to the work that the steam could have done had it been allowed to expand (with the same heat loss) behind a piston in a cylinder.

The fact that any moving substance possesses energy, or the ability to do work, is shown by many everyday examples. A stream of water discharged from a fire hose may break a window glass if directed against it. When the speed of an automobile is reduced by the use of brakes, an appreciable amount of heat is generated. In like manner the steam turbine permits the steam to expand and attain high velocity. It then converts this velocity energy into mechanical energy. There are two general principles by which this can be accomplished. In the case of the fire hose, as the stream of water issued from the nozzle, its velocity was increased, and owing to this impulse it struck the window glass with considerable force. A turbine that makes use of the impulsive force of high-velocity steam is known as an "impulse turbine". While the water issuing from the nozzle of the fire hose is increased in velocity, a reactionary force is exerted on the nozzle. This reactionary force is opposite in direction to the flow of the water. A turbine that makes use of the reaction force produced by the flow steam through a nozzle is a "reaction turbine". Practically in all commercial turbines a combination of impulse and reactive forces is utilized. Both impulse and reaction blading on the same shaft utilize the steam more efficiently than does one alone.

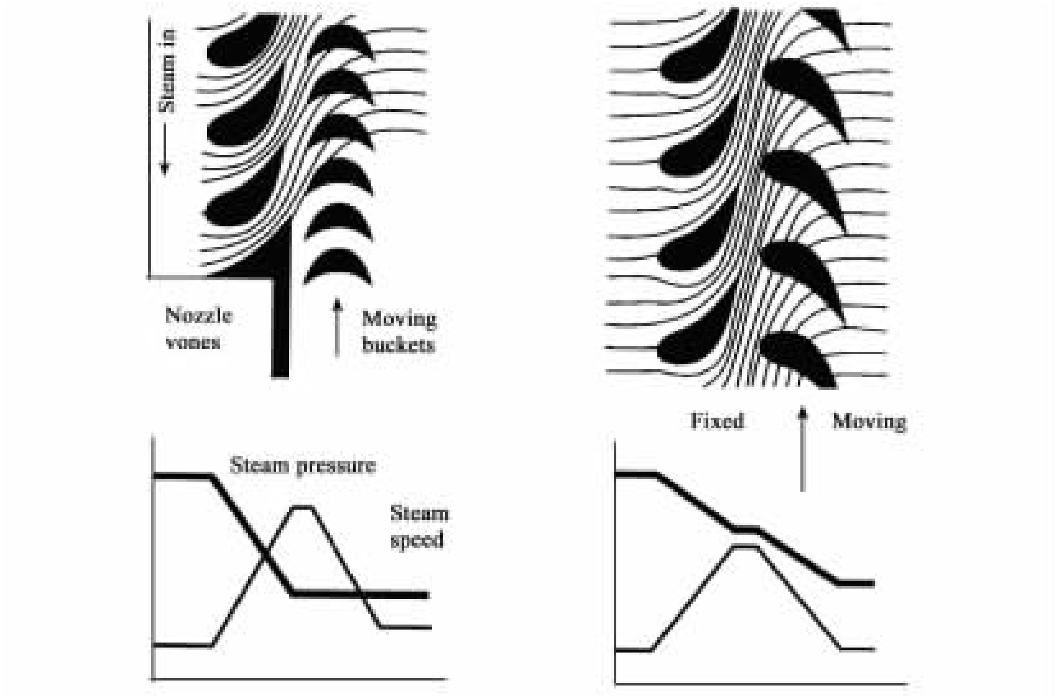
Impulse-turbine nozzles organize the steam so that it flows in well-formed high-speed jets. Moving buckets (blades) absorb the jet's kinetic energy and convert it to mechanical work in a rotating shaft (Figure 猿员. When the bucket is locked, the jet enters and leaves with equal speed and develops maximum force F but no mechanical work is done. As the bucket is allowed to speed up, the jet moves more slowly and force F shrinks. Figure 猿圆shows how both force and work done vary with the blade speed. The steam jet does maximum work when the bucket speed is just one-half of the steam speed. In this condition, the moving bucket leaves behind it a trail of inert steam, since all kinetic energy is converted to work. The starting force or torque of this ideal turbine is double the torque at its most efficient speed.



[illegible]

For practical reasons, most impulse turbines mount their buckets on the rims of disks (wheels), and nozzles feed steam from one side (Figure 猿猿. Pressurized steam from the nozzle box flows through parallel converging nozzles formed by vanes or foils. Steam leaves as a broad high-speed jet to flow through the slower moving-bucket passages, which turn the steam flow to an axial direction as they absorb its kinetic energy. The steam leaves with lower internal energy and speed.

Steam pressure and speed vary through the true impulse stage. When the impulse stages are pressure-compounded, which are called Rateau stages, pressure drop occurs in steps and exhausted steam from one-stage flows through following similar impulse stages, where it expands to a lower pressure. If the impulse stages are velocity-compounded, which are called Curtiss stages, steam velocity is absorbed in a series of constant-pressure steps.



[illegible]

In the reaction stage (Figure 猿源, steam enters the fixed-blade passages; it leaves as a steam jet that fills the entire rotor periphery. Steam flows between moving blades that form moving nozzles. There it drops in pressure, and its speed rises relative to the blades, which creates the reactive force that does work. Despite the rising relative speed, the overall effect reduces the absolute steam speed through one stage. When the enthalpy drop is about equal in moving and stationary blades, it is called a 缘园 percent reaction stage.

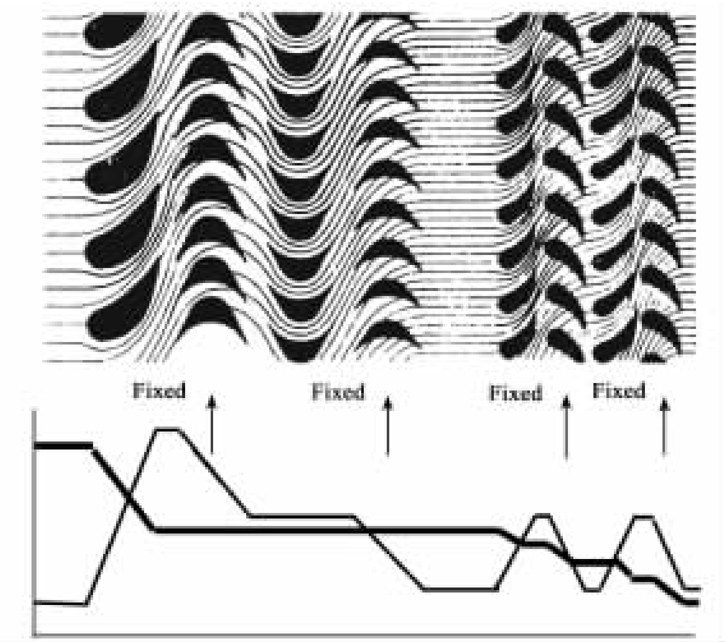
Figure 猿缘 shows a velocity-compounded control stage followed by two reaction stages. The high-speed steam jet gives up only part of its kinetic energy in the first row of moving buckets. Then come reversing blades that redirect the slowed-up steam into the second row of moving buckets, where most of its remaining kinetic energy is absorbed. Steam then enters the series of reaction stages.

In practice, so-called impulse-stage turbines use about 缘% to 员园% reaction in their design. This means there is a small steam pressure drop through the moving-blade passages. These buckets, instead of taking the symmetrical shape, have a longer tail to form a slightly converging passage at the exit.

[illegible]

heat engine摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇热机

缘源



[illegible]

convert. . . into	把…转变成
steam engine	蒸汽机
internal-combustion engine	内燃机
issue from	从…喷出,从…流出
heat content	热值
kinetic energy	动能
available	可得到的,现有的,有用的
heat loss	热损
piston	活塞
cylinder	气缸,汽缸
nozzle	喷嘴,喷管,燃烧器
discharge from	从…排出,从…流出
fire hose	消防水龙头
brake	制动器,刹车
impulsive force	冲击力
impulse turbine	冲击式透平,冲击式汽轮机
reactionary force	反击力
reaction turbine	反击式透平,反击式汽轮机
commercial turbine	商业透平,商业汽轮机
balding	叶片,叶栅

jet	汽流,射流,喷气式发动机,喷气式飞机
moving bucket/blade	动叶
rotating shaft	转轴
shrink	收缩,减小,热套
rim of disk/wheel	轮缘
converging nozzle	渐缩喷嘴
vane	叶片,轮叶,刀片,节气阀
foil	叶形饰,翼,薄片
leave behind	遗留,把…丢在后面,超过
nozzle box	喷嘴室
Rateau stages	托拉级,压力级
pressure drop	压降
Curtiss stage	柯蒂斯级,复速级
velocity-compounded stage	复速级
enthalpy drop	焓降
control stage	调节级
give up	释放,放弃,中断
reversing blade	转向导叶片
symmetrical	对称的

[illegible]

Steam turbines may be classified into different categories depending on their construction, the process by which heat drop is achieved, the initial and final conditions of steam used and their industrial usage as follows.

员 According to the number of pressure stages:

(员 Single-stage turbines with one or more velocity stages usually of small-power capacities;

(圆 Multistage impulse and reaction turbines; they are made in a wide range of power capacities varying from small to large.

圆 According to the direction of steam flow:

(员 Axial-turbines in which the steam flows in a direction parallel to the axis of the turbine;

(圆 Radial-turbine in which the steam flows in a direction perpendicular to the axis of the turbine; one or more low-pressure stages in such turbines are made axial.

猿 According to the number of cylinders (casings):

(员 Single-cylinder turbines;

(圆 Double-cylinder turbines;

(猿 Three-cylinder turbines;

(源 Four-cylinder turbines.

Multicylinder turbines which have their rotors mounted on one and the same shaft and coupled to a single generator are known as single shaft turbines; turbines with separate rotor shafts for each cylinder placed parallel to each other are known as multiaxial turbines.

源 According to the method of governing:

(员 Turbines with throttle governing;

(圆 Turbines with nozzle governing;

(猿 Turbines with bypass governing in which steam besides being fed to the first stage is also directly led to one, two or even three intermediate stages of the turbine.

(源 Turbines with sliding pressure governing in which steam pressure varies with the speed or load of turbine;

缘 According to the principle of steam turbine:

(员 Impulse turbines;

(圆 Reaction turbines;

远 According to the heat drop process:

(员 Condensing turbines with regenerators: in these turbines steam at a pressure less than atmosphere is directed to a condenser; besides, steam is also extracted from intermediate stages for feed water heating. Small-capacity turbines of earlier designs often do not have regenerative feed heating.

(圆 Condensing turbines with one or two intermediate stage extractions at specific pressures for industrial and heating purposes.

(猿 Back pressure turbines, the exhausted steam from which is utilized for industrial or heating purposes.

(源 Topping turbines: these turbines are also of the back pressure type with the difference that the exhausted steam from these turbines is further utilized in medium-and low-pressure condensing turbines. These turbines, in general, operate at high initial conditions of steam pressure and temperature, and are mostly used during extension of power station capacities, with a view to obtain better efficiencies.

(缘 Back-pressure turbines with steam extraction from intermediate stages at specific pressures; turbines of this type are meant for supplying the consumer with steam of various pressure and temperature conditions.

(远 Low-pressure (exhaust-pressure) turbines in which the exhausted steam from reciprocating steam engines, power hammers, presses, etc, is utilized for power generation purpose.

(苑 Mixed-pressure turbines with two or three pressure stages, with supply of exhausted steam to its intermediate stages.

The turbines enumerated under "b" or "e" usually have extractions for regenerative feed-heat, in addition to the extraction of steam at specific pressures for other purposes.

苑 According to the steam conditions at the inlet of turbines:

(员 Low-pressure turbines, using steam at pressures of 园员圆to 园圆MPa.

(圆 Medium-pressure turbines, using steam at pressures of up to 猿怨MPa.

(猿 High-pressure turbines, utilizing steam at pressures of 员远愿MPa and higher and temperatures of 缘猿缘C and higher.

(源 Turbines of supercritical pressures, using steam at pressures of 员圆 圆MPa and above and temperatures of 缘猿愿C and above.

愿 According to their usage in industry:

(员 Stationary turbines with constant speed of rotation primarily used for driving alternators.

(圆 Stationary steam turbines with variable speed meant for driving turbo-blowers, air circulators, pumps, etc.

(猿 Non-stationary turbines with variable speed; turbines of this type are usually employed in steamers, ships and railway locomotives (turbo-locomotives).

All these different types of turbines described above depending on their speed of rotation are either coupled directly or through a reduction gearing to the driven machine.

[illegible]

initial condition of steam	蒸汽初参数
final condition of steam	蒸汽终参数
single-stage	单级
multistage	多级
power capacity	容量,功率
axial-turbine	轴流式透平,轴流式汽轮机
radial-turbine	辐流式透平,辐流式汽轮机
parallel to	平行于
perpendicular to	垂直于
casing	汽缸,气缸,机匣,机壳
single-cylinder turbine	单缸汽轮机
multicylinder turbine	多缸汽轮机
singe shaft turbine	单轴汽轮机
multiaxial turbine	多轴汽轮机
throttle governing	节流调节
nozzle governing	喷嘴调节
bypass governing	旁路调节
sliding pressure governing	滑压调节
intermediate stage	中间级
heat drop process	热力过程
condensing turbine	凝汽式汽轮机
back pressure turbine	背压式汽轮机
topping turbine	前置式汽轮机
with a view of	为了…的目的
steam extraction	抽汽
power hammer	汽锤
enumerate	数,计点,枚举,计算
railway locomotive	火车机车
reduction gearing	减速齿轮

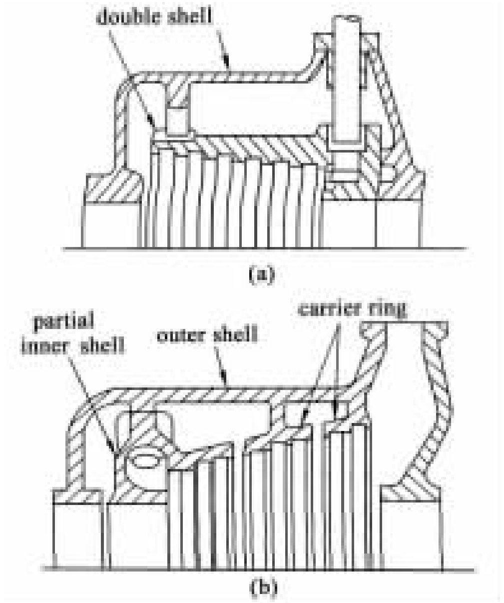
[illegible]

A turbine cylinder is basically a pressure vessel. Its weight is normally supported at each end. It is, therefore, designed to withstand hoop stresses in the transverse plane, and to be very stiff in a longitudinal direction to maintain accurate clearances between the diaphragms or fixed blades and the rotor. Stress complexities are introduced by the gland housings, the horizontal flange and steam entry and exit passages. Furthermore, the external mass of the flanges may be such that, when starting, they warm up more slowly than the remainder of the shell, and the difference rates of expansion set up temperature stresses and distortion. Distortion can be minimized by special design, such as incorporating passages through which steam is passed during the starting period.

Where the steam conditions are high, the high-pressure cylinder is generally of double shell design, in which steam at exhaust pressure fills the space between the shells, enabling each shell to be designed for a relatively small pressure differential. See Figure 猿远(a). The reduced shell thickness, together with the increase of area in contact with the steam, permits quicker warming of the turbine when starting without undue temperature stress. The casings are simpler to manufacture and are, as a result, sounder.

Sometimes reversed flow blades are adopted, to raise the inter-shell pressure, and hence to reduce the stress in the hot inner shell at the expense of that in the outer shell. The steam is led from the governing valves to an annular chamber preceding the nozzles of the first stage. Where nozzle governing is employed, the chamber is divided into segments, each controlled by a separate valve, opening in sequence. With throttle governing the whole annulus may be used, although it is commonly blanked off at the horizontal joint to save the joint having to withstand full steam pressure. The latter method is often preferred for temperatures in the range of 源园园°C—缘缘园°C because the full circumference is then subjected to a uniform temperature. For temperature in excess of 缘缘园°C separate nozzle boxes made of special steel, are sometimes employed, so as to protect the main casing from the full temperature. On turbines utilizing reheated steam the steam enters the intermediate pressure cylinder at high temperature but medium pressure and, therefore, the design of the casing is an easier problem than for the high-pressure cylinder, the wall thickness being smaller. Nevertheless, a partial double shell is sometimes adopted as illustrated in Figure 猿远(b).

Most of the bled steam tapping points are located in the intermediate pressure and



low pressure cylinders, and annular recesses are provided at extraction points. Some of the latest turbines utilize bled steam to supply a separate turbine driving the boiler feed pump, and the bled steam may be tapped from this turbines as well. Where the steam conditions are moderate the stationary blading is often supported on carrier rings. This permits the cylinder casing to be of simple design, and the same pattern can be used for different stage arrangements.

Cylinder flanges require careful design. It is made thick for stiffness and to bring the bolt centre line tangential to the shell, and narrow to promote quick heating. The flange faces are assumed to be pressurized, the out edge only being in contact.

The bolting of high-pressure cylinder is a problem, especially with single shell designs, and, to fit in a sufficient number of bolts, cap nuts may have to be used, alternate nuts being raised on spacer rings. The bolts are made of high tensile steel with root diameter shanks and have a central hole in which a carbon rod heater can be fitted. When the cylinder is being assembled, the nuts are hand-tightened, and the bolts are heated electrically from a low voltage transformer to a prescribed temperature. When they have expanded sufficiently the nuts are tightened to a prescribed amount. When the bolts cool they take up a known stress and give the flange a tight but even nip.

High pressure and intermediate pressure cylinders are usually fitted with "paw" supports, which rest on the bearing pedestals. The concentricity of the rotor and cylinder depends on the accurate positioning of these brackets. On modern turbines the paws are generally horizontal with the palms level with die horizontal joint. In this way concentricity is unaffected by expansion of the cylinder. The palms incorporate transverse keys, which transmit axial expansion of the cylinder.

A variety of methods have been used to support the low-pressure cylinders because of the difficulties caused by the presence of the condensers. The gap in the foundation block for the condenser may be spanned by steel beams, by reinforced beams, by a reinforced concrete arch, or by pre-stressed concrete beams. Alternatively the low pressure cylinder may be designed to form a stiff structure requiring only end support. Extreme rigidity is required to eliminate all possibility of resonant vibration at or below running speed. On large turbines it is usual for the condenser and low-pressure exhaust casing to be rigidly connected, to withstand the compressive stress caused by vacuum. Spring supports under the condenser ensure that the weight of the condenser is not carried by the turbine casing.

In an axial direction the cylinders of a turbine are rigidly fixed together, and a positive anchor with the foundations is arranged at one point only, usually beneath one low-pressure exhaust. The turbine is thus free to expand from this point. At the governor end pedestal this movement may be one inch or more. Central sliding keys between, the pedestals and the foundations are used to maintain transverse alignment.

Impulse-type turbines require diaphragm to divide the cylinders into a series of chambers, each at a progressively lower pressure. A diaphragm relies entirely on the fixed blading for its support, and is divided across the horizontal centre line, the joint being tongued and grooved. The section generally tapers towards the inner diameter, and may be "dished". The outer periphery is located in an annular groove in the casing or carrier ring, in such a way that concentricity is maintained in spite of radial expansion. Grooving in the inner periphery carries the replaceable gland.

Turbine casings are normally steel castings. Components located, however, where the temperature never exceeds [illegible]C, for example, low-pressure cylinders on non-reheat machines, are sometimes made of cast iron. On large reheat turbines the temperature of the steam entering the low-pressure cylinder may be more than [illegible]C and, because of this and the large overall dimensions, low-pressure cylinders are usually fabricated from steel castings and plates. This type of construction provides greater protection in the event of blading failures, and also speeds manufacture.

Each section of a turbine cylinder is hydraulically tested after manufacture and is subjected to a pressure [illegible] percent, in excess of the highest working pressure in the section. The low-pressure exhaust casings are designed to give the maximum possible area of flow for the exhausted steam, so that the pressure drop is kept to a minimum. To turn the huge volume of steam through [illegible] in an evenly distributed flow curved vanes are employed. On the largest turbines the low-pressure cylinder is suspended within and entirely surrounded by an exhaust casing. Thus, it is held at vacuum temperature, and in spite of its size expansion difficulties are minimized.

[illegible]

The hot external surfaces of the cylinders must be efficiently insulated, to ensure that the expansion of the steam is as nearly as possible, adiabatic, and also to protect the cylinder walls from severe temperature gradients, which would cause cracking. An outer covering known as cleading, which consists of planished steel, enameled steel or aluminum sheets, serves to reflect a certain amount of heat, and also improves the appearance of the turbine.

晕藉 宰爆凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽择

pressure vessel	压力容器
withstand	承受,经受,顶得住
hoop stress	圆周应力
transverse plane	横截面
stiff	刚性的,硬的,不易弯曲的,不灵活的,强烈的
clearance	间隙,空隙,间距
diaphragm	隔板,膜片,孔板
fixed blade	静叶,喷嘴
gland housing	汽封体
flange	法兰
set up	建立,装配,计划,安排
temperature stress	热应力,温度应力
distortion	变形,挠曲,扭曲
undue	过度的,不相称的,不适当的,非常的
reversed flow	逆留,回流
governing valve	调节阀
annular chamber	环形室
blank off	闷死(弯头),堵死,锁住
tap point	抽汽口,抽汽点
carrier ring	持环
tangential to	与…相切
cap nut	盖形螺帽
spacer ting	垫圈
paw	猫爪
transverse key	横销
sliding key	滑销
curved vane	扭转叶片,弯曲叶片
longitudinal	长度的,纵向的,轴向的

[illegible]

There are two types of turbine rotors in use on large turbines of the impulse type:

(员 The built-up rotor, which consists of a forged steel shaft on to which separate forged steel wheels are shrunk and keyed.

(圆 The integral rotor, otherwise known as "solid" or "gashed" in which the wheels and shaft are formed from one solid forging.

The built-up rotor is the cheaper of the two, since the discs and shaft are relatively easy to forge and inspect for flaws. Also the machining of these components can be carried out concurrently. On the other hand integral rotors are expensive and difficult to forge, and there is a high incidence of rejects. A large amount of machining time and waste material is involved. Nevertheless, the advantages of integral rotors are such that they are invariably used for the high-pressure rotors on modern reheat turbines, and sometimes for the intermediate pressure and low-pressure rotors as well. This is because of the difficulty of ensuring on these turbines that shrunk-on wheels do not become loose, particularly at the high temperature end, where at times the wheels may become hot and the shaft cool. This would be accentuated if there were rough contact at the bore causing poor conductivity. Another source of trouble under conditions of high temperature and stress is the phenomenon of creep, which again could cause the shrunk fit to disappear after prolonged running.

The main problem with low-pressure rotors is one of centrifugal stress, the last stage disc being the most heavily stressed part of the turbine. (The safety factor, based on yield point, may be about 圆园at 员缘percent overspeed.) The centrifugal load of the large rotating blades sets up a tensile stress in the rim of the wheel, which increases with decreasing radius, its maximum value being at the bore of the hub. Therefore the larger the bore of the hub, the greater the maximum stress. If the bore is very small then the hoop stresses are lessened. If there is no hole, the hoop stresses throughout the disc are theoretically halved. This fact is made use of in certain welded low-pressure rotors, which have no central hole, and to some extent in integral low pressure rotors, which have only a small hole used for inspecting the forging.

On large turbines, using 缘园percent reaction, four types of rotors are used:

(员 The Hollow Drum rotor, which, because it is designed with the same thickness of material as the casing, promotes even temperature distribution. Its diameter is limited by stress considerations.

(2) The Solid Drum rotor which is suitable for cylinders where there are lower temperatures but large diameters, for example in intermediate pressure cylinders without reheat.

(3) The Built-up rotor, already described which is used mainly for low pressure.

(4) The Welded Disc rotor which is used for low-pressure rotors. It has two main advantages: it obviates the need for large shaft forgings, which are expensive and difficult to manufacture, and, not having central holes in the discs, it carries much lower stresses. Both the machine welding process and the subsequent heat treatment have to be performed with great care.

When fully assembled the rotor is balanced both statically and dynamically. Static balance means that the weight is evenly disposed around the axis of the shaft and may be checked by rolling the rotor on horizontal knife-edge supports.

Dynamic balance means that the moments of the out-of-balance weights along the axis, about either bearing, add up to zero. This is checked by spinning the rotor on resilient bearings, detecting the vibration, and adding weights until it is negligible. A modern-balancing machine, which eliminates to a large extent the trial and error processes used in the past enables balancing to be carried out with a high degree of accuracy. Nevertheless a very small out-of-balance force always remains.

A stationary shaft supported between bearings has a natural frequency of vibration, depending on the size of its diameter in relation to the distance between the bearings. If its speed of rotation corresponds to its natural vibration frequency, the residual out-of-balance force causes resonance, which can build up to a dangerous extent. This speed, known as the critical speed, is sometimes above the running speed and sometimes below. If above, the shaft is said to be "stife". If below, the shaft is said to be "flexible". The critical speed should be passed as quickly as possible when running up the turbine. British Standards require that the critical speed shall not be within 10 percent of the running speed. The prediction of critical speed is very complex, and depends on such factors as the flexibility of the supporting structure.

During the manufacture of turbine shafts great efforts are made to ensure that the forging is "stable"; that is, that the physical properties of the forging do not change in service. There are three types of instability:

(1) Permanent, caused by asymmetrical coefficients of expansion across a diameter. This is obviated by close metallurgical control at the ingot stage.

(2) Temporary, caused by "locked-up" stresses in the rotor. This is relieved by rotating the shaft in a special furnace both before and after machining.

(3) Transient, caused by differences in conductivity and emissivity. This is normally overcome by the use of turning gear.

An unstable shaft is likely to develop a deflection when in service, producing out-of-balance forces and consequent vibrations.

[illegible]

built-up rotor	套装转子
integral rotor	整锻转子
solid rotor	实心转子
gashed rotor	整锻转子
flaw	缺陷,裂缝
creep	蠕变
shrink fit	过盈配合,冷缩配合,红套配合
centrifugal stress	离心应力
yield point	屈服点
tensile stress	拉应力
hollow drum rotor	空心鼓式转子
welded disc rotor	焊接盘式转子
static balance	静平衡
dynamic balance	动平衡
out-of-balance weight	不平衡质量
resilient bearing	刚性轴承
natural frequency	固有频率
critical speed	临界转速
stiff rotor	刚性转子
flexible rotor	柔性转子,挠性转子
physical property	物理特性
asymmetrical	不对称的
coefficient	系数
ingot	铸锭
lock-up	集中,闭,锁住
conductivity	传导系数,传导率

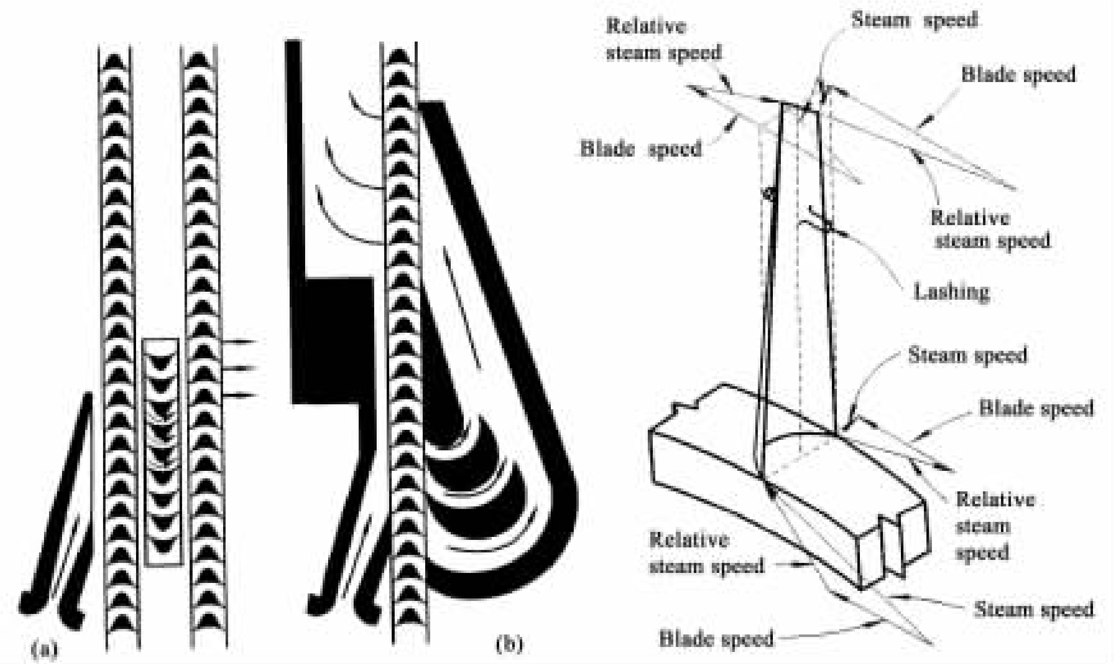
As mentioned earlier, nozzles may be either converging or converging-diverging; selection depends on the pressure ratio of steam across the nozzle. Nozzles are grouped so they can be controlled by individual valves. In the high-pressure end of the turbine, nozzles vanes are usually welded into the nozzle diaphragm; in the low-pressure end, nozzle vanes may be cast as an integral part of a diaphragm.

In a small turbine, converging-diverging nozzles are drilled into the block, and a set of stationary reversing buckets is attached for the two-row control or velocity-compounded stage. Steam passages through the nozzles have a circular cross section. A single converging-diverging nozzle usually has attached reversing blading and fits a small turbine with a two-row single wheel. In a nozzle row for a drum-type block, no inner diaphragm is needed because the drum occupies this space. Figure 猿苑(a) shows nozzle, wheel, and stationary blading for the two-row single-wheel unit.

Velocity compounding can be done with a single row of moving buckets. Steam may pass just once through the blades (Figure 猿苑(a)), or stationary reversing nozzle (Figure 猿苑(b)) may guide high-speed steam into a second pass through the moving buckets. In another method of velocity compounding, steam flowing from a converging-diverging nozzle makes three passes through buckets milled into the edge of a solid wheel. Stationary reversing chambers return the high-speed steam to the wheel buckets along a helical path. The control stage for a large turbine differs slightly from that of a small turbine, since vanes have a small percentage of reaction built in.

Blades (or buckets) take many forms. They receive the working force of the steam and transmit it as a moving torque to the wheels and disks to which the blades are mounted. The blade height and stage diameter increase in succeeding stages to accommodate the volume of steam that expands as its pressure drops. Shroud bands cover the blade tips to keep steam from spilling out radially.

In high-efficiency turbines, every effort is made to confine steam flow to the working passages through nozzles and buckets. Sealing strips between bucket shrouds and casing diaphragms minimize steam leaking past the bucket tip and into the following nozzle. Some turbines use pure, impulse buckets without any pressure drop across them. In other designs, the stage may have some degree of reaction—员园percent or less—to produce a small pressure drop across the bucket. This small drop can be very useful in keeping all buckets running full of steam, with the shaft thrust positive in one direction.



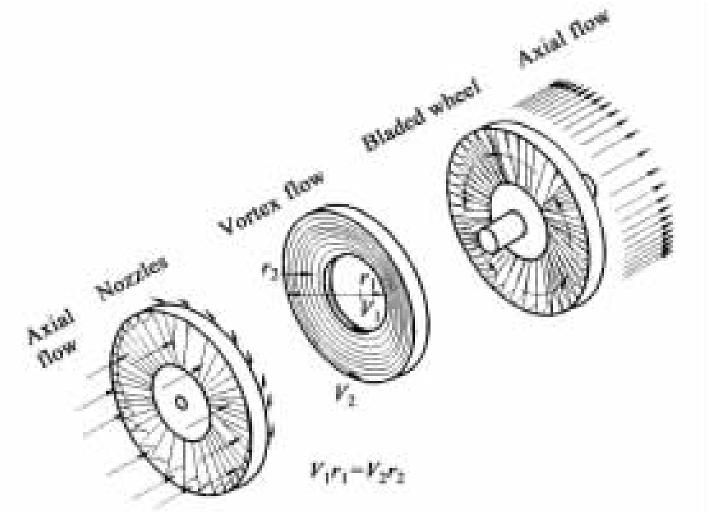
[illegible]

In many turbines that rely on velocity-compounded control stages, steam flows over only a part of the total periphery of the stage. In the "idle section", buckets churn the stagnant steam. This windage loss reduces turbine efficiency; to minimize the loss, shields fit closely over the idle part of the bucket travel. The shields limit the amount of steam whipped about by the nonworking buckets.

Blade Geometry

When blade height becomes a significant part of the total stage diameter, the ratio of steam to bucket speed changes over length of the bucket. To counteract this change, warped buckets are installed (Figure 猿愿. An exploded view (Figure 猿怨 shows a nozzle diaphragm steam vortex flow, a bladed or bucketed wheel, and the leaving exhausted steam. Ideally steam enters the nozzles in an axial direction and leaves in a circumferential direction, forming a vortex flow or eddy that is contained by the turbine casing before steam enters the moving buckets. To avoid cross currents in the vortex flow, the product of linear velocity of steam and the radius of the circle it travels in must be constant, that is, $v_{员}r_{员}$越$v_{圆}r_{圆}$ The steam pressure must be higher at the outer rather than at the inner radius.

Steam leaves nozzles at the inner radius with higher linear speed than at the outer



[illegible]

radius. But the bucket's linear speed increases with radius. So a steadily growing ratio of blade to steam speed occurs as one moves from root to tip. Figure 猿愿 shows velocity diagrams at the root and tip of a blade that receives a steam jet moving in vortex flow. The blade root has been designed for impulse flow, which is equivalent to 园 percent reaction and no pressure drop.

The blade's entrance angle is fixed by the angle of approach of the steam's relative speed, so steam slides smoothly over the blade. In the ideal situation, the absolute steam speed should just about double the blade speed. At the blade's exit edge, the vector difference of relative steam and blade speeds shows that steam has residual absolute speed in an axial direction.

Since the blade speed at its tip is about double the absolute steam speed, the steam must approach the blade from a direction almost opposite to its motion. The blade section must be twisted to receive the steam smoothly all the way up the blade. But since entering steam pressure is higher at the tip than at the root, there will be a pressure drop through the blade. Thus a reaction blade section must be used with the relative steam speed higher at the blade exit. A pure reaction force acts at the blade tip, a pure impulse force at the root. At the tip exit, the vector difference of relative steam speed and blade speed (Figure 猿愿) indicates that steam leaves with low velocity in an axial direction, just as at the root.

Bearings and Seals

Bearings range from pressure-lubricated journal types for large turbines through ball bearings for small turbines. Larger bearings are almost universally designed with oil grooves in their top halves to build an oil wedge that presses down on the journal.

The steam pressure differential across most turbine stages creates a net thrust along the shaft. This must be counterbalanced to keep the rotor in proper position. A Kingsbury thrust bearing is used for this purpose, in which individual movable thrust shoes bear on leveling plates. A thrust collar, fixed to the shaft, pushes on the shoes and holds the clearance between moving and fixed components.

Steam leakage cannot be avoided entirely. Some steam will leak out of turbine casings where the shaft must pass through. In condensing turbines, air tries to leak along the shaft into the low-pressure condensing space. Seals are installed to stop leakage. In a slant-top packing-ring seal, carbon (or comparable material) packing rides directly on the shaft. Springs anchored at the top hold packing segments in place and against the sealing surfaces. Steam that does manage to leak past the seals may be channeled to a lower-pressure stage of the turbine, channeled to a heater, or vented to atmosphere. Condensed steam usually accumulates in the last section of the seal and then drains to waste.

Stepped labyrinth-gland seals also control shaft leakage. Intermediate leakoffs direct the steam to lower turbine stages or heaters. The large intermediate chamber may connect to the suction of a blower that holds a vacuum lower than the turbine's last stage. This would draw in low-pressure steam from one side and air from the blower side. The blower discharges the mixture to a condenser, where the steam is recovered.

Seal strips have tapered edges, so any accidental rubbing will wear them down quickly without overheating the shaft. Steps milled in the shaft match longer seal strips, forming a long, tortuous path with high flow resistance. Enough axial distance is needed between the strip and step to avoid contact when the shaft and casing expand or contract at different rates.

[illegible]

converging-diverging nozzle	缩放喷嘴
pressure ratio	压比
a helical path	螺旋通道
shroud band	围带
blade tip	叶顶
sealing strip	汽封片
stagnant steam	滞留汽体
windage loss	鼓风损失
shield	护罩
vortex flow	涡流,旋流
blade root	叶根
be equivalent to	相当于,等于,与…等效

exit edge	出汽边
vector difference	矢量差
twist	扭转,弯曲,扭曲
journal bearing	轴颈轴承
ball bearing	球面轴承
oil groove	油槽
oil wedge	油楔
counterbalance	反平衡
Kingsbury bearing	金斯布里轴承
thrust bearing	推力轴承
thrust shoe	推力瓦
bear on	压在…上
thrust collar	推力盘
packing ring seal	密封环汽封
labyrinth-gland seals	迷宫式汽封,曲颈式汽封
blower	鼓风机,排气器/口
tortuous	曲折的,弯曲的,不在一个平面的
exploded view	部件分解图

哉揪擅醪殇霸摇 粤憩罾霆搴赌耘择憩罾霆皂藻鲅

Condensers

A steam condenser is a vessel in which exhausted steam is condensed by contact with cooling water. Various auxiliaries are required for the proper operation of a condenser. Circulating pumps must provide water to condense the steam and produce a satisfactory back pressure or vacuum; condensate pumps must remove the steam thus condensed; a vacuum pump or ejector must remove the air and non-condensable gases, to avoid pressure in the condenser, an atmospheric-pressure-relief valve is required.

Condensate pumps remove the water from the hot well and maintain a continuous water supply through the extraction heaters to the boiler feed pumps.

The functions of the condenser are to:

(员 Provide the lowest economic heat rejection temperature for the steam cycle.

(圆 Convert the exhausted steam to water for reuse in the cycle.

There are two main types of condenser: the surface condenser and the jet condenser.

In the surface condenser, the steam to be condensed is usually passed over a large number of tubes through which cooling water is passing. The steam is condensed on the surface of the tubes as it gives up its enthalpy to the cooling, water passing through the tubes. The condensate and cooling water leave separately.

A further division in the condensers is possible because of the difference of the relative directions of flow of the condensing steam and the cooling water. There are three possibilities here:

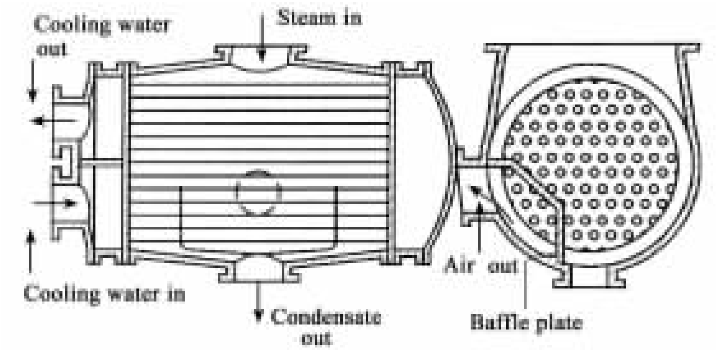
(员 Transverse flow in which the steam flows across the path of the cooling water. This is only possible in the surface type condenser;

(圆 Parallel flow in which the steam flow is in the same direction as the cooling water;

(猿 Counter flow (sometimes called contra-flow), in which the steam flows in the opposite direction to the cooling water.

Figure 猿员园 illustrates a surface condenser.

In the jet condenser, the steam to be condensed comes into direct contact with the cooling water, which is usually introduced in the form of a spray from a jet. The steam gives up its enthalpy to the cooling water spray, is condensed and finally leaves as



云蚤早援 猿援员园摇 杂怎则枣葬糟藻摇糟燥灶凿藻灶泽藻则

condensate with the cooling water.

Modern condensers are generally of the surface type operating under vacuum. There are limits to the vacuum, which can be economically employed, since the volume of each pound of steam increases rapidly with decrease in pressure.

Air Ejectors

The operating medium of an air ejector can be either high-pressure gas or liquid. This is passed through a nozzle and the pressure energy is converted into velocity energy. The high-velocity fluid aspirates the air and the non-condensable gases and the mixture is projected into a diffuser, which reconverts the velocity energy into pressure energy. Steam is a suitable operating medium and is used in the steam-jet air ejector. The steam consumption is controlled by the compression ratio of the air and this factor influences the decision to adopt either single or multiple-stage ejectors for a particular condition. To meet the requirements when raising vacuum a starting ejector is provided. This is a high capacity, high steam consumption ejector of single stage and without an after-condenser.

A main air ejector with standby unit is usually provided for normal operation. The heat in the operating steam is partially recovered in the condensate, which flows through the inter and after coolers.

Oil Coolers

The efficiency of a centrifugal pump may be of the order of 缘豫% and the remaining 源豫% of the pump input energy generates heat in the oil. The oil also absorbs a large amount of heat from bearing friction and shaft conduction. To remove this heat the oil is passed through coolers, which reduce the temperature to that required for the bearings.

Coolers are designed to have the maximum surface area for heat transfer compatible with a small pressure drop between entrance and exit. They are usually mounted vertically, for easy removal of the tube nest, and water passing upwards through the tubes ensures complete flooding at all times. Dirt in the water falls to a sump at the bottom, and the bores of the tubes can be cleaned by removing the top water box. Oil enters at the top and passes across the tubes in a zig-zag manner, guided by baffles.

For high thermal conductivity the tube nest consists of 苑园/猿园 brass tubes expanded or sweated into brass tube plates. One tube plate is fixed, while the other can slide past an annular seal, to allow for expansion.

The oil and water passes are arranged in counter-flow. This arrangement has thermodynamic advantages, and also reduces the amount of sludge precipitated in the cooler, as the hot oil entering the cooler does not strike the coldest part of the oil cooler tubes.

It is usual to provide two 员园园% duty or three 缘园% duty coolers, so that one may be taken out of service for cleaning without shutting down the plant. The oil circuits work in parallel, and special combination valves are used, interlocking the changeover of oil and water connections.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

circulating pump	循环水泵
ejector	喷射器
non-condensable	不能凝结的
atmospheric-pressure-relief valve	大气压力安全阀
condensate pump	凝结水泵
hotwell	热井
extraction heater	抽汽加热器
boiler feed pump	锅炉给水泵
reuse	重新使用
conterflow	反向流动,逆流
contra flow	对流,逆流
jet condenser	喷水凝汽器
come into contact with	与…接触
spray	喷水,喷雾
air ejector	抽气器
aspirate	吸出(空气等)
diffuser	扩压器,扩压管
compression ratio	压缩比
adopt	采用
compatible with	与…相容(相似,一致)
thermal conductivity	导热率,导热系数
oil cooler	冷油器

sump	**油盘，曲柄箱**
zig-zag	**锯齿形的，Z 字形的，曲折形的**
tube nest	**管束**
sweat into	**熔焊，焊接，渗漏**
sludge	**污泥，油泥，油泥渣**
precipitate in	**沉淀，淀析，析出，凝结**

[illegible]

The function of the governor of a turbine is to regulate automatically the speed and power output, and to make changes when required. To regulate the speed, a device is necessary, which will sense the magnitude of the speed within a prescribed range, and produce a corresponding displacement, which can be used as a corrective control. Three methods of doing this are in use: namely hydraulic, electrical and mechanical.

A hydraulic governor for a turbine consists of a centrifugal pump driven from the main shaft, the pressurized oil from it being led into a cylinder containing a spring loaded piston. The pressure is proportional to the square of the speed, so that the position of the piston is a function of the speed.

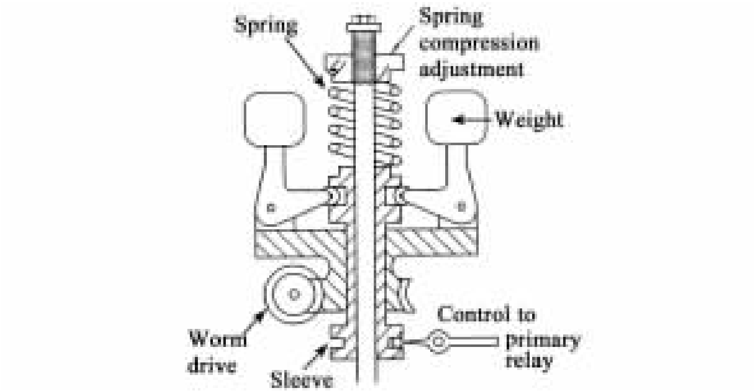
The electrical governor is a more recent innovation, made practicable by the development of robust servomechanisms and circuit components. An AC generator driven from the turbine shaft provides an electric signal of a frequency proportional to the speed of the shaft. A frequency-sensitive circuit produces a voltage proportional to this frequency, which, after amplification by a magnetic amplifier, is fed to a torque motor, which produces a proportional displacement. This method is widely used in large turbines.

The majority of turbines are controlled by a mechanical centrifugal governor, which is driven from the main shaft through gearing. The centrifugal force, acting on two revolving weights, is opposed by the elastic force of a spring, so that the weights take up a different radius for each speed.

In practice two tension springs may be used to connect the two weights directly; alternatively, compression springs may be used outside the weights. These arrangements have the advantage that the centrifugal force and controlling force balance each other directly without the use of levels, so that there is very little friction. On the other hand they are more difficult to design, since the effect of centrifugal force on the coils of the springs has to be taken into account.

In the type shown in Figure 猿灵the spring is unaffected by centrifugal force, and the controlling force can be adjusted while running by means of a screw. The change in radius of the weights is transmitted by means of levers to a sliding collar and the axial movement of this collar actuates the control lever.

To ensure quick response to changes of centrifugal force it is desirable that the radial inertia and friction forces should be small. Hence, a good governor might be



[illegible]

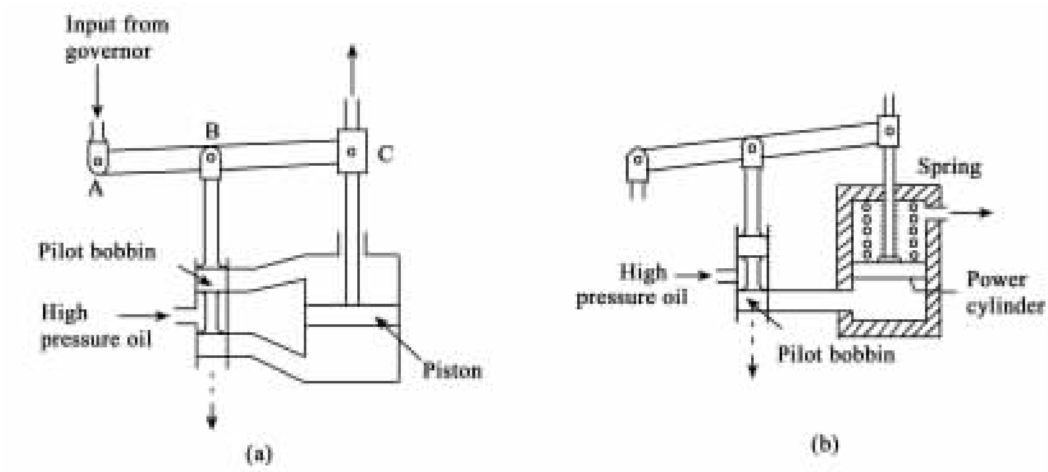
designed with small weights, the speed of revolution being increased to compensate for the loss of output force. To relieve the governor of work in moving the control mechanism a primary relay is employed.

Relays or servos are used extensively in turbine control gear and are operated by means of high-pressure oil. Two types of relay are in common use, namely the double-acting relay and the single-acting spring return relay.

Figure 猿援圆(a) shows a primary relay of the double-acting type. When A is raised by the governor, C is held stationary by the fixed volume of oil above and below the piston, and B consequently raises the pilot bobbin, the pressure force on which are balanced. Oil is thus drained from the bottom of the power cylinder and the piston moves down under oil pressure. There is no further motion of A and the pilot valve is reset to its neutral position. Since the pilot valve begins and ends in this position, the lever may be regarded simply as having its fulcrum at B. The high-pressure oil is always connected to the centre of the pilot bobbin, to avoid the need for glands. For a lever arrangement where the control point A comes between B and C, the oil channels to the power cylinder must be cross-connected.

Figure 猿援圆(b) shows a power relay for operating the turbine governing valves of the single-acting spring return type. The spring provides a reserve of energy which, in the event of a failure of the oil pressure, will close the valves automatically. Only one of the bobbins on the pilot valve is used as a valve, the function of the other being to balance the pressure force. With this type the pilot valve is always slightly open, since the pressure under the piston has to be maintained in spite of leakage.

By making the valve and piston of a relay concentric, the need for a resetting lever may be made unnecessary. To overcome friction between pilot valves and their sleeves, the valve may be made to rotate, or artificial "dither" may be introduced by means of small pulsations in the high-pressure oil.



[illegible]

Sequential operation of two or more governing valves is achieved by connecting all the relays to the same control rod, but displacing each pilot valve from the neutral position by progressively increasing amounts. Thus, while the first power piston is opening its valve, the second cylinder remains drained until its pilot valve passes the neutral position and high-pressure oil is admitted. The valves of nozzle-governed turbines are sometimes operated from a camshaft, driven by a single power servo.

The output of the primary relay controls the valve relay through a system of rods, levers and shafts. Alternatively, the pilot valve of the primary relay may be separated from its power cylinder, the latter being incorporated into the valve relay. This does away with mechanical linkage and necessitates only a pipe connection for the transmission of a pressure signal.

For a turbine driving an AC generator, it is desirable that the relationship between power output and speed should be linear, the speed falling slightly with increasing load. This feature is necessary to ensure that, when connected in parallel with other generators, the generator will supply its share of the load demand. The slope of the speed-load graph is termed as the "regulation". The percentage f regulation is defined as the change in speed from no load to full load as a percentage of the rated speed. The regulation is about 源% —远% . It will be realized that this change in speed only actually takes place if the generator is supplying power independently of the grid, but the fact that the governor tries to conform to this falling characteristic while the set is connected to the grid enables the power output to be controlled.

[illegible]

hydraulic governor 液压调速器

殉愿

centrifugal pump	离心泵
be proportional to	和…成正比
electrical governor	电调速器
innovation	改革,改进,创新,新技术
robust	坚固的,耐用的,健全的,增强的
servo-mechanism	伺服机构
magnetic amplifier	电磁放大器
torque motor	力矩马达
tension spring	拉伸弹簧
compression spring	压缩弹簧
sliding collar	滑环
servo	伺服机构,随动机构
pilot bobbin	错油门滑阀,导阀滑阀
power cylinder	油动机
fulcrum	支点,转轴,可转动的
in the event of	万一,在…情况下
sleeve	套筒,空心轴,轴套
dither	高频振动
pulsation	脉动,波动
camshaft	凸轮
the percentage of regulation	速度变动率
rated speed	额定转速

[illegible]

Drax power station is located on the south bank of the River Ouse. The first three units, referred to as "Drax First Half", were put into operation in 员怨苑猿 and 员怨苑源 respectively, and the last three units, referred to as "Drax Completion", were put into operation in 员怨愿猿 The turbine generators in the station are single line 远远园 MW units fitted with twin pannier condensers and running at a speed of 猿 园园园 r/min. Each machine consists of one single flow HP turbine of triple casing construction, one double-flow double casing IP turbine and three double-flow single casing LP turbines. The turbine rotors, which are rigidly coupled together, are each supported by two bearings housed in their corresponding bearing blocks whilst the whole rotor assembly is located axially by a thrust bearings mounted at the HP end of the IP turbine rotor. The machine is supported on a steel foundation block to which the bearing block pedestals are secured. The turbines are arranged such that the bearing blocks are free to slide in their pedestals, thus accommodating the movement of the cylinders and rotors during thermal changes. A system of guides, keys and anchor points is employed to ensure that longitudinal and transverse alignment is maintained at all times, whilst accommodating freedom of movement due to thermal expansion.

The machine is driven by HP superheated steam, which is reheated between the HP and IP turbines to give greater thermal efficiency. Steam from the boilers is admitted to the HP turbine by two HP steam chests, which house the steam admission and control valves (CV). The steam chests, which are mounted one on each side of the turbine, are connected to the HP turbine by interconnecting pipes designed to absorb expansion as it occurs, thus relieving the chests of additional stress. After passing through the HP turbine the steam is exhausted to the boiler reheater and is returned to the IP turbine through the twin reheat steam chests which house the reheat steam control valves. The reheat chests, which are mounted one on each side of the turbine, are connected to the IP turbine by interconnecting pipes which absorb expansion as it occurs, thus relieving the chest of additional stresses. Relief valves, provided in the steam lines between the reheater and the reheat steam chests, discharge the steam in the reheater to atmosphere, when the governor and intercept valves (IV) close on overspeed. This eliminates the risk of the HP blading overheating in the event of rejection of full load.

Exhausted steam from the IP turbine is led to the three IP turbines by four interconnecting pipes, two of which are connected to No. 员 LP turbine and one connected to each of No. 圆 and No. 猿 LP turbines respectively. The steam flows in both directions through each of the IP turbines and is exhausted into the condensers, which are under a constant vacuum.

Two surface type condensers, which for maximum thermal efficiency operate at vacuum conditions, are provided to condense the steam exhausted from the LP turbines and also to provide the means for air and vapour released from the heaters and other equipment associated with the condensate system.

Five 圆缘% duty air extractor units are provided to maintain the vacuum in the condenser. A quick-start air pump is also provided for use during the initial starting-up period.

As with boiler development, information obtained from experience of 缘园园MW units was used in the design and development of the Drax First Half turbines. Casings of simpler but stronger shape evolved and rotors of solid single-piece construction were adopted which were substantially stiffer than earlier units and proved greater stability.

On-going development and changes in manufacturing techniques led to the introduction of further design changes for the Completion turbines. Advantage was again taken of operating experience to improve plant performance. Important changes can be summarized as follows:

(员 IP and LP turbine diaphragms were manufactured to improved techniques and standards but rotor interchangeability for all six units was maintained.

(圆 The turbine gland sealing system was redesigned to incorporate detailed modifications and improvements to eliminate problems, with automatic control and, so minimize operator attention and maintenance.

(猿 A flange warming system was incorporated on the HP and IP turbine casings to overcome plant limitations and facilitate flexible operation of the unit whilst avoiding excessive differential expansion on cold startup. Detailed changes were also made to HP rotor and casing geometry to improve their thermal fatigue characteristics.

(源 Modified and improved designs of first stage HP and last stage LP turbine blades were fitted.

(缘 The lubricating oil system was modified to reduce bearing leakage. The design of oil coolers was also modified to improve the cooling performance.

(远 The main and boiler feed pump turbine governor and trip system were manufactured to an improved design.

(苑 The high silt content of river water causes erosion problems in the condenser tubes. To avoid the need for re-tubing during unit life, the tube material was changed from aluminum brass to titanium.

(愿 The change from direct contact to tubular LP heaters in the feed heating system required a condenser extraction pump with a higher generated head to overcome additional system losses. Advantage was taken of the latest design practices to reduce cavitations and air ingress and the type of pump was changed from horizontal to vertical caisson type.

(怨 The air extraction plant was updated from four to five vacuum maintaining units to ensure continuous, satisfactory performance. The quick-start pumps were fitted with air ejector augmentors.

Many of the changes and improvements were backfitted on the earlier units following satisfactory development for the new units.

Turbine Design Data

Type摇摇摇缘cylinder tandem-compound single reheat

Speed 猿园园园r/min

Steam consumption at CMR摇摇摇摇缘愿圆kg/s

Steam pressure 员缘怨远MPa

Heat rate 愿员苑kJ/kwh

Power output 远园园MW (at generator terminals)

Steam Conditions at Turbine Inlets

HP Cylinder 员缘怨远MPa and 缘猿缘C

IP Cylinder 源园员MPa and 缘猿缘C

LP Cylinder 园远远圆MPa and 猿园愿C

Vacuum (average) 缘源园kPa

Barring gear (turning) speed 圆/min

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

pannier	挂在机动车(脚踏车)两侧的装物袋
single-flow	单向流动
triple casing	三层汽缸
double-flow double casing	双流程双层缸
three double-flow single casing	三个双流程单层缸
bearing block	轴承箱
anchor point	死点
steam chest	蒸汽室
interconnection pipe	连通管
relief valve	溢流阀,安全阀
surface type condenser	表面式凝汽器
condensate system	凝结系统
a quick-start air pump	快速启动空气泵
on-going	正在进行的,前进的
a flange warming system	法兰加热系统

differential expansion	胀差
cold startup	冷态启动
geometry	结构，几何学
thermal fatigue	热疲劳
last stage	末级
titanium	钛
tandem-compound single	单轴多缸
heat rate	热耗率
barring gear (turning) speed	盘车速度

Part Four摇Generator and Electrical 摇摇摇摇摇摇 Equipment

[illegible]

Introduction

Electric generators convert mechanical energy to electrical energy, which is more easily transmitted to remotely located points of application. The first large electric generating systems used direct-current (DC) generators, mainly because direct current was better understood than alternating current (AC). However, DC generators are limited to generating power at relatively low voltages, largely due to problems at their commutators.

As power networks developed, higher and higher voltages were required to transmit large blocks of power over longer and longer distances. Electric transformers can easily change the normally low voltage generated to the high voltages needed for efficient power transmission, and, of course, transformers only work on alternating current. AC generators, or alternators as they are commonly called, are so much simpler mechanically, so much more efficient, and require so much less maintenance than DC machines that all large generating plants output alternating current today. Although DC transmission lines can transport extremely large blocks of power very efficiently over long distances, the power is always generated as alternating current, transformed to the voltage required, rectified and transmitted as direct current, and then inverted back to alternating current at the point of application.

Mechanical Energy

The mechanical energy for driving the generator must be derived from a source with enough reliability and capacity to make it economically feasible to develop and transmit the energy electrically to the point of use. A small water supply running only during exceptionally wet years or located at a great distance from electrical consumers would probably not be suitable. Mechanical energy sources which cannot be moved, such as hydraulic turbines or even wind machines, must have the cost of transporting the energy produced (among other factors) taken into account when overall costs are calculated. Steam turbine power plants, however, can be located near a coal seam, lumber mill, or a reliable source of cooling water to save the transportation costs.

Some mechanical power may be obtained from sources more easily located near the point of utilization. Gas turbines and reciprocating gas or diesel engines fall into this category. Except for standby emergency power generators, even here it might be more economical to install large units and transmit the power to the point of use. Large power plants will generally have better operating efficiencies than small ones, and it may be desirable to locate a large plant near the center of use and then distribute the power generated outward, assuming the fuel supply is transportable.

Each type of mechanical driver has its own peculiarities, and some have a sizable impact on the generator configuration. There are marked differences as to the engine output speeds available, the speed pulsations possible, the chances of overspeed, etc.

Normally, the generator shaft is horizontal and direct-connected to the driver. Sometimes speed-changing gear boxes are installed between a high-speed turbine and a lower-speedy generator. These allow the turbine to run at its most efficient speed, a speed that may be too high for the generator. Small hydraulic turbines usually have their shafts mounted horizontally; large hydraulic machines have their shafts direct-connected and vertically mounted. The generator may include special bearings to carry the thrust imposed by the water flowing through the turbine.

[illegible]

commutator	换向器 整流器 整流子
rectify	整流
seam	矿层 煤层
hydraulic turbines	水轮机
wind machines	风机
take into account	考虑
lumber	锯开的木材(板、条)
mill	制造厂,工厂
reciprocal	互利的 相互的 往复的
diesel engine	柴油机
standby generator	备用发电机
peculiarity	独特性,特色
have impact on	对…有影响
direct-current (DC)	直流发电机
alternating current (AC)	交流发电机
speed-changing gear box	变速调节箱
generator shaft	(发电机)机轴

[illegible]

There are two quite distinct forms of modern alternator. While the principle of operation of each is the same, i. e. , the movement of magnetic poles past stationary coils, their constructions are very different. The reason for this is that each has been designed to "match" its prime mover, i. e. , to suit the mechanical device that is to tap the two principal natural power resources—failing water, on the one hand, and steam, generated by heat from fossil fuels or nuclear fuels, on the other.

To match the output of the turboalternators, the water wheel generators must therefore be multi-polar and hence of large diameter and small axial length. There is a limit to the length of a turboalternator, based largely on the mechanical considerations involved in supporting a large rotor mass between bearings at each end. At 猿园园园 or 猿远园园 r/min (缘园 or 远园 Hz) the rotor must be extremely well balanced and its surface smooth. With the lower speed water powered machine, such precautions can be relaxed with a view to making the larger rotor cheaper to make.

The fundamental difference in shape between the rotors of the two types of machine is consequent upon the above considerations, but now a secondary difference is introduced by what could be termed the experience and skill of the designer.

It is necessary to produce a sine wave of induced e. m. f. The factors that affect the instantaneous value e of this are the flux density b, the length l of the conductor, and the velocity v (the use of small letters indicating the instantanous values). Thus:

e 越 blv

A reasonably clear definition of what constitutes a "pole" can be given by defining a pole pitch rather than a pole per se. A pole pitch is the distance (p) between points where the current flow is a maximum. The number of poles in the machine is then the periphery (圆πr) divided by p. This definition fits easily into linear motor technology, where the number of poles need be neither even nor an integer. The speed of rotation expressed in Table 源员 as 圆f/n (r/s), where n was the number of poles, can always be converted to a linear speed, for the periphery 圆πr contains n pole pitches each of length p so that 圆πr 越 np. Hence the rotational speed 圆f/n (r/s) "translates" into a linear speed, v_s, such that

[illegible]

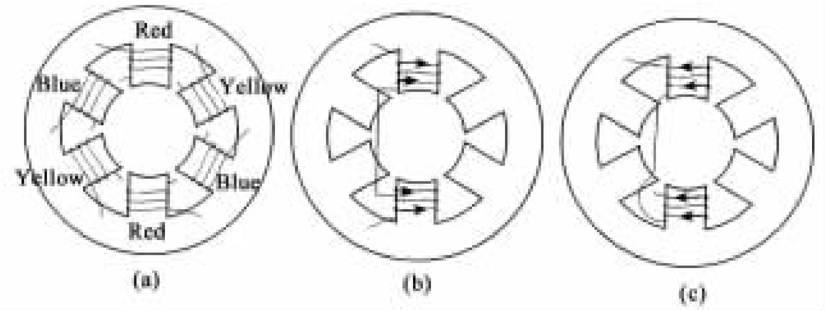
This is simply the "common sense" statement that a traveling wave moves two pole pitches (越 one wavelength, λ) each cycle of events. (This corresponds to the well-known formula v 越$f\lambda$ for all wave motions.)

耘耀藻滠员 杂赞藿阔燥粤赠鄹耀蜜赡藿赠赡释藿赞圆鄹 (赠释

晕耀燥猿鬟释	杂赞藿阔掣鄹缘匀扎		杂赞藿阔掣鄹远匀扎	
	赠耀蜜	赠赡释	赠耀蜜	赠赡释
圆	猿圆圆	员圆	猿远圆	员圆
源	员缘圆	缘圆	员愿圆	远圆
远	员圆圆	员圆 辕	员圆圆	源圆
愿	苑圆	圆缘	怨圆	猿圆
员园	远园	圆园	苑园	圆源
员圆	缘园	员园 辕	远园	圆园
圆园	猿园	员园	猿源	员圆
员园园	远园	圆	苑园	圆缘

Three-phase machine stator is shown in Figure 源员(a). It does not, as it appears at first sight, have six poles, even though it has six obvious "polar projection". These are to be seen as six "teeth" in a slotted stator with a three-phase "distributed" winding only in the condition of three-phase distribution. Unless such a diagram makes clear how the two coils in each phase are connected, no one can say whether it has two poles or four. It is worth studying figure 源员 carefully, first to appreciate the differences between (b) and (c), hence to "see" the kind of difficulty that can arise in the mind of the student being confronted with the problem for the first time, and finally to demolish the problem so that it never arises in the future. For the connections shown at (b), both red-phase coils assist each other in driving flux diametrically across the machine. So do both yellow-phase coils and both blue-phase coils. So, whatever instantaneous currents flow in the system as a whole, the resultant flux will be the vector sum of three diametral fluxes which therefore is itself diametral and the machine corresponds to the two-pole system. But if opposite pains send opposing fluxes into the rotor then the only possible resultant flux pattern corresponds to that of Figure 源1 (c) and the machine has four poles.

In this crude example the lack of winding "distribution" is now obvious, since a two-pole, three-phase machine with only six slots has one slot per pole per phase, or, as is now more "fashionably" written, one slot per pole and phase, The four-pole version has only half a slot per pole and phase, which gives a very "lumpy" kind of traveling field to be avoided in practice if at all possible by having a larger number of slots. The reader will appreciate, however, that if a more realistic example of two-and four-pole machines with, say, twenty-four slots each had been chosen, the diagrams might have become too obscure to make the point about "pole counting".



[illegible]

⑴ Stators

The rapidly varying magnetic flux in the stator iron causes hysteresis losses as the iron resists changes in the flux density. The varying magnetic flux also causes electric currents, called eddy currents, to flow in the iron laminations; losses also result from this current flow. The stator is built from thin laminations to minimize the electrical losses and of specially rolled silicon steel to minimize the hysteresis losses. For small machines, the laminations are circular, in the shape of the finished stator. For large machines, the laminations are punched as semicircles and then assembled into the finished circular stator. Slots are punched for future installation of the windings.

The winding slots are suitably insulated to provide both electrical insulation between the windings and the grounded stator and protection from abrasion damage to the windings, by the stator iron. Windings are specified with the proper span, wire size, and the amount of insulation required by the machine rating.

For smaller machines, the windings are wound with loose coils of round wire, which are inserted into the slots provided in the stator, turn by turn, and fastened with slot wedges to prevent movement of the windings. To get as much conductor and stator iron as possible into the machine, large units are wound with square or rectangular wire, which is formed into rigid coils with insulation between the individual wires and around the coils themselves. The coils are inserted into the stator slots, which have parallel walls to provide a snug fit between the coils and the stator iron; slot wedges hold the coils in place. Coil ends are connected into the proper groupings to provide the configuration of poles, voltage, and other parameters for which the machine is rated.

圆 Rotors

Two basic types of rotors see service in synchronous alternators. High-speed machines (two-and four-pole) are built with round rotors; slots are cut into the rotor for the field windings. These alternators are referred to as uniform-air-gap machines.

Slower-speed machines have field poles that stick out from the rotor shaft, with the field winding wound around the projecting poles. The air gap obviously is not uniform. These alternators are called salient-pole machines.

Each pole on the alternator rotor has a winding through which direct current, usually at 125, 250 or 375V, is circulated to "excite" the field and create a magnetic field. The power required for field excitation is normally only a small percentage of the output, about 1 to 2 percent of the alternator rating. The DC excitation is obtained either from direct-connected machines driven by a prime mover or from separately mounted exciters that derive their power from other sources. The exciter output voltage level must be adjustable and have enough capacity to enable the alternator to produce rated voltage at rated output.

(3) Exciters

Over the years, field excitation has been provided by three main exciter designs—rotating brush, rotating brushless, and static types.

Rotating Brush Type. Rotating, compound-wound DC designs were the only exciters used for many years. Exciters driven via a speed-increasing belt-and-pulley arrangement were sometimes specified so that less expensive, higher-speed exciters could be paired with slower-speed alternators. Direct current is delivered to the alternator rotor slip rings, which consist of two circular brass-alloy rings mounted on and insulated from the alternator shaft. Connections are made from the slip rings to the alternator field. Brushes riding on the slip rings are connected to the exciter.

The rotating brush exciter still sees service, but continual maintenance problems are associated with delivering large currents through slip rings, commutators, and brushes. These problems, together with the development of reliable, inexpensive semiconductors, make the brushless exciter the dominant choice today.

Brushless Type. The brushless exciter is simply a special type of alternator mounted on the same shaft as the main exciter. It is special because its field, which must be excited with direct current, is stationary, and its AC output comes from the rotating parts. The output is rectified and connected to the main alternator's field by means of cables run along and fastened to the alternator shaft. Brushes, commutators, slip rings, and their maintenance are eliminated.

Static Type. As prices go down and the reliability and ratings of semiconductors go up, special cubicle-mounted controlled rectifiers, called static exciters, are becoming an increasingly popular choice. Their lower cost, reduced losses, reduced maintenance, and more flexible outputs also make them good choices for replacements of damaged rotating exciters.

A static exciter consists of an input transformer, silicon controlled rectifiers (SCRs), rectifier controls, and voltage regulator controls. The complete assembly functions to rectify the incoming AC voltage into a properly controlled DC exciter voltage required by the alternator. Static exciter input may be connected to any convenient AC power source, such as station power (assuming it is available when the alternator is not running), but it is normally connected to the alternator output leads. Fuses and disconnect switches are installed between the alternator and exciter to protect against faults in the system.

Once there is direct current passing through an alternator field winding, a small amount of residual magnetism remains. When the alternator is run again at rated speed without excitation, an AC voltage of 圆to 员园percent of rated can lie measured at the alternator's output terminals. This voltage is generated by the residual magnetic flux in the rotor acting on the stator windings. When it is connected to the alternator's output, the static exciter rectifies this residual AC voltage into direct current, which is applied to the alternator field windings. This action further increases the excitation, which builds up until, in a very short time, the rated output voltage is obtained. Obviously, the correct connections must be made; if the output of the static exciter is in opposition to that of the residual voltage, no buildup will occur.

The exciter output is connected to the alternator field via the slip rings, which will require some brush and ring maintenance, but not as much as is required by the brush and commutator arrangement in a rotating exciter. Sometimes the residual magnetism is lost or it is desirable to reverse the direction of the residual magnetism. The field can be "flashed" by momentarily connecting a battery to the alternator field to establish some residual magnetism in the correct direction. On some static exciters this field flashing is done automatically every time the unit is started.

Static exciters also find application where the alternator must have special response characteristics, such as for starting abnormally large motors. The starting current of an induction motor is on the order of 远times its normal full-load current. Starting a large motor (larger than one-half the generator load) causes the generator output voltage to drop, possibly enough to cause the motor starters to drop out. Reduced-voltage starters of several types are available to reduce the motor-starting current, but they are expensive and introduce time delays that may not be desirable. A static exciter can be provided with special "field forcing" equipment to give a quick increase in excitation in response to the demands of starting a large induction motor. Field forcing allows the generator to be smaller and less expensive than standard equipment.

(源 Motor-Generator Sets

Separately mounted DC generators driven by engines or AC motors are sometimes used as exciters. They are called motor-generator sets. The sets are occasionally specified as a replacement for a damaged direct-connected exciter. At one time, special types of motor-generator sets with voltage-regulating exciters were also used.

magnetic摇摇摇摇摇摇摇摇摇摇摇摇摇	磁性的
tap	抽取
turboalternator	涡轮发电机
sine	正弦
flux	流量,通量,电通量,磁通量
pole pitch	磁极距
periphery	圆周,周界线;(圆体的)外面 边缘 ;周围
integer	[数]整数 ;完整的东西
slotted	开槽的,切槽的,有槽(沟、裂痕)的
be confronted with (by)	面临着
version	型号,种类,形式(态),模型
lumpy	(成)块状的,多块的,成团(块)的,笨重的,凸凹不平的,波浪起伏的
traveling field	行波场
obscure	(阴)暗的,模糊的,不清楚的 ;含糊的,难的
hysteresis	磁滞(现象),滞后(量,现象,作用)
eddy current	涡流,杂散(涡流)电流
lamination	层压,叠合,叠层,层状,交替片组
semicircle	半圆(形)的
punch	冲压,冲加压,模冲
abrasion	擦伤(掉,去),刮掉(去) ;磨损
span	间距(隔)
rating	额定(标称,规定)值
wedge	楔,楔形物
rectangular	长方形的
snug	舒适的
salient	突出的,凸起的
pulley	滑轮,滑车,辘轳
slip ring	滑环,集流环
residual excitation	剩磁激励
residual magnetism	剩磁
silicon controlled	硅(可控) 整流器
lead	铅板
fuse	熔断器
field winding	励磁绕组
on the order of	属于…同类的,跟…相似的

[illegible]

Protective relays are included in all electric circuitry to protect equipment and maximize continuity of service. A vast array of protective devices is available to do this job. Fortunately, the National Electrical Manufacturer's Association (NEMA) has set up and published a system of function numbers, standards, and specifications for protective relays. NEMA standards are adhered to by virtually all manufacturers.

Many relays meeting NEMA standards are available in both standard speed and sensitivity and in the more expensive high-speed and/or special-sensitivity models. The latter are specified for the larger, more important, or more critical machines in the system. Most protective relays are now available in both electromechanical and static designs. The prices are about the same for the two types, but the static models are finding increasing acceptance, mostly because of their flexibility and the reduced maintenance associated with them.

Protective Relays

Protective relay schemes must provide coordination and backup between the various relays, as well as protection. Coordination means that the relays nearest a problem will operate first to remove the problem section without disturbing the rest of the system. Backup means that if the relays nearest the problem cannot or do not remove the problem section, then protective relays nearer to the source will operate to back up those relays that did not operate. When backup relays operate, it usually means that more of the system will be removed from service.

Protective relays may be connected to trip one or more circuit breakers, sound an alarm, or trip only if another event occurs. On [illegible]V and lower-rated circuit breakers, overcurrent devices normally are built into the circuit breaker, and they trip it directly. Other relays may be mounted separately and actuate the shunt trip on the circuit breaker. A battery, a capacitor trip, or a reliable source of alternating current is needed for this scheme. On circuit breakers rated at [illegible]V and above, the relays are always separately mounted, are fed from current and/or potential transformers, and perform their trip or alarm function with the power obtained externally.

Here are some typical protective devices for the alternator itself. This treatment is by no means complete, nor are the schemes discussed the only ones used.

Overcurrent Protective Devices

NEMA device 缀园 represents instantaneous overcurrent protection, which can be provided either as a self-contained overcurrent trip in a 远园园V circuit breaker or as a separately mounted relay fed from a current transformer mounted somewhere in the generator output circuit. Device 缀园 is set to trip instantaneously at a point above which all the other instantaneous relays on the feeders are set. Sometimes device 缀园 in a 远园园V circuit breaker will be arranged with a very small time delay, to enable the circuit breakers further down the line to trip first. This is called a selective trip.

NEMA device 缀员 is a time-delay overcurrent relay. Again, it may be part of a 远园园V circuit breaker overcurrent trip, a separate relay, or combined with NEMA device 缀园 in one relay. Device 缀员 comes in a multitude of different time-overcurrent curves, all designed for easier coordination or to protect a particular type of load or method of system operation. As a separate relay, NEMA device 缀员 may be provided with either voltage control or voltage restraint. The former means that the overcurrent contact can act only when the voltage on the circuit falls below a certain point. The latter means that the overcurrent-sensing element of the relay will trip at a point proportional to the voltage; with full voltage the relay will trip normally, and with no voltage it will trip at about 圆园 percent of normal current. These devices are both NEMA 缀员V. Usually, an instantaneous element is included in the same case, but it is not influenced by the voltage element.

As mentioned, the idea behind the 缀员V relay is coordination and backup. If a short circuit occurs at some distance from the alternator, the machine's current will rise, but the generator voltage, because of the voltage drops in the long feeder lines, will remain high. The voltage element keeps the 缀员V relay from tripping until a distant relay can act to clear the fault. When the fault is close to the alternator, possibly on the station bus, the voltage at the relay will drop, and the 缀员V relay acts to trip the alternator circuit breaker.

Undervoltage and Overvoltage Relays

Some alternators contain NEMA device 圆苑 (undervoltage) and device 缀怨 (overvoltage) relays. Undervoltage may be caused by a generator or voltage regulator failure or by a severe overload. Sometimes device 圆苑 is included simply to ensure that the circuit breaker is tripped when the generator is shut down. If the voltage falls to zero in the voltage-sensing circuit of the regulator (perhaps caused by a blown fuse), the regulator acts as if the generator voltage were too low and tries to raise it, probably to the generator ceiling voltage. This can obviously damage loads and possibly the generator and its excitation equipment. Voltage regulators are available that will protect against this danger. An overvoltage relay NEMA device 缀怨 can provide protection in many circumstances.

Differential Current Relays

Differential relays, NEMA device 愿苑 act if there is an internal fault in the alternator. They operate by comparing the current going into a particular phase with that going out. If the currents are not identical, some immediate action must be taken. Internal leakage in the alternator probably means that the generator has suffered some winding damage already, and the problem now is to limit the damage. If the 愿苑relays are specified, it will usually limit the damage to the alternator windings and will protect against more serious and expensive damage to the stator laminations. The 愿苑relay not only should trip the output circuit breaker, but also should remove the field excitation. To do this, the 愿苑relays are connected to trip NEMA device 愿远 the lock-out relay.

Device 愿远relays are multicontact, electrically tripped, hand-reset switches that trip the alternator circuit breaker and remove alternator field excitation. They must be reset by hand because the alternator damage indicated by device 愿苑relays must be investigated before the machine is restarted.

Directional Power Relays

When alternators are connected in parallel, there is always the possibility that a prime mover may, for some reason, lose power. The alternator connected to that prime mover will then run as a motor and drive the prime mover. Not only is this situation a waste of electrical energy, but also it can damage the prime mover. NEMA 猿圆directional power relays are connected in the generator output circuit to detect power flowing into the motoring machine and to trip the alternator circuit breaker.

NEMA type 愿员overfrequency and underfrequency relays may be used to detect, indirectly, overspeed and underspeed of the prime mover and take appropriate action. NEMA type 源园relays can protect the alternator field against open circuits, over-excitation or underexcitation, etc. Many other types of protective relays are available, but mostly they are special-purpose devices, selected for special applications.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

relay摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇继电器
array 一批,大量
actuate 动作 激励,驱使
shunt 分路(器),分流(器)
directional power relay 功率方向继电器
protective relay 保护继电器
electric circuitry 电路
circuit breakers 断路器

overcurrent devices	过流保护器
shunt trip	分路器
capacitor	电容器
instantaneous	瞬间的
time-delay overcurrent relay	延时过流继电器
station bus	电站母线
undervoltage relay	欠压继电器
overvoltage relay	过压继电器
voltage regulator	电压继电器
voltage-sensing circuit	电压感知电路
blown fuse	熔断了的保险丝
differential current relay	差动电流继电器
multicontact	多触头
remove alternator field excitation	灭磁
overfrequency relay	过频继电器
underfrequency relay	欠频继电器

[illegible]

On the basis of the generator of Drax Coal-fired Power plant, the design and the operation of electric equipments in the coal-fired power plant are introduced in detail.

Design Data

Generator output	远园MW
MVA	苑远MVA at 园愿缘PF
Voltage	圆援缘kV
Current	员怨苑远A
Efficiency	愿缘怨%
Hydrogen pressure	源bar
Hydrogen to charge system	苑缘m猿
Rotor volts and amps	缘园V at 源缘园A
Hydrogen coolers gas flow	猿苑远m猿/s
Hydrogen coolers water flow	苑园愿L/s
Main exciter	猿愿园kVA and 缘员园A
Pilot exciter output	怨园kVA and 圆园A
Stator coolant pressure	猿愿bar
Stator coolant pump capacity	猿远L/s

Operation of Generator

This generator is of the water and hydrogen cooled type, coupled to direct-driven main and pilot exciters.

The generator stator is constructed in two parts, comprising an inner frame, which supports the core and windings and an outer casing containing the hydrogen coolers. The stator winding is of the double layer, diamond coil type and formed from hollow section copper conductors contained in slots in the stator core.

The stator windings are cooled internally by demineralised water circulated around a closed circuit system. The coolant is circulated through the winding conductors from the current carrying terminals at the exciter end to the non-current carrying terminals at the turbine end of the generator. The coolant is circulated by one of two 员园园% duty AC stator coolant pumps. A DC stator coolant pump is employed to circulate the coolant in the event of failure of the AC supply. Coolers are incorporated in the system to extract heat from the stator coolant after it has passed through the winding. A purifier plant located in the system maintains the purity of the coolant.

In addition to the stator coolant flowing through the winding conductors, the stator core and the generator rotor are cooled by hydrogen which is circulated within the stator casing by two centrifugal fans mounted one at each end of the rotor.

Hydrogen seals of the thrust collar type prevent gas leakage at the points where the rotor emerges from the stator casing. Oil is supplied to the seals by one of two 员园园% duty AC seal oil pumps, at a pressure which exceeds that of the hydrogen within the stator casing. In the event of failure of both oil pumps, a back-up supply is available from the lubricating oil system. Should there be failure of both the oil pumps and the back-up supply, a DC seal oil pump will supply oil to the seals.

The rotor is machined from an alloy forging with forged steel sliprings located at the exciter end. The rotor windings are formed from hard drawn silver bearing copper strip and directly cooled by hydrogen. Brushgear is provided to feed current into and out of the rotor windings through the sliprings. A forced air ventilation system is employed to dissipate the heat generated by friction between the brushes and the sliprings.

Each end of the generator rotor is supported in a spherically seated journal bearing, housed in a pedestal and lubricated from the turbine lubricating oil system. The pedestal at the turbine end also houses the LP猿turbine shaft bearing. The circulation of currents through the bearings and the oil film is prevented by insulation between the exciter end pedestals and other equipment, including lubricating oil pipework.

Excitation for the generator rotor field is provided by direct-driven main and pilot exciters.

The pilot exciter provides a 猿phase power supply to control equipment (thyrister converter), which regulates the excitation of the main exciter field. The 猿phase power output from the main exciter is fed to a static rectifier, which supplies DC excitation power for the generator rotor field via a main field breaker. Cooling for the pilot exciter is provided by a fan on the rotor shaft, which circulates air through an open circuit ventilation system that also supplies cooling for the generator brushgear and the main exciter brushgear.

The main exciter ventilation consists of a closed circuit system. The air is circulated through the system by two centrifugal fans, one being located at each end of the exciter rotor shaft.

Housed in a pedestal positioned between the generator sliprings and the main exciter is the barring gear drive, which is provided to rotate the shafts of the machine slowly before runup and after shutdown to prevent distortion or uneven heating or cooling of the shafts. The drive comprises a clutch secured to a barring gear shaft and triple reduction gearing driven by an AC motor. Also housed in the pedestal are the generator rotor steady bearing and the main exciter inboard bearing.

a multitude of	一大批，一大群
dissipate	消散
spherically	球面地
thyrister converter	晶闸管变换器
ventilation	通风 流通空气
clutch	离合器
secure M to N	把 M 固定在 N 上
main exciter	主励磁机
pilot exciter output	辅励磁机
stator coolant pressure	定子冷却剂压力
stator coolant pump capacity	定子冷却泵容量
demineralised water	除盐水
rotor windings	转子绕组
a main field breaker	灭磁开关
barring gear drive	盘车
triple reduction	三级减速
steady bearing	稳定轴承
inboard bearing	内轴承

哉灶蚤贼 缘 孕燥憎藻则 孕造葬灶贼 阅藻泽糟则蚤责贼蚤燥灶

Each generating station must be connected to the electrical grid so that it can feed power to the system and have power available for startup. In addition, the necessary transformer and switchgear for station equipment must be available.

In this section, detail information of station will be introduced with the example of the Drax coal-fired power station.

A 圆猿援缘kV/员员kV unit transformer takes power directly from the generator terminals to supply the unit auxiliaries via an 员员kV unit board. The unit transformers for the First Half are rated at 源园MVA; those for the Completion are rated at 源愿MVA.

Each unit needs a sufficiently large supply to enable it to startup. The unit transformer is obviously not available for this duty, so the unit auxiliaries are taken from station transformers. A 员猿圆kV substation supplies four 缘苑MVA, 员猿圆kV/员员kV station transformers, each transformer then supplying an 员员kV station board.

400 kV Substation

The substation is an outdoor main and reserve busbar type, in sections, equipped with pressurised air blast circuit breakers for the First Half, and with $SF_{远}$ circuit breakers for the Completion. The change from air to $SF_{远}$ is a result of rapid development of switchgear using $SF_{远}$, where a much more compact unit is now obtainable because it is a greatly improved insulant compared with air. The main busbar for the First Half is connected to that for the Completion units via a 员猿园园MVA fault limiting reactor, and the main busbar and reserve busbar sections can be connected together with bus couplers. The substation has 圆园园MVA, 源园园kV/员猿圆kV supergrid auto transformer (which supply the 员猿圆kV substation) and 源园园kV outgoing feeders connect to the National Grid.

11 kV System

The system layout came about as a result of the gap of about 员园years between the design of the system for the First Half and its modification to cater for all six units.

Each station transformer feeds onto its own 员员kV station board; the boards are interconnected as in Figure 源援圆. The two 员员kV systems are never connected together through the bus section switches on station boards 猿and 源.

Each 员员kV unit board has three major power sources (and hence high fault level infeeds) connected to it, they are the unit transformer, station board interconnector and gas turbine, as well as major drives and auxiliary step-down transformers.

All the 11kV switchgear is rated at 900MVA make, 750MVA break and is of the air break type. The difference in make and break ratings is due to the fault contribution of running induction motors which appears during a make, but not during a break sequence.

The 11kV system would have been an extremely complex system to operate with an extensive hardwired interlocking system and at the same time it was undesirable to operate a system without interlocking as this could lead to switchgear fault levels being exceeded.

A microprocessor-based unit was designed and installed, which prevents the closure of 11kV circuit breakers, if so it would exceed the switchgear fault level on either make or break duty. The unit is provided with an override facility which enables the operator to override the interlocking function on a switchboard or a per circuit basis, and a simulation facility which enables him to check what the effect of his action would lie without actually carrying out any switching.

Two visual display units are provided in the control room, one giving a coloured display of the state of the various 11kV switchboards, which can be selected by the operator, and one giving alarms associated with the unit and system. All 11 kV switchgears are channeled through the microprocessor.

There are two exceptions where the microprocessor fault level calculation process is by-passed: an emergency start of the starting and standby boiler feed pumps, where time is of the essence, and gas turbine starts where the unit board is not interconnected to station board. In this case, the gas turbine has to synchronise in a time and time spent in the calculation stage can be saved if it is known that fault levels cannot be exceeded.

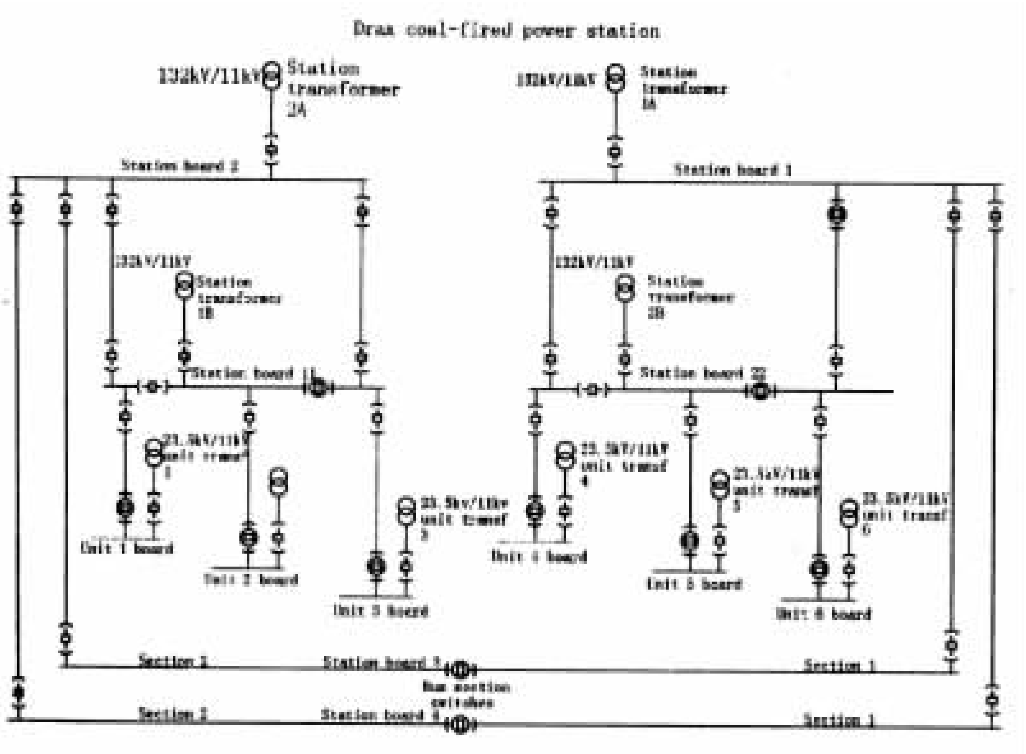
3.3 kV System

The system comprises an extensive station scheme, derived from the various 11kV station boards via 11kV/3.3kV auxiliary transformers, and a unit scheme derived from each 11kV unit board via two 12.5MVA auxiliary transformers of similar voltage ratio.

The station system comprises boards for general station services and others for coal plant services, ash and dust plant services, dust disposal services, and other special services, supplied through either 8MVA or 10MVA transformers.

The unit system carries all the equipment and drives the units having its own purposes, e.g. pulverised fuel mills, primary air fans, feed suction pumps.

A 3.3kV standby auxiliary board fed from a 11kV station board via a transformer, is provided for the First Half which can be interconnected to each unit board at the same time to provide a supply in the event of non-availability of either or both the unit



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auxiliary transformers. It also provides a maintenance supply.

415 V System

源缘V system is extensive and complicated by the fact that the switchgear for the First Half and original station auxiliaries was no longer manufactured by the time the switchgear for the Completion was due to be ordered. Some of the original station boards had to be extended to cater for the extra equipment that had to be provided for the three new units; mainly on the coal plant, ash and dust plant and CW system. The new switchgear had to be fitted at the ends of the existing gear, the main area of difficulty being the busbar extensions and the fitting of the panels.

The 源缘V system for the First Half is derived from 猿猿kV/源缘V transformers, whereas for the Completion, the supplies are derived from 员kV/源缘V transformers. The reason for the difference in obtaining the unit supplies is that operational experience of the First Half showed that voltage regulation problems existed, and the elimination of an intermediate transformer helps the regulation. In addition, automatic on-load tap changing has been fitted to the 员kV/源缘V unit auxiliary transformers. The voltage of the 源缘V unit services board is measured and used to operate the tape changer.

Like the 源员缘V unit boards, the Completion units also have used station boards. This is a new concept whereby some supplies for each unit are taken from the station supplies and is intended to cater for the increase in auxiliary load and gives improved flexibility.

A 源员缘V standby services board is provided for the Completion units and can feed each unit services board (one at a time), providing a maintenance facility and back-up.

DC Systems

Battery maintained systems at 缘园V, 员员园V and 圆缘园V provide secure supplies to the following:

Essential instruments;

Controls;

Switching closing and tripping functions;

Telecommunications;

Protection;

Interlocks;

Alarms;

Essential standby plant;

Emergency lighting;

Emergency oil pumps;

Gas turbine auxiliaries.

At 圆缘园V, each switchboard has two float chargers rated at 猿园园A each and one boost charger. At 员员园V, there is one float and one boost charger per switchboard. Centre point earthing is used throughout the systems, replacing the earlier biased earthing.

The 缘园V system on the Completion is provided by 源园园Ah batteries. In ancillary buildings, 缘园V is provided by self-contained battery charger units except in the CW and compressor houses where a transformer rectifier is fed from a 员员园V AC supply.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

board	配电盘
air blast	空气熄弧
bus coupler	母线联络开关
busboard	汇流条板
interlocking	联(闭)锁,联锁(闭塞)装置
extensive	广大的,扩大的,粗放的,彻底的
hardwired	电路的,硬连线的
override facility	人控功能
visual	可视的
display unit	显示部件(单元,装置)

by-pass	旁通，给…设旁路
synchronise	同步，并网
suction	吸，空吸
cater for	为…服务，满足（需要）
boost charge	增强放电
biased	偏压的，附加励磁的
unit transformer	（厂用）变压器
reactor	电抗器
modification	更改
primary air fan	一次风机
float charger	浮充盘
boost charger	调压柜

哉状匮窈藉韶 马贝燥藻葬藻蒜壮杂赠蕹藻皂泽

Protective Relaying

Most electrical engineers have no more than a casual understanding of protective relaying, and most power plant engineers are only dimly aware of its existence. It is a foreign subject, talked about and written with foreign symbols, that the average power user does not need to understand.

For the utility engineer, however, protective relaying is a way of life. The utility's relay engineers spend all day figuring possible combinations of faults that might occur in the network and designing relay circuits to protect against them. In the process, relay engineers have developed a highly systematic approach to relaying and an efficient shorthand for designing circuits and specifying relays.

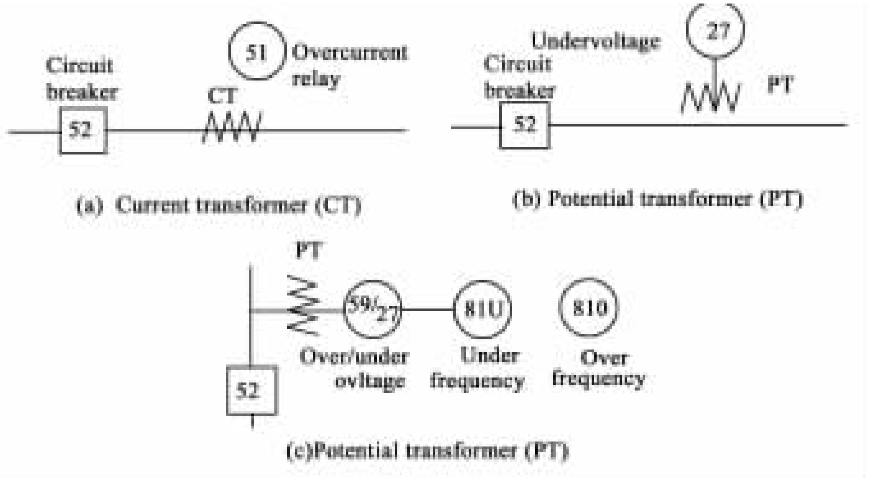
The purpose of protective relays is to detect unsafe or out-of-limit conditions in a power system and to trip appropriate circuit breakers. The prime intent of the protective relay circuit is to isolate the faulty section of the circuit so that the remainder of the network can continue to deliver power without interruption. If the circuit breakers can be opened fast enough to prevent damage to electrical components, so much the better.

The most commonly needed relays in an interconnected system are overcurrent, overvoltage and undervoltage, overfrequency and underfrequency, differential, and relays that detect the direction of power flow. The relay engineer shows each of these relay types along with many others on a relay diagram, not by its name, but by a number.

Instrument Transformers

Instrument transformers transmit current, voltage, or frequency signals to the protective relays (Figure 源猿. Two types of instrument transformers are the current and potential. They are needed because the high voltages and currents in a power circuit must be reduced to values that can be conveniently handled by instruments and protective relays.

A current transformer (CT) uses the power conductor as its primary winding, and it produces a small current in its secondary winding that is proportional to the power line current. Normally, 缘A at the secondary is equivalent to full-load current flowing in the primary.



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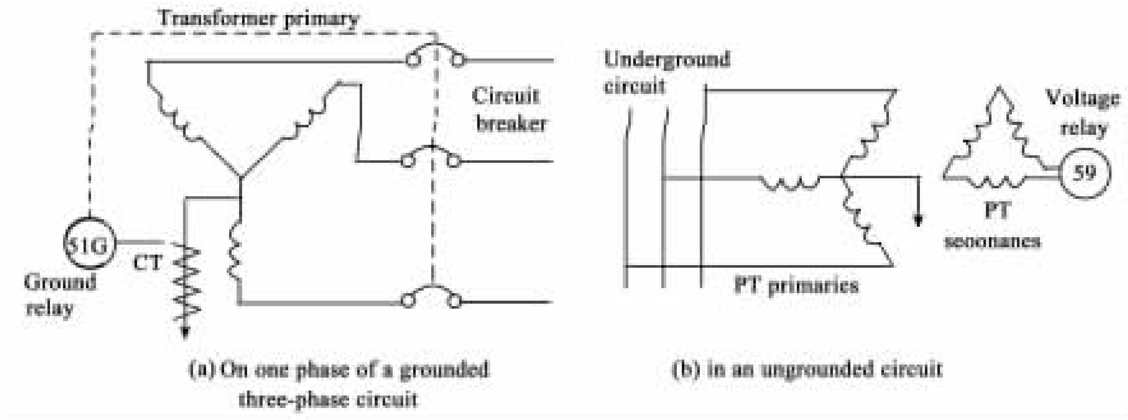
A potential transformer (PT) has its primary winding connected between two of the three power lines or between one phase and ground, and it produces a voltage at its secondary winding proportional to the line-to-line or line-to-ground voltage, respectively. Normally, 员圆园V at the secondary winding is equivalent to the rated voltage at the primary winding.

Most power circuits are three-phase and may use three or four conductors, but they are specified by using one-line diagrams. At each measurement point, there may be one, two, or three instrument transformers and up to three relays. But only one transformer and one relay are indicated on the relay diagram.

Ground Faults

A ground fault on one phase of a grounded three-phase circuit produces an unbalanced current in the grounded leg of a wye-connected transformer or generator (Figure 源源(a)). The ground current may be quite small initially and will go undetected by the regular overcurrent relay, which is set to read hundreds of thousands of amperes. But a sensitive ground overcurrent relay can be set to detect current flowing in the neutral leg and to trip the appropriate breaker.

A ground fault in an ungrounded circuit can be detected only as an imbalance in the line-to-line voltages (Figure. 源源(b)). This is done with three voltage transformers connected in what is known as an open delta. As soon as the circuit becomes unbalanced due to a ground fault, a voltage appears across the open delta and can be detected by a voltage relay.



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Types of Relays

Directional relays are vital in interconnected systems to control the flow of power (Figure 源缘 (a)). They are usually set to detect a value of current, but since current flows both ways in an AC circuit, they detect direction in terms of power flow. Two instrument transformers are needed: a CT to measure magnitude and a PT to polarize the relay to read in one direction only. A directional relay is always needed to ensure that power does not flow into the interconnected generator, causing it to act as a motor.

A synchronizing relay supervises the manual synchronization of an interconnected generator (Figure 源缘 (b)). An operator manually adjusts the speed and frequency of the in-plant generator, using a synchroscope to judge when the generator is in phase with the utility system, at which point the operator closes the circuit breaker. But the damage that could be inflicted by closing the circuit breaker out of synchronism is so great that a supervisory synchronizing relay is usually mandatory. This relay needs two PTs, one on each side of the circuit breaker.

An automatic synchronizer makes the frequency adjustment by itself. All the operator has to do is to push a button; no separate protective relay is needed.

Differential relays are needed to detect internal faults in the windings of transformers and generators (Figure 源缘 (c)). They do this by looking at the current flowing into and out of each phase winding. Any imbalance in these readings indicates there is a fault between windings, and the circuit breaker must be opened before the damage gets worse. A differential relay needs six CTs, two for each phase.

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ampere 安培

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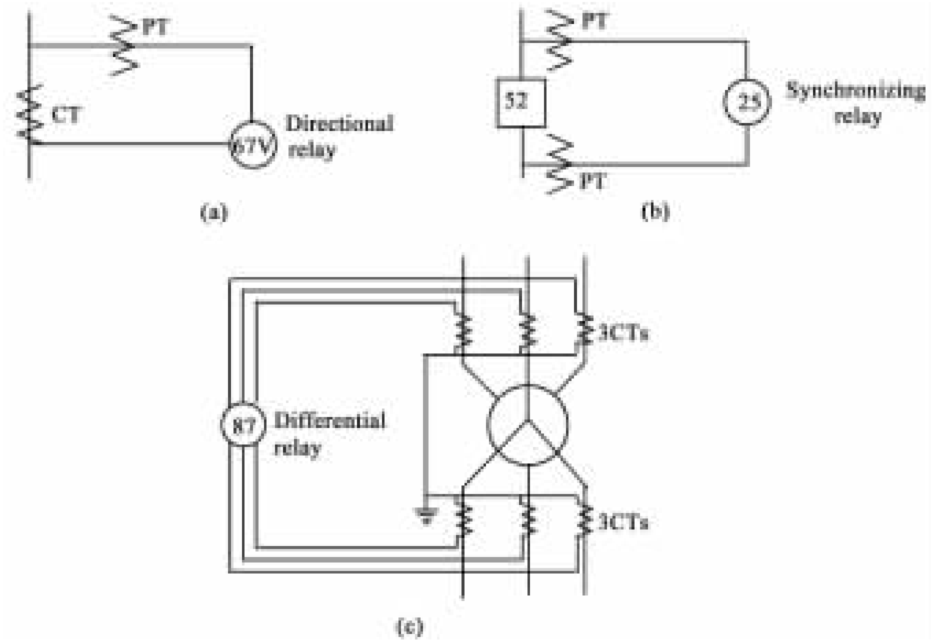

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synchroscope	同步指示仪
sophisticated	复杂的,高级的,尖端的
controversial	争论的,引起争论的
inevitable	不可避免的,无法回避的,必然(发生)的
grossly	严重地
shed	摆脱,抛弃
reclosure	重合闸
catastrophic	毁灭的,灾难的
shear	切断
inhibit	抑制,禁止
hazard	危险
dimly	模糊地
shorthand	速记
open delta	开口三角形
synchronizing relay	同步继电器
mandatory	必须遵循的,强制性的
supervisory	监控的,监视的

哉状擅戒藻蘸摇杂责藻蘸噪曹孕灰燥藻蘸蘸灶酝藻蔡憩燥释

Once a generator is interconnected and operated in parallel with the utility network, it becomes part of a vast, sophisticated machine. So it needs sophisticated protection against what the network can do to the generator and what the generator can do to the network.

Main Circuit Breaker Trips

Isolation of the customer's generator occurs if the utility circuit breaker opens for any reason (such as for clearing a fault). This leaves the generator coupled to the full plant load and to all adjacent customers connected with downstream of the tripped circuit breaker. In such an event, it is almost inevitable that the generator will be grossly overloaded and will immediately start to drop in both voltage and frequency, with possible damaging results. Thus, in any interconnected system, the customer's main circuit breaker must trip whenever utility power is interrupted.

Usually underfrequency or overfrequency relays can cause the main circuit breaker to trip. Typically, these are set at 59 and 61 Hz so that the circuit breaker trips as soon as the generator output reaches these frequency limits. But it is just possible that the customer's governor works better than expected, so that the generator maintains exactly 60 Hz for a few seconds after being isolated. For this reason, most utilities are also insisting on overvoltage and undervoltage relays in addition to the frequency relays.

Once the main circuit breaker has opened, the customer is responsible for what he or she does with the generator output. Hopefully, the customer will be able to shed nonessential loads and continue to operate essential loads on her or his own generator. Usually this means opening the generator circuit breaker first, then shedding nonessential loads, next reconnecting essential loads to the generator. With suitable high-speed relaying, it may be possible to shed nonessential loads quickly enough to avoid interrupting generator output.

Main Circuit Breaker Reclosures

Automatic reclosing of utility circuit breakers can be catastrophic for the customer-generator. If the in-plant generator has fallen well out of phase by the time the utility circuit breaker recloses, the resulting shock can, be enough to shear the generator shaft, not to mention the electrical damage that will be done. There is no way that plant circuit breakers can operate fast enough in this situation to prevent damage.

The only sure protection is to keep the in-plant generator off the line until the utility system has stabilized. The utility may or may not agree to inhibit automatic reclosing if the customer's circuit breaker is still closed, Normally, inhibiting is done with a voltage relay on the customer's side of the circuit breaker, which prevents reclosing if the line is live.

Reclosing of the customer's circuit breaker presents further problems. Clearly, this circuit breaker must not close onto a dead utility line or onto a live line to which it is not synchronized. If the utility will not provide an interlock between circuit breakers or agree to inhibit automatic reclosing, then a time delay is needed to ensure that the utility system is stable.

Synchronizing equipment is also needed across both the customer's main circuit breaker and individual generator circuit breakers. It can be either automatic synchronizer or a synchronism check relay. In the latter case, the generators are synchronized and the circuit breaker is closed manually, but the check relay prevents reclosing out of synchronism. If the plant has become disconnected from the utility and is running on its own generators, the main circuit breaker's synchronizer allows the plant to reinterconnect without stopping the generators.

Proper Relay Settings

Relay settings are an endless source of misunderstanding between the utility and the customer-generator. This is largely because the utility's standard approach is to drop a generator offline at the moment trouble is detected, while the customer's main interest is uninterrupted power for the plant. Thus, even if the utility has published protection requirements and has inspected the relaying on an interconnected system, there may be no clear-cut agreement on where relay trip limits should be set.

A typical problem is voltage surges on the utility's line, caused by the switching of banks of power-factor correction capacitors. Often these surges are sufficient to trip the undervoltage relays and drop out the customer's plant along with the generator. The utility is not about to forewarn the customer of these surges. In at least one case, the customer discovered the cause of repeated plant trips only after realizing that they were occurring at the same time every day.

Conversely, relay coordinating is becoming a big headache for utilities. A small interconnected generator does not present too many problems here, but as the generator gets larger, phase overcurrent relays that are a normal part of any generator must be capable of coordination with utility relays. The utility may insist on voltage-controlled overcurrent relays.

What constitutes a large or a small generator? Southern California Edison Co. has published two sets of relay requirements for generators under and over [illegible]kVA. Georgia

Power Co. classifies all generators over 缘MVA as large and all others as small. Hawaiian Electric Co. has set 缘园园kVA as the limit for small generators. From the point of view of the relay engineer, however, the importance of the generator's size depends more on its output relative to the capacity of the feeder to which it is interconnected than on its absolute kilovoltampere rating.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

legitimate	合乎逻辑的，正当的
inadvertently	不注意地，漫不经心地；非故意地
clear-cut	干净利落的；明确的；确定的，清晰的
surge	电涌
interconnected system	互联系统
out of phase	非同相的
off the line	离线（与主线路脱离）
live	（文中指）通有电的路线
power-factor	功率因素
correction capacitors	校正电容
drop out	解剖

Grounding

Three-phase power systems may be operated grounded or ungrounded. In either system, the power is carried on three conductors or phases. The grounded system may also include a fourth neutral conductor, which carries only the unbalanced current, if any. The windings in transformers, generators, and other three-phase equipment may be connected in wye or delta form. Generally, the delta connection is used in ungrounded systems, and the wye in grounded systems, with the common or neutral point connected to ground and/or the neutral conductor. The neutral conductor operates essentially at ground potential if the three phases are balanced.

Three Types of Systems

The grounded system provides two voltage levels: line-to-line voltage (源园园V in the common 源园园V system) and line-to-ground or line-to-neutral voltage. The line-to-ground voltage is 员/√猿(越园.缘苑) times more than the line-to-line voltage. Typical four-wye systems provide 源园园/圆猿园V for power and lighting or 圆园愿/员圆园V. If a ground fault develops on one of the phase conductors, a ground protection relay immediately detects the large unbalanced current in the neutral conductor and trips a circuit breaker, isolating the fault and cutting off power to the process.

The ungrounded system has a fixed line-to-line voltage only. In the event a ground fault develops on one conductor, that conductor falls to ground potential, while the potential of the other two conductors rises to the line-to-line voltage above ground. If the fault current is small, which is often the case, the system can continue to operate until the ground fault can be located and repaired. This is why the ungrounded system is preferred by many plant operators.

Problems arise only if the ground fault is left unrepaired eventually, a second ground fault occurs on another phase in another part of the system. The result is a much more destructive line-to-line fault (at the higher line voltage), which damages equipment in two parts of the system.

An additional problem that can occur with ungrounded systems is overstressing of insulation. Even with a low-level fault, the two unfaulted conductors are raised above their rated potential. If a high-level fault occurs, transient voltages are generated as the fault arc strikes and restrikes, and in the circuit breaker as it operates to clear the fault. These transient voltages impose much higher stresses on the conductor insulation of the ungrounded system.

The resistance-grounded system is preferred by many industries. In this case, the neutral conductor is grounded, not solidly, but through a resistance. The size of this resistance is selected so that if a ground fault occurs, the current flowing through the neutral conductor will be large enough to trip the ground fault relay, but not so large that the fault arc can do serious damage, such as destroying motor laminations.

Utilities prefer large ground fault currents that ensure unambiguous operation of ground fault relays. Another reason that utilities prefer solidly grounded systems is that it allows them to use grounded-neutral lightning arrestors, which are less expensive and more effective than ungrounded arrestors.

Cable

Cable, basically, is one or more strands of metal, encased in insulating material. The term cable is also applied to multiple individual insulated conductors assembled together. The insulating material will be, for voltages higher than about 圆kV completely encased in a grounded electrostatic shield, to keep the voltage stresses uniform all around the insulation and to provide safety, should anyone touch the insulation. For protection of the relatively fragile shield, and to provide enclosure of the conductors of multiple-conductor cable, an outer jacket is a general component.

Cable Construction

In North America, most cables of No. 愿American wire gauge (AWG) and larger are stranded; smaller sizes are solid unless flexibility is of great importance. In stranded cable, individual strands are not larger than 猿圆缘mm in diameter, for flexibility and ease of installation in conduit. With this, the number of strands is one of 员,苑,员怨, 猿苑, or 远员, up through 员,园园园MCM (员,园园园 circular mils, or 缘园远mm圆) size.

In the rest of the world, where conduit is not used as predominantly, the conductors may be solid, or single-strand, up through quite large sizes. Cables are quite generally self-supporting between cable straps at suitable spacings.

(员) Conductor Materials.

The conductor materials are copper or aluminum, the former being predominant for sizes below about No. 圆AWG, with aluminum becoming widely used for feeders, etc. of larger size. Copper cable is almost universally annealed, for easy flexibility. Aluminum, however, has given problems in the electrically conductive (EC) grade, owing to cold flow away from terminal clamping fittings.

Consequently, the EC aluminum used for wiring has been generally the 猿源hard-drawn temper, which is springy and hard to bend. It also tends to break where bent when it is placed under a screw terminal. A newer alloy type containing about 园缘 percent iron, has displaced the EC type for circuit sizes.

Copper has greater conductivity than aluminum, size for size, but copper is 猿猿 times greater than specific gravity, and about double the cost per pound (kilogram) compared to aluminum, makes the latter economically attractive. On a cost-per-ampere basis, copper wire is about 源times as costly as aluminum.

(2) Major Insulation Types.

The modern medium-voltage insulated cables utilize, almost universally, one of two major insulation types: EPR and CLP. Another type is silicone rubber. EPR, a rubberlike material, is a cross-linked combination of ethylene and propylene with a number of additives. It looks like, and performs very much like the rubber-type insulations in use for many decades. Its performance has been excellent, especially in freedom from "treeing", a weakness of CLP cables. (Treeing is the slow progressing of microscopic channeling through insulation, usually from some void or point within the insulation.)

XLP or CLP, a milky-appearing hard material, is polyethylene cross-linked by using a kind of peroxide and other additives. The cross linking overcomes the melting temperature [221°F (105°C)] of pure polyethylene, although above this temperature it is softer than EPR. Its cost is slightly lower than that of EPR, making it more widely used for distribution lines but not favored where the highest reliability is desired.

Silicone rubber is a rather soft, rubbery material occasionally used where abnormally high or low ambient temperatures are encountered. Its electrical performance is excellent, but its low physical strength makes protection against any physical stresse obligatory. It is frequently used near boilers, steam and hot water lines, stacks, etc.

New Words and Expressions

overstressing	过压力
resistance	电阻
solidly	连续地,不间断地
unambiguous	不含糊的,清晰的 明白的,清楚的
arrestor	捕捉器
strand	(线、绳等)股
encase	(全部)盖住,围住
anneal	退火,焖火
clamp	夹住,夹紧
cold flow	低温下固体塑性变形流动
springy	有弹性的,挠性
screw	螺杆
hard-drawn	冷拉的,冷拔的
ethylene	乙烯
propylene	丙烯
peroxide	过氧化物
polyethylene	聚乙烯
obligatory	必需的

Part Five 摇Governing and Protecting 摇摇摇摇摇摇System

哉燥灌擞粤蕴擦 阅涛云 员灶贼则燥凿怎糟贼蚤燥灶

摇摇As a recent tendency, newly built thermal and atomic power plants are of larger and larger scales. Thermal power plants of 员，园园园MW class have already been in operation, and also atomic power plants of 员，员园园MW class are in operation. With these turbines of large capacity, the rotor moment of inertia is small in relation to the large output, and thus a governor is required which works with a quick response to loss of the load in order to limit the maximum ratio of speed rise.

On the other hand, as the components of the large-scale units are larger in number and more complicate, their operation is more generally controlled by an automatic controller and a computer system. The turbines also need to be controlled by a higher performance system for their more complicated and advanced system.

To accommodate such demands, an electro-hydraulic governor (EHG) had been developed as a new turbine controller, compared with the conventional mechanical-hydraulic governor (MHG), EHG has the valve drive unit which is compact and has an improved response speed owing to the increased control oil pressure. In addition, EHG provides a quality control since it is free from the influence of backlash and friction as integrated, which is unavoidable with MHG.

Hitachi analogue type EHGs are installed and being in operation in many power plants; based on the experiences with the analogue type EHGs, Hitachi developed a digital type electro-hydraulic (DEH) Governor in which latest highly advanced microcomputer is incorporated and which can cope with a variety of increasingly more complicated control and has a high reliability and maintainability. The first DEH Governor was put into operation in May 员怨苑怨援 A DEH Governor for 员，园园园MW power plant was also put into service in August 员怨愿猿援 Both have been running in order up to now.

The normal governing devices in the EHG operate the control valves through hydraulic relays. The various normal governing devices are:

(员 Speed control unit and load control unit;

(圆 Load limit control unit.

The pre-emergency devices in EHG function similarly to the normal governing devices in case of abnormal operating conditions. Pre-emergency devices, which may operate the intercept valves or the turbine control valves, are:

(1) Acceleration relay, which operates to close the intercept valves rapidly, overriding the normal speed control, when load rejection (1缘% and above) occurs;

(圆 Overspeed protection relay, which is operated by an unbalanced signal from the generator load/turbine output, to close both the turbine control valves and intercept valves, thus rapidly overriding the normal speed control when high load (源园% of rated and above) rejection occurs;

The emergency devices operate the turbine and reheat stop valves (SV) and the bled steam relay dump valve. The various emergency devices are as follows:

(员 Overspeed emergency governors with provisions for oil tripping;

(圆 Duplicate main trip solenoids (MTS). The following signals actuate the MTS;

① Turbine solenoid trip PB;

② Low vacuum trip;

③ Turbine thrust bearing wear failure;

④ Low T. G. oil system lubricating oil pressure trip;

⑤ Low main steam temperature trip;

⑥ High LP exhaust hood temperature trip;

⑦ High T. G. bearing vibration trip;

⑧ Low speed eccentricity trip;

⑨ EHG Major trouble;

⑩ EHG back up over speed trip;

⑪ Main oil tank level low;

⑫ High HP turbine exhausted steam temperature trip;

⑬ Generator trip;

⑭ Turbine HP/LP bypass control valves failure trip;

⑮ Boiler M. F. T. trip;

⑯ Thrust bearing metal temperature high;

⑰ Journal bearing metal temperature high;

(猿 Master trip lever (located on turbine front standard).

Overspeed Emergency Governors

Turbine unit is provided in overspeed emergency governor and emergency trip, which are designed to allow for the independent testing while carrying load.

The emergency governor is an unbalanced ring, which is held concentric with the shaft by a spring. When the speed reaches the emergency governor trip speed setting, the centrifugal force of the ring overcomes the force of the spring and the ring snaps to an eccentric position. In so doing, it strikes the trip finger and thereby operates the emergency trip valve to shut reheat stop, turbine stop and the bled steam relay dump valves. The emergency governor can be made to trip at normal speed by admitting oil through the oil trip valve.

The emergency trip valve is a three-way valve which feeds oil from the hydraulic line to the relay dump valve for the turbine and reheat stop valves (RSV) and to the bled steam relay dump valves. When it is operated, it dumps oil from the bled steam relay dump valve; from the relay dump valves of the turbine and reheat stop valves; with the result that all turbine steam admission valves closed. The emergency trip valve can be reset locally at the front standard by pulling the reset handle or the reset push-button on the UCP. The reset handle operates an oil pilot valve, which admits oil to a small piston mounted on the stem of the trip valve. This piston produces enough force to reset the emergency trip valve. When it is reset, the turbine stop valves and the reheat stop valves are opened and the bled steam relay dump valve is reset.

Limit switches are actuated by the rod of the emergency trip valve and the hydraulic reset piston to energize position indicating lights. These lights are all arranged close together on the front standard front wall near the corresponding handles.

Solenoid Trip

It is recommended that a trip button be provided for energizing the turbine solenoid trip from a location away from the turbine. This will permit shutting down the turbine in the event of fire or some other occurrence that makes it impossible to get to the trip levers of the turbine. In some cases the remote trip button will trip the boiler and some auxiliaries as well as the turbine.

[illegible]

moment of inertia	惯性矩
governor	调节器,调速器,调节系统
large-scale unit	大型机组
automatic controller	自动控制器
electro-hydraulic governor	电液调节系统
conventional	传统的,普通的
mechanical-hydraulic governor	机械液压调节系统
owing to	由于,归功于
backlash	齿隙,游隙,侧向间隙
analogue	模拟的
digital	数字的

cope with	克服,适应,对抗
maintainability	可维修性
put into service	投入使用,投入运行
in order	按顺序,处于…状态
abnormal	不正常
intercept valve（IV）	中压调节阀,再热调节阀
acceleration relay	加速度继动器
overspeed protection relay	超速保护继动器
stop valve（SV）	主汽门
reheat stop valve（RSV）	再热主汽门
overspeed emergency governor	危机保安器
main trip solenoid	主跳闸电磁线圈
exhaust hood	排汽缸
eccentricity	偏心
back up overspeed	附加超速保护
PB（push-button）	按钮
UCP（Unit Control Panel）	单元/机组控制板

[illegible]

Steam Generator Control

The objective of the steam plant control system is to provide the steam flow required by the turbine at design pressure and temperature. Further, it is desired that the steam plant respond rapidly to condition changes without any significant oscillations or hunting. The variables that can be controlled to provide the desired operations are fuel firing rate, airflow, gas-flow distribution, feedwater flow, and turbine valve setting. The key measurements that describe the plant performance are steam flow rate, steam pressure, steam temperature, primary and secondary airflow rates, fuel firing rate, feedwater flow rate and steam-drum level, and electrical power output. The control system must act on the measurement of these plant parameters so as to maintain plant operation at the desired conditions.

Most modern control instrumentation utilizes closed-loop control. In this mode, the actual output of the system is measured and compared to some demand signal (set point). The difference between the measurement and demand, called the error signal, is then used to reduce the difference between measurement and demand (set point) to near zero.

Proportional control is the simplest type of closed-loop control. In this mode, the controller output is proportional to the error signal. The control signal will be either directly or inversely proportional to the error signal, depending on the control action required.

To ensure stable behavior of a proportional controller, there is a dead band around the set point in which no controller output is provided. With a simple proportional controller, the final stable value of the control variable will then be "offset" from the set point by some small amount. This offset can be eliminated by incorporating integral or reset control action within the controller. In integral control, the control action is based on the integral of the deviation between the controlled variable and the set point over the time period in which the deviation occurs. By incorporating this action the offset produced by simple proportional control is eliminated while maintaining system stability. This use of the terminology reset control for this control mode comes about since the band of proportional action is shifted or reset so that the controlled variable operates about a new base point.

Almost all power plant control instruments combine both proportional and integral control actions. In some cases, derivative control is also added. A derivative control action is determined by the rate of change of the controlled variable. If a variable begins to change rapidly, a large control signal is provided. Once the rate of change is reduced, the proportional and integral actions take over and do the final positioning. The combination of all three modes of control action provides more rapid response and more operation than possible with simpler systems.

Steam Superheat Control

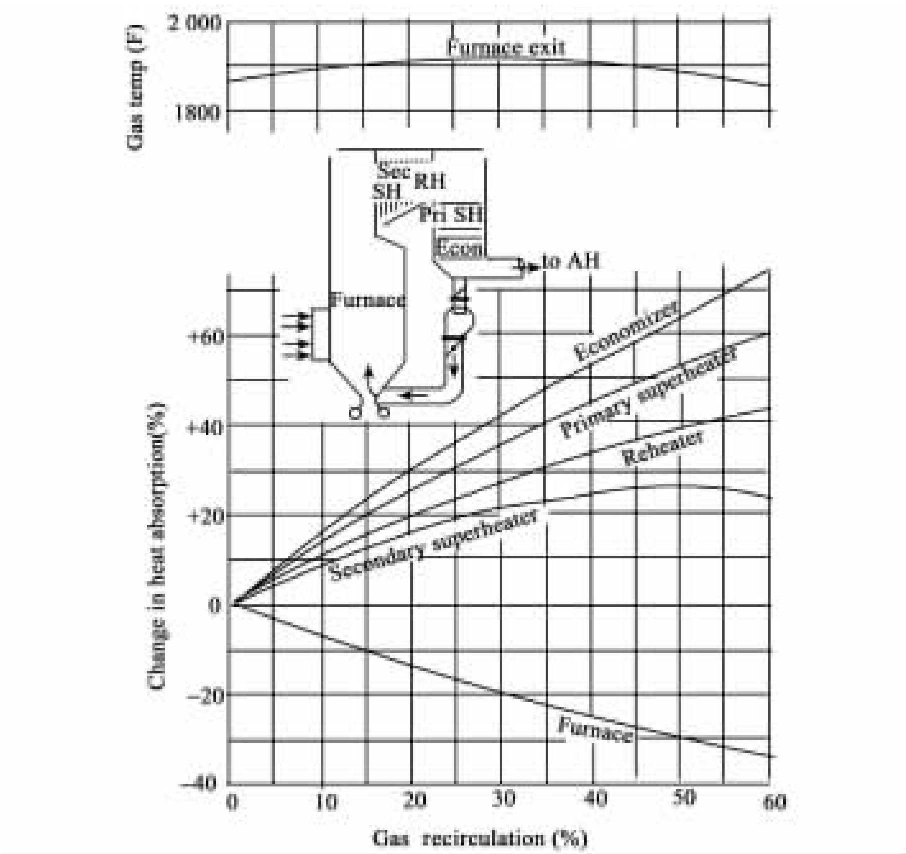
It is necessary to maintain steam temperature at or near the design point. Excessive temperatures will lead to excessive turbine corrosion, while low temperatures will cause a significant decrease in plant efficiency.

The temperature of the superheated steam reaching the turbine depends on a number of factors: load on the plant, amount of excess air used in combustion, feedwater temperature, heating surface cleanliness; distribution of heat input among the burners at different positions, variation in fuel characteristics, use of saturated steam for soot blowing, or auxiliaries. The most important of these factors is load variation.

Both the volumetric flow and temperature of combustion gases increase as load is increased. Thus in convective superheaters the steam temperature increases as load increases. In a radiant type of superheater, the radiant heat input does not increase much with load; therefore, the steam temperature decreases with load. By using a radiant superheater in parallel with a convective superheater it is possible to maintain a more constant steam temperature. However, since most of the heat is usually transferred in the convective superheater, an overall rise in temperature with load is still seen. Additional control and adjustment techniques are therefore required.

An additional technique for limiting variation in steam temperature with load is through burner control. Here the effective boiler furnace volume is varied in response to load variations. The effective boiler volume is reduced by not firing the upper burners at low loads. In addition, the burners can, in some designs, be tilted downward at low loads and upward at high loads. By changing the effective boiler area, the heat absorption at low loads is reduced and the gas temperature entering the convective superheater is kept near the desired level. This decreases the variation of steam temperature with load.

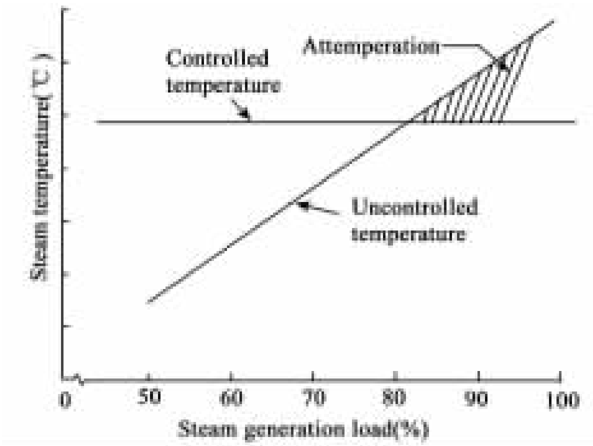
The effect of load variation may be minimized further by use of controlled gas recirculation. In this method (see Figure 缘灵 some gas from the boiler, economizer, or air heater outlet is reintroduced near the furnace inlet by means of suitable blowers and ductwork. The primary function of gas recirculation is to reduce the heat absorption in the furnace (boiler region) by diluting gases and thus lowering the temperature in the radiant zone. This reduces the heat absorption in the boiler zone while increasing the gas velocity going through the convective superheater and increasing its heat absorption. Thus, by recirculating gas at low loads, higher steam temperatures are possible at low loads.



[illegible]

In some gas recirculating systems recirculated gas is admitted near the furnace exit. This is called gas tempering. In this approach the furnace exit temperature is reduced without affecting furnace heat absorption. In once-through boilers, a combination of gas tempering and recirculated gas addition at the furnace inlet is common. Furnace exit-gas temperature and furnace heat absorption can then be independently controlled.

In general, gas recirculation and burner control can provide a nearly constant superheat temperature for a given furnace design from somewhat over 缘园% of full load to over 怨园% of full load. However, such control is generally not adequate to maintain the desired steam temperature at nearly full load. If design temperature conditions are maintained at the part loads, when all burners are on and tilted upward and there is no gas recirculation, the steam temperatures tend to exceed the design point as full load is approached (see Figure 缘圆. At these highest loads it is necessary to reduce the steam temperature. This is called attemperation. Such attemperators may be of the surface type, in which a heat exchanger is used, or of the direct contact type. The most common form of the direct contact attemperator is the spray attemperator. In this unit, feedwater is sprayed into the steam through a spray nozzle discharging into a venturi which provides mixing.



[illegible]

In controlling steam temperature via gas recirculation, a two-element control is generally used. Since the response to damper motion is slow, primary air flow usually governs the initial damper position. Final adjustment comes from integral action on the steam temperature. When beyond the gas recirculation range, the attemperator is controlled by balancing feedwater flow to the spray against steam flow or load with final integral action (reset) determined by the steam temperature.

It should be noted that the presence of a reheater will complicate the designer's task. The methods used for superheat control will also affect the temperature of the reheated steam. In a recirculating unit, reducing the effective furnace area will increase both superheat and reheat temperature. The latter action may be undesirable.

[illegible]

oscillations	振荡
hunting	波动
dead band	不工作区域,死区,非灵敏区
incorporate	引入
terminology	专门名词,术语
base point	基点
derivative	导数,微商
excess air	过剩空气

soot blowing	吹灰
volumetric	体积的，容积的
tilt	倾斜，摆动
recirculation	再循环
dilute	稀释，冲淡
once-through	直通的，一次的
attemperator	减温器
venturi	文丘里喷嘴
damper	挡板

[illegible]

The overall power plant station controls must sense and respond to changes in system load. The goal is to maintain bus-bar voltage and frequency constant. Consider a small system supplied by a single turbine generator and assume that a large industrial motor is switched on in the system. This reduces the overall electrical resistance of the system, allowing a larger current to flow through the generator armature circuit. This increase in current increases the turning resistance of the field rotor through an increase in armature magnetic field strength. The increased resistance slows the turbine-generator shaft rotational speed.

The reduction in the turbine shaft speed is sensed by the turbine governor. The governor signals the turbine steam valves to open, increasing the steam flow to the turbine. The increased steam flow to the turbine causes a pressure drop in the steam supply system. If the power plant is a fossil system, the pressure reduction signals the automatic combustion control system to increase the forced-draft and induced-draft fan speeds. The pressure reduction also signals the combustion control system to increase the firing rate. In a nuclear power system, the reduction in pressure would require an increase in the power level of the reactor. This would be achieved through a slight withdrawal of the shim control rods.

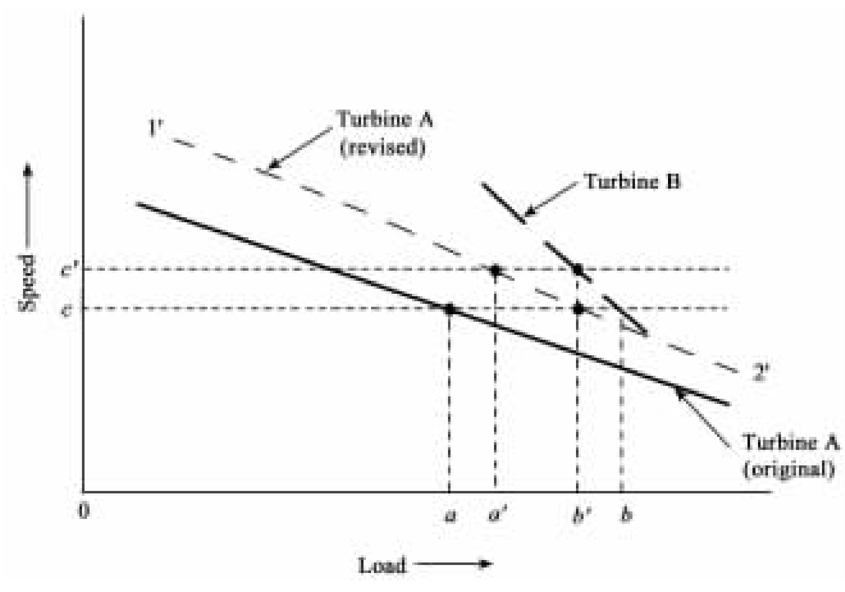
Power plant steady-state conditions are again achieved as the increased heat rate produces additional steam that again balances the system pressure. The governor reaches a new balance point, which maintains the higher load requirement, allowing an increased steam flow to bring the turbine-generator shaft speed back to design conditions.

In an actual system, there are a number of turbine-generators in parallel. When load and generation are in balance, all of the generators are locked into the speed, which produces the desired system frequency (synchronous speed). Since the generators are operated in parallel, all generators must always produce a common voltage and frequency under all circumstances.

The load that a turbine can deliver is determined by its load-speed characteristic. At a given position of the turbine speed controller, this load-speed characteristic is fixed. When additional load is suddenly added to the system, the only way that this can be immediately supplied is for the system frequency to drop slightly. Thus, if we have two turbines in parallel, with the load-speed characteristics shown in Figure 缘猿 the speed (which is proportional to frequency) is c, which is below the speed c' needed to produce the desired system frequency. To restore the system frequency, the load-speed characteristics of one of the turbines must be changed. This is accomplished by moving the turbine's speed controller in the direction that would increase speed. In a steam turbine, the speed-load curve is changed and the turbine admission valves are opened further.

Assume that in the example of Figure 缘猿 turbine A is to take the increased load. As shown in the figure, the load on turbine A would be increased until the system was operating at the desired frequency. At that time the new load-frequency curve of unit A would be 1′—圆 and it would have increased its share, of the load to 园–a′ while turbine B would have reduced its load to 园–b′.

If the load on the system were to decrease, the frequency would rise as both turbines increase their speed slightly. The speed-load characteristics of turbine A would then be changed by closing the turbine admission valves. A new equilibrium position would then be reached when the system frequency is restored to its desired value.



[illegible]

Behavior of a system containing a number of turbine-generators in parallel is essentially the same. Increasing the system load cause the speed of all turbine-generators to decrease slightly. The system dispatcher, or more likely dispatch computer, determines which turbine-generator will be used to take the load. The turbine admission valves to the selected turbine are opened, its speed-load characteristic is changed, and the system reaches a new equilibrium at a slightly higher frequency. The loads on the other turbines in the system will be decreased since they will be operating at a slightly higher speed. However, since there are normally a considerable number of turbine-generators in parallel, the load change of any turbine, except the one designated to take the load, is quite small. The reverse behavior would be seen on a load decrease. Note that the operation of this control scheme requires that all turbine-generators have a speed load characteristic curve with a reasonable negative slope. A nearly flat speed load curve would result in unstable operation since such a curve would lead to large changes in load for small changes in speed.

Electrohydraulic Speed Control System actions as the mechanical-hydraulic system just described. However, the basic signals received, and their initial amplification, are electrical rather than mechanical. The speed signal is generally a voltage proportional to turbine speed generated by a small alternator attached to the turbine shaft. The speed signal is electrically compared to the set point and an error signal produced. After appropriate amplification, the signal operates a servomotor, which produces the hydraulic pressure needed to reposition the control valves. The system differentiates the speed signal and uses this to limit the acceleration of the turbine during startup.

As indicated previously, the turbine speed is locked into the synchronous speed of the system when it is operated in parallel with other turbine-generators. To obtain a change in load, an electrical signal, which is equivalent to a speed error signal, is introduced (see Figure 缘源. The load error electrical signal added is proportional to the difference between the desired load and actual load (load torque). The amplified load error signal operates the servomotor, which in turn generates the hydraulic pressure to reposition the steam control valves.

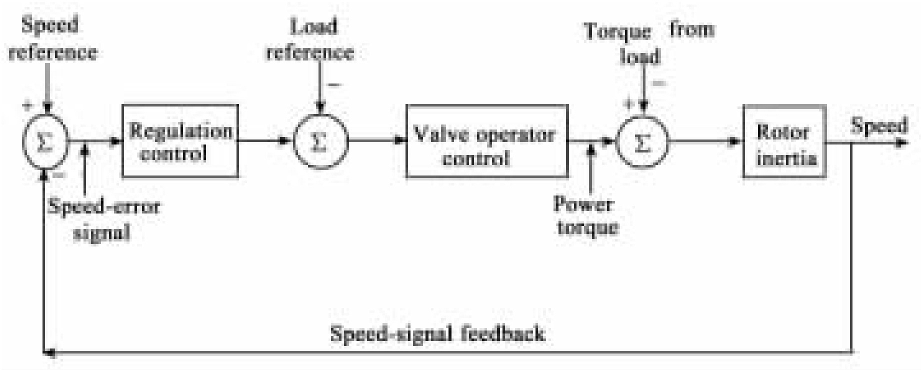
In addition to the normal operating controls, there is also an auxiliary pressure control that will close the control valves if the boiler pressure decreases below some predetermined value (such as 怨园% of design pressure). This system also regulates the control valves to limit pressure increases to less than some predetermined value, such as 员园% of design rated pressure.

Turbine overspeed protection is provided by an overspeed trip reference signal. If the turbine speed exceeds the overspeed trip reference speed, the stop valves are immediately closed.

There are several other signals that can shut down the turbine to prevent damage. These include excessive vibration, low pressure, bearing failure, and high temperature.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

armature	转子
field rotor	励磁转子
automatic combustion control system	燃烧自动控制系统
withdrawal	取出,拉动
shim	补偿棒



[illegible]

in parallel	**并列地**
synchronous speed	**同步速率**
speed controller	**调速器**
admission valves	**进汽阀**
equilibrium	**平衡（状态、图、曲线）**
behavior	**工作情况，运转状态**
dispatcher	**调度员，分配器**
slope	**斜坡，斜率**
electrohydraulic	**电动液压的**
amplification	**放大**
set point	**设定点**
differentiate	**求微分，微分运算**

Computer Application

Faced by an increasingly complicated existence, power utilities need efficient tools and aids to ensure that electrical energy, of the desired quality and availability can be supplied at the lowest cost. Centralized supervision gives a total overview of the momentary status in the power process. Computers supervise the current operation and give alarms to the operators when deviations from the normal state occur, e. g. unexpected circuit breaker operations or line flows exceeding operational limits.

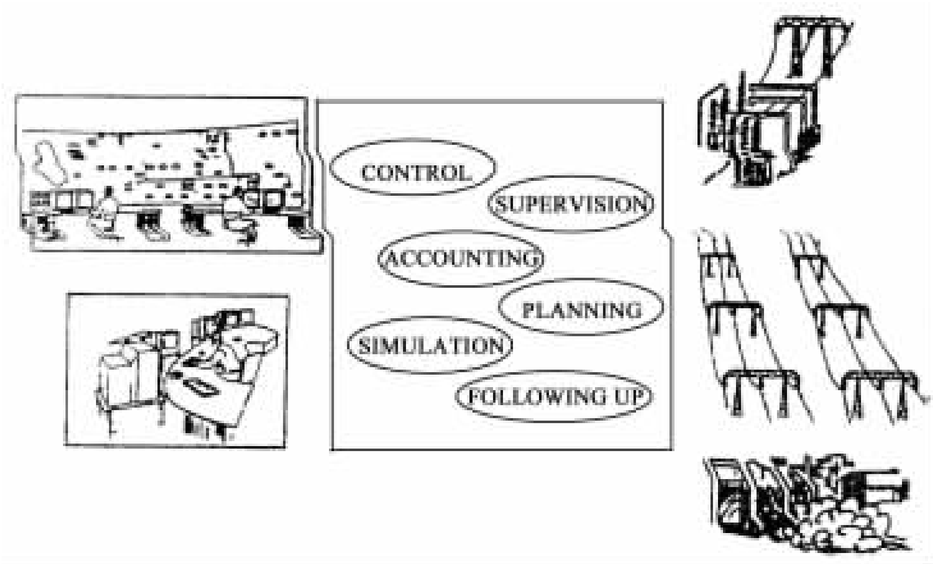
In addition to this, the alarms are grouped for selective presentation to further help the operator quickly trace the primary cause of error. The larger control centers use advanced network supervision and simulation tools to aid the operator in preventing disturbances. Production control programs that economically optimize the operation of the power system are usually included too.

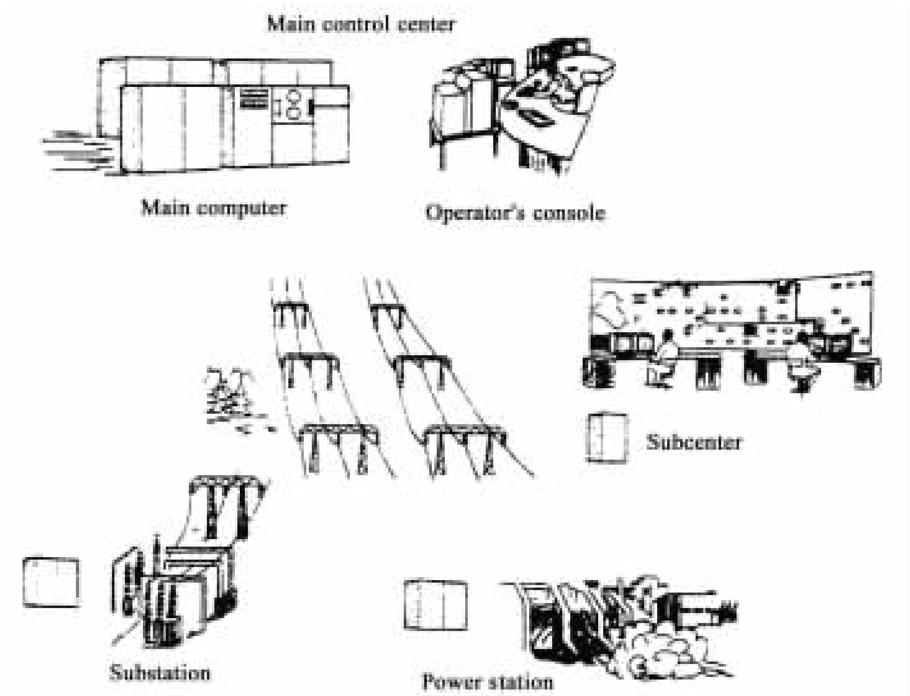
Centralized control of the power system means all control actions can be taken in one place. Thus the operator can operate circuit breakers, switch in and out substation bays and control production units.

The role of the operator has undergone a major change as a result of the introduction of computerized control systems. While his duties earlier were mainly of a recording nature, they have now become more analytical. The computer system carries out the recording and presents processed results. The operator then makes judgments and decisions and executes them with the aid of the computer system. The new role of the operator imposes great demands on the man-machine interface, i. e., the way information is displayed and how dialog routines are designed.

The functional requirements of the control systems put forward by the power utilities are extensive, but differ as to complexity depending on the application area. The basic requirements always include the so-called SCADA functions (SCADA 越 Supervisory Control And Data Acquisition); see Figure 缘缘 By adding the EMS functions (EMS 越Energy Management System), application oriented calculation tools are given to the operator to aid him further.

To meet the functional requirements, three keywords are important: hierarchical, distributed and reliable. The hierarchical requirement using decentralized functions is a natural consequence of the operational organization of power utilities. The control



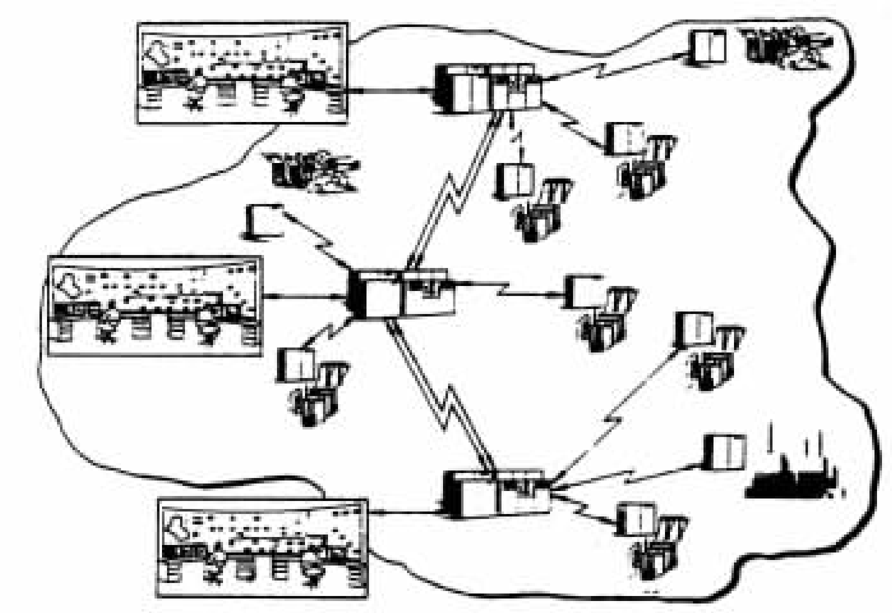


system must be adapted to this requirement; see Figure 缘远 A distributed system concept is motivated by the fact that the power process in itself is distributed, i. e.

geographically widespread. The consequential costs of incorrect or missing operator actions in a power system are so high that a series of demands must be made on the security of operation.

Based on this overall system philosophy, there exists today a set of computer-based units and modules that give efficient system, solutions for various applications, both large and small.

A list of modern supervisory control systems could be very long. Only one example will be mentioned here—the national monitoring and control system for Iraq's power generation and transmission network (源园园kV, 员猿圆kV), which became operational early in 员怨愿圆 This is a very good example of a hierarchical control center system; see Figure 缘苑



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Iraq is divided into three operational regions: the Northern, Central and Southern regions. Each region has a control center. These regional control centers are fully responsible for the power system operation in their own area. The regional control centers then form a hierarchy together with the Nation Control Center, which is responsible for the coordination and planning of operation, e.g. load forecasting, for the entire country. Every region has its own control system with associated remote terminal units. The control system of the Central region is temporarily undertaking the functions of the National Control Center, and is communicating with the other systems.

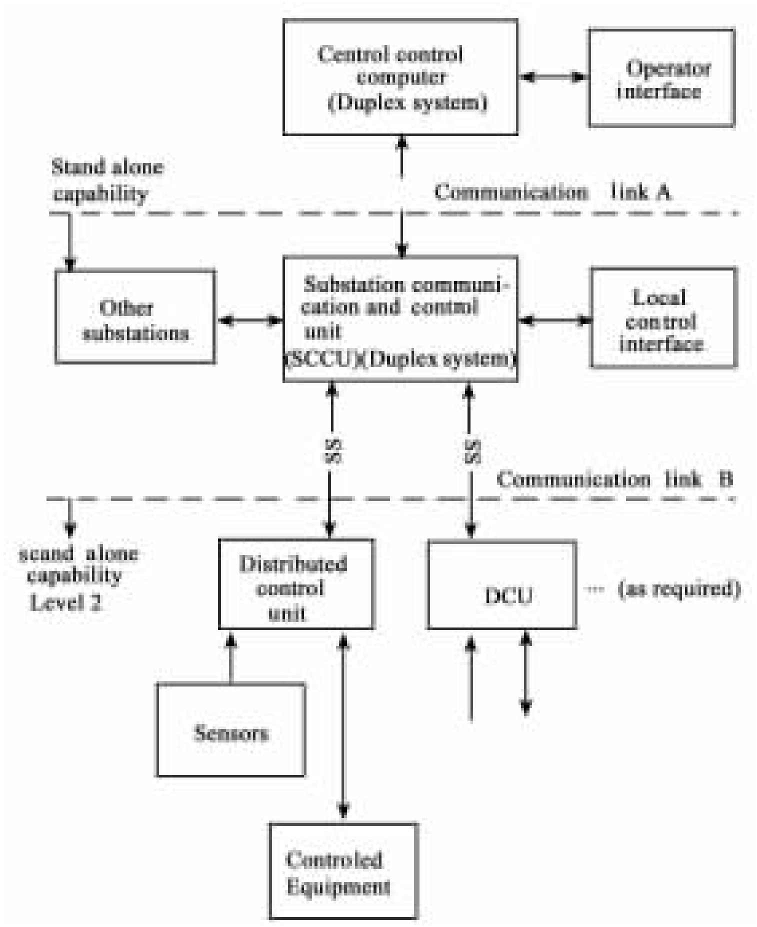
Subsystem Configuration for Distributed Processing

The subsystem configuration for distributed processing is shown in Figure 缘愿

The central computer system is capable of performing all the appropriate functions previously mentioned. It is through this central computer that all substations could be accessed by system operators. All substation information is processed by the central computer for presentation to the operator in the form of logs, alarms, system network diagrams, etc. Decisions affecting the operation of the whole power system or involving more than one substation could be made at this level and subsequent control activity transferred as appropriate to the individual substation.

The next level of control is physically located at the substation. Substation interface to the central computer is accomplished through a substation communications and control unit (SCCU). This "command center" coordinates all substation activity and handles all extra substation communications. Local control is accomplished by accessing the substation through this unit. Decisions are made at this level, which involve several substation control points. This system is a duplex, parallel configuration to provide maximum availability. Preprocessing of all data occurs at this level before transmission to the central computer and to provide maximum substation in dependence and critical function reliability, the SCCU has completed "stand alone" capability with respect to the central computer. Loss of communication link A will in no way degrade the substation control system response to a critical contingency, such as a transmission line fault. Hence, no critical control function depends on the availability of a long distance communication link, as stated in our previous system requirements.

Direct control and monitoring of the substation is accomplished using subsystems called dedicated control units (DCU), which interface directly with substation equipment and all sensors and transducers. It is at this level that the bulk of information processing and decision making is accomplished. For example, a DCU could be used to scan all substation transducers such as those for temperature, pressure, humidity, gas analysis, and fluid level. Should an abnormal condition be detected, predetermined action for that contingency can be immediately initiated while the SCCU notified of the condition, where it is located, and what action has been taken. This information would subsequently be transmitted to the central computer and the operator would be notified. Maximum speed is achieved using this technique and since the communication link is not required by the operation, a high degree of critical function reliability is achieved. A DCU could also be dedicated to each transmission line for fault detection and classification and to indicate loading trends. Note that this dedicated hardware duplicates the configuration previously used for protection hardware, but provides the system integration and remote addressability to the protection equipment, which was totally missing in previous systems.



[illegible]

[illegible]

power utility	发电站
availability	使用价值，（有效）利用率
bay	支座，支架
man-machine interface	人机接口
SCADA	监视控制及数据采集
EMS	能源管理系统
hierarchical	分层的，体系的
decentralize	分散
philosophy	基本原理（定律）
terminal unit	终端设备
subsystem	子系统

log	记录
SCCU	子站通讯及控制单元
duplex	双重的,冗余的
stand alone	(不受计算机影响系统控制的)独立
degrade	降低,减低
contingency	意外事故,偶然(性)
dedicated	专用的
DCU	专用控制单元
sensor	敏感元件
transducer	传感器,变送器
addressability	寻址

[illegible]

摇摇

Servomotor

Servomotor is the power amplifying element and execution mechanism of governor.

This unit is equipped with two CV servomotors, each of them could drive two CV by a cam, admission and distribution mechanism, and then it could control the inlet steam of HP cylinder.

The two IV servomotors are connected with the valve stem of the IV directly, and then it could control the inlet steam of IP cylinder.

The structure key parts of the two CV servomotors are same. They are composed of slide valve of servomotor, piston and feedback devices.

The slide valve is cutoff structure. Its input signal is the triple pulsating oil pressure, the stable value of it is P_m猿越园缘 The pressure $P_{园}$越员 缘远MPa acts on the bottom of slide valve, it could control the oil channels of where oil enters the upper or lower chamber of the piston. When the triple pulsating oil rises, the slide valve will go upwards and the piston will go downwards, and the inlet steam of turbine increases. When the piston goes upwards, it drives the feedback lever to move and make the opening of the slide valve oil port decrease and reduce the triple pulsating oil pressure. Until it restores to its stable value, the slide valve will return to the center position, and the unit will run stably in a new working condition. In this process, the area change of the oil port of the relay amplifier valve Δf_{middle} is equal to the area change of every servomotor feedback oil port $\Delta f_{opposite}$ (Δf_{middle} 越$\Delta f_{opposite}$). When the triple pulsating oil pressure is decreased, the action process is opposite.

The two IV servomotors are of single acting structures, their operating principle is identical to that of the CV servomotor. The difference is that they are not operated by the oil pressure difference, but by the imbalance action between the spring force and the oil pressure under the piston when the piston going downward, and the imbalance action could make the piston moved.

Both servomotors of CV and IV are equipped with adjusting device of speed variation rate.

The IV servomotor will be in fully opening position when the load of turbine is 猿园% of the rated load. In order to prevent the sticking of the valve stem of IV, valve sleeve and the IV servomotor during operating, the movable test on IV servomotor should be carried out regularly, and the corresponding triple pulsating oil pressure should be observed in the test.

The working principle of the governing system key devices are narrated as above, the actual example illustrating the working process of the governor is as follows:

When the frequency of grid is raised, the unit will decrease its power automatically. When the speed of turbine rises temporarily, the primary pulsating oil pressure from the speed governor pump will be increased. When the φ远园 slide valve of governor slide valve goes upwards, the draining port will be opened farther, the secondary pulsating oil pressure will be decreased dynamically, it makes the cut-off slide valve of relay amplifier valve go downwards, and makes the pulsating oil pressure of the lower chamber of the integration piston decrease, so the integration piston goes downwards, by the lever they could open the triple pulsating oil draining port which is controlled by the allocating slide valve. The triple pulsating oil pressure will decrease relatively (dynamically). Finally the servomotor pistons of HP and IV go downwards to close corresponding valves when the inlet steam is decreased, and the turbine power will be decreased depending on the static characteristic curve, until the turbine power agrees with the decreased load. And then the turbine will run stably in the new condition (after the load decreased the speed will be increased).

When the frequency of grid is decreased, the unit will raise its power automatically, and its process is opposite.

Startup valve

The startup valve is the program-controlled mechanism for the turbine starting. Its three functions are to latch the emergency cutoff valve, to open all stop valves and to open the CV servomotors.

By handling the startup valve, the turbine speed could be raised to about 圆,苑园园r/min. When the governing system is put into operation, the unit speed could be raised to the rated speed (猿园园园r/min).

The startup valve could be handled by the hand-wheel in the front of turbine manually, and could be handled by its motor remotely.

Synchronizer

The synchronizer is the given device of the governing system. It could adjust the turbine speed when the turbine is put in single unit; it could adjust the turbine power when the turbine is synchronized.

The synchronizer changes the pre-tightening force of the spring by the worm transmission mechanism, then it could control the opening of the secondary pulsating oil draining port.

The synchronizer could be handled by the hand-wheel in the front of turbine manually, and could be handled by its motor remotely. The designed upper limit speed is 猿圆园园r/min, and the lower limit is 圆远缘缘r/min.

FCV and Overspeed Limiting Slide Valve

FCV (Fast Close Valve) and overspeed limiting slide valve are special differentiation devices (acceleration relays). They will take part in the governing when the rejection of load occurs, and they are controlled by the oil trip valve.

When the rejection of load occurs, the FCV accepts the oil signal from trip valve and releases the secondary pulsating oil quickly. The overspeed limiting slide valve dumps the triple pulsating oil and accelerates the shutting off of all stop valve's servomotors. These actions restrain the rising up of turbine speed, and could make the highest rising up speed lower than executing speed of emergency governor.

They will reset after 圆依园缘s and the governing system will keep the turbine run no load. FCV and overspeed limiting valve could restrain dynamic highest rising up speed effectively after turbine rejecting load.

The resetting time of overspeed limited valve should not be over 圆缘s. If the setting time is too long the turbine will overspeed the secondary time, the result is that the overspeed limited valve is not put into operation.

Load limiter

The load limiter is put into operation when the power generated by the unit needs to be limited. The power generated by the unit is determined by the opening of the CV. Obviously the limiting value of the load limiter is concerned with the steam parameters and the exhaust pressure.

When the load limiter is put into operation, the unit load could be decreased (lowering the opening of the governor) but could not be increased (increasing the opening of the governor). Then the governing system controls unit load automatically in a single direction (decreasing load) and the other direction in opening loop situation, it could not be used to increase and decrease the load during the normal operation of turbine, and could not be put into operation for a long time.

The load-limiting device could be handled by the hand-wheel locally, and could also be handled by the motor of load limiter remotely.

羣藉睹 宰爆燥择葬灶凿耘曾责则藻泽泽蚤燥灶泽

valve stem 阀杆
slide valve 滑阀

triple pulsating oil	三次脉冲油
oil port	油口
relay amplifier valve	中间继动滑阀
the primary pulsating oil pressure	一次脉冲油压
draining port	泄油口
the secondary pulsating oil pressure	二次脉冲油压
cut-off slide valve	断流滑阀
integration piston	积分活塞
static characteristic curve	静态特性曲线
startup valve	启动阀
synchronizer	同步器
worm transmission mechanism	蜗轮传动机构
FCV（Fast Close Valve）	快控滑阀
Load limiter	功率限制器

Traditionally, distributed control systems (DCSs) have been dominant in the process industries. They offer high level, algorithm-based control for entire plants and power stations.

Tending to be large, expensive and complex, there are, however, disadvantages. It requires an engineer with specialist knowledge to operate and maintain a DCS properly. And, adapting a system to new tasks can be difficult.

Many process engineers, therefore, are looking to new developments in PLCs for an alternative.

The latest PLCs pose a considerable threat to DCSs. They are compact, lower cost, yet have a good functionality and can be connected in high or low level networks. Networking decentralizes control throughout the plant. So, PLCs are dedicated to specific tasks and located at the point of control, but still linked to a main control system. This enables the majority of their processing power to be concentrated on control and data collection, giving extremely fast response.

A PLC network maintains many advantages of the DCS. Entire plants can be monitored centrally via a SCADA or similar PC-based software package, yet a decentralized PLC network offers extremely high system reliability. With dual redundant loops, if one PLC stops operating, the others continue to operate,the system does not fail. Similarly, a section of plant can be taken off-line for scheduled maintenance, without shutting down the whole network.

Manufacturers are making PLCs compatible with high level open networks, such as Ethernet and Profibus. In this way, a wide variety of units can be linked on the same network. Engineers are not limited to just one manufacturer. Different makes can be chosen for different plant tasks.

Also, PLCs themselves are decreasing in cost and size as their internal components become less expensive and smaller. With fewer components, they are more reliable and less prone to interference from outside disturbances.

However, their functionality is generally no less than that of a DCS. Top of the range units boast advanced math functions, such as PID, *cos* and *tan*. Many have analogues, temperature monitoring, positioning and high speed counting modules. Some can use advanced programming languages, such as IEC 1131. Flow chart languages are optimized for many complex process systems.

The trend in process control, then, is decentralization. Machine intelligence is moving away from the control room to the plant floor. PLC manufactures are responding to this with smaller units, providing remote I/O control in reliable high speed networks.

Powerful networks are increasingly used instead of DCSs for many applications in the process industries. Besides lower capital and installation costs, PLCs are more readily available. They can be bought off the shelf.

Also, specialist skills are not needed for operation. Most control engineers are familiar with them and PLC training is now part of many engineering courses. Networks are easy to set up, and once the program is written it can be quickly downloaded to all units.

Generally, though, the trend of decentralization is leading to reduced costs, simplified control and higher efficiencies.

The PLC down-sizing trend will continue. As advances in microelectronics, smaller, more powerful components will be produced, PLCs will become smaller and more powerful.

But the nature of PLCs will change. They are already acquiring many features of PCs, like graphical software, built-in diagnostics and applied maths functions. And, this will become more pronounced. PCs, on the other hand, will acquire control functions, and overlap with PLCs in many areas.

[illegible]

process industry	制造 (加工) 工业
pose a threat to	成为…的威胁
functionality	功能度
majority	多数,大半
off-line	离线的,脱机的
compatible	相兼容的,相适应的
make	种类,型号,制成品
prone	有…倾向的,易于…的
off the shelf	现用的,流行的
built-in	固有的,内在的
pronounced	明显的,显著的
overlap	重叠,交错,并行

Part Six Power Plant Chemistry and Environment

[illegible]

Introduction

Aside from drinking and sanitary purposes, water has a number of uses in industry. The first is cooling: Every day, huge amounts of water go into removing unused heat from power plant condensers, compressors, and diesel engines; steel mills, oil refineries, and chemical plants consume large quantities. Power plants are also big consumers in another area-generation of steam to produce electricity. Other tasks for water are heating; transporting and processing materials, such as pulp and paper; as a raw material that goes into a finished product, such as canned goods and beverages; and to pass along domestic and industrial wastes.

Depending on the source, water can sometimes be used without treatment. But more often, it contains impurities that must be removed, reduced, or stabilized. If all water carried the same impurities, treatment could zero in on a nearly standardized prescription for each use. But pure water never occurs in nature, and impurities vary widely. The closest approach to purity is rain, but even rain contains enough dissolved oxygen and carbon dioxide to make it corrosive. Thus, water treatment is essential.

This chapter covers key systems, equipment, and techniques in water treatment-clarification, filtration, deaeration partial demineralization, and combination of these.

Clarification

Water clarification has two goals: to settle out those larger suspended particles that are readily settled and to condition smaller colloidal (suspended) particles to make them settle out, so that the subsequent filtering operation is not impeded. A sedimentation basin takes care of the first. Once the coarser matter is removed, the finer solids can be handled by equipment of moderate size.

The basin may take the form of a pond, reservoir, or tank large enough to permit suspended sediment to settle while passing through. More than likely, a fabricated unit would be equipped with a means for removing settled sludge periodically. The facility is usually sized for settling of the heavier solids in a matter of hours, compared with days or weeks for removal of finer particles in a facility of this type.

From the basin, the overflow proceeds to the clarifying station. The key to clarification is the addition of chemicals to agglomerate suspended solids, shortening the detention time for settling to a few hours at most. The basic goal of agglomeration is to overcome the factors that end to prevent finely divided matter from joining together, and to encourage further aggregation and growth to a size large enough to settle out of suspension.

The primary factor is electric charge. All particles of turbidity and color have an electric surface charge, usually negative. The charge attracts a compact layer of oppositely charged ions (counterions) in very close proximity and a more diffuse layer farther away (Figure 远员. The combination of the two layers forms an electrostatic potential—called the zeta potential around the particle, which repels other particles similarly charged (Figure 远圆.

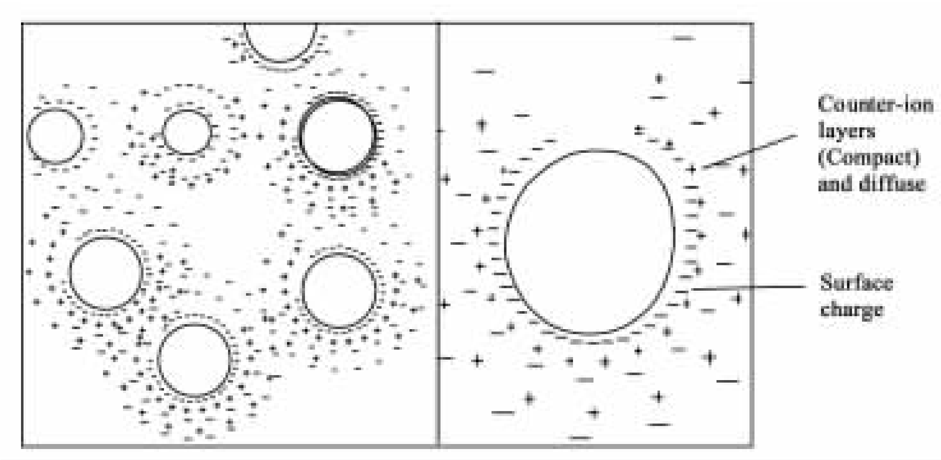
Coagulants: Physical Mechanisms

Chemicals called coagulants are added to the water to break down the zeta-potential barrier. They introduce ions of opposite charge—positive in this instance—which act to compress the double electrical layer, thus reducing the barrier to agglomeration. Actually, a second force exists, the van der Waals force, which is attractive in nature; it is the algebraic sum of these two forces—the net repulsive force that must be overcome to coalesce individual particles. This can be considered as neutralization of particles, to allow attachment to one another.

Metallic salts are often selected as coagulants, they introduce positive metal ions carrying two or more electric charges. Thus, they increase the concentration of counterions in the diffuse layers, enabling a thinner layer to maintain overall electrical neutrality in the vicinity of the particle. In this way, the range of the repulsive force between proximate particles decreases, and the barrier is reduced. With proper choice and amount of coagulant, the barrier is removed completely, allowing contact between particles.

Polymers: Chemical Mechanisms

Another set of chemicals also assists coagulants, but through a chemical rather than a physical mechanism. These are polyelectrolytes—synthetic organic polymers of high molecular weight, containing chemical groups that can interact with surface sites on colloidal particles, when a polymer molecule attaches to a particle in this way, the rest



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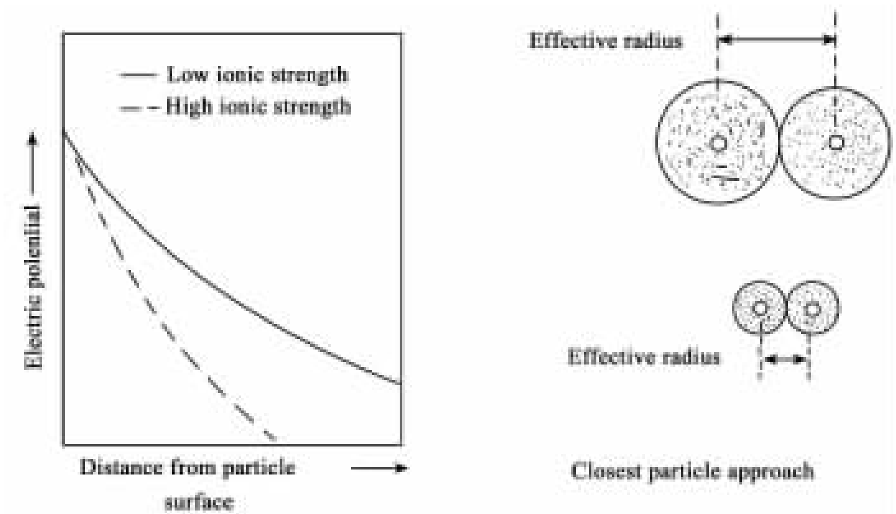

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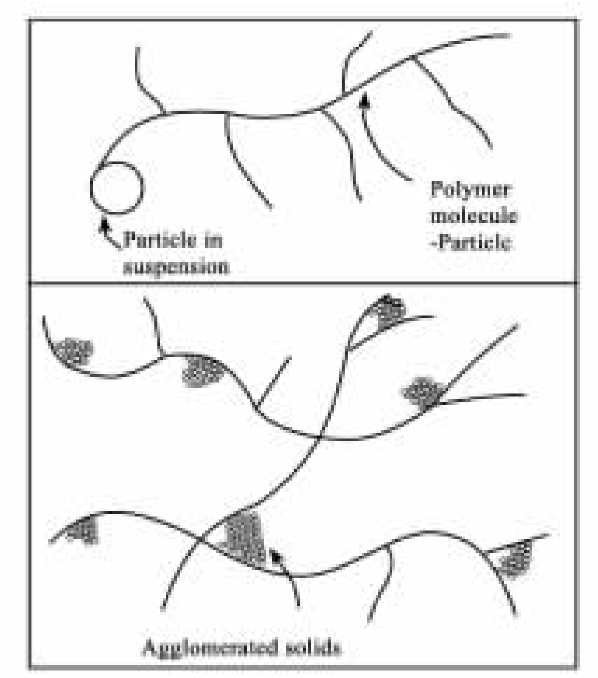
of it extending out into the bulk of water, other particles brought to the vicinity by gentle stirring—can become attached (Figure 远猿. This is the "bridging effect"—and the basic mechanism by which coagulant aids, also called flocculants, help pinpoint floc to grow into larger floc. Such aids act with surprising speed and are particularly helpful with water that is cold or high in color content.

Polymers are cationic (positively charged), anionic, or nonionic. Slightly an ionic



[illegible]

polyacrylamide with molecular weights up to [illegible] million generally appear to be the most effective, but some cationic and nonionic types have been found useful in certain cases. Because the optimum charge and molecular weight vary with the situation, tests are needed to determine the best choice.

Two developments have attracted interest in recent years. One is the selection of polyelectrolytes as primary coagulants. These are cationic polyamines with relatively low molecular weights (less than [illegible] [illegible] and very high charge densities. They become adsorbed on particle surfaces, neutralizing the repelling negative charge. To some extent, they also bridge particles, reducing the need for inorganic coagulants.

The other development is direct filtration. This technique dispenses with a clarifier per se, introducing water directly into a filtration system. Chemical coagulant is injected slightly upstream of the system and in smaller quantities than those used with clarifiers, to avoid interference with filter operation. Polymers, usually cationic, are preferred to inorganics for this application since they do not introduce additional solids loadings. A short mixing period is needed to provide for the optimum degree of chemical reaction, and dilution water may be needed to ensure adequate dispersion of the polymer.

sanitary	卫生保健
pulp	纸（木，矿，砂，泥）浆
beverage	饮料
pass along	传递，使向前传播
clarification	澄清
settle out	沉淀出来
readily	容易地，很快地
impede	阻碍，阻止
detention	阻止，拖延
turbidity	浑浊度
counterion	平衡离子
coagulant	絮凝剂
algebraic	代数
coalesce	聚结，凝聚
polyeletrolyte	聚合（高分子）电解质
colloidal particle	胶（体微）粒
polyacrylamide	聚丙烯酰胺
optimum	最佳的
polyamine	聚氨
dispense with	节省，废除
per se	本身，本质上
dilution	稀释，冲淡

[illegible]

Filtration

Even with clarifiers operating at optimum levels under anticipated conditions, additional solids-removal equipment is required downstream. It serves to reduce the remaining suspended solids to the parts-per-billion level required for boiler operation, and it provides backup to the clarifiers in case of severe upsets.

Filter development has progressed so far that, in some cases where water has moderate turbidity, addition of a small amount of coagulant allows the clarifier to be dispensed with entirely. But in preparing boiler feed water, filtration is generally needed to reduce clarified water in the range of 圆to 缘园Jackson turbidity units (JTU) to a fraction of 员JTU. This applies as well to condensate return, where the slightest, corrosion or in-leakage can contaminate boiler water intolerably.

Filtration is the process of placing a pervious (porous) barrier across flowing water to remove matter held in suspension. It can be accomplished simply through mechanical straining at the surface of the barrier or by removal throughout the depth of the medium. Surface filtration is generally suitable only for water extremely low in suspended solids, since operating cycles would otherwise be too short. For makeup preparation, however, more of the medium depth must be brought into play for practical operation.

Sand Filters

Granular media are the accepted standard for medium-depth filtration. Silica sand, the most common, has been the standby for over a century. The sand filter had its inception in England, and still finds application abroad in its original form. It features a bed of fine sand — 园怨to 员缘m thick—supported by a gravel subfill. Overlying water percolates down through the sand and is collected and removed by the underdrain system.

Proper performance does not begin until a layer of silt and bacterial matter has developed in the top inch or so of sand. The unit then produces exceedingly clear water, but at a rate no faster than 园 园愿m/s. The upper layer, where all the filtering action takes place, is then scraped off, washed externally, and restored to the bed. Adaptations of early sand filters feature circular tanks with built-in scrapers (Figure 远源 or in-situ cleaning by reverse-flow backwashing.

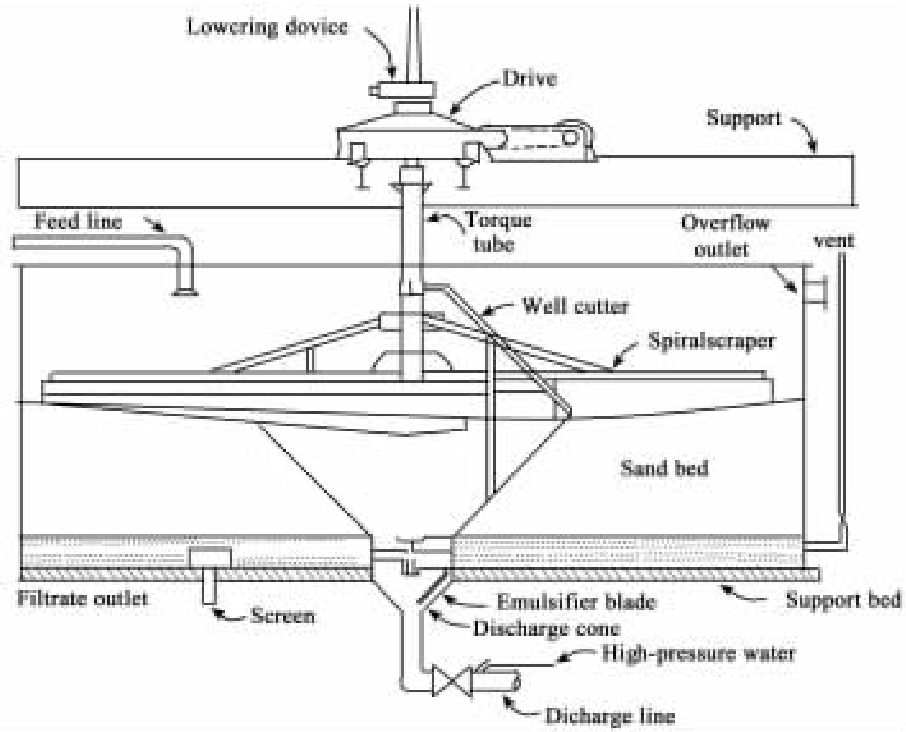
The effectiveness of slow filtration depends on the nature of the water being processed. Highly successful in Europe, where the absence of chemical costs offsets the high capital cost, slow filters are not well suited to domestic application because of the high concentrations of very fine clay often present in U. S. waters. Because the clay penetrates deep into the sand body, cleaning is far more difficult. The development of granular-media filters in the United States was based on pretreating the water and modifying the media used. With preconditioning provided by coagulation, whether it is done in a clarifier or in-line, filters take a variety of forms and provide filtration rates in the range of 园园源to 园圆圆m/s.

Reverse Osmosis

Reverse osmosis (RO) offers a means of removing ionic components from their aqueous solutions. It also serves to remove most soluble organic compounds; and to restrain the passage of insoluble particles, both viable and otherwise. The process is widely utilized for these purposes in the preparation of high purity rinsewaters in the electronics industry. Increasingly, RO is employed in the power industry in the preparation of makeup water, to replace that consumed in use or lost as steam. In the pharmaceutical industry, RO is designated by the USP as one of the two methods permissible in the preparation of Water for Injection; distillation is the other. The FDA, however, will permit its use for this purpose only when two-pass product-staged RO is involved; this is a recognition that RO membranes are not always of such perfect reliability as to ensure sterile effluent.

The two chief alternatives to RO for preparing high-purity water are distillation and ion exchange. Reverse osmosis requires a lower expenditure of energy than distillation; but is generally (although not universally) more sensitive to the pretreatment of feedwaters than ion exchange. A surface water with very high organic load could be purified using RO without undue fouling, by manipulation of, the amount of RO recovery. However, even macroreticular resins might become irreversibly fouled thereby. Nevertheless, RO seems more sensitive to abuse by operators than ion exchange.

Reverse osmosis membranes are thin microporous polymeric (usually) films. The RO pores derive from the interstitial spaces present in all solid matter. They are not the artificially enlarged pores common to the microporous filters of commerce. The dimensions of the pores of RO membranes are on the order of 圆缘to 员远园angstroms. Such small orifices severely restrict the permeation of water. A practical permeation rate therefore necessitates an aggrandizement of surface-to-liquid area interfacing, along with an enhanced thinness of the polymeric barrier. Both of these techniques have been developed for RO devices.



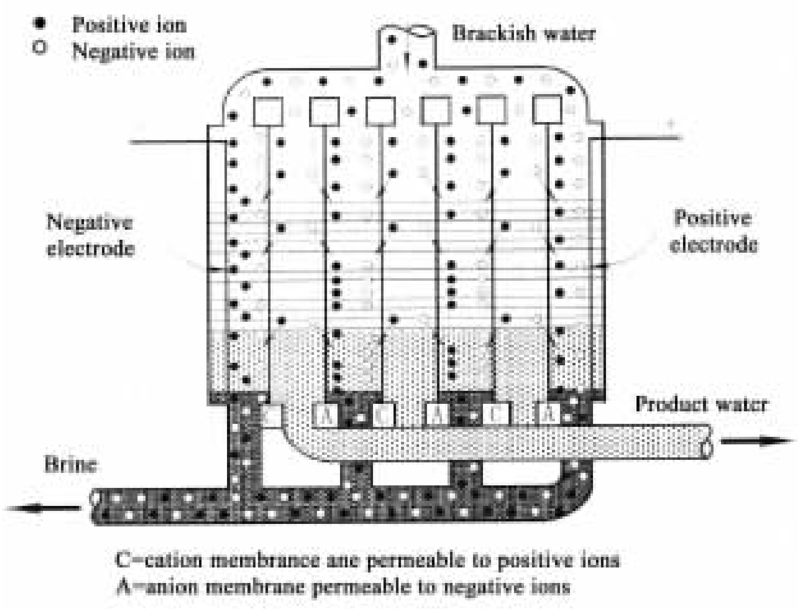
Osmosis and Osmosis Pressure

Osmosis occurs when at semipermeable membrane, permeable to water but not to salts or organic molecules in solution, separates water or a dilute solution from a more concentrated solution. Water molecules have a stronger tendency to escape from water than from a solution. Water flows through the membrane from the dilute to the concentrated side in an effort to equalize the osmotic pressures of the two solutions. If the juxtaposition of the two solutions is made in the two arms of a U-tube, with the semipermeable barrier in the horizontal section between them, the water rises in the more concentrated arm and diminishes in the arm containing the dilute solution, (or pure water). The relative heights of the solutions at equilibrium are a measure of their osmotic pressure differences.

Elctrodialysis

Electrodialysis (ED) has been the longest development. It differs from other membrane techniques and thermal evaporative processes in that it moves the dissolved minerals away from the water, rather than vice versa. Since the quantity of minerals is far less than that of the containing them, there are practical advantages.

For ED, the basic of operation is the passage of water between paired sets of parallel membranes, with an electric field applied perpendicular to the direction of flow (left to right in Figure 远缘. The field moves positive impurity ions toward the negative are selectively permeable, the one in each pair closer to the negative electrode (C) allowing passage of the positive ions (cations), the other (A) favoring negative ions.



[illegible]

Actually, hundreds of pairs of membranes of alternating sensitivity are assembled into membrane stacks. Plastic spacers separate the membranes, directing flow of water through a tortuous path to the membrane faces. Present removal rates justify ED costs for water with solids concentrations lip to those found in seawater, or 员园园园to 猿缘园园园 mg/L.

[illegible]

intolerably	不允许的
granular	粒状的
inception	开始,发端
overlying	上面覆盖的
percolate	砂滤,渗滤
percolate down though	透过…而不渗
underdrain	阴沟,地下沟道
silt	泥沙
in-situ	就地

emulsifier	乳化剂
osmosis	渗透
aqueous solution	水溶液
viable	有生命力的,能生存的
pharmaceutical	医药的
sterile	无菌的
manipulation	操作,处理,控制
macroreticular	大量网眼
polymeric	聚合的
interstitial	空隙的
angstrom	埃
permeation	渗透作用
aggrandizement	增加(大)
semipermeable	半渗透
juxtaposition	并置,斜接,邻近
regenerant	再生剂

The term scale describes a continuous, adherent layer of foreign material formed on the water side of a surface through which heat is exchanged. By adding certain chemicals the growth of scales can be inhibited and the insoluble particles can be dispersed in the recirculating water and removed by blowdown. Should the particles come out of suspension, however, they can accumulate as sludges in quiet sections of a boiler. Deposit is a rather general term applied to more-or-less loose accumulations often found in less turbulent sections of boilers and water-treating systems. Scales are objectionable because of their insulating effect. In a boiler tube, for instance, they cause overheating and eventual failure of the metal. Deposits often cause plugging in critical areas such as waterwalls, waterwall headers, in blowdown lines, and in gauge glasses.

Types of Scale

Many different mineral structures have been identified in boiler scales by the methods of x-ray diffraction, electron diffraction, and polarizing microscopy, Examples of silicate scales are: acmite, $Na_2O \cdot Fe_2O_3 \cdot 4SiO_2$; analcite, $Na_2O \cdot Al_2O_3 \cdot 4SiO_2 \cdot 2H_2O$; serpentine, $3MgO \cdot SiO_2 \cdot 2H_2O$; sodalite, $Na_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2NaCl$; and xonotlite, $5CaO \cdot 5SiO_2 \cdot H_2O$. When phosphate is used for internal treatment, ferric, phosphate, $FePO_4$, basicmagnesiumphosphate, $Mg_3(PO_4)_2 \cdot Mg(OH)_2$, and hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$, may also be encountered, as well as the more common anhydrite, $CaSO_4$, and aragonite, $CaCO_3$. As noted before, the presence of these and other scales impedes the circulation of water and reduces heat transfer, both of which cause overheating and failure of tubes.

Mechanism of Scale Formation

Scales and deposits form because the compounds of which they are composed are insoluble under the conditions prevailing in the boiler. Two factors combine to make calcium salts especially troublesome: certain anhydrous calcium salts, notably the sulfate, decrease in solubility as temperature and pressure increase, whereas increasing temperature shifts the equilibrium of the following reaction to the right, causing $CaCO_3$ to precipitate:

$$Ca^{2+} + 2HCO_3^- = CaCO_3 + H_2CO_3 \tag{6.1}$$

In addition, hydrolysis of excess bicarbonate increases the concentration of hydroxyl ion, precipitating $Mg(OH)_2$, the solubility product of which is 5.5×10^{-12}. The solubility of $CaSO_4$ decreases rapidly with increasing temperature, producing an extremely hard, adherent coating on boiler tubes, especially in locations where heat flux is high. The compositions of several scales containing aluminum, magnesium, calcium, and silicate are given above. Analcite and acmite, which form at high temperature, are invariably found beneath sludges of hydroxyapatite or serpentine, or under porous deposits of iron oxides. Occasionally other extremely, insoluble iron or magnesium silicates are also encountered, and now and then aquartz, SiO_2 appear, usually originating from colloidal silica, finely divided silt, or sand in the feed water.

Accumulations in boiler drums are most often in the form of mud or sludge. When oil is present as a contamination in boiler water, loose scales may form, particularly in water-wall tubes. Oil serves as a nucleus and binder for scaling at hot spots, although these scales are often merely baked mud that is easily dislodged by hammering the tubes. The "oil balls" found in steam drums and water-wall headers are typical formations in turbulent sections; they are especially common in steam drums, where they are formed by the rolling motion of water.

Chemical Treatments

Obviously, the most effective method for preventing scaling is to eliminate scale-forming elements from the feed water, or to transform them by some means into, an innocuous form. The methods for doing this are conveniently classified as external and internal treatments.

Chemical Softening. The treatments of water that are accomplished outside of the boiler are referred to as preboiler, or external treatments. The processes for removing calcium and magnesium ions from water are called softening, and are signal importance in preventing scales. It is apparent from the equation:

$$Ca^{2+} + 2HCO_3^- = CaCO_3 + H_2CO_3 \qquad (62)$$

That calcium is precipitated if carbonic acid is neutralized by adding an alkaline reagent. If an excess of alkali is added, magnesium hydroxide also precipitates and the total hardness of the water is reduced. Lime is the alkaline reagent most often used because its cost is low and it is relatively easy to handle; the process is called lime softening.

Softening by Cation Exchange. The removal of calcium and magnesium ions by cation exchange is commonly called zeolite softening, from the reaction characteristic of the mineral zeolites. The latter are hydrous sodium aluminum silicates in which the sodium is labile and exchangeable for calcium and magnesium ions flowing over through the mineral. The exchange reaction is:

$$Na_2Z + Ca^{2+} = CaZ + 2Na^+ \qquad (63)$$

In this type of treatment the cation exchange resin is in the acid form, while the anion exchange resin, which removes negative ions, is in the hydroxide form.

Precipitants. The amount of hardness that can be tolerated in feed water decreases as the pressure of the boiler increase, but in any case calcium and magnesium are potential formers of scale, so further treatment is required. Alkaline earth scales are prevented by adding phosphate to the boiler water; this precipitated both calcium and magnesium in a soft dispersed form. The precipitate formed by calcium and orthophosphate is usually represented as the normal phosphate, $Ca_3(PO_4)_2$. Attempts to precipitate this salt in the laboratory, however invariably produce hydroxyapatite, the formula of which can be written in various ways including $Ca_{10}(PO_4)_6(OH)_2$, $3Ca_3(PO_4)_2 \cdot Ca(OH)_2$, and $Ca_5(PO_4)_3OH$. A consideration of the solubility products $[Ca^{2+}][CO_3^{2-}] \approx 4.8 \times 10^{-9}$, $[Ca^{2+}]^3[PO_4^{3-}]^2 \approx 1.3 \times 10^{-32}$, and $[Ca^{2+}]^{10}[PO_4^{3-}]^6[OH^-]^2 \approx 3 \times 10^{-58}$ indicates that the basic salt forms in boiler water. Magnesium forms similar salts such as $Mg_3(PO_4)_2 \cdot Mg(OH)_2$ and $Mg_5(PO_4)_3(OH)$, which are undoubtedly much less soluble than $Mg(OH)_2$.

Magnesium salts are sometimes added to boilers operated at low pressure to precipitate magnesium silicate. This salt separates as a flocculent precipitate that can be removed by blowdown. Also, soda ash, Na_2CO_3, is used in low-pressure boilers fed with water containing 20–75 mg/L of hardness to precipitate $CaCO_3$ and $Mg(OH)_2$.

New Words and Expressions

come out of	有…结果
eventual	最后的
diffraction	衍射
polarize	偏振，极化
acmite	锥辉石
analcite	方沸石
serpentine	蛇纹石
sodalite	方钠石
xonotlite	硬硅钙石
hydroxyapatite	含氧酸磷灰石
anhydrite	酸酶
aragonite	散文石
prevailing	主要的，占优势的
anhydrous	无水的
hydrolysis	水解
hydroxyl	氢氧
binder	粘合
innocuous	无害（毒）的
zeolite	沸石
orthophosphate	亚磷酸盐

[illegible]

As civilization developed and cities grew, domestic sewage and industrial wastes were eventually discharged into drainage ditches and sewers, and the entire contents commonly emptied into the nearest watercourse. In the case of major cities, this discharge was often sufficient to destroy even a large body of water.

During the nineteenth century, the River Thames was so grossly polluted that the House of Commons had to have rags soaked in lye stuffed into the cracks in the windows of Parliament to reduce the stench.

Beginning with the pioneering work in the United States and England, sanitary engineering technology eventually developed to the point where it became economically, socially and politically feasible to treat the wastewater so as to reduce its adverse impact on watercourses. In this section, this technology is reviewed, beginning with the simplest (and earliest) treatment systems, and concluding with a description of the most advanced systems in use today. The discussion begins, however, by reviewing the characteristics of wastewaters, which make their disposal difficult, and showing why wastewater disposal cannot always be done onsite, and sewers and centralized treatment plants become necessary.

Wastewater Characteristics

The discharges in a sanitary sewerage system are comprised of domestic wastewater, industrial discharge and infiltration. Infiltration, of course, is only a problem in that it adds to the total volume of wastewater and seldom is it directly a cause of concern in wastewater disposal. Industrial wastes are of course another matter. These discharges vary widely with the size and type of industry, and the amount of treatment applied by the industry prior to discharge into public sewers. In the United States, the trend has been toward higher degree of pretreatment, prompted in part by regulations limiting discharges and by the imposition of local sewers surcharges. The latter are charges levied by a community to help pay for the extra treatment which an unusual discharge would require.

Commonly, the problems with industrial discharges are not BOD and SS, both of which can be readily reduced in a wastewater treatment plant, but chemicals such as toxic metals, redioactive materials, refractory organics, etc. Typically, local communities place tight restrictions on such discharges and thus force the industries to pretreat the wastewater prior to discharging to the public sewers.

The third component of municipal wastewater, domestic sewage, tends to vary substantially over time and from one community to the next. On the average, however, it is instructive to consider "typical" values for the characteristics of domestic wastewater, some of these are shown in Table **远员**

[illegible] [illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Onsite Wastewater Disposal

Environmental engineers have been severely (and sometimes rightly) criticized for having a "sewer syndrome" in that they want to collect all wastewater and provide the treatment at a large central location. Often this approach does not make much sense.

The original onsite system of course is the pit privy, glorified in song and fable. The privy, still used in camps and other temporary residences, consists simply of a deep (perhaps 圆m or 远ft deep) pit into which human excrement is deposited. When a pit fills up, it is covered and a new pit is dug.

A logical extension of the pit privy idea is a composting toiler, which accepts not only human wastes, but food waste as well, and produces a useful compost. With such a system, wastewaters, from other sources such as washing and bathing are discharged separately.

By far the greatest number of households with onsite disposal systems uses a form of the septic tank and tile field.

The wide use of waterborne wastewater disposal however caused another problem. Now the wastes of a community were all concentrated in one place, and a major effort was necessary to clean up the mess. This demand fostered what is known as centralized treatment.

Central Wastewater Treatment

The objective of wastewater treatment is to reduce the concentrations of specific pollutants to the level where the discharge of the effluent will not adversely affect the environment. Note that there are two important aspects of this objective. First, wastewater is treated only to reduce the concentrations of selected constituents, which would cause harm to the environment or pose a health hazard. Not everything in wastewater is troublesome, and thus is not removed. Secondly, the reduction of these constituents is only to some required level. It is obviously technically possible to produce distilled and deionized H_2O from wastewater, but this is not necessary, and can in fact be detrimental to the watercourse. Fish and other aquatic organisms cannot survive in distilled water.

For any given wastewater in a specific location, the degree and type of treatment therefore are variables, which require engineering decisions.

Often, the degree of treatment is dictated by the assimilative capacity of the recipient. The procedure by which the dissolved oxygen sag curves are drawn is reviewed earlier. As noted there, the amount of oxygen-demanding materials (BOD) discharged determines how far the dissolved oxygen level will be depressed. If this depression (deficit) is too large, some BOD must be removed in the treatment plant. Thus a certain plant on a given watercourse is required to produce a given quality of effluent. Such an effluent standard (discussed more fully later) dictates in large part the type of treatment required.

[illegible]

the House of Commons	(英国)下议院
lye	碱液
stench	臭气,臭味
sanitary engineering technology	卫生工程技术
sewerage	下水道系统
infiltration	渗透水
surcharges	超排量
imposition	赋税,课税,负担
refractory organic	耐火有机物
sewer syndrome	污水管综合症
excrement	排泄物
compost	堆肥,混合肥料
the septic tank	厌氧菌处理槽,发酵池
tile field	瓦管灌溉系统
deionized H_2O	去离子水
dictate	指挥,命令
dissolved oxygen sag curves	氧垂曲线
nutrient	营养素,营养品,养分
brackish	稍咸的

[illegible]

estuary	**河口**
toxic	**有毒的，毒性的 毒剂，毒物**
Ammonia Nitrogen	**氨氮**
Phosphorus	**亚磷的，三价磷的**
waterborne	**由水路运送的，(指疾病) 由引水传染的**

[illegible]

The petroleum mineral oils most commonly used in turbines contain oxidation and rush inhibitors. They nominally comply with the British Standard Specification BS 源愿怨 “Steam Turbine Oils” and their important properties, some of which are listed in Table 远圆 are described below.

[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	猿圆	远园
[illegible]	源园	员猿园
源园益	源远	源远
员园园益	远	源
[illegible]	园援缘	员援圆
[illegible]		
[illegible]		

Viscosity

Viscosity is the most important physical property of a lubricating oil and four grades are specified in BS 源愿怨. These have viscosities of 猿圆, 源远, 远愿 and 员园园 cst respectively at 源园 C. The first two are used in direct-coupled machines, the second and third in water turbines and the third and fourth in geared machines. A higher viscosity is required in geared units to combat the loading on the gear teeth and so prevent scuffing and wear, and the load on the thrust bearing often decides the viscosity choice for vertical water turbines.

Rust-preventing Characteristics

Three phases are present in a steam turbine in which rusting can occur if water or steam enters the system from a cooler leak or as a result of faulty operation or seals. These are the full oil flow, static water and vapour space phases.

Oils are formulated to pass the IP 员猿缘 “Rust preventing characteristics of steam turbine oil” test in the presence of a synthetic sea water. This assesses the oil in full flow and assures protection in service. Only a limited protection is given against corrossion under static water-film conditions and no protection is given to surfaces that are not covered or continually splashed with oil. So if moisture condensation occurs, or water films settle and lie on ferrous metal for any period of time, rusting will follow.

The effects of rusting can be very serious and, so far as possible, water should be excluded from the system. Suitable surface coatings and non-corrosive materials are used to reduce corrosion in vapour spaces and sensitive areas such as control gear.

Water ingress to water turbines by way of the runner seal is negligible, in water-lubricated runners where the seal is above the bearing. In the case of oil and grease-lubricated runners the seal is below the bearing, and water passing the seal has to be vented away before reaching the bearing. Oils containing anti-rust additives are used, however, to combat the effects of atmospheric water condensation in sensitive areas.

Oxidation Stability

Petroleum oils, which are a mixture of hydrocarbons, oxidise when subjected to high temperature and oxygen (air) with the formation of acids and a solid material that is familiarly known as sludge. These corrode the system, block the valves and oilways and result in malfunctioning of the equipment.

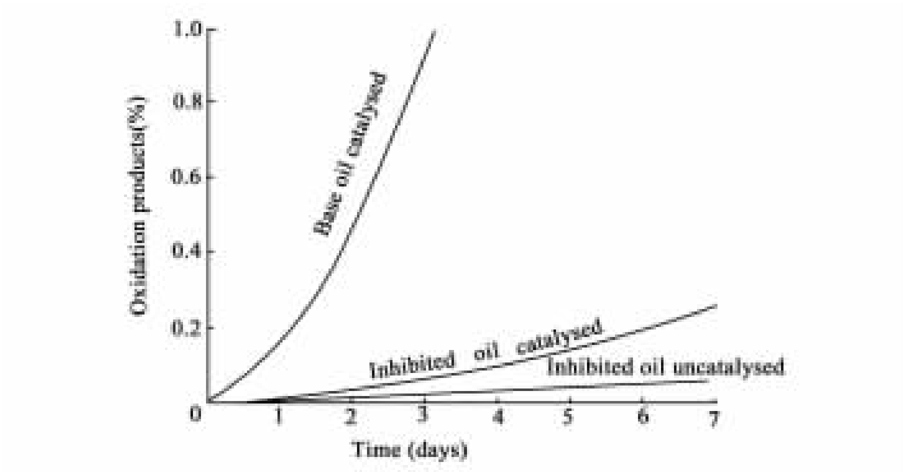
Many materials act as oxidation catalysts (that is, they increase the rate of oxidation) and in a turbine system copper, a very active catalyst, is picked up by mechanical and erosion mechanisms from bearings, piping, coolers, etc. Certain iron compounds, which may be formed by the action of oil oxidation products and water on steel, are also every active catalysts.

The oil is refined to a stage at which the addition of an oxidation inhibitor will further improve its stability. This anti-oxidant has also to counteract any adverse effects of the anti-rust additive. In addition to a conventional anti-oxidant, modern oils usually contain an additive that reduces the catalytic effect of metals, particularly those in solution.

The stability of turbine oil is assessed by a number of tests, the most important of which are IP 圆愿园“oxidation stability of inhibited mineral turbine oils” and an extended version of IP 猿远援 These tests use oxygen/solid copper arid oil-soluble cooper and iron salts as catalysts and are completed in 员远源 hours at 员圆园°C. Typical oxidation curves are shown in Figure 远远 IP 员缘苑 is also important as a long-term turbine oil oxidation test.

The level of stability required in an oil is a question of individual technical and economic requirements. The oil must be sufficiently stable to withstand the conditions encountered during passing through the system and additionally to remain in acceptable condition for an economic period. The oil in small turbines may be changed after a period of one year or so, but in large turbines a life of up to thirty years is desirable because of the outage and oil change costs involved.

Although it is customary to use the same quality oil in water turbines as in steam turbines, stability is of less importance because of the low temperatures and small oil volumes.



[illegible]

Foaming and Air Retention

Foam and air retained in oil lead to pump cavitation, loss of control and bearing damage. It is essential therefore that air is quickly removed from oil, and the system design precludes the formation of foam and air-oil emulsions. High-pressure oil passing through the valves, couplings, low suction heads and badly designed return lines are some of the causes of foam and entrained air.

The bubble size is the essential criterion that determines whether air creates foam or is entrained. Viscosity, and therefore temperature, and the rate at which air is injected into the oil are also important. The oil formulation can affect both properties and control in necessary. Anti-foam additives suppress foam but in doing so some types may prevent agglomeration of air bubbles and so slow down air release.

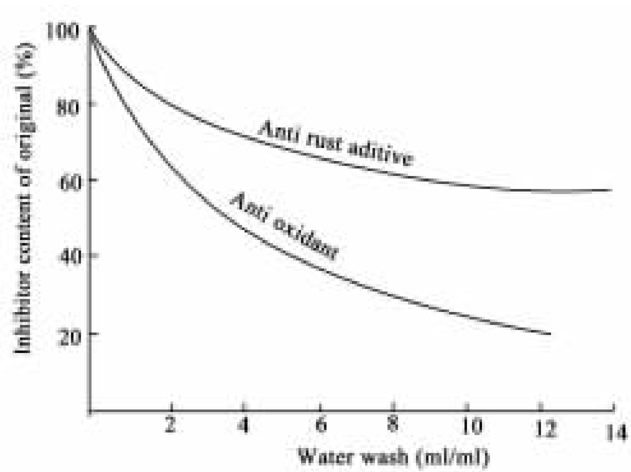
Tests designed to show the tendency of an oil to foam and retain air are the IP 员远 "foaming characteristics of lubricating oils" and the IP 猿猿 method "determination of air release properties". In the former air is bubbled slowly at low pressure into the oil and the amount and rate of dissipation of the foam measured, while in the latter air is injected into oil at high pressure and the amount of air entrained calculated from the change in oil density.

Demulsification

Water must readily separate from oil in the drain tank so that it is dry when pumped to the system. In a new oil this tendency is controlled by IP 灵愿 "demulsification number of lubricating oil", which measures the ability of water to separate from an emulsion formed by blowing steam into oil. Results on used oils are of less significance because of the effects of oxidation products and contamination. In service, oil treatment enables oils of relatively high demulsification numbers to be kept dry and perform satisfactorily.

Other Properties

The corrosive effect of oil on copper and its alloys, and the water solubility of additives are two further relatively important properties. However, both are generally covered by other tests. Copper corrosion is specifically covered in BS 源愿缘 but is also covered indirectly by the more severe condition of oxidation tests that use solid copper as a catalyst. Additive solubility in water is covered to a reasonable extent by the demulsification number and rusting characteristics tests, the results of which would be affected by water-soluble additives. Modern oils will withstand a high degree of water washing without impairment of the properties for which additives are included (See Figure 远苑).



[illegible]

Fire-resistant fluids

Fire-resistant fluids used in turbine control systems are based on organic phosphates, the most common being tri-cresyl and tri-xylenyl phosphates. The control system is separate from the lubrication system and mineral oil is still used to lubricate the bearings. The cost of such fluids is approximately three times more than mineral oil.

In general the same properties are of importance as with mineral oils. Additionally these fluids undergo hydrolysis and form corrosive compounds in the presence of water. In consequence they have to be kept particularly dry and this is achieved by filtering through an absorbent earth filter. Their oxidation and thermal stabilities are not good to mineral oils, so they must not be subjected to high spot temperature, such as in control gear, for any significant period of time. Their viscosity/temperature characteristics are less satisfactory than those of mineral oil and heating may be necessary on cold start-up. They have a higher density, so the design of the pump and pipework has to be more liberal. They are particularly good solvents and surface-coating have to be chosen carefully.

Many properties of these fluids are superior to those of mineral oil, and in particular their low compressibility and low vapour pressure ensure rapid control system response.

[illegible]

rust inhibitors	防锈剂
direct-coupled machines	直接耦合的机械
scuffing	磨损处
rust-preventing	防锈
ingress	进口,进口处,进入
grease-lubricated runners	润滑脂润滑的叶轮
anti-rust additives	防锈添加剂
petroleum oil	石油,油料
oxidation catalysts	氧化催化剂
refined	精炼,精制
foaming	泡沫
air retention	空气保持性
emulsions	乳状液
return line	回流管
entrained air	带走的空气
agglomeration	附聚(作用),烧结(作用)
dissipation	分散,散
demulsification	破乳化
demulsification number	破乳化度
solubility	溶解性
impairment	削弱,破坏,影响

[illegible]

Background

The first commercial application of flue gas desulfurization (FGD) to power plant sulfur oxide control was in the United Kingdom in the early 灵怨园. The Battersea A Power Plant (圆愿MW) of the London Power Company, London, UK, began flue-gas washing in 灵猿怨 The process utilized wet scrubbing with Thames River water providing most of the alkaline absorbent. The spent absorbent was discharged back into the Thames after settling and oxidation. The FGD system operated successfully at up to 怨缘% SO_2 removal efficiency until the Battersea A Power Plant closed down in 灵怨缘 A similar FGD system operated on the Battersea B Power Plant (圆缘MW) between 灵怨愿 and 灵缘愿 when FGD operation was temporarily suspended because of adverse effects on the Thames water quality.

The ICI Howden process, also developed in England, was developed to avoid discharged scrubber effluent into the Thames. A solid sludge was produced and barged to sea for dumping. This process was applied to the Swansea Power Plant in 灵猿缘 and the Fulham Power Plant in 灵猿苑 These systems operated successfully until early World War II when they were shut down.

The next FGD unit was installed at the Electrolytic Zinc company in Tasmania in 灵怨愿 Tidal water was used there as the absorbent for SO_2 from smelter gas.

In 灵怨圆 the first unit of the new oil-fired Bankside Power Station in London, UK, was commissioned. This FGD system is an improved version of the Battersea system, using water from the Thames. This system is still operating at up to 怨愿% removal efficiency and with a present capacity of 圆园园MW.

The 灵怨园 and 灵缘园 were a time of laboratory and pilot plant investigations of new processes. During the 灵怨园 the Tennessee Valley Authority (USA) investigated lime/limestone systems, both dry and wet, and dilute acid processes; in Germany the first major carbon adsorption processes were developed. During the 灵缘园 the magnesium oxide, copper oxide, and sulfite scrubbing processes were investigated among others.

Lime/limestone processes were installed in 灵缘源 on an iron ore sintering plant in Russia and on a large sulfuric acid plant in Japan in 灵远园

In 灵远园 Combustion Engineering developed a dry limestone injection process, which was installed at five boilers in the United States by 灵苑圆 Because of major problems associated with dry limestone injection including plugging (especially of the boiler tubes), low sulfur dioxide removal, and reduced particulate collection in the electrostatic precipitators, these systems proved inadequate. The five installations are now either closed down or converted to other control systems.

Japan has at present the largest installed capacity of FGD systems. Most of these systems were built between 员怨豫 and 员怨苑. Systems based on lime/limestone predominate. As of December 员怨苑 the United States had 圆苑 operating utility units treating about 猿豫伊员园远 Nm猿/h (normal conditions are 园C and 员bar), 猿源 units under construction to treat 缘园伊员园远 Nm猿/h, and 圆园 units are planned to treat 猿源伊员园远 Nm/h; in addition 圆缘 industrial boilers were operational or under construction with a capacity of about 缘伊员园远 Nm猿/h. In the Federal Republic of Germany, approximately 苑豫园园园 Nm猿/h of flue gas are being treated by lime and carbon adsorption processes, and in Norway 员豫园园园 Nm猿/h are treated by seawater scrubbers on oil-fired boiler.

Process Categories

FGD process can most conveniently and usefully be categorized by the manner in which the sulfur compounds removed from the flue gases are eventually produced for disposal. In this way three main categories result:

(员) Throwaway processes, in which the eventual product is disposed of entirely as waste. Disposal can include landfill, ponding, discharge to water course or ocean, or discharge to a worked-out mine.

The processes in this category involve wet scrubbing of the flue gases for absorption, followed by various methods for neutralizing the acidity, separating the sulfur compounds from the scrubbing liquor, and usually recycling at least part of the scrubbing liquor.

(圆) Gypsum processes, which are designed to produce gypsum of sufficient quality either for use as an alternative to natural gypsum or as well-defined waste product with good disposal characteristics.

As with the throwaway processes, this category involves wet scrubbing for absorption followed by various methods of neutralizing lime or limestone and recovering the sulfur compound. An oxidation step is included to insure recovery of the sulfur compounds in the form of gypsum.

(猿) Regenerative processes, which are designed specifically to regenerate the primary reactants and concentrate the sulfur dioxide that has been removed from the flue gases. Further chemical processing can then convert the concentrated SO圆 into sulfuric acid or elemental sulfur, or physical processing into liquefied sulfur dioxide. The surveyed processes in this category contain both wet scrubbing and dry adsorption processes.

Status of Operating FGD Systems

There are now 员源 known FGD systems operating on fossil-fueled combustion sources. Of these, 苑源 are operating on power utility boilers, representing about 苑园伊员园[缘] m[猿]/h of flue gas capacity from about 圆园 GW generation. The remainder is operating on industrial combustion sources, principally boiler plants, but also on iron-ore sinter plants and petroleum refinery plants.

In the NATO-CCMS Process Status Reports, 猿缘 FGD systems were surveyed. Although it was originally desired to include only the large, commercially available installations with adequate operating experience, it was necessary to include data on some smaller scale operation and some that had been installed originally for demonstration purposes in order to provide sufficient comparability between the various processes.

Throwaway Processes: This category includes the three processes that produce a calcium sulfite/sulfate sludge and also the seawater scrubbing process. The sludge processes are becoming the most widely used FGD systems; 猿园 systems are in operation and 缘苑 are planned or under construction. They have been used successfully on both coal and oil-fired plants with a wide range of fuel sulfur contents and are reported to have high SO圆 removal efficiencies, whereas plant availabilities are variable.

Double Alkali Process: It is a further development designed to overcome the scaling, plugging, arid erosion problems that have been generally associated with lime or limestone systems. Double alkali systems are presently used mainly with small to medium-sized boilers where the extra process equipment can be offset by lower maintenance coasts.

Gypsum Processes: These processes are designed to produce a quality of gypsum that may be used in place of natural gypsum in such markets as plaster or plaster wallboard, or as a setting retarder in cement manufacture. It is expected that if sufficient markets are not available for gypsum, it will be disposed of as a solid waste. Gypsum has better setting characteristics than sludges containing calcium sulfite from the throwaway processes.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

scrubbing	擦洗，洗涤
alkaline absorbent	碱性吸收剂
SO圆 removal efficiency	脱硫效率
ICI	帝国化学公司
solid sludge	污泥，泥渣
lime/limestone	石灰/石灰石
magnesium oxide	氧化镁
copper oxide	氧化铜

sulfite	亚硫酸
electrostatic precipitators	静电除尘器
predominate	支配,统治
worked-out	用过的,废弃的
neutralizing the acidity	中和酸
gypsum	石膏
recovering	回收
reactants	反应物
concentrate	浓缩,冷凝
sulfur dioxide	二氧化硫
elemental	单质的,元素的
NATO	北大西洋公约组织(即北约)
demonstration	表演,显示,游行
calcium sulfite	亚硫酸钙
calcium sulfate	硫酸钙
under construction	正在建设中
sulfur contents	含硫量
plaster	熟石膏,烧石膏
retarder	抑制剂,控制剂,阻滞剂

Part Seven摇Bidding

[illegible]

General

The purpose of international bidding is affording to prospective bidders from all member countries of the Bank and Switzerland adequate notification of a borrower's requirements and of providing all bidders an equal opportunity to bid on the necessary goods or works. In connection with any contract to be financed by the Bank, the Bank does not permit a borrower to deny prequalification, if required, to a firm for reasons in related to its capacity to supply the goods and works in question: nor does it permit a borrower to disqualify any bidder for such reasons. As an exception to the foregoing, firms of a member country or goods manufactured in a member country may be excluded if, as a matter of law or official regulations with that country, provided that the Bank is satisfied that such exclusion does not preclude effective competition for the supply of goods or works required.

Type and Size of Contracts

The bidding documents should state clearly whether contracts will be awarded on the basis of unit prices (for work performed or goods supplied) or of a lump sum of the contract, according to the nature of goods or works to be provided.

Contracts based principally on the reimbursement of actual costs are acceptable to the Bank only in exceptional circumstances.

The size and scope of individual contracts will depend on the magnitude, nature, and location of the project. For projects requiring a variety of works and equipment such as power, water supply, or industrial projects, separate contracts are normally awarded for the civil works, and for the supply and erection of different major items of plant and equipment.

On the other hand, for a project requiring similar but separate civil works or items of equipment, bids should be invited under alternative contract options that would attract the interest of both smaller and larger firms. Contractors or manufacturers, small and large, should be allowed to bid for individual contracts or for a group of similar contracts at their option, and all bids and combinations of bids should be opened and evaluated simultaneously so as to determine the bid or combination of bids offering the most advantageous solution for borrower.

In certain cases, e. g. where special processes or closely integrated manufacturing are involved, the Bank may accept a turnkey contract under which the engineering, all equipment, and the construction of a complete plant are provided through a single contract, or a single responsibility contract under which all the goods and works except the engineering are provided through a single contract.

Detailed engineering of the works or goods to be provided, including the preparation of technical specifications and other bidding documents, should precede the invitation to bid for the contract. However, in the case of turnkey contracts or contracts for large complex industrial projects, it may be undesirable to prepare technical specifications in advance. In such a case, it will be necessary to use a two-step procedure inviting unpriced technical bids subject to technical clarifications and adjustments, followed by the submission of the priced proposals.

Notification and Advertising

The international community should be notified in a timely manner of the opportunity to bid. Normally this is done by transmitting copies of the invitation to bid, or the advertisement of the invitation to local representatives of the Bank's member countries and Switzerland that are potential suppliers of the goods or works required and, if it so requests, to the Bank also. If any such country does not have local representation, the invitation or advertisement should be sent to the government agency responsible for its foreign trade. This notification should be made at the same time as the advertisement of the invitation to bid.

Invitation to bid should be advertised in at least one newspaper of general circulation in the borrower's country. For large specialized, or important contracts, the Bank may, in addition, require that invitations to bid be advertised in well-known technical magazines, newspapers, and trade publications of wide international circulation in sufficient time before bids are to be opened to enable prospective bidders to request bidding documents and prepare bids.

If the preparation and issue of bidding documents for a project is likely to extend over a period of years, a brief description of the works to be undertaken and the types of goods and services required should be advertised and notified to, the international community, as described above, at least [illegible] days before the first formal invitations to bid are issued, with a request that those who wish to be included in mailing list and to receive invitations to bid should express their interest by ratification to the borrower.

The borrower should invite bids from all suitably qualified parties expressing such interest.

[illegible]

bid	出价,投标
afford	给予,供给
prospective	预期的
finance	财政,金融
borrower	借款人,借用者
in connection with	在…方面,关于,与…有关
prequalification	资格审查
disqualify	取消资格
unit price	分项价格
preclude	排出,阻止
lump sum	总数,总额
reimbursement	偿还
civil works	土建,土木工程
turnkey contract	交钥匙合同,包到投产的合同
responsibility contract	责任合同
technical specifications	技术规格
submission	提交意见
notification	通知
advertising	广告
community	社会,团体
foreign trade	外贸
circulation	循环,流通,发行
formal	正式的,形式的
loan	贷款,借出

[illegible]
摇摇摇摇 [illegible]

摇摇

Time Interval Between Invitation and Submission of Bids

The time, allowed for preparation of bids should depend on the magnitude and complexity of the contract. Generally, not less than 源缘days from the date of invitation to bid should be allowed for international bidding. Where large civil works are involved, generally, not less than 怨园days from the date of invitation should be allowed to enable prospective bidders to conduct investigations at the site before submitting their bids. The time allowed, however, should be governed by the particular circumstances of the project.

Bid Opening Procedures

The data, hour, and place for latest delivery of bids by the bidder, and of the bid opening, should be announced in the invitation to bid, and all bids should be opened at the stipulated time. Bids delivered after the time stipulated should be returned unopened unless the delay was not due to any fault of the bidder and its late acceptance would not give him any advantage over other bids. Bids should normally be opened in public. The name of the bidder and total amount of each bid, and, of any alternative bids if they have been requested or permitted, should, when opened, be read aloud and recorded.

Extension of Validity of Bids

Extension of validity of bids normally should not be requested; if, in exceptional circumstances, an extension is required, it should be requested of all bidders before the expiration date and the Bank should be notified. Bidders should have the right to refuse to grant such an extension without forfeiting their bid bond, but those who are willing to extend the validity of their bid should be neither required nor permitted to modify their bids.

Clarifications or Alterations of Bids

Except as otherwise provided in particular paragraph of these guidelines, no bidder should be permitted to alter his bid after bid has been opened. Only clarifications not changing the substance of the bid may be accepted. The borrower may ask any bidder for a clarification of his bid but should not ask any bidder to change the substance or price of his bid.

Procedures to Be Confidential

It is undesirable that information relating to the examination, clarification, and evaluation of bids and recommendations concerning awards be communicated after the public opening of bids to bidders or to persons not officially concerned with these procedures until the award of a contract to the successful bidder is announced.

Examination of Bids

Following the opening, it should be ascertained whether material errors in computation have been made in the bids, whether the bids are substantially responsive to the bidding documents, whether the required sureties have been provided, whether documents have been properly signed, and whether the bids are otherwise generally, in order. If a bid is not substantially responsive to the bidding documents, or contains inadmissible reservations, it should be rejected, unless it is an alternative bid permitted, or requested, under the bidding documents. A technical analysis should then be made to evaluate each responsive bid and to enable bids to be compared.

A detailed report on the evaluation and comparison of bids setting forth the specific reasons on which the decision for the award of the contract, or rejection of all bids, is based should be prepared by the borrower or by its consultants. The loan agreement with the Bank will specify whether this report should be submitted to the Bank for its review prior or subsequent to a final decision on the award being made.

Award of a Contract

The award of a contract should be made, within the period specified for the validity of bids, to the bidder whose responsive bid has been determined to be the lowest evaluated bid, and who meets the appropriate standards of capability and financial resources. Except in cases where the circumstances set, out in paragraph related would apply, such bidder should not be required, as a condition of award, to undertake responsibilities or work ;not stipulated in the specifications or to modify his bid.

[illegible]

bid opening	**开标**
award of contract	**授予合同**
conduct	**指导,处理**
stipulate	**约定,规定**

delivery	交付,交货
validity	有效期
expiration	期满,终止
forfeit	投标保证金
alteration	更改,变更
confidential	机密的
ascertain	查明,确定
surety	保证
inadmissible	不能允许的

[illegible]

(Answer for Bidder's Questionaries on TI & BI Pre-bid Meeting for A World Bank Loaned Thermal Power Plant)

1. Q: How important is load service for the client?

A: It is required that the power plant shall be capable of moderating with peak load, and frequency. Stable operation is important. Part load efficiency will be evaluated in the overall bid evaluation. The operating mode shall be used for economic evaluation as indicated in Vol. 猿 P. 猿远 item 圆猿猿员

圆 Q: Volume 猿 page 怨圆 item (e)

For the required design review by Buyer, we would like to propose the following 圆 reviews, each leading to a design phase.

Conceptual review of key project documents GA, P& ID, one-line. Detailed design prior to issue of drawings for construction.

Please confirm.

A: Based on the requirements of TA 猿圆 section 圆 员猿 员 the Bidder shall supply the preliminary design, detailed design documents, and drawings to the Buyer for review. This does not mean, however, that the Contractor's responsibility will be relieved. If the Buyer has not responded for the review of documents by the specified review time, then the Contractor can hold that they have been confirmed. There shall be a clear mark on the revised part of the drawings supplied by the Bidder.

猿 Q: Volume 猿 Page 圆苑 item 源圆

Please clarify if pressure switches (multiple) are within Turbine Island scope. The flow diagram indicates only one pressure switch within the Turbine Island scope.

A: It should be noted that the flow diagram within the Turbine Island scope is only a schematic one. The number of instrument, pressure switches etc. shall be determined by the Contractor, and the pressure switches shall be supplied by the Turbine Island Contractor, please see volume 猿 section 缘 item 员圆猿

源 Q: Volume 猿 Page 员缘 item 员源远(c)

We interpret this statement to be that Turbine Island Contractor will provide Plans Sections of all foundations it designs; i. e. Turbine Generator and BFP pedestals, and plans and sections of all pits and tunnels it requires.

The last sentence of this statement states that the Buyer will be provided concrete for all elevated floors and equipment supports and elevated floor arid, further that the T.

G. and BFP pedestals & foundations will be by the TI Contractor, which disagrees with page 员 item 猿圆圆which states concrete and masonry work is in buyer scope.

Please clarify.

A: Works below ground will be in Buyer's scope. The arrangement plans and cross sections of all the equipment foundations, pits, trenches, tunnels at or below ground level shall be provided by the TI Contractor. Detailed drawings of these underground facilities shall be designed by the Buyer.

The last sentence of this statement shall be changed as follows: the Buyer shall provide concrete for all elevated floors. Concerning about the detailed requirements for TG & BFP pedestals, please see T源苑远缘

缘 Q: Volume 猿Page 源圆 item 圆猿愿员

(员 This statement states that the Turbine Island Contractor will provide stress analysis of the high pressure, high temperature piping within its scope. Contractors whose systems are supported from TI Contractor structures will provide normal and abnormal loading conditions in a timely manner to permit one time structure design (timing, will be defined by TI Contractor).

(圆 TI Contractor will provide circulating water system design interface information to the buyer so its engineer can perform water hammer analysis.

Please clarify and confirm.

A: (员 With regard to the stress analysis of piping, please see TA 猿猿员general arrangement, section 员源源 mechanical interface. "j".

(圆) TI Contractor shall provide circulating water system design interface information to the Buyer so that its engineer can perform water hammer analysis.

远 Q: We were unable to find the steam conditions to be used in the design for this project. Find attached a table of steam conditions we have assumed for bid purposes. In the past steam conditions have been issued. We have included steam flows and velocity that you might consider as design parameters.

A: The steam conditions of boiler and steam turbine shall be coordinated. The bid price shall not be affected.

苑 Q: Please define extent of boiler proper.

A: Please see reference drawing. The extent of the thermal insulation for boiler proper is defined to be all the equipment and pipes between column H and column M except the steam pipe, oil pipe, air duct and flue gas duct. (The interfaces are at the equipment outlets).

愿 Q: Bid Evaluation: Please, confirm the maximum BMCR capacity which will be evaluated at US $ 源愿圆圆圆圆圆per 员% BMCR.

A: The guaranteed value of the BMCR capacity proposed by the BI Contractor in the proposal shall satisfy item 猿源圆on page 员猿愿of volume 猿 If the capacity exceeded this value, the price calculation in the bid evaluation shall not be changed. If the capacity is below the above value, it shall be evaluated by this.

The BI Contractor shall also satisfy the requirements of item 圆猿源员on page 源of volume 猿

怨 Q: Please clarify following: Boiler downcomer header between boiler and slag device shall be tentatively determined as 员园缘m. Does this mean that the furnace inlet headers shall be 员园缘above ground level?

A: The elevation of the furnace water wall lower inlet headers shall be tentatively determined as 员园缘m above the ground level. The elevation of boiler hopper shall be coordinated by BI Contractor and Ash Island Contractor.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

TI&BI	汽机岛和锅炉岛
Pre-bid Meeting	标前会
operating mode	运行方式
pressure switches	压力开关
BFP	锅炉给水泵
masonry work	石工,污工(建筑物)
trench	沟,槽
interface	界面,接口
boiler proper	锅炉本体
flue gas duct	烟风管道
slag device	除渣装置
hopper	渣口
Ash Island Contractor	除灰承包商

[illegible]

Content

员 Invitation for Bids

圆 Instructions to bidders

猿 Bid datasheet

源 General conditions of contract

缘 Special conditions of contract including data sheet

远 Schedule of requirements

苑 Technical specifications

愿 Sample forms

Bid form and price schedules

Bid security form

Contract form

Performance security form

Bank guarantee form for advance payment

Manufacturer's authorization form

Qualification documents

Specimen of letter of credit issued by the purchaser

怨 Eligibility for the provision of goods, works, and services in bank-financed procurement

Invitation for Bids (IFB)

Date: (date of issuance of IFB)

Loan/Credit No: 摇摇摇摇摇摇

IFB No 摇摇摇摇摇摇

员 The 摇摇摇摇摇摇 (name of Borrower) has applied for/received; a loan/credit from the International Development Association (hereinafter called the World Bank) in various currencies towards the cost of 摇摇摇摇 (name of Project). It is intended that part of the proceeds of this loan/credit will be applied to eligible payments under the contract for 摇摇摇摇 (title of Contract).

圆 The 摇摇摇摇 (name of Procurement Agent), for and on behalf of 摇摇摇摇贼 (name of Project Entity) (Purchaser) invites sealed bids from eligible bidders for the supply of 摇摇摇摇 (brief description of the goods and related services).

猿Interested eligible bidders may obtain further information from and inspect the bidding documents at the office of：摇摇摇摇 (name of Procurement Agent)，(mailing address of appropriate office for inquiry and issuance of bidding documents and cable，telex，and/or facsimile numbers).

源 A complete set of bidding documents may be purchased by any interested bidder on the submission of a written application to the above between 摇摇摇摇 am/pm (Beijing time) starting from 摇摇摇摇 at the above address (Sunday and holidays except) and upon payment of a nonrefundable fee of RMB 摇摇摇摇 or US $ 摇摇摇摇 for one set of bidding documents.

缘The provisions in the Instructions to Bidders and in the General Conditions of Contract are the provisions of the World Bank Standard Bidding Documents：Procurement of Goods.

远Bids must be delivered to the above office on or before 摇摇摇摇 (Beijing time.) on 摇摇摇摇 (date) and must be accompanied by a security of 摇摇摇摇 (fixed sum or percentage of bid amount).

苑 Bids will be opened in the presence of bidder s representatives who choose to attend at 摇摇摇摇摇 (time and date) at the office of 摇摇摇摇 (address of appropriate office).

Name of Procurement Agent：摇摇摇摇摇

Detailed Address：摇摇摇摇摇

Cable：摇摇摇摇摇

post code 摇摇摇摇摇

Telex No：摇摇摇摇摇

Fax No：摇摇摇摇摇

Clarification of Bidding Documents

A prospective Bidder requiring any clarification of the bidding documents may notify the Purchaser in writingor by cable (hereinafter，the term cable is deemed to include telex and facsimile) at the Purchaser's address indicated in IFB Clause，灵恕1. The Purchaser will respond in writing to any request for clarification of the bidding documents which is received in no later than thirty (猿园) days prior to the deadline for the submission of bids prescribed in the Bid Data Sheet. Written copies of the Purchaser s response (including an explanation of the query but without identifying the source of inquiry) will be sent to all prospective bidders which have received the bidding documents.

Amendment of Bidding Documents

At any time to the deadline for submission of bids，the Purchaser，for any reason， whether at its own initiative or in response to a clarification requested by a prospective Bidder, may modify the bidding documents by amendment.

At prospective bidders that have received the bidding documents will, be notified of the amendment in writing or by cable, and will be binding on them. In order to allow prospective bidders reasonable time in which to take the amendment into account in preparing their bids, the Purchaser, at its discretion, may extend the deadline for the submission of bids.

Eligible Bidders

This Invitation for Bids is open to all eligible source countries as defined in Guideline: Procurement under IBRD Loans and IDA Credits, dated January 灵怨缘 hereinafter referred to as the IBRD Guidelines for Procurement, except as provided hereinafter.

Bidders should not be associated, or have been associated in the past, directly or indirectly, with a firm or any of its affiliates which have been engaged by the Purchaser to provide consulting services for the preparation of the design, specifications, and other documents to be used for the procurement of the goods to be purchased under this Invitation for Bids.

Government-owned enterprises in the purchaser's country may participate only if they are legally and financially autonomous, if they operate under commercial law, and if they are not a dependent agency of the Purchaser.

晕藻赠 宰[illegible]

invitation for bids (IFB)	招标通知,招标文件
bid date sheet	招标时间表
bid security form	招标保密形式
bank guarantee form	银行担保形式
advance payment	合理的付款方式
eligibility	符合,合格,适当性
procurement	采购
credit	信贷
currencies	现汇
on behalf of	代表
sealed bids	密封的标书
telex	用户/直通电报, 电报用户直通电路
facsimile	传真,传真通讯,复制
nonrefundable fee	不能归还的费用
IBRD loan	世界银行贷款
IDA Credits	国际开发协会信贷
hereinafter	在下(文)

affiliate	使…加入，合并，参与，接纳…为分支机构
government-owned enterprise	国有企业
financially autonomous	财政/财务独立
deem to	认为，想，相信

Definitions

In this Contract, the following terms should be interpreted as indicated:

"The Contract" means the agreement entered into between the Purchaser and the Supplier, as recorded in the Contract Form signed by the parties, including all attachments and appendices thereto and all documents incorporated by reference therein.

"The Contract price" means the price payable to the Suppliers under the contract for the full and proper performance of its contractual obligations.

"The Goods" means all of the equipment, machinery, and/or other materials, which the Supplier is required to supply the Purchaser under the Contract.

"The Services" means those services ancillary to the supply of the Goods, such as transportation and insurance, and any other incidental service, such as installation, commissioning, provision of technical assistance, training, and other such obligations of the Supplier covered under the Contract.

"GCC" means the General Conditions of Contract contained in this section.

"SCC" means the Special Conditions of the Contract.

"The Purchaser" means the organization purchasing the Goods, as named in SCC.

"The Supplier" means the individual or firm supplying the Goods and Services under this Contract.

"The world Bank" means the International Bank for Reconstruction and Development (IBRD) or the International Development Association (IDA).

Application

These General Conditions shall apply to the extent that are not superseded by provisions of other parts of the Contract.

Country of Origin

All Goods and Services supplied Under the Contract shall have their origin in the countries and territories eligible under the rules of the World Bank, as further elaborated in the SCC.

For purposes of this Clause, "origin" means the place where the Goods were mined, grown, or produced, or from which the Services are supplied. Goods are produced when, through manufacturing, processing of substantial and major assembly of components, a commercially-recognized new product results that are substantially different in basic characteristics or in purpose or utility from its components.

Inspections and Tests

The Purchaser or its representative shall have the right to inspect and/or to test the Goods to confirm their conformity to the Contract specifications at no extra cost to the Purchaser. SCC and the Technical Specifications shall specify what inspections and tests the Purchaser requires and where they are to be conducted. The purchaser shall notify the Supplier in writing a timely manner, of the identity of any representative retained for these purposes.

The inspections and tests may be, conducted on the premises of the Supplier or its subcontractor (s), at point of delivery; and/or at the Goods; final destination. If conducted on the premises of the Supplier or its subcontractor (s), all reasonable facilities and assistance, including access to drawings, and production data, shall be furnished to the inspectors at no charge to the Purchaser.

Should any inspected or tested Goods fail to conform to the Specifications, the Purchaser may reject the Goods, and the Supplier shall either replace the rejected Goods or make alterations necessary to meet specification free of cost to the Purchaser.

The Purchaser's right to inspect, test and, where necessary, reject the Goods after the Goods' arrival in the Purchaser's country shall in no way be limited or waived by reason of the Goods having previously been inspected, tested, and passed by the Purchaser or its representative prior to the Goods' shipment from the country of origin.

Nothing in GCC Clause 愿shall in any way release the Supplier from any warranty or other obligations under this Contract.

Packing

The Supplier shall provide such packing of the Goods as is required to prevent their damage or deterioration during transit to their final destinations as indicated in the Contract. The packing shall be sufficient to withstand rough handling during transit and exposure to extreme temperatures; salt and precipitation during transit and open storage, packing case size and weights shall be taken into consideration, where appropriate, the remoteness of the Goods' final destination and the absence of heavy handling facilities at all points in transit.

The packing, marking, and documentation within and outside the packages shall comply strictly with such special requirements as shall be expressly provided for in the Contract, including additional requirements, if any, specified in SCC, and in any subsequent instructions ordered by the Purchaser.

Delivery and Documents

Delivery of the Goods shall be made by the Supplier in accordance with the terms specified in the Schedule of Requirements. The details of shipping and/or other documents to be furnished by the Supplier are specified in SCC.

For purposes of the Contract, "EXW", "FOB", "FGA", "CIF", "CIP", and other trade terms used to describe the obligations of the parties shall have the meanings assigned to them by the current edition of incoterms published by the international Chamber of Commerce, Paris.

Documents to be submitted by the Supplier are specified in SCC.

Insurance

The Goods supplied under the Contract shall be fully insured in a freely convertible currency against loss or damage incidental to manufacture or acquisition, transportation, storage and delivery in the manner specified in SCC.

When delivery of the Goods is required by the Purchaser on a CIF or CIP basis, the Supplier shall arrange and pay for cargo insurance, naming the Purchaser as the beneficiary. Where delivery is on an FOB or FCA basis, insurance shall be the responsibility of the Purchase.

Transportation

Where the Supplier is required under the Contract to deliver the Goods on FOB, transport of the Goods, up to and including the point of putting the Goods on board the vessel at the specified port of loading, shall be arranged and paid for by the Supplier, and the cost thereof shall be included in the Contract Price. Where the Supplier is required under the Contract to deliver the Goods on FCA, transport of the Goods and delivery into the custody of the carrier at the place named by the Purchaser or other agreed points shall be arranged and paid for by the Supplier, and the cost thereof shall be included in the Contract Price.

Where the Supplier is required under the Contract to deliver the Goods on CIF or CIP, transport of the Goods to the port of destination or named place of destination in the Purchaser's country, as shall be specified in the Contract, shall be arranged and paid for by the Supplier, and the cost thereof shall be included in, the Contract Price.

Where the Supplier is required under the Contract to transport the Goods to specified place of destination within the Purchaser's country, defined as the Project Site, transport to such place of destination in the Purchaser's country, including insurance and storage, as shall be specified in the Contract, shall be arranged by the Supplier, and the related costs shall be included in the Contract Price.

Where the Supplier is required under the Contract to deliver the Goods on CIF of CIP, no restriction shall be placed on the choice of the carrier. Where the Supplier is required under the Contract (a) to deliver the Goods on FOB or FCA; and (b) to arrange on behalf and at the expense of the Purchaser for international transportation on specified carriers or on national flag carriers of the Purchaser's country, the Supplier shall arrange for such transportation on alternative carriers if the specified carriers or national flag carriers, are not available to transport the Goods within the period (s) specified in the Contract.

Incidental Services

The Supplier may be required to provide any or all of the following services, including additional services, if any specified in SCC:

(员 Performance or supervision of on-site assembly and/or start-up of the supplied Goods.

(圆 Furnishing of tools required for assembly and/or maintenance of the supplied Goods.

(猿 Furnishing of a detailed operations and maintenance manual for each appropriate unit of the supplied Goods.

(源 Performance or supervision or maintenance and/or repair of the supplied Goods, for a period or time agreed by the parties, provided that this service shall not relieve the Supplier of any warranty obligations under this Contract; and

(缘 Training of the Purchaser's personnel, at the Supplier's plant and/or on-site, in assembly, start-up, operation, maintenance, and/of repair of the supplied Goods.

Prices charged by the Supplier for incidental services, if not included in the Contract Price for the Goods, shall be agreed upon in advance by the parties and shall not exceed the prevailing rates charged for other parties by the Supplier for similar services.

[illegible]

supersede	代替,取代,更换,废除
territory	土地,领土,范围,领域
subcontractor	子承包商,二包,转包人
at no charge	免费
in no way	决不,一点儿也不
warranty	理由,保证,保险,执照,许可证
deterioration	变坏,降低(品质),恶化,损坏,消耗
transit	通过,移动,运输,转运口
marking	标记,标志,商标
convertible	可逆的,可转变的,自由兑换
acquisition	获得,发现,学识
cargo insurance	货物保险
custody	保管,监视,收容,监禁
carrier	搬运公司,货运公司,载体,托架

Spare Parts

As specified in SCG, the Supplier may be required to provide any or all of the following materials, notifications, and information pertaining to spare parts manufactured or distributed by the Supplier.

(a) Such spare parts as the Purchaser may elect to purchase from the Supplier, provided that this election shall not relieve the Supplier of any warranty obligations under the Contract.

(b) And in the event of termination of production of the spare parts:

(i) Advance notification to the Purchaser of the pending termination, in sufficient time to permit the Purchaser to procure needed requirements; and

(ii) Following such termination, furnishing at no cost to the Purchaser, the blueprints, drawings, and specifications of the spare parts, if requested.

Warranty

The Supplier warrants that the Goods supplied under the Contract are new, unused, of the most recent or current models, and that they incorporate all recent improvements in design and materials unless provided otherwise in the Contract. The Supplier further warrants that all Goods supplied under this Contract shall have no defect, arising from design, materials, or workmanship (except when the design and/or material is required by the Purchaser's specifications) or from any act or omission of the Supplier, that may develop under normal use of the supplied Goods in the conditions prevailing in the country of final destination.

This warranty shall remain valid for twelve (猿圆) months after the Goods, or any portion thereof as the case may be, have been delivered and accepted at the final destination indicated in the Contract, or for eighteen (猿愿) months after the date of shipment from the port or place of loading in the source country, whichever period concludes earlier, unless specified otherwise in SCC.

The Purchaser shall promptly notify the Supplier in writing if any claim arising under this warranty.

Upon receipt of such notice the Supplier shall, within the period specified in SCG and with all reasonable speed, repair or replace the defective Goods or parts thereof, without costs to the purchaser other than, where applicable, the cost of inland delivery of the repaired or replaced Goods or parts from, EXW or the port or place of entry to the final destination.

If the Supplier, having been notified, fails to remedy the defect (s) within the period specified in SCC, within a reasonable period, the Purchaser may proceed to take such remedial action as, may be necessary, at the Supplier's risk and expense and without prejudice, to any other rights, which the Purchaser may have against the Supplier under the Contract.

Payment

The method and condition of payment to be made to the Supplier under this Contract shall be specified in SCC.

The Supplier's request (s) for payment shall be made to the purchaser in writing, accompanied by an invoice describing, as appropriate, the Goods delivered and Services performed, and by documents submitted to GCC clause 员园, and other obligations stipulated in the Contract.

Payments shall be made promptly by the Purchaser, but in no case later than sixty (远园) days after submission of an invoice, or claim may be made by the Supplier.

The currency or currencies in which payment is made to the Supplier under this Contract shall be specified in SCC subject to the following general principle: payment will be made in the currency or currencies in which the payment has been requested in the Supplier's bid.

Prices

Prices charged by the Supplier for Goods delivered and Services performed under the Contract shall not vary from the prices quoted by the Supplier in its bid, with the exception any price adjustment authorized in the Purchaser's request for bid validity extension, as the case may be.

Change Orders

The Purchaser may at any time, by a written order given to the Supplier pursuant to GCC Clause 猿员, make changes within the general scope of the Contract in any one or more of the following:

员 Drawings, designs, or specifications, where Goods to be furnished under Contract are to be specifically manufactured for the Purchaser;

圆 The method of shipment or packing;

猿 The place of delivery;

源 The Services to be provided by the Supplier.

If any such change causes an increase or decrease in the cost of, or the time required for, the Supplier's performance of any provision under the Contract, an equitable adjustment shall be made in the Contract Price or delivery schedule or both, and the Contract shall accordingly be amended. Any claim by the Supplier for adjustment under this clause must be asserted within thirty (猿园) days from the date of the Supplier's receipt of the Purchaser's change order.

Contract Amendments

Subject to GCC Clause 猿愿, no variation in or modification of the terms of the Contract shall be made except by written amendment signed by the parties.

Assignment

The Supplier shall not assign, in whole or in part, its obligations to perform under this Contract, except with the Purchaser's prior written consent.

Subcontracts

The Supplier shall notify the Purchaser in writing of all subcontracts awarded under this Contract if not already specified in the bid. Such notification, in the original bid or later, shall not relieve the Supplier from any liability or obligation under the Contract. Subcontracts must comply with the provisions of GCC Clause 猿.

Delays in the Supplier's Performance

Delivery of the Goods and performance of Services shall be made by the Supplier in accordance with the time schedule prescribed by the Purchaser in the Schedule of Requirements.

If at any time during performance of the Contract, the Supplier or its subcontractor (s) should encounter conditions impeding timely delivery of the Goods and performance of Services, the Supplier shall promptly notify the Purchaser in writing of the fact of the delay, its likely duration and its cause (s). As soon as practicable after receipt of the Supplier's notice, the Purchaser shall evaluate the situation and may at its discretion extend the Supplier's time for performance, with or without liquidated damages, in which case the extension shall be ratified by the parties by amendment of the Contract.

Except as provided under GCC Clause 圆缘, a delay by the Supplier in the performance of its delivery obligations shall render the Supplier liable to the imposition of liquidated damages pursuant to GCC clause 圆苑, unless an extension of time is, agreed upon pursuant to GCC Clause 圆园.圆 without the application of liquidated damages.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

spare parts	备件,附件
pertaining	有关系的,附属的,为…所固有的 (to)
elect	选举,推荐

blueprints	蓝图
workmanship	工作质量，工艺，技巧，作品，制造物
omission	省略，删除，疏忽
claim	要求，索赔
remedial	治疗的，修补的
prejudice	偏见，伤害，损害
invoice	发票，发货单，开发票
validity extension	有效期
consent	同意，许可，万能插口
liability	责任，义务，债务
liquidate	液化，清理（算，除），偿还，破产
ratify	批准，认可
pursuant	按照，遵循，依据，追踪

Part Eight摇Reading Materials

哉灶蚤贼摇员摇晕怎糟造藻葬则摇孕燥憎藻则摇蚤灶摇悦澡蚤灶葬

摇摇Nuclear power development in mainland China commenced in 员怨苑园 and the industry has now moved to a steady development period. While coal is the main energy source in China, most reserves are in the north or northwest and present an enormous logistic problem.

Most electricity produced in mainland China is supplied by fossil fuels (about 愿园%, mainly coal) and hydro power (about 员缘%). Two large hydro projects are under construction: Three Gorges of 员愿援圆GWe and Yellow River of 员缘援愿GWe.

Nationally about 猿缘远GWe is installed and 员,缘源苑TW·h was generated in 圆园园圆援 Nuclear power has an important role, especially in the coastal areas remote from the coalfields and where the economy is developing rapidly. In 圆园园猿 it provided 源员援远 billion kWh — 圆援圆% of total, and now has 远援远GWe installed.

The first two nuclear power plants in mainland China were at Daya Bay near Hong Kong and Qinshan, south of Shanghai, with construction starting in the mid 员怨愿园泽.

The two reactors at **Daya** Bay were standard 猿-loop French units supplied by Framatome, with GEC-Alston turbines. Electricite de France (EDF) managed construction, starting in August 员怨愿苑 with the participation of Chinese engineers. The plant produces about 员猿 billion kW·h per year, with 苑园% transmitted to Hong Kong and 猿园% to Guangdong.

Qinshan-员 in Zhejiang Province 员圆园 km SW of Shanghai, is China's first indigenously-designed and constructed nuclear power plant (though with the pressure vessel supplied by Mitsubishi, Japan). Construction work spanned 远援缘 years from March 员怨愿缘 with criticality in Dec 员怨怨员援 It was shut down for 员源 months for major repairs from mid 员怨怨愿援 **Qinshan phase 圆** (units 圆 and 猿) are locally-designed and constructed 圆-loop reactors, scaled up from Qinshan-员援 Unit 圆 started up at the end of 圆园园员 and entered commercial operation in April 圆园园圆援 Unit 猿 started up in March 圆园园源 with commercial operation in May 圆园园源援 **Qinshan phase 猿** (units 源 and 缘) use the CANDU 远 technology, with Atomic Energy of Canada (AEC) being the main contractor of the project on a turnkey basis. Construction began in 员怨苑 They are each about 远缘MW net. Unit 源 started up in September 圆园园圆 and unit 缘 in April 圆园园猿

Lingao-员 started up in February 圆园园圆 and entered commercial operation in May. **Lingao-圆** was connected to the grid about September 圆园园圆 The two Lingao reactors use French technology supplied by Framatome ANP, virtually a replica of Daya Bay next door in Guangdong province. The operating mainland nuclear power reactors are shown in Table 愿员

表愿援员 韵责藻则葬贼蚤灶早 皂葬蚤灶造葬灶凿 灶怎糟造藻葬则 责燥憎藻则 则藻葬糟贼燥则泽

哉灶蚤贼	栽赠责藻	晕藻贼 糟葬责葬糟蚤贼赠 (藻葬糟澡)	杂贼葬则贼 怎责
阅葬赠葬 月葬赠 员 驭 圆	孕宰砸	怨愿源 酝宰藻	员怨怨源
匝蚤灶泽澡葬灶 员	孕宰砸	圆愿愿 酝宰藻	粤怎早 员怨怨源
匝蚤灶泽澡葬灶 圆 驭 猿	孕宰砸	远圆园 酝宰藻	圆园园圆, 圆园园源
蕴蚤灶早葬燥 员 驭 圆	孕宰砸	怨猿缘 酝宰藻	圆园园圆, 圆园园猿
匝蚤灶泽澡葬灶 猿 员 驭 缘	孕匀宰砸	远缘缘 酝宰藻	圆园园圆, 圆园园猿
栽燥贼葬造 (怨		远缘愿缘 酝宰藻	

Two Russian AES-怨员 power plants (with 员园园园 MW VVER reactors) are being constructed at Jiangsu Tianwan in Lianyungang under a cooperation agreement between China and Russia. They incorporate Finnish safety features and Siemens instrumentation and control systems. The nuclear power reactors under construction are shown in Table 愿圆

表愿援圆 晕怎糟造藻葬则 责燥憎藻则 则藻葬糟贼燥则泽 怎灶凿藻则 糟燥灶泽贼则怎糟贼蚤燥灶

孕造葬灶贼	栽赠责藻	晕藻贼 糟葬责葬糟蚤贼赠	[illegible]	杂贼葬则贼 怎责
栽蚤葬灶憎葬灶 员	孕宰砸 (灾灾耘砸)	怨缘园 酝宰藻	员怨怨怨	圆园园源
栽蚤葬灶憎葬灶 圆	孕宰砸 (灾灾耘砸)	怨缘园 酝宰藻	员怨怨怨	圆园园缘
栽燥贼葬造 (圆		员 怨园园 酝宰藻		

* [illegible]

From 圆园园缘 when all the 员员 units operate, nuclear power will provide some 愿缘园园 MW of the total electric capacity.

Current policy and plans

China has set the following points as key elements of its nuclear energy policy:

- PWRs will be the mainstream but not sole reactor type.
- nuclear fuel assemblies are fabricated and supplied indigenously.

- domestic manufacturing of plant and equipment will be maximized, with self-reliance in design and project management.
- international cooperation is nevertheless encouraged.

The government plans to increase nuclear generating capacity to [illegible]GWe by [illegible] requiring an average of 圆GWe per year being added. Table 愿.猿 shows the planned / proposed nuclear power units:

Uranium resources, fuel

China's known uranium resources of [illegible]tU, will be sufficient to fill the requirements for the mainland nuclear program for the short-term. Production of some [illegible] t/yr including that from heap leach operations at several mines in Xinjiang province supplies current needs.

Operating uranium mines

In addition, the Hengyang underground uranium mine is on stand-by. The mine, which started up in [illegible] has a nominal production capacity of [illegible]tU per year.

The Lanzhou enrichment plant in Gansu province uses Soviet-era diffusion technology and has supplied Daya Bay. It is being replaced with Russian centrifuge technology, which will reach [illegible] tSWU/yr about [illegible] Another small plant at Hanzhong, Shanxi province, is operating and being expanded to [illegible]tSWU/yr by [illegible] A contract with Urenco supplies [illegible]% of the enrichment for Daya Bay from Europe.

[illegible] [illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]		[illegible]

A PWR fuel fabrication plant at Yibin, Sichuan province, supplies Qinshan-员with 员圆 tonnes a year of fuel assemblies. A second production line was established in the same factory to supply 圆远tonnes per year of fuel assemblies to the Daya Bay units.

Spent fuel and reprocessing

When China started to develop nuclear power, a closed fuel cycle strategy was also formulated and declared at an IAEA conference in 员愿苑 The spent fuel activities involve: at-reactor storage, away-from-reactor storage, and reprocessing. China National Nuclear Corp (CNNC) has drafted a state regulation on civil spent fuel treatment, which is being reviewed prior to issue by the government and formulation of a long-term program.

The cumulative arising from China's operating PWRs amounts to less than a thousand tonnes, but the units under construction will soon raise annual PWR spent fuel arisings to 员愿t, while the two new CANDU units, with lower burn-up, will discharge 员苑远tonnes of spent fuel annually.

Based on expected installed capacity of 圆园GWe by 圆园员园and 源园GWe by 圆园圆园 the annual spent fuel arisings will amount to about 远园园tonnes in 圆园员园and 员圆园园tonnes in 圆园圆园 the cumulative arisings increasing to about 猿愿园园tonnes and 员园猿园园tonnes, respectively.

Construction of a centralized spent fuel storage facility, located in Lanzhou Nuclear Fuel Complex, began in 员怨怨源 The initial stage of that project will have a storage capacity of 缘缘园tonnes in 圆园园员and could be extended with an additional capacity of 缘缘园 tonnes.

A Pilot reprocessing plant is under construction, and cold commissioning was expected in 圆园园猿 A full-scale commercial reprocessing plant could follow.

Research & Development

A 员园MWt high-temperature gas-cooled demonstration reactor (HTR-员园, having fuel particles compacted with graphite moderator into 远园mm diameter spherical balls (pebble bed) was commissioned in 圆园园园by the Institute of Nuclear Energy Technology (INET) at Tsinghua University near Beijing. It reached full power in 圆园园猿and has an outlet temperature of 苑园园C—怨缘园C and may be used as a source of process heat for heavy oil recovery or coal gasification. It is similar to the South African PBMR intended for electricity generation. It was subject to a test of its intrinsic safety in September 圆园园源 when as an experiment it was shut down with no cooling. Fuel temperature reached less than 员远园园C and there was no failure.

Initially the HTR-员园has been coupled to a steam turbine power generation unit, but second phase plans are for it to operate at 怨缘园C and drive a gas turbine, as well as enabling R&D in heat application technologies. This phase will involve an international partnership with Korea Atomic Energy Research Institute（KAERI），focused particularly on hydrogen production.

A commercial prototype HTR-PM of 灵缘MWe（源豫园MWt）is then envisaged，to be built in Oct. 圆园远at Weihai in Shandong province and initially to drive a steam turbine. China Nuclear Engineering & Construction will have a 猿缘% stake and Tsinghua University INET 缘% . Huaneng，one of China's major generators，is the lead organization in the consortium with 缘园% share. Cost is expected to be US $ 员缘园园 kWe.

The HTR-PM will pave the way for 员愿（远伊猿） further units at the same site — total 猿愿园园MWe — also with steam cycle. Then a series of HTRs，possibly with Brayton cycle directly driving the turbines，will be factory-built and widely installed throughout China.

A 远缘MWt fast neutron reactor — the Chinese Experimental Fast Reactor（CEFR）— is under construction near Beijing and due to achieve criticality in 圆园园缘. There has been some Russian assistance in its development. R & D on fast neutron reactors started in 员怨远源.

A 圆园园MWt NHR-圆园园integral PWR has been developed by INET near Beijing for desalination and district heat. It is developed from the NHR-缘prototype，which started up in 员怨愿怨.

About ten other research reactors ranging up to 员缘MW，and one 员圆缘MW test reactor（HFETR）are operational.

Organisation

The China Atomic Energy Authority（CAEA）is responsible for planning and managing the peaceful use of nuclear energy and promoting international cooperation. The CAEA is the key body reviewing and approving feasibility studies for new plants，though the State Development and Planning Commission is finally responsible for approval.

The National Nuclear Safety Administration（NNSA）was set up in 员怨愿源and is the licensing and regulatory body，which also maintains international agreements regarding safety. The State Environment Protection Administration（SEPA）is responsible for radiological monitoring and radioactive waste management. A utility proposing a new plant submits feasibility studies to the CAEA，siting proposals to the NNSA and environmental studies to SEPA.

The China Nuclear Engineering and Construction group（CNEC）is responsible for construction. The China National Nuclear Corporation（CNNC）controls other nuclear sector business.

晕藁韵 宰爆醋醛蕖凿耘磨赞赣鏊择

Framatome摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇摇法玛通（法国）

Framatome ANP	（法国）法玛通先进核能公司
GEC-Alston	通用阿尔斯通（法国）
criticality	危险程度
turnkey	交钥匙，总承包
replica	复制品
reserves	储量
indigenously-designed	自行设计的
locally-designed	自行设计的
sole	惟一的
Uranium	铀
IAEA（International Atomic Energy Agency）	国际原子能组织
CANDU（Canadian deuterium uranium reactor）	加拿大重水铀反应堆
HTR（high temperature reactor ）	高温反应堆
PBMR（pebble bed modular reactor）	球床模块反应堆
The China Atomic Energy Authority（CAEA）	中国原子能机构
The National Nuclear Safety Administration（NNSA）	国家核安全局
The State Environment Protection Administration（SEPA）	国家环境保护总局
envisage	正视
China Nuclear Engineering and Construction group（CNEC）	中国核工业建设集团公司
The China National Nuclear Corporation（CNNC）	中国核工业集团公司
Institute of Nuclear Energy Technology	核能研究院

[illegible]

摇摇

Introduction

Researchers select topics based on the progress made in the past studies. Much knowledge can be obtained by reviewing the previous studies. Based on the obtained knowledge, experiments will be designed and analysis will be performed. Accordingly, the methods adopted in the current studies and the expected results are also under the influence of previous studies.

The relationships between the current and future studies are similar to the aforementioned relationships between the previous and current studies. Most of future study plans will be made on the knowledge obtained through the current studies. This implies that the current studies are on a starting point for the future studies. Therefore, the topics in the current studies should be determined by considering the prediction for the future studies.

It is important to direct young researchers for conducting meaningful future studies. In this paper, previous and current studies are compared in their concepts, methods, and results; and criteria for meaningful future studies are discussed.

Historical Achievement in Combustion Research

The history of combustion research might start with the history of human kind. Early activities must be far different from those in modern combustion research. However, the purposes would be the same as those of current combustion research, i.e., to find out better ways to utilize the energy released by combustion or to mitigate adverse effects caused by combustion.

Understanding of combustion phenomena would be the purpose of early activities. Life would become rich by accumulating knowledge on flammability of materials. Such knowledge is indispensable to classify fuels on the basis of their purposes. A good fuel for cooking is different from that for light. At the same time, they can have a safe way with fuels in a house.

The initiation of combustion, ignition, was the most troublesome process until the last century. The development of combustion technology depends largely on the improvement of the means of ignition. In this case also, we need knowledge on material flammability.

Torches and candles have been used for their brightness caused by combustion. Some aspects of them have been symbolized as combustion research. A number of physicists and chemists have investigated the characteristics and structures of flames of torches and candles. For such investigations, knowledge on combustion reaction is necessary.

Not only the light but also smell, smoke, and other combustion products including toxic materials are generated as a result of combustion. Some of them are beneficial to us and others are not. These phenomena are closely related to combustion reaction. Thus, knowledge of combustion reaction, which is indispensable to control combustion causing the above phenomena, is necessary to utilize the beneficial characteristics of combustion and to avoid the non-beneficial ones.

During the Industrial Revolution, the importance of combustion as the energy conversion process had increased. At the same time, the disadvantage of combustion had become obvious. For preventing the disasters caused by explosions, modern combustion research had started. Well-known studies in this period were performed on the basis of knowledge accumulated by physicists and chemists for centuries.

Knowledge on combustion phenomena had increased at this period, and at the last half of the 员怨h century, the structure of a candle flame and mechanisms of flame propagation were basically understood, and even a simple flame theory was proposed.

Recent Progress in Combustion Research

At the first half of the 圆园h century, our knowledge on combustion had been gradually accumulated. The results were presented in the proceedings of the first through fourth symposia on combustion. During this period, many important aspects of combustion phenomena had been revealed and some basic mathematical models had been proposed. The time came to found a society. Consequently, the Combustion Institute was founded on July 员, 员怨缘源 in the State of Delaware, U. S. A. just before the 缘h Symposium (International) on Combustion. This time, i. e., the time at the foundation of the Combustion Institute can be postulated to be the starting point of the recent progress in combustion research.

The subjects of studies and methods adopted in the studies at a period can be assumed to represent respectively what researchers were interested in and what their technical background was at the period. Thus, the trend of the research at a period can be inferred on the basis of the subjects and methods.

The progress of combustion research in one subject is necessarily different from another. For the prediction of future combustion research, such a difference must be needed to understand. In the following, the progress in 猿 subjects, "electrical aspects of combustion", "turbulent premixed combustion", and "fire" is described briefly.

The first researcher who studied the electrical aspects of combustion would be W. Gilbert at about [illegible] Since then, a number of physicists and chemists have studied various electrical aspects of combustion. In the Third Symposium (International) on Combustion, Calcote presented the results of an experimental study in which he inferred the ion number density in the reaction zone based on the effects of electrical fields on the flame behavior. After this paper, many papers have been published on the measuring techniques for flame ions, identification of ionized species, mechanisms of ion generation, effects of electric and/or magnetic fields on flame behavior or reaction mechanisms, and application of electrostatic probes to flame diagnostics. The research on electrical aspects of flames has gained a gradual progress. The problems then had been solved gradually in the next period. At present, the mechanisms of idolization in hydrocarbon flames are almost clear and the electrical properties have been applied to the measurement and control of combustion phenomena.

In the studies on electrical aspects of combustion, clear steps of the progress in the accumulation of knowledge can be found. Studies at a period had been performed on the basis of the studies before that period.

It is well known that for understanding the characteristics of turbulent flames there are a number of problems to solve. In early studies on turbulent premixed flames, the enhancement of the burning velocity by turbulence had been attempted to explain. However, most explanations were based on hypotheses. This situation has never been improved. Although a number of theories have been proposed, they have not provided us with detailed mechanisms or physical understanding on turbulent premixed flames but with unsolved problems to be proved. Urgent studies on turbulent premixed flames should be performed for accumulating knowledge on elementary processes in the flame zones of turbulent premixed flames in existence.

In most studies on turbulent premixed flames, researchers have attempted to solve the aforementioned unsolved problems, which are sometimes unsolvable problems. The studies performed at a period had been not necessarily based on the results of the studies before that period. So little knowledge has been accumulated on which every researcher agree, although so many studies have been performed on this subject.

Fire research is interdisciplinary involving so many fields other than combustion. When the importance to prevent forest fires was increased, combustion characteristics of various kinds of woods, large piles of wood, or grass beds of various degrees of humidity would be examined. After oil reservoirs of large capacities were built, large oil reservoir fires should be studied. With the progress of aerospace technology, studies on fires under microgravity conditions have increased in their importance. In fire research, the problems have changed with our life, although the needs to accumulate basic knowledge on fires do not change. Each problem closely related to our life should be solved within a certain period. If the problem could not be solved, some project would be stopped. If the result would not be correct, accidental fires would occur.

Expectations for Combustion Research in the Future

As aforementioned, the major purposes of combustion research are to find out better ways to utilize the energy released by combustion and to mitigate adverse effects caused by combustion. These purposes have never changed throughout the history of combustion research and have been accomplished through basic and applied studies on combustion phenomena. However, the subjects having been studied have gradually changed as mentioned in the previous sections.

The change of the subjects should be caused by the change of researchers' interest, which is closely related to public expectations. The public expectations at a period for combustion research, necessarily depend on the social demands at that period. Thus, for accurate prediction of major subjects in future combustion research, we have to predict future social demands.

The importance of combustion research has rapidly increased for recent decades because of enlargement of the social demands for energy and environment. The results of combustion research have been considered at determination of policies and directly affected social life. In the future this trend will be more marked.

The extent to which one can understand and control combustion phenomena depends on his knowledge on fundamental aspects of combustion, which can be accumulated only by combustion research.

Combustion researchers are responsible to give the best solution to our future life.

[illegible]

mitigate	减轻
flammability	易燃,可燃性
postulate	假定,基本条件,基本原理
indispensable	不可缺少之物,不可缺少的,绝对必要的
symbolize	象征,用符号表现
diagnostics	诊断学
idolization	偶像化,盲目的崇拜
premixed	预混合料,预拌和料
hypotheses	臆测,假定
interdisciplinary	各学科间的

[illegible]

Position of the Problem

According to references, it can be ascertained that the level of fire science used in application to safety and investigation processes is relatively weak compared to other engineering disciplines and areas of technology. Therefore, the current use of fire science is consistent with this base of knowledge and its dissemination. Consequently the practice of fire safety and fire investigation is empirical, and based on established practices. Despite this current state, there is a growing awareness and appreciation of fire science and a growing use of engineering analysis in fire application. The real interest for fire safety has risen during the latter half of the 20th century, and the present period is surely to see a complete restructuring of how fire issues are considered. Moreover, the growing development of mathematical computing methods will make complex problems such as those of fire more tractable, The state of fire science can be measured by the ability to present consistent and generalized explanations for its phenomena, and to be able to predict important variables with generalization. Several textbooks or handbooks provide a good overall balance of the state of the art.

In the near future, empirical and experimental based formulas will be the most practical method to advance the state of the art. Although current computational and instrumentation based results can yield much detail about fire phenomena, there are limitations to their generalization. It is important to increase our understanding of various phenomena like: turbulence, buoyant flows, flame structure, chemical kinetics, pyrolysis, prior to improve our ability to better predict respectively: flow and combustion, entrainment and air supply, heat transfer and radiation, combustion products, burning rate of solids.

Among the classical combustion problems related to fire safety, two examples are of great importance: pool fires and wall fires. Liquid or solid combustible materials often burn such that a diffusion flame is established across the combustible surface, in the absence of a significant flow parallel to the surface, buoyantly dominated pool fires occur. If the gaseous oxidizer flows parallel to the surface, the diffusion flame stabilizes itself in the boundary layer developing above the surface. In a horizontal configuration with forced flow, it corresponds to the floor burning situation (or Emmons problem). In a vertical ones, it relies on wall burning.

The Behavior of Pool Fires

Some pertinent contributions to some of the issues that should be addressed to meet fire safety requirements，have been extracted from the literature devoted to the study of pool fires. The characteristics of pool fire flame and plume structure，including flame height，the entrainment of air，the pulsation of the flame and the influence of cross-flow，the formation and properties of soot，the heat feedback，and mass burning，including radiation transport and radiative energy blockage have been addressed by considering experimental approaches and numerical modeling. It appears that among the various parameters that play an important role in the characterization of pool fires，some have been satisfactorily taken into account but some have not.

It is clear that reliable prediction of fire processes is required for fire protection engineering. The need for immediate solutions to the fire threat and the complexity of the fire problem have led the researchers，in the fire community，to look for practical engineering solutions，often empirical，for the prediction of fire development and control. However，it is widely recognized that the reliability of the prediction of fire processes necessarily depends upon the quality and amount of knowledge of the process involved. Definitively，the formation and characterization of soot，or the radiative energy blockage near the surface of the pool require more basic research，especially for establishing a systematic methodology to evaluate the real threat due to large pool fires and to provide solutions to control their impact. Studies related to the formation of soot，to the characterization of the radiative properties and of thermal radiation are under the way，together with the understanding of extinction phenomena.

Vertical Wall Fires

Among the different phenomena basically involving in the development of a fire in a room，the wall fire problem and its interaction with the neighborhood appears of importance. It has long been observed that the fastest growth of a fire is up a vertical surface. In an earlier work，it has also been noticed that a detailed and fine evaluation of fire risk in a particular building requires rather sophisticated models. Models also based upon a good knowledge of the different thermo-dynamical，aero-dynamical and chemical phenomena involved during the burning of materials in an environment of complex geometry. Moreover it has been demonstrated that distinction between wall （or vertical） and pool （or horizontal） is somewhat arbitrary since，except for the physical difference between a liquid and a solid，the phenomena underlying both burning processes are basically the same. For many years the literature related to the study of wall fires concerned one burning wall. Both experimental and numerical approaches have been focused on the development of fire with a buoyancy induced flow along the wall. More recently，the development of a wall fire in an enclosure and its interaction with its surrounding (ceiling, corner wall, stratified atmosphere), phenomenon of great importance from the point of view of fire safety, have received some attention. However these situations require, prior to be realistically modeled, a rather precise description of the basic physical processes of concern.

Nevertheless, for nearly 圆缘years a laboratory in Poitiers has been working on experimental and numerical studies related to such fire situations. The experimental studies have been carried out, at laboratory or medium scale, using PMMA but more often sintered water-cooled porous wall burner considering different configurations from a lonely vertical (or horizontal pool) wall to the interaction between two vertical walls or between a pool and a vertical wall. The first experimental approach, concerned the influence of different parameters such as channel width, burner length, gas supplied flow rate and mass transfer number B on the establishment of a steady turbulent fire. The flow field was characterized through LDV measurement. Mean and fluctuating temperatures were also obtained using thin wire thermocouples. It has been observed as the distance between the walls decreases, radiation is no longer the dominant mode of heat transfer and the flow changes from natural to forced convection. Among the different numerical developments, the last two papers provide a satisfactory modeling of the observed phenomena with PMMA as with porous burner. The numerical study has been conducted to investigate the fire structure, heat transfer and pyrolysis rate between vertical parallel burning surfaces with a fire induced flow. The strong coupling of the two initially unknown important parameters, such as the burning and fire-induced mass flow rates, is modeled using a parabolic numerical technique which takes into account the effects of the stream-wise pressure gradient in parallel configuration. Transport equations for mass, momentum, gas-phase chemical species, enthalpy are solved using a finite volume method. The turbulent flow field is solved using a standard k-ε turbulence model in conjunction with a wall function. A two-dimensional adaptation of the discrete ordinates method is used for estimating the flame radiation energy to the burning wall. Soot model is also included in order to permit application to radiative heal transfer within a flame. The results indicate that with decrease of the wall spacing/height ratio (L/H), convection flux decreases slightly, whereas, contribution by radiation increases considerably from 死园% — 怨园% of the total heat feedback to the pyrolizing surface. Of particular interest is a maximum local burning rate for a wall spacing/height ratio (L/H ≈ 园员 due to enhanced convection and radiation flow.

Modeling of Compartment Fires

The situation of the problem is clearly presented in some papers. As mentioned earlier, fire is a physical and chemical phenomenon that is strongly interactive by nature. In an enclosure fire mainly involves mass fluxes and heat fluxes to and from the fuel and the surroundings.

Mathematical modeling of fire, however, is still a developing area of Computational Fluid Dynamics (CFD). Complexity of the phenomena makes it extremely challenging from the mathematical point of view. Several problems like fluid mechanics, including turbulence, and combustion have still to be resolved prior to be incorporated into more global computational code. The models can be classified in two categories: probabilistic or deterministic. Probabilistic models are not concerned because they do not make direct use of the physic and chemical principles. The deterministic models can roughly be divided into three categories: the hand calculation models (collection of simplified solutions and empirical methods), two zone models (the compartment is divided in an upper hot layer or zone and in a lower cold zone) and the CFD models or field models which solve the complete set of equations including the Navier-Stokes equations. An exhaustive review of the literature connected to the computational fluid dynamics modeling of compartment fires is presented in a paper. This paper gives an overview of general problems arising in the fire modeling and provides description of the different major approaches, it also provides a comparison between zone and field models. Zone models provide limited information about fire environment and require a knowledge of the structure of the flow. In contrary field models are able to achieve high spatial resolution and theoretically applicable to any situation, the change in flow structure and fire environment being automatically accounted for. However, field models are also not free from assumptions due to a lack of knowledge on turbulence, chemical kinetics, radiation. Most of the time the field models are classified based on the two methods by which they treat turbulence: Reynolds Averaged Navier Stokes (RANS) and Large Eddy Simulations (LES) models. Coupling between the gas-phase and the solid or liquid burning phase is also of great concern as the more specific problem related to fire suppression. The performance of the RANS model is really good in many situations but further improvements are likely to increase quality of predictions. Moreover it allows an important extension for applications to fire suppression.

However the major limitations are related to the inadequate modeling of turbulent reacting flow. Nevertheless, considerable effort is still required before fire extinguishment models can be reliability used for engineering purposes. Turbulent diffusion flame extinguishment requires further experimental and theoretical investigations, as fire suppression due to solid phase cooling. Current fire extinguishment studies are limited to water sprinklers, but there is an increasing need for studies on fire suppression using fine water mists. The current success of Lagrangian models in fire suppression suggests their dominant position in the near future, while some special cases would need to be covered by the Eulerian-Eulerian type models. Considering the limitations of the RANS approach, the LES approach has been considered. As turbulent flow contains a wide range of length and time scales, they all cannot be resolved in most practically important cases. In LES the large scale motion is solved exactly, and approximated modeling is required only for the small scale motion. LES are essentially three-dimensional and unsteady flow calculations. The filtered non-dimensionalized Navier-Stokes equations for compressible flow with chemical reactions are written and the viscous stress tensor is modeled using the subgrid scale (SGS) Reynolds stress approximation. The resolution involves explicit time-advanced methods, of the second to fourth order of accuracy. Motion of large eddies, and especially the plume is of great interest. It is these structures that may be expected to make the most significant contributions to the transport of heat, radiation, chemical species (toxic compounds) and soot. To the large extend, production transport of soot also controls fire growth, therefore LES should be expected to provide more accurate prediction of fire spread. A lot of work is still required for these models to become more accepted predictive tool: to effect different SGS models (like Smagorinsky and dynamic Smagorinsky), turbulent combustion modeling (flamelet, fast and finite chemistry...), soot formation (including Conditional Moment Closure (CMC)), coupling gas phase-solid and heat feedback. More should also be done for extinguishment. In conclusion, recent progress in CFD fire modeling suggests optimistic prediction of the replacement, in a near future, of small and large scale experiments by adapted fire field models.

[illegible]

dissemination	分发
tractable	易驾驭的,驯良的,易管教的,易处理的
pyrolysis	高温分解
pool fire	池式燃烧
wall fire	墙式燃烧
diffusion flame	扩散火焰
pertinent	有关的,相干的,中肯的
thermocouple	热电偶
parabolic	抛物线的,抛物线状的
sintered	烧结的,熔结的,热压的
pyrolizing surface	热解表面
Large Eddy Simulations	大涡模拟
Lagrangian model	拉式模型
spatial resolution	空间分辨率
blockage	封锁,妨碍
stratified	成层了的,层积了的,分层的
Computational Fluid dynamics (CFD)	计算流体力学
probabilistic	盖然论的,或然说的
deterministic models	确定模式,确定性模型
exhaustive	无遗漏的,彻底的,详尽的

[illegible]

sprinklers	洒水车，洒水装置
subgrid scale（SGS）	亚网格尺度
Conditional Moment Closure（CMC）	条件矩封闭模型

哉1鄄敲云燥赃摇圆伊怨园园酝宰 杂怎责藻则糟则蚤贼蚤糟葬造
摇摇摇摇摇月燥蚤造藻则择造藻则宰 葬责责藻葬则葬贼怎泽
摇摇摇 孕葬则贼 粤泽泽藻皂遭造赠 云怎灶糟贼蚤燥灶泽

摇摇

Development and Characters of Supercritical Boilers

Supercritical technology was introduced more than 源园 years ago. Alston has been a leader in the development of advanced supercritical technologies, with 缘园% of the installed supercritical capacity world wide. Building on the experience in subcritical designs, our knowledge and expertise in super-critical technology has been developed.

With the two 远园园MW boi员ers in ShiDongKou, the supercritica员 technology was introduced in China. Today, state-of-the-art is defined by the brown coal fired 员园园园MW boiler Niederaussem K in Germany, the two 愿园园MW boilers for the Korean nationa员 utility at Yonhung in Korea and the two 怨园园MW boilers for Wai GaoQiao in Shanghai, P. R. of China.

The application of supercritical steam parameters coincides necessarily with the application of the once-through technology. There is no difference in the design and operation mode between sub- and supercritical once-through boilers. In contrast herewith are drum type boilers with thick-walled components thus having some operational restrictions. Furthermore, drum type boilers are clearly restricted by subcritical steam parameters.

Once-through technology offers the benefits of supercritical conditions as well as proven operational success increase of pressure to supercritical conditions and higher temperatures are means of improving the efficiency. Supercritical plants are using advanced materials and achieve excellent availabilities and load change behaviors.

Among others, the major advantage of supercritical boilers is the higher efficiency. Plant efficiency and, fuel cost savings, can be improved by 愿% to 员苑% over subcritical cycles. The corollary to higher efficiency are lower emissions for the same unit electrical output. As a direct function of efficiency, $CO_{圆}$ is also reduced by 愿% to 员苑%, as are NO_x and $SO_{圆}$, which are contributors to acid rain. Particulate emissions are similarly affected.

Faster start-up times increase available unit time as well as they reduce start-up fuel costs. Turbine bypass system is utilized to accommodate start-up flexibility. While both subcritical and supercritical units can be equipped with turbine bypass systems, they are more commonly installed on supercritical applications. This is due to the fact that customers that place a high value on improved efficiency to lower coal costs, also place a value on reducing start-up fuel costs. Elimination of the thick-walled steam drum component in a once-through system significantly reduces concerns related to pressure part stress during start-ups. This increased flexibility offers the customer the ability to fulfill nearly every load demand and to operate the power station in an economically optimized mode.

Given that demand has shifted from base-load to cycling operation mode, most supercritical units are designed with sliding pressure capability which maximizes efficiency not only at high loads, but at all loads. Plant components no longer have to run at full throttle, therefore, auxiliary power consumption is reduced. With sliding pressure capability supercritical units operate at reduced pressure over the complete load range that results in lower average thermal stress on pressure parts such as critical boiler components and steam turbine piping over the life of the unit. Less wear on components means less maintenance required.

Through feedwater control, a supercritical boiler is able to achieve the rated steam outlet temperature at all loads with all fuels. This additional degree of freedom can be used to compensate any different fouling condition. Especially for coal-fired boilers with a wide range of fouling properties, this compensation capability is a significant advantage.

Pulverized Fuel Firing and Grinding System

The tangential firing system (abbreviated as T-firing system) is very common in China. More than 80% of the installed firing systems are of this type. The T-firing system consists of jet type burners arranged in the corners of the furnace, directed to a virtual tangential circle. This creates a vortex in the furnace and minimizes "dead zones" in the furnace corners, which results in a uniform heat release zone on all furnace walls. The general features of the T-firing system are low carbon losses combined with low NO_x and CO emissions and a very uniform heat transfer in the furnace with homogeneous temperature profiles in the furnace cross section and over the height of the furnace.

The biggest advantage of the T-firing system is the flexibility for different types of fuels, especially for difficult fuels like high slagging coals. For high slagging coals combined with low emissions of NOx and CO, the concentric T-firing system was developed. In this arrangement a part of the secondary air — the offset air — is directed to a second tangential circle. This feature has several functions. Areas close to the furnace wall are created with high excess air and high oxygen content to avoid a reducing atmosphere. This leads to lower flue gas temperatures in these areas; minimizes slagging and avoids corrosion at the furnace walls. This kind of distribution of secondary air, the radial air, staging, creates substoichiometric conditions in the furnace. These substoichiometric conditions are the main driver for a low NO_x firing behavior. To maximize carbon conversion in the furnace, overfire air above the burners has to be added, known as axial air staging.

The Wai Gaoqiao plant will burn coals with high slagging potential. The high content of iron oxide ($Fe_{圆}O_{猿}$) of 员缘% in combination with the high calcium oxide (CaO) content of 圆缘% indicates a high slagging potential. This is also visible in the ash melting behavior of the specified coals (Initial deformation 员圆圆园C / Softening 员猿园园C / Fluid temperature 员猿缘园C). A similar combination of slag forming components could be found in the high slagging brown coals in Germany. To burn such German brown coals, large furnaces with large cross-sections are necessary. The largest furnace in operation is the furnace of the 圆伊愿园园MW power plant Schwarze Pumpe in the eastern part of Germany. The furnace dimensions are 圆源m wide 伊圆源m deep and a height of 愿源缘m. A lignite T-firing system is used. This unit has been in commercial operation for about three years.

With all this experience, a single-furnace with a low plane area heat release rate of 缘猿MW/m圆— specified by the customer — was proposed. This results in a furnace plane area of 圆员缘m 伊圆员缘m. An analysis of the furnace outlet gas temperature (员,圆缘园C) resulted in a furnace height of 缘园m. This single-furnace dimension, especially the plane area, is now the largest tangential bituminous coal fired boiler in the world.

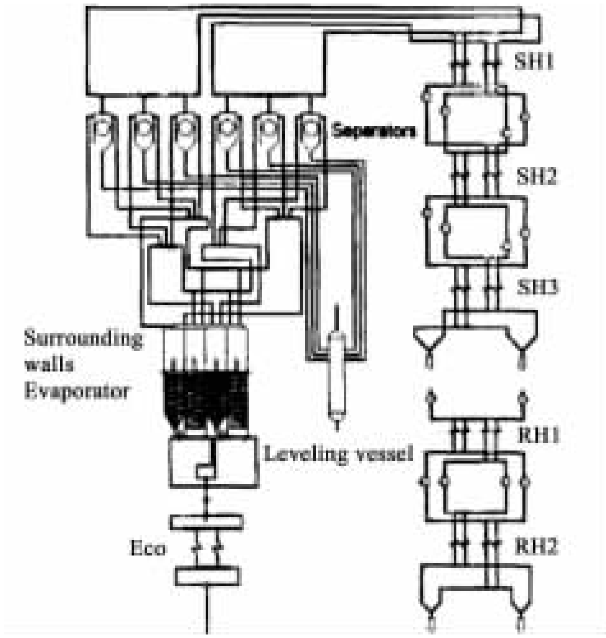
Computational Reactive Fluid Dynamic (CRFD) analysis was performed to assess the firing behavior of this large single-furnace. The mathematical modeling approach for the pulverized coal combustion was based on a Eulerian / Eulerian concept.

The realization of the concentric tangential firing system for Wai Gaoqiao will allow the unit to operate with an excess air of only 圆园% when using high slagging Chinese hard coals with NO_x emissions of less than 远缘园mg/m猿 and a carbon loss of approximately 园缘%.

Heat Exchanger Arrangement

The economiser, as topmost convective heating surface of a true tower-type boiler, is arranged with feedwater in parallel flow. The preheated water is fed to the hopper, which is incorporated into the spiral-wound design of the furnace. The furnace walls with inclined tubing in the lower part and vertical tube walls of the upper convective path were arranged both as evaporator. Six separators are arranged downstream of the evaporator. The steam supplied by these separators is fed to the support tubes. Superheating and reheating is performed by three HP superheaters and two reheater stages. More detailed information is shown in the water/steam diagram in Figure 愿 员

All SH and RH heating surfaces are characterized by a 源line design. In addition, a



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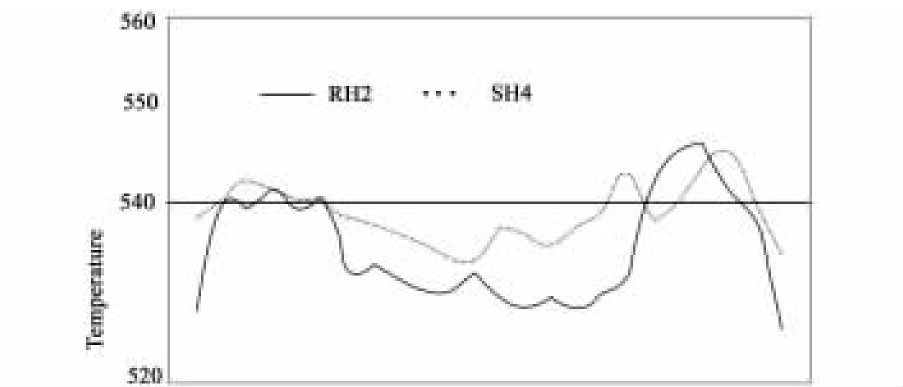
U-shaped arrangement was designed for each individual heating surface for the supply and discharge of the steam. This ensures that the steam-side mass distribution to the numerous tubes in the individual superheater heating surfaces is as homogeneous as possible. For example, Figure 愿圆 shows the steam temperature distribution at the final superheater and reheater outlet of an existing German 苑园园MW unit (Scholven F).



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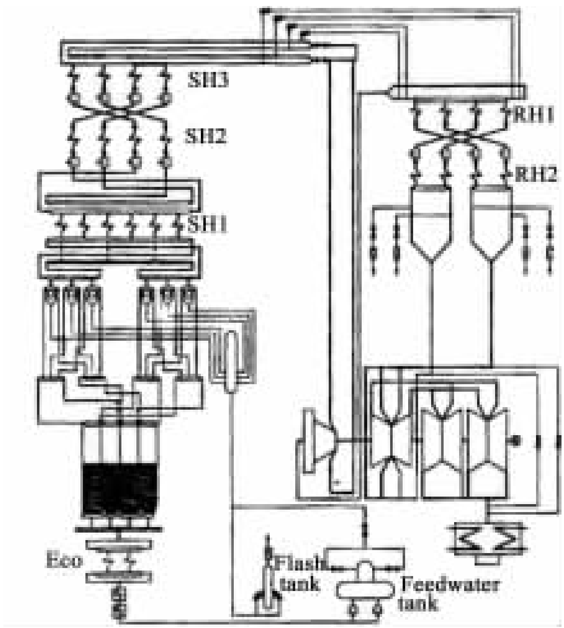
The different kinds of materials are selected for the convective path. For all HP-superheaters and for the final reheater stages the modified 怨% Cr-material T怨员 will be used. The mechanical properties of T 怨员 are very well evaluated, but fireside corrosion

圆缘

and steam-side oxidation behavior have to be assessed carefully. For this reason, a test loop in a supercritical boiler in the Danish power station Vestkraft has been installed and operated at steam temperatures up to 远园园°C. Up to now, about 猿园园园园 operation hours have been accumulated providing valuable corrosion data. The evaluation of the corrosion properties and the smaller requirement of temperature margins led to the selection of the SA-圆员猿T 怨员 material. In steady-state operation temperature control is achieved by the feedwater mass flow at the HP-side and by tilting burners at the RH-side. During transient conditions the steam temperature control is assisted by two spray water attemperators on the HP and the RH side.

Operational Startup System

The start-up system consists of the water/steam separating system with six cyclone separators, the leveling vessel, the discharge system to the deaerator of the feedwater tank and the discharge system via the atmospheric flash tank to the condenser (Figure 愿 猿.



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The purpose of the discharge system to the feedwater tank is to recover the energy of the separated saturated water when the boiler load is lower than the minimum once-through load. This helps to avoid a significant feedwater temperature reduction during start-up.

The separator water is discharged via the flash tank when the water cannot be discharged into the feedwater tank due to the feedwater tank pressure.

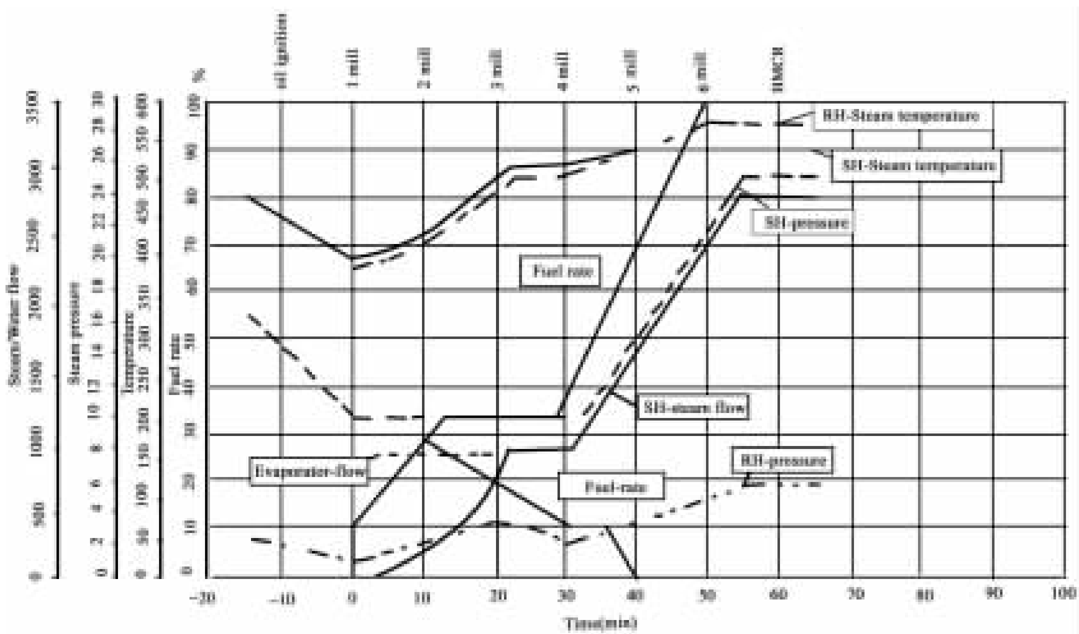
By increasing the firing capacity the water discharge will decrease until the evaporator outlet flow is superheated, the leveling vessel gets dry and the feedwater control changes from level control to enthalpy control.

The high level of water and energy recovery of the saturated water discharge results in short start-up times and low auxiliary fuel consumptions (Figure 愿源. Additionally, a very low life expenditure of the thick-walled pressure parts is achievable.

During start-up and emergency conditions the HP pressure will be controlled by the HP bypass valves. The HP bypass is designed for 元园% BMCR and is able to avoid a boiler trip in the event of a turbine trip, since the HP outlet is connected to the reheater inlet. Furthermore, the HP bypass valves serve as a pressure relief device. Additional safety valves on the HP boiler pressure parts can be eliminated.

The 缘园% BMCR LP bypass system serves as a bypass for the IP and LP part of the turbine and connects the hot reheat side of the boiler with the condenser. Similar to the HP bypass station, the LP bypass stations control the pressure in the RH of the boiler during start-up.

The LP bypass valves protect the condenser and therefore, unlike the HP bypass station, do not serve as safety devices against excess pressure in the boiler. The protection of the boiler RH is done by four dedicated safety valves with a capacity of 元园% BMCR including the HP bypass spray injection flow.



[illegible]

herewith	同此，因此
corollary	必然的结果
sliding pressure capability	滑压能力
tangential	切线的
T-firing system （tangential firing）	切圆燃烧
vortex	漩涡，旋风
substoichiometric	亚（不足，低于）化学计量的
staging	分段运输
tilting	倾斜
deaerator	除氧器

[illegible]

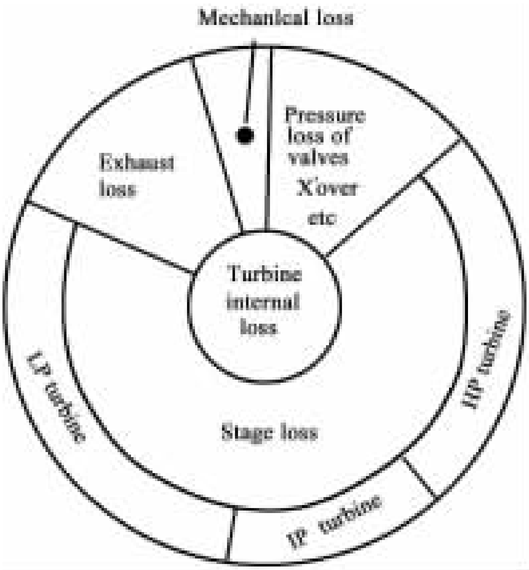
Introduction

There are several approaches to improving steam turbine cycle efficiency, such as Ultra-Super-Critical Pressure, Double Reheat, Combined Cycle, etc. The upgrading and life extension for existing steam turbines shall be focused on, because, first at all, a lot of the existing steam turbines were designed and manufactured based on conventional technologies. Secondly, the construction of new power generation plants has recently been restricted, whereas retrofitted technologies and techniques have progressed in application of the latest advanced steam paths and rotors with modification and replacement of nozzles, blades and rotors, etc. Finally, there is indeed much demand for upgrading and life extension on the important existing components such as nozzles and blades, etc. for performance, reliability and maintainability in order to provide a stable power supply without increasing carbon dioxide to the global environment problem.

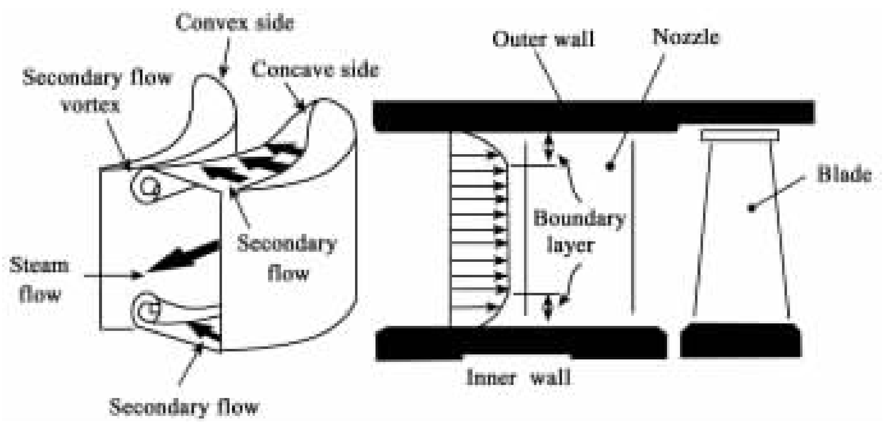
Steam turbine internal losses may arise from various factors. Accordingly, analysis of these factors resulting in loss is very important in order to assess actual gains in efficiency. In Figure 愿缘result of the analysis, made principally on those locations where losses occurred is presented. It shows that approx. 圆猿of the total losses take place in stages. The pressure losses at the steam valves such as those for main stop, control, intercept and other functions, or at crossover pipes cannot be neglected, because of the rather high loss rate, which is about 员远of the total. The rate of the exhaust loss at the last stage of the low pressure turbine varies depending on the selection of the last stage blade length or on the loading of the machine, and it occupies rather a large part of the total loss, from about 员园% to 员缘%.

Advanced steam path technologies

Figure 愿远shows the generating mechanism of the complex secondary flow vortex in the vane passage, which leads to loss of steam energy. This phenomenon is caused by



fluid viscosity in the boundary layer of flow passage, and is typical at the inner and outer side wall of nozzles and blades. The advanced flow pattern (AFP) is one of the advanced steam path designs to match the suitable aerofoil profiles and to improve the efficiency. It minimizes the loss by distributing the largest portion of steam to the high efficiency zone as well as by shifting the streamlines near the side walls strongly toward the walls at the exit and eventually reducing the secondary flow losses. It's realized this steam path design with the assistance of computerized three dimensional flow analysis in conjunction with the experimental approach. Nozzles and blades are excellently designed and precisely manufactured in a three dimensional shape to realize high performance.



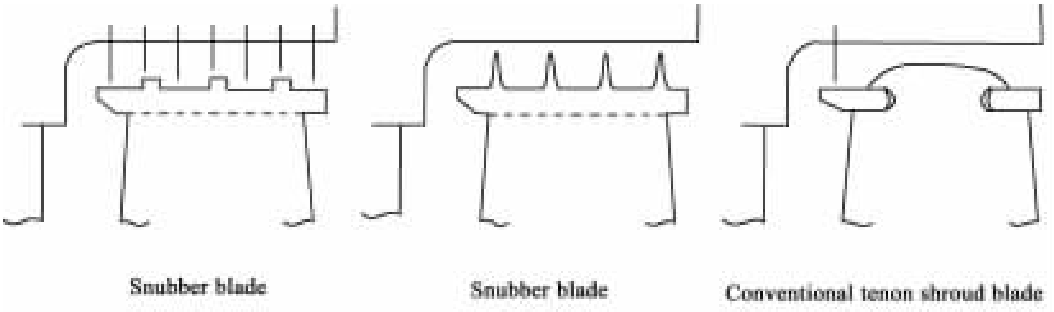
The snubber blades, of which aerofoil and tip cover are manufactured from a single forging or a bar material, have several important characteristics that contribute to the enhanced reliability and performance of the blading. Elimination of the tenon and shroud structure removes a corrodent trap and reduces stresses at the junction between blades and shrouds. It naturally excludes the possibility of erosion damage on the tenons, which is sometimes observed in conventional steam turbines. The integral covers are butted together between adjacent blades and thus, the entire blading assembly in essence performs as a 猿园C continuous shroud. These continuously coupled integral covers form a circumferential boundary of the steam path and provide an optimal interstage sealing with a minimum of leakage losses. The blade tip leakage control of conventional turbine stages utilizes a single fin as structural constraints of the tenon and shroud configuration, and did not allow any other arrangement, but snubber blades with integral cover enable the application of the improved blade tip leakage controls, as shown in Figure 愿苑 And also, the contact between adjacent covers limits the amplitude of vibration and produces high damping when stimulating steam forces work. The blades are, therefore, highly resistant to vibratory excitation. In addition, as the blades are not mechanically connected to each other, they can be dis- and reassembled easily when required. This leads to better maintainability and a saving of maintenance costs in future operations.

In some of the conventional nozzle designs, large numbers of nozzle partitions, that are small nozzle profiles, are being selected to avoid resonance with the rotating blades. In combination with the snubber blades, however, it is allowed to choose smaller numbers of partitions, that is larger nozzle profiles, as they have excellent damping against vibratory excitation. Large nozzle partitions are robust and less sensitive regarding the effect of deposits that are quite often observed in conventional existing steam turbines, on the turbine performance and power. The design using a combination of the snubber blades and large nozzle partitions is one of the life extension technologies for steam path components.

Long last stage blade

Exhaust loss also accounts for a large portion of the turbine internal loss, about 员园% to 员缘% of the total. In order to reduce the loss, the vane profile of the last stage blades has been improved, and longer blades are employed to lower the exhaust velocity, contributing greatly to enhancing thermal efficiency. It is not too much to say that development of the last stage blades holds the key to technological progress for the steam turbines.

Mass flow distribution of the last stage has a three-dimensional non-compressive pattern including large radial distribution of steam pressure, velocity and angle. In addition, the circumferential speed at the tip of the long last stage blades exceeds the speed of sound, so the relative velocity in the vane cascade becomes transonic, locally changing from subsonic to supersonic. Therefore, the steam path design of the last stage blades requires a full three-dimensional flow design and convergent-divergent supersonic passage design to optimize mass flow distribution and efficient acceleration. Recently, numerical analyses have been carried out to put three-dimensional flow calculation codes into practical use, which consider the viscosity of the fluid.



云蚤早援猿 悦燥灶贼蚤灶怎燥怎泽造赠 糟燥怎责造藻凿 造燥燥泽藻 糟燥灶灶藻糟贼蚤燥灶 遭造葬凿藻泽

On the other hand, it is also important to secure strength and reliability against vibration for the long last stage blades. That is, it is essential to ensure sufficient static and dynamic strength for enduring large centrifugal force, evading dangerous resonances and providing preferable vibration properties. Because the untwist of the long blades due to centrifugal forces is larger, the stress distribution and the untwist deformation are more complex in three dimensions.

Furthermore, it is recognized that the stress level due to the vibration of the last stage blades tends to be high when the flow rate in the last stage is low and/or the back pressure is high. It means that it is necessary to reinforce blade rigidity and increase structural damping against the self-excited vibration, namely the random vibration of flutter, which may occur during operation under low-load or high exhaust pressure conditions. The continuously coupled loose connection structure which is the most effective vibration damper reduces the large vibration response during operation over a wide range, particularly at very low-load and/or high exhaust pressure.

At present, 源园inch and 猿远inch long last stage blades for 猿园园园rpm machines, and 源园inch long last stage blades for 猿远园园rpm machines have been developed and are being put into practical use. 猿远inch last stage blades and 源园inch last stage blades can be replaced for the 猿猿援缘inch last stage blades by minimum modification of the existing low pressure turbine.

Replace to 36-inch last stage blades for 50Hz units

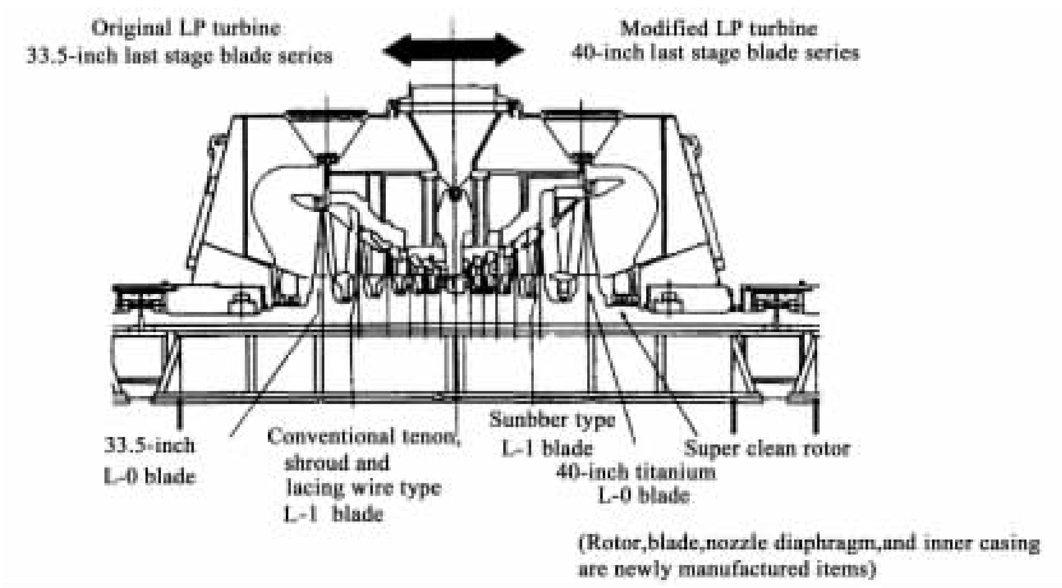
The 猿远inch long last stage blades are basically of a continuous coupled loose connection structure with cover pieces at the tip portion and with lugs and sleeves in the middle portion. The dovetail is the same finger type as the conventional 猿猿援缘inch last stage blades, which is designed to be used to make the blades longer by replacement of the existing machines. The blades are of 员圆% Cr steel material of higher strength than the conventional ones, thereby improving reliability.

Together with the last stage blades, L-员 and L-圆 blades have been developed as series blades. The dovetail of these blades is similar to that of the conventional 猿缘 inch last stage blade series, so as to replace the rotor of the existing machine. The snubber construction is employed at the tip of these blades, thereby improving reliability.

The 远园MW class steam turbines with 猿缘inch last stage blades can be replaced with the 猿远inch last stage blade series on the original low pressure turbine rotors. This improves the turbine heat rate by 园缘% to 园远% combined with the modification of nozzles and blades in order to match the flow pattern on the L-圆stage through the L-园 stage.

Replace to 40-inch last stage blades for 60Hz units

源园inch titanium long last stage blades have been applied in the 殉园园MW class steam turbines, and can also be employed in the existing low pressure turbines with conventional 猿缘inch last stage blades. Figure 愿愿shows one of applications to the existing 殉园园MW machine. As the dovetail of 源园inch long last stage blades is of the



[illegible]

curved entry type, the existing low pressure rotor with the finger type dovetail of 猿缘 inch last stage blades must be replaced with a new one. In addition, as the tip diameter of the last stage blades is larger than that of the conventional 猿缘inch last stage blades, the low pressure internal casing as well as the nozzles must be renewed. The modification scope is larger than that of the 猿远inch last stage blade series, but the turbine heat rate improves by 员圆% . This modification has been made in the existing 殉园园MW machines and also shows good operating conditions.

Repowering of existing thermal power plants

Repowering is a useful upgrading method for existing thermal power plants, thereby increasing output and improving thermal cycle efficiency. As the gas turbine and generator sets are added on the existing steam turbine and generator cycle, the pure steam turbine and generator cycle is upgraded to the combined cycle.

Repowering has a great effect on the reuse of site and generating equipment as well as on the shortening of construction periods. The full-fired heat recovery system enables the minimization of the period in which operation has to be stopped for modifying existing thermal power plant equipment to a combined cycle to about six months, because the scope of the modification is smallest among the above mentioned systems. Therefore, the full-fired heat recovery combined cycle system is the most popular.

Table [illegible] shows an overview of the [illegible]MW class repowering plant. A [illegible]C class firing temperature, [illegible]MW gas turbine is added on a [illegible]MW existing steam turbine cycle about [illegible] to [illegible] years after construction, and thermal efficiency is improved by [illegible]% . As for the method of operation, the system is designed with a view that the gas turbine and generator set is not used for independent operation. On the other hand, the existing steam turbine and its cycle auxiliary equipment were modified to enable both the combined cycle operation and independent operation, in order that the existing but large-capacity steam turbine and generator cycle can be widely operated. Added and/or modified equipment for the repowering system are as follows:

([illegible]) Gas turbine and generator set

The independent power building for the gas turbine and generator set and its auxiliary equipment is installed on the side of the existing boiler, and the gas turbine exhaust gas duct connects to the boiler. In addition, a main transformer and house transformer are added as new gas turbine power generation equipment.

[illegible] [illegible]

[illegible]	[illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]	
[illegible]	[illegible] [illegible] [illegible]
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[illegible] [illegible]	[illegible] [illegible]
[illegible] [illegible]	

(圆 Modification of existing boiler and steam turbine

The repowering combined cycle increases the amount of boiler exhaust gas, resulting in a rise in draft loss. Thus, the induced draft fan (IDF) is added and capacity of the denitrizer is increased. On the other hand, the modification scope of the exhaust gas duct system, feedwater piping system, condensatewater piping system, low-oxygen combustion burner system, and steam turbine nozzles and blades for increasing the steam flow rate of the steam turbine cycle can be minimized.

The existing smokestack is used as it is. And also, the condenser duty increases with the amount of heat exchange, but the condenser system is not required to be modified, because it still has enough capacity.

(猿 Exhaust gas heat exchanger

Three blocks of gas feedwater heaters (stagger gas coolers) are added on the feedwater system, and the thermal efficiency is enhanced by heat recovery from the gas turbine and boiler exhaust.

A switching damper and an isolation damper are provided on the gas path side of the gas turbine and boiler exhaust system, in consideration of switching between the combined cycle operation and the independent steam cycle operation and for operation at the start-up of the gas turbine and generator set.

(源 Power source and controller

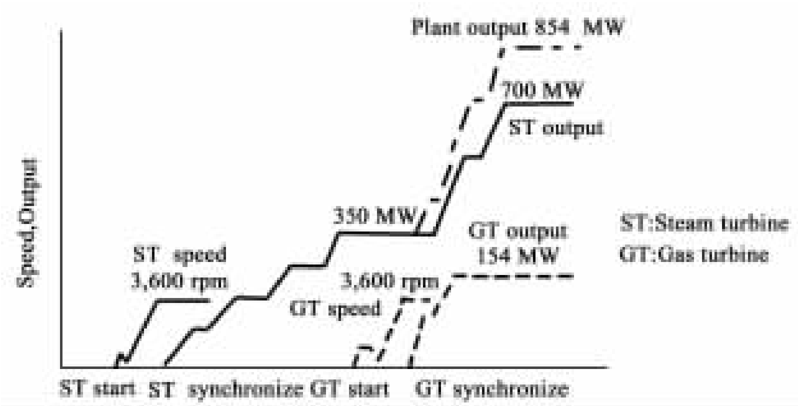
A set of the latest computers have been installed for control and comprehensive monitoring of the plant, and the control panel of the control operating room is completely modified or partially added so as to coordinate with the gas turbine and generator set and the combined cycle operation. The functions of the controller are added or modified for the boiler and auxiliary equipment, and a set of power sources is provided on the gas turbine and generator set and its auxiliary equipment.

Figure 愿怨 shows the starting-up curve for the combined cycle operation. The system becomes complex, but operativity and controllability are similar to those of the conventional steam turbine and generator cycle plant. The rate of normal load change during the combined cycle operation is 猿% /min.

Thermal efficiency is improved up to about 源% , but this is because the forced draft fan (FDF) is partially operated in order to maintain the balance of boiler combustion when the gas turbine is operating.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

upgrade	上升,提高等级,提升,加强
retrofit	更新 改型 改造
crossover pipe	连通管
viscosity	粘度,粘性系数
aerofoil profile	叶型



snubber 减振器 缓冲器
snubber blade 带阻尼结构的叶片,带阻汽片的叶片
tenon (叶片)铆钉头,榫头
corrodent 腐蚀剂
integral cover 整体围带
butted 对接的
exhaust loss 排汽损失
transonic 接近音速的
supersonic 超音速,超声波,超声频
untwist 拆开(搓合的绳,线等),解开,非扭转
lug 拉金,接线片,凸耳,吊耳,猫爪
dovetail 楔形榫头 鸠尾
repower 改建动力装置,增容
denitrizer 脱硝器,脱氮器
auxiliary equipment 辅助设备
condensatewater 凝结水
smokestack 烟囱

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摇摇摇 [illegible]
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Introduction

To improve thermal efficiency, blades for the last low-pressure stage of steam turbines have become longer and wider. Long blade with a fork-type root is one of the recently developed kinds. A blade with several forks at the bottom is fastened to the disk by three fork pins, which are axially inserted. The maximum stress arises at the contact area between the blade-fork and a fork pin. Increases in the size of the blade and frequent start-stops due to recent operating-mode changes can increase the potential for low-cycle fatigue at local stressed areas, such as the blade and disk attachments. Hence, an accurate evaluation method of low-cycle fatigue for fork-type root attachments is indispensable in developing new, longer blades.

In general, conventional methods for evaluating low-cycle fatigue life at a local stressed area use the following approach. The total strain range at the local area is estimated using the peak elastic stress calculated by finite element method (FEM) analysis and Neuber's rule. Low-cycle fatigue life is then obtained by combining the calculated total strain range and low cycle fatigue data for small, plain specimens. But the conventional method has several problems when it is applied at the contact area of pin joints:

员 Stress (or strain) distribution from the surface to the inner body is not considered.

圆 The peak stress at a contact area depends on the element size of FEM analysis due to the singularity problem.

猿 Surface roughness and corrosive environments in actual machines can cause earlier crack initiation than that in plain specimens.

In this study, to cope with the singularity problem at the contact area, the strain distribution from the contact surface to the inner body along the crack extension direction, which is less affected by the singularity problem, is used for evaluation instead of the surface peak stress (or strain) only. To verify the developed evaluation method, we conducted low-cycle fatigue tests on pin joint models, in which the crack behavior at the inner surface of the pin hole was observed by interrupting the tests.

Low-cycle Fatigue Evaluation Method for Pin Joints

To develop a low-cycle fatigue life evaluation method for the contact areas of pin joints, low-cycle fatigue tests and FEM analysis of pin joint models simulating the fork-type root attachments of actual blades were performed.

Test Procedure

The tested materials were 员园% -Cr forged steel for forks and 缘% -CrMoV steel for fork pins. The chemical compositions and mechanical properties are shown in Table 愿缘 and Table 愿远 respectively.

耘葬遭造藻 愿缘　　悦澡藻皂蚤糟葬造 糟燥皂责燥泽蚤贼蚤燥灶泽 燥枣 贼藻泽贼藻凿 皂葬贼藻则蚤葬造泽 (憎贼豫)

酝葬贼藻则蚤葬造		悦	杂蚤	酝灶	孕	杂	晕蚤	悦则	酝燥	灾
云燥则噪	员园豫 悦则 泽贼藻藻造	园援员员	园援园员	园援远苑	园援园园圆	园援园园园苑	员援圆苑	员援缘豫	园援远愿	园援远园
孕蚤灶	缘豫 悦则酝燥灾	园援源	园援园怨	园援远愿	园援园员	园援园园园缘	缘援园	员援苑	园援员员	

耘葬遭造藻 愿远　　酝藻糟澡葬灶蚤糟葬造 责则燥责藻则贼蚤藻泽 燥枣 贼藻泽贼藻凿 皂葬贼藻则蚤葬造泽

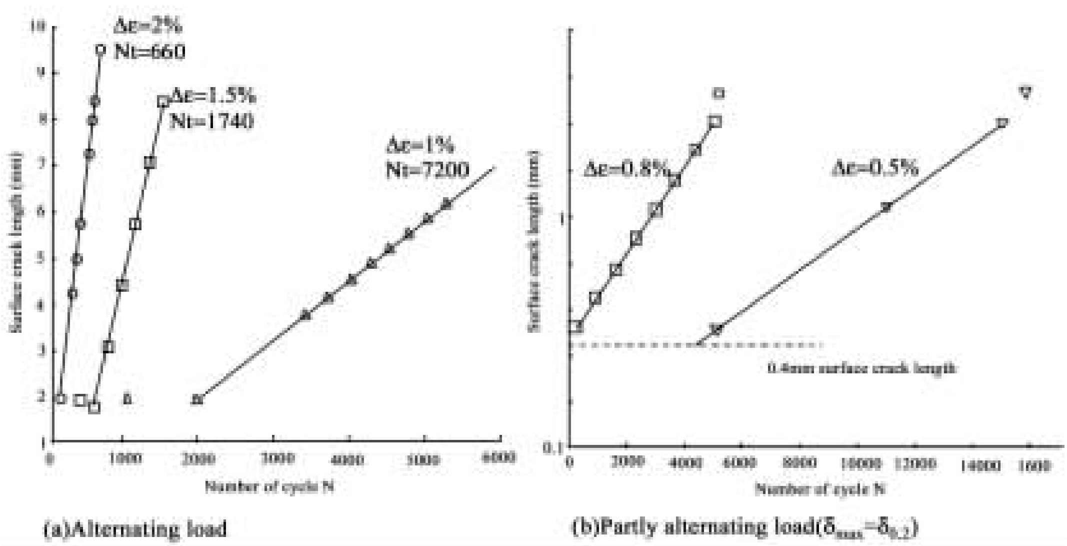
酝葬贼藻则蚤葬造		园援圆豫 责则燥燥枣 泽贼则藻泽泽 $\sigma_{园援圆}$ (酝孕葬)	栽藻灶泽蚤造藻 泽贼则藻灶早贼澡 $\sigma_{月}$ (酝孕葬)	耘造燥灶早葬贼蚤燥灶	砸藻凿怎糟贼蚤燥灶 燥枣 葬则藻葬 豫
云燥则噪	员园豫 悦则 泽贼藻藻造	员园缘	员员圆园	圆园	远苑
孕蚤灶	缘豫 悦则酝燥灾 泽贼藻藻造	员苑愿	员愿苑	圆员	苑园

Two kinds of tests were conducted. First, strain-controlled low-cycle fatigue tests were carried out using cylindrical plain specimens 远mm in diameter and 圆缘mm in gage length to obtain the relationship between crack growth rate and crack length for short cracks. The applied strain ranges, Δε, were 圆园 员缘 员园 园愿 and 园缘% at a frequency of 园员—员Hz. The crack growth behavior was observed by intermittently taking replicas of the specimen surface. In the cases of 园愿% and 园缘% strain range, which are within the range of elastic fatigue, semi-elliptical electrical discharge machining (EDM) notches of 园源mm in surface length and 园圆mm in depth were introduced, and the crack growth rates at the notch were obtained. Alternating stress was applied in the cases of 员% —圆% strain range (elastic-plastic fatigue test), and partly alternating stress, with a maximum stress equal to 园圆% proof stress, $\sigma_{园圆}$, was applied in the cases of 园缘% and 园愿% strain range (elastic fatigue test). This was done because the stress and strain conditions in a region away from the notch root of a pin joint under a pulsating load change from alternating stress to partly alternating stress.

Second, low-cycle fatigue tests were also conducted on pin joint models under load-controlled pulsating load. The stress ranges applied at the smallest cross section of the fork, $\Delta\sigma_n$, were 逦园缘园 and 源猿园MPa. During the test, the crack growth behavior at the inner surfaces of the pin holes was observed by taking replicas after removing the pins and the wear debris on the inner surface.

Test Results

The relationship between surface crack length and number of cycles, N, is shown in Figure 愿 虎园 which was obtained by strain controlled low-cycle fatigue tests of plain specimens. In this test, fatigue cracks initiated from small flaws and propagated as semi-circular surface cracks. The fatigue crack propagation curves show linear relationships between N and the logarithm of crack length in all cases tested with the various strain ranges.



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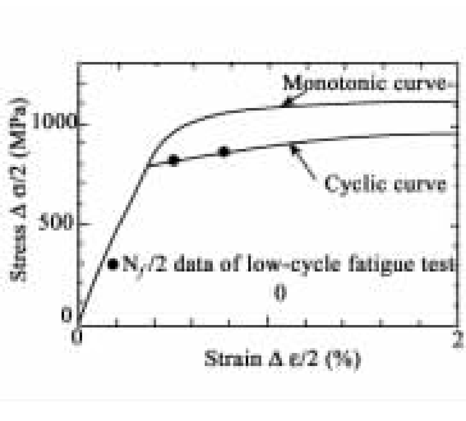
Most cracks initiated at the angle from the load direction, θ, of about 愿园. The parallel lines are reaming traces. It's found that many short cracks (园.园原—园.园愿mm) nucleated at the convex of the reaming traces in a contact area during an early stage of the fatigue life. After several thousand cycles, some short cracks were worn out, while some grew to become main fatigue cracks.

FEM Analysis of Pin Joints

The strain range occurring at the contact area for pin joint tests under a pulsating load history was calculated by elastic-plastic FEM analysis. The FEM analysis model is established. Because of symmetry, only a quarter of the fork was modeled with the appropriate boundary conditions. The load was applied at the center of the pin, and a four-node plane stress condition was used. The smallest element size near the contact area was 园圆缘mm. To understand the influence of element size, an analysis with a fine mesh (smallest element size of 园圆员mm) was performed for comparison. For the fork material, the cyclic stress-strain data shown in Figure 愿员 was used. This data was obtained by strain-controlled low-cycle fatigue testing, in which the stress-strain hysteresis loop at half the fatigue life was taken as the stable behavior. The Mises yield criterion and kinematic work hardening were used. Contact elements were introduced between the pin and pin hole, with the friction coefficient assumed to be 园缘 The nominal stress range at the smallest cross section of the fork, $\Delta\sigma_n$, was a parameter of the analysis, with $\Delta\sigma_n$ 越源愿园缘园园 and 远园园MPa. The analysis software was ANSYS 缘远

Figure 愿员园 shows the circumferential strain range distribution, $\Delta\varepsilon_\theta$, around the pin hole calculated by FEM analysis. The maximum strain range arose at an angle from the load direction, θ, of about 愿园, which is almost correlated with the crack initiation position obtained by the experiments. Figure 愿员猿 shows the circumferential strain range distribution from the surface to the inner body along the crack extension direction at the angle where maximum $\Delta\varepsilon_\theta$ arises. The results calculated by a fine-mesh model with 园圆员mm for the smallest element size are shown in Figure 愿员猿 for comparison. Although the peak strain range at the contact surface depends on the element size because of the singularity problem, the strain distribution in a region more than 园员mm from the contact surface is hardly affected by the element mesh size. In this study, the strain range distribution was used for the low-cycle fatigue estimation in section 圆源 instead of the peak value only.



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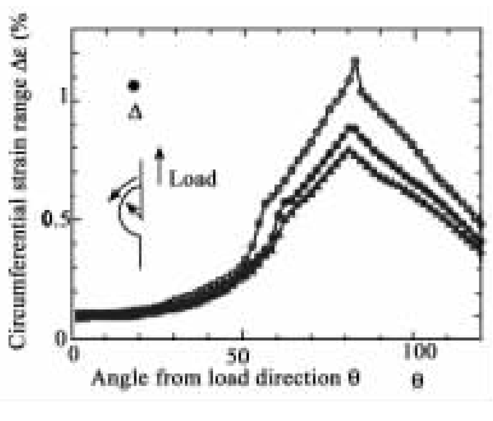

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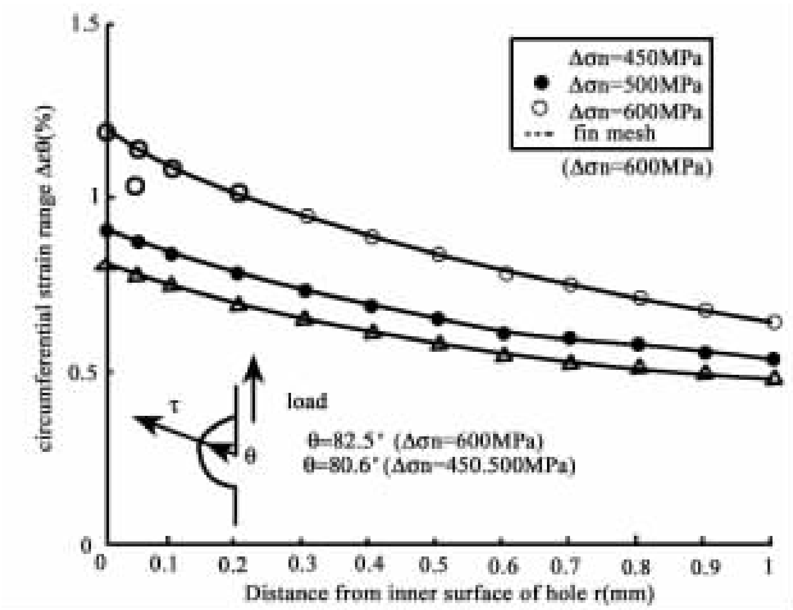
Stress Analysis of a Whole-blade with Fork-type Root Attachments

Performing three-dimensional inelastic analysis, including contact elements at each pin joint between fork and fork pins is time-consuming and unrealistic. Hence, FEM analysis was performed in two steps: three-dimensional analysis of a whole-blade model, and two-dimensional elastic- plastic contact analysis of a blade-fork model.



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Three-dimensional FEM Analysis of a Whole-blade Model

The FEM analysis model is shown in Figure 愿员源 Large-deformation theory was applied because the stiffness of the twisted blade changes as it deforms. The load and constraint conditions were as follows:

(员) Load conditions

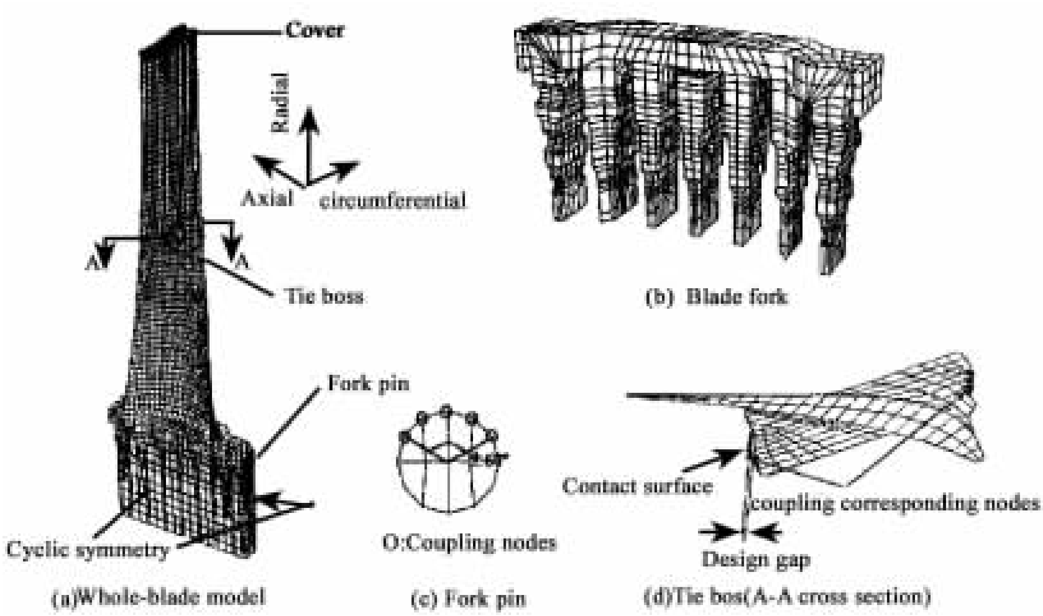
Centrifugal force and steam bending force were applied.

(圆) Constraint conditions

The cover and tie boss touch those of the next blade when the twist-back force associated with centrifugal force is applied. To model this effect, contact planes were introduced at the distance of a design gap, and the corresponding nodes were coupled to each other, as shown in Figure 愿员源(d).

Corresponding nodes at the contact region between the forks and fork pins were coupled in a 依砸 range, as shown in Figure 愿员源(c).

A cyclic symmetry condition was applied to the cut plane of the disk.



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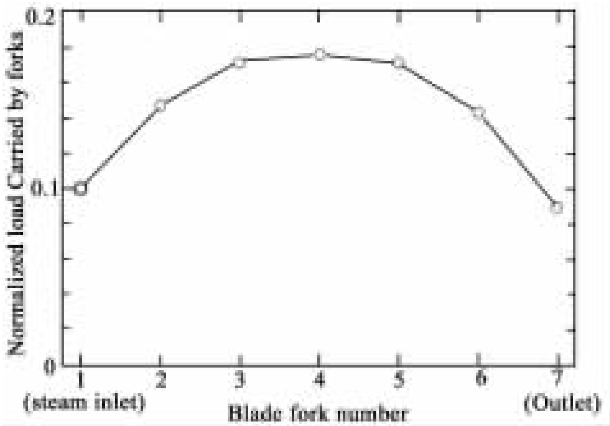
An example of the load distribution carried by each blade-fork is shown in Figure 愿员缘 The load was normalized by the total load. A blade-fork located at an axially centered position carries the highest load.

Two-dimensional FEM Analysis of a Blade-fork Model

Two-dimensional elastic-plastic contact FEM analysis of a blade-fork was also done. Loads in the radial and circumferential directions calculated by the three-dimensional model were applied at the top of the blade-fork. Bending effects from blade's convex side to the concave side were considered in this model. Link elements were introduced, whose stiffness was calculated from the load and deformation of fork pins obtained by the three-dimensional analysis. The strain range distribution near the pin hole under a start-stop load cycle was calculated. The low-cycle fatigue life can be obtained using the evaluation method.

[illegible]

finite element method（FEM）	有限元方法
electrical discharge machining（EDM）	电子放电加工
singularity	奇点，奇异点
four-node	四节点
low-cycle fatigue	低周疲劳



[illegible]

crack	裂缝,裂纹
ream	铰刀
notch	槽口，凹口,刻凹痕，用刻痕计算，开槽
Mises yield criterion	米赛斯屈服准则
pulsating load	脉动载荷
convex	凸出的
concave	凹的，凹入的 ;凹，凹面
kinematic	运动学上的

[illegible]

摇摇The major challenge facing the power generation industry over the coming decades will be to increase the efficiencies of fossil-fuelled power plants while also meeting more stringent environmental goals. This text has been prepared to provide a panorama of the international，especially in Europe，state of the art for Ultra-Supercritical （USC） technologies，which can increase the efficiencies of fossil-fuelled power plants and reduce their emissions.

USC in Europe

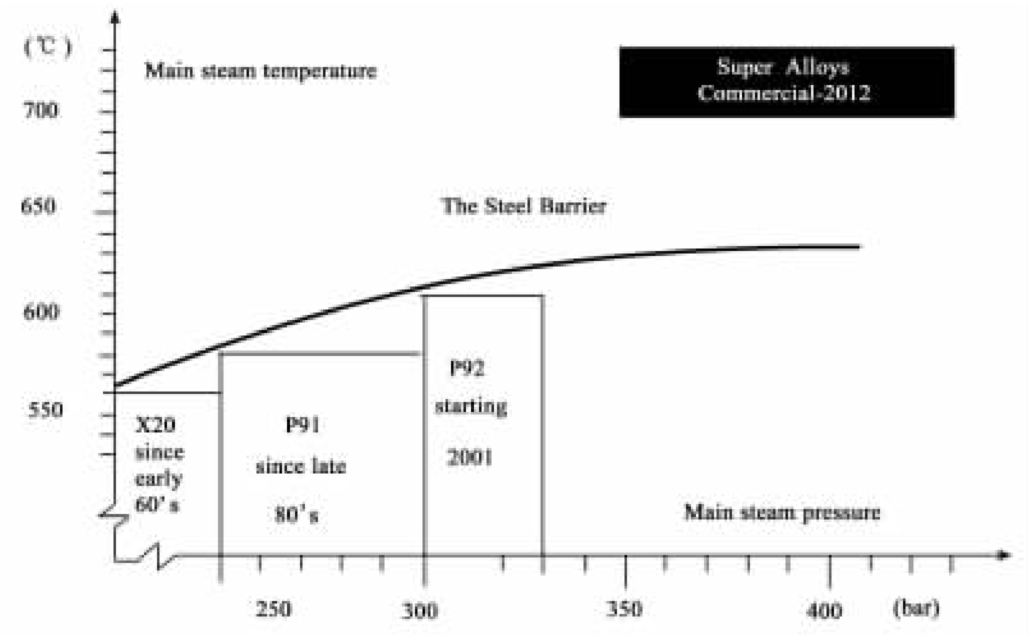
In Europe，with finance from the EU and national research programs，as well as from industry，intense advanced research has been carried out on the development of USC boiler technologies. The reference project，started in 员怨怨愿， is the AD 苑园园 project，which involved the participation of 猿缘 of the most important industrial and university research centers.

The fundamental problems in achieving ultra-supercritical conditions lie in the availability of suitable materials of construction. As shown in Figure 愿援员， there is an upper temperature limit to the use of steels，above which much more expensive nickel alloys will be required.

The goal of the AD 苑园园 project is to demonstrate that it is possible to operate USC steam plants with steam conditions of 苑园园/苑圆园℃，猿苑缘 bar. This can lead to efficiencies of 缘园% —缘缘% （LHV），compared to 源苑% with currently best available PF USC technology.

Another European project，the E-max initiative，aimed towards the same goal，was initiated by VGB in 圆园园员， and is backed by a number of major European utilities. E-max targets the direct demonstration of a 源园园 MW AD 苑园园 technology power plant. Basic to the E-max project is the wish of the European utilities to have the AD 苑园园 technology ready for the boom in construction of new generating capacity expected in the period 圆园员园—圆园圆园.

Since late 圆园园员， efforts have been made to coordinate the objectives and time schedules of AD 苑园园 and E-max. This led to a proposal to establish a full-scale test facility，in which the complete HP section of a 源园园 MW AD 苑园园 power plant，including the HP steam turbine, can be demonstrated. This would have the advantage that fabrication and welding of full-scale HP steam lines and bends could also be demonstrated, while other crucial components, such as a [illegible]% HP by-pass can be demonstrated and tested.



[illegible]

Long-term development of high-strength materials with sufficient fire-side and steam-side corrosion resistance have also been funded by COST (Cooperation in Science & Technology) program. In Europe, the COST [illegible] program, involving steelworks, power plant manufacturers, power station operators and research institutes, has led to the development of materials which allow a live steam temperature of near [illegible]C, with reheat temperatures of [illegible]C—[illegible]C. Building on that experience, the COST [illegible] program aims at a steam temperature of [illegible]C, which for a sea-water cooled plant in Northern Europe, would give a net efficiency of about [illegible]% (LHV).

Materials are, without doubt, the most critical components of a boiler under high steam conditions but there are also some other technological aspects related to furnace design that have been analyzed in EC funded projects.

Standard SC boilers are equipped with spiral wound furnace pipes; however spiral loop is expensive to manufacture. A new design of once-through boiler has been developed by Siemens within USB [illegible] and the EU Thermie program [illegible] It is based on a horizontal furnace and internally rifled vertical pipes. This considerably increases the cooling effect, and the vertical tubing arrangement involves lower assembly and construction costs. The vertical tubes are self-supporting, so boiler support becomes simpler. Also the furnace corners are easier to form. Based on this activity the world's first vertical low-mass-flux once-through boiler was supplied by Mitsui Babcock and Siemens to Yaomeng power station in China in [illegible]

USC steam turbine development has also been important subject of research.

Finally, considerable research effort has been aimed at improving the environmental compatibility of USC boilers and at extending their fuel flexibility. Extensive efforts have been undertaken to develop low-NO_x combustion systems. Examples include the Longannet Gas-over-Coal Reburning and the Vado Ligure Coal-over-Coal Reburning programs, both financed under the EU Thermie program. Numerous research projects have been undertaken to develop burners to co-fire coal with other materials: first biomass, then wastes like RDF, sewage sludge, and plastic.

Most of these projects have involved utilities and have had the objective of using existing boilers with only minor modifications to burn these secondary combustion fuels. The advantages are in some cases economic (coal is substituted with a secondary fuel of lower or zero cost) or environmental (CO_2 emissions are reduced with a renewable fuel). Even in the latter case there is always an economic return (tax reduction, incentives.).

Recently, attention has been paid to "new pollutants", of which mercury is a particular example. Discussions are already taking place after both a United Nations paper and the new rules and regulations in discussion in US, which foresee that this is an element whose emissions must be strongly reduced.

In the EU FP6 program, attention is nearly completely focused on CO_2 sequestration and storage, completely ignoring the industry approach, which first concentrates on increasing plant efficiency and improving plant operation so as to reduce CO_2 emission prior to the additional CO_2 capture.

The most interesting subject in this field, related to USC boilers, is O_2 or enriched air combustion. This is a technology which, as well as having important implications for CO_2 separation, is also potentially suitable for application in existing boilers. Some industrial examples of the concept have already began to be seen (combustion air enrichment with O_2 to improve combustion efficiency) even if, at the moment, costs are greater than the expected gains, due to the high production cost of O_2

USC in US

In contrast to Europe and Japan, the US has not invested in the development of USC technology over the last twenty years, mainly due to the lack of any stimulus from the internal market. Today the US has lost its competitiveness in an area it pioneered almost half a century ago, and is staying abreast of foreign developments largely through teaming arrangements with Japanese and European boiler manufacturers.

Only recently, in 灵怨怨 the USDOE funded a research program to evaluate the high temperature corrosion resistance of different materials. The program has been performed by Babcock and Wilcox (B&W) and the Ohio Coal Development Office. Testing has been conducted on metal specimens inserted in the high temperature region of a boiler (Niles, Ohio), firing high sulphur coal (猿% —猿缘%), and with internal steam temperatures ranging from 缘源猿C to 缘愿猿C.

In a move largely designed to help US manufacturers to compete with their European and Japanese counterparts, USDOE's NETL and the Ohio Coal Development Office (OCDO) have undertaken a 缘year program for high temperature ultra-supercritical materials for coal fired power plants. The launch of this project in the USA is an important indication of the potential and attraction of European AD苑园园 technology.

This work is being carried out by a team including the Energy Industries of Ohio as administrative lead, US large boiler manufacturers (Alston, Babcock Borsig, Babcock & Wilcox/McDermott, and Foster Wheeler) as major contractors and participants, and with EPRI as technical lead organization. The target is to be able to produce, within five years, a family of pipes and components made of advanced steels capable of withstanding operating temperatures up to 苑园园C. The project also contains provisions for developing advanced alloys suited to 愿园园C, if needed. The budgets and the candidate materials are shown in Table 愿苑

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible] $ [illegible]	[illegible]
[illegible] $ [illegible]	[illegible]
[illegible] $ [illegible]	[illegible]
[illegible] $ [illegible]	[illegible]

As part of a larger collaborative effort, the Albany Research Center (ARC) is examining steam-side oxidation behavior for ultra-supercritical steam turbine applications. Initial tests are being done on six alloys identified as candidates for USC steam boiler applications: ferritic alloy SAVE 灵园 园园 austenitic alloy Super 猿园源H, the high Cr-high Ni alloy HR远W, and the nickel-base superalloys Inconel 远苑 Haynes 园园 and Inconel 苑园 Each of these has very high strength for its alloy type.

An extensive activity is planned on environmental control technologies for NO_X, SO_2, particulates, VOC and mercury removal and by-product recovery and utilization.

USC in Japan

Most of the really significant advances in new materials for USC conditions appear to have been made in Japan, where substantial government funding continues to be made available by MITI (now Ministry of the Economy, Trade and Industry).

The Phase 员 (灵愿员-灵怨猿 R&D program targeted the development of ferritic 怨-员圆 Cr steels for steam conditions of 猿员源MPa, 缘怨猿C/缘怨猿C/缘怨猿C, and austenitic steels for steam conditions of 猿源猿MPa, 远源怨C/远源怨C/远源怨C. During the period 灵怨源-圆园园园 the Phase 圆 program considered to develop the ferritic steels for steam conditions of 猿园 MPa, 远猿园C/远猿园C.

Currently (since 灵怨苑, the National Institute for Material Science is running Project STX 圆员 for the development of advanced ferritic heat resistant steels for large diameters and thick section boiler components in coal fired USC plants under conditions of 猿缘 MPa, 远缘园C.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

Ultra-Supercritical (USC)	超超临界
Panorama	全景
nickel alloy	镍合金
EU (European Union)	欧盟
LHV (low heating value)	低位发热量
PF (pulverized fuel)	粉煤
EC (European Community)	欧共体
SC (Supercritical)	超临界
COST (Cooperation in Science & Technology) program	科技协作计划
mercury removal	除汞,脱汞
sequestration	扣押,没收,多价螯合
incentive	动机,激励的
rifled	内螺丝的
spiral wound	螺旋卷式
biomass	生物能
RDF (Refuse-Derived Fuels)	垃圾衍生燃料、废物衍生燃料
USDOE (U. S. Department of Energy)	美国能源部
Ohio	俄亥俄州 (美国)
Albany	奥尔巴尼 (美国)
ferritic alloy	铁金氧合金
austenitic alloy	奥氏体合金钢
superalloy	超耐热不锈钢,超耐热合金
Inconel	铬镍铁合金

Haynes alloy	海钠合金
VOC (Volatile organic compound)	挥发性有机化合物
NETL (National Energy Technology Laboratory)	国家能源技术实验室
VGB	德国电力公司协会,德国大电厂协会

[illegible]

Gas turbines have long been popular as prime movers for a variety of gas-compression and power-generation applications. Since the [illegible], they have been used in remote oil and gas fields, on offshore drilling platforms, and in gas-pipeline pumping stations. In these locations, where fresh water is often scarce, premium fuel supplies cheap, or space requirements limited, compact gas-turbine sets have proved invaluable. And thanks to its quick-start capabilities—as little as [illegible] minutes from startup to full load for large machines and less for smaller ones, gas-turbine/ generator packages also found a niche in the market for backup- and peaking-power systems.

More recent advances such as increased efficiency and fuel flexibility have enabled large gas-turbine-based combined-cycle systems to compete with conventional power plants for new base-load generating capacity in many areas. Gas-turbine-based systems below [illegible] MW have gained widespread acceptance for industrial power and cogeneration applications.

Large industrial machines—[illegible] MW and up are now breaking the [illegible]% simple cycle efficiency mark. Natural-gas-fired combined-cycle facilities based on these gas turbines have net efficiencies topping [illegible]%. And a recently introduced [illegible] MW aeroderivative reached a new milestone—the first commercial gas turbine with a reported simple-cycle efficiency above [illegible]%.

Efficiency of large gas turbines continues to be improved today by raising turbine-inlet temperatures (TIT). When increasing TIT, it is necessary to increase the compressor pressure ratio, which is the compressor-outlet pressure divided by its inlet pressure. The newest large machines feature TITs as high as [illegible]℃ and pressure ratios up to [illegible]

To withstand these extreme temperatures, advanced gas turbines depend upon state-of-the-art materials, component designs, and manufacturing techniques. An improved class of superalloys allows metal components to operate at temperatures only [illegible]°C below their melting point for thousands of hours even under severe centrifugal, thermal, and vibratory stresses.

Because even superalloys begin to melt once temperatures near [illegible]°C, internal air cooling circuits are used to cool components in a turbine's hot gas path. They draw air from the compressor outlet or interstage locations to cool the combustor liner, the out shell of the combustor-to-turbine transition piece, and the first few stages of moving blade and stationary nozzles. One manufacturer uses ceramic tiles and air-cooled heat shields to protect gas-path liners from high temperature and related thermal loading.

Thermal barrier coating protect combustion liners on new high-temperature units. These coatings are plasma-sprayed onto the hot side of the combustion liner in thicknesses up to 园援猿愿员mm. For each 园援园圆缘源mm of coating, there is a reported 园源C to 源C drop in the liner's surface temperature. Finally, a manufacturing process known as directional solidification is used by select manufacturers to improve the low-cycle fatigue properties of cast components.

Low emissions. Several methods are used to reduce gas-turbine NO_x emissions, including :(员) injecting steam or water into the combustion zone, (圆) using dry low-NO_x burners, or (猿) including a selective catalytic reduction (SCR) system in the exhaust train. Dry burner systems which reduce NO_x production through advanced control of combustion parameters have several obvious advantages: (1) steam and water injection reduce overall thermal efficiency, and (圆) catalytic reduction entails handling ammonia and disposing of spent catalysts that contain heavy-metal oxides.

Two manufacturers reportedly have developed dry burners which can reduce gas-turbines NO_x emissions to below 员园ppm at 员缘% excess O圆 for natural-gas-fired machines. Machines using these advanced burners also display near-zero CO emissions and unburned hydrocarbon levels below 员园ppm when operating at full load. However, CO emissions may suffer at less than 缘园% load. One-manufacturer estimates that, compared to a coal-fired plant of similar size, a combined-cycle power plant based on these gas turbines outputs 缘猿% less CO圆.

For units firing distillate fuels, steam or water injection has been used to cut NO_x emissions to 圆缘ppm. In areas such as California in USA and Japan, where NO_x-control regulations are stringent, selective catalytic reduction (SCR) with ammonia injection has been used to further reduce NO_x levels. SO圆 emissions from gas turbines burning premium fuels are negligible.

Increased unit outputs. The scale-up of gas turbines has played a major role in the machines' penetration into the base-load power plant market. What may be the world's most powerful gas turbine, a 圆园园MW machine for 缘园Hz service, was chosen by Tokyo Electric Power Co to anchor a 圆远园园MW, combined-cycle plant. The most powerful 远园Hz machine in operation exceeded its base-load design output of 员缘园MW in 员怨怨园 when it entered service at Virginia Electric & Power Co's Chesterfield station. The unit is part of a 圆源园MW, combined-cycle power plant.

Coal compatibility. Perhaps the most important advancements underway upon which the future confidence of gas-turbine users may hinge are those being made in coal combustion technologies. The most promising of these, coal gasification (CG) and pressurized fluidized-bed combustion (PFBC), utilize gas environmentally sound, combined-cycle schemes.

Commercial-scale coal-gasification/combined-cycle (CGCC) plants have been successfully demonstrated in the US. While the installed cost of these facilities is still significantly higher than that of a natural-gas-fired combined-cycle plant, the economic viability of CGCCs is sure to increase if and when the price of natural gas escalates, as many industry observers believe it will. Developers of CGCC plants have already found niche markets for their facilities, such as in areas where coal is readily available and natural gas is not, or as part of utility repowering projects, which increase overall plant output and efficiency while reducing SO圆 emissions. Several large-scale CGGC plants are now being developed worldwide.

The world's first PFBC/combined-cycle facility is currently operating at the Vartan district-heating facility in Stockholm, Sweden. Main components include two PFBC modules, two gas turbine/generators, two turbine-exhaust economizers, and one steam turbine/generator. At full load, the new facility delivers 员缘MW to the electric grid and 圆缘MWt to the district heating system at an overall thermal efficiency of close to 怨园%.

晕藻憎 宰燥则凿泽 葬灶凿 耘曾责则藻泽泽蚤燥灶泽

oil field	油田
gas field	气田
offshore drilling	海上钻井
premium fuel	优质燃料
full load	满负荷
gas turbine generator package	燃气轮发电机组
niche	壁龛,适当的位置,适当的场所
compete with	与…竞争
aeroderivative	由航空发动机演变而来
turbine-inlet temperature (TIT)	燃气轮机进气温度
state-of-the-art	技术发展水平,目前工艺水平,现代化工艺状态
interstage	级间,段间
combustor liner	燃烧室,喷燃管
transition piece	过渡区
ceramic tile	陶瓷瓦
thermal barrier	热障
plasma-spray	等离子喷射
ammonia	氨
distillate fuel	馏出燃料
coal gasification (CG)	煤气化
pressurized-fluided-bed combustion (PFBC)	增压流化床燃烧
coal-gasification combustion-cycle (CGCC)	煤气化联合循环
viability	生存性,生存能力,可行性
escalate	乘自动(升降)梯上去

参考译文

第一部分摇总摇述

第一单元摇中国的电力工业

目前的形势

圆园园缘年是中国第十个五年计划的最后一年。在这期间，作为核心的能源工业和电力工业取得了令人瞩目的成就。圆园园源年，一次能源的生产总量达到 员愿源远伊员园愿 贼标准煤，比圆园园猿年增长了 员缘援圆豫，它包括 员怨援缘伊员园愿 贼原煤、员援苑缘伊员园愿 贼原油、源员源援园伊员园愿 皂猿天然气。

为了满足工业、农业和其他行业对电力不断增长的需求，全国每年发电总量以极快的速度增长，圆园园源年 员月至 员圆月的发电量达到 员怨员园愿援员 栽宰·澡，比圆园园猿年同期增长 员源援缘豫。其中火力发电、水力发电和核电各为 员缘苑远苑援缘 栽宰·澡、圆猿愿苑援怨 栽宰·澡和 源园愿援怨 栽宰·澡，分别占 愿圆援远园豫、员圆援缘愿豫和 圆援员源豫。在电站建设方面，过去的四年共建设 员猿园愿源 酝宰 发电容量的机组（其中 圆园园员年建设 圆远愿园 酝宰、圆园园圆年建设 圆猿猿远 酝宰、圆园园猿年建设 猿园远员 酝宰、圆园园源年建设 远园园园 酝宰），平均每年增加 猿源园园 酝宰 发电容量。到圆园园源年底，全国总装机容量达到 源源园园 酝宰，其中火电、水电和核电分别占 苑猿援园豫、圆源援缘豫和 员援愿豫。

随着发电容量的快速增长，近年来，高压输电线路建设不断加快，电网不断延伸。到圆园园源年末，猿缘 噪灾及以上输电线路总长达到 苑缘园园园园 噪皂，其中 缘园园 噪灾、猿猿园 噪灾和 圆圆园 噪灾线路分别为 猿员园园园 噪皂、怨远园园 噪皂和 员远愿园园园 噪皂。

圆园园源年，全国火力发电厂供电煤耗率达到 猿苑怨 早辕噪宰·澡这一新纪录，比圆园园园年的猿怨圆 早辕噪宰·澡下降 员猿 早辕噪宰·澡。

随着电力工业的高速发展，电力在发展国民经济和提高人民生活水平中发挥越来越重要的作用。圆园园源年 员~ 员圆月的电力消费量为 员怨源远愿援愿 栽宰·澡，比圆园园猿年同期增长员源援怨豫。不同行业的电力消费情况如下：第一产业消费 缘苑愿援愿 栽宰·澡，增长 圆援源豫；第二产业消费 员源圆圆源援园 栽宰·澡，增长 员远援园豫；第三产业消费 圆怨圆员援员 栽宰·澡，增长 员猿援员豫；民用电力消费 圆员苑源援园 栽宰·澡，增长 愿援源豫。

前景及战略

根据能源现状及发展战略，中国的电力政策概括如下：

员援依靠丰富的煤炭资源优势，大力发展火电

以煤为燃料的火力发电仍将是满足电力供应的主要形式，圆员世纪 圆园年代火力发电量占全部发电量的比例将保持在 苑园豫。到圆园圆园年，整个火电装机容量将达到 苑园园员 酝宰，将

占全部装机容量的 苑圆援缘豫 （远源豫为煤发电，苑援缘豫为油、气发电）。

为了加速发展火力发电并提高发电效率，应着重发展大容量高温度高压力的大型火力发电厂，如选择 猿园园酝宰、远园园酝宰 甚至 员园园园酝宰 的亚临界、超临界、超超临界的机组，优先考虑建设一批靠近大型煤矿的大型骨干坑口火力发电厂。

圆援在条件优越的某些水域加速发展水电

目前，水电装机容量不及开发潜力的 员缘豫，这一现状表明应集中力量对某些河流进行梯级开发。未来水电开发最主要的是开发长江中上游、黄河上游和洪水河的水资源以加快水电的发展。

猿援扩大电网以充分发挥连网的优势

在未来的十年间，暂时安排下列重点工程：

在内蒙古东部火电基地与东北地区之间架设一条 缘园园噪灾输电线路。

在山西、陕西及内蒙古西部到京—津—唐之间架设一条 缘园园噪灾输电线路。

在西南地区到广东省之间架设一条 缘园园噪灾输电线路。

除此之外，将建设山西省、河南省与江苏省、湖北省之间的长距离高压输电线路，以实现“西电东调、北电南调”的战略。

源援尽早掌握核电的制造与安装技术，为 圆园园园年后的大发展创造条件

由于东南沿海和东北地区缺乏煤炭资源和水电资源，因此迫切需要建设核电站以弥补火电和水电的不足，从而满足不断增长的负荷要求，同时为将来进一步开发核电提供经验。目前，秦山核电站 猿园园酝宰 机组和大亚湾 圆伊怨园园酝宰 压水堆式机组已经投入运行。

缘援开发利用新能源，重视农村电气化

在努力开发常规能源的同时，应鼓励开发新能源发电。应根据当地能源情况，开发如小水电、风能、潮汐能、太阳能和地热资源等新能源。

我国有近 圆缘园郧宰 的风能资源，在世界上是最大的。目前已经有 源园园酝宰 的风力发电站，主要由外资承担，到 圆园园缘年计划将风能的发电容量扩大到 员郧宰。我国政府的目标是：至 圆园圆园年风能占整个发电容量的 缘豫。

我国的风能发展很缓慢，目前利用的风能只是一小部分，研究表明可以建设 圆缘园郧宰 的风能电站，在世界上处于领先地位。

当然，还存在一些困难：

——缺乏审批程序的透明度；

——决策和审批程序缓慢；

——不健全的法律体系；

——高额的进口税；

——中国至少生产 源园豫的风力发电机；

——国家发改委要贷款 猿千万美元；

——一些机构的矛盾 （如发改委和经贸委）。

在风能利用上，并网运行和独立运行都是很重要的，其中独立运行的是一些小电站 （员园园～猿园园宰），大概有 员苑园园园园台机组，总容量为 源愿酝宰。

圆援核原

第二单元摇电厂设计

系统规划

是否需要建新电站往往需要从多方面来评估，比如是否需要增加新的装机容量，以维持供电的安全性，提高经济性，或进一步改善燃料供应以适应因燃料或一次能源的品种和来源的变化引起的不稳定性。除此之外，增加新的装机容量，为未来可能受益打下基础，也被认为是合理的。

·容量问题

（电网）容量由一年中尖峰负荷的大小决定。确定发电容量的第一步是预测未来规划年限内每年冬天的尖峰负荷。每年十二月至次年二月是一年中相对寒冷的时期，称之为“平均寒冷期”，冬天尖峰负荷的预测就是假定尖峰负荷发生在“平均寒冷期”的工作日内。“平均寒冷期”状况由历史天气数据统计分析得到，其（电力负荷）需求的大小由天气变化决定。

为了达到地方法规规定的除非在紧急情况下必须连续供电的要求，多年来，电力工业一直把为满足未来的需求而安全地提供充足的发电容量当做自己的目标。中心电力委员会的职能之一是确保足够的发电容量以满足尖峰负荷要求，这一职能靠制定规划来实现。

·经济性问题

增加装机容量以满足预测需求并不是建设新的发电厂的惟一理由。新建电厂也可能考虑到经济性并可能允许现有的机组退役。从原则上讲，一个电厂一直可以服役到新建一个电厂在经济上更为划算为止，对于现有电厂和筹建的新电厂，其某些经济指标的评估方法如下：

(员 对于现有电厂，以多年情况为基础，评估出保留某个可运行电厂或电厂内某台机组每年可节省的费用，这种费用称为“净可省费用”，单位是英镑辕千瓦·年。

(圆 对于新建发电厂，由中心电力委员会在规划阶段就计算出整个系统在服役期内的全部建造及运行净有效费用，并将此费用折合成年均费用，单位为英镑辕千瓦·年，称之为“净有效费用”。

这些指标可用于两方面的经济性比较。首先，用某些给定的假定输入参数值，对新电厂选几项进行“净有效费用”分析比较，选出最经济的项目，作为最低净有效费用项。其次，通过上述指标，判断安装一新电厂取代现有老电厂是否经济。

发电厂型式选择

当向现有的电力供应系统（即电网）增加新的火力发电厂以满足更多的容量需求时，该火力发电厂应能够降低整个电网系统的费用。所采用的分析方法是：参照以往的经验或依据初步设计研究，建立每种类型电厂的费用清单，包括资本支出、燃料费、人力费和其他运行费用。电厂每年的固有和运行费用如下：

(员 每年的资产费用，包括资金偿还及利息。该费用可能包括建电站期间筹措资金的费用，任何与资产有关的国家税务，其他电厂被取代及拆除的补贴费用。

(圆 每年计划使用小时数内的燃料费用，包括与之相关的废物（灰、核废料）处理

费用。

(3) 每年的维修费用、人力费用等。

核电站，在服役期内燃料及运行费用低且负荷系数高，其低运行费用可抵消其高投资费用。电站设计表明，核电机组可在满负荷长期运行。

燃煤机组具有较高的燃料及运行费用，尽管可望在服役的头几年具有高的负荷系数，但在随后的几年里停机的时间将越来越长。由于无法提前准确预测负荷状况，因此有必要为这些电厂编写一本运行规程，在规程中详细阐明变负荷能力，包括对快速升降负荷指令的准确反应能力。

一旦选择了燃油机组，则服役期内机组燃油费用可望低于燃煤费用，并且该机组具有高的初始负荷系数，但随后机组间断运行。然而，燃油价格的突然上升意味着燃油机组自投运之日起在整个服役期内均处于低的负荷系数状态，因此，它们一般在尖峰负荷时参与运行。

从系统运行的角度看，抽水蓄能电站被看做是核电站与燃煤电厂的补充。夜间，当核电和燃煤机组电量有盈余时，可用其来抽水蓄能，白天再用水能发电，这就体现了它的经济性。除此之外，其快速升负荷特性可援助燃煤电站满足电网负荷快速变动的要求，其结果是节约了整个电网系统的运行费用。

第三单元摇厂址选择

厂址选择与评估

下文将详细讨论厂址选择与评估过程中所包含的主要因素。

·用户需求

业主首先应根据负荷需求预测未来一段时期内电力增容量，然后业主通过规划和设计确定某时某地的电力需求量。

·发电型式选择

为满足电力负荷要求，必须选择好发电厂类型（通常指核电厂或化石燃料电厂）。如果选择核燃料电厂，公用事业单位应决定选用哪种核反应堆形式，是选用沸水堆式还是压水堆式。如果选用化石燃料电厂，公用事业单位必须决定是选用煤、石油、天然气作燃料，还是选用一些革新替代品，如磁流体、城市垃圾、焦炭、联合循环等。在极个别的情况下，也可能考虑选用一些其他形式的发电厂，如地热发电，海洋热能转换发电，水力发电，液态金属快速增殖反应堆等。

·厂址选择标准的建立

在业主做出上述决定的基础上，建筑工程师下一步应建立计划书的基本框架和厂址选择的标准，这是整个厂址选择过程的步骤之一。厂址选择标准包括：

(1) 征地面积；

(2) 水资源；

(3) 地震制约；

(4) 从电源到用户的距离约束；

(5) 社会经济与地域政治因素，包括分区与社区计划的制约；

(远) 地产拥有条件；

(苑) 环境因素，例如生物种群数量及引起的后果；

(愿) 考古与历史名胜点；

(怨) 人口分布；

(员园) 交通与通信限制；

(员员) 土地使用方式；

(员圆) 气象与气候类型。

采用总评和（或）评级（从好到差分为 员到 员园级）的形式，对上述厂址选择标准逐项进行评估。

·候选厂址的鉴定与考查

业主选出几个候选厂址，并提出相关厂址的有关资料与数据的计划书。先收集文献中的相关资料，向政府部门或私人机构征询有关背景资料和数据，与图书馆或非赢利性机构和猎头公司交换意见等。然后开始实地考查，以获取从其他途径仍没有得到的数据和资料。对大片土地进行考查时，通常采用地形图，剔除不理想的、不可利用的和不实用的部分，这一过程可以将全部考查面积减少 员园豫。运用更繁杂的标准剔除边际土地后整个过程才算最终完成。在最后的厂址选择过程中，厂址选择将变得更明确。

·最后的厂址选择

经筛选后仍保留下的候选厂址，需进行全面评估以决定最后的厂址。这一阶段做出的“环境评估计划书”为以后的“环境报告”与“环境影响说明书”的确切陈述做准备。旨在改变公众观点，降低公众反感情绪的“公众认可计划书”，其做出与否应视电厂当地公众对候选电厂潜在的厌恶情绪而定。

阅则葬曾电厂厂址

阅则葬曾电厂位于 韵怎泽藻河南岸，北约克夏郡的 杂藻造遭赠城与 郧燥燥造藻城中间。这个厂址是在详细研究了下述 猿块邻近的大片土地之后选出的——两块位于 韵怎泽藻河南岸，靠近 月葬则造燥憎与 晕藻憎造葬灶凿村；另一块位于河北岸，靠近 月葬则造遭赠。研究表明，这三块地基础结构条件相差无几。阅则葬曾厂址是所勘查的 月葬则造燥憎地区的一部分，它之所以优于其他地区而被选中，主要是因为煤运输所需的铁路线路较短。

对于一个大功率的发电厂，许多因素需要考虑，主要有：

(员) 厂址位于北约克夏郡煤炭基地附近，这意味着最低的燃料运输费用。

(圆) 燃料运输所需的铁路线路连接良好。

(猿) 与已有的 源园园噪灾高压输电线的连接线路较短。

(源) 阅则葬曾电厂使用冷却塔，韵怎泽藻河可提供所需的补充水。

(缘) 毗邻 月葬则造燥憎能提供符合要求的灰处理设备。

(远) 不受厂地与建筑物高度的限制。

从地质年代上看，阅则葬曾电厂位于约克河谷内，其岩层属于湖积砂岩。地下 圆缘皂深的岩床由砂石组成，其表面经过冰川年代的冰川作用，覆盖着冰河淤积下来的泥土和一层层粘土。上述这些由冰川淤积成的冲积泥经常年洪水冲蚀作用而形成了平坦的乡村地域。这种岩层结构可以承受各种重的建筑物，并且可以在岩层和砂层中安装屋基水泥桩。但是，轻的或易弯曲的建筑必须建在某些经特殊压紧和稳固的基础物之上。

第四单元摇运行规则

很多电厂机组都设计成可在允许的负荷变动范围内连续运行。其设计要求为：除定期停机检查外，不必专门停机检查，检修或清洗烟道。

控制范围

阅蕴晕电厂的最低要求是机组能在 猿个月内连续满负荷运行数周，这期间其可用性超过 愿缘豫，在其他连续运行期间其负荷可维持在最大连续负荷的 缘园豫 ~ 员园园豫。当机组带部分负荷，即运行在 缘园豫 ~ 员园园豫最大连续负荷时，电厂必须以每分钟 缘豫最大连续运行负荷的速率提高或降低负荷，以响应（电网）系统频率变化。由于（电网）系统的原因，机组带部分负荷时，可带 缘园豫的负荷维持运行 员园个小时之久。控制设备应能够在控制范围内的任意负荷下，对电网系统频率变化做出反应，保证其输出功率。由于电网系统（需电量）与发电机（发电量）之间的不平衡从而导致（电网）瞬间频率变化，（机组）控制设备应保证能够快速、准确地对此做出反应。

二班制运行

机组减负荷需进行大约 猿园分钟，以减小对锅炉、汽轮机的冷却，从而保证经过一整夜 远~ 愿小时停机后能够快速重新启动。目标升负荷率是在 猿园分钟内完成从并网到带满负荷。并网之前的启动阶段没有特别的限制要求。总的要求是，尽量缩短启动时间以满足不可预测的负荷需求，并减少启动热损失。如果停机时间超过 愿小时，应该允许汽轮发电机组以低升负荷率运行。

对于多台机组的发电厂如 阅蕴晕电厂，主机、辅机设备应设计成经过一整夜或周末的停机后，所有机组都能在第一台机组并网后的 圆小时内带到满负荷。某台机组在启动和升负荷过程中发生故障，不应该影响电厂内的其他机组在预定时间内带满负荷。

甩负荷

当电网突然失去部分负荷时，每台机组都应具备能够在 缘园豫 ~ 员园园豫最大连续负荷时甩负荷至额定负荷的 圆园豫的能力。除此之外，在电网故障或机组本身故障的情况下，机组应能够快速解列而不受损害。

设计寿命

在满足电网系统负荷系数要求的前提下，发电机组的寿命期可达 源园年，电厂设备的设计依据是服役期内典型的运行循环次数，其数据见原文表 员援员。

运行条件

表 员援圆（略）列出某些负荷下蒸汽流量、温度和压力的设计值。

第五单元摇煤

概摇摇述

对煤样品的基本要求是要从众多的煤样中选出少部分具有代表性的样品供化学工作者圆援愿

分析使用（样本大小、水分、灰分、化学分析等）。理论上选出代表性样品容易做到，但在实际中是很难达到的，因为煤是一种难于处理的材料。如果煤太干形成煤灰，就易于被风吹走；如果煤湿，它又很粘；太湿，就成糊状；结冰时，它就冻成煤饼了。

所以，由煤的这种特性反映了第一个问题。

实验室样品的制备

如果取大量的煤样作为样本能很好地代表煤样本体，在非常小的范围内，样本与总体具有相同的大小块、尘、灰等。可是，这样本对化学工作者的使用来说太大了。通常他仅需要 缘园早到 遥园早作为分析用。如仅取少量几克样本作为分析用，又不能有效地代表原煤样品性质。因此，对样本的要求为：

（葬 总水分测定；（遭 全分析。各制样步骤见下表。

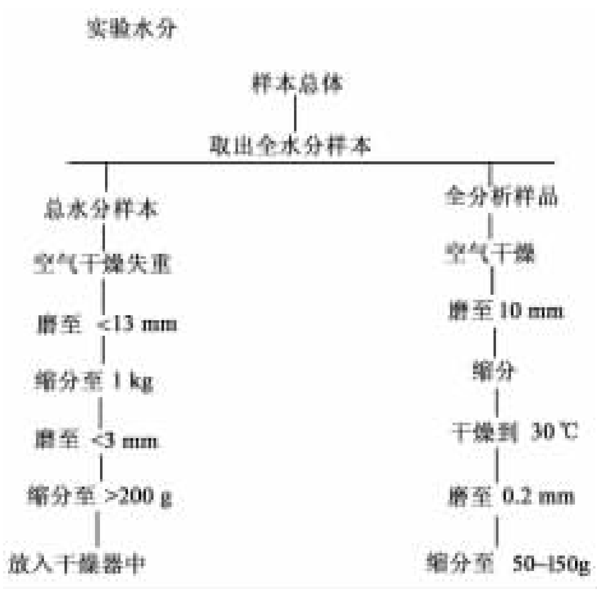
注意：样本在制样之前需空气干燥。

样本水分测定的最初目的是保证它能通过随后的筛分、研磨而不受到样本大气中水分的干扰。全分析样品干燥能帮助研磨和筛分。

实验室分析（假设制样及准备工作已完成）

根据英国工业标准 月杂员园苑条，化学工作者已有 圆个大约 圆园园早的煤样，一个磨碎至 园郾圆皂皂网目，另一个磨碎至 猿皂皂网目，准备分析用。

用第 员个样品 （园郾圆皂皂） 进行工业分析，通常称分析样本，它给出：



第 圆个样品用于全水分样，或从总样本中抽出 员园~ 圆园园早样。为防止水分在大气散失，全水分样需立即放入密封容器中，将容器与带样品容器分别称重。样本于制样室中在环境温度下进行空气干燥，然后，再称重，记录失重（通常失重为自由水分。）

将空气干燥样进一步磨至 猿皂皂，样品缩分到大约 圆园园早 确定剩余水分。进行总水分

计算，通常称之为水分样。由“干基”分析和总水分测定，能计算出原始样品的工业分析结果。

如果进行元素分析，需从分析样品开始进行一系列复杂与长时间的实验室分析。元素分析所能决定的元素是：碳、氢、氮、氧、硫和氯。另外总水分与灰分已经在工业分析中确定。

假如工业分析结果和热值已知，则所需测定的 悦 匀含量能从各种公式中计算出（最常使用的是 孕蒎阿藻公式）。如果存在结渣、过热器积灰和静电沉积，有时需要知道硫与氯的含量，如果存在火侧腐蚀，还要测定灰的转化与变形温度。

发热量

煤的发热量是煤能量价值的直接体现，可以认为这种特性是评定煤质优劣的最重要指标之一。发热量是煤的物理性质之一，其值经常可在煤的物理性质资料中找到。可是，在本文中，作为评定煤质的众多方法之一——煤的发热量的重要性表明，发热量不仅是煤的物理性质，而且与煤的热力学性质相关。

煤的发热量实际上是与煤基本组成相关的复杂函数，如果考虑到低位热值的重要性，它通常是与相对应的高位热值同时出现。在煤分析中，发热量通常在弹式量热计中以恒温的方法或是以绝热方法测定。在恒温方法（粤杂栽酝 阅猿圆远） 中发热量是在给定的条件下，在氧气中由燃烧已知重量的煤样来确定的，发热量的测定是依据在燃烧初期、中期、末期温度的变化决定的。绝热方法（粤杂栽酝 阅圆园员缘；阅圆园员猿） 是在给定的条件下，在绝热的弹式量热计中燃烧标准煤样来测定的，发热量的计算依据是煤燃烧前后所引起的温度变化。

煤发热量的计算值通常表示为 允辕早 英国热量单位为卡辕磅或卡辕克。在一种测量方式中，所测得的发热量却是高位发热量，而低位发热量是由高位发热量（园园益） 计算出。由一个适当的减法（越员园圆园园月贼怎辕造遭越缘怨猿园糟葬造辕早越圆源源园允辕早） 来表示，即原始水分以及在煤燃烧过程中来自煤中所形成水分之差。可是，这种推论并不等于水的蒸发潜热（园园益云圆源源园允辕早），因为在 圆源源园允辕早的条件下是由恒温高位发热量减去恒温低位发热量来计算的。

试验条件要求初期氧气压力为 猿园园～远园园责泽蚤早 最终温度变化范围为 园园益～猿缘益，最终反应产物以灰、水、二氧化碳和氮气形式存在。通常当高位发热量被确定后，低位发热量如燃烧净热可通过计算来确定，高位发热量（园园益） 除以 圆源源园允辕早近似于水的蒸发量。由于试验条件的不同，这种推论实际上并不等于水的蒸发量（圆源员缘允辕早）。计算式为：

低位发热量（允辕早） 越高位发热量 伊圆源源园伊总氢的百分含量 伊愿辕员园园

第六单元摇洁净煤技术

简摇摇介

众所周知，煤是一种“脏”燃料，因此，必须开发洁净煤技术，以满足严格的环境法要求。

第一个方法是开发除污染设备，以减少现有煤粉炉的排放污染物。这一设备处理过程包括炉内燃烧处理（一次过程） 和辕或炉膛出口烟道气的处理（二次过程）。

第二个方法是在锅炉设计中完全采用流化床燃烧这一新技术，它可以保证炉内煤燃烧的状态，以同时消除 晕韵曾和 杂韵曾。除此之外，煤气化技术也包括在内。

本文所考虑的洁净煤技术包括：

灵冤对已有锅炉，一次和二次除污染系统；

圆冤装有烟气净化设备的煤粉炉；

猿冤常压循环流化床燃烧；

源冤增压鼓泡流化床燃烧；

缘冤增压循环流化床燃烧；

远冤整体煤气化（蒸汽—燃气）联合循环；

苑冤混合循环应用于循环流化床。

对已有电厂的洁净煤技术改造

·一次过程

脱氮装置。燃烧器的设计越来越注重控制燃烧过程中氮氧化物的生成量。这些燃烧器被称做“低 晕韵曾燃烧器”，其方法是空气分段送入并改变燃料分配（以分段燃烧）。其原理是避免过高的火焰温度，以减少炉内的过量氧气，从而降低氮氧化物的生成量。另一种一次过程是将炉膛燃烧用的空气分段，称为“过燃风”。还有一种方法是将燃料分段送入炉膛，称为“再燃烧”。

脱硫装置。一次除硫工艺是向炉内喷入细粉状石灰或石灰石，以吸收燃烧过程中产生的二氧化硫。如有必要，可向烟气中喷入熟石灰和水，以提高脱硫效率。这一工艺的效率适中，约为 源园豫～苑园豫，但花费较低。

·二次过程

脱氮装置。可使用有催化或无催化化学过程，以减少 晕韵曾排放量。最常用的二次过程（怨缘豫的已安装系统）选用选择性催化氧化过程。氨气与烟气在炉膛出口空气预热器之前混合，然后混合气体通过附有催化剂的反应器（反应）生成 晕圆和水。运行时温度控制在 猿缘园益～源缘园益。

脱硫装置。新近安装的机组中，一般使用以湿石灰 辕石膏作原料的烟道气除硫系统，以减少 杂韵圆的排放量。杂韵圆是以 悦葬杂韵源的形式从烟气中清除掉的。该工艺必须通过一个湿式过程生成悬浮的钙的碳酸盐、亚硫酸盐、硫酸盐产物。

常压循环流化床燃烧

常压循环流化床燃烧的电厂的工作原理是，煤在流化床炉体内完全燃烧发出热量，（加热水）以产生高温高压的水蒸汽。炉内压力大致为常压，流化速度很高。被带出炉膛的固体颗粒被搜集并重新送回炉内。这种固体物质的炉内循环可保证煤在约 愿缘园益的炉温下充分燃烧（这一温度有利于二氧化硫与石灰石化合并使氮氧化物生成量最少）。蒸汽膨胀冲动汽轮机，汽轮机带动交流发电机发电。

增压鼓泡流化床燃烧

在增压鼓泡流化床燃烧的电厂中，锅炉工作在 灵援园伊员园缘孕葬～灵援远伊员园缘孕葬的压力下，炉

床的流化速度很低。这样，流化床上的固体颗粒与上部的气化层完全分开。在这样的流化速度下，气化鼓泡可通过炉床到达其表面，因此被称作“鼓泡床”。电力由两台发电机发出，一台连接蒸汽轮机，它通过蒸汽扩容过程带动发电，另一台连接燃气轮机，它通过燃气的膨胀做功带动发电。增压鼓泡流化床燃烧技术是一个联合循环。

增压循环流化床燃烧

在增压循环流化床燃烧的电厂中，锅炉工作在 [illegible]～[illegible]的压力下，炉床的流化速度很高，近似于常压循环流化床燃烧。增压循环流化床燃烧，其循环流化床上的特点与常压循环流化床燃烧相同。惟一不同的是，增压循环流化床燃烧，其炉膛是在增压的条件下运行。

整体煤气化（蒸汽—燃气）联合循环

在整体煤气化联合循环中，首先将煤气化产生的煤气净化，特别是除尘、除硫化物，再燃烧，（燃气）一般进入燃气轮机以带动发电。余热锅炉利用燃气的部分显热产生蒸汽。这些蒸汽也被用来驱动蒸汽轮机发电。

今天，残煤或残油的气化新技术为高效率的联合循环发电提供可能。整体煤气化联合循环技术分多种类型。它们既可以按气化床的种类（固定床，流化床）划分，也可以按所用的氧化剂（空气或氧气）种类和按燃气净化系统不同来划分。

第二部分摇锅摇摇炉

第一单元摇锅炉及其发展

蒸汽发生系统，通常称为锅炉，是一种将燃烧产物的热能转换为水的热能而生产热水或蒸汽的系统。燃烧在炉膛中进行，在炉膛中热能主要通过辐射传给水冷壁，它构成蒸汽发生器的蒸发段。在离开炉膛后，烟气经过过热器。蒸汽在过热器中吸收烟气的热能，使其温度上升至饱和温度以上。因为离开过热器段的烟气缸度仍然很高，现代的蒸汽发生器常常利用附加传热面以利用烟气热能，附加传热面包括再热器、省煤器和空气预热器。

锅炉按照其应用情况可分为猿种类型：工业锅炉、船用锅炉和中心电站锅炉。一般来说，工业锅炉生产饱和蒸汽或热水，其压力通常较低。船用锅炉大得多且通常生产过热蒸汽。中心电站锅炉在蒸汽参数和蒸发量上则有很大的不同，蒸汽压力可以是超临界的或亚临界的，其温度常常在缘源园益左右。

锅炉也可以按照燃烧产物的相对位置来分类。一种锅炉叫火管锅炉，燃烧产物在管内流动而管子周围是水。这种锅炉常常用于许多蒸汽机车和小型工厂，有时用于建筑物供暖。另外一种锅炉叫水管锅炉，燃烧产物在充满水的管子的外面流过，水管两端与联箱或锅炉汽包相连。在汽包中蒸汽与饱和水分离，然后，饱和蒸汽进入过热器，在其中蒸汽温度增加。所有的高压和大型锅炉均是水管锅炉，水管锅炉的小管子比火管锅炉的大锅筒在承受高压上要好得多。

锅炉可以燃烧各种燃料，这些燃料包括烟煤、褐煤、无烟煤、天然气和油，不同的燃料导致不同的锅炉设计与运行。

为了得到高的系统效率，蒸汽发生器通常由蒸发段、过热器、再热器、省煤器和空气预热器组成。在电站系统设计中，一台蒸汽发生器常常与一台汽轮机组相匹配，因此，蒸汽发生器机组容量随汽轮机组容量增大而增大。

自圆园世纪缘园年代普遍采用煤粉锅炉以来，机组容量已有相当大的增加。在一个阶段容量的迅速增加，导致某些从较早设计进行过多推断的情况，而使随后的可靠性标准降低。考虑到这一点，对电站机组采取了广泛测试的措施，这一措施提供了达到更高的电站可靠性标准的资料。

不断发展和改进的制造技术导致了进一步的设计变化。重要变化归纳如下：

（员）由于设计和制造的发展，汽包内部部件已经更改，以改进汽水分离，并允许汽包间的部件互相交换。

（圆）对过热器和再热器管子的厚度和材料已作了改变，以提高设计寿命和改进腐蚀余量。由于运行经验和公认的结构改变改进了制造方法和工艺，屏的设计作了改变。由于制造的困难，从再热器出口联箱到联箱两端蒸汽出口的联箱系统都作了改变，这也使得蒸汽能更好地分配到再热蒸汽热段。

（猿）炉膛内部作了改变以使传热特性更好，而且简化了结构程序。

（源）锅炉管子须经员园园豫的超声波检查，以按照更严格的说明书要求去做，所有承压部件都具有历史状况记载。每一部件的设计、制造和质量情况的完整记录都提供出来，以

确信承压部件能够长期运行。

（缘 一些电站的运行经验表明，送风机和引风机上使用的双速马达优点有限，因为在切换时可能跳闸，总是趋于在高速下运行，因而通常使用单速电动机。

第二单元摇锅炉布置

所有电站锅炉都为水管式，水在管内循环，当它吸收燃烧产物的热能时部分变成蒸汽。由于水自身的密度差而在锅炉内发生水循环，该锅炉称为自然循环锅炉。在这种锅炉中，水从锅炉汽包中经过几根管子（通常称作下降管）首先往下流到蒸发受热管的底部，然后，水改变流动方向，吸收炉膛的热量后又回到汽包。因为蒸发管（通常称作上升管）含有汽水混合物，上升管中的平均密度总是低于下降管中的密度。这一密度差提供了一个驱动力以克服水—汽循环的所有摩擦力。图 匮贠（粤 （略）表示一个按自然循环原理运行的水管锅炉的示意图。自然循环是一种简单而有效的技术，常常在锅炉设计中采用。

当锅炉压力越来越高时，下降管和上升管间流体的密度差将变得越来越小，在一定的锅炉压力下，与密度差成正比的驱动力，将不足以大到平衡摩擦阻力。一种选择是利用水泵驱动水流过蒸发管，使用循环泵的锅炉叫做强制循环锅炉。图 匮贠（月 （略）表示一个强制循环水管锅炉的示意图，从图中看到，循环水泵从汽包中取水，将其送到锅炉下联箱，水吸收燃烧产物的热量，从联箱中往上运动。因为得到了足够的驱动力，在强制循环锅炉中能够使用较小直径的管子，进一步说，它能给每一根管子提供一个孔板，以得到更均匀的流动和更均匀的管子温度。这些优点常常抵消循环泵的投资及其消耗的泵功。与强制循环锅炉类似的是图 匮贠（悦 （略）所示的直流锅炉。从图中可见，没有锅炉汽包，水流过蒸发段而没有任何循环。这种布置通常在蒸汽压力为超临界的锅炉中采用。

在上述猿种锅炉布置中，每一种都有自己的省煤器、蒸发段和过热器，在图中没有示出再热器和空气预热器，而它们在现代锅炉设计中都被采用。省煤器是一种用来提高给水温度的热交换器。锅炉炉膛四周的蒸发段用来产生饱和蒸汽以供给过热器，在过热器中蒸汽进一步加热，使其温度上升到饱和温度以上，然后，过热蒸汽流到汽轮机主汽门前向汽轮机提供发电用蒸汽。再热器也属于蒸汽发生器，通常位于过热器附近，再热器接收在汽轮机高压缸中部分膨胀后的蒸汽。在再热器中，蒸汽吸收燃烧产物的热量，而使温度提高。出口温度通常等于蒸汽离开过热器的温度。为了维持高的炉膛温度和锅炉效率，在锅炉设计中常常采用空气预热器，它通常布置在热烟气刚离开蒸汽发生器系统的前面位置。

燃烧产物在锅炉炉膛中产生，热烟气通过辐射和对流将热量传给蒸发段，然后，这些烟气离开炉膛进入过热器和再热器区。在这些区域，烟气进一步传热，基本的传热机理仍然是对流和辐射。接下来烟气流入省煤器，在省煤器中烟气的热量传给水，因为燃烧产物温度较低，对流传热是主要方式。在空气预热器中，烟气温度进一步降低，烟气温度越低，锅炉效率越高。但是，烟气温度将不低于烟气中水蒸汽的露点，任何水的凝结将会增加酸液的形成，它会导致空气预热器表面的腐蚀。

在燃烧烟煤或褐煤时，锅炉燃烧设备可以是煤粉燃烧器系统或旋风炉膛，通常，锅炉的燃烧、蒸汽温度和给水流量等都是完全自动控制的。

直流锅炉通常适用于大型汽轮发电机组。像自然循环锅炉一样，这种形式的锅炉可以烧烟煤，褐煤，油和天然气。在直流锅炉中，给水泵的速度和汽轮机主汽门前的压力被用

来控制蒸汽流量和蒸汽压力，蒸汽温度由燃料燃烧速率和烟气来控制。蒸汽离开再热器时的温度也很重要，它通常由烟气再循环或温度调节来控制。

许多中心电站锅炉安装有空气污染控制系统，它们通常包括高效除尘器，有时也包括脱杂韵圆系统。另外，足够的烟囱高度常用来保证电站周围环境的污染浓度达到可接收的水平。

第三单元摇锅炉燃料

在锅炉炉膛中，能量通过氧气与燃料中可燃成分的化学反应而释放。任何燃料都有一个完全燃烧所需氧气的最小值，含有这一最小氧气量的空气量称为理论空气量，它随燃料性质而变化。燃料中的氮和灰分是惰性的，因而不能参与燃烧过程。理论空气量线性与燃料的高位发热量成正比。

因为在理论空气量下燃料不可能得到完全燃烧，所以必须供给过量空气。过量空气的数量取决于许多因素，包括燃料特性、燃烧器形式和炉膛的设计。对于燃煤锅炉机组，过量空气在员园豫～圆缘豫范围内变动。燃烧所需总空气量为理论空气量与过量空气量之和，当燃料消耗被确定时，燃烧所需总空气量能够很容易地计算出来。

在锅炉设计中燃烧产物很重要，它们包括悦韵圆、悦韵、韵圆、匀圆韵以及杂韵圆等成分。杂韵圆的量相当小，在测量中通常可忽略。烟气分析器测定基于干燥基的烟气成分，读数包括悦韵圆、悦韵、韵圆和晕圆的容积百分比。总的烟气重量为总的空气和燃料量之和减去灰分量。总的空气和烟气重量决定锅炉风机的容量。

锅炉燃料消耗量与其负荷紧密相关，另外，它也取决于燃料发热量和锅炉效率。

燃料发热量是单位燃料在完全燃烧且燃烧产物冷却到初始燃料温度时所释放的热量。当燃烧中的水以蒸汽形式存在时，发热量称为低位发热量。如果燃烧产物中水完全凝结，这样得到的发热量称为高位发热量。低位发热量可以通过高位发热量减去蒸发煤中水分以及燃烧中生成的水分所需的热量而得到。

锅炉效率基于燃料的高位发热量或低位发热量，因此，在定义锅炉效率时，清楚地表明是使用高位发热量还是低位发热量非常重要。

锅炉效率也能借助于锅炉热损失来表示。为了确定这些损失，必须得到燃料和烟气的分析数据。

锅炉效率取决于锅炉设计参数，另外，它随锅炉运行条件如它的负荷而变化。在现代锅炉设计中，使用固体燃料的，锅炉效率总在愿缘豫～怨园豫范围内，使用天然气的锅炉只有愿园豫～愿缘豫的较低效率，因为在燃烧产物中有较多的水蒸汽。

煤油混合物（悦韵酝）

悦韵酝的发展有员园园多年的历史。悦韵酝由磨碎到苑缘μ皂以下的猿缘豫的煤粉，远缘豫的重油和员豫的稳燃剂组成。

•悦韵酝的制备和处理

能利用的悦韵酝必须在数周、最好是在数月内都是稳定的，流态性能必须能用泵输送和雾化，悦韵酝混合物必须有效燃烧，且污染物数量满足可接受的排放标准。一般来说，稳定性的改进是以增加粘度为代价的。为了充分燃烧，在锅炉内要求加强雾化。对结渣的

控制和长寿命雾化器的改进都将是很有潜力的发展方向。惝犸酝所取得的火焰稳定性非常好。

惝犸酝成功地应用于工业要求该混合物稳定，流态性能有利，也希望尽可能增加煤的份量，使用颗粒尺寸小而不要求为制备消耗过多的磨制能量。

这些变量之间的关系表明，好的稳定性和有利的流态性能是相冲突的，因此，稳定性改进了，但随着煤粉浓度增加，粒子更细，以及油粘度的增加，混合物粘度也增加。添加少量的水 （到 缘豫） 和约 员豫的表面活性剂能产生可接受的溶液。

目前人们对 惝犸酝稳定的机理知之甚少。化学添加剂的作用可由它们对静电的、位势的和流体中絮凝网状物的作用来解释。但是，添加物性能与 惝犸酝稳定性之间的关系，最多也只是半经验的，还希望对这一领域有更进一步的了解。

•惝犸酝的燃烧和污染排放

几个实验室中的燃烧研究都强调使煤油燃烧性能相适应的必要性，并表明当使用不同煤种时焦炭燃烧效率在较宽范围内变动。

在工业型的紊流扩散火焰中，惝犸酝的燃烧在近流场 （即靠近燃烧器） 中油火焰的特性占优势，而在远流场直至火焰末端，残余焦炭燃烬特性是主要的，单一的 惝犸酝液滴的着火比油滴更容易，也许是因为存在固体颗粒而增加了对热辐射的吸收性。如果使用无烟煤，当粒子仍然被液相包围时开始发生热分解，高分子重焦油从煤中分解，部分被油蒸馏，煤粒子膨胀，生成烧结块。当油燃烧结束，留下固态含碳残余物，并包围部分释放了挥发分的煤焦粒子。当氧到达表面时，焦炭烧结块的温度上升，引起煤挥发分的进一步释放和内部压力的增加，焦炭表面变成球形，这一新生球最终破裂而让挥发分经过气孔逃逸出去，焦炭新生球在火焰尾部燃烬，这里温度高而氧浓度低，因为油和煤挥发分优先燃烧。火焰稳定性因燃烧器中热的燃烧产物的形成而降低。但由烟气再循环引起的降低是可取的。否则，临近燃烧器的高温与可能附着墙上的沉积物焦炭 （从未燃烬燃料中） 结合起来，能够引起严重的结渣问题。雾化质量必须要高，因为焦炭新生球尺寸近似于它们原先母滴的尺寸，而其燃烬时间与初始粒径的平方成正比。

预计从 惝犸酝中 晕韵曾的排放将比单独从油中更高，主要因为 惝犸酝中燃料氮含量增加。但是，由于在 惝犸酝中使用分级燃烧，在空气中煤氮释放，而氧气被完全耗尽，结果 晕韵曾排放减少。晕韵曾的排放对所用过量空气数量变动很敏感。

硫的排放与混合物中煤和油的总的硫含量有关。在煤的制备中减少硫，是一个重要的考虑。

由于煤粒子的存在，火焰辐射能力增加，因而可以预见从火焰的辐射传热会加强。但是，这一过程没有使燃烧室中传热增加，因为灰渣在传热表面的沉积产生绝热影响。因为完全燃烧需要更多的过量空气，烟气容积必然增加，而在燃烧室中传热又减少，这就导致更大比例的烟气焓被送到锅炉的对流式过热器区段。

煤—水混合物 （悦宰酝）

煤水混合物的应用是煤利用的一个相当新的领域，最初使用时是希望将 悦宰酝作为工业锅炉中油的代替品，这种燃料也用于燃气轮机和高压气化中。

•悦宰酝的制备和处理

目前卓有成效的研究建议锅炉的混合物采用 苑园豫的煤和 猿园豫的水，对于燃气轮机，煤的百分比可以低一些。掺和的煤粒子大小不一，最大为 缘园目。通常，为控制粘度和扩散而采用的添加剂的百分比较小，要求混合物在相当长的时间 （一个月） 中是稳定的。

• 悦宰酝的雾化和扩散

在雾化和扩散领域，将进行以下研究：（葬） 决定各个变量的影响，如质量流量，压力，控制液滴分配的喷嘴的结构，以及煤粒尺寸和分布；（遭） 决定喷嘴设计，二次风流动图像和混合速率的关系，以取得最优的燃烧器设计，控制煤的烧结。

在燃烧和污染生成领域，希望进行一系列研究：（葬） 需要进行 悦宰酝的燃烧速率、沾污及污染生成特性的测量，包括最佳煤粒水平、具有低灰分的有益煤种的使用，以及添加剂的影响。关于足够的火焰稳定性、喷嘴腐蚀控制、高的碳转化，以及灰分和 晕韵曾水平的控制的研究特别重要；（遭） 完成 悦宰酝最佳燃烧器结构的设计；（糟） 需要在大型燃油机组锅炉上进行 悦宰酝的长期运行的测试，着重测试煤浆混合物稳定性、焰稳定性、沾污、灰分和喷嘴腐蚀的控制，高的碳转化，以及 晕韵曾水平的控制，这一任务必须在其广泛的商业应用前成功地完成。

第四单元摇燃烧设备

蒸汽发生系统既庞大又复杂，它由燃烧设备、炉膛和各种受热面组成。另外，蒸汽发生系统还有一些为了有效运行所需要的附属设备，这些附属设备至少包括锅炉风机 （送风机和引风机）、烟囱、除尘器和脱 杂韵圆系统。

燃烧设备的选择取决于所用燃料的类型。对于固体燃料，例如煤，猿种燃烧系统 （机械层燃炉，煤粉燃烧器，旋风炉膛） 都是适用的。在锅炉历史上，机械层燃炉首先得到发展，几乎所有的煤都能在某些形式的层燃炉上燃烧。层燃炉的其他优点包括耗能低、运行范围广。因为容量小，它们很少用于今天的中心电站。

煤粉燃烧器系统在 圆园世纪 猿园年代引入。这一系统克服了机械层燃炉的尺寸限制。现代煤粉系统已经发展到几乎能燃烧任何煤种，特别是更高等级的煤。另外，这一系统已改进到能适应负荷的变化，具有更高的燃烧效率，而运行中需要的人力更少。

图 圆鄄圆 （略） 表示典型的煤粉燃烧系统，这一系统的功能是磨煤，将煤粉送至燃烧器，在炉膛中完全燃烧。该系统必须连续运行，并能够在合理的时间内自行调整以适应负荷的要求。系统中有两个主要的设备：磨煤机和燃烧器。磨煤机接收从煤斗经给煤机送来的煤，按照细度要求生产出煤粉。同时，磨煤机接收从一次风机来的热空气，干燥煤粉并将煤粉送至燃烧器。通常每一台磨煤机与几个燃烧器相连。运行中，给煤量与负荷的要求成正比，一次风供给量与给煤量相适应。风煤比是这样决定的：它使离开磨煤机的风煤混合物有一个合适的湿度和温度。总的来说，对于烟煤，温度和湿度分别为 透缘益和 员豫～圆豫。

除了输送足够的空气外，一次风机还要保持磨煤机排出管道中的气粉混合物有高的速度，这一速度要使得管道中不会有煤的沉积和漂移。在燃烧器中气粉混合物与二次风结合，两者一起喷入炉膛，如图 圆鄄圆 （略） 所示。一次风与二次风均来自锅炉空气预热器，当煤的湿度低于最高水平，或者锅炉处于低负荷条件下，常用冷空气掺和到一次风中。

油和天然气的燃烧设备相对简单，不需要磨煤机、碎煤机或其他燃料制备装置。因为

燃油的粘度高，在储油罐中通常需要某种加热器暖油，以方便油泵输送。油泵吸取来自过滤器的油，然后经过加热器输送到燃烧器。为了维持良好的燃烧，进入燃烧器的燃油温度应在 迸缢左右。再循环管路应用于燃油系统，它用来防止停滞油聚积于管路系统而冷却到凝固点，燃油燃烧器则类似于煤粉的燃烧器。

第五单元摇锅炉炉膛

锅炉炉膛是进行燃烧和将辐射热传给水汽混合物所需要的空间。锅炉炉膛也将部分煤灰集聚在炉底，然后再将其排出。炉底形式有两种，即视其灰分是液态还是固态。当炉膛中烟气温度高于灰分熔点时，灰分成熔融状态而往下流动，最终被收集在渣池中。这种布置通常叫做液态排渣炉膛，总灰分的约 缘园豫收集在炉膛内，灰分的剩余部分将离开炉膛。当炉膛中烟温低于灰分溶点时，灰分仍呈固态，落到炉膛底部。在这种固态排渣炉膛中，灰分积聚在耐火砖砌成的灰斗中，灰斗表面由放置在耐火材料上的水管冷却。固态排渣炉能收集约 圆园豫的煤灰，因此它能为除尘器收集相当多的飞灰，而除尘器对所有锅炉来说都是需要的。

炉墙由水冷壁管来保护，它形成一个连续完整的墙，背面紧贴耐火材料。这些管子几乎构成了炉膛的整个受热面，这些表面主要是通过辐射方式来吸收燃烧产物的热量。吸收的热量取决于释放的能量和炉膛的容积，吸收的热量多意味着炉膛温度降得多，使得烟气出口温度也低。炉膛出口温度在锅炉设计中起着重要作用。当炉膛出口烟温超过灰熔点时，灰呈熔融态，于是灰渣就在锅炉的对流传热面如过热器和再热器上生成。灰渣的沉积将对传热面的运行产生有害的影响，要求进行周期性的表面清扫。另一方面，出口烟温低将导致后面传热面的温差大大减小，使传热面积增加。在设计中，离开炉膛的烟温要比燃煤的熔点稍微低一些，这一烟气温度水平通过控制能量释放量和炉膛尺寸来实现。经验表明，每单位受热面积的释放热量是一个重要参数，释热量增加，出口烟温也增加。

锅炉炉膛中的辐射传热很复杂，准确预见炉膛出口烟温很困难，许多变量能够影响炉膛辐射，它们至少包括炉膛特性和燃烧产物的成分。表面特性不仅与管道材料有关，也与管道表面条件，如渣与积灰的厚度有关。燃烧产物包括各种气体、水蒸汽和固体微粒。其精确的成分取决于燃料种类和所用的过量的空气量。某些成分，包括二氧化碳，一氧化碳，水蒸汽和固体微粒都是参与发射和吸收炉膛辐射能的介质。其他成分，如氧和氮则是非参与介质，它们对热辐射是透明的。另外，炉膛热辐射受炉膛几何形状复杂性以及运行条件的变化的影响。很明显，在目前不可能存在一个预测辐射和炉膛出口烟温的理论模型。我们现在提供一个近似方法以解决这一复杂问题。

双拱 云宰 炉膛

对于一个由 云宰 公司提供的再热机组，它为顶部支撑，位于炉拱的垂直燃烧器由位于地面的钢球磨煤机引出的管道供给燃料空气混合物。考虑到高灰分燃料的低可磨性以及整个磨煤机负荷范围内所希望的细度，选择可靠的 云宰 钢球磨，由一次风机送出，热的干空气经管式一次风加热器提供给磨煤机，二次风机通过回热式二次风加热器将空气供给拱下的前后墙。

在炉膛下部形成了 宰 形火焰。当烟气在上部炉膛中上升时，燃烧继续进行，直到与

炉膛鼻端相切的出口垂直平面。烟气穿过通廊，然后向下，分开进入回热区的两个分开的对流表面通道，通道之一含有所有的再热器受热面，通过烟气比例来控制再热蒸汽温度，前部通道装置有初级对流式过热器和上部省煤器。灰分被收集起来，并从炉膛下的灰沟、烟道下的灰斗以及静电除尘器中排出。

第六单元摇过热器与再热器

过热器是一种将热量传给饱和蒸汽以提高其温度的换热器。蒸汽过热是中心电站所采用的设计特点之一，过热增加了整体循环效率。另外，它降低了汽轮机末级叶片的湿度，因此提高了汽轮机的内效率。

一般而言，过热器可分为辐射式过热器、对流式过热器，或联合式过热器，这取决于热量是怎样从烟气传给蒸汽的。这些过热器具有不同的运行特性，在机组负荷的宽范围内如能保持出口汽温不变，这样的特性是最有希望的。当出口汽温变得过高，则会引起过热器因部分过热而失效。

对流式过热器位于炉膛出口，或能够从燃烧的高温产物吸收热能的区域。对流式过热器常常通过一束水冷管来遮蔽炉膛辐射热。当这些管子留有足够的间隔时，也能拦截渣粒而减少过热器上的结渣问题。在大型蒸汽发生器系统中，对流式过热器常常分为两部分：一级过热器和二级过热器。饱和蒸汽首先进入一级过热器而接收初始过热，一级过热器位于相对低的烟温区，在部分过热后，蒸汽进到二级过热器而完成其过热过程。使过热器分为两级的主要原因是为蒸汽再热器提供一个空间，使烟气向蒸汽有效传热。

辐射式过热器不像对流式过热器那样得到普遍使用。当需要辐射式过热器时，它通常位于炉膛壁上代替一段水冷管。另一种布置是使辐射式过热器刚好在屏式管后面，辐射式过热器是二级过热器的中间部分。

中心电站锅炉采用蒸汽再热。再热器一般是对流式，且通常位于一级与二级过热器之间的空间。当蒸汽在汽轮机中部分膨胀后，它返回锅炉再热。离开再热器的蒸汽温度通常等于过热蒸汽温度。因为再热器的设计与运行本质上与过热器一样，过热器的讨论将同样适用于再热器。

在过热器的热力设计中，首先确定蒸汽温度。一般而言，这个过程是在电站系统设计中完成的，以平衡电站初始费用和服役期运行费用。近年来，蒸汽发生器系统的最佳蒸汽温度约为 缘猿愿益。热力设计中的第二步是近似确定所要求的过热器表面积。

在过热器表面积被确定后，下一步要考虑的是选择管子的长度、管径和管子数。显然，选择是一个反复的过程，先求得一个尝试解，再查看其是否满足各种约束，再从各种可接受的解中找到最优解。最佳过热器应该具有足够的传热表面以保证设计汽温。管子参数（长度和直径）使得蒸汽压降和管子金属温度将不超过设计值。管子金属温度是一个重要参数，对管子材料的选择有很大影响。另外，最佳过热器要使管子布置得使所产生的灰和渣最少。

现代过热器有许多管子通道，管子都采用顺排布置而不用错排布置。管子通常是圆管，外径为 缘糟皂皂或 远圆援缘皂皂。没有附在管子上的扩展表面（如肋片），材料的选择取决于蒸汽温度和压力。碳钢的允许温度达 源缘园益，常常用于低温过热器。铬—钼钢、不锈钢或某些类似的耐热合金能承受高达 远缘园益的温度，因而它们被选作高温区过热器。

在过热器分为一级和二级的情况下，前述步骤同样适用。每一级过热器都单独设计，并考虑每级过热器的约束条件。第一级过热器和第二级过热器的传热速率可能不同，因为遇到的温度不同。这两级过热器可能有两种不同的管子材料。再热器通常位于一级与二级过热器之间的区域。对再热器的设计考虑也类似于对过热器的考虑。再热器的设计必须特别注意蒸汽的压降，蒸汽压降太大将减少由于蒸汽再热带来的效益。温度调节与控制对过热器与再热器都很重要，蒸汽温度调节常常要在锅炉指定的时间内进行，主要方法是增加或减少传热面积。蒸汽温度也可以通过调节热烟气温度和质量流量来实现。一般而言，这些都是通过改变过量空气或者蒸发段效果来完成的。

在锅炉运行中，有许多因素影响离开过热器和再热器的蒸汽温度，它们包括锅炉负荷、过量空气、给水温度和受热面的清洁度。运行中蒸汽温度的控制必须在不改变设备布置的情况下完成，最有效的措施包括：烟气旁路、燃烧器控制、温度调节、烟气再循环、过量空气以及分隔炉膛。

烟气旁路用来控制烟气流过过热器的流量，这种方法的主要缺点是高温区可动闸板操作运行困难，且对负荷变化的响应慢。

燃烧器控制通常是控制火焰位置和燃烧速度，燃烧器倾斜可以使火焰指向或偏离过热器，这将改变炉膛的吸热和过热器的烟气温度。随着锅炉负荷减小，燃烧器将逐一退出运行，这将改变燃烧速度，从而改变流经过热器的烟气流量。

温度调节是常使用的方法之一，温度调节器通常位于一级与二级过热器之间。有两种基本形式的温度调节器：一种是管式，一部分过热蒸汽通过换热器管，将热量传给锅炉水（可以是锅炉给水或锅炉汽包中的水），随后进入温度调节，从一级过热器分开的蒸汽将会合在一起而进入二级过热器；第二种温度调节器是将给水喷入过热蒸汽流中。给水蒸发使蒸汽温度降低。控制给水量就可以控制蒸汽的温度。必须注意要使喷水足够纯净，喷水要和过热蒸汽很好地混合，从而使得第二级过热器的入口没有水滴。

烟气再循环通常通过改变炉膛和过热器的吸收率来控制蒸汽温度，当需要蒸汽温度升高时，从省煤器出口取出的一部分烟气将循环返回炉膛底部。因此，炉膛温度降低，导致炉膛吸热减少，而炉膛出口烟温升高。烟温高，加上烟气流量增加，将增加过热器的传热速率，使蒸汽出口温度升高。

温度控制也受所使用的过量空气量的影响，过量空气越多，蒸汽出口温度将越高，其原因与烟气再循环方法的原因类似。必须指出，太多的过量空气将导致锅炉燃烧效率降低。分隔炉膛锅炉是将饱和蒸汽的生产安排在一段，而将过热蒸汽的生产安排在另一段。过热汽温是通过控制两个炉膛中的燃烧速率来调节的，这一方法不经济，很少应用于中心电站锅炉。

第七单元摇省煤器和空气预热器

中心电站锅炉通常都设置省煤器和空气预热器，省煤器产生的温度每增加 员园℉，锅炉效率就上升 员豫。空气预热器的使用不仅通过降低烟温改善了锅炉效率，而且通过提高燃烧空气的温度改进了燃烧条件。

省煤器通常位于烟气流中空气预热器的前面。当希望燃烧空气温度高时，可以将空气预热器分为两段，为了有效传热而将省煤器置于两段之间。在某些情况下，特别是在大型

高压蒸汽发生器中，还可能包括附加低温省煤器，置于烟气流中空气预热器之后。这种省煤器，常常叫做烟道冷却器，用来代替一个低压给水加热器。离开烟道冷却器的水温在苑园益 ~ 愿园益之间。

省煤器是管式换热器，从最后一级给水加热器出来的水流经管子，吸收从过热器和再热器排出的烟气的能量。最近的设计均采用钢管，其外径在 源园皂皂~ 苑缘皂皂，所有的管子从入口联箱到出口联箱都是连续的。在烟气流中有几个水平段，给水经过底部联箱进入省煤器，向上流动，而烟气从省煤器的顶部进入，往下流过传热管的外部。省煤器管子是光管或肋片管，肋片管比光管更优越，其优点包括初始费用低、安装空间小等，但必须注意肋片管子引起的通风损失和潜在的积灰污染。

省煤器在中心电站中被证明是有效的，因为与锅炉的其他传热面相比它能以更低的费用吸收一些热量。省煤器的正确尺寸由许多变量决定，如进入给水的温度和锅炉压力。给水温度在大约 圆猿园益 ~ 圆愿园益之间变动，它与给水加热器的数量和抽汽条件有关。锅炉压力通常预先设定了省煤器水温的上限。沸腾式或非沸腾式也影响省煤器面积，在沸腾式省煤器中，部分水流蒸发，离开的水温自然等于相应锅炉压力下的饱和水温，非沸腾式省煤器的出口水温通常低于饱和温度。

在锅炉系统设计中，省煤器不能与空气预热器分开，烟气能量的分配通常要优化，要考虑设备费用和燃料费用。对于给定的烟道温度，有一个离开省煤器的最佳烟温，烟温增加将使省煤器尺寸减小，使空气预热器尺寸增大。烟道温度的选择很重要，从能量利用的观点看，烟道温度应尽可能低，但必须注意传热面的腐蚀，腐蚀可以通过将烟气温度（即烟道温度） 设定在高于露点来避免。当低于露点时，烟气中的水蒸汽会在表面凝结，而与烟气中的二氧化硫结合生成酸。

对管式空气预热器，烟气通常在管内流动而空气在管外流动，这些管子可以垂直布置也可以水平布置。在两种情况下管子既可焊接，也可胀接在管板上，其中之一必须悬浮以允许管子膨胀。管径在 源园皂皂~ 苑缘皂皂之间，管材通常是钢。因为总的传热系数低，管式空气预热器相当笨重，因而占据相当大的空间。

除管式空气预热器外，对于预热燃烧用空气也采用板式空气预热器。这些加热器由平板组成，它为烟气和空气提供交替的通道，管板间的空间约 员圆郾缘皂皂。与管式空气预热器类似，这种加热器总传热系数低，因此传热面很大。为了提供高温燃烧空气，有时采用蒸汽盘管空气预热器。在这种情况下热量由蒸汽传给空气，蒸汽通常来自汽轮机抽汽。当要预热空气而烟温又较低时，蒸汽盘管加热器特别适用。

中心电站所用空气预热器可分为间壁式和再生式，间壁式就是上面所描述的空气预热器。总的来说，烟气在板或管的一边而空气在另一边，热量通过对流和热传导从烟气传给空气，它们具有静态的结构，从空气到烟气只有名义的泄漏。在再生式空气预热器中，烟气流过紧密堆砌的填充介质而使其温度升高，然后，空气经过同样的填充介质以吸收热量。填充介质或机壳应是转动的，以在连续的循环中实现这一点。再生式空气预热器比间壁式更优越，其布置紧凑，初期投资低。但是，再生式空气预热器的空气泄漏比间壁式更严重。

在再生式空气预热器中，安装有传动齿轮箱的转子缓慢地转动，使传热的填充介质分别流过烟气和空气流。传热填充介质吸收烟气流热量，再将热量传给空气流。主要的缺点

是空气到烟气的泄漏，泄漏发生在径向密封处和转子与转动齿轮间的环形空间。再生式空气预热器的另一个问题是传热填充介质中空气和烟气的输送。

再生式空气预热器所用的传热填充介质通常是高性能型的，对单位容积应具有大的传热面积，使得结构紧凑，因为安装所需空间小，其初期投资通常比管式空气预热器低。

第八单元摇阅读材料摇电站的燃煤机组

汽摇摇包

汽包是一个整体焊接的圆筒结构，由两个从钢架引出的 哉形吊环支撑。汽包在工厂整体制造，通过海洋运输到现场。它长 猿源郾园皂，内径 圆郾愿皂，连内部设备总重 猿缘园贼

远缘只圆锥形旋风分离器分成 源行布置在汽包中，每只分离器上面是一个倾斜的初级洗汽装置。二级洗汽装置则位于接近饱和汽出口的较高处。汽包由高张力钢制造，在其应力被释放后，汽包上不允许进行焊接。

围梁隔板上的开孔让汽水混合物进入旋风分离器，它被布置成一对，沿汽包的前后成两行。汽水混合物切向进入每只旋风筒体，在圆筒体内旋转，产生强烈旋涡。在其圆筒体中，汽和水产生分离，蒸汽集中在中心，从顶部排出，而水则往下沿螺旋路线回送到汽包水空间，经过炉膛水冷壁进行再循环。饱和蒸汽往上流入初级倾斜式洗汽装置，以除去离开分离器后蒸汽可能带走的残余水分。蒸汽再经过汽包顶部的二级洗汽装置，使蒸汽离开汽包前进行最后的汽水分离，然后进入过热器回路。

送风系统

送风系统包括 圆台送风机 （云阅）、圆台引风机 （陨阅）、圆台回转式空气预热器和 猿台电气除尘器。燃烧用空气通过 圆台送风机经空气预热器 （锅炉烟气加热送入的空气） 送入燃烧器调风挡板。流出烟气由引风机抽经 猿台电气除尘器，然后将烟气排入烟囱。炉膛则由送风机、引风机保持平衡以维持其压力略低于大气压。

送风机和引风机在机械上是类似的，引风机具有更高的功率，风机在电气上以常速运转，空气或烟气容积由径向入口导叶来控制。

空气预热器用来加热炉膛助燃用空气，以使燃料被更经济地利用，它们由燃烧层的锅炉主钢架支撑，位于炉膛后部，每台空气预热器位于烟气出口烟道下面的锅炉的每一侧。

空气预热器采用逆流设计，从送风机来的燃烧空气向上流过空气预热器，经过热风管进入燃烧器，而从锅炉出口烟道来的炉膛烟气向下流经空气预热器进入除尘器。这两股气流流经转子的径向相对的扇形体，彼此间由一个小的空段分开，空段中带有密封板分开这两股气流。

每台空气预热器都装有自己的吹灰和水洗联合设备，火焰监测器和灭火装置，以及为润滑转子轴承的压力油供给系统。

转子的直径为 员园郾源皂，是空气预热器的中心部分，它含有传热片。每台转子的正常加热面积为 缘员愿园园远皂圆。从中枢延伸出的径向板将转子分成 圆源段，通过分段板再交替地分为热段和中间段部分，径向板加强了转子，并带动热段和中间段部件运转。在转子的冷段，径向分隔板间焊接的格栅，起着与段分隔板同样的作用，但它能使冷段部件从空气预

热器中沿径向取出。转子的重量由下部的球形滚珠推力轴承来承担，而顶部的球形滚珠导向轴承则承担径向负荷。

转子由一台小的异步电机，通过一对蜗轮减速器和专用齿轮连至转子中枢来驱动。

除尘器

每台锅炉有 猿台电气除尘器，安置在烟气排出口，以收集锅炉烟气中的烟尘。当烟气进口温度为 员圆园益，流量为 愿猿源园园园皂猿辕澡时，除尘器的除尘效率为 怨怨援愿豫。载灰烟气被引入电气除尘器。电气除尘器中安有放电极和集电极，可变的高压直流加于电极上。

除尘器位于地面上的钢支撑结构上，有 远行集尘板，形成多个平行烟气路径，在其路径上有垂直悬吊的放电极导线。锅炉烟气经过进口隔板，再经过由收集板间的空间形成的烟气通道进入除尘器。清洁后的烟气由引风机抽出，再经烟囱排入大气。在收集板以及放电极上所收集的灰，通过间隔地敲击收集板和电极除去。取出的灰落入灰斗中，灰斗紧吊在除尘器下并由钢结构支撑。灰斗中收集的灰通过与灰斗出口联结的除灰设备运走。

高压发生与控制系统，敲击控制系统，以及加热系统都位于除尘器烟气进口侧的地面层。

吹灰器

煤燃烧所形成的部分灰粘结在锅炉管的外表面，这些灰必须除掉以维持锅炉效率。为达到这一目的，通过自动的、能伸缩的吹灰器来防止锅炉管上的灰垢，吹灰器位于锅炉的四周。吹灰器由控制系统来运行，该控制系统对 员远园个吹灰器进行周期性的、有选择的控制。如果实际情况有更多的要求，则还能进一步控制 圆园园只吹灰器。

压缩空气用作吹灰介质，它由服务于所有锅炉机组的共同母管供应。每台锅炉机组吹灰器的空气都由对隔离阀的遥控来供给。

第三部分摇汽轮机设备

第一单元摇汽轮机原理

热机是把热能转换成机械能的机器。因此，同蒸汽机和内燃机一样，蒸汽轮机也被称为热机。当蒸汽从窄小的通道喷出时速度增加，汽轮机利用的便是这种高速汽流。蒸汽速度的大小取决于蒸汽膨胀前后蒸汽的热值。热值的变化量代表膨胀过程中热能转变成动能的数量。动能或蒸汽离开喷嘴时所具有的做功能力正好等于同等热损条件下，蒸汽在汽缸内推动活塞所做的功。

现实生活中有很多例子可以说明运动物质具有能量或者说具有做功能力。如果消防水龙头喷出的水流直接喷在玻璃窗上，玻璃窗就会被冲碎。用刹车使汽车减速时，就会产生一定数量的热量。同理，汽轮机使蒸汽膨胀并加速，然后再把动能转换成机械能。汽轮机的做功原理有两个：对于消防水龙头，当喷嘴射出的高速水流冲击在玻璃窗上时，其冲击力很大。利用高速汽流冲击力的透平称之为“冲击式透平”。当消防水龙头喷嘴喷出的水流加速时，水流对喷嘴施加了反击力，其方向与水流的方向相反。利用汽流对叶片产生的反击力做功的透平称之为“反击式透平”。实际上，所有商业透平都同时利用冲击力和反击力。在同一轴上同时安装冲击叶片和反击叶片比单独使用一种叶片的效率要高。

冲击式汽轮机的喷嘴使蒸汽在其出口处形成高速汽流。动叶吸收汽流的动能并把它转换成转轴的机械功 （如图 猿援员（略） 所示）。当动叶静止不动时，汽流的入口速度等于出口速度，并对动叶产生最大的力 云， 但不对动叶做机械功。当动叶运动加速时，汽流速度相应降低，力 云减小。图 猿援圆（略） 表示力和功随叶片速度的变化规律。当动叶速度恰好为蒸汽速度的一半时蒸汽做功最大。在这种条件下，由于所有动能都被转变成功，所以蒸汽在动叶出口边速度降低至零。这种理想透平的初始力或初始力矩是最佳速度下的力矩的两倍。

实际工作中，多数冲击式汽轮机都把其动叶安装在轮缘上，喷嘴则向动叶的一侧供蒸汽 （如图 猿援猿（略） 所示）。平行安装的喷嘴叶片形成渐缩喷嘴流道。当来自喷嘴室的高压蒸汽从中流过时，膨胀加速并进入速度较慢的动叶流道，蒸汽在动叶中吸收蒸汽的动能，改变方向沿轴向流动。蒸汽离开动叶时内能和速度都较低。

在纯冲动级中，蒸汽的压力和速度都要变化。多个冲动级构成“拉托级”，即压力级，在压力级中蒸汽压力逐级降低，上级排汽进入下一低压级膨胀做功。双列速度级，又称为柯蒂斯级，蒸汽流过喷嘴后，其动能在定压下被两列动叶逐级利用。

在反动级中 （如图 猿援源（略） 所示），蒸汽先进入喷嘴流道，然后进入动叶流道再由转子全周排汽。动叶流道和喷嘴流道形状相同。蒸汽在动叶中膨胀加速，并产生反击力使动叶做功。无论相对速度增加了多少，总的效果是蒸汽流过一级时绝对速度降低。当动叶和喷嘴中的焓降相同时称之为反动度为 缘园豫的反动级。

图 猿援缘（略） 表示某一以速度级作为调节级的汽轮机，调节级后采用两个反动级。高速汽流在第一列动叶仅释放部分动能，然后进入转向导叶，改变方向后再进入第二列动叶。在第二列动叶中多数动能被利用，然后蒸汽在串联的反动级中逐级膨胀做功。

实际上，所谓的冲动级都带有 缘豫～员园豫的反动度。这就是说，蒸汽流过动叶时有一小部分压降。这些叶片为不对称结构，而且有一个较长的尾部，在出汽边略呈渐缩形。

第二单元摇汽轮机的分类

根据汽轮机的结构，蒸汽的热力过程，蒸汽的初终参数，以及汽轮机的用途，可以按如下方式对汽轮机进行分类：

员郾根据压力级的级数来分：

(员) 单级汽轮机：带一个或几个速度级，这种汽轮机一般用做小容量机组。

(圆) 多级汽轮机：具有多个冲动级和反动级，它们的功率变化范围很大。

圆郾根据汽流的流动方向来分：

(员) 轴流式汽轮机：汽流的流动方向与汽轮机的轴线平行。

(圆) 幅流式汽轮机：汽流的流动方向与汽轮机的轴线垂直，这种汽轮机带一个或几个低压轴流级。

猿郾根据汽缸的数目来分：

(员) 单缸汽轮机；

(圆) 双缸汽轮机；

(猿) 三缸汽轮机；

(源) 四缸汽轮机。

当多缸汽轮机的各转子装在同一转轴上，并用联轴器与发电机的转子连成一条直线时称之为单轴汽轮机；当多缸汽轮机各转子的轴线相互平行时称之为多轴汽轮机。

源郾根据汽轮机的调节方式来分：

(员) 节流调节式汽轮机；

(圆) 喷嘴调节式汽轮机；

(猿) 旁路调节式汽轮机。使用旁路调节的汽轮机，主蒸汽除了供给第一级外，还直接供给一个、二个甚至三个汽轮机的中间级。

(源) 滑压调节式汽轮机。这种汽轮机的压力随汽轮机转速或负荷变化。

缘郾根据汽轮机的做功原理来分：

(员) 冲动式汽轮机；

(圆) 反动式汽轮机。

远郾根据热力过程来分：

(员) 带回热加热器的凝汽式汽轮机：汽轮机的排汽进入压力低于大气压的凝汽器，此外，还从汽轮机的中间级抽出蒸汽来加热给水。早期设计的小容量汽轮机不设回热加热装置。

(圆) 调整抽汽式汽轮机：从汽轮机中间某一级或两级抽出一定压力的蒸汽供工业或采暖使用，排汽进入凝汽器。

(猿) 背压式汽轮机：排汽压力高于大气压，供工业或采暖使用。

(源) 前置式汽轮机：也属于背压式，但与背压式汽轮机不同的是，这种汽轮机的排汽还进一步用于中压和低压凝汽式汽轮机。总的来说，这种汽轮机的蒸汽初始压力和初始温度都很高，主要用于电厂的增容扩建，其效率较高。

(缘 调整抽汽式供热汽轮机：这种汽轮机可以向用户提供不同压力和温度的蒸汽。

(远 低压式汽轮机（又称为排汽压力汽轮机）：来自往复式蒸汽机、汽锤、锻压机等的排汽被用来发电。

(苑 混压式汽轮机：有两个或三个压力级，将其他来源的蒸汽引入汽轮机中间某级做功。

汽轮机一般用字母“遭”或“藻”加数字来做下标，表示有几段抽汽用于加热给水，抽汽也可用于其他用途。

苑郾根据汽轮机的进汽参数来分：

(员 低压汽轮机：初压为 园郾员~园郾圆酝孕葬

(圆 中压汽轮机：初压为 猿郾缘酝孕葬

(猿 超高压汽轮机：初压大于或等于 员猿郾缘酝孕葬，初温高于或等于 缘猿缘益；

(源 超临界汽轮机：初压高于或等于 圆圆郾员酝孕葬，初温高于或等于 缘远园益。

愿郾根据用途来分：

(员 等转速固定式汽轮机：主要用做驱动发电机的原动机。

(圆 变转速固定式汽轮机：主要用做驱动透平鼓风机、空气循环器、泵等的原动机。

(猿 变方向移动式汽轮机：主要用做蒸汽机、船、火车机车（透平机车）的原动机。

根据各自的转速，上述各种形式的汽轮机均可直接或通过变速箱与被驱动的机器连接。

第三单元摇汽缸结构

汽缸基本上是一个压力容器，其重量一般由其端部承受。因此，汽缸设计不仅能承受横截面的圆周应力，而且在纵向具有很高的刚性，以维持隔板或喷嘴与转子之间精确的间隙。汽封体、水平法兰、进汽室或排汽室都使应力分布复杂化。启动时，法兰的外侧比汽缸的其他部位加热要慢一些，从而导致热膨胀不同，进一步引起热应力和热变形。通过特殊设计可以减小热变形，如设计供启动时使用的蒸汽通道。

对于蒸汽参数高的汽轮机，其高压缸一般采用双层缸，在两层缸之间通入排汽，使每层缸的内外壁压差都相对减小，如图 猿郾远 (葬)（略）所示。由于汽缸厚度减小，加上汽缸与蒸汽接触的空间增大，所以在启动时可使汽轮机快速加热而不产生过大的热应力。这种汽缸的结构简单、便于制造，所以得到了广泛的应用。

汽缸有时采用逆流结构，以提高两层缸之间的蒸汽压力，这样就可以用加大外层缸应力的办法来减小内层缸的热应力。蒸汽首先从调节阀引入通往第一级喷嘴的环形室。采用喷嘴调节时，环形室被分成几部分，每一部分都单独由一个调节阀控制并按顺序依次打开。采用节流调节时，可采用全周进汽，虽然为了避免水平接缝承受过高的主蒸汽压力，通常将水平接缝闷死，所有实际上也是部分进汽。当主蒸汽温度在 源愿圆益~缘远远益时，因为全周进汽汽缸温度均匀一致，所以一般都采用这种方法。当主蒸汽温度超过 缘远远益时，为防止汽缸温度过高，有时采用特种钢制成的喷嘴室。对于再热式汽轮机，因为进入中压缸的蒸汽温度高而压力低，而且汽缸壁要薄一些，所以中压缸的设计比高压缸要简单一些。尽管如此，有时候仍然需要采用部分双层缸，如图 猿郾远 (遭) 所示（略）。

多数抽汽口布置在中压缸或低压缸上，在抽汽口布置有环形凹槽。有些最新设计的汽

轮机使用抽汽来拖动一台小汽轮机，借以拖动锅炉给水泵。小汽轮机也可以有自己的抽汽口。当采用中等参数蒸汽时，喷嘴一般由持环固定。而采用持环的优点是可以使汽轮机汽缸的结构简化，因为同一个持环可以适应不同喷嘴级数的设计要求。

汽缸法兰的设计需要认真仔细，其厚度要满足刚度要求，而且螺栓中心线与汽缸相切；同时法兰不能太厚，以满足快速加热的要求。法兰接合面承受蒸汽压力，只有法兰外缘才保持接触。

高压缸的螺接非常重要，尤其对于单层缸的设计来说，需要用大量的螺栓，而且要求采用盖形螺帽，螺帽要安放在垫圈上。螺栓的螺杆要采用优质抗拉钢材料，并要开设可安装碳棒加热器的中心孔。安装汽缸时，先用手将螺母拧紧，然后用低压变压器的电源将螺栓加热至一定的温度。当螺栓充分膨胀时，再将螺母拧紧至所要求的紧度。当螺栓冷却时，即产生预紧力，使法兰均匀受力，紧密结合。

高、中压缸一般采用“猫爪”支撑，后者支撑在轴承座上。转子与汽缸的同心度取决于轴承座的定位是否精确。对于现代汽轮机，其“猫爪”一般有一个水平接合面。这样，缸胀对同心度就没有影响。此外，系统还有纵销来引导汽缸的轴向膨胀。

由于凝汽器的影响，目前低压缸的支撑方式很多。各凝汽器基础台板的间隙可以有钢梁、钢筋混凝拱或预应力混凝梁等来弥补。此外，低压缸也可以设计成仅要求末端支撑的刚性结构便可。为了消除在工作转速下或低于工作转速时产生共振的可能性，要求低压缸刚度很高。对于大型汽轮机，一般将凝汽器与低压排汽缸刚性连接，以承受真空产生的压应力。凝汽器下面的支撑弹簧可以保证汽缸不承受凝汽器的重量。

汽缸在轴线方向也呈刚性连接。一般在低压排汽缸处有一个死点，汽轮机从死点向四周自由膨胀。在汽轮机前箱调速器处，这种膨胀量可达一英寸甚至更多。设置在轴承箱和基础之间的各种滑销被用来保证横向对中。

冲动式汽轮机要求用隔板把汽缸分成一个个串联级，各级压力依次递减。隔板的类型完全取决于其固定的喷嘴的类型。隔板沿水平中心线分为上下两半，采用舌榫接合。隔板的内环处呈锥形。隔板外环安装在汽缸的环形槽内和持环内，这样在汽缸产生径向膨胀时也能保证同心度。隔板体的内圆上开设有凹槽，以便安装可更换的隔板汽封。

汽缸一般采用铸钢，对于工作温度不超过 [illegible]的情况，如无再热的低压缸，有时采用铸铁。对于进入低压缸的蒸汽温度高于 [illegible]的大型机组，由于温度高和尺寸大，一般要采用铸钢。采用这种材料不仅可以在叶片损坏时使汽缸免受较大破坏，而且可以加快制造速度。

制造完毕后，汽缸的每一部分都要进行水压试验，需承受超过该部分最高工作压力的[illegible]以上的压力。低压排汽缸的设计要能够为排汽提供最大的流动面积，以减小压降。为了将大量的蒸汽均匀地转向 [illegible] 需采用导流板。对于大型汽轮机，低压缸被排汽室所围住。因此，在真空条件下，无论其尺寸大小，低压缸都可以自由膨胀。

必须对高温汽缸的外壳进行保温，以保证蒸汽绝热膨胀，同时防止汽缸因温度梯度过大而产生裂纹。外层罩壳由抛光钢、搪瓷钢或铝板制成，它不仅可以反射一定的热量，而且可以改善汽轮机的外观。

第四单元摇转子和叶轮结构

大型冲动式汽轮机转子有两种类型：

(员　套装转子：由锻造转子和锻造叶轮红套而成，并用键固定。

(圆　整锻转子：其叶轮和转子由一个锻件制成。

两种转子中，套装转子因为轮盘和主轴分别加工，加工起来相对容易一些，而且检测制造缺陷也比较容易。此外，上述零部件还可以同时加工，所以价格便宜。而整锻转子除了价格昂贵、锻造困难之外，还有一些其他的不利条件，如加工报废率高等。由于整锻转子的优点也很多，所以广泛用于现代再热式汽轮机的高压转子。这种转子有时也用于中、低压转子。这是因为很难保证套装转子的套装叶轮不松动，尤其在高压端，当叶轮温度高、主轴温度低时。需特别关注当叶轮与转子过盈量不足，仅靠定位键保持转子和叶轮的接触引起导热条件差的情况。高温高应力带来的另外一个问题是材料的蠕变，蠕变也会在长期运行时使过盈量消失。

低压转子的主要问题是离心应力，末级叶轮是汽轮机应力最高的部分（依赖于材料屈服点，超速 员缘豫时材料的安全系数为 圆。长叶片的离心力使轮缘产生很大的拉应力。拉应力随半径减小而增加，拉应力最大的部位在轮毂。所以，轮毂中心孔越大，最大应力也越大。如果中心孔很小，那么圆周应力就减小。如果没有中心孔，则整个叶轮的圆周应力理论上减为一半。某些低压转子采用焊接转子，无中心孔；而某些低压转子采用中心孔很小的整锻转子，中心孔的作用是检测锻件的质量。

反动度为 缘园豫的大型汽轮机，其转子分为 源种：

(员　空心鼓式转子：其厚度设计成与汽缸材料的厚度一样，以实现温度的均匀分布，其直径受应力的制约。

(圆　整锻鼓式转子：适用于无再热汽轮机的中压缸，其转子直径大，温度低。

(猿　套装转子：如前所述，适用于低压转子。

(源　焊接叶轮转子：适用于低压转子，它有两个优点：一是避免采用价格昂贵、加工困难的大型锻件，轮盘无中心孔；二是应力很低。但在焊接过程中和热处理过程中要倍加小心。

安装就绪的转子需经过静平衡和动平衡。静平衡是将转子重量绕轴线均匀分布，可以通过滚动置于刃形支撑（静平衡架）上的转子来检查。

动平衡是指在每个轴承处转子不平衡重量沿轴线方向产生的动量之和为零。动平衡的方法是在刚性轴承上转动转子，测量振动值，并加平衡重量，直到动不平衡消失为止。现代平衡机在很大程度上消除了过去平衡技术的试验过程和误差，使得平衡精度提高。然而，转子上总有很少量的不平衡力存在。

两端支撑在轴承上的静止不动的转子具有固有的振动频率，固有频率的大小与转子的直径相对转子的长度（两轴承之间的距离）的大小有关。如果转子转速与固有频率一致，则残余不平衡力将引起共振，使振动值突然大幅增加。这种转速称为临界转速。临界转速有时高于工作转速，有时低于工作转速。当临界转速高于工作转速时，转子称为刚性转子；当临界转速低于工作转速时，转子称为挠性转子。在启动过程中，应尽快通过临界转速。英国标准规定临界转速不能在工作转速的上下 圆园豫的范围内。临界转速的预测十分

复杂，主要取决于诸如支撑刚度等因素。

在转子的加工制造中，要特别保证锻件的稳定性，也就是说，保证在使用过程中锻件的物理性能不能改变。材料的不稳定性有 猿种：

（员） 永久性：由径向不对称膨胀系数产生，可以在铸锭阶段中通过严格的金相控制来消除。

（圆） 临时性：由转子内的应力集中产生，在加工前或加工后在特殊的炉膛中通过转动转子而消除。

（猿） 瞬态性：由不同的导热系数、发射系数产生，可以通过盘车装置来消除。

不稳定转子在运行中可能产生变形，产生不平衡力和相应的振动。

第五单元摇喷嘴和动叶

如前所述，喷嘴要么为渐缩型，要么为缩放型，其选择取决于流过喷嘴的蒸汽压力比。喷嘴分成几组，分别由各自的阀门调节控制。汽轮机高压端的喷嘴叶片一般焊接在隔板上，而低压端的喷嘴则可以和隔板铸成一体。

对于小汽轮机，缩放喷嘴直接用钻头钻制而成，而对于双列速度级或复速级，要设置一排静止导向叶片。喷嘴的蒸汽流道呈圆弧形截面。单列缩放喷嘴往往和导向叶栅配合使用，并和在一个轮盘上安装的两列动叶构成双列速度级。对于鼓式汽轮机，因为转鼓所占空间大，所以不需要隔板体。图 猿远（葬） （略） 表示双列速度级的喷嘴、动叶和导叶。

速度级可以采用单列级，蒸汽可以从动叶流一次，如图 猿远（葬） （略）；也可以经转向导叶再次流过动叶，如图 猿远（遭） （略）。在另外一种类型的速度级中，从缩放喷嘴流过的蒸汽可以从同一个叶轮上流过 猿次，静止的导流室使高速汽流沿螺旋通道返回动叶。大型汽轮机的调节级与小型汽轮机的调节级稍有不同，一般略带一点反动度。

动叶 （动叶栅） 的形式很多，其作用是将蒸汽的作用力转变成推动叶轮转动的驱动力矩，叶轮的作用是装置动叶。为了适应蒸汽压力逐级降低、比容逐级扩大的要求，叶片的高度和级的直径逐级增加。围带的作用是将叶顶封住，避免蒸汽沿径向逸出。

对于高效率汽轮机，其喷嘴和动叶流道的设计十分关键。为此，设计时在叶顶需加叶顶汽封，在隔板处加隔板汽封以防止蒸汽泄漏。有些汽轮机采用纯冲动式叶片，蒸汽在动叶中没有压降；而有些汽轮机则采用反动度为 员园豫以下的冲动式结构，蒸汽在动叶中略有压降。动叶中很小的压降对保证蒸汽充满动叶流道十分有益，也可以使轴向推力保持向某一方向。

许多依靠速度级作为调节级的汽轮机，采用部分进汽。而部分进汽将产生鼓风损失，使汽轮机效率降低。为减小这部分损失，要在对应于未装喷嘴的动叶弧段加装防护罩，防护罩可以减小非工作动叶产生的蒸汽涡动。

叶型

当叶片高度占平均直径的很大一部分时，蒸汽速度与叶片速度之比随叶片的高度变化而变化。为了克服这种变化带来的影响，需采用变截面扭叶片 （如图 猿愿（略） 所示）。图 猿怨（略） 表示蒸汽流过喷嘴，形成蒸汽涡流，再流过动叶并排出的流程分解图。理论上，蒸汽沿轴向进入喷嘴，沿圆周方向离开喷嘴。在进入动叶前，蒸汽在汽缸内形成涡流

或旋涡。为了避免产生涡流，蒸汽的线性速度与旋转半径的乘积应为常数，即 增则越增则。顶处的蒸汽压力必然大于叶根处的蒸汽压力。

叶根处蒸汽线性出口速度高于叶顶处蒸汽线性出口速度。但是动叶的线性速度随叶高的增加而增加，所以蒸汽速度从叶根到叶顶稳步增加。图 貅绘出了动叶叶根和叶顶的进出口速度三角形。叶根设计成冲动式，相当于反动度为零，无压降。

叶片的进口角由蒸汽进口相对速度的角度而定，以保证蒸汽平滑地进入动叶。在理想情况下，蒸汽的绝对速度应该是动叶速度的两倍。在动叶的出汽边，蒸汽相对速度和叶片速度的矢量差表示沿轴线方向蒸汽有绝对分速度存在。

由于叶顶处叶片速度为蒸汽绝对速度的两倍，所以蒸汽进入动叶的方向必然与其运动方向相反。因此，必须将动叶制成扭转叶片，才能满足蒸汽沿叶高均能平稳进入动叶的要求。然而，叶顶处蒸汽入口压力高于叶根，所以沿叶高方向存在压差。因此，反动式叶片在动叶的出汽边的相对速度要高一些。纯反击力作用在叶顶，纯冲击力作用在叶根。在叶顶出口，蒸汽相对速度与叶片速度的矢量差表示蒸汽以低速沿轴线方向离开动叶，如同叶根部分一样。

轴承和轴封

轴承的类型很多，有大型机组采用的高压润滑轴颈轴承，有小型机组采用的球面轴承。大轴承总是设计成上瓦有油槽，以产生油楔，油楔作用在轴颈上。

各级前后的蒸汽压力差将产生轴向推力。为了保证转子的正确位置，必须平衡这种推力。金斯布里推力轴承正是用于此目的，它将可调整的轴瓦压在推力盘上。推力盘则安装在转子上，紧贴在推力轴承的工作瓦块上，以维持转动部分和静止部件之间的间隙。

漏汽不可能完全避免，少量蒸汽从主轴穿出的汽缸处漏出。对于凝汽式汽轮机，空气也可能从轴的伸出处漏入低压凝汽部分，所以要加装轴封。在密封环式轴封中，采用炭精汽封 （也可以采用其他材料），炭封片上装有弹簧，以便将其压在被密封的表面上。经过轴封的少量漏汽可以引入低压级，或引入加热器，或排入大气。一般在轴封的末端有蒸汽凝结，疏水 （蒸汽凝结水） 排入疏水槽。

迷宫式轴封也可以防止轴端漏汽。迷宫式轴封将漏汽引入低压级或加热器，大的中间汽室与排气风机的吸气侧连接，排气风机可以使中间汽室的压力低于末级压力。这样可以从一侧吸入低压蒸汽，而从排气机一侧吸入空气。排气机把空气与蒸汽的混合物排入凝汽器，使蒸汽回收。

汽封片的端部制成锥形，一旦发生摩擦，汽封片便磨损，但不会造成轴颈过热。在轴端加工出汽封槽，以装配汽封片，并形成一个长的凹凸不平的流道，增加流动阻力。为了适应转子和汽封以不同的速率膨胀或收缩的要求，汽封片与汽封槽之间必须留有足够的轴向距离。

第六单元摇辅助设备

凝汽器

凝汽器是通过冷却水将汽轮机的排汽凝结的装置。为了使凝汽器正常运行，必须设置

各种辅助设备。循环水泵向凝汽器提供冷却用水，以便使蒸汽凝结，并使汽轮机的排汽压力和凝汽器的真空满足要求。凝结水泵将凝汽器中的凝结水抽出，而真空泵或抽气器则将凝汽器中的不凝结气体抽出。同时，还需要一个大气压力安全阀。

凝结水泵不断从热井中抽出主凝水，然后送至加热器加热，再送至锅炉给水泵。

凝汽器的作用有两个：

（员） 降低蒸汽循环的排汽温度，提高经济性；

（圆） 将排汽凝结成水，供再次循环使用。

凝汽器主要有两种类型：表面式凝汽器和混合式凝汽器。

对于表面式凝汽器，冷却水在大量的冷却水管中流动而蒸汽在冷却水管表面凝结。当蒸汽流过冷却水管时，将热焓传递给冷却水，并在冷却水管表面凝结。冷却水和凝结水分别离开凝汽器。

由于凝结蒸汽和冷却水流动的方向不同，凝汽器可进一步分为 猿类：

（员） 横向流动：蒸汽和冷却水的流动方向垂直，仅适用于表面式凝汽器；

（圆） 平行流动：蒸汽和冷却水的流动方向相同；

（猿） 反向流动：又称逆流，蒸汽和冷却水的流动方向相反。

图 猿原圆（略） 表示一个表面式凝汽器。

对于混合式凝汽器，待凝结的蒸汽与飞溅的冷却水直接接触后，蒸汽将其热焓传递给冷却水并凝结，凝结水与冷却水混合，并一起流出凝汽器。

现代凝汽器一般都采用表面式真空凝汽器。由于随着压力的降低，每磅蒸汽的体积迅速增加，这种凝汽器对真空度有些限制要求。

抽气器

抽气器的工作介质是高压气体或液体。当工质流过喷管时，压力能变成动能。高速流体吸出空气及其他不凝结气体并与其混合，混合流体被带入扩压管，扩压管再将动能转变成压力能。射汽抽气器采用蒸汽做工质，蒸汽的消耗量受空气压缩比的控制，而空气压缩比又决定了是采用单级抽气器还是采用多级抽气器。为了满足建立真空的各种要求，要设置一台启动抽气器。这是一种大功率、大流量的单级射汽抽气器，蒸汽不需要凝结。

如要正常运行，除主抽气器之外，还要设置备用抽气器。用做工作介质的蒸汽在凝结过程中，其部分热量得到回收，然后再流入相应的冷却器。

冷油器

离心泵的效率大约为 缘园豫，其余 源园豫的输入功率转变成热量，并被润滑油吸收。油还从轴与轴承的润滑油中吸取大量的热量。为了将这部分热量带走，需采用冷油器使油温满足要求。

冷油器的设计要满足进出口压差小而换热面积最大的要求，它们一般采用立式结构，以便于换热管束的更换，冷却水自下而上流动。冷却水中的杂质落入冷油器底部的排污室，将顶部端盖打开可清洗管束。油从顶部进入，然后流过由挡板形成的 在形流道。

为了提高导热系数，管束采用 猿园园园黄铜管材，黄铜管胀接或纤焊在黄铜管板上。一端的管板固定，另一端的管板在膨胀时能在一个环形密封圈中滑动。

油和冷却水采用逆向流动。这种结构热效率高，而且可以减少在冷油器中形成的油泥。当高温油进入冷油器时不会对冷油管产生热冲击。

一般采用两台容量为 员园园豫或 猿台容量为 缘园豫的冷油器，以保证在正常运行时不需要停机便可将其中一台切除并清洗。冷油器采用并联布置，并需对其油、水回路采用专门的阀门，以实现联锁控制。

第七单元摇调速器及调节系统

汽轮机调节系统的作用是自动调节汽轮机的转速或输出功率，并使上述值达到要求。为此，需要一个能够在所要求的范围内感受转速变化的调速器，该调节系统可输出相应的、便于精确控制的位移量。常用的调节系统有 猿种：液压式调节系统、电调节系统和机械式调节系统。

在液压式调节系统中，由主轴驱动的离心泵所输出的高压油作用在油动机活塞的一端，油动机活塞的另一端受弹簧力的作用。油压正比于转速的平方，所以活塞的位置可以表示转速。

电调节系统是现代更新产品，由提升力大的液压伺服机构和电气回路组成。汽轮机主轴带动的交流电机产生一个正比于转速的电信号。频率感受回路产生一个正比于此频率的电压信号，该电压信号经过电磁放大器放大后，送入一个力矩马达，后者产生一个与电压信号成正比的位移信号。这种方法广泛用于大型汽轮机调节。

绝大多数汽轮机由机械离心式调速器控制，离心式调速器通过齿轮装置由主轴驱动。作用在两个飞锤（回转质量）上的离心力由弹簧的弹力平衡，所以在不同的转速下飞锤的作用半径不同。

实际上，可用两个拉伸弹簧将飞锤直接连接，也可以在飞锤外侧使用压缩弹簧。这种结构的优点是不使用连杆就可以平衡离心力和控制力，所以摩擦很小。然而，因为要考虑弹簧本身的离心力的影响，这种结构设计起来比较困难。

图 猿鄄远员（略）表示弹簧不受离心力影响的结构，运行中可以用调整螺钉的方法来调整控制力。杠杆将飞锤半径的变化传递给滑块，而滑块的轴向移动则带动操纵机构动作。

为了能快速感受离心力的变化，要求调速器的径向惯性力和摩擦力均很小。因此，好的调速器应设计成飞锤质量小，转速变化大以补偿输出力的损失。错油门用来减小调速器带动控制机构的力。

错油门或油动机（伺服机构）均由压力油控制，广泛用于汽轮机的控制机构。常用的错油门或油动机有两种类型：单侧进油、弹簧返回结构和双侧进油结构。

图 猿鄄远圆（葬）（略）表示具有一次放大机构的双侧进油液压机构。当调速器将 粤点升高时，油动机活塞在上下油腔油压的作用下处于平衡位置，悦点保持静止，而 月点随 粤点升高，带动错油门滑阀升高，两侧压力平衡。此时，油动机活塞下腔泄油，油动机活塞在油压的作用下向下移动。此时，粤点不再移动，而错油门滑阀回到中心位置。由于错油门滑阀总是从中间位置开始移动，并总是要回到中间位置，所以认为 月点是杠杆的支点。压力油总是通往错油门滑阀上下两阀瓣之间，所以不必设密封。对于控制点 粤处在 月点和 悦点之间的结构，油动机的油路应该是交叉式的。

图 猿鄄远圆（遭）（略）表示靠油压打开、弹簧力关闭的单侧进油油动机结构。弹簧可以

储存能量，一旦压力油失压，阀门就会在弹簧的作用下自动关闭。错油门滑阀只有一个阀瓣起阀的作用，另外一个阀瓣起平衡压力的作用。在这种结构中，错油门油口总是稍微打开一些，以便在有泄漏的情况下保持油动机活塞下的压力不变。

由于错油门滑阀可以回到中间位置，所以不需要设置复位杠杆。为了减少错油门滑阀与其套筒之间的摩擦，可采用旋转套筒，也可在高压油中人为制造微小扰动，以产生“高频振动”。

将所有错油门与同一操纵（控制）杆相连接，并使错油门依次动作，便可对两个或更多的调节阀实现顺序控制。这样，当第一个油动机打开其阀门时，第二个油动机仍处于平衡位置，直到其错油门滑阀离开中间位置、压力油进入油动机为止。对于喷嘴调节的汽轮机，其调节阀有时由凸轮带动，而凸轮则由一个油动机带动。

具有一次放大机构的液压系统通过各种连杆、杠杆机构控制其错油门滑阀。有时错油门导阀与油动机之间不是通过杠杆连接的，而油动机本身就是一个错油门，这样就可以避免采用机械连接，只需要一根传递油压的管路。

对于电站用汽轮机，要求其输出功率与转子转速成线性关系，而且转速随功率的增加稍有降低。这一特性对于并列运行的发电机组十分有益，可确保各机组的功率分配。转速一负荷曲线的斜率称之为速度变动率。速度变动率定义为空负荷对应的转速与满负荷对应的转速之差对额定转速之比。速度变动率一般为 源豫 ~ 远豫。需要指出的是，只有单机运行的机组才存在这种转速差，而并网运行的机组总是要根据速度变动率来调节各机组的负荷，并维持电网频率稳定。

第八单元摇阅赠宰电站的汽轮机

阅赠宰电站位于 韵葬藻河南岸。电站的前 猿台机组为 阅赠宰电站的一期工程，分别于 员怨苑猿年和 员怨苑源年投入运行；后 猿台机组称为 阅赠宰电站的二期工程，于 员怨愿猿年投入运行。阅赠宰电站的汽轮发电机组采用单轴 远园园酝宰 机组，有两个侧向布置的凝汽器，工作转速为猿园园园则/皂蚤灶。每台机组都有一个高压缸（三层缸结构），一个双流程中压缸（双层缸结构）和三个双流程低压缸（单层缸结构）。每个转子都刚性连接起来，由两个轴承支撑，轴承安装在各自轴承箱内，推力轴承装在中压转子的高压端。汽轮机设计成轴承可以在轴承座上自由滑动，以适应汽缸和转子的热膨胀要求。为了时刻保证热膨胀时各部件纵向和横向的对中，采用了一套包括导轨、滑销和死点在内的滑销系统。

本机组采用高压过热蒸汽。为了提高效率，蒸汽流过高压缸后再热，然后进入中压缸。锅炉来的蒸汽经过两个蒸汽室进入高压缸，蒸汽室内安装有进汽管和调节阀。两个高压蒸汽室分别安装在汽轮机的两侧，之间设有连通管，以吸收热膨胀并减小蒸汽的应力。高压缸的排汽进入锅炉再热器再热，然后经过两个安装有再热调节阀的蒸汽室进入中压缸。中压蒸汽室也安装在汽轮机的两侧，其间也设有连通管以吸收热膨胀，减小蒸汽室的应力。在再热器和再热管之间设有安全溢流阀，其作用是在高压调节阀和中压调节阀关闭时，将再热器中的蒸汽排向大气。这种设计在甩满负荷时可以消除高压叶栅过热的危险。源只连通管将中压缸排汽引入 猿个低压缸，其中两根导汽管与 员号低压缸连接，另外两根分别接 圆号、猿号低压缸。低压缸均采用双流程，其排汽进入凝汽器。

本机组有两个表面式凝汽器，在真空条件下，凝汽器可使机组获得最高热效率。它将

低压缸的排汽凝结，并提供了将加热器或与凝结水系统相关的其他设备中的空气或蒸汽抽出的设备。

为了维持凝汽器的真空，机组设有缘台容量为圆猿豫的抽气器。此外，还设置了一台快速启动泵。

随着锅炉的发展，并从缘园园酝宰机组的设计和运行中吸取了经验，阅蕴圆电站一期工程的汽轮机结构简单，但强度更高。转子采用整锻结构，其刚性得到提高，稳定性得到改善。

随着制造工艺的发展和提高，二期工程汽轮机的设计有了进一步改善。其运行性能提高，主要体现在以下几个方面：

⑴ 中压缸、低压缸隔板采用改进工艺和标准，而远台机组的转子仍然可互换。

⑵ 重新设计汽轮机的轴封系统，其性能在很多方面得到了改善，以适应自动控制的要求，并可减少运行和维修人员的工作强度。

⑶ 高压缸和中压缸采用法兰加热系统，以克服冷态启动时对设备的各种限制，提高设备的灵活性，避免产生过大的胀差。为了改善热疲劳的特性，对高压缸转子和汽缸的几何形状都做了改进。

⑷ 对高压缸第一级和低压缸末级叶片都进行了改进设计。

⑸ 对润滑油系统进行了改进，以减小轴承的泄漏，同时为了提高冷却效果，对冷油器也进行了改进。

⑹ 对锅炉给水泵的调节和保护系统进行了改进。

⑺ 河水中的含沙量高，使凝汽器冷却管束磨损严重。为了避免在服役期更换管束，将管材由铝铜更换为钛管。

⑻ 将低压加热器由混合式改变成表面式，采用管式结构。为此，给水加热系统中设置了一台凝结水泵，以克服增加的系统阻力、提高给水压力，并且采用最先进的设计来减小气蚀；凝结水泵由卧式改为立式。

⑼ 抽气器由原来的源台增加至缘台，容量有所增加，可满足真空抽气系统连续运行的要求。增设了一台快速启动泵。

此外，与老机组相比，新机组还在许多方面进行了改进，以适应新的发展需要。

汽轮机的设计数据：

类型：单轴缘缸、再热、凝汽式

转速：猿园园园则辕皂蚤灶

最大连续流量下的汽耗率：缘援愿园园噪早辕噪宰澡

蒸汽压力：员猿援猿猿酝孕葬

热耗率：愿苑远远噪允辕噪宰澡

功率：远园园酝宰（发电机端）

汽轮机进汽参数：

高压缸进汽参数：员猿援猿猿酝孕葬，缘猿缘益

中压缸进汽参数：源援园员酝孕葬，缘猿缘益

低压缸进汽参数：园援苑远缘酝孕葬，猿猿园益

真空度：缘援园噪孕葬

盘车速度：圆则辕皂蚤灶

第四部分摇发电机和电气设备

第一单元摇发电机

概述

发电机是将机械能转化成电能的电力设备，而电能可以很容易地传输给远距离的用户。直流电机之所以首先被应用于大发电系统，主要是由于直流电流与交流电流相比较能更好地被人们理解。然而，由于直流电机存在换向器的问题，所以仅仅用于低电压下的发电。

随着电网的发展，为了将大量的电力传输到越来越远的地方，电压也就要越来越高。电力变压器能轻易地将电机正常发出来的低电压转变为所需要的高电压，以利于能源的有效传输。当然，变压器只能在交流状态下工作。交流发电机通常称为交流电机，比起直流电机来机械结构更简单，使用效率更高，所需维修更少，所以今天大型电厂的输出都为交流电流。尽管直流输电能很有效地将绝对多的能源进行长距离传输，然而，电能还是先以交流电形式发出，再被转换到所要求的电压等级，经整流，以直流方式传送，最后在用户端再被转换成交流形式使用。

机械能

用来驱动发电机的机械能必须来源于具有高可靠性和大容量的能源，以便能经济可行地发电，并将电能传输给用户。在雨季才有一定的流速的小水源或者距离电力用户非常遥远的水源是不适宜当做机械能的源泉的。机械能源不能移动，如水轮机和风机，因此它传输能量的费用必须在计算费用时加以考虑。而汽轮机电厂却可以建造在离煤层、木材厂或一个可靠的冷却水源较近的地方，从而节约了这笔费用。

有些机械能可以很容易地从用户附近的资源中得到。燃气轮机和往复式内燃机或柴油机都属于这一类。除了用于紧急状态下的备用发电机外，这儿甚至是建设大电厂和传输电力更经济的地方。一般来说大电厂要比小电厂运行起来更有效率，如果燃料供应方便，人们会期望在用电中心建立一个大电厂，然后将发出的电向外传送。

每一种机械驱动形式都有它自己的特点，并且对发电机的结构具有相当大的影响。每种电机输出的适当速度，可能产生的速度波动，以及可能产生的超速等都有着显著的不同。

通常发电机机轴是水平放置的且与传动装置直接相连。有时在高速汽轮机和低速发电机间连接一个速度变化调节盒，这些都是为了汽轮机能以最有效的速度运转，而这个速度对发电机而言又太高了。小型水轮发电机常常将轴水平置于支架上，大型水轮发电机则将轴直接连接且垂直置于支架上。发电机可能含有一些特殊的轴承，以承担水流通过水轮机所施加的侧向压力。

第二单元摇发电机的基本原理和结构

现代交流电机有两种迥异的形式。尽管它们的工作原理相同，即磁极运动使磁力线切割稳定线圈产生电流，但两者的线圈结构完全不同。这是由于每一种形式都要设计成与它的原动机相配合，即要适合能将自然界中主要的两种能源——落水和来自矿物燃料或核燃料的热产生的蒸汽——抽取上来的机械装置。

为了配合涡轮发电机的输出，水轮发电机必须是多极性、大直径、短轴长的。要限制涡轮发电机的长度（也就是用来支撑大型转子的两个轴承之间的距离），这主要是基于机械方面的考虑。当发电机转速在 猿园园园则早蚤灶或 猿远园园则早蚤灶（缘园匀扎或 远园匀扎）时，转子必须具有相当好的平衡性，且表面要光滑。当电机用低速水流提供动力时，这种谨慎的要求可以有所放松，目的是为了使大转子制造成本更低些。

两种形式的转子外形上的根本区别主要是基于上述的考虑，非根本区别就得归于设计师的经验和技术了。

有必要建立感应 藻皂枣 的正弦波。瞬态值 藻的影响因素是磁通密度 遭 导体长度 造以及运动速度 增(这个小写字母表示瞬态值)，这样有：

藻越遭造增

通过定义一个磁极距而非每台主发电机的电极可以得到对一个“极”的组成的明确定义。一个磁极距是指两个电流最大值点间的距离（责，一个圆周（圆desc则 被 责分成几部分就是几个极。这种定义比较符合线性电动机技术，因为其极数既不必均分也不必为整数。表 源援猿中转子的转速表示为 圆澡早蚤灶(则早蚤灶，这里 灶为极数。转子的转速通常被转换成线性速度，因为圆周 圆仔则包含了长度为 责的 灶个磁极距，因此，圆仔则越灶责 于是，转速 圆澡早蚤灶(则早蚤灶就转换成一个线性速度 增泽，这样

增泽越(圆澡早蚤灶(圆仔则 越(圆澡早蚤灶(灶责 越圆枣责

这只是行波每行驶一圈走过两个磁极（等于二个波长 λ）的“一般意义”上的表达式（这相当于众所周知的对所有波运动适用的公式 增越枣λ）。

三相电机的定子如图 源援缘(葬（略）所示。很明显，它没有六个极。如果它有六个显而易见的“凸出物”，这些凸出物可以被看做含有三相分布线圈的开槽定子里的 远个“齿”，但这种情况只限于三相分布状态。只有在图 源援缘中才能弄清楚每相两个线圈是如何连接的，除此之外，没有人能说出定子有 圆个极还是 源个极。图 源援缘值得仔细研究，首先体会图中的（遭 和（糟 之间的差别，然后弄明白首次面临这类问题的学生，在他们的思想上可能存在的困难。如（遭 所示的连接方式，两个红色相线圈产生的径向通过电机的磁通是彼此互助的，两个黄色相线圈和两个蓝色相线圈也是如此。所以，总的来说，系统里无论流过什么暂态电流，其合成磁通都将是 猿个径向磁通的矢量和。因此，这 猿个径向磁通本身是径向的，而电机相当于二级系统，但是如果相反的部分往转子里发反向磁通，那么合成磁通只有可能如图 源援缘(糟 所示，此时电机有 源个极。

目前，在这个粗浅的例子里显然缺少线圈分布的内容，因为只有 远个槽的两极三相电机每极每相有一个槽。按时下流行的写法，是一个槽，每极每相。四极型每极每相只有半个槽，这使得行波场非常“凹凸不平”，但实际上这种情况在槽数很多时能尽可能地避免。读者将会意识到，如果举一个更现实的例子，两极或四极电机，也就是说，每个都有

圆原个槽被选中，这些图就可能显得太模糊而不能标明“极计数”点。

(员 定子

由于定子铁芯抵制磁通密度的变化，使得快速变化的磁通在定子铁芯中引起磁滞损耗。变化的磁通还引起“涡流”电流，流进铁芯片中。损耗也是由该电流引起的。定子采用特殊的硅钢材料和许多薄的钢片做成，以使磁滞损耗最小和电流损耗最小。对于小电机而言，钢片制成整圆的；对于大电机而言，钢片被冲成半圆形，然后再拼成完整的圆形定子。为了嵌放定子绕组，在定子铁芯内冲出许多开关相同的槽。

绕组的槽间必须可靠绝缘，以保证绕组和接地定子间的电气绝缘及绕组免遭定子铁芯的擦伤。应该详细说明绕组适当的间距、线距和电机的额定值所要求的绝缘等级。

对于较小的电机而言，绕组由很多松散的圆形线圈绕制而成，再一个挨一个地嵌进定子槽里，用槽模固定，防止绕组松动。为了使电机的导体面积和定子铁芯尽可能大，导线可采用方形或长方形以形成坚硬的线圈，这些线圈的导线之间是相互绝缘的且环绕成同心式。线圈嵌进有平行壁的定子槽内，平行壁的作用是为了在线圈和铁芯间提供一个适当位置。槽模能固定线圈。线圈末端被适当地连接在一起，以满足极的结构要求，电压的要求，以及电机所规定的其他参数的要求。

(圆 转子

两种基本形式的转子在同步电机里都可见到。高速电机（二极和四极）都是由圆形转子制成，转子内被冲成槽，供磁场绕组使用，这种电机称为均匀气隙电机。

慢速电机具有许多从转子轴伸出的磁场极，这些幅射状磁极被磁场绕组呈螺旋状包围着，因而气隙不均匀。这种电机称为凸极电机。

电极转子的每一个极都有一个通过直流电流的绕组，通常电压为 远猿， 员圆缘， 圆缘园或 猿缘园灾，该电流形成环流，以激励场并产生磁场。用于场激励所需的能量通常只占输出部分很少的百分数，约为电机额定输出的 员豫 ~ 圆豫。直流励磁可从由原动机驱动的直流电机处获得，也可从自其他能源处获取动能的分散安置的励磁电机处获得。励磁机的输出电压水平必须是可调节的，并且有足够的容量能使电机在额定输出时产生额定电压。

(猿 励磁机

多年来，场激励都是由 猿个主要的励磁机设计——有电刷旋转、无电刷旋转和静止式提供的。

有电刷旋转式。旋转的复合线绕直流式设计是惟一使用了很多年的励磁机形式。由加速带驱动和滑轮调节的励磁机有时价格上很便宜，较高速度的励磁机可以与较低速度的交流发电机配合使用。直流电流被送到交流发电机转子的滑环里，滑环由两个铜合金圆环组成且与交流电机的轴绝缘。滑环联系着交流电磁场，并借电刷装置引至出线。

尽管旋转式电刷励磁机一直还在使用，但是为了保证滑环、换向器和电刷上能够通过大电流，必须对其不间断地进行维修。随着可靠性要求的不断提高以及半导体器件价格的不断下调，再加上上述这些问题，使得无刷励磁机成为今日主流。

无电刷旋转式。无刷励磁机作为主要的励磁机形式，只是套在同样的转子支架上的交流电机的一种特殊形式。它的特殊性在于它的场是稳定场，且必须由直流电流激励，并且它的交流输出来自转子转动部分。无电刷励磁机的输出被整流后，经电缆与主发电机场连接，并固定在电机主轴上。关于电刷、整流子、滑环和维护的内容在此省略。

静止式。当半导体的可靠性和性能提高而价格却下降的时候，一种特殊的称之为静止式励磁机的立式可控整流器日益受到普遍的欢迎。它造价低、损耗少、维修少、输出方式更灵活，所有这些使之成为已损坏的旋转式励磁机的良好替代品。

一台静止式励磁机由输入变压器，可控硅（杂悦砸），整流控制器及电压调节控制器组成。完全组装后具有将交流电压整流成交流电机所要求的适于控制的直流励磁电压的功能。静止式励磁机可与任何便利的交流源相连，例如变电站能源（假定交流电机不运行时变电站能源也可获得），但它常常与交流电机的输出铅板连在一起。为防止系统故障，在交流电机和励磁机之间安装了熔断器和分离开关。

一旦交流电机的励磁绕组中有电流通过，就会留有少量的剩磁。当交流电机再次以额定转速运行时，无需励磁就可在交流电机的输出端测得圆豫～员园豫的额定交流电压值。该电压是作用于转子里的定子绕组的剩磁通量产生的。当励磁机与交流电机的输出相连时，它就把这个剩余的交流电压转换成直流电压，用在交流电机的励磁绕组上。这种作用会促进励磁，且能够在很短的时间内加强直至达到额定输出电压。显然，必须进行正确的连接。如果励磁机输出与剩余电压的输出相反，则上述作用不会得到加强。

励磁机的输出通过滑环与交流电机的磁场相连，因此需要对电刷和滑环保养，但这种需求没有旋转式励磁机里电刷和换向器所需求的那么多。有时候剩磁会损失掉或者希望反转剩磁方向，这时候磁场会立即被连接在一起的电池激发到交流磁场中，以便在正确的方向上建立剩磁。在有些静止式励磁机上，当装置每次开始启动的时候，这种场激励是自动完成的。

静止式励磁机也应用在交流电机必须有特别响应特性的地方，例如非正常启动大型电动机时。一个感应电动机的启动电流是它满负荷电流的远倍。启动一个大型电动机（大于发电机负荷的员园豫）会引起发电机输出电压降低，有可能引起电动机启动装置脱落。有几种类型的降压启动器可用于降低电动机的启动电流，但其价格昂贵且据说时间的延迟并不理想。静止式励磁机可配以特殊的“场推动”装置以加快励磁，满足大型感应电动机的启动需要。运用场推动设备比起标准设备来，只需较小的发电机，并且价格便宜。

（源）电动机原发电机装置

由发动机驱动的分散安置的直流发电机或交流电动机有时可以当做励磁机使用，称之为电动机原发电机装置。这套装置偶尔可以替代损坏的直流励磁机，有时也用一些带有电压可调节励磁机的电动机原发电机装置的特殊形式。

第三单元摇发电机保护

所有的电气电路都有保护继电器，它们用来保护设备和维护运行的可靠性。有许多保护装置可供选择来完成该工作。幸好，全国电气制造协商会（晕耘酝粤）（指全美，译者注）已制定并出版了一系列的关于保护继电器的功能数字，标准及说明。所有制造商都遵守晕耘酝粤的标准。

许多满足晕耘酝粤标准的继电器可用于标准速度和敏感性模型上，也可用于昂贵的高速模型或具有特别敏感性的模型上。后者是指系统里较大、较重要的或较关键的电机。电力机械设备和静止设备使用保护继电器最多。两者价格上差不多，但静止设备日益受到欢迎，这主要是因为它们的灵活性和较少的维修保养。

保护继电器

保护继电器系统在起保护作用的同时，各个继电器之间也要保持一致性和相互支持性。一致性是指最靠近故障点的继电器首先动作，排除故障部分，但不干扰系统其余部分的正常工作。支持性是指假如最靠近故障点的继电器不能动作或不能排除故障，那么离故障点较近的其他继电器会动作以支持不能动作的那些继电器。当起支持作用的继电器工作时，通常意味着更多的系统将退出服务。

保护继电器只有在另外的事件发生时才跳开一个或多个电路断路器，发出报警或跳闸。在 远画囤灾和低额定值的电路断路器上，通常都装有过流保护器，它能直接将断路器断开。其他的继电器都分散安置，能启动分路器切断断路器。这套装置还需要电池，或一个电容器，或交流电流所需的可靠能源。在额定电压为 圆源画囤灾及以上的断路器上分散地安装着继电器，这些继电器从电流互感器或电压互感器处获得信号，并用外部能源实现跳闸和警报功能。

以下是一些典型的交流电机保护装置。尽管并不完整，但也有一定的普遍性。

过流保护装置

晕杂陨粤装置 缘园表示暂态过电流保护，它既可以通过自行断开 远画囤灾断路器来完成，也可以由多个分立安装的继电器来完成，这些继电器的信号来自于安装在电机输出端某一点上的电流互感器。装置 缘园被设置成在某一点瞬间跳闸，在这一点上装有所有输电线上的其他瞬时继电器。有时装在 远画囤灾断路器里的装置 缘园会有一个小的延时，以便能将断路器电压进一步降到线电压之下而首先跳闸。这种情况称为“可选择性跳闸”。

晕杂陨粤装置 缘员是一个延时过流继电器。它可以是 远画囤灾断路器过流限制的一部分，还可以是一个独立的继电器，还可以与装置 缘园合成为一个继电器。装置 缘员常产生大量不同的时间——过电流曲线。所有的装置 缘员都设计成易于调整且能保护特别的负荷或系统运行方式。用控制电压或限制电压方式可以将 晕杂陨粤装置 缘员作为独立的继电器使用。前者是指只有当电路上电压下降至某一点之下时，过流接触器才动作，后者是指继电器的过流感应单元将在与电压成正比的某点跳闸。当电压达到满幅值时，继电器将正常跳闸，而电压为零时，继电器将在正常电流值的 圆缘豫处跳闸。这些装置都为 晕杂陨粤缘员灾。这种情况通常也包括暂态因素，但不受电压的影响。

值得注意的是，继电器的一致性和支持性。如果距离发电机一段距离处发生短路，电机的电流将升高，但电机的电压由于反馈线上电压的下降而将保持高电位。由于电压作用使得继电器要到远方继电器动作将故障消除后才跳闸。当此故障靠近电机时，可能发生在电站母线上，继电器上电压将下降，并且 缘员灾继电器会跳开电机断路器。

欠压和过压继电器

一些交流电机里包含有 晕杂陨粤装置 圆苑（欠压） 和装置 缘怨（过压） 继电器。欠压可能是由交流电机或电压调节器故障或者严重过载而引起的。有时装置 圆苑还能保证断路器在发电机被迫停机时断开。如果调节器里电压感知电路中的电压降到零 （可能是由保险丝熔断引起），调节器就动作，好像电机电压过低而试图抬起它至电机的最高电压。这样明

显会损坏负荷且可能造成电机和它的励磁设备的损坏。为了避免这种情况发生，有必要使用电压调节器。一种过压继电器 晕耘酝粤装置 缘怨则能在很多环境中完成这种功能。

差动电流继电器

差动继电器即 晕耘酝粤装置 愿苑 它在电机内部发生故障时起作用。它反应被保护对象的线路两侧电流大小和相位的差异。如果电流大小不一，继电器会立即发挥某些功能。交流电机内部泄漏可能是指电机内的某些线圈绕组已经损坏，而现在的问题是如何抑制这种损坏。如果采用继电器 愿苑 它能抑制电机绕组的损坏并能防止对定子叠片更严重的损伤。愿苑继电器不仅能跳开断路器的输出，还能灭磁。为此，愿苑继电器与脱扣 晕耘酝粤装置 愿远（一种锁定继电器） 连在一起使用。

装置 愿远继电器是多触头的电跳闸手动复位的开关，可跳开电机断路器且能灭磁。必须采用手动复位是因为通过装置 愿苑体现出来的电机损伤必须在电机重新启动前仔细查看。

功率方向继电器

当发电机并联连接时，原动机就有可能因为某种原因而损失能量。此时，与原动机相连的发电机就以电动机方式运行，驱动原动机。这种情况不仅损失电能，还可能造成原动机损伤。晕耘酝粤装置猿圆功率方向继电器接在发电机的输出电路里，检测流进电动机的功率，跳开发电机的断路器。

晕耘酝粤装置愿员过频和欠频继电器可间接检测原动机的速度大小并采取相应的措施。晕耘酝粤装置源园继电器能保护电机磁场不开路，不过激磁或欠激磁，等等。其他很多类型的继电器也可用，但其中大多数都只有单一用途，只能在某种特殊的应用中使用。

第四单元摇阅读材料电厂的发电机

以 阅读材料火力发电厂为例，详细介绍火力发电厂电气设备的设计及运行。

设计数据：

发电机输出：摇摇摇摇摇摇摇摇摇摇远园园酝宰
兆伏安：　苑远园酝灾粤 葬贼园援怨缘孕云
电压：　圆圆噪灾
电流：　员怨圆苑园粤
效率：　怨愿援怨豫
氢压：　源援员噪早 辕糟皂
氢压合系统：　苑园豫宅
转子的伏安：　缘园园灾 葬贼源缘园园粤
氢冷却气流速：　猿园苑园皂 辕泽
氢气冷却水流速：　苑园园园造辕泽
主励磁机：　猿愿园园噪粤 和 缘远园园粤
辅助励磁机：　怨园噪粤 和 圆怨园粤
定子冷却剂压力：　猿援愿噪早 辕糟皂

圆苑园

定子冷却剂泵流量：　　　　　　　　猿远藻葬

发电机的运行

这种发电机有水冷和氢冷两种类型，与直驱式主励磁机和辅助励磁机连在一起。

发电机定子由两部分构成，内部框架用来支撑铁芯和绕组，外部套管里是氢气冷却剂。定子绕组有两层，用嵌在定子铁芯里的空心铜导体组成菱形线圈。

定子绕组通过除盐水沿闭路系统流动来进行内部冷却，冷却液从励磁机末端的载流端到发电机的汽轮机端（非载流端）循环地冷却绕组导体。用两个容量为 员园园豫的交流冷却泵中的一个来循环冷却液。当交流供电出现故障时，用一台直流冷却泵来循环冷却液。定子冷却液流过绕组后，带出的热由接入到系统里的散热器吸收。位于系统内的净化器可保持冷却液的纯净。

除了流过绕组导体的定子冷却液外，定子铁芯及发电机转子也要由氢气来冷却，氢气通过安装在转子两端的离心式风扇在定子套管里循环。

推力盘式的氢气密封方式能阻止转子露出定子套管处的气体泄露。有两个容量为员园园豫的交流密封油泵，用其中之一将密封油灌入密封处，所用压力超过将氢气压入定子套管里的压力。若两个油泵都出现故障，可使用上油系统。若两者都损坏了，则可用直流油泵。

在励磁机尾部装有锻造的铁滑环，它附在一块合金锻件上，加工成转子。转子绕组由坚硬的拉长银丝组成，银丝可支撑铜条直接通过氢冷却。电刷装置可通过滑环将电流送入或传出转子绕组。电刷和滑环间摩擦产生的热量通过一个强制性通风系统消散掉。

发电机转子的两头都支撑在安装在底座上的球形轴颈轴承上，轴承安放在轴承架中，由汽轮机润滑油系统润滑。汽轮机端的轴座内还安装有汽轮机低压缸 猿（蕴孕猿） 的轴承。励磁机端的轴承座和其他设备（包括润滑油管道）的绝缘作用，避免了电流穿过轴承和油膜。

发电机转子的励磁场由直流式主辅励磁机产生。

辅助励磁机为用于调节主励磁机的场励磁的控制设备（晶闸管变换器）提供三相电源。这三相电源从主励磁机输出进入静止换向器，它通过主断路器为发电机转子提供直流励磁电源。通过安装在转子轴上的风扇对辅励磁机进行散热。风扇通过一个开式的通风系统循环空气，此系统也对发电机的电刷装置和主励磁机的电刷装置进行散热。

主励磁机的通风系统由一个闭式系统组成。空气通过两个离心风扇作用在此系统内循环，这两个风扇安装在励磁机转轴的两端。

盘车位于滑环和主励磁机之间的轴承座内，以便在电机启动之前和停机之后能缓慢地盘动转子，防止转子变形或冷热不均。盘车装置由交流电动机驱动，有一个离合器和三级减速装置。发电机转子支持轴承和主励磁机内轴承也安装在该轴承座内。

第五单元摇变电站

每个变电站都必须与电网相连以便能将电能送入系统中并启动系统运行。另外，变压器、开关等电站设备都是变电站所必需的。

在此节中，将以 阅再月 为例详细介绍变电站的情况。

通过一个 员员噪灾的配电盘，一台 圆猿圆缘噪灾辕员员噪灾的变压器能直接将发电机发出的电提供给辅助设备。为 阅源机组电厂一期配备的变压器的额定值为 源愿酝灾粤，为 阅源机组电厂二期配备的变压器额定值为 源愿酝灾粤。

变电站内每个单元都需要足够的能量，以保证其启动运行，而厂用变压器显然不能完成该工作。所以辅助设备单元能量都取自电站变压器。一座 员猿圆噪灾的变电站能支持 源台缘园酝灾粤，员猿圆噪灾辕员员噪灾的变压器工作，而每台变压器能支持一个 员员噪灾的电站配电盘工作。

源园园噪灾变电站

此变电站为户外型，由主母线带旁路母线，一期变电站分段配备了压缩空气断路器，而二期变电站分段配备的是 杂云远断路器。从空气断路器到 杂云远断路器这一转变是使用 杂云远开关装置快速发展的结果。现在已使用更加紧凑的设备，与空气相比，其绝缘性能要强得多。一期母线通过一台 员猿园园酝灾粤的故障限流电抗器与二期母线连在一起，而主母线与旁路母线可用母线联络开关分段联结在一起。该电站有一台 圆园园酝灾粤，源园园噪灾辕员猿圆噪灾超高压电网自耦变压器（向 员猿圆噪灾变电站供电）和 源园园噪灾的输电线，与全国电网相连。

员员噪灾系统

员员噪灾系统从一期工程开始建立，之后经过 员园年的运行，在二期得以改善，目前 远台机组均有 员员噪灾系统。

每台电站变压器以自身 员员噪灾的电站配线为电源，电站配线见图 源援圆（略）。图中两个 员员噪灾系统不通过电站配电线 猿和 源上的母线分段开关而相互连在一起。

每个 员员噪灾配电系统都有 猿个主电源（因此隐含较高的故障水平）相连，它们是变压器单元，电站配电转接器和燃气轮机，以及主驱动器和辅助的降压变压器。

所有的 员员噪灾开关设备值为闭合额定容量 怨园园酝灾粤，开断容量 苑缘园酝灾粤，都为空气断开型。开关的闭合和断开的额定值的不同是由于运行中的感应电动机的故障总是出现在开关闭合状态，而在开关断开时则没有。

员员噪灾系统是一个复杂的系统，通过大面积硬结线联锁系统运行。同时，由于可能导致系统电压超出开关设备的故障级，所以过去是不希望在没有联锁情况下运行一个系统的。

机组设计和安装了一套采用微处理机的装置以避免 员员噪灾断路器闭合会超出开关设备的故障级。机组设置了一套超越保护装置，该装置使操作者可以越过联锁装置，根据开关柜或每一段电路来控制；机组还设置了模拟装置，能使操作者在不实际操作任何开关的情况下检查自己操作的效果。

控制室里有两种可视显示装置：一种用颜色标示不同的 员员噪灾开关柜的状态，可由操作者选择；另一种发出有关机组或系统情况的警报。所有 员员噪灾开关装置的信号都送入该微处理机。

有两种例外的情况，微处理机故障级计算过程会被旁路：一种是启动锅炉和备用锅炉给水泵的紧急启动，在这种情况下时间至关重要；另一种是当机组的配电装置与电站的配电盘未联锁时燃气轮机启动，在这种情况下，燃气轮机必须在某一时间内是同步的，所以

已知未超过故障级，就可以节约计算时间。

猩藤嗪敦系统

该系统由一个大范围的厂系统和机组系统组成，前者通过一台 员嗪敦辕猩藤嗪敦辅助变压器从各种 员嗪敦变电站配电单元中获取能源，后者通过两台相同电压等级的 员猩藤酝穴粤辅助变压器从各种 员嗪敦配电单元中获取能源。

厂系统包括各种为电站提供常规服务的配电盘，还有一些为煤场、灰场、除灰除尘服务和其他一些特殊场合服务的配电盘。这些配电盘都由一台 愿酝穴粤或 员园酝穴粤的变压器提供电源。

机组系统可操作所有设备，能驱动一些具有特殊目的的装置，如磨煤机、主风扇和水泵。

一期工程上设置了一台 猩藤嗪敦备用辅助配电盘，它通过变压器从 员嗪敦变电站配电盘上获取电源，同时与每个配电装置相连，即便在一台变压器或两台变压器都失效的情况下，它也能提供电源。它还提供持续电源。

源缘穴系统

源缘穴系统范围很广，并且由于一期的开关设备和到二期开关设备订购时就不再生产了，从而使得 源缘穴系统复杂化。原始电站配电盘中的一部分不得不被扩展以便为三台新机组所用的额外装置服务；大部分配电盘还是用于煤场、灰场和 悦宰 系统。新的开关设备必须安装在已有装备的后面，主要困难在于汇流条的外接和控制板的安装。

一期的 源缘穴系统的电源来自 猩藤嗪敦辕源缘穴变压器，而二期的 源缘穴系统的电源来自 员嗪敦辕源缘穴变压器。这两者存在差异，因为一期的运行经验表明存在电压调节问题，而去掉中间变压器有助于电压调节。另外，自动带负荷分接头切换也已适用于 员嗪敦辕源缘穴辅助变压器。测量 源缘穴单元服务配电盘的电压，然后用该电压运行抽头变换器。

与 源缘穴机组配电系统一样，二期工程机组的配电系统均利用厂变电站的配电盘。这是一个新概念，即靠从变电站取电源提供给每台机组，以满足后备负荷的增长需要，提高灵活性。

二期工程配备了一台 源缘穴的备用配电服务器，可满足每台机组配电服务的需要（每次一个），并提供维护设备和备用零件。

直流系统

利用蓄电池持续供电系统有 缘园、员圆园和 圆园园穴三种，可为下列情况提供安全供电：

- 重要仪器
- 控制
- 开关闭合和跳开功能
- 无线电通信
- 保护
- 联锁装置
- 报警

· 重要的备用设备
· 紧急照明
· 事故油泵
· 燃气轮机辅助设施

在 圆园园灾档时，每个开关柜都有两个浮充盘 （单个额定通过电流为 猿园园粤） 和一个调压柜。在 员园园灾档时，每个配电柜里有一个悬浮电极和一个推动电极。系统中心点接地替代了早期的偏点接地。

源园园粤澡电池为二期 缘园灾系统供电。在附属建筑物中，除了 悦宰 系统和压缩机房外，缘园灾电压是由自持电池充电装置提供的。压缩机房里一台变压器整流器由 员园园灾直流供电。

第六单元摇保护系统

保护继电器

大多数电气工程师对保护继电器的认识只不过是一般性的了解，并且大多数电厂工程师也只模糊地知道它的存在。这是个外来东西，谈论它记录它都用外文符号，对一般的电力用户而言不必去了解它。

然而对一个应用工程师而言，保护继电器就是一种生活方式。继电保护工程师要投入所有精力考虑可能发生在网络里的各种故障，且要设计出继电保护电路来防止故障的发生。在此过程中，继电保护工程师已开发出一套高系统化的继电保护方法和一种有效的用于设计电路和详细说明继电器的速记法。

保护继电器的目的是检查系统内是否有不安全的或超限的情况，然后跳开相应的断路器。保护继电器电路的主要作用是将故障电路从系统中隔离出来，以便电网的其余部分能不中断地传输电能。如果断路器能足够快地断开故障点以保护电路，则是最好不过了。

互联网络系统中最常用的继电器有过流继电器，过压及欠压继电器，过频及欠频继电器，以及功率方向继电器。继电保护工程师要在继电保护图上用数字而非名称标明这些继电器的类型 （还有许多其他类型）。

互感器

互感器能够传送电流、电压或频率信号给保护继电器 （图 源鄄猿 （略））。目前有电流式和电压式两种形式的互感器。要将电网中较高的电压或电流降至适于仪器和保护继电器工作的值，需要这两种互感器。

电流互感器 （悦栽） 用电力传输线作为它的一次绕组，在二次绕组中产生一个与电力传输线电流成比例的小电流。通常，二次绕组中的 缘粤相当于一次绕组的满负荷电流。

电压互感器 （孕栽） 有自己的一次绕组，被连结在 猿根传输线中任意两根之间或相地之间，它在二次绕组中产生一个分别与线—线电压或线—地电压相对应的电压。通常，二次绕组中的 员圆园灾电压相当于一次绕组的额定电压。

大多数线路都是三相的，且具有 猿~ 源根导线，但都用一线图来表示。每个测量点上都有一个，两个或三个互感器和至多三个继电器，但在示意图中都只标有一个互感器和一圆个

个继电器。

接地故障

三相接地电路中有一相发生接地故障时，再连接变压器或发电机的接地支路中会产生不平衡电流 （如图 灏原（葬 （略））。这个电流起初可能很小，用一般的过流继电器不能检测出来，因为过流继电器设置的可读电流为成百上千安培。但现在有一种灵敏的地线过流继电器，它可以检测出中性线中的电流，并跳开相应的断路器。

不接地回路中的接地故障只能通过检测线—线电压的不平衡来检测 （图 灏原（遭（略））。用三个电压传感器连接成一个开口三角形。如果三相平衡，则三角形开口处无电压显示；一旦由于接地故障而使电路不平衡，开口三角形就出现一个电压，此电压可由电压继电器检测出来。

继电器类型

在互联系统中，方向继电器对控制功率流向起着重要作用 （图 灏缘（葬 （略））。方向继电器通常被设计来检测电流值，但是由于交流电流是双向的，所以它就检测在功率流方向的电流值。这里需要两个互感器：一个 悦栽（电流互感器） 用来测量幅值，一个 孕栽（电压互感器） 用来极化继电器，使其只在一个方向上读数。使用方向继电器通常需要确保功率不流入相连的发电机中，以免发电机以电动机状态工作。

同步继电器用来监视相连发电机的手工操作是否同步 （图 灏缘（遭）。工作人员可手工调节现场发电机的速度和频率，可使用同步指示仪来判断什么时候发电机与整个系统同相。达到同相时，工作人员闭合断路器。然而，由于非同步合上断路器可能造成极大的损失，因此，必须使用一个监控同步继电器。这种继电器需要两个电压互感器，断路器每边一个。

自动同步指示仪可自动调节频率，工作人员只需按一下按钮就行，无需分散的保护继电器。

差动继电器用来检测变压器或发电机绕组间存在的故障。它通过监视流入和流出每一相绕组的电流来达到此目的。这些读数间稍有不平衡就表明绕组和绕组间存在着故障，必须在故障恶化前打开断路器。差动继电器需要 远个 悦栽 每相两个。

第七单元摇具体保护措施

当发电机与整个电网并联运行时，它就成为了复杂的大电机的一部分，因此需要高级保护以避免电网对电机的正常运行或者电机对电网产生不良影响。

主断路器跳闸

如果由于各种原因 （例如清除故障） 使得主断路器断开，用户的发电机就被隔离开来。这使得发电机与满负荷设备连接在一起，同时与跳开的断路器的下路连接在一起的所有相邻用户连接在一起。在这种情况下，发电机将严重超负荷，必然会立即引起电压和频率的下降，最终可能造成严重后果。因此，在所有的互联系统中，只要电能被切断，用户的主断路器必须跳闸。

通常，过频或欠频继电器能使主断路器跳闸。典型的设置为 缘怨匀扎和 远员匀扎以便主断路器在发电机输出达到此极限时就跳闸。但由于用户的控制器有可能工作得比预期的好，所以发电机频率能在被隔离后的几秒钟内仍精确地保持为 远园匀扎。为此，大多数电网除了使用频率继电器外，还坚持使用过压或欠压继电器。

一旦主断路器已经跳闸，用户就得对发电机的输出负责。值得庆幸的是，用户有可能卸掉不需要的负荷，而继续在其发电机上运行必要的负荷。这通常意味着首先要打开发电机断路器，然后卸下不需要的负荷，再将必要的负荷接到发电机上去。要使用可靠的高速继电器，它有可能足够快地卸下不需要的负荷，避免中断发电机的输出。

主断路器的重合闸

公共断路器的自动重合对用户发电机而言可以说是灾难。当系统断路器重合时，现场发电机会产生严重的不同相，其结果是可能产生足以使发电机转子断裂的严重振动，更不用说产生电力系统的破坏了。在这种情况下，没有什么断路器能以足够快的动作来阻止这种事故的发生。

惟一可靠的保护措施是让发电机离线直至系统稳定。如果用户断路器一直闭合，则此系统可能会也可能不会阻止自动重合闸。通常在断路器的用户方用电压继电器来阻止自动重合闸，如果线路正在通电，则此断路器可阻止重合闸。

而用户方断路器的重合闸又会引起新问题。显然，断路器不能将一条不通电的线路或一条通电线路合到与其不同步的线路上去。如果电力系统不能提供断路器的联锁或不能阻止自动重合闸，那么就需要延时器来保证电力系统稳定。

在主断路器和独立发电机断路器之间也需同步设备。它既可以是自动同步指示仪也可以是同步检测继电器。对于后者，发电机的同步化和断路器闭合都是由手工操作完成的，但检测继电器可防止非同步性重合闸。如果设备已脱离电网且独立运行发电，那么主断路器的同步指示仪允许该设备在不停机的情况下与电网重新相连。

继电器的适当配置

在发电厂与电网之间，继电器如何配置永远都值得研究。这主要是因为电网的标准是在进行故障检测时希望发电机离线停机，而发电厂则希望不中断地进行发电。这样，即便电网已制定了保护要求并已经对联网系统上的继电器进行了检查，也不一定能使双方就继电器的跳闸极限应如何设置达成一致。

由功率因素校正电容开关引起的主要问题是电网上的电压浪涌，这些电涌足以使过压继电器跳闸，并沿着发电机方向解列（用户）设备。电网不向用户预告这些电涌，用户也只有在发现每天同一时间都发生重复性跳闸情况之后，才会明白原因之所在。

相反，继电器的一致性问题也成了电网的一大难题。小电机并没有太多这类问题，但当电机日益增大时，作为电机中的一般部分的相过流继电器就必须与电网继电器保持一致。电网中一直使用电压控制过流继电器。

大电机或小电机是如何区分的呢？南加利福尼亚 耘凿蚤泽燥灶公司针对以 圆园园园噪灾粤为界的两种发电机制定了两套继电器要求，郧造燥遭葬造电力公司将 缘酝灾粤以上的发电机分类为大发电机，其余的为小发电机。夏威夷电力公司将 缘园园噪灾粤作为小发电机的界限。然而，从

继电保护工程师的观点来看，发电机的大小关键在于发电机的输出容量，此输出大小与输电线容量有关，而不在于它的绝对额定值 （嚎穹）。

第八单元摇接地与电缆

接地

三相电力系统有接地运行和不接地运行两种。不论哪种，电能都在三相导线上传输。接地系统还有一根中性线，它仅仅传输不平衡电流。变压器和发电机的绕组及其他三相设备可被连接成“再”型或“△”型。“△”型连接通常用于非接地系统，而“再”型连接用于接地系统，接地系统的中性点与地相连或者与中性导线相连。假如三相平衡，则中性线上电位基本上是地电位。

系统的 猿种类型

接地系统有两个电压水平：线—线电压 （源园灾系统中为 源园灾） 和线—地或线—中性点电压。线—地电压为线—线电压的$\frac{员}{\sqrt{猿}}$（越圆豫苑） 倍。典型的四线系统提供电压 源园灾辕圆苑灾或者提供电压 圆园愿灾辕员圆园灾用于动力和照明。如果三相输电线中有一相发生接地故障，接地保护继电器会立即在中性线上检测出大的不平衡电流，然后跳开断路器，隔离故障点，切断电源。

非接地系统只有一个固定的线—线电压。在一相输电线出现接地故障的情况下，此相输电线的电位就会降至地电位，而其他两相输电线的电位会上升至线—线电压。如果故障电流较小，系统常能继续运行直到故障点被找到并修理好，这就是为什么很多电厂都采用不接地系统的原因。

只有在接地故障未被排除，而系统中另一部分另外一相也出现二次接地故障时，才会产生问题。其结果是引起具有极大毁灭性的线—线故障 （在很高的线电压下），损坏系统的电气设备。

不接地系统中附带的问题是绝缘承受过大的应力。即使一相出现小故障，其余两相电压也会升高至额定电压之上。如果出现大故障，随着故障点电弧的触发及熄灭后再触发，会产生瞬态电压，此电压在断路器清除故障时也会出现在断路器中。这些瞬态电压给不接地系统的导线绝缘施加了很大的应力。

很多工厂采用电阻接地系统。此时，中性线不直接接地，而是通过一个电阻接地。电阻大小的选择要使得当接地故障发生时，流过中性线的电流要足够大，能使接地故障继电器跳开。但也不能太大，以免让电弧造成严重损害，例如损伤电动机层绝缘。

大电网更希望有较大的接地故障电流，能确保接地故障继电器毫不含糊地动作。电网更愿意选择直接接地系统的另一个原因是它允许系统使用中性点接地避雷器。这种避雷器比不接地避雷器更便宜，更有效。

电缆

电缆基本上就是一股金属或多股金属，外面包裹一层绝缘材料。电缆一词也适于组装在一起的多个相互间绝缘的导体。由于电压高于 圆嚎灾，绝缘材料完全被包在两个接地的

静电屏蔽体中，以保持绝缘各处的电压均衡，并提供安全保障，使人可以接触绝缘体。为了保护相对脆弱的屏蔽体以及给多导体电缆的导线提供一个闭合的空间，一般在外层包有一层壳。

电缆结构

在北美，第愿号全美线路标准中大多数电缆及大型电缆都是多股的。除非对柔软性的重要性提出要求，否则小型电缆都是硬质的。多股电缆中为了在导管中安装方便，要求每股直径不大于猿圆缘皂皂。因此，电缆的股数一般为员，苑，员怨，猿苑或远员，最大到员园园园酝悦酝（员园园园平方密耳，即缘园苑皂皂圆）大小。

在世界其他并不用导管的地方，他们的电缆是固体的，或单股的，具有相当大的尺寸。在适当空间里，位于电缆钢带之间的电缆可自我支撑。

（员） 导体材料

导体材料主要是铜或铝，尺寸在第圆号粤宰郧规定之下的电缆主要用铜，而铝主要用于输电线等大尺寸导体。为了易于弯曲，铜电缆几乎都经过退火处理。而铝由于在接头夹紧下出现冷变形，对电力传输（耘悦）等级有一定影响。

因此，用做传输线的耘悦铝一般是猿辕源冷拉淬火的硬铝线，有弹性，难以变曲。但置于接头螺柱下的弯曲点也易发生断裂。一种新型的含有园援缘豫铁的合金铝已替代了耘悦型铝，并用于电路中。

在同样尺寸下，铜比铝具有更高的导电率，但铜的重量是铝的猿援猿倍，且每磅（公斤）的价格又是铝的两倍，这使得使用铝更经济些。以每安培通电量的价格计算，铜导线的价格是铝线的源倍。

（圆） 主要的绝缘式

现代中压绝缘电缆多采用两种主要的绝缘形式：耘孕砸和悦蕴孕。另外一种形式是硅橡胶。耘孕砸是一种类似于橡胶的材料，由乙烯和丙烯及一些添加物交联而成。多年来耘孕砸一直像橡胶绝缘一样被使用。它的作用相当大，特别对消除悦蕴孕电缆的一种缺陷——“树”状放电的作用明显。（“树”是一种缓慢贯穿绝缘微小通道的进程，通常由绝缘体内部的一些空洞或点发展而成）。

载蕴孕或悦蕴孕是一种表面呈乳白色的硬材料，称为交联聚乙烯，这种交联聚合物能耐受纯聚乙烯的溶点［圆愿园°F（员猿缘益）］。尽管在该温度下它比耘孕砸要软些，但由于它在价格上比耘孕砸要便宜得多，使得载蕴孕广泛用于输电线路，然而它不适用于可靠性要求较高的地方。

硅橡胶是一种相当软的橡胶材料，偶尔用于环境温度过高或过低的地方。它的电性能优越，但机械强度较差，在受到一定的机械压力时要采取保护措施。它经常用在锅炉、蒸汽管、热水管及烟囱群等附近。

第五部分摇控制和保护系统

第一单元摇阅耘匀数字电液调节和保护系统

目前的发展趋势是，新建的火电厂和核电厂的规模越来越大。员园园园酝宰等级的火电厂和员园园园酝宰核电厂已投入运行。对于这些大容量的汽轮机，转子的惯性矩相对减小了。因此，要求汽轮机控制系统能够对电负荷做出快速响应，以便限制最大升速率。

另一方面，因为大容量机组的零部件越来越多，结构越来越复杂，所以目前广泛采用自动控制器和计算机系统。汽轮机需要性能越来越优良的控制系统，来适应其日趋复杂和先进的系统。

为了满足上述要求，电液调节系统（耘匀郧）作为一种新的汽轮机控制系统应运而生。与传统的机械液压式调节系统（酝匀郧）相比，耘匀郧具有结构更紧凑的液压驱动机构，同时其动作由于控制油压升高而加快。另外，耘匀郧采用集成电路，没有机械元件之间的间隙和摩擦（这是机械液压式调节系统不可避免的），所以控制精确度高。

日立公司研制的模拟式电液控制系统已在许多电厂安装并投入运行。在模拟电液控制系统的基础上，日立公司又开发了数字式电液控制系统（阅耘匀匀）。这种系统采用最新的微型计算机，能够处理日益复杂的控制信号，并具有可靠性高，可维护性好的特点。第一套阅耘匀匀系统在员怨愿远年缘月投入运行，员园园园酝宰电厂的阅耘匀匀系统在员怨愿苑年愿月投入运行，目前它们的运行情况良好。

耘匀郧系统中的正常调节装置通过液压机构使调节阀动作。正常调节控制装置为：

（员）速度控制单元和功率控制单元；

（圆）功率限制单元。

耘匀郧系统中的预保护装置的作用同普通调节系统在非正常运行时的作用一样，预保护系统可以调节高压调节汽门和再热调节汽门。预保护系统主要包括以下部件：

（员）加速度继动器：在甩负荷员园豫以上时，可以越过正常调速系统，使再热调节汽门迅速关闭。

（圆）超速保护继动器：由发电机功率与汽轮机输出功率不平衡信号控制，在甩负荷源园豫以上时，可以越过正常调速系统，使高压调节汽门和再热调节汽门同时关闭。

危急保护装置控制汽轮机高压主汽门、再热主汽门和抽汽逆止门。危急保护装置包括如下三种：

（员）带油跳闸的危急保安器；

（圆）两个主跳闸线圈（酝栽悦），下列信号使这两个主跳闸线圈动作：

①汽轮机跳闸按钮；

②低真空跳闸；

③推力轴承磨损；

④机组润滑油压低跳闸；

⑤主蒸汽温度低跳闸；

⑥低压缸排汽温度高跳闸；

⑦机组轴承振动大跳闸；

⑧低速偏心跳闸；

⑨耘云郧系统主故障；

⑩耘云郧附加超速跳闸；

⑪主油箱油位低跳闸；

⑫高压缸排汽温度高跳闸；

⑬发电机跳闸；

⑭汽轮机高辕低压旁路故障跳闸；

⑮锅炉主燃料跳闸；

⑯推力轴承金属温度高跳闸；

⑰支持轴承金属温度高跳闸；

(猿 主跳闸杠杆（安装在前轴承箱）；

超速保护装置

超速保护装置包括危急保安器和危急跳闸机构，该装置可以在带负荷工况下进行单独的试验。

危急保安器为飞环式，飞环通过一个弹簧保持与转轴同心。当转速达到危急保安器的跳闸转速时，飞环的离心力克服弹簧的作用力，飞环飞出至偏心位置，从而撞击跳闸装置的搭爪，使危急跳闸阀跳闸，关闭高压主汽门、再热主汽门和抽汽逆止门等。危急保安器还可以在正常转速下通过向油跳闸阀注油进行试验。

危急跳闸阀是一个三通阀，将油管中的油液提供给高压主汽门、再热主汽门和抽汽逆止门的错油门。当危急跳闸阀动作时，它使高压主汽门、再热主汽门和抽汽逆止门的错油门均泄油，进而使汽轮机的所有进汽门都关闭。危急跳闸阀可以通过机组控制板上的复位手柄或复位按钮，在前箱上就地复位。复位手柄带动一个油导阀动作，后者使油液进入一个安装在跳闸阀阀杆上的小活塞内。小活塞产生足够大的力，使危急跳闸阀复位。危急跳闸阀一旦复位，汽轮机高压主汽门、再热主汽门和抽汽逆止门的错油门便复位。

危急跳闸阀连杆和液压复位活塞使极限开关动作，并打开位置指示灯。所有指示灯均安装在前箱，靠近相应的手柄处。

电磁线圈跳闸

建议设置一个遥控跳闸按钮，以便在远离汽轮机的位置使电磁线圈跳闸。这样，就可以在发生火灾或其他事故、又不能触摸到汽轮机跳闸连杆的情况下关闭汽轮机。在有些情况下，遥控跳闸按钮不仅可以使汽轮机跳闸，而且可以使锅炉及某些辅助设备跳闸。

第二单元摇锅炉控制

蒸汽锅炉控制

蒸汽动力发电厂控制系统的目标就是维持汽轮机所需的蒸汽压力和温度。进一步说，也就是要求蒸汽动力发电厂能够对工况变化做出快速响应而不产生显著的振荡或波动。正

常运行可进行调整的变量有燃料的燃烧率、空气流量、烟气流量分布、给水流量以及汽轮机阀门位置。用于描述电厂性能的主要测量值为蒸汽流速、蒸汽压力、蒸汽温度、一次风及二次风流速、燃料燃烧率、给水流速、汽包水位以及电力输出功率。控制系统必须根据这些电厂参数的测量值进行动作以便维持电厂在设定的条件下运行。

大部分现代控制设备都采用闭环控制。在这种控制方式中，测量系统的实际输出并将测量值与某些定值信号（设定点）作比较。测量值与定值之间的差称为偏差信号，利用该偏差信号将测量值与定值（设定点）之间的差减小到接近为零。

比例控制是闭环控制中最简单的一种类型。在这种控制方式中，控制器的输出与误差信号成比例。根据所要求的控制动作，控制信号正比或反比于误差信号。

为了确保比例控制器能够稳定工作，以设定点为中心设有一个死区，在此死区内，控制器没有输出。如果只用一个简单的比例控制器，控制变量的最终稳定值与设定点之间会产生少量的偏移，可以通过在控制器中引入积分或复位控制作用来消除这个偏移量。在积分控制方式中，控制作用是建立在对被控变量与设定点之间的偏差所进行的积分之上的，只要偏差存在，积分作用就存在。通过引入积分作用，在维持系统稳定的同时消除了由单一的比例控制引起的偏移。在这种控制方式中用到了“复位控制”这个术语，这是由于比例作用的范围被偏移或复位而使被控变量在一个新的基点周围变化。

几乎所有的电厂控制设备都综合了比例和积分控制作用。在某些情况下，还加入了微分控制。微分控制作用是由被控变量的变化率决定的。如果一个变量开始迅速变化，则会产生一个很大的微分控制信号。一旦变化率降低，比例和积分作用将取代微分作用并进行最后的定位。如果系统将三种控制方式综合使用，会比只用单一的控制方式时做出更快的响应并更稳定地运行。

过热汽温控制

将汽温维持在设定点或在设定点附近是十分必要的。过高的汽温会增加汽轮机的腐蚀，而过低的汽温又会造成电厂效率的明显降低。

进入汽轮机的过热蒸汽的温度与若干因素相关：电厂所带的负荷、燃烧中所用的过剩空气量、给水温度、加热器表面的清洁度、处于不同位置的燃烧器中热输入的分配情况、燃料品质的变化、吹灰时或辅机中饱和蒸汽的使用。在这些因素中，最重要的就是负荷变化。

随着负荷的增加，烟气的流量和温度都会增加。因而，在对流过热器中，蒸汽温度会随负荷上升而上升。而在辐射式过热器中，辐射热输入的增加小于负荷增加所需的吸热量，因此，蒸汽温度会随负荷上升而降低。如果将一台辐射过热器和一台对流过热器并行使用，就有可能更好地将汽温维持为常值。然而，由于大部分的热通常都是在对流过热器中传送，所以随负荷上升总体汽温仍会上升。因此，还需要采用其他的控制及校正手段。

用于限制汽温随负荷改变而变化的另一手段是对燃烧器进行控制。此处，有效的炉膛容积随负荷变化而有所不同。在低负荷时，上层燃烧器不工作，有效的炉膛容积会减小。另外，在有些设计中，燃烧器可在低负荷时向下摆动而在高负荷时向上摆动。通过改变有效的炉膛区域，就可降低低负荷时的吸热量，同时可将进入对流过热器的烟气温度维持在要求值的附近。这样就减少了蒸汽温度随负荷改变而产生的变化。

通过控制烟气再循环可以进一步减小负荷变化带来的影响。在此方法中 （见图 缀圆员（略）），来自锅炉、省煤器或空预器的一部分烟气由适当的风机及管路重新引至炉膛入口的附近。烟气再循环的主要功能就是通过稀释炉膛烟气从而降低辐射区的温度来减少炉膛（锅炉区） 内的吸热量。这样当通过对流过热器的烟气速率增加且吸热量增加时，锅炉区的吸热量却减少了。因此，在低负荷时采用烟气再循环就有可能在此时获得较高的汽温。

在某些烟气再循环系统中，再循环烟气可到达炉膛出口的附近。这称为烟气回转。用这种方法，既降低了炉膛温度而又不影响炉膛的吸热量。在直流锅炉中，综合使用烟气回转及炉膛入口处的再循环烟气是十分普遍的。这样就可以分别控制炉膛出口烟温及炉膛吸热量。

通常，对于一台给定的锅炉，如果所带的负荷在略高于 缀园豫满负荷至略高于 怨园豫满负荷之间，使用烟气再循环和燃烧器控制就可以将过热汽温维持为近似常值。然而，要在接近满负荷时将汽温维持为要求值，这样的控制通常是不够的。如果在部分负荷时维持设定的温度条件，当所有的燃烧器工作并向上摆动而此时又没有烟气再循环，蒸汽温度会在接近满负荷时超过设定点 （见图 缀圆圆（略））。在这样的高负荷情况下，就必须降低蒸汽温度。这就是减温。这种减温器可以是内部使用热交换器的表面式减温器，或者是直接接触式减温器。直接接触式减温器最普遍的形式是喷水减温器。在该装置中，给水通过喷嘴喷入蒸汽中，两者在文丘里管中进行混合。

当用烟气再循环控制蒸汽温度时，通常采用双冲量控制。由于系统对挡板运动的响应比较迟缓，通常用一次风流量控制初始挡板位置。最终的校正则来自对蒸汽温度的积分作用。当超出烟气再循环的范围时，则通过将蒸汽流量或负荷与用于喷水的给水流量平衡及由蒸汽温度所确定的最后积分作用来控制减温器。

需要指出的是，使用再热器会使设计变得复杂。用来控制过热汽温的方法同样也会影响再热汽温。在一个再循环机组中，减少有效炉膛区域会使过热汽温和再热汽温同时升高。再热汽温的升高或许是我们不希望发生的。

第三单元摇汽轮机控制

电厂的总体控制必须能够感知系统负荷的变化并作出反应。控制的目标就是维持母线电压和频率为常数。假定有一个由一台汽轮发电机支持的小系统，一台大型的工业电机接入该系统中，这样，系统的总电阻会降低，因而将有较大的电流通过发电机转子回路。电流的增加会导致转子磁场强度增加，从而增加励磁转子的转动阻力。增加的阻力降低了汽轮发电机轴的转动速率。

汽轮机调速器检测出汽轮机转子转速降低，调速器发出信号开大汽轮机蒸汽阀，增加进入汽轮机的蒸汽流量。进汽流量的增加会导致供汽系统的压力下降。如果该电厂是一个燃煤系统，压力的降低会发出信号给燃烧自动控制系统来增加送风机和引风机的动叶转速。同时，压力的降低也发信号给燃烧控制系统来增加燃烧率。在核电系统中，压力的降低将要求增加反应堆电平，这只需轻微地提一下补偿控制棒就可以实现。

当增加热耗所产生的蒸汽重新与系统压力相平衡时，电厂重又回到稳态。调速器达到一个新的平衡点以维持更高的负荷需求，也就允许蒸汽流量增加以使汽轮发电机转子转速返回到设定状态。

在一个实际系统中，会有数个汽轮发电机并列运行。当负荷和发电量相平衡时，所有的发电机都锁入到能产生所要求的系统频率的速率中（同步速率）。由于这些发电机是并列运行的，所有的发电机必须在各种条件下始终产生一个共同的电压和频率。

汽轮机可传送负荷的大小是由它的负荷鄄速率特性曲线决定的。在汽轮机调速器的某一给定位置处，汽轮机的负荷鄄速率特性曲线是固定的。当有额外的负荷突然加到系统上时，能立即满足这些额外负荷的惟一方法就是略微降低系统频率。因此，如果有两台汽轮机并列运行，根据图 缘鄄猿猿（略）所示的负荷鄄速率特性曲线，速率（它与频率成比例）为 糟 低于需用来产生所要求的系统频率的速率 贼乙 若要恢复系统频率，必须改变其中一台汽轮机的负荷鄄速率特性曲线。这就需要将汽轮机速率控制器向能增加速率的方向改变来实现。在一台汽轮机中，其速率鄄负荷曲线被改变，同时汽轮机的进汽阀进一步开大。

假定在图 缘鄄猿猿所示的例子中，由汽轮机 粤承担增加的负荷。如图中所示，汽轮机 粤所带的负荷将会增加，直到系统在要求的频率下运行。此时，汽轮机 粤的新负荷 原频率曲线为 员乙 园乙 而且其承担的负荷份额将增加至 园～葬乙 而汽轮机 月承担的负荷份额则减少到 园～遭乙

如果系统所带负荷减少，由于两台汽轮机的速率都略微增加，频率会上升。这时汽轮机 粤关进汽阀从而改变了它的速率鄄负荷特性曲线。当系统频率恢复到要求值时，将会到达一个新的平衡位置。

假若一个系统中有若干个汽轮发电机并列运行，其工作情况与上述基本相同。增加系统负荷会导致所有的汽轮机略微降低它们的速率。系统的调度员，或调度计算机，确定由哪一台汽轮机来承担负荷。打开那些通往被选中汽轮机的进汽阀，它的速率鄄负荷曲线相应改变，于是系统在一个稍高频率处达到新的平衡状态。由于系统中的其他汽轮机将在稍高的速率下运行，它们所带的负荷将会减少。然而，由于通常有相当数量的汽轮发电机并列运行，除了那台指定为承担负荷的汽轮机，其他任意一台汽轮机的负荷变化是很小的。反之亦然。需要注意的是，在这种控制方案的操作中，要求所有汽轮发电机的速率鄄负荷特性曲线都有适当的负斜率。一个近似水平的速率鄄负荷曲线会导致不稳定运行，因为一旦速率发生微小变化，将造成很大的负荷变化。

电液调速控制系统和前面所述的机械鄄液动系统所提供的基本控制功能是相同的。然而，在这种系统中所接收的基本信号以及这些信号的一次放大都是电信号而不是机械信号。速率信号通常是一个与汽轮机速率成比例的电压信号，该信号是由连在汽轮机轴上的一个小振荡器产生的。经过适当地放大，该信号驱动伺服电机产生液压来重新置位控制阀。系统对速率信号进行微分，并以此限制汽轮机在启动期间的加速度。

前面已经指出，当与其他的汽轮发电机并列运行时，汽轮机的速率将锁定为系统的同步速率。若要获得负荷改变，则要引入一个等同于速率偏差的电信号（见图 缘鄄猿源（略））。加入的负荷误差电信号与要求负荷和实际负荷之间的差值（负荷转矩）成比例关系。放大的负荷误差信号驱动伺服电机，接着产生液压来重新确定蒸汽控制阀的位置。

如果锅炉压力降至预先设定的值（如设计压力的 怨园豫）以下，除了正常的操作控制，还设有辅助的压力控制来关闭控制阀。该系统同时调整控制阀以限制压力的增加使其不至超过某些预先设定的值，如设计压力的 员员园豫。

汽轮机超速保护是由超速跳闸参照信号触发的。如果汽轮机的速率超过了超速跳闸参

照速率，截止阀会立即关闭。

还有一些其他的信号会使汽轮机停转以避免事故。这些信号包括振动过大、低压、轴承故障及高温信号。

第四单元摇计算机在电厂中的应用

计算机应用

面对不断复杂化的情况，发电站需要有效的工具和设备来确保能以最低的成本提供品质合格的电能。集中监控对发电过程的瞬时状态进行全面观察。计算机监视当前操作，并当和正常状态有偏差时对操作员提出报警，例如意外的断路器动作或流量超过允许范围。

除此之外，还将报警分组来进行选择性的显示，这样就可以进一步帮助运行人员迅速追踪误差产生的主要原因。大型的控制中心则运用先进的网络监控及仿真工具来帮助运行人员防止扰动。通常还有从经济上对电站系统的运行进行最优化的生产控制。

电站系统的集中控制意味着可以在一个地方实施所有的控制功能。因而运行人员可以操作断路器，接通或断开变电站，控制生产设备。

引入计算机化的控制系统后，运行人员的角色发生了很大的变化。过去运行人员的任务主要是记录原始数据，而现在则变得更具有分析能力。计算机系统执行记录并显示出过程结果。然后运行人员进行判断并借助计算机系统实施决策。运行人员的新任务对人机接口提出了很高的要求，如信息、显示的方式以及如何设计对话规则。

发电站所要求的控制系统功能是十分广泛的，但在不同的应用领域其复杂程度也有所不同。最基本的控制要求通常都包括所谓的 杂悦粤阅粤控制功能 （杂悦粤阅粤代表监视控制及数据采集），见图 缘郾猿（略）。如果加入 耘酝杂功能 （耘酝杂代表能源管理系统），面向应用的计算工具将给运行人员提供更大的帮助。

要满足功能上的需求，有三个十分重要的关键词：分层、分散、可靠。发电站的组织结构在运行中自然要求使用分散功能来层次化。控制系统必须适应这样的要求，见图 缘郾远（略）。由于发电站本身的电力生产过程是分散的，也就是在地理位置上广泛分布，因此引发出分散控制系统的概念。在电力系统中，运行人员的误操作和漏操作会带来很大的损失，所以必须对操作的安全性提出一系列的要求。

基于这个总体的系统原理，当今有一系列基于计算机的设备和模件，它们可在不同的应用场合 （无论是大型的还是小型的） 给系统提供有效的解决方案。

现代的监控系统非常多。在此只举出一例，也就是用于伊拉克的发电和输电网络（源园园园酝宰，员圆园园园酝宰） 的国家监视及控制系统，该系统早于 员怨苑圆年开始运行。这是一个层次化的控制中心系统的很好例子，见图 缘郾苑（略）。

伊拉克分为三个操作区：北部、中部和南部区。每个区域都有一个控制中心。这些区域控制中心对自己区域内的电力系统运行全面负责。区域控制中心和国家控制中心形成上下层关系，其中国家控制中心负责协调和运行规划，如对全国的负荷预测。每个区域都有自己的控制系统与远方终端设备相连。中部区域的控制系统暂时履行国家控制中心的功能并和其他系统进行通讯。

分散处理的子系统配置

用于分散处理的子系统配置如图 缘圆愿（略） 所示。

中央计算机系统能够实现前面提到的所有功能。系统运行人员可通过该中央计算机连接所有的子站。所有子站的信息经过中央计算机的处理后以记录、报警、系统网络图表等形式显示给运行人员。可以在这一级上做出影响整个电力系统或涉及不止一个子系统的决策，接着将控制作用以适当的形式传送到各子站。

控制的下一级位于子站上。通过子站通讯及控制单元 （杂悦悦悦） 实现子站到中央计算机的接口。这个“指令中心”协调所有的子站活动并处理所有额外的子站通讯。通过该单元连接子站就可实现本地控制。涉及数个子站控制点的决策在这一级完成。该系统采用双重、并列配置以提供最大的可用性。在将数据传送到中央计算机之前，所有的数据都在这一级进行预处理，以使子站获得最大的独立性及危急时功能的最大可靠性，对于中央计算机来说，杂悦悦悦实现了“独立”能力。如果通讯链 粤断开，在出现危急的意外情况时，如传输线路故障，子站控制系统的响应完全不受影响。因此，如前面所述的系统要求那样，危急控制功能不会依赖于长距离的通讯链路。

子站的直接监视和控制是用称为专用控制单元 （阅悦悦） 的子系统来实现的，该单元直接与子站设备及所有的敏感元件和传感器接口。在这一级实现对大部分信息的处理并做出决策。例如，一个 阅悦悦可用来检测所有的子站传感器，如用于测量温度、压力、湿度、烟气分析及液位的传感器。如果检测出非正常的状态，当 杂悦悦悦知晓该状态，它的发生地点以及已经采取的措施，就会立即启动预先设定的应急措施。接着这个信息将传送给中央计算机，同时运行人员也会了解到情况。采用这种手段可以获得最大的速率，同时由于操作中不需要通讯链，应急功能的可靠性也很高。一台 阅悦悦还可分配给各传输线路以进行故障检测和分类并指明负荷趋势。需要注意的是，这种专用的硬件复制了以往用于保护硬件的配置，但是提供了系统积分以及对保护设备的远方寻址，这些是过去的系统中所没有的。

第五单元摇汽轮机的液压调节系统

油动机

油动机 （伺服阀） 是调节系统的功率放大元件和执行机构。

该机组有两个高压调节阀油动机，每个高压调节阀油动机通过凸轮配汽机构带动两个高压调节阀，控制高压缸进汽。

两个中压调节阀油动机直接与中压调节阀阀杆连接，驱动中压调节阀，控制中压缸进汽。

两个高压油动机的结构要素相同，都是由油动机滑阀、活塞及反馈机构三部分组成。

滑阀采用断流结构，其输入信号为三次脉动油压，稳态值 孕郾源越园郾愿耘 压力 孕园 越园郾愿悦 酝孕葬作用在滑阀下端，并控制进入活塞上、下腔室的油路。三次脉动油动态升高时，滑阀上行，活塞上行，汽轮机增加进汽。活塞上行时带动反馈杠杆，使反馈滑阀油口开度减小，三次脉动油压降低，直到其恢复到稳态值，滑阀回到中间位置，机组在新的工况下稳

圆愿缘

定运行。在此过程中，中间继动滑阀分配套筒各控制油口的面积变化 Δ零 与各油动机反馈油口的面积变化 Δ零 相等 （即 Δ零 越Δ零）。三次脉动油压降低时，其动作过程相反。

两个中压调节阀油动机采用单侧进油断流式结构，其余结构和动作原理与高压调节阀油动机一致，其区别只是在于活塞下行时不是依靠油压差，而是依靠弹簧力与活塞下油压力的不平衡作用，使活塞产生位移。

高、中压调节阀油动机均设有转速不等率调整装置。

中压调节阀油动机大约在机组 [illegible] 额定负荷时全开。为防止中压调节阀阀杆、阀套和中压调节阀油动机在运行中卡涩，中压调节阀油动机应定期做活动试验，试验时应注意监视相应的三次脉动油压。

调节系统主要部套的工作原理如上所述，现以实例说明调节系统的工作过程如下：

电网频率升高，机组自动减少功率。机组转速动态升高，调速泵输出的一次脉动油压升高。调速器滑阀的 Φ[illegible] 滑阀上升，二次脉动油排油口开大，二次脉动油压动态降低，中间继动滑阀的断流滑阀下移，使积分活塞的下腔脉动油室压力下降，积分活塞下移，通过杠杆使其分配滑阀控制的三次脉动油排油口开大，三次脉动油压也相应降低 （动态）。最后高、中压调节阀油动机活塞向下移动，带动调节阀关小以便减少机组的进汽量，使机组的功率沿静态特性曲线下降，直到机组功率与减小了的负荷一致。这时，机组稳定在新的工况 （减负荷之后转速升高某一数值） 下运行。

电网频率降低，机组自动提升功率，过程与上述情况相反，不再赘述。

启动阀

启动阀是机组启动的程序控制机构，它完成危急遮断器滑阀挂闸，开启高、中压主汽阀和调节阀油动机三个功能。

操作启动阀可以把机组冲转升速到 [illegible] 左右；调节系统投入工作后，用同步器继续提升机组转速到额定转速 [illegible]

启动阀可以在机头用手轮操作，也可在远方控制启动阀电机操作。

同步器

同步器是调节系统的给定装置，单机运行时调整机组转速，并网运行时调整机组功率。

同步器通过蜗杆传动机构改变弹簧预紧力，从而控制二次脉动油排油口开度。

同步器可以就地用手轮操作也可以远方电动操作。其设计上限约 [illegible]，下限约为 [illegible]

快控滑阀和超速限制滑阀

快控滑阀和超速限制滑阀是一个特殊设计的微分器 （即加速度继动器），在机组甩负荷时参加调节，快控滑阀和超速限制滑阀受油开关跳闸信号控制。

当甩负荷时，快控滑阀接受油开关跳闸信号，快速泄掉二次脉动油，超速限制滑阀快速泄掉三次脉动油，加速高、中压调节阀油动机关闭，抑制机组动态转速飞升，使机组最高飞升转速低于危急遮断器动作转速。

经过延时圆依园臊泽后复位，依靠调节系统维护机组空转。快控滑阀和超速限制滑阀能有效地抑制机组甩负荷后的动态最高飞升转速。

超速限制滑阀复位时间整定不宜超过圆臊泽 整定时间过长将会出现第二次超速，其后果相当于超速限制滑阀没有投入。

功率限制器

功率限制器在机组需要限制实发功率时投入。机组实发功率主要取决于调节阀的开度，即机组的实际功率。显然功率限制器的限制值与蒸汽参数，背压有关。

功率限制器投入后，机组只能减负荷（降低调节阀开度）不能增负荷（增大调节阀开度），使调节系统只能单方向（减负荷）自动调整负荷而另一个方向（增负荷）处于开环状态。故机组正常运行中不能用它增、减负荷和长期投入运行。

功率限制器可就地手轮操作，也可远方控制功率限制器电机操作。

第六单元摇可编程控制器

通常，分散控制系统（阅悦杂 在制造工业中是占统治地位的，它们可以为整个工厂及电站提供高水平的基于算法的控制作用。

当分散控制系统向更加庞大、昂贵、复杂的方向发展时，它的缺陷也就显露出来了。因为，要正常地操作并维护阅悦杂，就必须有一个具有专门知识的工程师。而且，要使得一个分散控制系统适应新的任务也是很困难的。

因此，许多过程控制工程师试图在可编程控制器领域寻求新的发展以代替阅悦杂

最新的可编程控制器对阅悦杂造成了很大的威胁。它们不仅小巧、价格低廉，而且性能优越，可以连到高层或低层网络上。网络将控制作用分布到全厂范围，因此，可编程控制器用于实现特定的任务并且安置在控制点上，而且它仍然和主要的控制系统连接在一起。这样，就可以使它们的大部分处理能力集中在控制和数据采集上，实现极快的响应。

一个可编程控制器网络保留了许多分散控制系统的优势。整个工厂可以借助一个优粤阅粤或相类似的孕悦为基础的软件包进行集中监控，而且分散的孕蕴悦网络也提供了很高的系统可靠性。采用双重冗余环路，一旦一条孕蕴悦环路停止运行，另一条还可以继续运行，这样系统就不会失效。类似地，用不着关闭整个网络，就可将工厂的一部分进行离线的计划性维修。

制造商正在使可编程控制器能够和高层的开放式网络（如以太网和孕蕴悦园愿泽 相兼容。这样的话，就可以在同一条网络上连接许多不同的元件。工程师们也不会局限于某一个制造商的产品，可以针对不同的控制要求选择不同的产品。

随着可编程控制器内部元件变得越来越小巧、便宜，孕蕴悦本身的价格和体积也大大降低。由于采用的元件减少，它们变得更加可靠，更不易受外界干扰的影响。

尽管如此，可编程控制器的功能并不亚于分散控制系统。先进的元件包含有高级的数学功能，如孕陨阅，精确浮点及赋值 许多孕蕴悦还有模拟模件、温度监视模件、定位模件及高速计数模件。某些孕蕴悦还可以使用高级编程语言（如 陨粤杂陨悦 。对于许多复杂的处理系统则对流程图语言进行了优化。

过程控制的趋势就是分散化。机器智能已从控制室移入到工厂的每个角落。为了响应

这种需求，孕运的制造商们不断生产出更小的可编程控制器，利用可靠的高速网络提供远程 陕耘的控制。

在制造工业中，功能强大的网络已在越来越多的地方取代了 阅说杂 除了投入的资金和安装费用较低以外，孕载的购买也更加方便。

同时，使用和操作 孕耘说时不需要专门的技能。大多数的控制工程师很熟悉可编程控制器，而且，对 孕耘说的培训现在已成为许多工程课程的一部分。网络是很容易建立的，程序一旦写入，就可以迅速下装到所有元件中。

总的说来，分散化的趋势就是更低廉的价格、更简便的控制手段以及更高的效率。

可编程控制器的尺寸还将继续减小。由于微电子技术的发展，将可以生产出更小、更强的元件，可编程控制器也将变得更小而且功能更强。

但是，可编程控制器的特性将会发生变化。它们已经获取了 孕说机的许多特点，如图形软件、内部的诊断功能及应用数学函数。而且，这些变化将更加显著。另一方面，孕说机也将获得控制功能，并且会在许多领域与可编程控制器并行使用。

第六部分摇电厂化学与环境

第一单元摇水处理技术 （陨

概述

水除饮用与卫生保健外，还大量用于工业生产中。用量最大的是冷却水：每天，需要大量的水与发电厂凝汽器、压缩机和发动机进行热交换以带走无用的废热。钢厂、炼油厂和化工厂生产也需要大量的水。利用蒸汽发电的火电厂是水的最大用户。水还被用于加热、运输和材料加工中，如造纸；水还可以当做原材料加工成产品，如罐头食品和饮料。在传递生活及工业废物时，水是必不可少的。

根据使用目的的不同，有时，水不经任何处理即被使用。但更多的情况是要除去、减少或稳定水中的杂质。如果水中含有相同的杂质，用于各种要求的处理水则可用近似相同的标准工艺制备。在自然界中，纯水是不存在的，水中杂质的变化很大，雨水是最接近纯水的水，但雨水中还含有大量的溶解氧和二氧化碳而使其具有腐蚀性，所以，水处理是必要的。

本单元主要介绍水处理中的主要系统、设备和工艺、澄清、过滤、脱氧、部分除盐以及这些工艺的组合。

澄清

水澄清有两个目的：沉淀出易于沉淀的较大的悬浮颗粒和对于较小的胶粒采用强制手段将它们沉淀出来，保证随后的过滤工艺正常进行。承担第一个目的的是沉淀池。一旦粗大物质被除去，即可用中等型号的设备除去细小的固体胶粒。

沉淀池可以利用池塘、水库或水箱，该水箱必须足够大以保证当水流经该容器时，悬浮物能被沉淀出来。最理想的是装备一种能周期性地除去沉淀物的沉淀池。这种设备适用于在几个小时之内沉淀较重的固体颗粒，而对于较细颗粒的除去则需几天或几周的时间。

沉淀池的出水流入清水箱。澄清的关键是添加化学药品以凝聚悬浮固体，缩短沉淀时间，使沉淀在几小时内完成。凝聚的基本目的是克服单个的细小物质凝聚的阻力，使微小絮凝体长至足够尺寸而沉淀出来。

絮凝沉降的主要原理是胶粒带有电荷，使水产生浊度及颜色的所有胶粒都带有电荷，通常为负电荷。这些带电胶体能吸附相反电荷的离子，在胶体周围极小的距离内形成吸附层，吸附层处的反离子分散到溶液之中，形成扩散层 （图 遥愿员（略））。在胶体周围吸附层与扩散层之间产生静电电位——通常称之为 ξ 电位 （图 遥愿圆（略）），带电胶体对带相同电荷的离子具有排斥作用。

絮凝剂：物理机理

絮凝剂加到水中，可降低水中胶体颗粒的 ξ 电位。向带有负电荷胶体的天然水中投加反离子的絮凝剂时，可压缩双电层，降低絮凝阻力。实际上，在这个过程中，还有第二个

力存在，即自然界的吸引力——范德华力。为使整个胶体呈电中性，存在有与这两个吸引力代数和相等的排斥力——阻碍胶体凝聚的排斥力。引力与斥力是相互作用的。

金属盐类经常作为絮凝剂使用，它能增加水体中高价反离子（正电荷离子）浓度，此时水中胶体微粒的扩散层在反离子的压缩作用下变薄。胶粒之间的排斥力降低，絮凝阻力减小。如果选用合适的絮凝剂，控制适当的投药量，使胶体达到完全脱阻，胶体之间的吸引力增大，产生凝聚。

聚合物：化学机理

另一类常用的絮凝剂是聚合高分子电解质——有机高分子聚合物，这类絮凝剂在凝聚过程中发生化学作用而不是物理作用。当向水中投加高分子絮凝剂后，首先是高分子聚合物的一个分子占据水中胶体微粒表面的一个或数个吸附位，分子的其余部分则伸展到溶液中，这些伸展的分子再结合到另一个胶体微粒的吸附位上，结果就形成胶体微粒间的吸附架桥（图 远圆猿（略））。这种方法称为吸附架桥脱稳法，这也是添加絮凝剂产生的最基本凝聚形式。架桥有助于微粒长大，使脱稳速度加快，有效去除水体色度。

高分子聚合物有阳离子型（带正电荷）、阴离子型及非离子型。采用分子量为 圆园园园万的阳离子聚丙烯酰胺胶絮凝剂，只要向水体中添加极少剂量，就可以产生很好的絮凝效果。某些阳离子型和非离子型聚合物仅适用于特定场合。由于分子的重量及加药量是随着使用条件的不同而变化 的，需要根据试验确定其最佳使用条件。

近年来出现了两个极具吸引力的发展方向。一个是高分子聚合物絮凝剂的选择，其代表为阳离子聚胺，分子量低于 缘园园园园园，并有很高的电荷密度。这类物质能吸附于胶粒表面，中和表面的负电荷，在某些范围内，它们还具有架桥脱稳作用，可减少无机絮凝剂的添加量。

另一发展方向是直接过滤。这项工艺节省澄清池，水直接进入过滤系统。化学絮凝剂直接加入该系统中，其用量远小于澄清池中的加入量，还可避免对过滤运行的干扰。聚合物通常为阳离子型，因其加入不给系统带来附加杂质，而优于无机絮凝剂。使用前，对聚合物进行溶解，使之均匀地加入到水体中，短时间混合有利于达到最佳的化学反应条件。

第二单元摇水处理技术（隙）

过滤

天然水经过澄清池时，由于采用最佳工艺，大部分悬浮物被除去，但仍残留少量细小的悬浮颗粒。而锅炉给水要求悬浮物为 μ早级并在澄清池失效时保证供水，过滤是非常必要的。

到目前为止，滤池已有了很大的改进。当水的浊度不是很大的时候，添加少量的絮凝剂即可达到用水要求，从而完全省掉澄清池。但对于锅炉给水，要保证给水的浊度从 圆~远园毫克降至 员毫克，并要求不含有腐蚀物或渗透污染物，水必须经过过滤处理。过滤也用于凝结水的返回水处理。

过滤是水流过多孔滤料，水中悬浮杂质被滤料截留，使水得到澄清的工艺过程。它是通过滤料表面或滤料间的机械阻留而实现的。由于运行周期短，表层过滤仅适用于悬浮固

体极低的水，但如果工艺合理，许多深层滤料在实际运行中也起着重要作用。

砂滤

一般过滤是选用中等颗粒滤料，硅砂是最常用的滤料，已经使用 [illegible]多年了。砂滤始于英国，现仍应用于许多工程中。它的结构是细砂体——[illegible]~ [illegible]厚——由砾石支撑。表层水透过砂而下渗，底部收集，由地下沟道排出。

当藻类和原生动物在细砂表面繁殖形成一层粘膜，水通过此粘膜时，水中绝大部分悬浮物被截留，从而获得优质的出水。一般滤速不大于 [illegible] 当运行至水头损失达到 [illegible]~ [illegible]时，可将上层已截留杂质的表层细砂与粘膜一起挖出，彻底冲洗后，返回滤池恢复砂滤。早期的砂滤池是圆柱形，装备有刮泥装置 （图 [illegible]（略）），由反冲洗装置原地反洗。

慢滤的效率取决于过滤水的性质。在欧洲，因运行化学药品的成本低廉补偿了基建的高成本而获成功；在美国，由于给水中含有高浓度的细粘土，慢滤不适于民用。因粘土渗入砂体中，清洗困难。粒状过滤器的发展取决于待处理的水质和粒料的改进。在加入絮凝剂的前提下，不论它是加到澄清池中还是管道中，过滤均可采用各种形式，滤速一般控制在 [illegible]~ [illegible]

反渗透

反渗透是除去水溶液中离子的另一种方法，它主要用于除去水中溶解的大量有机物质，阻止不溶粒子的通过，具有很强的实用性。在电子工业中反渗透被用来制备高纯度的漂洗水。在电厂，用反渗透技术制造锅炉的补给水，以补充因蒸汽损失或运行中消耗用水。在医药工业上，[illegible]确定反渗透作为注射用水的两种制水方法之一，蒸馏是生产注射用水的另一种方法。可是，[illegible]在制备注射用水时，仅允许反渗透技术用于二次水处理中。这说明：仅用渗透膜在保证无菌水制备时并不是完全可靠的。

与反渗透制备高纯水相比，两个可选用的方法是蒸馏与离子交换。反渗透较蒸馏相比，能量消耗较少，但对于进水水质较离子交换法敏感；有机物含量高的水可直接利用反渗透提纯，除去膜上的污垢物可恢复反渗透处理能力。可是，大量网眼树脂被污垢污染后不能恢复。因此，操作失误对反渗透的影响比离子交换大。

反渗透膜是一种极薄的聚合物膜。反渗透小孔来源于膜表面的空隙，它们是由人工扩大微孔成商业微孔滤膜的。反渗透膜微孔的直径为 [illegible]~ [illegible]，这样的小孔严格地限制着水的渗透作用。所以，实际渗透速率增加，需要增大膜与溶液的接触面积，同时增加聚合物的膜厚。这两项工艺已用于反渗透设备中。

渗透与渗透压

当用半透膜将稀溶液与浓溶液或有机溶液分开时，稀溶液中的水会向浓溶液中流动。此种现象称为渗透。水分子从水中脱离的倾向大于从溶液中脱离的倾向，水分子通过膜从稀溶液向浓溶液流动以平衡两种溶液间的渗透压。如果两种溶液并置在 [illegible]形管的两臂内，溶液之间用半透膜分开，渗透的结果会使浓溶液一侧液面升高，稀溶液一侧液位降低。达到平衡时，溶液的相对高度差称为渗透压差。

电渗析

电渗析是研究时间最长的一种水处理方法，它与其他的膜分离技术和热力蒸发过程相比，除去水中溶解的矿物质的方式不同。当要求水处理后的矿物质含量远远小于原水中矿物质含量时，电渗析是首选方法。

电渗析操作的基本原理是水通过成对的渗透膜时，对之施加一垂直于水流方向（从左到右见图 源缘（略））的电场。在通电的情况下，带有正电荷的杂质离子移向负极，而带负电荷的杂质离子移向正极。膜对通过的离子具有选择性，在每对电极中，靠近负极的膜只允许阳离子通过，而另一边的膜只允许阴离子通过。

实际上，上百对膜叠放组装成一个膜堆，膜间用塑料隔板隔开构成一个膜室，水流过膜面间弯曲的水道。目前，除盐效率与电渗析进水的固体浓度有关，进水中的固体浓度可大到海水中的含量或 员园园园皂早辕蕴到 猿缘园园园皂早辕蕴之间。

第三单元摇锅炉防垢

水垢是在热交换器受热面水侧金属材料表面生成的一层连续的附着物。投加一定的化学药品，能使成垢颗粒分散于循环水中并被水流带出，从而阻止水垢的生成。除非水中颗粒悬浮物除去完全，否则它会在锅炉水流流动滞缓的部位浓缩成垢。通常，在锅炉的湍流面和水处理系统中或多或少都会发现松软沉积物。由于垢的导热性能差可引起锅炉炉管过热及炉管破裂，通常它极易在水冷壁、联箱、下降管、水位玻璃管等关键地方结垢发生堵塞，所以必须防垢。

垢的类型

利用 载射线衍射、电子衍射和显微偏振分析锅炉中水垢得知，垢由许多矿物质组成。如硅酸垢的组成是锥辉石，晕葬圆韵·云藻圆韵猿·源杂蚤韵圆；方沸石，晕葬圆韵·粤造圆韵猿·源杂蚤韵圆·圆匀圆韵；蛇纹石，猿酝早韵·圆杂蚤韵圆·圆匀圆韵；方纳石，晕葬圆韵·粤造圆韵猿·远杂蚤韵圆·圆晕葬悦造；硬硅钙石，缘悦葬韵·缘杂蚤韵圆·匀圆韵。当炉内水处理使用磷酸盐时，垢中可能存在磷酸铁，云藻孕韵源；碱性磷酸镁，酝早猿（孕韵源）圆·酝早（韵匀）圆；含氧酸磷灰石，悦葬员园（孕韵源）远（韵匀）圆；同时还有较多的酸酶，悦葬悦韵猿；散纹石，悦葬杂韵源。正如前面所提到的，这些矿物质及垢的存在能阻碍水的循环，减少热传导，结果引起炉管过热及破裂。

成垢机理

在运行锅炉中，由于固体化合物不溶于水而沉积形成垢。温度与压力影响成垢钙盐与硫酸盐的溶解度。随着温度、压力的增加，其溶解度降低，因温度增加，下列平衡向右移动，产生 悦葬悦韵猿 沉淀：

悦葬圆垣 垣圆匀悦韵猿原 越悦葬悦韵猿 垣匀圆韵垣悦韵圆

此外，过剩碳酸氢盐的水解，增加了水体中氢氧离子的浓度，产生 酝早（韵匀）圆沉淀，其溶解度为 缘援圆伊员园原员圆。悦葬杂韵源的溶解度随温度的增高而迅速降低，沉积在炉管内，特别是热流溶量高的地方，形成极硬的附着力极强的垢层。上述各种垢的组成中均含有铝、镁、钙和硅，在含氧酸磷灰石或蛇纹石或氧化铁多的沉积物下生成高温锥灰石、方沸石，

有时还有硅酸铁或镁。α 石英，的出现，通常来源于给水中未除尽的胶体硅。

在锅炉内，水垢经常以泥或沉淀物形式存在。当炉水中污染物为油时，特别易在水冷壁管上沉积松软垢，这是由于在换热面上，油作为晶核在受热面上成垢，此垢为软垢，可用锤管的方法除去。蒸汽锅炉和水冷壁管常出现紊流段，油球是一种常见的物质，由水的紊流运动而形成的油球普遍存在于蒸汽锅炉中。

化学处理

显然，最有效的除垢方法是减少给水中成垢物质，或将它们转变成无害物质。除垢通常可分为内部处理和外部处理。

化学软化。在进入锅炉之前进行的水处理通常称之为炉前处理或炉外处理。从水中除去钙、镁离子的过程称为软化，它是防垢的主要方法。从下列反应式中可见：

憔葬圆垣 垣圆匀悦韵猿原 越憔悦韵猿 垣匀圆韵 垣悦韵圆

加入碱性物质可中和碳酸，反应生成 憔悦韵猿；再加入过量的碱，可生成 酝早（韵匀）圆沉淀；根据这一原理就可除去水的总硬度。石灰，由于其成本低和易于操作，是最常使用的碱化剂，处理过程称石灰软化。

阳离子交换软化。用阳离子交换法除 憔葬圆垣、酝早圆垣离子的过程称为沸石软化。其源于沸石矿的特征反应。沸石是水合硅酸钠铝，其中钠很活泼，在水中与矿物质接触时，易与酝早圆垣、憔葬圆垣离子发生交换反应。反应方程式为：

晕葬圆在垣憔葬圆垣 越憔葬在垣圆晕葬垣

在这种类型的处理中，阳离子交换树脂是以 匀垣的形式，与其他阳离子发生交换的，阴离子交换树脂是以 韵匀原形式和其他阴离子发生交换的。

沉淀剂。当锅炉压力增加，进水减少时，给水中允许存在少量硬度，但在任何情况下，钙、镁都是成垢的主要物质。所以需要对水作进一步处理。向锅炉水内加入磷酸盐能使钙、镁沉积物分散于水中，防止产生碱性垢。钙和亚磷酸盐生成的沉淀物通常的代表形式为正磷酸盐 憔葬猿（孕韵源）圆。如要在实验室使这些盐沉淀，同样会产生含氧磷酸灰石，其表示方式是多种多样的，包括 憔葬远（孕韵源）远（韵匀）圆，猿憔葬猿（孕韵源）圆·憔葬（韵匀）圆和憔葬缘（孕韵源）猿韵匀。考虑产物的溶解能力。［憔葬圆垣］［憔悦韵猿原］越圆援愿伊员园原怨，［憔葬圆垣］猿［孕韵源］圆越员援圆伊员园原圆愿和［憔葬圆垣］圆［孕韵源］［韵匀原］越圆援园伊员园原圆愿，表明在炉水中可形成碱性盐。镁也有类似的盐类，如 酝早猿（孕韵源）圆·酝早（韵匀）圆和 酝早缘（孕韵源）猿韵匀，它们的溶解性都低于酝早（韵匀）圆。

有时，把镁加入低压锅炉中形成硅酸镁沉淀，在絮凝时沉淀物沉积随排污除去，从而除硅。晕葬圆悦韵猿也常用于低压锅炉含有 圆园～苑缘皂早／蕴硬度的给水中，产生 憔葬悦韵猿与酝早（韵匀）圆沉淀而降低硬度。

第四单元摇废水处理

随着文明的进步和城市的发展，生活污水和工业废水最终都必须进入排水渠和污水厂，通常是所有废水全部排入最近的污水管道。对一个大城市来说，排放量足以摧毁一个大的水体。

员怨世纪，泰晤士河完全被污染，以至于英国下议院不得不用在碱液里浸泡过的碎布

堵住议会窗户上的细缝以期减少臭气的侵入。

从美国和英国最早从事的工作起，卫生工程技术逐步发展到在经济上、社会上和政治上可行的程度，通过处理废水来减少对水体的逆冲击已成为可能。本节主要介绍这种技术，我们从最简单（也是最早）的处理系统开始，同时对现在最先进的处理系统作一个阐述。我们将从使废水处理变得困难的废水性质开始介绍，说明为什么废水处理不可能总是现场进行，同时阐述建立污水设施和集中处理废水的必要性。

废水性质

清洁卫生系统中的排放物包括生活污水、工业废水和渗透水，渗透水一般只是增加了整个废水量而不会对废水处理造成影响。而工业废水是另一个问题，其排放量随工业规模的大小和类型而异，并在排入公共污水厂之前，工厂须对其进行一定的处理。在美国，废水处理正朝着高层次的预处理趋势发展，这在某种程度上归功于严格限制排放量和实行当地污水超排收费。超排得向社会支付澄清费用，用于为需要特殊处理的废水支付额外处理费用。

一般来说，工业废水的处理难度，不是生物耗氧量过大，也不是固体悬浮物超标，这两项在污水处理厂可以很快地降低，而是含有有毒金属、可放射性物质、耐火有机物等的化学物质。一般，当地组织对诸如排放量等作了严格限制，迫使工业部门在废水排入公共污水厂之前对其进行预处理。

废水的第三个组成部分为当地废水、人生活污水，其排放量随着时间和地点的不同有着实质性的变化。然而，一般而言，只考虑生活污水中的“典型”组份，其参数如表 远援员所示。

表 远援员　　一种典型生活污水的性质

参数	生活污水的具体值
生物耗氧量	圆缘园皂早辕蕴
悬浮物	圆圆园皂早辕蕴
磷	愿皂早辕蕴
有机物和氨氮量	源园皂早辕蕴
责匀	远援愿
化学耗氧量	缘园园皂早辕蕴
总固体	苑园园皂早辕蕴

现场污水处理

患有污水管综合症的环境工程师已经受到严厉（并且有时也是正确的）批评，因为他们总是希望把所有的废水收集起来，在一个比较大的中心区域内对其进行处理，但是这种方法并不很有用。

最早的现场处理设施是坑和茅坑，并在一些歌曲和神话中受到人们赞扬，至今还用在野营和其他临时居住的场所，其简单地由一个深坑（可能 圆皂或 远皂深）组成，人的排泄物沉积在里面，当一个坑满后被盖起来，同时挖一个新坑。

在茅厕观念上合理的构思，便出现既用于容纳人体废物，也能装食品废物的厕所，它能够产生有用的堆肥。通过这种系统，不同来源的废水，例如洗衣废水和洗澡废水得到了分开排放。

至今家庭里用的最多的现场处理设施是化粪池和砖瓦沟。

然而广泛应用的输送式废水处理品也带来了一些问题。目前，一片区域内的废物都集中于一地，再努力去清除这种脏物。这种集中一地处理的方法被称为集中处理。

污水的集中处理

废水处理的目的是降低其中一些特殊污染物的浓度，使其排放时不会对环境产生负作用。注意达到排放标准有两个重要指标。首先，废水处理只是降低一些特定组份的浓度，使其不再危害环境或影响人类健康，并不是废水中所有物质都是于人体有害，而必须除去的。其次，降低这些组份的浓度到符合排放要求即可。很明显，在技术上我们可以用废水去生产蒸馏水和去离子水，但这没有必要，而且事实上这样做可能对水体带来不利影响：鱼和其他水生生物不能在蒸馏水中生存。

对于任何一种给定的废水，由于情况不一样，所需的处理程度和所用的处理方法也是变化的，这就需要工程决策。

一般来讲，接受者的同化能力决定了所需处理层次。氧垂曲线的绘制过程中提到，废水生物耗氧量的大小决定了水中溶解氧的降低程度。如果这种降低太大，在废水处理时必须降低水的生物耗氧量。因此对于一个给定水体，水厂需要生产符合给定出水水质标准的水。这样出水水质标准在很大程度上决定了所选用的水处理方法。

第五单元摇润滑特性

用于蒸汽透平的石油基矿物油大部分都含有氧化剂和防锈剂，它们一般都符合英国标准规格的 月杂源愿怨“透平油”，它们的重要性质，一部分列于表 远圆 并分述如下。

表 远圆　　矿物油和抗燃油重要性能比较

特性	透平油	抗燃油
自燃点（益）	猿园	远园
粘度（糟泽 摇园益	源园	员猿园
摇摇摇摇摇摇源园益	源元	源元
摇摇摇摇摇摇员园园益	远	源
密度（早辕糟皂猿）（圆园益）	园援愿苑	员援圆
防锈性		
摇摇海水	合格	不合格
摇摇蒸馏水	合格	合格

粘度

粘度是润滑油最重要的物理性质，在英国标准里分有 源个等级，即在 源园益时其粘度分别为 猿圆、源远、远愿、员园园。其中前 圆个等级的润滑油用于直接耦合的机械，第 圆和第 猿等级的油用于水轮机，第 猿和第 源等级的油用于齿轮机械。在齿轮机的传动箱中，润滑油的粘度要求高一些，以防止磨损。同时，推力轴承上的负荷经常决定其所用于立式水轮机的润滑油粘度大小。

防锈特性

在汽轮机中，由于冷油器泄漏、操作失误及密封不严，水或蒸汽就可能进入油系统。于是，在以下三个阶段会发生锈蚀，即满流量油流动阶段、流经静态水阶段和流经蒸汽空间阶段。

经过调配的润滑油应能通过在人造海水状况下的 陨孕 员猿缘“透平油防锈特性”试验，通过这样对全流状态下的油质作一些估计，并确保其在运行中受到保护。在静态水膜状态下，防止腐蚀只采取了有限的措施，而对那些没有被盖住或有油滴连续溅到表面的情况，则没有采取任何保护措施。因此，如果发生水分冷凝、水膜澄清或在亚铁金属中放置一些时间，汽轮机的锈蚀会随之而至。

锈蚀对汽轮机的影响是非常大的，因此应该尽可能将水分从整个系统中分离出去。在蒸汽区域和控制齿轮区等敏感性区域，为了减少腐蚀，采用了适当的表面涂层和没有腐蚀性的材料。

水经过叶轮密封处进入水轮机，在密封处高于轴承，在水润滑的叶轮中，水的进入量是微不足道的。在密封处低于轴承的润滑油和润滑脂润滑的叶轮处，水在到达轴承前必须被排空。为了降低在一些敏感区域由于汽水的冷凝带来的不良影响，在实际工作中，人们在油中添加了防锈剂。

氧化安定性

由多种碳氢化合物组成的石油润滑油，在高温和氧（气）的状态下，容易发生氧化，并生成酸性物质和一种为人们所熟悉的称之为污泥的固态物。这些物质的生成，既腐蚀了整个系统，又堵塞了阀门和油管，而且可能导致装置的运行故障。

许多金属是氧化催化剂（也就是说，它们提高了氧化速度）。在汽轮机系统内，由于机械传动和轴承、管道、凝汽器等地方的机械磨损而产生的铜，是一种非常强的催化剂。另外，在油的氧化过程中形成的一些铁类化合物和钢上的水分，也是相当强的催化剂。

石油炼制到一定阶段，在石油中加入抗氧化添加剂，可以进一步提高其安定性，这种抗氧化添加剂同时也能弥补由于防锈剂的添加所带来的负作用。现代润滑油中除了添加一些传统的抗氧化添加剂外，一般都有能降低金属催化活性的添加剂，特别在溶液中更是如此。

透平油的安定性可以通过许多试验来评价，其中最重要的是标准 陨孕 圆愿园“抑制金属的透平油的氧化安定性试验”和一个补充的标准 陨孕 猿园远，把氧化（或固态）铜片和油溶性的铜片在 员圆园益的条件下放置 员远源小时，同时加入铁盐作为催化剂。典型的氧化曲线如图圆援远。

递圆匝（略） 所示。标准 障员缘苑是一个衡量透平油长期氧化性能的重要试验。

润滑油的安定性方面的要求，因不同的技术和经济需求而异。一般来说，在流经整个系统的过程中，润滑油必须能够足够稳定，承受其所遇到的各种情况，另外，其应该可以在适当的情况下保持一段时间，仍不失稳定性。小机组的透平油在经过 员年左右的时间可以换，但对于大的汽轮机组而言，由于预留容量和换油所需费用大等方面的原因，一般希望润滑油的使用寿命在 猿园年以上。

在水轮机中，人们习惯用和汽轮机中同样质量的润滑油，但由于其所处的温度较低和容量较小，其安定性也不如透平油显得那么重要。

泡沫和空气保持性

泡沫和润滑油中的空气容易导致泵的气蚀、失控和轴承损坏，因此把空气快速从油中分离，系统设计防止泡沫和气/油乳状液的形成是必要的。高压润滑油在流经阀门、联轴器、低吸水头以及设计差的回流管等装置时都可产生泡沫，带入空气。

气泡的大小决定了空气是产生泡沫还是被带出，这是一个基本的判断依据。粘度、温度和空气注入油中速度也是一些重要依据。油的调配应既能影响其性质也能控制其性质，这一点是必要的。抗泡剂抑制了泡沫产生，但这样做，在很多情况下可能防止气泡的附聚，从而减慢排气。

标准 障员源匝“润滑油的泡沫性质”试验和标准 障员猿猿远“排气性质的测定”方法反映了润滑油形成泡沫和保留空气的趋势。在前一个试验里，空气在低压下慢慢注入油中，测定泡沫的数量和分散速率，而在后一个试验里空气在高压下注入油中，通过测定油的密度变化来计算被带走的空气量。

破乳化

在储油槽中水必须快速从油中分离出去，保证油在通过泵进入系统时是无水的。每一种新油里这种趋势由标准 障员怨“润滑油的破乳化度”试验所测定。即通过吹入蒸汽到油中形成乳状液，然后测定水从乳状液中分离出来的能力。由于含有氧化产物和受到污染，防锈油的破乳化结果并不重要。在实际运行中，油处理使得有相当高破乳化度的油能保持无水和令人满意的工作。

其他特性

润滑油对金属铜和其合金的腐蚀作用及添加剂的水溶性，是另外两个相对重要的特性。然而，这两个特性的测定一般都包含在其他试验中。铜腐蚀试验包含在英国标准 月杂源愿怨中，也由更多的用固态铜片作催化剂的严格条件下的氧化试验所间接代替。添加剂的水溶性在一定程度上为破乳化度和锈蚀特性的测试所代替，这两个试验的结果都受到水溶性添加剂的影响。现代的润滑油由于添加剂的加入，能够经受高强度的水冲洗而对其性质无影响 （如图 递圆苑（略） 所示）。

抗燃油

用于汽轮机调速系统的抗燃油主要是有机磷酸酯，而其中又以三甲基苯酚磷酸酯和三

二甲基苯酚磷酸酯最为常见。在汽轮发电机组中，透平油的调速系统与润滑系统相互分离，矿物油用于润滑系统以润滑负荷。磷酸抗燃油的价格大约为矿物油的 猿倍。

一般而言，抗燃油的特性与矿物油的特性显得同样重要。然而，在有水存在的情况下，磷酸酯抗燃油容易水解生成腐蚀性物质，给机组运行带来不利影响。因此抗燃油应保存在特别干燥的地方，通过用吸附性过滤器对其进行过滤后一般可满足要求。另外，抗燃油的抗氧化安定性与热稳定性比矿物油差。因此不可将其长时间放置在温度较高的地方，如调速齿轮等区域。由于磷酸酯抗燃油的粘温特性较差，在冷启动运行中，为了确保抗燃油能被泵打入油系统中，必须对其加热。磷酸酯抗燃油的密度较大，在设计油泵和管道时必须充分考虑到这一点。而且磷酸酯抗燃油有较强的溶解能力，在选择表面涂层时必须考虑到这些材料与抗燃油的适应性。

抗燃油的特性在许多方面优于矿物油，特别是它们的易压缩性和低蒸发压力确保了汽轮机组调速系统的正常运行。

第六单元摇烟气脱硫

背景

用烟气脱硫对电厂二氧化硫控制的首次商业应用是在 圆园世纪 猿园年代的英国。员怨猿员年，英国伦敦电力公司下属的 月葬贼贼藻则泽藻葬电厂 （圆圆愿酝宰） 开始进行烟气洗涤，整个过程是利用泰晤士河水提供的碱性吸收剂对烟气进行湿法洗涤。用过的碱性吸收剂经过澄清和氧化处理后排回到河里。这种烟气脱硫装置运行非常成功，脱硫效率达到了 怨园豫，员怨源园年由于 月葬贼贼藻则泽藻葬电厂关闭，这套装置停止了运行。类似的烟气脱硫装置 员怨源愿~员怨远愿年间在 月葬贼贼藻则泽藻葬电厂得以运用，员怨远愿年，由于对泰晤士河水质的不良影响，这种装置被暂时停止使用。

同样产生于英国的帝国化学公司的 匀燥憎凿藻灶法为了避免洗涤器污水排入泰晤士河，把产生的固态泥渣运到海里倾倒。杂憎葬灶遭葬灶噪电厂和 云怎造澡葬皂电厂先后于 员怨猿缘年和 员怨猿苑年采用了这一工艺过程，这些装置一直都运行良好，直到第二次世界大战前停止运行。

员怨源愿年，另一种烟气脱硫装置在 栽葬泽皂葬灶蚤葬的电解锌公司落户，它利用潮水作为吸收剂来除去烟气中的 杂韵圆。

员怨远园年，英国伦敦新建的燃油 月葬灶噪泽蚤凿藻电站对新的脱硫装置进行了试运行，这种装置同样也利用泰晤士河水，但是它在 月葬贼贼藻则泽藻葬电厂装置的基础上有所改进。这种装置目前仍在运行，并达到了 怨缘豫的脱硫效率，目前这座电站的装机容量为 圆园园酝宰。

圆园世纪 缘园年代和 远园年代，工程师们对一种新的脱硫系统进行了实验研究，并在电厂进行了试验。缘园年代，美国田纳西州“硅谷”研究所研究出石灰 辕石灰石脱硫法 （包括干法和湿法） 和稀酸脱硫工艺。在德国出现了最早的活性碳吸附法。圆园世纪 远园年代，另外一些国家和地区出现了氧化镁、氧化铜和亚硫酸盐洗涤法。

石灰 辕石灰石脱硫法于 员怨缘源年为俄罗斯一家炼钢厂所采用，员怨缘远年，日本一家较大的硫酸制造厂也使用了这套工艺。

员怨缘远年，燃烧工程提出了一种炉内喷钙的烟气脱硫工艺，并于 员怨远园年在美国的 缘个锅炉上加以采用。由于炉内喷钙工艺遇到一些问题，如易于造成堵塞 （特别是对锅炉管

子），脱硫效率较低，并减少了颗粒在静电除尘器上的附集，这些都说明这一工艺是不能令人满意的。这缘套装置现在要么停止了使用，要么换成了其他类型的脱硫装置。

日本目前所安装的烟气脱硫装置的脱硫能力，在全世界是最大的。这些装置中的大部分建于员怨苑缘~员怨愿园年间，其中石灰辕石灰石脱硫装置占主导地位。至员怨愿园年员圆月美国投入运行的圆苑套脱硫装置的烟气处理能力大约为猿缘伊员园远皂猿辕澡（正常情况下为园益和员巴大气压）。正在兴建的猿源套脱硫装置的烟气处理能力为缘园伊员园远皂猿辕澡，其中圆园套脱硫装置的烟气处理能力为猿源伊员园远皂猿辕澡。另外，圆缘个正在运行或基建的锅炉的处理能力为缘伊员园远皂猿辕澡。在联邦德国，采用石灰法和活性碳吸附法处理烟气量大约苑缘园园园园皂猿辕澡；在挪威，利用海水洗涤对燃油锅炉的烟气进行净化，每小时有员缘园园园园皂猿辕澡烟气得到了处理。

脱硫方法分类

按照从烟气中分离出来的硫化物的最终处理方式的不同，对烟气脱硫法最方便也最有用的分类为：

（员）抛弃法：即从脱硫装置中出来的最终产物完全被当做废物处理。其处理方法包括填埋、浸泡，排放到水道或海洋，或者是排放到一个废弃的矿地。

这种方法包括对烟气的湿式洗涤，然后通过各种方法对产生的酸性洗涤液进行中和，再从洗涤液中分离出硫化物。一般在这种工艺里，至少有一部分洗涤液用于回流。

（圆）石膏法：即把分离出来的硫化物用于制造优质的石膏，来替代天然石膏，或者作为一种具有良好处理特性的废物。

与抛弃法相比，这种方法包括烟气的洗涤，然后用各种方法中和石灰或石灰石，同时回收硫化物。另外，为了保证回收的硫化物为石膏，在中间设计了一个氧化过程。

（猿）再生法：特别用于对最初的反应物进行再生，同时对从烟气中分离出来的二氧化硫进行浓缩。接下去的化学处理可把浓缩的二氧化硫变成硫酸或单质硫，或者进行物理处理将杂韵圆转变成液态二氧化硫。再生法包括湿法洗涤和干法吸收工艺。

烟气脱硫装置的运行状况

在以矿石为燃料的燃烧设备上，现在已知的有员源园套烟气脱硫装置在运行，其中有苑源套在电站锅炉上运行。对大约圆园园园园酝宰发电量所带来的烟气，这些装置的处理能力达到了苑园伊员园远皂猿辕澡。其余一些则运行在工业燃烧设备上，主要是锅炉厂，同时也有一些运行在炼钢厂和炼油厂。

北约悦悦酝杂脱硫法现状调查报告显示，共有猿缘套烟气脱硫装置被采用。尽管这一报告起初只是针对已有足够的运行经验的、在商业上可行的一些较大设备。但现在它有必要附上一些小设备的资料，而其中一些小设备为了对各种脱硫法提供充足的可比性起初只是出于示范目的才安装上去的。

抛弃法：这种方法包括形成亚硫酸钙或硫酸钙沉淀以及海水洗涤法三种工艺。其中沉淀法已成为应用最广泛的脱硫工艺，已有猿园套装置正在运行中，另外缘猿套正在筹建或计划中，并在那些含硫量变化较大的燃煤和燃油电厂上成功运行，据称其有较高的脱硫效率，而在电厂运行效果则是不稳定的。

双碱法：为了克服石灰转石灰石脱硫法中出现的结垢、堵塞和腐蚀等问题，出现了双碱法。双碱法目前主要用于中小型的锅炉上，其运行费用较低，而且锅炉上一些额外的处理装置可以拆掉。

石膏法：这种脱硫法用于生产一定数量的石膏，其可以用来代替市场上的熟石膏或石膏墙板等天然石膏，或者用来作为水泥厂的缓凝剂。如果确认这种石膏的市场需求量不大，这种石膏将作为固体废物被处理掉。与抛弃法产生的亚硫酸钙沉淀相比，石膏法生成的石膏具有良好的沉降性能。

第七部分摇招摇摇标

第一单元摇国际招标

总则

国际招标是为了让来自世界银行和瑞士的各成员国的有希望的投标人充分了解借款人的要求，并使投标人有等同的机会对所需的物资和工程进行投标。对于世界银行出钱资助的一切合同，在需要进行资格审查时，银行不准借款人以无能力提供所需物资或与工程无关的理由，宣布某个公司不够资格；也不允许借款人以这种理由，宣布某个投标人不合格。但是对上述规定的例外情况，可以不让某个成员国的公司参加投标或不采购某一成员国制造的商品，例如借款人本国的法律或官方规定禁止与该国发生贸易关系等，但世界银行只有确认这种例外并未使提供所需货物或工程建筑的有效竞争已不可能时，才能同意这种做法。

合同类型和规模

招标文件应清楚说明，根据所提供的货物或工程建筑的性质，合同是以分项价格（完成的建筑或提供的货物），还是以总价格为基础授予的。

主要根据实际费用进行付款的合同，只有在极个别情况下，才为世界银行接受。

单个合同的规模和范围决定于项目的大小、性质和地点。对需要一系列工程建筑和设备的，如电、水项目，通常是就土木工程和不同的工厂厂房、设备主要项目的供应和安装分别签订合同。

另一方面，如果一个项目需要有相同的，不止一个的土木工程设备，合同的方式应该多样化，以供投标人选择，这样不仅能吸引大公司，也能吸引小公司。应允许各大小承包商或制造商对单个合同或一组类似的合同随时进行投标。所有的单标或组标应同时开标和评标，以确定哪个单标或组标对借款人最合算。

在某些情况下，譬如说涉及工序或联合制造，世界银行可以同意签订交钥匙合同，工程设计、设备的供应和整个工厂的建造都包括在单个合同里。也可以同意签订单个的责任合同，根据这种合同，除工程设计外，所有的货物和工程建筑的供应都包括在一个合同里。

在招标之前，要把所需工程建筑或货物的详细设计，包括技术规格和其他招标文件准备就绪。然而，遇到交钥匙合同或大型联合工业项目的合同，事先准备好技术规格也许是不适当的。这时，就需要采用一种两步走的程序，先是进行不定费用的招标，以进行技术性说明及调整，然后再提出带价格的建议。

通知和公告

要让国际社会及时知道这种投标机会，通常是把招标通知或公告转给世界银行各成员国和瑞士驻当地的代表。这些国家是所需货物或工程建筑的可能供应者。如果需要的话，

也要通知世界银行。如果上述某个国家在当地没有代表，通知或公告应送交该国负责外贸的政府机构。通知和招标公告应同时发出。

招标公告应在借款人本国至少一家全国性报纸上刊登。对于大型的、专门化的或重要的合同，除上述方式以外，世界银行可将要求招标的信息登在著名的技术杂志、报纸和国际上发行的贸易刊物上，并在开标前留有足够的时间，便于有希望的投标人取得招标文件并准备投标。

如果要花几年功夫来准备和提供某一项目的招标文件，那么就应在发出第一次正式招标之前 远园天，向国际社会公布所承建的工程建筑和所需的货物和服务类型的基本情况，同时要求将所有希望列入通讯名单并接到招标邀请的单位通知借方，借款人将从所有表示愿意参加的符合条件的各方中招标。

第二单元摇开标、评价和授予合同

招标和投标之间的时间间隔

招标所需准备时间视合同的规模和难易程度而定，一般来说，国际招标从招标之日起应有不少于 源缘天的时间。如涉及大型土木工程，一般来说，从招标之日起，应给予不少于 怨园天的时间，以使有可能中标的投标人在投标之前，能在当地进行调查。而到底给多少时间，应视工程项目的具体情况而定。

开标程序

投标人投标截止日期、时间和地点，以及开标的日期、时间和地点都要在招标时公布。所有的投标都要在规定的时间打开，在截止时间以后收到的投标都要原封不动地退回，除非迟到的原因不在于投标人，而且晚收并不使他们比其他投标人占便宜。投标要在公开场合打开，投标人的姓名、每个投标的总金额，包括要求他们或允许他们提出可供选择的投标，都要在开标时大声读出，记录在案。

延长投标有效期限

一般来说，不应延长投标有效期限。如果在特殊情况下，需要延长投标期限，就要在终止日期之前向所有投标人提出要求，并通知世界银行。投标人有权拒绝延长期限，并不得因此丧失其投标保证金。对同意延长投标期限的投标人，不要求、也不允许修改他们的投标。

说明或改动投标

除非在本指南有关条款中另有具体规定，在开标以后，任何投标者都不能修改投标。只允许进行不改动投标实际内容的说明。借款人可以要求投标人对其投标加以说明，但不能要求投标者改动实际内容或报价。

保密程序

在公开开标以后，宣布合同中标者之前，是不允许把有关对投标的审查、说明、估价

和建议授予的情况告诉投标人，或告诉与这些程序没有正式关系的人员。

投标的审查

开标以后，就要弄清楚报价里有无计算错误，投标是否基本上回答了招标文件提出的要求，有没有提供所需保证，文件是否都签了字，投标材料在其他方面是否都妥当。如果投标基本上没有回答招标文件提出的要求，或关键问题含糊不清，就应该加以拒绝，除非这些是根据标书要求，或文件所允许的供选择的参考投标。随后，就要进行技术分析，以对每个投标进行估价，并互相进行比较。

借款人或其咨询人要准备一个估价和对投标进行比较的详细报告。报告里要写明其所依靠的具体理由。并应决定谁为中标人，或所有投标都不能接受。这个报告是在最后决定中标人之前还是之后呈送给世界银行复审，则视其与世界银行所签订的贷款协议而定。

合同的授予

要在规定的投标有效期内，把合同授予确定为最低评估价投标的而其能力和财力方面符合相应标准的投标人。除非有关条款规定的特殊情况，否则不应要求投标人承担说明中没有规定的责任或任务，或要求修改投标，并以此作为授予合同的条件。

第三单元摇确认

（世行贷款给某火电项目汽机岛辕锅炉岛标前会对投标商提出问题的部分答复）

员郾问：部分负荷对买方的重要性如何？

答：要求该电厂有调峰、调频的能力，稳定运行是重要的，部分负荷效率应在整个评标过程中予以评价，运行方式应使用于效益评价中，如第三卷，第猿远页，第圆郾猿郾远条所述。

圆郾问：第三卷，第怨圆页，藻条

对于业主所要求的设计审核，我们建议以以下两种方式，每一种针对一个设计阶段。

对工程关键文件（总布置图、孕驭陨图、单线图）的概念审核。

施工图出版前的详细设计审核。

请确认。

答：投标商应按栽责携表圆第圆郾缘郾员节的要求提供初步设计和详细、设计图纸文件供买方审查，但买方对图纸文件的审查并不排除承包商的责任。如买方对图纸的审查超过规定的时间且不给予答复，承包商可以认为已认可，可继续进行工作（规定的审查时间后定）。投标商对所提供图纸的修改部分应有明显的标记。

猿郾问：第三卷，第圆怨苑页，第源郾圆条

请确认压力开关是否属于汽机岛范围，流程图中汽机岛范围仅标了一个压力开关。

答：请注意，汽机岛范围内的流程图仅为示意图，图中的仪表、压力开关等的数量由承包商确定，压力开关应由汽机岛承包商提供，参见第三卷，第五部分，第员郾圆郾猿条，用于检测和传送过程参数的仪表均由汽机岛提供。

源郾问：第三卷，第员缘页，第员郾源郾远（糟）条

我们认为此条的意思是：汽机岛承包商提供所设计的所有基础，例如汽轮发电机、锅

炉给水泵基座和基础的布置图和剖面图以及所需的所有坑、沟道的布置图和剖面图，请予以确认。

此条最后一句话的意思应是所有楼板及楼板上的设备支墩所用的混凝土提供给买方，进而汽轮发电机、锅炉给水泵基座和基础的混凝土由汽机岛承包商提供，这与第一页第猿援圆援员条所说的混凝土和砖混工程属买方的范围不符。

请予以澄清。

答：零米以下的工程属于买方范围，但位于零米或以下的设备基础、坑、沟、隧道等平面及剖面图由汽机岛承包商提供，详图由买方设计。此条最后一句改为：

所有楼板及楼板以上的设备支墩所用的混凝土由买方提供，汽轮发电机、锅炉给水泵基座和基础的详细要求见 栽源援远援猿援缘

缘援问：第三卷，第 源园页，第 圆援猿援源援猿援员条

（员） 该文描述汽机岛承包商应提供其范围内的高温、高压管道的应力分析，对于那些其结构需要由汽机岛承包商所承包的支撑系统支撑的承包商，应以一种及时的方式提供正常和异常的负荷工况，从而可同时做结构设计（提供时间由汽机岛承包商确认）。

（圆） 汽机岛承包商应将循环水系统设计接口资料提交给业主，从而业主工程师能够进行水锤分析。

答：（员） 关于管道应力计算详见 栽源援员“总则”，第 员援猿援员节机械接口，“粤”。

（圆） 同意该条意见。

远援问：我们不能找到用于该工程的设计蒸汽工况。为了投标，我们假设了一个蒸汽工况的表格，如后所示。以往蒸汽参数已经发表过。我们列出的蒸汽流量和速度，是否可考虑作为设计参数？

答：待中标后，协调机炉参数，不会影响机炉总报价。

苑援问：请规定锅炉本体的大小范围。

答：从 匀柱至 酝柱之间的除汽水、油管道、烟风道、送风管道外（分界线在设备接口处）的所有设备的管道都属于锅炉本体保温范围。

愿援问：投标报价中请确认在评标时按锅炉最大连续出力 怨缘源园万元 辕援缘 月酝悦砸

答：锅炉岛承包商在投标方案中提出的 月酝悦砸出力保证值应满足第 猿卷，第 员苑页猿援源援圆援员条的要求。若超过本条标准，评标时价格不调整；若低于本标准，评标时价格将按本条评估。

锅炉岛承包商还应保证满足 猿卷 源页 圆援猿援源援圆援员条的要求。

怨援问：请明确，锅炉下联箱和锅炉除渣装置标高初步规定为 员园援缘皂，是否意味着锅炉进口联箱距离地面 员园援缘皂？

答：锅炉的水冷壁下联箱的标高初步定为 员园援缘皂，除渣装置和锅炉渣口的连接标高将由锅炉承包商和除灰承包商协商决定。

第四单元摇中国标准标书

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招标邀请书

日期：(招标公布日期)

贷款 辕信用证编号摇摇摇摇

招标邀请书编号摇摇摇摇

员郾摇摇摇摇（借方名称）已向国际开发组织（后称世界银行）申请（获得）用于摇摇摇摇（项目名称）的多种货币贷款，并打算将此项贷款的一部分用于本招标的付款。

圆郾摇摇摇摇（买方名称）征招资格合格的投标商递交有关 摇摇摇摇（货物名称及相应的服务）密封标书。

猿郾对此感兴趣的符合资格的投标商请向摇摇摇摇（代理机构名称）索取详细资料和标书（有关咨询机构和标书发布单位的通讯地址、电报、电话和传真）。

源郾对此感兴趣的符合资格的投标商请于摇摇摇摇（日期）摇摇摇摇上午辕下午（北京时间）之前从上述地址向上述机构购买全套标书文件，每套标书文件价值摇摇摇摇（人民币）或摇摇摇摇（美元），款项恕不退换。

缘郾投标者须知和合同的一般条款须按世界银行标准标书格式撰写：参阅世界银行编写的《信贷采购指南》。

远郾投标商请于摇摇摇摇（北京时间）摇摇摇摇（日期）之前向上述机构发出标书，并附保证金摇摇摇摇（总额或投标总额的百分数）。

苑郾恳请投标商代表于摇摇摇摇（时间）在摇摇摇摇（地点）参加开标会。

代理机构名称摇摇摇摇

详细地址摇摇摇摇

邮编摇摇摇摇

电报摇摇摇摇
电话摇摇摇摇
电传摇摇摇摇

招标文件的澄清

任何要求澄清招标文件的未来投标者均应在投标提交截止日期前 员个月，按招标通告中所列（招标者名称）的通讯地址（见招标邀请书条款第 员援圆员条）书面通知买方。对于投标提交截止日期 员个月内收到的澄清招标文件的任何要求，招标者将给予书面答复。招标者（买方）的书面答复将分别寄给所有收到招标文件的未来投标者（包括对各种疑问的解释，但不指明是谁提出的疑问）。

招标文件的修改

在投标提交截止日期之前任何时候，招标者可以任何理由，主动地修改招标文件，或在答复未来投标者提出的澄清要求时，修改招标文件。

对招标文件的修改将以书面形式通知所有收到招标文件的未来投标者，并对他们具有约束力。为使未来投标者在准备投标时有合理的时间来考虑修改内容，招标者可以酌情延长提交投

标的截止日期。

合格的投标者

招标邀请向所有符合世界银行贷款和国际开发协会信贷采购指南 员怨怨缘年 员月规定的国家和地区发布，下文若无特殊说明，均指须满足世界银行贷款采购指南要求。

投标者在设计、规范和货物购买的其他文件等诸多方面，不允许与招标者的任何机构或公司有直接或间接关系。

中国国内的国有企业，若具有独立法人权，按商业法运作，并与招标者独立，则有权参与投标。

第五单元摇合同一般条款（陨

定义

本合同的下列术语应理解为：

“合同”系指在买卖双方签署的合同格式中列明的双方已经达成的协议，包括合同格式规定的所有文件和附件。

“合同价格”系指根据合同规定，在卖方全部适当地履行合同义务时，应支付给卖方的价格。

“货物”系指根据合同规定，卖方须向买方提供的一切设备、机械、仪表、备件、工具、手册和其他技术资料，或其他材料等。

“服务”系指根据合同规定卖方必须承担的安装、调试、技术协助、校准、培训等方面的义务。

猿援远

“则悦况’系指合同一般条款。“杂悦况’系指合同特殊条款。
“买方”系指“杂悦况’中规定的购买货物的组织者（招标者）。
“卖方”系指“杂悦况’中规定的根据合同提供货物和服务的公司或实体。
“世界银行”系指国际复兴开发银行和国际开发协会。

应用

本合同条款不能被其他合同条款所代替。

原产地

合同项目下提供的所有货物和辅助服务，其原产地应符合现行世界银行采购指南规定的国家和地区，详见特殊条款的规定。

本条款所说的“原产地”系指货物的开采、生长和生产的地方，或提供这些服务的地方。经过制造、加工或元件组装后的商业新产品，必须在其基本性能或使用上与原产品有本质不同。

检测

买方或其代表有权免费检验并测试（检测）卖方的货物是否符合合同规定的要求。在合同特殊条款和技术规范中应注明买方要求检测哪些项目、在何地进行检测。买方应及时以书面形式向卖方通报商检结果。

卖方及其子承包商应准许其任何货物在发货途中或抵达目的地接受检测。卖方及其子承包商对相关货物的质量、服务等方面的文件，包括图纸和生产数据均应免费提供给买方。

如果货物的质量和规格与合同不符，买方有权拒收货物，并且卖方应免费向买方更换货物或提供必要的修复使货物达到规定要求。

在货物抵达买方所在国后，买方仍然有权检测货物，必要时仍有权拒收货物，而不应受货物在原产地已接受检测并获得通过的任何限制。

合同一般条款的第八条不能减轻或解除卖方对合同的保证和义务。

包装

卖方应按合同要求包装其货物，并保证其货物在抵达目的地的途中不受损坏或变质。包装应能承受运输途中的粗鲁搬运，还需防潮、防高温。应考虑包装的尺寸和重量，有条件的话，还要考虑货物抵达目的地偏远并缺乏起重设施等因素的影响。

货物的包装、商标以及包装箱内外的标签都应严格与合同要求相一致，如果买方在合同特殊条款中有其他要求，上述内容还必须与其相一致。

交货和文件

卖方应根据要求交付货物。在合同特殊条款中，应对卖方需提供何种装运和辕载其他文件作详细规定。

有关工厂交货价、离岸价、到岸价（成本加保险费、运输费）或其他描述买卖双方

义务的贸易条款，都应按现行版本的格式签订。

合同特殊条款应规定卖方必须提供文件。

保险

合同中的所有货物可根据合同特殊条款中的规定就制造、发现、运输、贮存进行保险。

在 悦阅云或 悦陨孕合同条款下，由卖方对货物投保，买方受益。在 云韵月或 云悦粤合同条款下，应由买方投保。

运输

合同规定卖方按 云韵月交付货物时，卖方需要支付包括运输、货物到岸、装卸等在内的费用，该项费用计入合同价格。合同规定卖方按 云悦粤交付货物时，卖方需要支付包括运输、保管和其他费用在内的费用，该项费用计入合同价格。

合同规定卖方按 悦阅云或 悦陨孕交付货物时，卖方需要支付将货物运输到合同规定的目的地或买方所在国的指定地点的费用，该项费用计入合同价格。

合同规定卖方将货物运输到合同规定的买方所在国的指定地点，即现场时，合同应注明卖方支付包括运输、保险和贮存在内的费用，相关费用计入合同价格。

合同规定卖方按 悦阅云或 悦陨孕交付货物时，不应对运输方式有任何限制。合同规定卖方（葬） 按 云韵月或 云悦粤交付货物时；（遭） 代表买方租用国际运输船只（工具）或租用悬挂买方国国旗的船只（工具）时，若规定的船只（工具）或悬挂买方国国旗的船只（工具）因故不能运输时，在合同规定的期限内，卖方应安排更替上述运输工具将货物运输到合同规定的指定地点。

技术服务费

卖方应提供下列任何一种或全部服务，如果合同特殊条款有特殊规定，还应提供附加服务：

（员） 所供货物在现场的组装和启动的性能保证和控制。

（圆） 提供所供货物的安装和维修所需工具。

（猿） 提供每套所供货物的运行和检修手册。

（源） 在买卖双方同意的时期或时间内，卖方应提供所供货物的维修及检修的性能保证和控制服务，这些服务并不解除合同规定的卖方所承担的任何义务和责任。

（缘） 在卖方厂家或现场，为买方员工在所供货物的组装、启动、运行、检修或设备修复等方面进行培训。

如果合同价格未特别说明，买卖双方应事先达成协议，确定卖方是否应收取技术服务费，而且收费标准不应超过卖方向其他单位提供同样服务的现行费用。

第六单元摇合同一般条款（陨原）

备件

正如合同特殊条款中所规定的一样，卖方要提供下列任何一种或全部有关备件制造、

猿援远

材料发放、说明和资料等。

（葬 只要不解除卖方在合同中的任何义务，买方可选择购买卖方的备件

（遭 对于保证期后的备件，可采取下列两种措施：

（蚤 事先通知买方保证期终止时间，使买方有足够的时间采购所需备件。

（蚤 在超过保证期后，如果买方要求，卖方应免费提供备件的蓝图、图纸和规程等。

质量保证

卖方应保证货物是崭新的、未使用过的，并且是第一流的工艺、以最优良的适当材料制造的，并完全符合合同规定的质量、规格和性能要求。卖方还应保证在买方所在国，在货物使用期限内，并在正确安装、适当操作和维护的情况下，货物性能令人满意，不得由于设计、工艺或材料的缺陷而发生任何故障。

卖方应保证其货物及其零部件在验收后 员圆个月内或从产地国发货后 员愿个月内的质量，除非合同有特殊规定。

在保证期内若发现货物有任何缺陷，买方应及时以书面形式通知卖方。

卖方收到通知后，应根据特殊条款的规定以适当的速度免费为买方修复或更换损坏货物及其零部件，买方应承担货物在发货地至目的港的内陆运输费用。

如果卖方在收到通知后，未在合同特殊条款规定的时间内，以适当的速度修复缺陷，买方可视情况提出索赔，卖方不能以此歧视买方并应承担其它风险和义务。

支付

在合同特殊条款中应明确向卖方的付款方式。

卖方应以书面形式通知买方其对付款方式的要求，并附上描述货物运输、服务的清单，一般条款第十条的文件以及合同的其它义务说明。

买方应在收到发票 远园天内，及时向卖方付款，否则卖方可提出索赔。

合同特殊条款中应根据卖方投标书中的要求规定买方以一种货币或多种货币向卖方付款。

价格

在投标者履行合同期间，投标者在投标价格表中标明的价格为固定价，在任何情况下不得改动。除非投标者提交的投标按可调整价格计算。

投标的修改

按照合同一般条款第 猿员条，在任何时候，买方可以书面形式通知卖方更改下列任意一项或多项条款：

（员 为买方特别制造的货物的图纸、设计或规程；

（圆 运输或包装方式；

（猿 运输地点；

（源 卖方提供的服务。

如果这种更改引起卖方成本相应地增加或减少，或交货时间的变化，那么，需对价格

和 辏交货日程进行修正，也应相应修正合同的有关内容。卖方若对这种更改提出任何索赔，都应在收到买方更改通知的 猿园天内提出。

更改合同

根据合同一般条款，不能对合同的条款进行修改，除非买卖双方对此达成协议。

合同转让

卖方不得全部或部分转让合同规定其履行的义务，除非事先取得买方的书面同意。

分包合同

卖方应将本合同项目下的所有分包合同以书面形式通知买方，这种通知并不解除卖方合同项目下的任何责任和义务。分包合同必须符合一般条款中第 猿条的规定。

迟交

货物及其相关服务必须根据买方制订的日程进行交付。

在合同有效期内，如果卖方或其子承包商不能如期交付货物并提供相关服务，则应及时以书面形式通知买方迟交、延误时间及其原因。买方收到卖方的通知后，应尽快估计形势，视情况（有无预订违约金）谨慎放宽供货期限，延长期限由双方协商而定。

除非在合同一般条款第 圆缘条的情况下，若卖方迟交，就应按照条款第 圆源条支付损害赔偿金，除非根据条款第 圆圆援圆条，买方同意在延长期内不要求索赔损害赔偿金。

附录

[illegible]

a flange warming system摇摇摇摇摇摇摇摇摇	法兰加热系统 （[illegible]
a helical path	螺旋通道 （[illegible]
a main field breaker	灭磁开关 （[illegible]
a multitude of	一大批，一大群 （[illegible]
a quick-start air pump	快速启动空气泵 （[illegible]
abnormal	不正常 （[illegible]
abrasion	擦伤（掉，去），刮掉（去）；磨损 （[illegible]
abrupt	意外的，突然的 （[illegible]
acceleration relay	加速度继动器 （[illegible]
acid	酸 （[illegible]
acmite	锥辉石 （[illegible]
acquisition	获得，发现，学识 （[illegible]
acreage	英亩数 （[illegible]
actuate	动作；激励，驱使 （[illegible]
additive	添加剂 （[illegible]
addressability	寻址 （[illegible]
adequate	符合要求的，令人满意的 （[illegible]
adiabatic	绝热的 （[illegible]
adjacent	毗邻的，邻近的 （[illegible]
admission valves	进汽阀 （[illegible]
adopt	采用 （[illegible]
advance payment	合理的付款方式 （[illegible]
advertising	广告 （[illegible]
aeroderivative	由航空发动机演变而来 （[illegible]
aerofoil profile	叶型 （[illegible]
affiliate	使…加入，合并，参与接纳…为分支机构 （[illegible]
afford	给予，供给 （[illegible]
aforementioned	上述的，前述的 （[illegible]
agglomerate	烧结块，烧结 （[illegible]
agglomeration	附聚（作用），烧结（作用） （[illegible]
aggrandizement	增加（大） （[illegible]
air blast	空气熄弧 （[illegible]

air ejector	抽气器 ([illegible]
air injection staging	空气分段送入 ([illegible]
air retention	空气保持性 ([illegible]
Albany	奥尔巴尼 (美国) ([illegible]
algebraic	代数 ([illegible]
alkaline absorbent	碱性吸收剂 ([illegible]
allowance	特别经费，被允许的东西，留量 ([illegible]
alloy	合金 ([illegible]
alluvial	冲积 ([illegible]
alteration	更改，变更 ([illegible]
alternating current (AC)	交流发电机 ([illegible]
alternator	交流发电机，振荡器 ([illegible]
ambient	周围的 ([illegible]
amenable	有义务的，经得起检验的 ([illegible]
ammonia	氨 ([illegible]
Ammonia Nitrogen	氨氮 ([illegible]
ampere	安培 ([illegible]
amplification	放大 ([illegible]
analcite	方沸石 ([illegible]
analogue	模拟的 ([illegible]
anchor point	死点 ([illegible]
angstrom	埃 ([illegible]
anhydrite	酸酐 ([illegible]
anhydrous	无水的 ([illegible]
anneal	退火，焖火 ([illegible]
annual	一年一次的 ([illegible]
annular	环形的 ([illegible]
annular chamber	环形室 ([illegible]
anthracite	无烟煤 ([illegible]
anti-rust additives	防锈添加剂 ([illegible]
aperture	孔，口，开度 ([illegible]
approach	态度，方法 ([illegible]
aqueous solution	水溶液 ([illegible]
aragonite	散文石 ([illegible]
arch	拱，拱顶 ([illegible]
archaeological	考古学的 ([illegible]
armature	转子 ([illegible]
array	一批，大量 ([illegible]
arrestor	捕捉器 ([illegible]

ascertain	查明，确定
Ash Island Contractor	除灰承包商
aspect	样子，外表
aspirate	吸出（空气等）
asymmetrical	不对称的
at no charge	免费
at the expense of	以…为牺牲，在损害…的情况下
atmospheric-pressure-relief valve	大气压力安全阀
atomization	雾化
attainment	达到
attemperation	温度调节，温度控制
attemperator	减温器，保温装置
austenitic alloy	奥氏体合金钢
automatic combustion control system	燃烧自动控制系统
automatic controller	自动控制器
auxiliary	辅助的
auxiliary equipment	辅助设备
availability	使用价值，（有效）利用率
available	可得到的，现有的，有用的
avoidable	可避免的
award of contract	授予合同
axial-turbine	轴流式透平，轴流式汽轮机
back pressure turbine	背压式汽轮机
back up overspeed	附加超速保护
backbone	主干，中坚
backlash	齿隙，游隙，侧向间隙
baffle	挡板，隔板，导流板，节气门
balding	叶片，叶栅
ball bearing	球面轴承
bank	组，管束
bank guarantee form	银行担保形式
bare	裸的，露出
barring gear drive	盘车
barring gear (turning) speed	盘车速度
base point	基点
bay	支座，支架
be confronted with (by)	面临着
be equivalent to	相当于，等于，与…等效
be proportional to	和…成正比

bear on	压在…上
bearing	轴承
bearing block	轴承箱
behavior	工作情况，运转状态
beverage	饮料
BFP	锅炉给水泵
biased	偏压的，附加励磁的
bid	出价，投标
bid date sheet	招标时间表
bid opening	开标
bid security form	招标保密形式
bilateral trade	危险程度
binder	粘合
biomass	生物能
bituminous	烟煤
blade root	叶根
blade tip	叶顶
blank off	闷死（弯头），堵死，锁住
blend	混合，掺和
blockage	封锁，妨碍
blower	鼓风机，排气器/口
blowhole	气孔，砂眼
blown fuse	熔断了的保险丝
blueprints	蓝图
board	配电盘
boiler feed pump	锅炉给水泵
boiler proper	锅炉本体
boiling water reactor	沸水堆
boost charge	增强放电
boost charger	调压柜
borrower	借款人，借用者
bottom	底部，炉底
brackish	稍咸的
brake	制动器，刹车
breeder reactor	增殖反应堆
Bubbling Fluidized Bed（BFB）	鼓泡流化床
built-in	固有的，内在的
built-up rotor	套装转子
bulky	体积大的，笨重的

bunker	容器，仓 ([illegible]
burner	燃烧器 ([illegible]
bus coupler	母线联络开关 ([illegible]
busboard	汇流条板 ([illegible]
butted	对接的 ([illegible]
by-pass	旁通，给…设旁路 ([illegible]
bypass governing	旁路调节 ([illegible]
calcium	钙 ([illegible]
calcium sulfate	硫酸钙 ([illegible]
calcium sulfite	亚硫酸钙 ([illegible]
camshaft	凸轮 ([illegible]
CANDU (Canadian deuterium uranium reactor)	加拿大重水铀反应堆 ([illegible]
cap nut	盖形螺帽 ([illegible]
capacitor	电容器 ([illegible]
capacity	容量，生产力，功率 ([illegible]
capital	资本，资金 ([illegible]
carbonaceous	含碳的 ([illegible]
carbonate	碳酸盐 ([illegible]
cargo insurance	货物保险 ([illegible]
carrier	搬运公司，货运公司，载体，托架 ([illegible]
carrier ring	持环 ([illegible]
casing	汽缸，气缸，机匣，机壳 ([illegible]
catalyst	催化剂 ([illegible]
catastrophic	毁灭的，灾难的 ([illegible]
category	种类，类型 ([illegible]
cater for	为…服务，满足（需要） ([illegible]
CECB (Central Electricity Generating Board)	中心电力委员会（英国） ([illegible]
centrifugal pump	离心泵 ([illegible]
centrifugal stress	离心应力 ([illegible]
ceramic tile	陶瓷瓦 ([illegible]
chimney	烟囱 ([illegible]
China Nuclear Engineering and Construction group (CNEC)	中国核工业建设集团公司 ([illegible]
chrome-moly	铬-钼 ([illegible]
circuit breaker	断路器，(油)开关，电路保护(制动)器 ([illegible]
Circulating Fluidized Bed (CFB)	循环流化床 ([illegible]
circulating pump	循环水泵 ([illegible]
circulation	循环，流通，发行 ([illegible]
civil works	土建，土木工程 ([illegible]

claims	要求，索赔 （殖陇
clamp	夹住，夹紧 （源愿
clarification	澄清 （远圆
Clean Coal Technology （CCT）	洁净煤技术 （员陇
clearance	间隙，空隙，间距 （猿缘
clear-cut	干净利落的，明确的，确定的，清晰的 （源陇
climatological	气候学的 （员缘
clutch	离合器 （源源
coagulant	絮凝剂 （远圆
coal consumption rate	煤耗率 （员圆
coal gasification	煤气化 （员陇
coal gasification （CG）	煤气化 （愿愿
coal mine	煤矿 （员圆
coal/oil/gas fired	燃煤/油/气 （员圆
coalesce	聚结，凝聚 （远圆
coal-gasification combustion-cycle （CGCC）	煤气化联合循环 （愿愿
coefficient	系数 （猿源
coil	盘绕，成圈状 （园陇
coke	焦炭 （员缘
cold flow	低温下固体塑性变形流动 （源愿
cold startup	冷态启动 （猿愿
colloidal particle	胶（体微）粒 （远圆
combined cycle	联合循环 （员缘
combustor liner	燃烧室，喷燃管 （愿愿
come into contact with	与…接触 （猿陇
come out of	有…结果 （远缘
commence	开始 （园缘
commercial turbine	商业透平，商业汽轮机 （猿圆
commission	委托，代办，交付运行 （员园
community	社会，团体 （殖圆
commutator	换向器；整流器；整流子 （源圆
compact	紧凑的，紧密的，压紧的，小型的 （员缘
compactness	紧密度，坚实度 （园陇
compatible	相兼容的，相适应的 （缘陇
compatible with	与…相容（相似，一致） （猿陇
compete with	与…竞争 （愿愿
complement	补充物 （员园
comply with	照做 （园圆
component	部分，成分 （员源

compost	堆肥，混合肥料
compression ratio	压缩比
compression spring	压缩弹簧
comprise	由…组成，构成
Computational Fluid dynamics（CFD）	计算流体力学
concave	凹的，凹入的；凹，凹面
concentrate	浓缩，冷凝
condensate pump	凝结水泵
condensate system	凝结系统
condensatewater	凝结水
condensation	凝结
condensing turbine	凝汽式汽轮机
Conditional Moment Closure（CMC）	条件矩封闭模型
conduct	指导，处理
conductivity	传导系数，传导率
conduit	管道，管路，导管，导线管
confidential	机密的
configuration	构造，外形
conflict	斗争，冲突
conical	圆锥的
consent	同意，许可，万能插口
consignment	委托，交付
constrains	约束，制约
constraint	强制，约束
conterflow	反向流动，逆流
contingency	意外事故，偶然（性）
continuous maximum rating（CMR）	最大连续出力
contra flow	对流，逆流
control stage	调节级
controversial	争论的，引起争论的
conventional	传统的，普通的
converging nozzle	渐缩喷嘴
converging-diverging nozzle	缩放喷嘴
convert	使（一种形式）转变成（另一种形式）
convert... into	把…转变成
convertible	可逆的，可转变的，自由兑换
convex	凸出的
cope with	克服，适应，对抗
copper oxide	氧化铜

corollary	必然的结果 ([illegible]
correction capacitors	校正电容 ([illegible]
corrodent	腐蚀剂 ([illegible]
corrosion	腐蚀 ([illegible]
COST (Cooperation in Science & Technology) program	科技协作计划 ([illegible]
counterbalance	反平衡 ([illegible]
counterion	平衡离子 ([illegible]
crack	裂缝，裂纹 ([illegible]
credit	信贷 ([illegible]
creep	蠕变 ([illegible]
criteria	标准，准则 ([illegible]
critical speed	临界转速 ([illegible]
criticality	双边贸易 ([illegible]
crossover pipe	连通管 ([illegible]
crude oil	原油 ([illegible]
crusher	破碎机 ([illegible]
cubic meter	立方米 ([illegible]
currencies	现汇 ([illegible]
Curtiss stage	柯蒂斯级，复速级 ([illegible]
curved vane	扭转叶片，弯曲叶片 ([illegible]
custody	保管，监视，收容，监禁 ([illegible]
cut-off slide valve	断流滑阀 ([illegible]
cyclone	旋风，旋风分离器 ([illegible]
cylinder	气缸，汽缸 ([illegible]
damper	挡板 ([illegible]
DCU	专用控制单元 ([illegible]
dead band	不工作区域，死区，非灵敏区 ([illegible]
deaerator	除氧器 ([illegible]
decentralize	分散 ([illegible]
decomposition	分解 ([illegible]
dedicated	专用的 ([illegible]
deem to	认为，想，相信 ([illegible]
degrade	降低，减低 ([illegible]
deionized H_2O	去离子水 ([illegible]
deliver	释放，发出 ([illegible]
delivery	交付，交货 ([illegible]
demineralised water	除盐水 ([illegible]
demonstration	表演，显示，游行 ([illegible]

demulsification	破乳化 （[illegible]）
demulsification number	破乳化度 （[illegible]）
denitrification device	除氮装置 （[illegible]）
denitrizer	脱硝器，脱氮器 （[illegible]）
deplete	使耗尽，使空虚 （[illegible]）
deposit	矿床，矿层 （[illegible]）
derivative	导数，微商 （[illegible]）
desulphurization devices	除硫装置 （[illegible]）
detention	阻止，拖延 （[illegible]）
deterioration	变坏，降低（品质），恶化，损坏，消耗 （[illegible]）
deterministic models	确定模式，确定性模型 （[illegible]）
devolatilize	脱挥发分 （[illegible]）
dew point	露点 （[illegible]）
diagnostics	诊断学 （[illegible]）
diaphragm	隔板，膜片，孔板 （[illegible]）
dictate	指挥，命令 （[illegible]）
diesel engine	柴油机 （[illegible]）
differential current relay	差动电流继电器 （[illegible]）
differential expansion	胀差 （[illegible]）
differentiate	求微分，微分运算 （[illegible]）
diffraction	衍射 （[illegible]）
diffuser	扩压器，扩压管 （[illegible]）
diffusion flame	扩散火焰 （[illegible]）
digital	数字的 （[illegible]）
dilute	稀释，冲淡 （[illegible]）
dilution	稀释，冲淡 （[illegible]）
dimly	模糊地 （[illegible]）
direct-coupled machines	直接耦合的机械 （[illegible]）
direct-current （DC）	直流发电机 （[illegible]）
directional power relay	功率方向继电器 （[illegible]）
discharge	排出，离开 （[illegible]）
discharge from	从…排出，从…流出 （[illegible]）
dislodge	取出，移动 （[illegible]）
dismantle	拆除…之设备 （[illegible]）
dispatcher	调度员，分配器 （[illegible]）
dispense with	节省，废除 （[illegible]）
dispersion	扩散，弥散，泄漏 （[illegible]）
display unit	显示部件（单元，装置） （[illegible]）
disqualify	取消资格 （[illegible]）

dissemination	分发 ([illegible]
dissipate	消散 ([illegible]
dissipation	分散，散 ([illegible]
dissolved oxygen sag curves	氧垂曲线 ([illegible]
distillate fuel	馏出燃料 ([illegible]
distortion	变形，挠曲，扭曲 ([illegible]
dither	高频振动 ([illegible]
double-flow double casing	双流程双层缸 ([illegible]
dovetail	楔形榫头；鸠尾 ([illegible]
downcomers	下降管 ([illegible]
draining port	泄油口 ([illegible]
drifting	漂移，偏差 ([illegible]
drop out	解剖 ([illegible]
droplet	小滴，飞沫 ([illegible]
drum	汽包，汽鼓 ([illegible]
dry basis	干燥基础 ([illegible]
dry-bottom furnace	固态排渣炉膛 ([illegible]
duplex	双重的，冗余的 ([illegible]
duration	持续时间，期间 ([illegible]
duty	功率，负荷 ([illegible]
dynamic balance	动平衡 ([illegible]
EC (European Community)	欧共体 ([illegible]
eccentricity	偏心 ([illegible]
economizer	省煤器 ([illegible]
eddy current	涡流，杂散（涡流）电流 ([illegible]
effluent	流出的 ([illegible]
ejector	喷射器 ([illegible]
elect	选举，推荐 ([illegible]
electric circuitry	电路 ([illegible]
electrical discharge machining (EDM)	电子放电加工 ([illegible]
electrical governor	电调速器 ([illegible]
electricity demand	电力需求 ([illegible]
electrohydraulic	电动液压的 ([illegible]
electro-hydraulic governor	电液调节系统 ([illegible]
electrostatic	静电的 ([illegible]
electrostatic precipitators	静电除尘器 ([illegible]
elemental	单质的，元素的 ([illegible]
eligibility	符合，合格，适当性 ([illegible]
eliminate	除去，剔除 ([illegible]

embed	埋置，把…嵌入 ([illegible]
emissions	发出，排出物 ([illegible]
emissivity	辐射能力，辐射系数 ([illegible]
EMS	能源管理系统 ([illegible]
emulsifier	乳化剂 ([illegible]
emulsions	乳状液 ([illegible]
encase	（全部）盖住，围住 ([illegible]
enclosure	围绕，封入 ([illegible]
encompass	围绕，包围 ([illegible]
energy resource	能源 ([illegible]
enhance	加强，提高 ([illegible]
enthalpy drop	焓降 ([illegible]
entrained air	带走的空气 ([illegible]
entrainment	带走，输送 ([illegible]
enumerate	数，计点，枚举，计算 ([illegible]
envisage	正视 ([illegible]
equilibrium	平衡（状态、图、曲线） ([illegible]
escalate	乘自动（升降）梯上去 ([illegible]
estuary	河口 ([illegible]
ethylene	乙烯 ([illegible]
EU (European Union)	欧盟 ([illegible]
evaporation	蒸发量 ([illegible]
evaporative	蒸发的 ([illegible]
eventual	最后的 ([illegible]
excess air	过剩空气 ([illegible]
excrement	排泄物 ([illegible]
exhaust hood	排汽缸 ([illegible]
exhaust loss	排汽损失 ([illegible]
exhaustive	无遗漏的，彻底的，详尽的 ([illegible]
exit edge	出汽边 ([illegible]
expiration	期满，终止 ([illegible]
explicit	明确的，明白表示的 ([illegible]
exploded view	部件分解图 ([illegible]
exploitation	开发 ([illegible]
extensive	广大的，扩大的，粗放的，彻底的 ([illegible]
extract	蒸馏出，抽取 ([illegible]
extraction	（可调）抽汽，排热 ([illegible]
extraction heater	抽汽加热器 ([illegible]
extrapolation	外推，推断 ([illegible]

facilitate	使方便 (圆郾源
facsimile	传真，传真通讯，复制 (苑郾源
FCV (Fast Close Valve)	快控滑阀 (缘郾缘
feeder	给煤机，输电线 (圆郾源
feedwater	给水 (圆郾苑
ferritic alloy	铁金氧合金 (愿郾苑
field rotor	励磁转子 (缘郾猿
field winding	励磁绕组 (源郾圆
fin	肋片，鳍 (圆郾远
final condition of steam	蒸汽终参数 (猿郾圆
finance	财政，金融 (苑郾员
financially autonomous	财政/财务独立 (苑郾源
finite element method (FEM)	有限元方法 (愿郾远
finned	有鳍片的，有散热片的 (圆郾苑
fire hose	消防水龙头 (猿郾员
fitness	适合，恰当 (圆郾源
fittings	零件，设备 (圆郾愿
fixed blade	静叶，喷嘴 (猿郾猿
flammability	易燃，可燃性 (愿郾圆
flange	法兰 (猿郾猿
flaw	缺陷，裂缝 (猿郾源
flexible	易弯曲的，柔软的 (员郾猿
flexible rotor	柔性转子，挠性转子 (猿郾源
float	漂浮，漂移 (圆郾苑
float charger	浮充盘 (源郾缘
flocculation	絮凝作用 (圆郾猿
flow	流量 (员郾源
flue	烟道，风道 (圆郾缘
flue gas	烟道内烟气 (员郾远
flue gas duct	烟风管道 (苑郾猿
fluidized bed combustion	流化床燃烧 (员郾远
flux	流量，通量，电通量，磁通量 (源郾圆
foaming	泡沫 (远郾缘
foil	叶形饰，翼，薄片 (猿郾员
forced draught	送风机 (圆郾员
forced-draft	送风机 (圆郾源
foreign trade	外贸 (苑郾员
forfeit	投标保证金 (苑郾圆
formal	正式的，形式的 (苑郾员

fossil-fuel	化石燃料
foul	积灰，污垢
four-node	四节点
Framatome	法玛通（法国）
Framatome ANP	法国法玛通先进核能公司
friction	摩擦
fulcrum	支点，转轴，可转动的
full load	满负荷
functionality	功能度
furnace	炉膛
fuse	熔断器
fusion	熔化
gas field	气田
gas turbine generator package	燃气轮发电机组
gaseous ammonia	氨气
gashed rotor	整锻转子
gasifier	气化床
GEC-Alstom	通用阿尔斯通（法国）
generation efficiency	发电效率
generator shaft	（发电机）机轴
geologically	地质学地
geometry	结构，几何学
geothermal power	地热发电
girth	围梁
give up	释放，放弃，中断
glacial	冰川的
gland housing	汽封体
governing valve	调节阀
government-owned enterprise	国有企业
governor	调节器，调速器，调节系统
granular	粒状的
grease-lubricated runners	润滑脂润滑的叶轮
grid	高压输电线路网，网格，格栅
grindability	可磨性
grossly	严重地
ground	磨碎；基础，地
gypsum	石膏
hard-drawn	冷拉的，冷拔的
hardwired	电路的，硬连线的

haulage	运输 （[illegible]
have impact on	对…有影响 （[illegible]
Haynes alloy	海钠合金 （[illegible]
hazard	危险 （[illegible]
header	联箱，母管 （[illegible]
heat content	热值 （[illegible]
heat drop process	热力过程 （[illegible]
heat engine	热机 （[illegible]
heat loss	热损 （[illegible]
heat rate	热耗率 （[illegible]
helical	螺旋的 （[illegible]
hereinafter	在下（文） （[illegible]
herewith	同此，因此 （[illegible]
hierarchical	分层的，体系的 （[illegible]
high voltage	高压 （[illegible]
high （low） heating value	高（低）位发热量 （[illegible]
history	过去事的记载，来历 （[illegible]
hollow drum rotor	空心鼓式转子 （[illegible]
hood	机壳，机罩 （[illegible]
hoop stress	圆周应力 （[illegible]
hopper	渣口 （[illegible]
hot start	热态启动 （[illegible]
hotwell	热井 （[illegible]
housing	齿轮箱，支架 （[illegible]
HTR （high temperature reactor ）	高温反应堆 （[illegible]
hub	轮毂，中枢，轴套 （[illegible]
hunting	波动 （[illegible]
Hybrid cycle	混合循环 （[illegible]
hydraulic governor	液压调速器 （[illegible]
hydraulic turbines	水轮机 （[illegible]
hydro power	水电 （[illegible]
hydrolysis	水解 （[illegible]
hydroxyapatite	含氧酸磷灰石 （[illegible]
hydroxyl	氢氧 （[illegible]
hypotheses	臆测，假定 （[illegible]
hysteresis	磁滞（现象），滞后（量，现象，作用）（[illegible]
IAEA （International Atomic Energy Agency）	国际原子能组织 （[illegible]
IBRD loan	世界银行贷款 （[illegible]
ICI	帝国化学公司 （[illegible]

IDA Credits	国际开发协会信贷
idolization	偶像化，盲目的崇拜
imbalance	不均衡
impairment	削弱，破坏，影响
impede	阻碍，阻止
implication	含意
imposition	赋税，课税，负担
impulse turbine	冲击式透平，冲击式汽轮机
impulsive force	冲击力
in connection with	在…方面，关于，与…有关
in no way	决不，一点儿也不
in order	按顺序，处于…状态
in parallel	并列地
in the event of	万一，在…情况下
inadmissible	不能允许的
inadvertently	不注意地，漫不经心地；非故意地
inboard bearing	内轴承
incentive	动机，激励的
inception	开始，发端
Inconel	铬镍铁合金
incorporate	引入
indigenously-designed	自行设计的
indispensable	不可缺少之物,不可缺少的,绝对必要的
induced draught	引风机
induced-draft	引风机
inevitable	不可避免的,无法回避的,必然(发生)的
infiltration	渗透水
ingot	铸锭
ingress	进口，进口处，进入
inhibit	抑制，禁止
initial condition of steam	蒸汽初参数
initiate	开始，着手
inlet	入口
in-line	顺排的，平行排列的，同轴的
innocuous	无害（毒）的
innovation	改革，改进，创新，新技术
in-situ	就地
installed/generating capacity	装机/发电容量
instantaneous	静态的

Institute of Nuclear Energy Technology	核能研究院 ([illegible])
insulate	绝缘，隔离 ([illegible])
integer	（数）整数；完整的东西 ([illegible])
integral cover	整体围带 ([illegible])
integral rotor	整锻转子 ([illegible])
Integrated Gasification Combined Cycle (IGCC)	整体煤气化（蒸汽—燃气）联合循环 ([illegible])
integration piston	积分活塞 ([illegible])
intent	目的，意向 ([illegible])
intercept valve (IV)	中压调节阀，再热调节阀 ([illegible])
interconnected system	互联系统 ([illegible])
interconnecting networks	联网 ([illegible])
interconnection pipe	连通管 ([illegible])
interface	界面，接口 ([illegible])
interlocking	联（闭）锁，联锁（闭塞）装置 ([illegible])
intermediate stage	中间级 ([illegible])
intermittently	间歇地，断续地 ([illegible])
internal-combustion engine	内燃机 ([illegible])
internals	内部部件 ([illegible])
interstage	级间，段间 ([illegible])
interstitial	空隙的 ([illegible])
intolerably	不允许的 ([illegible])
intractable	难控制的，难加工的 ([illegible])
invitation for bids (IFB)	招标通知，招标文件 ([illegible])
invoice	发票，发货单，开发票 ([illegible])
iso thermal	恒温，等温线 ([illegible])
issue	排出，流出 ([illegible])
issue from	从…喷出，从…流出 ([illegible])
iterative	重复 ([illegible])
jet	汽流，射流，喷气式发动机，喷气式飞机 ([illegible])
jet condenser	喷水凝汽器 ([illegible])
journal bearing	轴颈轴承 ([illegible])
justify	证明是正当的 ([illegible])
juxtaposition	并置，斜接，邻近 ([illegible])
kernel	核心 ([illegible])
kinematic	运动学上的 ([illegible])
kinetic energy	动能 ([illegible])
Kingsbury bearing	金斯布里轴承 ([illegible])
labyrinth-gland seals	迷宫式汽封，曲颈式汽封 ([illegible])
Lagrangian model	拉式模型 ([illegible])

laminate	辗压成薄片 ([illegible]
lamination	层压，叠合，叠层，层状，交替片组 ([illegible]
Large Eddy Simulations	大涡模拟 ([illegible]
large-scale unit	大型机组 ([illegible]
last stage	末级 ([illegible]
latchstring sandstone	湖积砂岩 ([illegible]
lead	铅板 ([illegible]
leaf	薄板，节流门 ([illegible]
leakage	泄漏 ([illegible]
leave behind	遗留，把…丢在后面，超过 ([illegible]
legislation	法律 ([illegible]
legitimate	合乎逻辑的，正当的 ([illegible]
LHV (low heating value)	低位发热量 ([illegible]
liability	责任，义务，债务 ([illegible]
life span	寿命期限 ([illegible]
lifetime	使用时间，寿命 ([illegible]
lignite	褐煤 ([illegible]
lime	石灰 ([illegible]
lime/limestone	石灰/石灰石 ([illegible]
limestone	石灰石 ([illegible]
liquidate	液化，清理 (算，除)，偿还，破产 ([illegible]
live	(文中指) 通有电的路线 ([illegible]
load factor	负荷系数，满载系数 ([illegible]
Load limiter	功率限制器 ([illegible]
load rejection	甩负荷 ([illegible]
loan	贷款，借出 ([illegible]
locally-designed	自行设计的 ([illegible]
lock-up	集中，闭，锁住 ([illegible]
locomotive	机车 ([illegible]
log	记录 ([illegible]
longitudinal	长度的，纵向的，轴向的 ([illegible]
low-cycle fatigue	低周疲劳 ([illegible]
lug	拉金，接线片，凸耳，吊耳，猫爪 ([illegible]
lumber	锯开的木材 (板、条) ([illegible]
lump	煤块，块，团，总结 ([illegible]
lump sum	总数，总额 ([illegible]
lumpy	(成) 块状的，多块的，笨重的，波浪起伏的 ([illegible]
lye	碱液 ([illegible]
macroreticular	大量网眼 ([illegible]

magnesium oxide	氧化镁
magnetic	磁性的
magnetic amplifier	电磁放大器
magnetofluid	磁流体
main	总管，母管
main exciter	主励磁机
main trip solenoid	主跳闸电磁线圈
maintainability	可维修性
majority	多数，大半
make	种类，型号，制成品
mandatory	必须遵循的，强制性的
manipulation	操作，处理，控制
man-machine interface	人机接口
manpower cost	人力费
marginal	边际的
marine	船舶的，海的
marking	标记，标志，商标
masonry work	石工，污工（建筑物）
match	匹配，使协调
matrix	填质，型片
mechanical-hydraulic governor	机械液压调节系统
medium	介质，方法
mercury removal	除汞，脱汞
meteorological	气象学的
mill	制造厂，工厂
minimize	将…减至最小量或最低程度
Mises yield criterion	米赛斯屈服准则
mitigate	减轻
modification	更改
modify	更改，改变
molten	熔化的
moment of inertia	惯性矩
mount	机座；安装；装置
moving bucket/blade	动叶
multiaxial turbine	多轴汽轮机
multicontact	多触头
multicylinder turbine	多缸汽轮机
multistage	多级
municipal	市政的

municipal solid waste	城市固体废物，城市垃圾 （[illegible]
NATO	北大西洋公约组织 （即北约） （[illegible]
natural frequency	固有频率 （[illegible]
NETL (National Energy Technology Laboratory)	国家能源技术实验室 （[illegible]
network	网眼织物，网状物 （[illegible]
neutralizing the acidity	中和酸 （[illegible]
niche	壁龛，适当的位置，适当的场所 （[illegible]
nitrogen oxide	氮氧化物 （[illegible]
nomefundable fee	不能归还的费用 （[illegible]
nominal	额定的，名义的，标称的 （[illegible]
non-condensable	不能凝结的 （[illegible]
notch	槽口，凹口，刻凹痕，用刻痕计算，开槽（[illegible]
notification	通知 （[illegible]
nozzle	喷嘴，喷管，燃烧器 （[illegible]
nozzle box	喷嘴室 （[illegible]
nozzle governing	喷嘴调节 （[illegible]
nuclear power plant	核电站 （[illegible]
nutrient	营养素，营养品，养分 （[illegible]
obligatory	必需的 （[illegible]
obscure	暗的，模糊的，不清楚的，含糊的，难的（[illegible]
off the line	离线 （与主线路脱离） （[illegible]
off the shelf	现用的，流行的 （[illegible]
off-line	离线的，脱机的 （[illegible]
offset	抵消，弥补，支管 （[illegible]
offshore drilling	海上钻井 （[illegible]
Ohio	俄亥俄州 （美国） （[illegible]
oil cooler	冷油器 （[illegible]
oil field	油田 （[illegible]
oil groove	油槽 （[illegible]
oil port	油口 （[illegible]
oil wedge	油楔 （[illegible]
omission	省略，删除，疏忽 （[illegible]
on behalf of	代表 （[illegible]
on the order of	属于…同类的，跟…相似的 （[illegible]
once-through	直通的，一次的 （[illegible]
once-through boiler	直流锅炉 （[illegible]
onerous	苛繁的 （[illegible]
on-going	正在进行的，前进的 （[illegible]
open delta	开口三角形 （[illegible]

operating mode	运行方式（[illegible]
optimum	最佳的（[illegible]
orifice	孔板，节流板（[illegible]
orthophosphate	亚磷酸盐（[illegible]
oscillations	振荡（[illegible]
osmosis	渗透（[illegible]
out of phase	非同相的（[illegible]
outlet	出口（[illegible]
out-of balance weight	不平衡质量（[illegible]
Over Fire Air（OFA）	过燃风（[illegible]
overcurrent devices	过流保护器（[illegible]
overfrequency relay	过频继电器（[illegible]
overhaul	检修，检查（[illegible]
overlap	重叠，交错，并行（[illegible]
overlay	覆盖，包（[illegible]
overlying	上面覆盖的（[illegible]
override facility	人控功能（[illegible]
overspeed emergency governor	危机保安器（[illegible]
overspeed protection relay	超速保护继动器（[illegible]
overstressing	过压力（[illegible]
overvoltage relay	过压继电器（[illegible]
owing to	由于，归功于（[illegible]
oxidation catalysts	氧化催化剂（[illegible]
oxidizer	氧化剂（[illegible]
pa 越per annum	每年（[illegible]
packing ring seal	密封环汽封（[illegible]
pannier	挂在机动车（脚踏车）两侧的装物袋（[illegible]
panorama	全景（[illegible]
parabolic	抛物线的，抛物线状的（[illegible]
parallel to	平行于（[illegible]
partial	部分的（[illegible]
pass along	传递，使向前传播（[illegible]
paw	猫爪（[illegible]
PB（push-button）	按钮（[illegible]
PBMR（pebble bed modular reactor）	球床模块反应堆（[illegible]
peak demand	尖峰负荷需求（[illegible]
peculiarity	独特性，特色（[illegible]
per se	本身，本质上（[illegible]
percolate	砂滤，渗滤（[illegible]

percolate down though	透过…而不渗 ([illegible])
performance	性能，特性曲线，执行 ([illegible])
periphery	圆周，周界线；外面；边缘；周围 ([illegible])
permeation	渗透作用 ([illegible])
peroxide	过氧化物 ([illegible])
perpendicular to	垂直于 ([illegible])
pertaining	有关系的,附属的,为…所固有的 (to) ([illegible])
pertinent	有关的，相干的，中肯的 ([illegible])
petroleum oil	石油，油料 ([illegible])
PF (pulverized fuel)	粉煤 ([illegible])
pharmaceutical	医药的 ([illegible])
phase	阶段，时期 ([illegible])
philosophy	基本原理 (定律) ([illegible])
Phosphorus	亚磷的，三价磷的 ([illegible])
physical property	物理特性 ([illegible])
pile	(作屋基的) 木、铁、水泥桩 ([illegible])
pilot bobbin	错油门滑阀，导阀滑阀 ([illegible])
pilot exciter output	辅励磁机 ([illegible])
piston	活塞 ([illegible])
pit	沟，槽 ([illegible])
pit-head	煤矿坑入口 ([illegible])
plasma-spray	等离子喷射 ([illegible])
plaster	熟石膏，烧石膏 ([illegible])
platen	屏 ([illegible])
polarize	偏振，极化 ([illegible])
pole pitch	磁极距 ([illegible])
pollution	污染 ([illegible])
polyacrylamide	聚丙烯酰胺 ([illegible])
polyamine	聚氨 ([illegible])
polyeletrolyte	聚合 (高分子) 电解质 ([illegible])
polyethylene	聚乙烯 ([illegible])
polymeric	聚合的 ([illegible])
pool fire	池式燃烧 ([illegible])
pose a threat to	成为…的威胁 ([illegible])
postulate	假定，基本条件，基本原理 ([illegible])
powder	煤粉 ([illegible])
power capacity	容量，功率 ([illegible])
power cylinder	油动机 ([illegible])
power hammer	汽锤 ([illegible])

power utility	发电站
power-factor	功率因素
Pre-bid Meeting	标前会
precipitate in	沉淀，淀析，析出，凝结
precipitator	除尘器
preclude	排出，阻止
predominate	支配，统治
preferable	更可取的，更好的
prejudice	偏见，伤害，损害
preliminary design	初步设计
premium fuel	优质燃料
premixed	预混合料，预拌和料
prequalification	资格审查
preset	预调，预置
pressure drop	压降
pressure ratio	压比
pressure switches	压力开关
pressure vessel	压力容器
pressurized-fluided-bed combustion（PFBC）	增压流化床燃烧
prevailing	主要的，占优势的
primary air fan	一次风机
primary energy	一次能源
prior	在先的，优先的
probabilistic	盖然论的，或然说的
process industry	制造（加工）工业
procurement	采购
prone	有…倾向的，易于…的
pronounced	明显的，显著的
propylene	丙烯
prospective	预期的
protective relay	保护继电器
protracted	延长的，长时间的
provision	供应
proximate analysis	工业分析
proximity	接近
pulley	滑轮，滑车，辘轳
pulp	纸（木，矿，砂，泥）浆
pulsating load	脉动载荷
pulsation	脉动，波动

Pulverized Coal（PC）	煤粉 （员愿苑
pulverizer	磨煤机 （园愿圆
pumped storage plant	抽水蓄能电站 （员愿圆
punch	冲压，冲加压，模冲 （源愿圆
pursuant	按照，遵循，依据，追踪 （远愿苑
put into operation	投入运行 （员愿员
put into service	投入使用，投入运行 （缘愿员
PWR（Pressurized Water Reactor）	压水堆 （员愿员
pyrolizing surface	热解表面 （愿愿缘
pyrolysis	高温分解 （愿愿缘
radial-turbine	辐流式透平，辐流式汽轮机 （猿愿圆
railway locomotive	火车机车 （猿愿圆
raise finance	筹措资金 （员愿圆
rap	敲击 （园愿源
Rateau stages	托拉级，压力级 （猿愿员
rated speed	额定转速 （猿愿苑
ratify	批准，认可 （远愿苑
rating	额定（标称，规定）值 （源愿圆
raw coal	原煤 （员愿员
RDF（Refuse-Derived Fuels）	垃圾衍生燃料、废物衍生燃料 （愿愿苑
reactants	反应物 （远愿苑
reaction turbine	反击式透平，反击式汽轮机 （猿愿员
reactionary force	反击力 （猿愿员
reactor	电抗器，反应堆 （源愿缘
readily	容易地，很快地 （远愿员
ream	铰刀 （愿愿苑
reburning	再燃烧 （员愿苑
reciprocal	互利的；相互的；往复的 （源愿员
recirculation	再循环 （缘愿圆
reclosure	重合闸 （源愿苑
recovering	回收 （远愿苑
rectangular	长方形的 （源愿圆
rectify	整流 （源愿员
recuperative	还原的，间壁换热的 （园愿苑
reducer	减速器 （园愿源
reduction gearing	减速齿轮 （猿愿圆
refined	精炼，精制 （远愿缘
refractory	耐火材料；耐火的，耐热的 （园愿缘
refractory organic	耐火有机物 （远愿源

regenerant	再生剂 （[illegible]
regenerative	再生式，回热式，蓄热式 （[illegible]
regime	制度 （[illegible]
register	调风器，挡板 （[illegible]
reheat stop valve （RSV）	再热主汽门 （[illegible]
reheater	再热器 （[illegible]
reimbursement	偿还 （[illegible]
relay	继电器，继动器，错油门 （[illegible]
relay amplifier valve	中间继动滑阀 （[illegible]
reliably	可靠地 （[illegible]
relief valve	溢流阀，安全阀 （[illegible]
relieve	援助 （[illegible]
remedial	治疗的，修补的 （[illegible]
remove alternator field excitation	灭磁 （[illegible]
replica	复制品 （[illegible]
repower	改建动力装置，增容 （[illegible]
reserves	储量 （[illegible]
residential consumption	民用电消费量 （[illegible]
residual excitation	剩磁激励 （[illegible]
residual magnetism	剩磁 （[illegible]
residue	残存 （[illegible]
resilient bearing	刚性轴承 （[illegible]
resistance	电阻 （[illegible]
responsibility contract	责任合同 （[illegible]
retain	保持，保有 （[illegible]
retarder	抑制剂，控制剂，阻滞剂 （[illegible]
retention	被保留 （[illegible]
retirement	退役 （[illegible]
retractable	缩进的 （[illegible]
retrofit	更新；改型；改造 （[illegible]
return line	四流管 （[illegible]
reuse	重新使用 （[illegible]
reversed flow	逆留，回流 （[illegible]
reversing blade	转向导叶片 （[illegible]
rheological	流态的，流变的 （[illegible]
rifled	内螺丝的 （[illegible]
rim of disk/wheel	轮缘 （[illegible]
risers	上升管 （[illegible]
robust	坚固的，耐用的，健全的，增强的 （[illegible]

rotating shaft	转轴 ([illegible])
rotor	转子，旋翼 ([illegible])
rotor windings	转子绕组 ([illegible])
row	行，列 ([illegible])
rupture	破裂 ([illegible])
rust inhibitors	防锈剂 ([illegible])
rust-preventing	防锈 ([illegible])
salient	突出的，凸起的 ([illegible])
sanitary	卫生保健 ([illegible])
sanitary engineering technology	卫生工程技术 ([illegible])
saturation	饱和 ([illegible])
SC (Supercritical)	超临界 ([illegible])
SCADA	监视控制及数据采集 ([illegible])
SCCU	子站通讯及控制单元 ([illegible])
screw	螺杆 ([illegible])
scrubber	洗汽装置，湿式除尘器 ([illegible])
scrubbing	擦洗，洗涤 ([illegible])
scuffing	磨损处 ([illegible])
SDPC (State Development Planning Commission)	国家发展计划委员会（中国）([illegible])
seal	密封，封闭 ([illegible])
sealed bids	密封的标书 ([illegible])
sealing strip	汽封片 ([illegible])
seam	矿层；煤层 ([illegible])
secure M to N	把 M 固定在 N 上 ([illegible])
segment	扇形体 ([illegible])
seismic	地震的 ([illegible])
Selective Catalytic Reduction (SCR)	选择性催化剂脱氮装置 ([illegible])
semicircle	半圆（形）的 ([illegible])
semipermeable	半渗透 ([illegible])
sensible heat	显热 ([illegible])
sensor	敏感元件 ([illegible])
sequestration	扣押，没收，多价螯合 ([illegible])
serpentine	蛇纹石 ([illegible])
servo	伺服机构，随动机构 ([illegible])
servo-mechanism	伺服机构 ([illegible])
set point	设定点 ([illegible])
set up	建立，装配，计划，安排 ([illegible])
SETC (State Economic and Trade Commission)	国家经济贸易委员会（中国）([illegible])
settle out	沉淀出来 ([illegible])

settling	沉淀，沉降 （[illegible]
severity	严寒 （[illegible]
sewer syndrome	污水管综合症 （[illegible]
sewerage	下水道系统 （[illegible]
shear	切断 （[illegible]
shed	摆脱，抛弃 （[illegible]
sheet	板，板料 （[illegible]
shield	护罩，电屏 （[illegible]
shim	补偿棒 （[illegible]
shorthand	速记 （[illegible]
shrink	收缩，减小，热套 （[illegible]
shrink fit	过盈配合，冷缩配合，红套配合 （[illegible]
shroud band	围带 （[illegible]
shunt	分路 （器），分流 （器） （[illegible]
shunt trip	分路器 （[illegible]
shutdown	停机，关闭 （[illegible]
silicon controlled	硅 （可控） 整流器 （[illegible]
silt	泥沙 （[illegible]
simultaneous	同时发生的 （[illegible]
sine	正弦 （[illegible]
sing	吊环，吊索 （[illegible]
singe shaft turbine	单轴汽轮机 （[illegible]
single-cylinder turbine	单缸汽轮机 （[illegible]
single-flow	单向流动 （[illegible]
single-stage	单级 （[illegible]
singularity	奇点，奇异点 （[illegible]
sintered	烧结的，熔结的，热压的 （[illegible]
slag device	除渣装置 （[illegible]
slagging	结渣 （[illegible]
slaked lime	熟石灰 （[illegible]
sleeve	套筒，空心轴，轴套 （[illegible]
slide valve	滑阀 （[illegible]
sliding collar	滑环 （[illegible]
sliding key	滑销 （[illegible]
sliding pressure capability	滑压能力 （[illegible]
sliding pressure governing	滑压调节 （[illegible]
slip ring	滑环，集流环 （[illegible]
slope	斜坡，斜率 （[illegible]
slotted	开槽的，切槽的，有槽（沟、裂痕）的（[illegible]

sludge	污泥，油泥，油泥渣
slurry	煤泥，泥浆
smokestack	烟囱
snubber	减振器；缓冲器
snubber blade	带阻尼结构的叶片，带阻汽片的叶片
snug	舒适的
SO_2 removal efficiency	脱硫效率
sodalite	方钠石
solar power	太阳能发电
sole	惟一的
solid rotor	实心转子
solid sludge	污泥，泥渣
solidification	凝固，浓缩
solidly	连续地，不间断地
solubility	溶解性
solution	溶液
soot blowing	吹灰
sophisticated	复杂的，高级的，尖端的
spacer ting	垫圈
span	间距（隔）
spare parts	备件，附件
spatial resolution	空间分辨率
specification	说明书
specify	指明，详述
speed controller	调速器
speed-changing gear box	变速调节箱
spherically	球面地
spiral wound	螺旋卷式
spray	喷水，喷雾
springy	有弹性的，挠性
sprinklers	洒水车，洒水装置
spur	专用线，支线
stabilize	使坚固，使稳定
stack	烟囱，冷却塔
staggered	错列的，叉排的
staging	分段运输
stagnant	停滞的，不流动的
stagnant steam	滞留汽体
stand alone	（不受计算机影响系统控制的）独立

stand by generator	备用发电机 （[illegible]
standard coal	标准煤 （[illegible]
startup valve	启动阀 （[illegible]
state-of-the-art	技术发展水平，目前工艺水平，现代化工艺状态 （[illegible]
static balance	静平衡 （[illegible]
static characteristic curve	静态特性曲线 （[illegible]
station bus	电站母线 （[illegible]
stator coolant pressure	定子冷却剂压力 （[illegible]
stator coolant pump capacity	定子冷却泵容量 （[illegible]
statutory	法定的，依照法规的 （[illegible]
statutory intervals of inspection	规定的停机检查 （[illegible]
steady bearing	稳定轴承 （[illegible]
steam chest	蒸汽室 （[illegible]
steam engine	蒸汽机 （[illegible]
steam extraction	抽汽 （[illegible]
steelwork	钢结构，钢架 （[illegible]
stench	臭气，臭味 （[illegible]
steric	空间的，位的 （[illegible]
sterile	无菌的 （[illegible]
stiff	刚性的，硬的，不易弯曲的，不灵活的 （[illegible]
stiff rotor	刚性转子 （[illegible]
stipulate	约定，规定 （[illegible]
stoker	层燃炉 （[illegible]
stop valve （SV）	主汽门 （[illegible]
strainer	过滤器，滤网 （[illegible]
strand	（线、绳等） 股 （[illegible]
strata	（地壳的） 岩层、地层 （[illegible]
stratified	成层了的，层积了的，分层的 （[illegible]
strenuous	费力的 （[illegible]
stringent	严格的 （[illegible]
sub- critical parameters units	亚临界参数机组 （[illegible]
subcontractor	子承包商，二包，转包人 （[illegible]
subgrid scale （SGS）	亚网格尺度 （[illegible]
subject	有待…的，须经…的，受人支配的 （[illegible]
submission	提交意见 （[illegible]
substoichiometric	亚 （不足，低于） 化学计量的 （[illegible]
subsystem	子系统 （[illegible]
suction	吸，空吸 （[illegible]

sulfite	亚硫酸 ([illegible])
sulfur contents	含硫量 ([illegible])
sulfur dioxide	二氧化硫 ([illegible])
sulphate	硫酸盐 ([illegible])
sulphite	亚硫酸盐 ([illegible])
sulphur dioxide	二氧化硫 ([illegible])
sump	油盘，曲柄箱 ([illegible])
super- critical parameters units	超临界参数机组 ([illegible])
superalloy	超耐热不锈钢，超耐热合金 ([illegible])
superheater	过热器 ([illegible])
supersede	代替，取代，更换，废除 ([illegible])
supersonic	超音速，超声波，超声频 ([illegible])
supervisory	监控的，监视的 ([illegible])
surcharges	超排量 ([illegible])
surety	保证 ([illegible])
surface type condenser	表面式凝汽器 ([illegible])
surfactant	表面活性剂 ([illegible])
surge	电涌 ([illegible])
surplus	盈余的，剩余的 ([illegible])
suspension	悬浮 ([illegible])
sweat into	熔焊，焊接，渗漏 ([illegible])
swell	膨胀，增长 ([illegible])
symbolize	象征，用符号表现 ([illegible])
symmetrical	对称的 ([illegible])
synchronise	同步，并网 ([illegible])
synchronization	同时发生，同速进行，并网 ([illegible])
synchronizer	同步器 ([illegible])
synchronizing relay	同步继电器 ([illegible])
synchronous speed	同步速率 ([illegible])
synchroscope	同步指示仪 ([illegible])
take into account	考虑 ([illegible])
tandem-compound single	单轴多缸 ([illegible])
tangential	切线的 ([illegible])
tangential to	与…相切 ([illegible])
tap	抽取 ([illegible])
tap point	抽汽口，抽汽点 ([illegible])
tar	焦油 ([illegible])
technical specifications	技术规格 ([illegible])
telex	用户/直通电报，电报用户直通电路 ([illegible])

temper	缓和，调温，回火
temperature stress	热应力，温度应力
tenon	（叶片）铆钉头，榫头
tensile	张力的，拉力的，能伸长的
tensile stress	拉应力
tension spring	拉伸弹簧
terminal unit	终端设备
termination	结束
terminology	专门名词，术语
territory	土地，领土，范围，领域
tertiary industry	第三产业
T-firing system （tangential firing）	切圆燃烧
The China Atomic Energy Authority （CAEA）	中国原子能机构
The China National Nuclear Corporation （CNNC）	中国核工业集团公司
the House of Commons	（英国）下议院
The National Nuclear Safety Administration （NNSA）	国家核安全局
the percentage of regulation	速度变动率
the primary pulsating oil pressure	一次脉冲油压
the secondary pulsating oil pressure	二次脉冲油压
the septic tank	厌氧菌处理槽,发酵池
The State Environment Protection Administration （SEPA）	国家环境保护总局
the tenth Five-year Plan	第十个五年计划
thermal barrier	热障
thermal conductivity	导热率,导热系数
thermal fatigue	热疲劳
thermal power	火电
thermocouple	热电偶
three double-flow single casing	三个双流程单层缸
throttle	节流阀,调速汽门
throttle governing	节流调节
thrust	推力
thrust bearing	推力轴承
thrust collar	推力盘
thrust shoe	推力瓦
thyrister converter	晶闸管变换器
TI&BI	汽机岛和锅炉岛
tidal power	潮汐发电
tile field	瓦管灌溉系统

tilt	倾斜,摆动
tilting	倾斜
time-delay overcurrent relay	延时过流继电器
tip	端点,端头
titanium	钛
topographical	地形的
topping turbine	前置式汽轮机
torque motor	力矩马达
tortuous	曲折的,弯曲的,不在一个平面的
toxic	有毒的,毒性的；毒剂,毒物
tractable	易驾驭的,驯良的,易管教的,易处理的
transducer	传感器，变送器
transit	通过，移动，运输，转运口
transition piece	过渡区
transmission line	输电线
transonic	接近音速的
transparency	透明，透明度
transverse key	横销
transverse plane	横截面
trap	捕捉，搜集
traveling field	行波场
trench	沟，槽
trip	解扣，跳闸
triple casing	三层汽缸
triple pulsating oil	三次脉冲油
triple reduction	三级减速
trunk	母管，本体
tube nest	管束
turbidity	浑浊度
turbine-inlet temperature （TIT）	燃气轮机进气温度
turboalternator	涡轮发电机
turnkey	交钥匙，总承包
turnkey contract	交钥匙合同，包到投产的合同
twist	扭转，弯曲，扭曲
UCP （Unit Control Panel）	单元/机组控制板
ultimate analysis	元素分析
Ultra-Supercritical	超超临界
unambiguous	不含糊的,清晰的；明白的,清楚的
under construction	正在建设中

underdrain	阴沟，地下沟道 （[illegible]
underfrequency relay	欠频继电器 （[illegible]
undervoltage relay	欠压继电器 （[illegible]
undue	过度的，不相称的，不适当的，非常的 （[illegible]
unit price	分项价格 （[illegible]
unit transformer	（厂用）变压器 （[illegible]
untwist	拆开（搓合的绳，线等），解开，非扭转 （[illegible]
upgrade	上升，提高等级，提升，加强 （[illegible]
Uranium	铀 （[illegible]
USDOE （U[illegible]Department of Energy）	美国能源部 （[illegible]
vale	山谷 （[illegible]
validity	有效期 （[illegible]
validity extension	有效期 （[illegible]
valve stem	阀杆 （[illegible]
vane	叶片，轮叶，刀片，节气阀 （[illegible]
variation	差异 （[illegible]
vector difference	矢量差 （[illegible]
velocity-compounded stage	复速级 （[illegible]
vent	排出，出口 （[illegible]
ventilation	通风；流通空气 （[illegible]
venturi	文丘里喷嘴 （[illegible]
version	型号，种类，形式（态），模型 （[illegible]
vestibule	前厅，通廊 （[illegible]
VGB	德国电力公司协会，德国大电厂协会 （[illegible]
viability	生存性，生存能力，可行性 （[illegible]
viable	有生命力的，能生存的 （[illegible]
vicinity	附近，邻近地区 （[illegible]
vigorously	大力地 （[illegible]
viscosity	粘度，粘性系数 （[illegible]
visual	可视的 （[illegible]
VOC （Volatile organic compound）	挥发性有机化合物 （[illegible]
voltage regulator	电压继电器 （[illegible]
voltage-sensing circuit	电压感知电路 （[illegible]
volumetric	体积的，容积的 （[illegible]
vortex	漩涡，旋风 （[illegible]
vortex flow	涡流，旋流 （[illegible]
wall fire	墙式燃烧 （[illegible]
warm start	温态启动 （[illegible]
warranty	理由，保证，保险，执照，许可证 （[illegible]

[illegible]

waterborne	由水路运送的，(指疾病) 由引水传染的
water-cooled wall	水冷壁
wedge	楔，楔形物
weld	焊缝，焊接
welded disc rotor	焊接盘式转子
wet-bottom furnace	液态排渣炉膛
wind machines	风机
windage loss	鼓风损失
with a view of	为了…的目的
withdrawal	取出，拉动
withstand	承受，经受，顶得住
worked-out	用过的，废弃的
workmanship	工作质量，工艺，技巧，作品，制造物
worm	螺杆，蜗杆
worm transmission mechanism	蜗轮传动机构
xonotlite	硬硅钙石
yield point	屈服点
zeolite	沸石
zig-zag	锯齿形的，Z 字形的，曲折形的

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